INVITATION FOR BIDS
CCK-2400-19
Project # 2402.13
INTERVENTIONAL SERVICE PROJECT
BP-01 TC-168A Controls
ADDENDUM #2
4/19/2019

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

**IMPORTANT: RFP AND ADDENDUM MUST BE RECEIVED BY 4/26/2019 @ 3:00 P.M. LEXINGTON, KY TIME**

Bidder must acknowledge receipt of this and any addendum as stated in the Invitation for Bids.

1. Please refer to and incorporate within the Offer the attached Written Questions and Answers Interventional Services Bid Package #01, TC-168A Controls Project #2402.13, Question 1 through 5.

2. In addition, refer to and include in the Offer the attached ADDENDUM NO. 2 from GBBN Architects, Inc. dated April 19, 2019 including revisions to specifications 23 0901, 23 0903 and 23 0923.

OFFICIAL APPROVAL
UNIVERSITY OF KENTUCKY

[Signature]
Contracting Officer / (859) 257-5409

University of Kentucky
Purchasing Division
322 Peterson Service Building
Lexington, KY 40506-0005
**Written Questions and Answers**
**Interventional Services**
**Bid Package #01 TC-168A Controls**
**Project #2402.13**
**CCK-2400-19**

<table>
<thead>
<tr>
<th>NO.</th>
<th>Question</th>
<th>Responder</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Attached is a page from the controls spec for the UK Internal Services project that bids next week. It looks like it might be from a previous revision of the controls spec. I wanted to make sure that I’ll be OK bidding Distech controls on this since it only lists Honeywell, Johnson Controls, and Vykon.</td>
<td>UK</td>
<td>Yes, please bid according to our new standard. Vykon at Tier 1 and Distech at Tier 2 is acceptable.</td>
</tr>
<tr>
<td>2</td>
<td>Are brushed aluminum covers required for sensors as specified under 23 0903-9 Section 2.5.3?</td>
<td>AEI</td>
<td>Standard white thermostats are acceptable.</td>
</tr>
<tr>
<td>3</td>
<td>Will we be required to integrate into the lighting system as specified under 23 0901-5 Section 1.5N, or is this integration provided by the owner or already in place?</td>
<td>AEI</td>
<td>Yes. See section 1.6 R 3.</td>
</tr>
<tr>
<td>4</td>
<td>Will floating control for damper actuators on terminal units be acceptable?</td>
<td>AEI</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>In reviewing the contract documents I have run into a question I hope you can clarify. In the UK bid document it is asking for a bid bond but in the Turner documents, “Attachment B”, Page 8 or 15, paragraph G (attached) there is an exclusion for the payment and performance bond. Can you please verify if bond is not required?</td>
<td>UK</td>
<td>Yes, KRS45A.185 (1) requires Bidder security shall be required for all competitive sealed bidding for construction contracts when the price is estimated by the Commonwealth to exceed forty thousand dollars ($40,000). Bidder's security shall be a bond provided by a surety company authorized to do business in this Commonwealth, or the equivalent in cash, in a form satisfactory to the Commonwealth.</td>
</tr>
</tbody>
</table>
ADDENDUM NO. 2

BY: GBBN Architects, Inc.
609 West Main Street
Louisville, Kentucky 40202
502.583.0700

SUBJECT: University of Kentucky
Renovate/Expand UK Healthcare Facilities
Pavilion A - Interventional Services
UK # 2402.13

FOR: University of Kentucky
222 Peterson Service Building
Lexington, Kentucky 40506

TO: All Bidders of Record

Acknowledge receipt of this Addendum by inserting its number and date in the space provided on the Bid Form. Failure to do so may subject bidders to disqualification. This Addendum forms a part of the Bidding Documents and revises the Bidding Documents as follows:
PART 1 PROJECT MANUAL

1.1 Specifications

A. 23 0901
   1. Added Distech to Acceptable Bidders list

B. 23 0903
   1. Revised thermostat type to white plate type

C. 23 0923
   1. Added acceptable manufacturers for B-BC controllers.

PART 2 ATTACHMENTS

2.1 Specifications

A. 230901

B. 230903

C. 230923

2.2 Drawings

A. None

2.3 Sketches

A. None
2.4 Copy of RFI’s

A. None

2.5 Supplemental Information

A. None

END OF ADDENDUM
SECTION 23 0903
CONTROL INSTRUMENTATION

PART 1 - GENERAL

1.1 RELATED WORK
   A. Section 23 0901 - Control Systems Integration
   B. Section 23 0905 - Instrument Point List
   C. Section 23 0993 - Control Sequences
   D. Section 23 2120 - Piping Specialties

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 GENERAL
   A. Devices containing mercury are not allowed.

1.4 SUBMITTALS
   A. Devices shall be indexed by bill of material for each system as detailed in Section 23 0901 -
      Control Systems Integration.
   B. Device data sheets submittal shall be submitted simultaneously with Control Systems Integration
      submittal. Refer to submittals section in 23 0901.
   C. Thermostat/Room Temperature Sensor Schedules:
      1. Submit thermostat/room temperature sensor schedule with shop drawings. Thermostat/room
         temperature sensor schedule shall have detailed listing of which type is used for each room, including
         data concerning service and model numbers, sizes, cover types, and engineering data sheets for each control device.
   D. Warranty
      1. Provide 1 year warranty on all materials and labor.
      2. Warranty requirements shall include furnishing and installing software upgrades issued by
         the manufacturer during the 1 year warranty period.

1.5 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.
PART 2 - PRODUCTS

2.1 GENERAL

A. Pressure and temperature ratings of devices indicated in Part 2 of this Section are minimum required. Devices shall be designed to withstand maximum pressures and temperatures encountered in respective systems.

B. No devices containing mercury will be allowed under this Specification.

2.2 GENERAL INSTRUMENTATION

A. Pressure Gauges:
   1. Refer to Section 23 2120 - Piping Specialties

B. Thermometers (Dial-Type):
   1. Refer to Section 23 2120 - Piping Specialties

C. Analog Electronic Instrument Indicators:
   1. Electronic indicators, used for displaying sensor and/or output values as measured by current or voltage, shall be panel mount type and at least 2" square. Output may be either analog needle type or digital with 1/2" high LED or backlit LCD displays.
   2. Electronic indicators shall be marked in appropriate units (degrees, psi, % rh, gpm, cfm, etc.) and with appropriate range of values. Panel mounted indicators shall have minimum accuracy of 1% of scale range. Digital units shall be scaled to show 3 digits plus 1 decimal point.

D. Building Utility Meters:
   1. All building utility meters shall be equipped with pulse initiators which shall be connected to a totalizer input on the FMS. This includes but is not limited to electric meters, water meters, condensate meters, and BTU meters.

2.3 DISCRETE ELECTRIC INSTRUMENTATION

A. General:
   1. Electrical devices, switches, and relays shall be UL listed and of type meeting current and voltage characteristics of project. Terminal connections shall be made at terminal blocks inside of NEMA 1 enclosures unless otherwise specified. Outdoor units shall be NEMA 4 with concealed adjustment.
   2. Ratings of normally open and normally closed contacts shall be adequate for applied load (minimum 5 amps at 240 Volts).
   3. Accuracy of devices shall be ± 1% of scale with adjustable offset unless otherwise specified.

B. Temperature Switches (Electric Thermostats):
   1. Line voltage or low voltage type suitable for application with adjustable setpoint and setpoint indication.
   2. Low voltage type to have heat anticipation.
   3. Thermostats with remote sensing bulb shall have liquid filled sensing element and exposed setpoint adjustment.
   4. Wall mounted space thermostat enclosure shall have concealed sensing element and exposed setpoint adjustment.
1. Unless otherwise stated, space thermostat covers shall be brushed aluminum or brushed nickel.

C. Temperature Low Limit Switches (Freezestats):
   1. Electric 2 position type with temperature sensing element and manual reset. Controls shall be capable of opening circuit if any 1 foot length of sensing element is subject to temperature below setting.
   2. Sensing element shall not be less than one lineal foot per square foot of coil surface areas. Unless otherwise indicated, calibrate temperature switch setpoint to 38°F.

D. Temperature Low Limit Switches (Freezestats):
   1. Electric 2-position type with temperature sensing element and manual reset. Controls shall be capable of opening circuit if any one foot length of sensing element is subject to temperature below setting.
   2. Sensing element shall not be less than one lineal foot per square foot of coil surface areas.
   3. Provide adjustable time delay relay for 0.5 to 5 minutes. Time delay relay shall be wired between freezestats and controller to allow air handling unit mixed air to stabilize upon startup or transition from unoccupied to occupied mode to prevent spurious trips from occurring when outside air damper(s) opens and cold outside air enters air handling unit.
   4. Where any freezestat is mounted higher than 6ft above the floor, manual reset to be provided by remote manual reset panel consisting of remote trip relays, master trip relay and master reset relay.
   5. Each freezestat operates its remote trip relay which is locked out upon freezestat trip. Indicator lamps at remote trip relay shall indicate which relay has tripped and therefore indicates which freezestat has caused trip.
   6. Remote trip relays will trip master trip relay that interfaces with BAS to cause air handling unit shutdown.
   7. Master reset relay is activated by reset pushbutton at remote manual reset panel to reset locked out trip relays and master trip relay.

E. Temperature Switches (Aquastats):
   1. Electric 2-position type with strap-on or immersion temperature sensing element. Switch contacts close on increasing temperature to provide start signal for unit heaters, cabinet unit heaters and open on high limit control for heating hot water heat exchangers.
   2. Sensing element shall be set for 100°F (FA) for unit heater control. For setpoints to aquastats for hot water heat exchangers, refer to control sequences for each hot water system. Provide screw-type terminals in NEMA 12 switch enclosure for field mounting at unit heaters.

F. Space Humidity Switches (Humidistats):
   1. SPDT line voltage or low voltage type suitable for application. Provide NEMA 1 metal enclosure suitable for intended use. Wall mounted space humidistat enclosure shall be designed with concealed sensing element and exposed setpoint adjustment.
      a. Humidity Range: 10 to 95% rh between 40 and 125°F
      b. Accuracy: ± 5% rh
      c. Offset Differential: 5% rh

G. Duct High Limit Humidity Switches (Humidistats):
   1. Manufacturers: Rotronic or approved equal
a. SPDT line voltage or low voltage type suitable for application. Provide NEMA 12 metal enclosure suitable for intended use. Duct mounted humidistat enclosure shall be designed with concealed setpoint adjustment.

b. Control signal to humidifier control valve shall be passed through normally closed (NC) contacts that open when humidity level exceeds high limit setpoint to interrupt the control signal to the humidifier control valve and fails it closed. Reset of the high limit humidistat will enable the humidifier control valve to operate again.

1. Humidity Range: 10 to 95% rh between 40 and 125°F
2. Accuracy: ± 5% rh
3. Offset Differential: 5% rh

H. Relays:
   1. Manufacturers: IDEC, Potter Brumfield, Square D, or Allen Bradley
   2. Equal to IDEC Type RH2B-U, miniature 8 blade pilot relay with DPDT silver cadmium oxide contacts rated at 10A, 30 VDC, or 120 VAC. Coil shall match control circuit characteristics. DDC outputs shall be 24 VDC with maximum current burden of 50 milliamps. Rectangular base socket mount with blade type plug-in terminals and polycarbonate dust cover.
   3. Provide DIN rail mountable (Snap type) mounting sockets equal to IDEC SH2B-05.

I. Enclosed Relay (Relay-in-a-Box):
   1. Manufacturers: Veris Industries, Kele & Associates, Functional devices, Inc. or approved equal
   2. 1 or 2 SPDT relays in NEMA 1 or better enclosure. Coil shall be selected for control circuit characteristics.
   3. Contacts rated at 10A, 28 VDC or 120 VAC. Conduit nipple is 1/2” NPT. Maximum coil current burden 50 milliamps.

J. Pressure Differential Switches (Air Systems):
   1. Manufacturers: Cleveland Controls, Dwyer, Honeywell, Johnson Controls/Penn, or TAC
   2. Adjustable set point, differential pressure type. Select switches for accuracy, ranges (20 to 80% of operating range) and dead-band to match process conditions, electrical requirements and to implement intended functions.
   3. Pressure differential switches for air systems shall have pressure rating of at least 10” WC.
   4. Pressure indicating differential switches for air systems shall be equal to Dwyer Series 3000 photohelic gauge.
      a. Maximum Temperature Rating: 180°F
      b. Repeatability: ± 1%

K. Pressure Differential Switches (Water Systems):
   1. Manufacturers: Allen Bradley, Ashcroft, Dwyer, Honeywell, Johnson Controls/Penn, TAC, SOR, or United Electric
   2. Adjustable set point, differential pressure type. Select switches for accuracy, ranges (20 to 80% of operating range) and dead-band to match process conditions, electrical requirements and to implement intended functions.
   3. Pressure differential switches for water systems shall be rated for 150 psig unless otherwise noted. Chilled water pressure differential switches shall be provided with totally sealed vapor tight switch enclosure on 300 psibody. Differential pressure switches to have 3-valve manifold for servicing.
      a. Maximum Temperature Rating: 300°F
b. Repeatability: \( \pm 1\% \)

**L. Target Type (Paddle) Flow Switches:**
1. Manufacturers: Honeywell, Johnson Controls, Kobold, McDonnell & Miller, Dwyer or SOR
2. Adjustable set point, paddle type. Select switches for accuracy and ranges to match process conditions, electrical requirements, to implement intended functions.
3. Air sensing switches shall be for duct mounting, top, side, or bottom. Mounting in vertical duct with downward flow is not allowed.
4. Furnish water sensing switches with NPT fittings suitable for piping mounting. Switches shall be rated for 150 psig except chilled water switches shall be rated for 300 psi.

**M. Thermal Dispersion Flow Switches:**
1. Manufacturers: Fluid Components, Inc., Delta M, Dwyer or Magnetrol
2. Units shall use thermal dispersion sensors to detect flow from heated reference elements whenever flow is above threshold setpoint. Setpoint shall be adjustable between 20 and 80% flow. Select units for proper installation orientation.
   a. Maximum Response Time: 1 minute
   b. Maximum Temperature: 200°F
   c. Repeatability: \( \pm 1\% \)
   d. Pressure Rating: 300 psi for chilled water, 150 psi for other applications

**N. Level Switches:**
1. Manufacturers: Drexelbrook, Magnetrol, Endress and Hauser or Dwyer
2. Radio Frequency (RF) type continuous level probe with multiple adjustable setpoints and SPDT snap action contacts to meet intended use. Probe shall have probe shielding to reject build up of conductive, sticky or viscous material. Probe length shall match vessel dimensions to measure within 6" of bottom.
3. Provide probe brace every 4 ft if probe length exceeds 6 ft, and not installed in stilling well.
   a. Supply Voltage: 120 VAC/60 Hz
   b. Fail Safe: Low Level output on instrument failure
   c. Ambient Temperature Limits: -40 to 160°F
   d. Minimum Enclosure Rating: NEMA 4
   e. Transmitter Mounting: Remote
   f. Performance:
      1). Accuracy: \( \pm 2\% \) nominal
      2). Linearity: \( \pm 1\% \) nominal
      3). Repeatability: \( \pm 1\% \) nominal
      4). Response Time: 20 milliseconds
      5). Ambient Temperature Effect: 2% per 100°F max.
      6). Voltage Variation Effect: \( \pm 0.2\% \) maximum per 10 V change

**O. Time Switches (Time Clocks):**
2. Programmable electronic clock type consisting of electronic clock, LED or LCD display, user interface keypad, and multiple normally open/fail close contacts. Time clocks shall be programmable for up to 8 start/stops per day for each 7 day period.

3. Provide each time clock with battery that will maintain programming schedule for up to 8 hours upon electric power failure and shall return to its programmed position after re-start.

P. Duct Mounted Smoke Detectors:

1. UL Listed for use in air handling systems. Detectors shall be designed to provide detection of combustion gases, fire and smoke in air conditioning and ventilating duct systems in compliance with NFPA and UL 167. Further they shall contain ionization type detector and air sampling chamber with sampling tubes extending through width of air duct. Alarm status indicating lights shall be visible on front of detector. Key controller test and reset switches plus easily accessible test jack shall be provided. It shall include alarm relay contact (DPDT) capable of handling loads of up to 5 amperes at 120 VAC or 28 VDC resistive. Unit shall have self-contained power supply requiring XXX power.

Q. Carbon Monoxide/Nitrogen Oxide Monitor:


2. Provide gas detection systems as listed below. Each system shall be complete package with remote or local space sensors, detection instruments, alarm contacts, local indication of current measured value for each sensor and status indicator lights for power and status of each sensor. Devices not requiring remote mounting shall be housed in metal control panel. All status indicators shall be mounted on panel faceplate.

3. Units shall have adjustable setpoints and self-test diagnostics.
   a. Carbon Monoxide
   b. Panel Location: Loading Dock
   c. Gas to be Detected: Carbon Monoxide, CO
   d. Alarm Setpoint: 35 ppm (FA)
   e. Range: 0-2.5 times Alarm Setpoint
   f. Nitrogen Dioxide
   g. Panel Location: Loading Dock
   h. Gas to be Detected: Nitrogen Oxide, NOX
   i. Alarm Setpoint: 1 ppm (FA)
   j. Range: 0-2.5 times Alarm Setpoint

4. Provide panel mounted alarm horn with silence switch.

5. Provide remote alarm/strobe panel as required when local alarm is not visible to occupants.

6. Oxygen depletion sensors for MRI rooms shall be mounted on wall in MRI suite at breathing height.

R. Position Switches (End Switches):

1. Manufacturers: Allen Bradley, Johnson Controls/Penn, Honeywell, Ruskin, Greystone Energy Systems, Reed National Air Products, NAMCO, Omron or Westlock

2. Provide damper position switches, as required to meet specified sequence. Rotary switches shall be cam action, lever, or proximity type. Provide damper brackets and connecting rods for connecting position switch actuation levers to damper blades or jackshafts.

3. "Tip Switches" or other position switches that contain mercury shall not be used for damper end switch applications.

S. E-P Switches (Solenoid Valves):
1. Manufacturers: Asco, Johnson Controls, TAC, Kele & Associates or MAC Valves
2. E-P switches shall provide control air for operation of fan isolation dampers, smoke or smoke/fire dampers, or other On/Off dampers. Line voltage actuators shall be Class "H" (high temperature) and listed by UL or CSA.
   a. Valve Body: Brass or bronze
   b. Valve Type: 2-way or 3-way
   c. Operating Voltage: 24 VDC, 24 VAC, 120 VAC or as specified
   d. Operating Temperature: 32 to 104°F
   e. Operating Pressure: Greater than maximum supply pressure
   f. Pipe Size: 1/4" NPT
   g. Enclosure Rating: NEMA 4 (locally mounted), NEMA 1 (Panel Mounted)
   h. Conduit Connection: 1/2"

T. Current Switches - Constant Load, Constant Speed:
   2. These shall be Induction type sensors clamped over single phase conductor of AC electrical power and shall be solid-state sensors with adjustable threshold and normally open contacts. Each current switch shall be selected for proper operating range of current.
      a. Output: Solid state relay or relay contacts
      b. Trip Setpoint: Adjustable by multi-turn potentiometer
      c. Operating Temperature: 32 to 131°F
      d. Response Time: < 0.5 seconds

U. Current Switches - Variable Load, Variable Speed
   1. Manufacturers: Veris Industries, N-K Technologies or approved equal
   2. These shall be induction type sensors clamped over single-phase conductor of AC electrical power and shall consist of solid-state sensors with self-calibrating threshold and normally open contacts. Each current switch shall be selected for proper operating range of current.
      a. Output: Solid state relay or relay contacts
      b. Trip Setpoint: Self-calibrating through microprocessor
      c. Operating Temperature: 32 to 131°F
      d. Response Time: < 0.5 seconds

V. Fume Hood Monitoring System:
   1. Manufacturers: Tek-Air, TSI, Flow Safe, Inc., Alnor, or Phoenix
   2. Provide local panel mounted on fume hood with visual and audible indication of face velocity, normal flow (green), low flow warning (yellow indication), and low-low flow alarm (red).
   3. Face velocity indication shall read in feet per minute and shall be either 2" analog indicator type or 1/2" digital readout.
   5. Face velocity shall be calculated based on velocity through through-wall type sensor or based on duct velocity and sash position.

W. Mechanical Room and Local Control Panel Alarm Horns:
   1. Manufacturers: Honeywell, Johnson Controls, Panalarm, TAC, or Ronan
2. 24 V alarm horn suitable for panel mounting.

X. Plant Alarm Horns:
1. Manufacturers: Panalarm, Johnson Controls/Penn, Honeywell, or Sonalert
2. Equal to Honeywell model SC806A rated at 64-100 dBA at 10 ft, 24 VAC operation. UL Listed and FM approved.

Y. Indicator Lights:
1. Manufacturers: Allen Bradley, GE, Square-D, or Idec
2. 1/4" minimum size or 1-1/4" maximum size, push-to-test type. Use green for normal, yellow for warning (low/high values), and red for alarm or fail (low-low or high-high conditions). AC or DC type with voltage matched to control circuit without transformers.

Z. Drain Pan Moisture Detector:
1. Manufacturers: Kele and Associates, DiversiTech or approved alternate.
2. Moisture detector is small, electronic control relay for detecting rising water levels, within drain pans or other containments. Moisture detector shall alarm when water levels reach 0.43" to prevent damage from overflow of drain pans. Relay shall reset when water levels decrease to 0.31" and relay re-energizes.
3. Relay is normally energized upon powering up and no water is present. When water level reaches the trip point the relay de-energizes for alarming in BAS.
4. Moisture Detector Relay Module (Model LD1-24):
   a. Supply Voltage: 24 VAC, 60 Hz
   b. Power Consumption: 1 W
   c. Cable length: 18-inches
   d. Relays Contacts:
      1). Type: SPDT
      2). Rating: 2.5A at 24 VDC; 5.0A at 120 VAC
   e. Enclosure Rating: Hermetically Sealed
   f. Dimensions: 0.87" H x 2.0" W x 1.25" L

2.4 PNEUMATIC INSTRUMENTATION

A. Multi-Probe Air System Static and Air Flow Sensing Elements:
1. Manufacturers: Tek-Air Systems, Ultratech or Air Monitor Corporation
2. Multi-probe type static and/or total pressure sensing station consisting of minimum

B. Single-Probe Air System Static Sensing Elements:
1. Sensors shall be similar to Dwyer Model A-301 or Tek-Air Model T-5PP7620 with angled tips and 1/4" metal tubing connections.

C. Space Static Pressure Sensor:
1. Manufacturers: Air Monitor Corporation, Tek-Air or Thermo Electron Corporation
2. Space static pressure probe shall be brushed aluminum with anodized finish or stainless steel with polished or painted finish selected by Architect.
3. Shielded static air probe shall be similar to Air Monitor Corporation Model 3 for flush ceiling mounting, complete with multiple sensing ports, pressure impulse suppression chamber, air flow shielding, and 3/8" FPT take-off fitting. Sensor shall be capable of sensing static
pressure within 1% of actual pressure value while being subjected to maximum air flow of 100 fpm from radial source.

D. Differential Air Pressure Indicator:
1. Dwyer model 2000 Series magnehelic gauge for surface or panel mounting. 4” dial readout, die cast aluminum housing. Case and aluminum parts Iridite-dipped. Exterior finish to be baked dark grey hammerloid. Hi/lo 1/8” pressure taps. Provide adapters to match tubing type.
   a. Accuracy: ± 2% of full scale.
   b. Ambient Temperature Range: 20 to 140°F
   c. Rated Total Pressure: -20” Hg to 15 psig
   d. Range: 0-2 times normal setpoint. (Use 0-0.25” WC for building and space pressure indication.)

E. Plastic Tubing:
1. Fire resistant virgin polyethylene, meeting stress-crack test ASTM D1693. Individual tube polyethylene or multi-tube instrument tubing bundle shall be classified as flame retardant under UL 94. Polyethylene material shall be rated as self-extinguishing when tested in accordance with ASTM D635.

2.5 ANALOG ELECTRONIC INSTRUMENTATION

A. Space Temperature Sensors:
1. Sensors shall be platinum RTD type, with the following minimum performance:
   a. Temperature Coefficient of Resistivity (TCR): 0.00385 ohm/ohm/°C
   b. Accuracy: ± .54°F + (0.005 X T) (Class B)
   c. Accuracy: ± .27°F + (0.005 X T) (Class A)
      T = Temperature of interest
   d. Conformance: DIN-IEC 751
   e. Operating Range: 32 to 122°F, 0 to 99% rh
2. Thermistors will be acceptable in lieu of RTD provided thermistor carries 5 year guarantee that device will maintain its accuracy within tolerance of ± 0.36°F between 32°F and 150°F, and 0.5°F between -20°F and 212°F.
3. Unless otherwise stated, space sensor cover shall be brushed aluminum or brushed nickel standard white plastic covers.
4. Provide visible setpoint, set point adjustment, and space temperature indication in all areas except public spaces. Thermostats are to have push buttons on the front face for adjusting the temperature setpoints. Thermostats are to have no doors.

B. Duct Mounted or Insertion Temperature Sensors:
1. Platinum RTD type, with the following minimum performance:
   a. Temperature Coefficient: 0.00385 ohm/ohm/°C
   b. Accuracy: ± .54°F + (0.005 X T) (Class B)
   c. Accuracy: ± .27°F + (0.005 X T) (Class A)
      T = Temperature of interest
   d. Conformance: DIN-IEC 751
   e. Operating Range: -50 to 170°F, 0 to 99% RH
   f. Standard lengths -- 5.5", 11.5" and 17.5". Other lengths with owner's written approval.
2. Install insertions sensors in stainless steel probes or wells.
3. Outside air sensors shall be weatherproof of noncorrosive construction and protected with solar shield. Mount outside air sensors on north side of building or in area intake wells for air handling systems to avoid thermal effects from direct sunlight.
4. Sensors mounted in air streams, such as air handling units, supply ducts, exhaust ducts or return ducts, shall be averaging type. Averaging type sensor to be installed in ducts larger than 24" x 24" or greater than 576in². Mount averaging sensor across duct area in a "Z" pattern using mounting clips specific for averaging temperature sensor probes.
5. Thermistors will be acceptable in lieu of RTD provided thermistor carries 5 year guarantee that the device will maintain its accuracy within a tolerance of ± 0.36°F between 32°F and 150°F, and 0.5°F between -20°F and 212°F.

C. Direct Insertion Temperature Sensors:
1. Sensor assembly shall be direct insertion, suitable for use with water systems, 150 lb class, minimum rating.
2. Sensor shall be platinum wound RTD, with the following minimum performance:
   a. Temperature Coefficient: 0.00385 ohm/ohm/°C
   b. Accuracy: ± .54°F + (0.005 X T) (Class B)
   c. Accuracy: ± .27°F + (0.005 X T) (Class A)
      T = Temperature of interest
   d. Conformance: DIN-IEC 751
   e. Operating Range: -50 to 170°F, 0 to 99% RH
3. Sheath diameter shall not exceed 5/16". Length shall be such that sheath, containing sensor, projects into process fluid from 2" to 2.5" beyond pipe wall when installed. Material to be 304 or 316 stainless steel. Process coupling to be 3/8" or 1/2" NPT.
4. Connection head to be NEMA 4, cast iron, with screw on cap. Provide internal termination for RTD and wire connection. Conduit connection shall be 1/2" NPT.
5. Provide hot tap assembly and extension. Material to be 304 or 316 stainless steel. Support hot tap at minimum of 2 points to eliminate vibration. Extension shall exceed insulation thickness by 1".
6. Refer to Section 25 3003 - Process Instrumentation Device Specifications.

D. RTD Temperature Sensor/Transmitters:
1. Manufacturers: Rosemount, Burns, Minco Products, Weed or Pyromation
2. Transmitters shall provide 2 wire, 4-20 mA current output signal proportional to specified temperature span of transmitter and compatible with DDC equipment.
   a. These shall be 100O platinum RTD type temperature instruments for process immersion or air duct mounting
   b. Operating Temperature: -20 to +180°F
   c. Power Supply Voltage: 13 to 35 VDC unregulated
   d. Accuracy or Output Error: 0.1% of span of sensor and transmitter combination
   e. Temperature Coefficient: 0.00385 ohm/ohm/°C
   f. Thermowells: By same manufacturer as Sensor/Transmitter or approved alternate.
3. Provide local temperature indicator with 3 LCD digital readout.

E. Space Humidity Sensors/Transmitters:
1. Manufacturers: General Eastern, Automation Components Inc., Veris Industries, Hy-Cal (Honeywell), Rotronic or Vaisala

2. Space humidity sensors shall be wall mount type with brushed aluminum or brushed nickel cover to match room thermostats and/or temperature sensors.

3. Sensing element shall be resistive bulk polymer, or thin film capacitive type. Sensor/transmitter shall have the following minimum performance:
   a. Accuracy: ± 2% rh at 25°C over range of 20-95% rh including hysteresis, linearity and repeatability
   b. Temperature Effect: Less than 0.06% per °F at baseline of 68°F
   c. Sensitivity: 0.1% rh
   d. Repeatability: 0.5% rh
   e. Hysteresis: Less than 1%
   f. Long Term Stability: Less than 1% rh drift per year
   g. Adjustment: ± 20% rh zero, non-interactive ± 10% rh span, non-interactive
   h. Operating Range: 0-99% rh, non-condensing, sensor 0-95% rh, non-condensing, electronics
   i. Output: 4-20 mA, 0-100% linear, proportional
   j. Power: 12-36 VDC

F. Duct Mounted Humidity Sensors/Transmitters:
   1. Manufacturers: General Eastern, Automation Components Inc., Veris Industries, Minco, Rotronic or Vaisala
   2. Probe type, temperature compensated, resistive bulk polymer or thin film capacitive type. Sensor/transmitter shall have the following minimum performance.
      a. Accuracy: ± 2% rh at 25°C over 20-95% rh including hysteresis, linearity and repeatability
      b. Temperature Effect: Less than 0.06% per °F at baseline of 68°F.
      c. Sensitivity: 0.1% rh
      d. Repeatability: 0.5% rh
      e. Hysteresis: Less than 1%
      f. Long Term Stability: Less than 1% rh drift per year
      g. Adjustment: ± 20% rh zero, non-interactive ± 10% rh span, non-interactive
      h. Operating Range: 0-99% rh, non-condensing, sensor 0-95% rh, non-condensing, electronics
      i. Output: 4-20 mA, 0-100% linear, proportional
      j. Power: 12-36 VDC

G. Combination Temperature/Humidity Transmitter:
   1. Manufacturers: Automation Components Inc., Veris Industries, Vaisala, Minco or General Eastern
   2. Combination Temperature and Humidity sensor/transmitter shall meet the following minimum requirements:
   3. Temperature:
a. Temperature Sensor: 100 or 1000 Ohm Pt RTD
b. Temperature Coefficient: 0.00385 ohm/ohm/°C
c. Accuracy: ±0.54°F + (0.005 X T) (Class B)
d. Accuracy: ±0.27°F + (0.005 X T) (Class A)
   T = Temperature of interest
e. Operating Range: -10 to 160°F
f. Supply Voltage: 18 to 36 VDC / VAC
g. Output Ranges: 2-wire, 4 to 20 mA or 3-wire, 0 to 5, 0 to 10 VDC or 4 to 20 mA (24 VAC)

4. Humidity:
   a. Temperature Compensated: Full range of rh signal
   b. Response Time: 30 seconds for 63% step
c. Accuracy Range: ±2% rh between 20 to 95% rh Span (including hysteresis, linearity repeatability).
d. Sensing Element: Resistance or Capacitance humidity sensor
e. Operating rh Range: 0 to 100% rh (non-condensing)
f. Supply Voltage: 24 VDC (current or voltage output) 24 VAC (contact factory)
g. Output Ranges: 4 to 20mA, 0 to 5V, 0 to 10V
h. Long Term Stability: Less than 2% rh drift per year

5. Enclosure shall be made of ABS Plastic or equivalent and include an optional LCD display on face of enclosure.

6. Optional LCD readout shall be capable of °C or °F operation with an adjustable display toggle switch to change from temperature to humidity display. Unit shall include capability of temperature and humidity setpoint value display during adjustment.

H. Dew Point Temperature Transmitter:
   1. Manufacturers: General Eastern, Kele & Associates or Vaisala
   2. Microprocessor type primary dew point temperature measurement using platinum RTD, 4 wire, 100 ohm temperature sensing element with 4-20 mA transmitter.
      a. Accuracy: ±1°F
      b. Repeatability: ±0.1°F
c. Hysteresis: None
d. Sensor Range: -10°F to +140°F dew point
      32°F to 140°F ambient
   3. Unit shall be selected for proper application (wall or duct mounted).

I. Ducted Air System Static Pressure and Differential Pressure (Velocity) Transmitters:
   1. Manufacturers: GE Modus, Setra, Ashcroft XLDP or approved equal
   2. Provide transducers/transmitters to convert velocity pressure differential or static duct pressure relative to sensor location into electronic signal.
   3. Unit shall be capable of transmitting linear 4 - 20 mA DC output signal proportional to differential (total minus static or static minus ambient) pressure input signals with the following minimum performance and application criteria:
a. Span: Not greater than twice duct static or velocity pressure at maximum flow rate, or more than 16 times velocity pressure at minimum flow rate.
b. Accuracy: ± 1.0% of span or ± 1.0% of full scale
c. Dead Band: Less than 0.5% of output
d. Hysteresis: Within 0.5% of span or within 0.5% of full scale
e. Linearity: Within 1.0% of span or within 0.5% of full scale
f. Repeatability: Within 0.5% of output
g. Response: Less than 1 second for full span input

4. Return and exhaust air system static pressure transducers/transmitters shall be furnished with protective integral air filters on pressure sensing lines from static pressure sensing stations and with static air probes to prevent migration of moisture and particulate matter into transducers. If inputs to pressure transducers/transmitters are dead-ended, integral air filters are not required. Supply air system sensors do not require integral air filters.

J. Space Pressure Monitoring System:

1. Manufacturers: Tek-Air Systems, TSI, or approved equal
2. Provide directional pressure monitoring system for clean rooms, isolation rooms, Biosafety research labs and hospital rooms. System shall include ultra-low differential pressure transmitter including thermal mass airflow sensor, two space pressure probes, room display for visual monitoring of space pressurization and LCD readout of space differential pressure.

3. Space pressure monitoring system shall have the following characteristics:
   a. Accuracy: ± 2% of set range.
   b. Pressure Range: 0.100 to -0.100° WC, full scale range, adjustable to ± 0.001, ± 0.005, to 0.010 or 0.10° WC.
   c. Analog Resolution: 0.0001° WC.
   d. Digital Resolution: ± 0.00005° WC.
   e. Output: 4-20 mA DC, self-powered, 5000 ohm load max.
   f. Power Supply: 24 VAC +/- 4 VAC, <10 VA.
   g. Communications: RS-485, RS-232, BACnet, or Ethernet.

K. BSL-3 and BSL-3(E) Room Pressure Differential Monitor:

1. Manufacturers for Differential Pressure Type: Critical Room Control, Paragon Controls Incorporated, Phoenix Controls, or approved equal
2. Provide ultra low differential pressure monitor connected to passive pressure probes located in each space to be monitored.
   a. Pressure probes shall have inline HEPA filters installed between sensing ports and monitor, as close to the pressure sensing ports as possible.
   b. Inline HEPA filters shall be 0.3 micrometer (99.999 % Retention) type; Cole-Parmer Model C-02909-60 or equivalent.
3. Monitor shall indicate pressure difference between each space with polarity indicating which space is positive or negative versus the reference space.
4. Monitor shall provide a linear output signal to BAS and local LCD/LED display.
   a. Two indicator lights on front panel show “Red” alarm light and “Green” normal light.
   b. Room pressure differential monitor shall have the following minimum characteristics:
      1). Pressure Range: ± 0.1° WC
      2). Accuracy: ± 1% of Full Scale Range
L. Building and Space Pressure Differential Transmitter:

1. Provide directional mass flow transmitter installed in 2" Schedule 40 black steel pipe between spaces to measure relative velocity created by pressure difference. Provide algorithm in software to convert air velocity to pressure differential \((\Delta P = C \left(\frac{V}{4005}\right)^2)\). Field determine coefficient \(C\) by calibrated measurement.

2. Air velocity transmitter shall be equal to Omega FMA-900 Series with the following characteristics:
   a. Accuracy: \(\pm 1.5\%\) full scale, \(\pm 0.5\%\) reading
   b. Repeatability: \(\pm 0.2\%\) of full scale
   c. Probe Temperature Range: \(-40^\circ F\) to \(250^\circ F\)
   d. Pressure Range: 150 psig, max
   e. Response Time: 400 msec. to within 63% of final value
   f. Output Signal: 4-20 mA
   g. Accessories: Compression Fittings - Omega 55 LK with Teflon Ferrules.

M. Industrial Grade Pressure/Differential Pressure Transmitter:


2. Pressure sensor and integral 4-20 mA VDC transmitter. Select instrument for intended usage (differential pressure, gauge pressure, level, etc.), range, maximum pressure/temperature. Sensor shall be capacitance or strain gauge type. Enclosure to be NEMA 4.

3. Differential pressure transmitters shall have 3-valve manifold for servicing.
   a. Diaphragm Material: Stainless Steel or Hastelloy
   b. Process Connection: 1/2" NPT Stainless Steel
   c. Power Supply Voltage: 13 - 35 VDC unregulated
   d. Over Pressure: 1000 psig or 2 times maximum operating pressure which ever is greater.
   e. Performance:
      1). Zero: Zero control shall be continuously adjustable between \(\pm 50\%\) of upper range limit. Total calibrated span and zero adjustment cannot exceed upper range limit. Zero span shall be independently field-adjustable with no interaction.
      2). Accuracy: \(\pm 0.25\%\) of calibrated span, including effects of linearity, hysteresis, repeatability dead band.
      3). Drift: \(\pm 0.1\%\) of upper limit for 6 months.
      4). Power Supply Effect: Less than 0.01% of output span per volt.
      5). Static Pressure Effect: Zero Error: \(\pm 0.1\%\) of upper range limit per 1000 psi
      6). Span Error: \(\pm 0.2\%\) of reading per 1000 psi
      7). Temperature Effect: \(\pm (0.025\%\) upper range limit plus 0.125% span) per 50°F
4. Provide remote sensing element(s) whenever operating temperature exceeds transmitter maximum temperature.

5. Five-Valve Manifold shall be provided for each hydronic pressure differential transmitter. Manifold can be field assembled or purchased as an assembly and shall include the following:
   a. Two isolation valves
   b. Two vent valves
   c. One equalizing valve

N. Differential Pressure Flow Element: Pitot Tube
   1. Manufacturers: Dieterich Standard, Preso, Veris Inc. or approved alternate
   2. These shall be averaging differential pressure type flow elements. Flow element shall consist of:
      a. Sensing tube with two internal chambers. One shall sense upstream pressure and one shall sense downstream pressure.
      b. These chambers shall have ports of quantity and size to accurately sense flowrate in piping line-size into which these are specified to be installed.
      c. Sensing tube shall have form so shaped as to minimize measurement inaccuracies.
      d. Sensing assemblies shall be provided with suitable supports to prevent damage to these assemblies at maximum flow-rate.
         1). Accuracy:  \( \text{Error} \pm 1.0\% \text{ of sensor rated range} \)
         2). Repeatability:  \( \text{Error} \pm 0.5\% \)
         3). Sensor Materials of Construction: Stainless Steel unless otherwise noted
   e. Insert/Retract "Hot Tap" including insertion device and isolation valve:
      1). Each sensor, which is required to be Hot-Tap shall be provided with isolating valve, packing gland and retraction tube assembly.
      2). Each sensor that is specified to be installed into line in which pressure is greater than 200 psig, or for acid or caustic service, or for hazardous chemical service shall be provided with retaining hardware to allow mechanical retraction and insertion.
   f. Refer to Section 23 2120 - Piping Specialties for Flow Sensors, provided for balancing purposes.

3. Five-Valve Manifold shall be provided for each hydronic pressure differential transmitter. Manifold can be field assembled or purchased as an assembly and shall include the following:
   a. Two isolation valves
   b. Two vent valves
   c. One equalizing valve

O. Magnetic Flowmeter/Transmitter:
   1. Manufacturers: Krohne, Fisher Rosemount, Invensys Foxboro or Yokogawa
   2. Electromagnetic induction type with linear response proportional to flow rate. Selected span shall be not greater than twice design flow range. Select units for 10:1 turndown.
   3. Unit shall be complete with 150 lb raised face flanged flowtube, PTFE, EPDM neoprene or PFA liner, magnetic coils, self-cleaning 316 stainless steel or Hastelloy C4 electrode, and 4-20 mA transmitter/power supply housed in NEMA 4 enclosure. Transmitter shall be fully field configurable microprocessor based unit.
      a. Minimum Accuracy:  \( \pm 0.5\% \text{ of Span including hysteresis} \)
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b. Repeatability: ± 0.1% of reading

c. Operating Temperature: 0-125°F

d. Power Requirements: 120 VAC / 60 Hz

4. Transmitter shall be integral mounted on flow meter.
5. Provide remote mounted indicator/transmitter. Indicator to be 1/2" LCD or back lit LED type.

A. Vortex Shedding Air Flow Sensors/Transmitters:
1. Manufacturers: Tek-Air
2. Velocity measured by each sensor shall be linearized, summed, averaged, and converted to
   4-20 mA output signal proportional to air flow rate (cfm) by transmitter electronics. Measured
   value converted to airflow (cfm) shall have accuracy within 2% rate ± 0.1% full scale
   throughout velocity range and temperature and humidity change of 40 to 130°F, and 10-95%
   rh (non-condensing). Transmitter shall be provided as part of air flow sensor, and shall
   include integral diagnostics with on-line zeroing and sensor operation verification.
3. Manufacturer shall provide cabling required to connect probe assemblies and transmitter
   electronics. Transmitter and/or systems, which require periodic calibration to maintain
   accuracy specified shall not be acceptable.

B. Insertion Type Turbine Flowmeter/Transmitter:
1. Manufacturers: EMCO, FTI Flow Technology, Onicon or approved equal
2. Provide turbine type flowmeter with hot tap type insertion assembly and microprocessor
   based transmitter. Selected span shall be not greater than twice design flow range. Select
   units for 10:1 turndown.
3. Hot tap assembly shall be insertion/extraction type with depth gauge and shutoff valve.
   Select turbine and body for intended service and pressure/temperature range. Transmitter
   shall have linear output of 4-20 mA with nominal 24 VDC power requirement. Enclosure
   shall be NEMA 4.
   a. Accuracy: ± 0.5% in linear range
   b. Repeatability: 0.25% in linear range
   c. Construction Materials:
      1). Non-wetted Parts: Aluminum
      2). Wetted Parts: 316 Stainless Steel
      3). Turbine: 17-4 pH Stainless Steel with tungsten carbide bearings
4. Transmitter shall be integral mounted on flow meter.
5. Provide remote mounted indicator/transmitter. Indicator shall be 1/2" LCD or back lit LED type.
6. Refer to Section 25 3003 - Process Instrumentation Device Specifications.

C. In-Line Turbine Flowmeter
1. Manufacturers: Brooks, EMCO, FTI Flow Technology, ABB Instrumentation, Aaliant
2. These shall be volumetric flow measuring and transmitting flow meters that produce output
   signals directly proportional to rate-of-flow process being measured.
3. Accuracy: Error ± 0.5% in linear range
4. Repeatability: Error ± 0.5%
5. Min Rangeability (Turndown): 10 to 1
6. Material of Construction:
   a. Body: Bronze
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b. Turbine: Reinforced polymer with stainless steel shaft and sapphire bearings
c. Body: Epoxy Coated Cast Iron
d. Turbine: Stainless Steel turbine with tungsten carbide bearings
e. Body: Stainless Steel
f. Turbine: Stainless Steel turbine with tungsten carbide bearings

7. Process Connection:
   a. Up to 2" line size: NPT
   b. 2" to 6": Wafer
c. 8": ANSI Class #150 Raised Face Flange

8. Process Connection: ANSI Class #150 Raised Face Flange
9. Process Connection: ANSI Class #300 Raised Face Flange
10. Process Connection: ANSI Class #600 Raised Face Flange
11. Local Indication: Digital (with resettable and non-resettable) or Mechanical Totalization
12. Output: 4-20 mA isolated current loop
13. Output: Frequency

14. Calibration Shift and Ambient Effects:
   a. Position: Transmitter shall operate in any position.
b. Vibration: Transmitter shall not be affected by industry normal piping vibration when operating within its normal range.
c. Ambient Temperature: Transmitter shall not be in error more than 1.0 % of span over change in ambient temperature of 100°F.

D. Ultrasonic Flowmeter:
1. Manufacturer: Krohne, Polysonics, FTI Flow Technology, GE Panametrics or approved alternate
2. These shall be transient time ultrasonic type flow meters to provide linear output signal proportional to flow rate. Sensors shall be mounted to pipe according to pipe size and materials per manufacturer’s installation instructions.
3. Instrument shall be microprocessor based and shall be fully field configurable via Highway Addressable Remote Transmitter (HART) communication protocol from controller.
   a. Sensor Mounting: Strap-on to pipe
   b. Converter Mounting: Remote Wall Mount
   c. Process Temperature Limits: 0°F to 300°F
d. Performance:
   1). Accuracy: ± 1.5% of Span
   2). Repeatability: ± 0.5% of Span

4. Process Media Requirements:
   a. Maximum Entrained Gas: 0.75% minimum
   b. Maximum Turbidity: 7500 ppm minimum

5. Power Requirements: 24 VDC or 120VAC / 60 Hz
6. Minimum Turn-Down: 10 to 1 of full scale
7. Minimum Enclosure Rating: NEMA 4
8. Output: 4-20 mA DC current or 10 kHz Frequency
9. Materials of Construction:
a. Sensor: 316 Stainless Steel
b. Strap Material: 316 Stainless Steel

10. Options:
   a. Local Indication: Digital LCD 3 digit minimum
   b. Smart Transmitter Protocol: HART

11. Calibration Shift and Ambient Effects:
   a. Position: Transmitter shall operate in any position.
   b. Vibration: Transmitter shall not be affected by industry normal piping vibration when operating within its normal range.
   c. Ambient Temperature: Transmitter shall not be in error more than 1.0 percent of span over change in ambient temperature of 100°F.

E. Vortex Flowmeter/Transmitter:
   1. Manufacturers: Invensys Foxboro, Yokogawa, Fisher Rosemount, ABB, or EMCO PhD Series
   2. Piezoelectric type with bluff body, separate downstream sensor, and 316 stainless steel wetted parts and NEMA 4 enclosure.
   3. Selected span shall be not greater than twice design flow range. Select units for 10:1 turndown.
      a. Temperature Range: 0-400°F
      b. Accuracy:
         1). Liquid: ± 1.0% of calibrated range
         2). Gas and Steam: ± 1.5% of calibrated range
      c. Power Supply: 14 - 30 VDC unregulated
      d. Output: 4 - 20 mA DC current
      e. Connection: ANSI Class 150 SS Raised Face Flange.
   4. Transmitter shall be integral mounted on flow meter.
   5. Provide remote mounted indicator/transmitter. Indicator shall be 1/2” LCD or back lit LED type.
   6. Refer to Section 25 3003 - Process Instrumentation Device Specifications.

F. Thermal Dispersion Air Flow Measurement Sensor/Transmitter:
   1. Manufacturers: Ebtron or approved equal
   2. Duct Mounted Flow Sensor:
      a. Multi-probe type thermal dispersion flow sensing station consisting of aluminum probe assembly with flanged connection and multiple hermetically sealed sensors in glass-filled polypropylene housing. Arrangement of sensors along probe assembly factory set to perform equal area traverse of duct cross section.
      b. Flow Sensor:
         1). Accuracy: ± 2% of reading
         2). Repeatability: ±0.25% of reading
         3). Materials:
            Probe – Aluminum
            Sensor Housing – Glass-Filled Polypropylene
            Mounting Brackets – 304 SS
4). Calibrated Range: 0 – 5,000 fpm
c. Temperature Sensor:
1). Accuracy: ± 0.15%
2). Sensor Temperature Range: -20°F to 160°F (0 – 1,500 fpm); 30°F to 160°F (>1,500 fpm)
3). Humidity Range: 0 – 99%, non-condensing
4). Probe Size Range: 8" to 120" 
d. Transmitter:
1). Power Requirements: 24 VAC (22.5 to 29 VAC), 8 VA max.
2). Enclosure: Aluminum Housing
3). Outputs: 4 to 20 mADC
4). Output Resolution: 0.025% of selected range
   a). Output 1: Airflow (0 – 5,000 fpm)
   b). Output 2: Temperature (-20°F to 160°F)
5). Ambient Temperature: -20°F to 120°F

G. Vortex Shedding Air Flow Sensors/Transmitters:
1. Manufacturers: Tek-Air
2. Velocity measured by each sensor shall be linearized, summed, averaged, and converted to 4-20 mA output signal proportional to air flow rate (cfm) by transmitter electronics. Measured value converted to airflow (cfm) shall have accuracy within 2% rate ± 0.1% full scale throughout velocity range and temperature and humidity change of 40 to 130°F, and 10-95% rh (non-condensing). Transmitter shall be provided as part of air flow sensor, and shall include integral diagnostics with on-line zeroing and sensor operation verification.
3. Manufacturer shall provide cabling required to connect probe assemblies and transmitter electronics. Transmitter and/or systems, which require periodic calibration to maintain accuracy specified shall not be acceptable.

H. Current Transformers:
1. Manufacturers: General Electric, Square D, Kele & Associates, N-K Technologies or Veris Industries
2. Alternating current transformers shall conform to latest applicable Standards including AEIC, EEI-NEMA, Standards for Instrument Transformers (MSJ-11) and ANSI Standard C57.13 for instrument transformers.
   a. Rated Voltage: 480 V
   b. Insulation Class: 600 V
   c. Basic Impulse Level: 60 Hz
   d. Short Time Current Rating: 100% (1 second)
   e. Accuracy Class: 0.3
   f. Continuous Current Rating: 150%

I. Rotary (Damper) Position Sensors:
1. Manufacturers: Kele & Associates, Fisher Controls or Westlock
2. Provide position 4-20 mA transmitter with potentiometer type (variable resistance) sensor for damper position measurement. Measurement to be linear to damper stroke.
   a. Performance:
      1). Power Supply: 24 VDC unregulated
2). Accuracy: ± 1% of output span
3). Repeatability: ± 0.5% of full span
4). Maximum Temperature: 125°F

J. Pressure (E-P) Transducers:
   1. Manufacturers: Brandt, Johnson Controls, Honeywell, Fairchild, Kele & Associates, Moore Industries, or TAC
   2. Units shall have following characteristics:
      a. Input 4-20 mA or 0-5 VDC
      b. Output 3-15 psig
      c. Linearity 1% of span
      d. Hysteresis 0.75% of span
      e. Maximum Air Consumption 0.008 scfm @ 20 psig

K. P-E Transducers (Pressure Transmitters):
   1. Manufacturers: Ashcroft, Mamac, Setra, Kele & Associates or GE Modus
   2. Units shall have the following characteristics:
      a. Input: Pressure 0-15 psig, minimum
      b. Output Signal: 4-20 mA, 0-5 VDC, 1-5 VDC, 1-10 VDC
      c. Accuracy: 1% of span
      d. Operating Temperature 32 to 125°F
      e. Power Requirements: 24 VDC (10-30 VDC)

L. Electronic Controllers:
   1. Manufacturers: Johnson Controls, Honeywell, or TAC
   2. Provide dedicated function type controllers with electronic analog and/or discrete electric type inputs and electronic analog and/or discrete electric type outputs, capable of performing sequences specified. Analog loop controllers shall have PID programs. Units shall have faceplate with adjustable setpoints, calibration, offset, gain factors, and visual display of parameters.

M. Fume Hood Velocity Control System:
   1. Manufacturers: TSI, Tek-Air, or Phoenix Controls
   2. Provide fume hood velocity control system with damper assembly, flow sensor, sash position or through wall velocity sensor, and microprocessor based controller. Damper assembly shall be equal to exhaust valve specified in Section 23 3600 - Air Terminal Devices.
   3. Velocity sensor shall be 316 stainless steel flow element compatible with controller.
   4. Provide local panel mounted on fume hood with visual and audible indication of face velocity, normal flow (green), low flow warning (yellow indication), and low-low flow alarm (red).
   5. Face velocity indication shall read in feet per minute and shall be either 2” analog indicator type or 1/2” digital readout.
   7. Calibrate velocity based on velocity through through-wall type sensor or based on duct velocity and sash position.

N. Capacitance Type Level Transmitter:
   1. Manufacturers: Drexelbrook, Magnetrol, or Endress & Hauser
2. Radio Frequency (RF) type continuous level probe with integral 4-20 mA transmitter. Output shall be linear to measured level. Probe shall have probe shielding to reject build up of conductive, sticky or viscous material. Probe length shall match vessel dimensions to measure within 6" of bottom.

3. Provide probe brace every 4 ft if probe length exceeds 6 ft and is not installed in stilling well.
   a. Supply Voltage: 120 VAC/60 Hz
   b. Output: 2 wire, 4-20 mA DC
   c. Fail Safe: Low Level output on instrument failure
   d. Ambient Temperature Limits: -40 to 160°F
   e. Minimum Enclosure Rating: NEMA 4
   f. Local Indicator: LCD meter
   g. Transmitter Mounting: Remote
   h. Performance:
      1). Accuracy: ± 2% nominal
      2). Linearity: ± 1% nominal
      3). Repeatability: ± 1% nominal
      4). Response Time: 20 milliseconds
      5). Ambient Temperature Effect: 2% per 100°F max.
      6). Voltage Variation Effect: ± 0.2% maximum per 10 V change

O. Air Quality Monitor:
   1. MSA, Toxalert, Vulcain, Honeywell, Texas Instruments, Vaisala, Kele & Associates, Automation Components Inc., BAPI, or approved equal
   2. Provide Air Quality Monitor as listed below for monitoring and control of minimum outside air for Building Areas. System shall be complete package with integral sensor, duct probe assembly, monitor, relay output, with local indication of current measured values for sensor and status of monitor. Device shall be housed in plastic enclosure. Indicator shall be mounted on enclosure faceplate.
   3. Unit shall have adjustable setpoints and self-test diagnostics.
      a. Gas to be Detected: Carbon Dioxide (CO₂)
      b. Power Requirements: 18 - 30 VAC, 50/60 Hz or 18-42 VDC
      c. Accuracy: ± 100 ppm
      d. Signal Input: Non-dispersive Infrared, Integral Sensor
      e. Signal Output: Linearized 0-10 VDC, or 4-20 mA DC
      f. Output Relay Rating: 2 Amp @ 24 VAC or 30 VDC
      g. Alarm Setpoint: User defined, software adjustable in 100 ppm increments via LCD or Interface Keypad
      h. Ranges: 0-2000 ppm
      i. Locations: Duct mounted in return duct or outside air plenum.
   4. Provide 120 VAC to 24 VAC transformer adjacent to Air Quality Monitor or provide 24 VAC from Temperature Control Panel nearest Air Quality Monitor.

P. Space CO₂ Sensors
   1. Manufacturers: Vaisala, Automation Components Inc., Toxalert, BAPI or approved alternate.
2. Provide Carbon Dioxide Monitor as listed below. The system shall be a complete package with integral sensor, monitor, alarm contacts, local indication of current measured value for sensor.
   a. Gas to be Detected: Carbon Dioxide (CO₂)
   b. Power Requirements: 24 VAC, 50/60 Hz, 50 VA
   c. Signal Input: Integral Sensor
   d. Signal Output: 4-20 mA DC or 0-10 VDC
   e. Alarm Relays: 1 Amps, 120 VAC, Form C
   f. Range: 0-2000 ppm
   g. Accuracy: ±75 ppm at 600 ppm and 1,000 ppm at sea level and 25°C
   h. Drift: ±5% of range over 5 years
   i. Sensor Infrared CO₂ Sensor
   j. Mounting: Wall-mounted

3. Provide local display for continuous reading of CO₂ levels. Data shall be recorded on system with DDC to the zone level.

4. Unit shall have adjustable set points and self-test diagnostics.

5. Sensor shall have barometric compensation capabilities.

6. Certified by manufacturer to require calibration no more frequently than once every 5 years. Provide 120 VAC to 24 VAC transformer adjacent to Air Quality Monitor or provide 24 VAC from Temperature Control Panel nearest Air Quality Monitor.

Q. Chart Recorders:
   1. Manufacturers: ABB, Invensys Foxboro, Yokogawa, Eurotherm Chessel or Honeywell
   2. Provide XXX channel chart recorder with one pen per channel. Unit shall be capable of receiving inputs matched to intended usage, 4-20 mA or 100 ohm RTD type. Unit shall be complete with NEMA 1 Enclosure, power supply, direct 3 digit LCD or LED readout, and pen controls.
   3. Unit shall be 7 day, 24 hour, 10" circular type.
   4. Unit shall be continuous chart line with take up roll.
   5. Unit shall be designed for surface mounting.
   6. Unit shall be designed for panel mounting.
      a. Performance:
      b. Accuracy: 0.1% of reading
      c. Hysteresis: 0.5%

PART 3 - EXECUTION

3.1 GENERAL

A. Install control equipment, wiring and air piping in neat and workmanlike manner and in accordance with manufacturer's recommendations. Maintain clearances, straight length distances, etc., required for proper operation of each device. Mark and detail on coordination drawings, exact locations of inline devices, wells, and taps to be installed by Mechanical Contractor.

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

C. Install control devices in accessible location.

D. Mount motor control devices within 5 ft of disconnect switch, or starting device furnished by Electrical Contractor unless noted otherwise. Maintain required NEC clearances.

E. Control Contractor and Mechanical Contractor shall review proposed static pressure sensor and flow meter locations with Owner and Engineer for approval prior to installation.

3.2 GENERAL INSTRUMENTATION

A. Thermometers (Temperature Indicators):
   1. Install thermometers at each point of temperature transmission and control, except for those that are indicated at local control panels. Install thermometers to permit easy reading from floor or operating platform (within 3 ft of line of sight). Provide remote bulb thermometers with readout indicators mounted within 3 ft of line of sight whenever sensing point is more than 3 ft from line of sight.
   2. Thermometer wells in piping will be installed by Mechanical Contractor.

B. Local Control Panels:
   1. Install remote mounted devices, controllers, I/O terminal blocks, power supplies, etc., inside of local control panels.
   2. Locate panels as shown on drawings.
   3. Locate panels adjacent to equipment served with minimum of 3 ft clearance in front of door. Provide sufficient clearances to allow full door swing and full access to internal components. Submit proposed panel locations with shop drawing submittals.
   4. Mount top of panels between 5 and 6 ft above floor so that gauges and indicators are at eye level.

C. Pressure Gauges (Pressure Indicators):
   1. Install pressure gauge for indication of supply and control pressure in pneumatic systems at output of controllers, I/P transducers, electric air solenoid valves, pressure switches and other points where visible indication of air pressure is required for operating and maintenance purposes.
   2. Provide test port for quick connection of test gauges at valve, damper motor and other actuator branch lines.
   3. Pressure gauge tappings in piping will be provided by Mechanical Contractor.

D. General Instrumentation at Local Control Panels:
   1. Provide record control drawings of systems served by each local panel, in location adjacent to or inside of panel cover. Provide protective cover for drawing.

3.3 DISCRETE AND ANALOG INSTRUMENTATION

A. Wall Mounted Space Thermostats/Temperature Sensors:
   1. Install space thermostats/sensors where indicated, as required to perform specified control sequences, and as directed to meet job site conditions.
   2. Provide space temperature sensors without remote setpoint adjustment in all public spaces, hallways, and mechanical rooms unless otherwise specified.
      a. Mount space thermostats/sensors at 5 ft above floor unless otherwise indicated.
b. Mount space thermostats/sensors with accessible setpoint adjustment or temperature reading (thermometer or digital temperature readout) at 4 ft above floor meeting ADA requirements.

3. Space thermostats/sensors located on exterior walls shall be mounted on thermally insulated sub-base.

4. Relocate space thermostats/sensors if required due to draft, interferences with cabinets, chalkboards, etc., or improper sensing.

5. Mount space thermostats/sensors in corridors, stairways and public toilets 7 ft above floor.

6. Space thermostats/sensors in gymnasium, locker rooms, corridor, stairways, vestibules and toilets shall be aspirating type.

7. Space thermostats/sensors in gymnasium, locker rooms and, XXX shall be protected by heavy-duty cast and die formed guard.

B. RTD Temperature Transmitters:
   1. Provide RTD temperature transmitters whenever DDCPs cannot receive RTD type inputs.

C. Low Limit Temperature Switches (Freeze Stats):
   1. Install low limit controls where indicated on drawings or as specified. Unless otherwise indicated, install sensing element on upstream face of cooling coil where cooling coil is provided, or at downstream side of heating coils where no cooling coil is provided.
   2. Distribute sensing element across entire area of medium being sensed. Install controls at accessible location with suitable mounting brackets and element duct collars where required.
   3. For low limit temperature sensors installed on roof top units and other outdoor equipment, install heaters in enclosures housing freeze stats to prevent freeze stat tripping.

D. Fume Hood Monitoring System:
   1. Coordinate installation of hood mounted equipment including alarm panel, sensor, wiring, etc. with fume hood manufacturer. Controls Contractor shall include cost of installation of controls at fume hood manufacturer's factory.

E. Static Pressure and Air Flow Stations:
   1. Furnish static pressure and air flow measuring stations to Mechanical Contractor for installation.
   2. Stations shall be installed in strict accordance with manufacturer's published requirements. These stations serve as primary signals for airflow control systems; therefore it shall be responsibility of Control Contractor to verify location and installation to assure that accurate primary signals are obtained.
   3. Pressure differential switches shall be piped across device creating differential between fan discharge and fan suction.

F. Outdoor Static Pressure Sensor:
   1. Furnish outdoor static pressure sensor as specified in control sequence. Mechanical Contractor will install sensor and associated pipe to below roof as shown on detail.

G. Direct Insertion Temperature Sensors:
   1. Install sensor so that sensor is pointed down stream.

H. Outside Air Temperature Sensors:
   1. Mount on north side of building or in intake area wells for air handling systems. Provide solar shields for installations where sensors may be exposed to sunlight conditions.
I. Building or Space Static Pressure Control System:
   1. Extend 2" pipe between spaces for room pressure control or between space and outside for building static pressure control. Mount velocity sensor in tee fitting with one foot of straight pipe on either side of sensor. Terminal space and points inside of sheet metal plenum attached to return/exhaust grille. Terminate outside sensors on prevailing windward side of building with flapper type damper and full weather cover shroud constructed of aluminum painted to match building exterior.

J. Water Flow Meters and Flow Switches:
   1. Install flow measuring devices with recommended straight pipe diameters upstream and downstream of elbows, tees, valves, or other fittings that cause uneven turbulent flow conditions.
   2. If no recommendations are given, provide straight pipe equal to 10 pipe diameters upstream and 5 pipe diameters downstream.

K. Sensor Wells:
   1. Wells mounted in pipe 3" and larger may be installed in horizontal or vertical lines provided that element is always in flow, (for condensate and other gravity return lines, install in bottom of pipe). Wells mounted in pipe 2-1/2" and smaller shall be installed at elbow tee fittings with well pointed upstream. Minimum of 2" pipe size for elbow tee installation.

L. Transmitters, Indicators, and Transducers:
   1. Locate transmitters at sensing devices or within 100 ft of remote mounted transmitters. For hot systems (150°F and higher) mount electronics on side of pipe or remotely mount. For indicating type instruments, locate indicating element within 6 ft of floor with readout easily visible from floor level. Provide remote readouts if necessary.
   2. Provide P-E transducers to convert analog pressure signals to analog electronic signals for input to DDC panels.
   3. Provide pressure transducers integral to DDC panels or separate components to convert digital analog signals to variable pneumatic air pressure signals.

M. Air Quality Monitors:
   1. Provide duct mounting hardware for mounting in return air duct and outside air duct. Where mounting in walk-in plenum, use wall mounted installation.
   2. Locate in duct with 3 diameters straight run of duct before monitor for good air flow pattern. Locate wall mounted units in area with good air flow representation.
   3. Provide 120 VAC to 24 VAC transformer where monitor requires 24 VAC power.

N. Aquastats:
   1. Aquastats for unit heaters and cabinet unit heats shall be mounted with sensing element in contact with leaving side of coil or the bottom of coil. If sensing element cannot be mounted in contact with coil, mount sensing element on pipe as close to discharge of coil as possible.

3.4 AIR PIPING

A. Conceal all piping, except for piping in mechanical rooms and other areas where mechanical system piping is exposed.

B. Install exposed piping and conduit parallel to or at right angles to building structure and support adequately at uniform intervals.
1. Provide tubing clamps with insulated standoffs where metallic tubing may come into contact with other dissimilar metals to prevent galvanic corrosion from occurring. Use of wire ties or hose clamps to fasten tubing to structure or other piping is not allowed.

2. Use of tubing channel designed for mounting polyethylene tubing shall be allowed.

C. Polyethylene tubing not exceeding 18" exposed may be used for connection to instrument or actuator.

D. Install polyethylene tubing with no concealed splices and number code all tubing.

E. Piping type shall be as follows:
   1. Inside Panels:
      a. Use polyethylene tubing.
   2. Exposed:
      a. Polyethylene tubing may be used if run in fully enclosed rigid metal raceway or metal conduit where environment is within temperature limits of polyethylene tubing. Use PVC coated copper tubing or stainless steel tubing for wet environments.
   3. Concealed:
      a. Use polyethylene tubing.

END OF SECTION
SECTION 23 0901
CONTROL SYSTEMS INTEGRATION

PART 1 - GENERAL

1.1 RELATED WORK

A. Section 20 0513 - Motors
B. Section 23 0550 - Vibration Isolation
C. Section 20-0514 – Variable Frequency Drive (VFD) System
D. Section 23 0902 - Control Valves And Dampers
E. Section 23 0903 - Control Instrumentation
F. Section 23 0923 - Direct Digital Controllers and Networks
G. Section 23 0993 - Control Sequences
H. Section 23 2118 - Valves
I. Section 23 3600 - Air Terminal Devices
J. Section 23 3614 - Laboratory Temperature and Airflow Control System
K. Section 26 0000 - General Electrical Requirements
L. Section 26 0533 - Raceway and Fittings
M. Section 26 0519 - Conductors and Cables
N. Section 23 8413 – Humidification Equipment
O. Section 26-0519 – Low-Voltage Electrical Power Conductors and Cables
P. Section 26-0533 – Raceway and Boxes for Electrical Systems
Q. Section 26-0926 – Lighting Control Systems
R. Section 26-2300 – Low Voltage Switchgear
S. Section 26-2713 – Electrical Metering
T. 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.

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

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. FLP: Fail Last Position
18. FMS: Facility Management System linking two or more BAS
19. FO: Fail Open position of control device or actuator. Device moves to open position on loss of control signal or energy source.
20. I/P: Current to pneumatic transducer
21. Instrument: Device used for sensing input parameters or used for actuation.
22. Modulating: Movement of control device through an entire range of values proportional to an infinitely variable input value.
23. Motorized: Control device with actuator
24. NC: Normally Closed position of switch after control signal is removed or normally closed position of manually operated valves or dampers.
25. NO: Normally Open position of switch after control signal is removed or normally open position of manually operated valves or dampers.
26. Node: DDCP, operator workstation, or other control device connected to communications network.
27. Operator: Same as actuator for motorized devices. Also refers to an individual who physically "operates" facility.
28. PC: Personal Computer
29. 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.

30. P: Proportional control, control mode with continuous linear relationship between observed input signal and final controlled output element.

31. 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).

32. 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).

33. Point: Analog or discrete instrument with addressable database value.

34. Self-Tune: Same as Auto-Tune

35. Solenoid: Electric two-position actuator. (See E/P.)

36. TCC: Temperature Control Contractor (Same as Control Contractor)

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

1. Johnson Controls, Inc.
2. Honeywell, Inc.
3. Distech
4. Vykon

A. 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:

1. Project Manager – 2 years
2. Controls applications Engineer – 2 years
3. Programmer – 2 years
4. Installation Supervisor – 2 years
5. Controls Technician – 5 years

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

C. Have experience with successful integrations of controls with Niagara Tridium systems.

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

E. 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.
F. 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. Provide supplementary BAS architecture, that is based on and consistent with the UK standard architecture, consisting of communication network, modular designed DDCPs with all points addressable and modifiable from existing BAS user workstations or from master DDCP using laptop computer. This system shall communicate with owner’s existing BACnet head-end software using BACnet/IP at the tier 1 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. BAS shall communicate via BACnet/MSTP or BACnet/IP communications protocol between the room level controllers and the building level controllers and BACnet/IP communications protocol between the building level controllers and the existing BAS server. All system components shall be fully BACnet compliant without the use of integration gateways. 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.

C. Provide all necessary BACnet-based-compliant 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. Provide all hardware and software to backup, restore, troubleshoot and install system.

D. 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.

E. 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.

F. 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.

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

H. 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.

J. 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.

K. 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.

1. Product Family: Niagara Framework, including N4 Web Supervisor, JACE 6XX at Release 3.8, JACE 8xxx at release 4.2 or greater using the most current version of JAVA or HTML 5.

L. 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.

M. 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.

N. Building Automation System (BAS) shall control building’s HVAC components and provide interface with Lighting Control System.

O. Division 27 Contractor shall provide Ethernet work connections for BAS equipment requiring network connects.

P. 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.

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

R. 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.

S. 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.

T. 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.

U. Safety devices shall function in both auto and hand modes on starter, and on VFD in auto, hand or bypass modes.

1. Dampers interlocked with fans shall operate in both auto and hand modes to prevent dead-head of fans.
2. Valves interlocked with pumps shall operate in both auto and hand modes of operation to prevent dead-head of pump.
3. All safeties shall be hardwired through starter/VFD safety circuit to prevent unsafe operation when in either auto or hand modes.

V. U. Safety devices shall function in both VFD and bypass modes.
1. Dampers interlocked with fans shall operate in both VFD and bypass starter modes to prevent dead-head of fans.
2. Valves interlocked with pumps shall operate in both VFD and bypass modes of operation to prevent dead-head of pump.
3. All safeties shall be hardwired through VFD/bypass starter safety circuit to prevent unsafe operation when in either VFD or bypass modes.

1.6 SCOPE OF WORK

A. Provide all labor and materials for complete fully functioning control systems in accordance with Contract Documents included in 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

B. 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.

C. 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.

D. 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.
   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.

E. 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.

F. 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.

G. 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 Electrical Rooms, Telecommunications Rooms and/or (IDF/EIDF) rooms, or as indicated on plans 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.

H. 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 the division 27 contractor.

I. Control Contractor shall be responsible to provide additional BAS data drops (from telecommunication room patch panel to field jacks/patch panels) that are not accounted for in the contract documents. Coordinate final Telecommunications room patch panel connections with network installation Contractor.

J. Control Contractor shall be responsible for maintaining master IP address list for all BAS devices throughout project to be handed over to Owner upon completion.

K. 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.

L. 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 Contractor.
at no additional cost to the Owner within two day working period from the time the problem was reported/discovered.

M. 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 Contractor within 2 days working period from the time the problem was reported.

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

O. All controls and wiring used for smoke control/life safety shall be UL 864 UUKL rated.

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

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

R. Contractor is responsible for integration of the following independent systems into BAS:

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.
   b. Electrical Metering
      1). 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.

2. Fire Alarm System (FAS) Monitoring:
   a. FAS provider will provide contact termination points and/or addressable relays for connection to BAS for Smoke Control and Equipment Shutdown. Contractor shall supply cabling, conduit, and hardware necessary to make connections from BAS to FAS. Contractor and FAS provider are responsible for coordination of testing point connections between systems, and joint commissioning of systems. Contractor to refer to P&ID’s, DDC Point Schedules and Control Sequences for programming and monitoring requirements.

3. 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.

4. Variable Frequency Drives (VFD):
   a. VFD provider will provide a termination point for a single point communication connection to the BAS utilizing BACnet MS/TP protocol. Contractor shall provide cabling and conduit to make an interface connection from the BAS to the VFD. Contractor and VFD provider responsible for 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 Section 20 0514 Variable Frequency Drive (VFD) System 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. All applicable software as detailed in this specification shall be updated by the EMS 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 Contractor.

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. 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. Data sheets shall include sufficient technical data to describe instrument parameters required as specified.
   2. 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
   3. Control contractor is required to bubble all changes when resubmitting shop drawings and schedules.
   4. BAS manuals to be in two parts: 1) Operation and maintenance, and 2) System application manuals.
5. One (1) electronic copy of BAS manuals shall be provided to Physical Plant by BAS contractor at date of submittal completion.

6. Submit data concerning type of signal wiring and installation methods including raceway types and grounding methods.
   a. Submit voltage drop calculations for all low voltage DDC circuits. Voltage drop to include number of devices and wiring run lengths, calculated voltage available at each device.

7. Submit control drawings in pdf format with bookmarks provided for each system and table of contents with links to each page. Control drawings shall include, but are not limited to, the following:
   a. Front sheet index for projects with more than 10 shop drawing sheets.
   b. 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.
   c. 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.
   d. Detailed wiring and piping diagrams showing point-to-point hookup details of transducers, relays, outputs, inputs and subsystem components. Label pneumatic lines and control wires with field ID numbers/colors.
   e. Bill of material identifying actual product model number used for each control device for each schematic control drawing.
      1) Bill of material shall be included on flow diagrams for each system and on panel layouts showing panel components.
   f. Drawings showing proposed locations of sensors and flow meters in ductwork and piping systems.
   g. Sequence of operation: Provide written narrative describing each control sequence indicating method of control. Identify sensors, controllers, and actuators used with references to tag number of controlled device. Include set points of each control loop.
   h. BACnet Compliance Documentation: The Protocol Implementation Conformance Statement for each component.

8. Control Instrumentation (23 0903) and Direct Digital Controllers and Networks (23 0923) submittals can be submitted as separate submittals from control shop drawings but must be submitted simultaneously with control shop drawings.

9. 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.

10. 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.

11. 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.

12. 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.

   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.

14. BACnet Compliance Documentation:
   a. The Protocol Implementation Conformance Statement (PICS) for each component.

15. 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

16. 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.

17. 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.

18. 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.

C. 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. BAS Ethernet network testing and benchmarking documentation showing network performance from switch to switch.

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

D. 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.

E. The following chart is supplied for the benefit of the Owner, Architect, Engineer and contractor to assure a complete submission of required information. It is a reference listing of documents required by the Specifications under this Section. Refer to Specifications Section - General Provisions for the general requirements of submittals.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>SHOP DRAWING</th>
<th>M&amp;O MANUAL</th>
<th>PARTS LIST</th>
<th>WRITTEN DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control equipment</td>
<td>x</td>
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<tr>
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<td>“As-builts” drawings</td>
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<td>Frequency drives</td>
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<tr>
<td>Air terminal units</td>
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<td></td>
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<td>x</td>
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<tr>
<td>I/O Summary Charts</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

1.8 WARRANTY

A. Warranty period shall begin as authorized by the Owner’s representative in writing. 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.
B. Warranty shall cover all costs for parts, labor, associated travel, and expenses for a period of one year from completion of system acceptance.

C. 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.

D. This warranty shall apply equally to both hardware and software. All applicable software as detailed in this specification shall be updated by the EMS 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 Contractor.

E. 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.

F. 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.

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

H. 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.

I. 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.
J. 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.

K. 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.

L. 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 system and continued operation.

1.10 OPERATION AND MAINTENANCE MANUALS

A. Refer to Division 01 - General Requirements.
   1. Two (2) 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.

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.
   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.
   5. Submit a copy of all graphic page files created during the execution of the project.
   6. Submit a copy of all secondary graphic files such as bitmaps, jpegs, etc. that were used in the creation of the graphic pages.

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. 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. 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 (MOV$s) 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.).
   5. Stranded twisted/shielded control conductors are required with shields to be terminated within variable frequency Drive enclosures to reduce effects of noise from VFD. Follow VFD manufacturer's installation instructions for wiring control conductors to VFD.

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. 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.

G. 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 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 4 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.

### 2.3 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. During construction, Contractor shall take necessary precautions to ensure all panels, wiring, instrumentation, etc. are kept clean and dry. Upon Project completion, control panels shall be clean of wire nuts, trash, and wire stripping. All excess material is to be turned over to Owner BAS group.

I. BAS floor level network to room/equipment controllers shall be confined to the same floor the respective building level controller is located on.

1. In applications where the floor level network must transition between floors, the transition shall be located in a clearly marked junction box on each floor of appropriate size to accommodate a screw terminal strip. Network cabling shall be labeled to indicate the previous connection prior to entering the junction box with the terminal strip. Terminal strip shall be used as a transition point from one floor to the next. Terminal strip shall be large enough to accommodate transitions to and from the floors below and above if floor transitioning is required.

3.2 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 motor 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 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 metal conduit or raceway system. Refer to Division 26 - Electrical for additional requirements.

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. Where penetrations of fire-rated assemblies are involved, seal penetrations with appropriate firestopping systems as specified in Section 26 0000 – General Electrical Requirements.

G. 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.

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

J. Low voltage wiring concealed above accessible ceilings does not require raceway. Cables not
   in raceway shall be routed along building structure lines using Bridal Rings, J-hooks or other
   mounting methods as approved by Engineer. Use of wire-ties for attaching cabling to duct
   brackets, piping or structure is not acceptable. Diagonal routing is not allowed. Label each cable
   not in raceway with unique wire ID number every 50 ft.

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

L. 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. 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. All communication/power/signal wiring terminating in a control panel/enclosure/junction box shall
   be provided with a minimum of 3” – 6” extra wiring length. Extra cable shall be loosely
   folded/looped and stored neatly in wireways or cable tray/headers above control panel.

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.

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

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

<table>
<thead>
<tr>
<th>Type</th>
<th>Configuration</th>
<th>Colors</th>
<th>Manufacturer Part No.</th>
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<tbody>
<tr>
<td>120 VAC, 14 AWG</td>
<td>2 Cond., Unshielded, Non-Plenum Rated</td>
<td>Cond. 1 - BLK</td>
<td>Belden 9411</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cond. 2 - RED</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jacket - Gray PVC</td>
<td></td>
</tr>
<tr>
<td>120 VAC, 14 AWG</td>
<td>3 Cond., Unshielded, Non-Plenum Rated</td>
<td>Cond. 1 - BLK</td>
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<td>Type</td>
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<td>Discrete Output, 18</td>
<td>Cond. 1 - BLK</td>
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### Type | Configuration | Colors | Manufacturer
---|---|---|---
AWG | Plenum Rated | Cond. 2 - RED, Jacket - Red FEP | 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
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

**R.** [Control Contractor's Company] [Owner's] standard cabling and color codes may be used instead of above specified cabling and color codes.

**S.** 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.

T. 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.

3.3 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.

E. 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.
3.4 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.

3.5 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. At the end of the project, the contractor is to supply a digital back-up copy of the final complete operating controls program.

3.6 SYSTEM START-UP AND ACCEPTANCE:

A. 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, 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.

B. This Contractor shall work with the Owner, who is developing the graphics, to ensure that all points report, function and alarm as required on the BACnet head-in 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 will assign all BACnet instance numbers for use by the Contractor.

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 16 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. Course content shall include, but not be limited to, the following topics:
   1. Classroom training will occur at a classroom location on the University of Kentucky campus coordinated with the Project Manager and PPDMC.
   2. Explanation of control sequences. Include which sensors are used and how output device operates.
   3. Explanation of control drawings and manuals, including symbols, abbreviations, and overall organization.
   4. Walk-through of Project to identify controller locations and general routing of network cabling.
   5. Review of operation and maintenance of hardware devices including air compressor, air dryers, controllers, instruments, and sensors. Include schedule for routine maintenance.
   6. Review of operation of operator's workstation; include hardware (PC's, printers, etc.).
   7. Review of operator's workstation software using specific examples of operating hardware.
   8. Review of portable operator's workstation software using specific examples of operating hardware.
   9. Programming Application Specific Controllers
      a). Backing up and Restoring Application Specific Programming
      b). Adding/Deleting/Editing points on Application Specific controllers
      c). Troubleshooting Application Specific controllers (inputs/outputs/logic/master – slave relationships/bus issues)
   10. Programming Building Specific Controllers
       a). Backing up and Restoring Building Specific Controllers Programming
       b). Adding/Deleting/Editing points on Building Specific Controllers controllers
       c). Troubleshooting Building Specific Controllers controllers (inputs/outputs/logic/network issues)
   11. How to use tools and cables
       a). Hands-on at the job site training.
   12. Any additional item(s) specifically requested by Owner.

D. 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.

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

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

END OF SECTION
Qualification Form

<table>
<thead>
<tr>
<th>Brief resume of key persons, specialists, and individual consultants anticipated for this project:</th>
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<tbody>
<tr>
<td>a. Name &amp; Title:</td>
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<tr>
<td>c. Name of Firm with which Associated:</td>
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<tr>
<td>With this Firm_________ Other firms____________</td>
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<td>e. Education: Degree(s)/Year/Specialization</td>
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<tr>
<td>g. Other experience and qualifications relevant to the proposed project (include training courses/certifications):</td>
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</table>

**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
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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.
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.
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 initiated when this criteria and the minimum send time requirement have been met. Also referred to as a “Change of Value”.

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AND NETWORKS
Project No. 13848.02
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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 DDC controllers shall be provided by the same manufacturer.

4. 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).

5. 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.

6. Provide input modules capable of interfacing with pulsed output type sensors as required.

7. 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.

8. 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.

9. 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.

10. Failure of network or control devices (i.e. building level controllers, floor level controllers, application specific controllers, routers, repeaters, etc.) shall be alarmed at the Operator Workstation as a Level 3 Critical Alarm.

11. 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.

12. 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.

13. 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.

B. BACnet Building Controller (B-BC):

1. All B-BC controllers shall have open licensing to connect to existing UK PPDMC Tridium BACnet BAS.

2. B-BC shall be from one of the following manufactures:
   a. Honeywell
   b. Johnson Controls
   c. Vykon

2.3. 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.

3.4. Building Controller shall as a minimum support MS/TP and Ethernet BACnet LAN types. It shall communicate directly via these BACnet LANs as a native 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

4.5. Communication between B-BC’s shall be through BACnet/IP communication. 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).

5.6. 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.

6.7. 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.

7.8. Batteries shall maintain volatile memory and 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

8.9. All database and backup shall be provided to the UK PPDMC Controls group.

9.10. B-BC Naming Convention
   a. B-BC devices shall be named using the following naming convention:
   b. B-BC devices shall be named using the following format:
   c. Building_Floor_RoomNumber_B-BC Device Type
   d. All B-AAC points shall be named using the following format:
   e. Building_Floor_RoomNumber_Device Type_Equipment ShortName_Function
10.11. Provide local visual indication and system annunciation of low battery power for each battery.

11.12. Each B-BC shall include its own micro-processor, power supply, input/output modules, and termination modules as required to perform intended function.

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

13.14. 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.

14.15. 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.

15.16. 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.

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

1. B-AACs are defined as having sufficient processor capabilities and RAM to implement all types of custom software applications.

2. B-AACs shall be capable of communicating to BAS network via BACnet MS/TP connected to Building Controller or via BACnet/IP directly.

3. All B-AACs controlling major mechanical equipment/systems and lab equipment monitoring shall communicate via BACnet/IP as indicated on BAS Network Architecture drawings.

4. Provide at least one extra communication port at each B-AAC for direct connecting a notebook computer or hand-held terminal.

5. All B-AAC controllers shall have open licensing to connect to existing UK PPDMC Tridium BACnet BAS.

6. 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.

7. 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.

8. 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.

9. 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.

10. B-AAC Naming Convention

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

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

   c. Building_Floor_RoomNumber_B-AAC Device Type_Equipment Short Name

D. BACnet Application Specific Controllers (B-ASC):
1. 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.

2. Application specific DDC Controller shall be capable of communicating to BAS network via low/medium speed network connected to B-BC.

3. 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.

4. 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.

5. B-ASC Naming Convention
   a. B-ASC devices shall be named using the following naming convention:
   b. B-ASC devices shall be named using the following format:
   c. Building_Floor_RoomNumber_B-ASC Device Type

E. BACnet Router
   1. BACnet MS/TP to BACnet/IP 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.

G. Non-Volatile Memory
   1. All control sequences programmed into the B-BC, and 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 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.
   2. All control sequences shall be fully programmable at the B-AAC and B-ASC, allowing for the creation and editing of an application control sequence, while at the unit.
   3. 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.
   4. The B-AAC, 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. The samples shall be protected against loss due to power interruptions through a battery or capacitor backup method for a minimum of 30 days.

5. 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.

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

7. 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.

### 2.2 DIRECT DIGITAL CONTROL SOFTWARE

**A. General:**

1. DDC Controller control strategies shall be Owner definable from engineering workstations.
2. 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.
3. 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.
4. 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.
5. Provide access control (user defined passwords) for system operation. There shall be a 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.
6. Each DDC Controller shall contain self-diagnostics that continuously monitor proper operation of panel.
7. If microprocessor malfunctions, control loop outputs shall continue to function using last value received from microprocessor.

**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.

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 XXX Engineering Workstations and XXX laptops.

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, signal repeaters, network hubs, etc.

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, converters, 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 as follows:
a. XXX Digital Inputs
b. XXX Digital Outputs
c. XXX Analog Inputs
d. XXX Analog Outputs

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 for air terminals 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.
   2. All control cabinets shall be labeled. Labels shall be keyed to the unique identifiers shown on the As-Built drawings

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.

F. Redundant Controls
   1. Redundant controls will be required where the loss of single controller will shut down entire system.
      a. Redundant controls shall utilize a master controller to share the system pump/AHU fan speed control signal to individual pump controllers or AHU controllers in the system. Redundant controls shall be designed to prevent domination by one controller during normal operation. When a single pump or AHU controller fails or communication network fails, remaining pump/AHU controllers shall continue to operate to provide water/air flow to critical areas.
   2. Redundant controls would be required but not limited to the following systems:
      a. CUP chilled water pumps
      b. Data center chilled water systems
      c. Surgery air handling systems
      d. Critical patient care air handling systems
      e. Critical process cooling water systems
   3. Provide UPS power for redundant control systems

3.4 CONTROL PANELS

A. 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.

B. As far as is practical, the control components for each system shall be grouped. Provide each group of components with identification.
C. 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.

D. 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.

E. Panel-Mounted Equipment: Temperature and humidity controllers, relays, and automatic switches; except safety devices. Mount devices with adjustments accessible through front of panel.

F. Door-Mounted Equipment: Flush-mount (on hinged door) manual switches, including damper-positioning switches, changeover switches, thermometers, and gages.

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

3.5 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.

F. 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 only Windows Internet Explorer. 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 Medical Center 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 configuration and programming tools required for the upgraded version must be provided at the time of installation.

3.6 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. Assign unique numbers to each new network installed on the BACnet internetwork. 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.
<table>
<thead>
<tr>
<th>Priority Level</th>
<th>Application</th>
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<tbody>
<tr>
<td>1</td>
<td>Manual-Life Safety</td>
</tr>
<tr>
<td>2</td>
<td>Automatic-Life Safety</td>
</tr>
<tr>
<td>3</td>
<td>(User Defined)</td>
</tr>
<tr>
<td>4</td>
<td>(User Defined)</td>
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<tr>
<td>5</td>
<td>Critical Equipment Control</td>
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<tr>
<td>6</td>
<td>Minimum On/Off</td>
</tr>
<tr>
<td>7</td>
<td>(User Defined)</td>
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<tr>
<td>8</td>
<td>Manual Operator</td>
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<td>9</td>
<td>(User Defined)</td>
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<td>10</td>
<td>(User Defined)</td>
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<td>11</td>
<td>Load Shedding</td>
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<td>(User Defined)</td>
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<td>16</td>
<td>(User Defined)</td>
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</tbody>
</table>

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 network 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 inputs and analog outputs shall be trended and shall fully configured and operational. Sample time shall be one minute.
2. Program historical file for run-times and quantity of start/stops of motor driven equipment
3. Trend logs are to be stored at the building controllers and uploaded to the BAS web server or data historian when the building controller trend buffer size reaches 90% full or every 30 minutes (FA).
4. Data points indicated to as “LEED M&V” in the DDC Point Schedules shall be have a sampling
time of one minute and averaged over 15 minutes.

I. Alarm/Event Management:
   1. All alarm handling shall be fully configured with consistent alarm messages and priorities or
category numbers to identify the system from which the alarm originates.

J. Provide programming of menus to assist new users in accessing screen displays of each point
group. Point groups (user definable) shall be initially arranged by DDC Controller for major
equipment and by floor and area for terminal devices. Terminal devices shall also be grouped by
air handling system where applicable.

K. 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. Controls Contractor shall verify with Owner if any
standard naming conventions are being used and continue with those naming conventions when
applicable.

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

M. 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.

N. 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, routers and repeaters.)
   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.

O. 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.
3.7 **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 programmed with a point name and detailed description. Control contractor shall submit point naming convention to Laboratory/Engineer for approval prior to system programming.

C. Work jointly with Owner to develop point naming convention prior to start of programming.

3.8 **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.

3.9 **GRAPHICS PROGRAMMING**

A. Graphics shall be provided by the University of Kentucky and are not required by the controls contractor. Coordinate with Owner’s graphics programmer to ensure all points are exposed and that all specified points and alarms operate and communicate with the Tridium BAS.

END OF SECTION