1. **Part 1 – General**

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   **1.1 Related Documents**

   **A.** All work of this Division shall be coordinated and provided by a single Building Automation Controls System (BACS) Contractor, approved contractor shall be Johnson Controls, Inc. (JCI Factory Office). Pricing shall be based on the current State of Kansas contract. JCI will subcontract to the Mechanical Contractor, unless otherwise directed by the DCM Project Manager.

   **B.** The work of this Division shall be scheduled, coordinated, and interfaced with the associated work of other trades.

   **C.** The work of this Division shall be as required by the Specifications, Point Schedules and Drawings.

   **D.** If the BACS Contractor believes there are conflicts or missing information in the project documents, the Contractor shall promptly request clarification and instruction from the design team.

   **1.2 Definitions**

   **A.** Analog: A continuously variable system or value not having discrete levels. Typically exists within a defined range of limiting values.
B. Binary: A two-state system where an “ON” condition is represented by one discrete signal level and an “OFF” condition is represented by a second discrete signal level.

C. Building Automation Controls System (BACS): The total integrated system of fully operational and functional elements, including equipment, software, programming, and associated materials, to be provided by this Division BACS Contractor and to be interfaced to the associated work of other related trades.

D. BACS Contractor: The single Contractor to provide the work of this Division. This Contractor shall be the primary manufacturer, installer, commissioner and ongoing service provider for the BACS work.

E. Control Sequence: An BACS pre-programmed arrangement of software algorithms, logical computation, target values and limits as required to attain the defined operational control objectives.

F. Direct Digital Control: The digital algorithms and pre-defined arrangements included in the BACS software to provide direct closed-loop control for the designated equipment and controlled variables. Inclusive of Proportional, Derivative and Integral control algorithms together with target values, limits, logical functions, arithmetic functions, constant values, timing considerations and the like.

G. BACS Network: The total digital on-line real-time interconnected configuration of BACS digital processing units, workstations, panels, sub-panels, controllers, devices and associated elements individually known as network nodes. May exist as one or more fully interfaced and integrated sub-networks, LAN, WAN or the like.

H. Node: A digitally programmable entity existing on the BACS network.

I. BACS Integration: The complete functional and operational interconnection and interfacing of all BACS work elements and nodes in compliance with all applicable codes, standards and ordinances so as to provide a single coherent BACS as required by this Division.

J. Provide: The term “Provide” and its derivatives when used in this Division shall mean to furnish, install in place, connect, calibrate, test, commission, warrant, document and supply the associated required services ready for operation.

K. PC: IBM-compatible Personal Computer from a recognized major manufacturer

L. Furnish: The term “Furnish” and its derivatives when used in this Division shall mean supply at the BACS Contractor’s cost to the designated third party trade contractor for installation. BACS Contractor shall connect furnished items to the BACS, calibrate, test, commission, warrant and document.

M. Wiring: The term “Wiring” and its derivatives when used in this Division shall mean provide the BACS wiring and terminations.

N. Install: The term “Install” and its derivatives when used in this Division shall mean receive at the jobsite and mount.

O. Protocol: The term “protocol” and its derivatives when used in this Division shall mean a defined set of rules and standards governing the on-line exchange of data between BACS network nodes.

P. Software: The term “software” and its derivatives when used in this Division shall mean all of programmed digital processor software, preprogrammed firmware and project specific digital process programming and database entries and definitions as generally understood in the BACS industry for real-time, on-line, integrated BACS configurations.
Q. The use of words in the singular in these Division documents shall not be considered as limiting when other indications in these documents denote that more than one such item is being referenced.

R. Headings, paragraph numbers, titles, shading, bolding, underscores, clouds and other symbolic interpretation aids included in the Division documents are for general information only and are to assist in the reading and interpretation of these Documents.

S. The following abbreviations and acronyms may be used in describing the work of this Division:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC</td>
<td>Analog to Digital Converter</td>
</tr>
<tr>
<td>AI</td>
<td>Analog Input</td>
</tr>
<tr>
<td>AN</td>
<td>Application Node</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>AO</td>
<td>Analog Output</td>
</tr>
<tr>
<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
</tr>
<tr>
<td>ASHRAE</td>
<td>American Society of Heating, Refrigeration and Air Conditioning Engineers</td>
</tr>
<tr>
<td>AWG</td>
<td>American Wire Gauge</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
</tr>
<tr>
<td>CRT</td>
<td>Cathode Ray Tube</td>
</tr>
<tr>
<td>DAC</td>
<td>Digital to Analog Converter</td>
</tr>
<tr>
<td>DDC</td>
<td>Direct Digital Control</td>
</tr>
<tr>
<td>DI</td>
<td>Digital Input</td>
</tr>
<tr>
<td>DO</td>
<td>Digital Output</td>
</tr>
<tr>
<td>EEPROM</td>
<td>Electronically Erasable Programmable Read Only Memory</td>
</tr>
<tr>
<td>EMI</td>
<td>Electromagnetic Interference</td>
</tr>
<tr>
<td>FAS</td>
<td>Fire Alarm Detection and Annunciation System</td>
</tr>
<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
</tr>
<tr>
<td>HOA</td>
<td>Hand-Off-Auto</td>
</tr>
<tr>
<td>ID</td>
<td>Identification</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>I/O</td>
<td>Input/Output</td>
</tr>
<tr>
<td>LAN</td>
<td>Local Area Network</td>
</tr>
<tr>
<td>LCD</td>
<td>Liquid Crystal Display</td>
</tr>
<tr>
<td>LED</td>
<td>Light Emitting Diode</td>
</tr>
<tr>
<td>MCC</td>
<td>Motor Control Center</td>
</tr>
<tr>
<td>NC</td>
<td>Normally Closed</td>
</tr>
<tr>
<td>NIC</td>
<td>Not In Contract</td>
</tr>
<tr>
<td>NO</td>
<td>Normally Open</td>
</tr>
<tr>
<td>OWS</td>
<td>Operator Workstation</td>
</tr>
<tr>
<td>OAT</td>
<td>Outdoor Air Temperature</td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer</td>
</tr>
<tr>
<td>RAM</td>
<td>Random Access Memory</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>RFI</td>
<td>Radio Frequency Interference</td>
</tr>
<tr>
<td>RH</td>
<td>Relative Humidity</td>
</tr>
<tr>
<td>ROM</td>
<td>Read Only Memory</td>
</tr>
<tr>
<td>RTD</td>
<td>Resistance Temperature Device</td>
</tr>
<tr>
<td>SPDT</td>
<td>Single Pole Double Throw</td>
</tr>
</tbody>
</table>
1.3 BACS Description

A. The Building Automation Controls System (BACS) shall be a complete system designed for use with the enterprise IT systems. This functionality shall extend into the equipment rooms. Devices residing on the automation network located in equipment rooms and similar shall be fully IT compatible devices that mount and communicate directly on the IT infrastructure in the facility. Contractor shall be responsible for coordination with the owner’s IT staff to ensure that the BACS will perform in the owner’s environment without disruption to any of the other activities taking place on that LAN.

B. All points of user interface shall be on standard PCs that do not require the purchase of any special software from the BACS manufacturer for use as a building operations terminal. The primary point of interface on these PCs will be a standard Web Browser.

C. All work on this project shall be loaded onto the existing Johnson Controls server located in the Computer Services Facility. Database will be updated to reflect all new systems resulting from the execution of this project for consistent user interface and data archiving across the JCI BACS network.

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

E. The BACS work shall consist of the provision of all labor, materials, tools, equipment, software, software licenses, software configurations and database entries, interfaces, wiring, tubing, installation, labeling, engineering, calibration, documentation, samples, submittals, testing, commissioning, training services, permits and licenses, transportation, shipping, handling, administration, supervision, management, insurance, temporary protection, cleaning, cutting and patching, warranties, services, and items, even though these may not be specifically mentioned in these Division documents which are required for the complete, fully functional and commissioned BACS.

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

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

H. The BACS as provided shall incorporate, at minimum, the following integrated features, functions and services:
   1. Operator information, alarm management and control functions.
   2. Enterprise-level information and control access.
3. Information management including monitoring, transmission, archiving, retrieval, and reporting functions.
4. Diagnostic monitoring and reporting of BACS functions.
5. Offsite monitoring and management access.
7. Standard applications for terminal HVAC systems.
8. Energy Reporting of Utility Data

1.4 Work By Others

A) The demarcation of work and responsibilities between the BACS Contractor and other related trades shall be as outlined in the BACS RESPONSIBILITY MATRIX

<table>
<thead>
<tr>
<th>BACS RESPONSIBILITY MATRIX</th>
<th>FURNISH</th>
<th>INSTALL</th>
<th>Low Volt. WIRING/Tube</th>
<th>LINE POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>BACS low voltage and communication wiring</td>
<td>BACS</td>
<td>BACS</td>
<td>BACS</td>
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</tr>
<tr>
<td>VAV box nodes</td>
<td>BACS</td>
<td>23</td>
<td>BACS</td>
<td>26</td>
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<tr>
<td>BACS conduits and raceway</td>
<td>BACS</td>
<td>BACS</td>
<td>BACS</td>
<td>BACS</td>
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<tr>
<td>Automatic dampers</td>
<td>BACS</td>
<td>23</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Manual valves</td>
<td>23</td>
<td>23</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Automatic valves</td>
<td>BACS</td>
<td>23</td>
<td>BACS</td>
<td>N/A</td>
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<tr>
<td>VAV boxes</td>
<td>23</td>
<td>23</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Pipe insertion devices and taps including thermowells, flow and pressure stations.</td>
<td>BACS</td>
<td>23</td>
<td>BACS</td>
<td>BACS</td>
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<tr>
<td>BACS Current Switches.</td>
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<td>BACS</td>
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<td>N/A</td>
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<tr>
<td>BACS Control Relays</td>
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<td>BACS</td>
<td>BACS</td>
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<tr>
<td>Power distribution system monitoring interfaces</td>
<td>26</td>
<td>26</td>
<td>BACS</td>
<td>26</td>
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<tr>
<td>BACS interface with Chiller controls</td>
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<td>BACS</td>
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<tr>
<td>Chiller controls interface with BACS</td>
<td>23</td>
<td>23</td>
<td>BACS</td>
<td>26</td>
</tr>
<tr>
<td>BACS interface with Classroom unit controls</td>
<td>BACS</td>
<td>BACS</td>
<td>BACS</td>
<td>26</td>
</tr>
<tr>
<td>Classroom unit controls interface with BACS</td>
<td>23</td>
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<td>26</td>
</tr>
<tr>
<td>ADD OTHER THIRD PARTY EQUIPMENT HERE</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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</tr>
<tr>
<td>All BACS Nodes, equipment, housings, enclosures and panels.</td>
<td>BACS</td>
<td>BACS</td>
<td>BACS</td>
<td>BACS</td>
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<tr>
<td>Smoke Detectors</td>
<td>26</td>
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<tr>
<td>Fire/Smoke Dampers</td>
<td>23</td>
<td>23</td>
<td>BACS</td>
<td>26</td>
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<tr>
<td>Fire Dampers</td>
<td>23</td>
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<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Chiller Flow Switches</td>
<td>23</td>
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<td>BACS</td>
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<tr>
<td>Boiler wiring</td>
<td>23</td>
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<tr>
<td>Water treatment system</td>
<td>23</td>
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<td>26</td>
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<tr>
<td>VFDs</td>
<td>23</td>
<td>26</td>
<td>BACS</td>
<td>26</td>
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<tr>
<td>Refrigerant monitors</td>
<td>23</td>
<td>BACS</td>
<td>BACS</td>
<td>26</td>
</tr>
<tr>
<td>Computer Room A/C Unit field-mounted controls</td>
<td>23*</td>
<td>23</td>
<td>BACS</td>
<td>26</td>
</tr>
<tr>
<td>Fire Alarm shutdown relay interlock wiring</td>
<td>26</td>
<td>26</td>
<td>26</td>
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<tr>
<td>Fire Alarm smoke control relay interlock wiring</td>
<td>26</td>
<td>26</td>
<td>BACS</td>
<td>26</td>
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<tr>
<td>Fireman’s Smoke Control Override Panel</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Fan Coil Unit controls</td>
<td>BACS</td>
<td>BACS</td>
<td>BACS</td>
<td>26</td>
</tr>
<tr>
<td>Unit Heater controls</td>
<td>BACS</td>
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<td>BACS</td>
<td>26</td>
</tr>
<tr>
<td>Packaged RTU space mounted controls</td>
<td>23*</td>
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<td>BACS</td>
<td>26</td>
</tr>
<tr>
<td>Packaged RTU factory-mounted controls</td>
<td>23*</td>
<td>23</td>
<td>BACS</td>
<td>26</td>
</tr>
<tr>
<td>Packaged RTU field-mounted controls</td>
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<td>BACS</td>
<td>BACS</td>
<td>26</td>
</tr>
<tr>
<td>Cooling Tower Vibration Switches</td>
<td>23</td>
<td>23</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Cooling Tower Level Control Devices</td>
<td>23</td>
<td>23</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Cooling Tower makeup water control devices</td>
<td>23</td>
<td>23</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Pool Dehumidification Unit Controls</td>
<td>23*</td>
<td>23</td>
<td>BACS</td>
<td>26</td>
</tr>
<tr>
<td>Starters, HOA switches</td>
<td>26</td>
<td>26</td>
<td>N/A</td>
<td>26</td>
</tr>
<tr>
<td>Control damper actuators</td>
<td>BACS</td>
<td>BACS</td>
<td>BACS</td>
<td>26</td>
</tr>
</tbody>
</table>

1.5 **Submittals**

A. **Shop Drawings, Product Data, and Samples**
   1. The BACS contractor shall submit a list of all shop drawings with submittals dates within 30 days of contract award.
   2. Submittals shall be in defined packages. Each package shall be complete and shall only reference itself and previously submitted packages. The packages shall be as approved by the Architect and Engineer for Contract compliance.
   3. Allow 23 working days for the review of each package by the Architect and Engineer in the scheduling of the total BACS work.
   4. Equipment and systems requiring approval of local authorities must comply with such regulations and be approved. Filing shall be at the expense of the BACS Contractor where filing is necessary. Provide a copy of all related correspondence and permits to the Owner.
   5. Prepare an index of all submittals and shop drawings for the installation. Index shall include a shop drawing identification number, Contract Documents reference and item description.
   6. The BACS Contractor shall correct any errors or omissions noted in the first review.
   7. At a minimum, submit the following:
      a. BACS network architecture diagrams including all nodes and interconnections.
      b. Systems schematics, sequences and flow diagrams.
      c. Points schedule for each point in the BACS, including: Point Type, Object Name, Expanded ID, Display Units, Controller type, and Address.
      d. Samples of Graphic Display screen types and associated menus.
e. Detailed Bill of Material list for each system or application, identifying quantities, part numbers, descriptions, and optional features.

f. Control Damper Schedule including a separate line for each damper provided under this section and a column for each of the damper attributes, including: Code Number, Fail Position, Damper Type, Damper Operator, Duct Size, Damper Size, Mounting, and Actuator Type.

g. Control Valve Schedules including a separate line for each valve provided under this section and a column for each of the valve attributes: Code Number, Configuration, Fail Position, Pipe Size, Valve Size, Body Configuration, Close off Pressure, Capacity, Valve CV, Design Pressure, and Actuator Type.

h. Room Schedule including a separate line for each VAV box and/or terminal unit indicating location and address

i. Details of all BACS interfaces and connections to the work of other trades.

j. Product data sheets or marked catalog pages including part number, photo and description for all products including software.

1.7 Record Documentation

A. Operation and Maintenance Manuals

1. Three (3) copies of the Operation and Maintenance Manuals shall be provided to the Owner's Representative upon completion of the project. The entire Operation and Maintenance Manual shall be furnished on Compact Disc media, and include the following for the BACS provided:

a. Table of contents.

b. As-built system record drawings. Computer Aided Drawings (CAD) record drawings shall represent the as-built condition of the system and incorporate all information supplied with the approved submittal. Provide “first draft” of as-built system record drawings to project commissioning agent no later than project completion date.

c. Manufacturers product data sheets or catalog pages for all products including software.

d. System Operator’s manuals.

e. Archive copy of all site-specific databases and sequences.

f. BACS network diagrams.

g. Interfaces to all third-party products and work by other trades.

2. The Operation and Maintenance Manual CD shall be self-contained, and include all necessary software required to access the product data sheets. A logically organized table of contents shall provide dynamic links to view and print all product data sheets. Viewer software shall provide the ability to display, zoom, and search all documents.

1.8 Warranty

A. Standard Material and Labor Warranty:

1. Provide a one-year labor and material warranty on the BACS.

2. If within twelve (12) months from the date of acceptance of product, upon written notice from the owner, it is found to be defective in operation, workmanship or
2. **Part 2 – Products**

2.1 **General Description**

A. The Building Automation Controls System (BACS) shall use an open architecture and fully support a multi-vendor environment. To accomplish this effectively, the BACS shall support open communication protocol standards and integrate a wide variety of third-party devices and applications. The system shall be designed for use on the Internet, or intranets using off the shelf, industry standard technology compatible with other owner provided networks.

B. The Building Automation Controls System shall consist of the following:
1. Standalone Network Automation Engine(s)
2. Field Equipment Controller(s)
3. Input/Output Module(s)
4. Local Display Device(s)
5. Portable Operator's Terminal(s)
6. Distributed User Interface(s)
7. Network processing, data storage and communications equipment
7. Other components required for a complete and working BACS

C. The system shall be modular in nature, and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, controllers and operator devices, while re-using existing controls equipment.

D. System architectural design shall eliminate dependence upon any single device for alarm reporting and control execution.
1. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices.
2. The System shall maintain all settings and overrides through a system reboot.

1. The System shall comply with the following NFPA Codes and Standards as applicable:
   a. NFPA 70 National Electrical Code
   b. NFPA 72 National Fire Alarm Code
   d. NFPA 90A Standard for the Installation of Air-Conditioning and Ventilation Systems
   e. NFPA 92B Guide for Smoke Management Systems in Malls, Atria, and Large Areas

2. The System shall comply with the following International Code Council (ICC) Codes:
   a. Building Officials and code Administrators International (BOMA) model code
2.2 **BACS Architecture**

**A. Automation Network**

1. The automation network shall be based on a PC industry standard of Ethernet TCP/IP. Where used, LAN controller cards shall be standard “off the shelf” products available through normal PC vendor channels.

2. The BACS shall network multiple user interface clients, automation engines, system controllers and application-specific controllers. Provide application and data server(s) as required for systems operation.

3. The automation network shall be capable of operating at a communication speed of 100 Mbps, with full peer-to-peer network communication.

4. Network Automation Engines (NAE) or LAN Gate Routers (LGR) shall reside on the automation network.

5. The automation network will be compatible with other enterprise-wide networks. Where indicated, the automation network shall be connected to the enterprise network and share resources with it by way of standard networking devices and practices.

**B. Control Network**

1. Network Automation Engines (NAE) or LAN Gate Routers (LGR) shall provide supervisory control over the control network and shall support all three (3) of the following communication protocols, as necessary for the specific project:
   a. BACnet Standard MS/TP Bus Protocol ASHRAE SSPC-135, Clause 9
      ◊ The NAE or LGR shall be BACnet Testing Labs (BTL) certified and carry the BTL Label.
      ◊ The NAE or LGR shall be tested and certified as a BACnet Building Controller (B-BC).
   b. LonWorks enabled devices using the Free Topology Transceiver (FTT-10a).
   c. The Johnson Controls N2 Field Bus.

2. Control networks shall provide either “Peer-to-Peer,” Master-Slave, or Supervised Token Passing communications, and shall operate at a minimum communication speed of 9600 baud (JCI) or 156k baud (ALC).

3. DDC Controllers shall reside on the control network.


**C. Integration**

1. Hardwired
   a. Analog and digital signal values shall be passed from one system to another via hardwired connections.
   b. There will be one separate physical point on each system for each point to be integrated between the systems.

2. Direct Protocol (Integrator Panel)
BUILDING AUTOMATION CONTROLS SYSTEM

a. The BACS system shall include appropriate hardware equipment and software to allow bi-directional data communications between the BACS system and 3rd party manufacturers’ control panels. The BACS shall receive, react to, and return information from multiple building systems, including but not limited to the chillers, boilers, variable frequency drives, power monitoring system, and medical gas.

b. All data required by the application shall be mapped into the Automation Engine’s database, and shall be transparent to the operator.

c. Point inputs and outputs from the third-party controllers shall have real-time interoperability with BACS software features such as: Control Software, Energy Management, Custom Process Programming, Alarm Management, Historical Data and Trend Analysis, Totalization, and Local Area Network Communications.

3. BACnet Protocol Integration - BACnet

   a. The neutral protocol used between systems will be BACnet over Ethernet and comply with the ASHRAE BACnet standard 135-2003.

   b. A complete Protocol Implementation Conformance Statement (PICS) shall be provided for all BACnet system devices.

   c. The ability to command, share point object data, change of state (COS) data and schedules between the host and BACnet systems shall be provided.

2.3 User Interface

   a. Existing.

2.4 Network Automation Engines (NAE)

   A. Network Automation Engine (NAE 55XX)

      1. The standard NAE provided at the University of Kansas shall be an NAE 55XX unless the application requires that a different model be utilized. Confirm with KU DCM and FO representatives on each specific project. The Network Automation Engine (NAE) shall be a fully user-programmable, supervisory controller. The NAE shall monitor the network of distributed application-specific controllers, provide global strategy and direction, and communicate on a peer-to-peer basis with other Network Automation Engines.

      2. Automation network – The NAE shall reside on the automation network and shall support a subnet of system controllers.

      3. User Interface – Each NAE shall have the ability to deliver a web based User Interface (UI) as previously described. All computers connected physically or virtually to the automation network shall have access to the web based UI.

         a. The web based UI software shall be imbedded in the NAE. Systems that require a local copy of the system database on the user’s personal computer are not acceptable.

         b. The NAE shall support up a minimum of four (4) concurrent users.

         c. The web based user shall have the capability to access all system data through one NAE.

         d. Remote users connected to the network through an Internet Service Provider (ISP) or telephone dial up shall also have total system access through one NAE.
e. Systems that require the user to address more than one NAE to access all system information are not acceptable.

f. The NAE shall have the capability of generating web based UI graphics. The graphics capability shall be imbedded in the NAE.

g. Systems that support UI Graphics from a central database or require the graphics to reside on the user’s personal computer are not acceptable.

h. The web based UI shall support the following functions using a standard version of Microsoft Internet Explorer:

◊ Configuration
◊ Commissioning
◊ Data Archiving
◊ Monitoring
◊ Commanding
◊ System Diagnostics

i. Systems that require workstation software or modified web browsers are not acceptable.

j. The NAE shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems.

4. Processor – The NAE shall be microprocessor-based with a minimum word size of 32 bits. The NAE shall be a multi-tasking, multi-user, and real-time digital control processor. Standard operating systems shall be employed. NAE size and capability shall be sufficient to fully meet the requirements of this Specification.

5. Memory – Each NAE shall have sufficient memory to support its own operating system, databases, and control programs, and to provide supervisory control for all control level devices.

6. Hardware Real Time Clock – The NAE shall include an integrated, hardware-based, real-time clock.

7. The NAE shall include troubleshooting LED indicators to identify the following conditions:

a. Power - On/Off
b. Ethernet Traffic – Ethernet Traffic/No Ethernet Traffic
c. Ethernet Connection Speed – 10 Mbps/100 Mbps
d. FC Bus A – Normal Communications/No Field Communications
e. FC Bus B – Normal Communications/No Field Communications
f. Peer Communication – Data Traffic between NAE Devices
g. Run – NAE Running/NAE in Startup/NAE Shutting Down/Software Not Running
h. Bat Fault – Battery Defective, Data Protection Battery Not Installed
i. 24 VAC – 24 VAC Present/Loss Of 24VAC
j. Fault – General Fault
k. Modem RX – NAE Modem Receiving Data
l. Modem TX – NAE Modem Transmitting Data

8. Communications Ports – The NAE shall provide the following ports for operation of operator Input/Output (I/O) devices, such as industry-standard computers, modems, and portable operator’s terminals.

a. Two (2) USB port
b. Two (2) URS-232 serial data communication port
c. Two (2) RS-485 port
d. One (1) Ethernet port

9. Diagnostics – The NAE shall continuously perform self-diagnostics, communication diagnosis, and diagnosis of all panel components. The Network Automation Engine shall provide both local and remote annunciation of any detected component failures, low battery conditions, or repeated failures to establish communication.

10. Power Failure – In the event of the loss of normal power, The NAE shall continue to operate for a user adjustable period of up to 10 minutes after which there shall be an orderly shutdown of all programs to prevent the loss of database or operating system software.
   a. During a loss of normal power, the control sequences shall go to the normal system shutdown conditions. All critical configuration data shall be saved into Flash memory.
   b. Upon restoration of normal power and after a minimum off-time delay, the controller shall automatically resume full operation without manual intervention through a normal soft-start sequence.

11. Certification – The NAE shall be listed by Underwriters Laboratories (UL).

12. Controller network – The NAE shall support the following communication protocols on the controller network:
   a. The NAE shall support BACnet Standard MS/TP Bus Protocol ASHRAE SSPC-135, Clause 9 on the controller network.
      ◊ The NAE shall be BACnet Testing Labs (BTL) certified and carry the BTL Label.
      ◊ The NAE shall be tested and certified as a BACnet Building Controller (B-BC).
      ◊ A BACnet Protocol Implementation Conformance Statement shall be provided for the NAE.
      ◊ The Conformance Statements shall be submitted 10 days prior to bidding.
      ◊ The NAE shall support a minimum of 100 control devices.
   b. The NAE shall support LonWorks enabled devices using the Free Topology Transceiver FTT10.
      ◊ All LonWorks controls devices shall be LonMark certified.
      ◊ The NAE shall support a minimum of 255 LonWorks enabled control devices.
   c. The NAE shall support the Johnson Controls N2 Field Bus.
      ◊ The NAE shall support a minimum of 100 N2 control devices.
      ◊ The Bus shall conform to Electronic Industry Alliance (EIA) Standard RS-485.
      ◊ The Bus shall employ a master/slave protocol where the NAE is the master.
      ◊ The Bus shall employ a four (4) level priority system for polling frequency.
      ◊ The Bus shall be optically isolated from the NAE.
      ◊ The Bus shall support the Metasys Integrator System.

B. LAN Gate Router (LGR XX)
1. The standard LGR provided at the University of Kansas shall be an LGR 25 unless the application requires that a different model be utilized. Confirm with KU DCM and FO representatives on each specific project. The Lan Gate Router (LGR) shall be a fully user-programmable, supervisory controller. The LGR shall monitor the network of distributed application-specific controllers, provide global strategy and direction, and communicate on a peer-to-peer basis with other Lan Gate Routers.

2. Automation network – The LGR shall reside on the automation network and shall support a subnet of system controllers.

3. Processor – The LGR shall be microprocessor-based with a minimum word size of 32 bits Motorola Power PC microprocessor with cache memory. Fast Ethernet controller, high performance 32-bit communication co-processor, ARCNET communication co-processor and I/O expansion CAN co-processor.

4. Memory – 16MByte non-volatile battery-backed SDRAM (with 12 Mbytes available for use), 8MByte Flash memory, 32-bit memory bus. (Shelf life of the battery is 10 years with 720 hours of continuous operation.)

5. Hardware Real Time Clock – The LGR shall include an integrated, hardware-based, real-time clock with Battery Back Up.

6. The LGR shall include troubleshooting LED indicators to identify the following conditions:
   a. Power - On/Off
   b. Ethernet Traffic – Ethernet Traffic/No Ethernet Traffic
   c. Ethernet Connection Speed – 10 Mbps/100 Mbps
   d. EIA-232/485 communications Bus
   e. ARCNET Communication – Data Traffic between LGR Devices
   f. Run – LGR Running/LGR in Startup/LGR Shutting Down/Software Not Running
   g. Bat Fault – Battery Defective, Data Protection Battery Not Installed
   h. 24 VAC – 24 VAC Present/Loss Of 24VAC
   i. Fault – General Fault

7. Communications Ports – The LGR shall provide the following ports for operation of operator Input/Output (I/O) devices, such as industry-standard portable operator’s terminals.
   a. Ethernet port (10/100Mbs) for BACnet over Ethernet communications
   b. EIA-485 port for ARCNET 156 Kbps or BACnet MS/TP
   c. EIA-485 MS/TP (9600 baud or 76.8 Kbps)
   d. EIA-232/485 configurable port for BACnet PTP
   e. Rnet port for RS room sensors and local BACview display
   f. Xnet (500Kbps) port of MEX I/O expansion modules
   g. Local access port.

8. Diagnostics – The LGR shall continuously perform self-diagnostics, communication diagnosis, and diagnosis of all panel components. The LAN Gate Router shall provide both local and remote annunciation of any detected component failures, low battery conditions, or repeated failures to establish communication.

9. Power Failure – In the event of the loss of normal power, The LGR shall continue to operate for a user adjustable period of up to 720 hours after which there shall be
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an orderly shutdown of all programs to prevent the loss of database or operating system software.

a. During a loss of normal power, the control sequences shall go to the normal system shutdown conditions. All critical configuration data shall be saved into Flash memory.

b. Upon restoration of normal power and after a minimum off-time delay, the controller shall automatically resume full operation without manual intervention through a normal soft-start sequence.

10. Certification – The LGR shall be listed by Underwriters Laboratories (UL).

11. Controller network – The LGR shall support the following communication protocols on the controller network:

   ◊ The LGR shall be BACnet Testing Labs (BTL) certified and carry the BTL Label.
   ◊ The LGR shall be tested and certified as a BACnet Building Controller (B-BC).
   ◊ A BACnet Protocol Implementation Conformance Statement shall be provided for the NAE.
   ◊ The Conformance Statements shall be submitted 10 days prior to bidding.
   ◊ The LGR shall support a minimum of 99 control devices.

b. The LGR shall support the Automated Logic ARCNET Network.
   ◊ The LGR shall support a minimum of 99 Nodes
   ◊ The Network shall conform to Electronic Industry Alliance (EIA) Standard RS-485.
   ◊ Fully programmable for the execution of complex control strategies for high-level system integration.
   ◊ The LGR shall supports a wide range of open and proprietary protocol translator drivers allowing to serve as a gateway to other manufactures equipment.

2.5 DDC System Controllers

A. Field Equipment Controller (FEC X610)

1. The Field Equipment Controller (FEC) shall be a fully user-programmable, digital controller that communicates via BACnet MS/TP protocol.

a. The FEC shall support BACnet Standard MS/TP Bus Protocol ASHRAE SSPC-135, Clause 9 on the controller network.
   ◊ The FEC shall be BACnet Testing Labs (BTL) certified and carry the BTL Label.
   ◊ The FEC shall be tested and certified as a BACnet Application Specific Controller (B-ASC).
   ◊ A BACnet Protocol Implementation Conformance Statement shall be provided for the FEC.
   ◊ The Conformance Statement shall be submitted 10 days prior to bidding.
2. The FEC shall employ a finite state control engine to eliminate unnecessary conflicts between control functions at crossover points in their operational sequences. Suppliers using non-state based DDC shall provide separate control strategy diagrams for all controlled functions in their submittals.

3. Controllers shall be factory programmed with a continuous adaptive tuning algorithm that senses changes in the physical environment and continually adjusts loop tuning parameters appropriately. Controllers that require manual tuning of loops or perform automatic tuning on command only shall not be acceptable.

4. The FEC shall be assembled in a plenum-rated plastic housing with flammability rated to UL94-5VB.

5. The FEC shall include a removable base to allow pre-wiring without the controller.

6. The FEC shall include troubleshooting LED indicators to identify the following conditions:
   a. Power On
   b. Power Off
   c. Download or Startup in progress, not ready for normal operation
   d. No Faults
   e. Device Fault
   f. Field Controller Bus - Normal Data Transmission
   g. Field Controller Bus - No Data Transmission
   h. Field Controller Bus - No Communication
   i. Sensor-Actuator Bus - Normal Data Transmission
   j. Sensor-Actuator Bus - No Data Transmission
   k. Sensor-Actuator Bus - No Communication

7. The FEC shall accommodate the direct wiring of analog and binary I/O field points.

8. The FEC shall support the following types of inputs and outputs:
   a. Universal Inputs - shall be configured to monitor any of the following:
      ◊ Analog Input, Voltage Mode
      ◊ Analog Input, Current Mode
      ◊ Analog Input, Resistive Mode
      ◊ Binary Input, Dry Contact Maintained Mode
      ◊ Binary Input, Pulse Counter Mode
   b. Binary Inputs - shall be configured to monitor either of the following:
      ◊ Dry Contact Maintained Mode
      ◊ Pulse Counter Mode
   c. Analog Outputs - shall be configured to output either of the following
      ◊ Analog Output, Voltage Mode
      ◊ Analog Output, current Mode
   d. Binary Outputs - shall output the following:
      ◊ 24 VAC Triac
   e. Configurable Outputs - shall be capable of the following:
      ◊ Analog Output, Voltage Mode
      ◊ Binary Output Mode

9. The FEC shall have the ability to reside on a Field Controller Bus (FC Bus).
a. The FC Bus shall be a Master-Slave/Token-Passing (MS/TP) Bus supporting BACnet Standard protocol SSPC-135, Clause 9.

b. The FC Bus shall support communications between the FECs and the NAE.

c. The FC Bus shall also support Input/Output Module (IOM) communications with the FEC and with the NAE.

d. The FC Bus shall support a minimum of 100 IOMs and FECs in any combination.

e. The FC Bus shall operate at a maximum distance of 23,000 Ft. between the FEC and the furthest connected device.

10. The FEC shall have the ability to monitor and control a network of sensors and actuators over a Sensor-Actuator Bus (SA Bus).


b. The SA Bus shall support a minimum of 10 devices per trunk.

c. The SA Bus shall operate at a maximum distance of 1,200 Ft. between the FEC and the furthest connected device.

11. The FEC shall have the capability to execute complex control sequences involving direct wired I/O points as well as input and output devices communicating over the FC Bus or the SA Bus.

12. The FEC shall support, but not be limited to, the following:

a. Hot water, chilled water/central plant applications

b. Built-up air handling units for special applications

c. Terminal units

c. Special programs as required for systems control

B. Field Equipment Controller (ME 812U)

1. The Field Equipment Controller (FEC) shall be a fully user-programmable, digital controller that communicates via BACnet ARCNET protocol.

a. The FEC shall support BACnet Standard ARCNET Bus Protocol ASHRAE

   ◊ The FEC shall be BACnet Testing Labs (BTL) certified and carry the BTL Label.

   ◊ The FEC shall be tested and certified as a BACnet Advanced Application Controller (B-AAC).

   ◊ A BACnet Protocol Implementation Conformance Statement shall be provided for the FEC.

   ◊ The Conformance Statement shall be submitted 10 days prior to bidding.

2. The FEC shall employ a finite state control engine to eliminate unnecessary conflicts between control functions at crossover points in their operational sequences. Suppliers using non-state based DDC shall provide separate control strategy diagrams for all controlled functions in their submittals.

3. The FEC shall be assembled in a rugged aluminum housing rated to UL916.

4. The FEC shall include a removable screw terminal blocks.

5. The FEC shall include troubleshooting LED indicators to identify the following conditions:

   a. Power On

   b. Power Off

   c. EIA-232/485 communication
d. Low Battery Status  
e. Seven segment status display for running, error, and power status  

6. The FEC shall accommodate the direct wiring of analog and binary I/O field points.  
7. The FEC shall support the following types of inputs and outputs:  
   a. Universal Inputs - shall be configured to monitor any of the following:  
      ◊ Analog Input, Voltage Mode  
      ◊ Analog Input, Current Mode  
      ◊ Analog Input, Resistive Mode  
      ◊ Binary Input, Dry Contact Maintained Mode  
      ◊ Binary Input, Pulse Counter Mode  
   b. Binary Inputs - shall be configured to monitor either of the following:  
      ◊ Dry Contact Maintained Mode  
      ◊ Pulse Counter Mode  
   c. Analog Outputs - shall be configured to output either of the following  
      ◊ Analog Output, Voltage Mode  
      ◊ Analog Output, current Mode  
   d. Binary Outputs - shall output the following:  
      ◊ 24 V–dc @ 50mA relay drive. With HOA switches & potentiometer  
   e. Configurable Outputs - shall be capable of the following:  
      ◊ Analog Output, Voltage Mode  
      ◊ Binary Output Mode  

8. The FEC shall have the ability to reside on a Field Controller Bus (FC Bus).  
   a. The FC Bus shall be a Master-Slave/Token-Passing ARCNET Bus supporting BACnet Standard protocol SSPC-135  
   b. The ARCNET Bus shall support communications between the FECs and the LGR.  
   c. The ARCNET Bus shall also support Input/Output Module (IOM) communications with the FEC and with the LGR.  
   d. The ARCNET Bus shall support a minimum of 99 ZNs and FECs in any combination.  

9. The FEC shall have the capability to execute complex control sequences involving direct wired I/O points as well as input and output devices communicating over the ARCNET Bus.  

10. The FEC shall support, but not be limited to, the following:  
    a. Hot water, chilled water/central plant applications  
    b. Built-up air handling units for special applications  
    C. Terminal units  
    c. Special programs as required for systems control  

2.6 Field Devices/Controllers  
A. Input/Output Module (IOM X710)  

1. The Input/Output Module (IOM) provides additional inputs and outputs for use in the FEC.  
2. The IOM shall communicate with the FEC over the FC Bus or the SA Bus.
   a. The IOM shall be BACnet Testing Labs (BTL) certified and carry the BTL Label.
   b. The IOM shall be tested and certified as a BACnet Application Specific Controller (B-ASC).
   c. A BACnet Protocol Implementation Conformance Statement shall be provided for the FEC.
   d. The Conformance Statement shall be submitted 10 days prior to bidding.
4. The IOM shall be assembled in a plenum-rated plastic housing with flammability rated to UL94-5VB.
5. The IOM shall have a minimum of 4 points to a maximum of 17 points.
6. The IOM shall support the following types of inputs and outputs:
   a. Universal Inputs - shall be configured to monitor any of the following:
      ◊ Analog Input, Voltage Mode
      ◊ Analog Input, Current Mode
      ◊ Analog Input, Resistive Mode
      ◊ Binary Input, Dry Contact Maintained Mode
      ◊ Binary Input, Pulse Counter Mode
   b. Binary Inputs - shall be configured to monitor either of the following:
      ◊ Dry Contact Maintained Mode
      ◊ Pulse Counter Mode
   c. Analog Outputs - shall be configured to output either of the following
      ◊ Analog Output, Voltage Mode
      ◊ Analog Output, Current Mode
   d. Binary Outputs - shall output the following:
      ◊ 24 VAC Triac
   e. Configurable Outputs - shall be capable of the following:
      ◊ Analog Output, Voltage Mode
      ◊ Binary Output Mode
7. The IOM shall include troubleshooting LED indicators to identify the following conditions:
   a. Power On
   b. Power Off
   c. Download or Startup in progress, not ready for normal operation
   d. No Faults
   e. Device Fault
   f. Normal Data Transmission
   g. No Data Transmission
   h. No Communication

B. Input/Output Module (MEX--xxxU)

1. The Input/Output Module (IOM) provides additional inputs and outputs for use in the FEC.
2. The IOM shall communicate with the FEC over the Xnet.
3. The IOM shall support BACnet Standard ARCNET Protocol ASHRAE SSPC-135,
a. The IOM shall be BACnet Testing Labs (BTL) certified and carry the BTL Label.
b. The IOM shall be tested and certified as a BACnet Advanced Application Controller (B-AAC)
c. A BACnet Protocol Implementation Conformance Statement shall be provided for the FEC.
d. The Conformance Statement shall be submitted 10 days prior to bidding.

4. The IOM shall be assembled in a rugged aluminum housing listed by UL916

5. The IOM shall have a minimum of 8 points to a maximum of 24 points.

6. The IOM shall support the following types of inputs and outputs:
   a. Universal Inputs - shall be configured to monitor any of the following:
      ◊ Analog Input, Voltage Mode
      ◊ Analog Input, Current Mode
      ◊ Analog Input, Resistive Mode
      ◊ Binary Input, Dry Contact Maintained Mode
      ◊ Binary Input, Pulse Counter Mode
   b. Binary Inputs - shall be configured to monitor either of the following:
      ◊ Dry Contact Maintained Mode
      ◊ Pulse Counter Mode
   c. Analog Outputs - shall be configured to output either of the following
      ◊ Analog Output, Voltage Mode
      ◊ Analog Output, current Mode
   d. Binary Outputs - shall output the following:
      ◊ 24 V–dc @ 50mA relay drive with HOA switches and potentiometer.
   e. Configurable Outputs - shall be capable of the following:
      ◊ Analog Output, Voltage Mode
      ◊ Binary Output Mode

7. The MEX shall include troubleshooting LED indicators to identify the following conditions:
   a. Power On
   b. Power Off
   c. EIA-232/485 communication
   d. Low Battery Status
   e. Seven segment status display for running, error, and power status

C. Networked Thermostat (TEC 26X6)

1. Networked thermostat shall be capable of controlling a variety of terminal HVAC systems or similar equipment. Exact model of TEC shall be determined by project.


3. The TEC shall be BACnet Testing Labs (BTL) certified and carry the BTL Label.
   a. The TEC shall be tested and certified as a BACnet Application Specific Controller (B-ASC).
   b. A BACnet Protocol Implementation Conformance Statement shall be provided for the TEC.
   c. The Conformance Statement shall be submitted 10 days prior to bidding.
4. The Networked Thermostat shall support remote read/write and parameter adjustment from the web based User Interfaceable through a Network Automation Engine.

5. The Networked Thermostat shall include an intuitive User Interface providing plain text messages.
   a. Two line, 8 character backlit display
   b. LED indicators for Fan, Heat, and Cool status
   c. Five (5) User Interface Keys
      ◊ Mode
      ◊ Fan
      ◊ Override
      ◊ Degrees C/F
      ◊ Up/Down
   d. The display shall continuously scroll through the following parameters:
      ◊ Room Temperature
      ◊ System Mode
      ◊ Schedule Status – Occupied/Unoccupied/Override
      ◊ Applicable Alarms

6. The Networked Thermostat shall provide the flexibility to support any one of the following inputs:
   a. Integral Indoor Air Temperature Sensor
   b. Duct Mount Air Temperature Sensor
   c. Remote Indoor Air Temperature Sensor with Occupancy Override and LED Indicator
   d. Two configurable binary inputs

7. The Networked Thermostat shall provide the flexibility to support any one of the following outputs:
   a. Three Speed Fan Control
   b. Two On/Off
   c. Two Floating
   d. Two Proportional (0 to 10V)

8. The Networked Thermostat shall provide a minimum of six (6) levels of keypad lockout.

9. The Networked Thermostat shall provide the flexibility to adjust the following parameters:
   a. Adjustable Temporary Occupancy from 0 to 24 hours
   b. Adjustable heating/cooling deadband from 2° F to 5° F
   c. Adjustable heating/cooling cycles per hour from 4 to 8

10. The Networked Thermostat shall employ nonvolatile electrically erasable programmable read-only memory (EEPROM) for all adjustable parameters.

D. Networked Thermostat (RC642)
1. Networked thermostat shall be capable of controlling a variety of terminal HVAC systems or similar equipment.
2. The RC642 shall communicate over the Field Controller Bus using BACnet Standard ARCNET Protocol ASHRAE SSPC-135
3. The RC642 shall be BACnet Testing Labs (BTL) certified and carry the BTL Label.
   a. The RC642 shall be tested and certified as a BACnet Advanced Application Controller (B-AAC).
   b. A BACnet Protocol Implementation Conformance Statement shall be provided for the TEC.
   c. The Conformance Statement shall be submitted 10 days prior to bidding.
4. The Networked Thermostat shall support remote read/write and parameter adjustment from the web based User Interface able through a WebCTRL Software.
5. The Networked Thermostat shall have a Large easy to read high contrast LCD display zone temperature, outside air temperature, heating and cooling setpoints, time, schedule, and local overrides.
6. The flexibility to support any one of the following inputs:
   a. Six Universal Inputs
   b. Four Relay Driven Binary Outputs
   c. Two 0-10V-dc Analog Outputs
7. The Networked Thermostat shall fully programmable for any terminal application.
8. The Networked Thermostat shall provide a minimum of six (6) levels of keypad lockout.
9. The Networked Thermostat shall provide the flexibility to adjust the following parameters:
   a. Adjustable Temporary Occupancy
   b. Adjustable heating/cooling deadband
10. The Networked Thermostat shall utilize a 16-bit microprocessor with 1 Mbyte Flash and 512 Kbyte of RAM—firmware upgrades with remote ability.

E. VAV Modular Assembly (VMA 26X0)
1. The VAV Modular Assembly shall provide both standalone and networked direct digital control of pressure-independent, variable air volume terminal units. It shall address both single and dual duct applications.
2. The VMA shall be BACnet Testing Labs (BTL) certified and carry the BTL Label.
   a. The VMA shall be tested and certified as a BACnet Application Specific Controller (B-ASC).
   b. A BACnet Protocol Implementation Conformance Statement shall be provided for the VMA.
   c. The Conformance Statement shall be submitted 10 days prior to bidding.
3. The VAV Modular Assembly shall communicate over the FC Bus using BACnet Standard protocol SSPC-135, Clause 9.
4. The VAV Modular Assembly shall have internal electrical isolation for AC power, DC inputs, and MS/TP communications. An externally mounted isolation transformer shall not be acceptable.
5. The VAV Modular Assembly shall be a configurable digital controller with integral differential pressure transducer and damper actuator. All components shall be connected and mounted as a single assembly that can be removed as one piece.
6. The VAV Modular Assembly shall be assembled in a plenum-rated plastic housing with flammability rated to UL94-5VB.
7. The integral damper actuator shall be a fast response stepper motor capable of stroking 90 degrees in 30 seconds for quick damper positioning to speed commissioning and troubleshooting tasks.

8. The controller shall determine airflow by dynamic pressure measurement using an integral dead-ended differential pressure transducer. The transducer shall be maintenance-free and shall not require air filters.

9. Each controller shall have the ability to automatically calibrate the flow sensor to eliminate pressure transducer offset error due to ambient temperature / humidity effects.

10. The controller shall utilize a proportional plus integration (PI) algorithm for the space temperature control loops.

11. Each controller shall continuously, adaptively tune the control algorithms to improve control and controller reliability through reduced actuator duty cycle. In addition, this tuning reduces commissioning costs, and eliminates the maintenance costs of manually re-tuning loops to compensate for seasonal or other load changes.

12. The controller shall provide the ability to download and upload VMA configuration files, both locally and via the communications network. Controllers shall be able to be loaded individually or as a group using a zone schedule generated spreadsheet of controller parameters.

13. Control setpoint changes initiated over the network shall be written to VMA non-volatile memory to prevent loss of setpoint changes and to provide consistent operation in the event of communication failure.

14. The controller firmware shall be flash-upgradeable remotely via the communications bus to minimize costs of feature enhancements.

15. The controller shall provide fail-soft operation if the airflow signal becomes unreliable, by automatically reverting to a pressure-dependent control mode.

16. The controller shall interface with balancer tools that allow automatic recalculation of box flow pickup gain (“K” factor), and the ability to directly command the airflow control loop to the box minimum and maximum airflow setpoints.

17. Controller performance shall be self-documenting via on-board diagnostics. These diagnostics shall consist of control loop performance measurements executing at each control loop’s sample interval, which may be used to continuously monitor and document system performance. The VMA shall calculate exponentially weighted moving averages (EWMA) for each of the following. These metrics shall be available to the end user for efficient management of the VAV terminals.

   ◊ Absolute temperature loop error
   ◊ Signed temperature loop error
   ◊ Absolute airflow loop error
   ◊ Signed airflow loop error
   ◊ Average damper actuator duty cycle

18. The controller shall detect system error conditions to assist in managing the VAV zones. The error conditions shall consist of:

   ◊ Unreliable space temperature sensor
   ◊ Unreliable differential pressure sensor
   ◊ Starved box
   ◊ Actuator stall
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◊ Insufficient cooling
◊ Insufficient heating
The controller shall provide a flow test function to view damper position vs. flow in a graphical format. The information would alert the user to check damper position. The VMA would also provide a method to calculate actuator duty cycle as an indicator of damper actuator runtime.

19. The controller shall provide a compliant interface for ASHRAE Standard 62-1989 (indoor air quality), and shall be capable of resetting the box minimum airflow based on the percent of outdoor air in the primary air stream.

20. The controller shall comply with ASHRAE Standard 90.1 (energy efficiency) by preventing simultaneous heating and cooling, and where the control strategy requires reset of airflow while in reheat, by modulating the box reheat device fully open prior to increasing the airflow in the heating sequence.

21. Inputs:
   a. Analog inputs with user defined ranges shall monitor the following analog signals, without the addition of equipment outside the terminal controller cabinet:
      ◊ 0-10 VDC Sensors
      ◊ 1000ohm RTDs
      ◊ NTC Thermistors
   b. Binary inputs shall monitor dry contact closures. Input shall provide filtering to eliminate false signals resulting from input “bouncing.”
   c. For noise immunity, the inputs shall be internally isolated from power, communications, and output circuits.
   d. Provide side loop application for humidity control.

22. Outputs
   a. Analog outputs shall provide the following control outputs:
      ◊ 0-10 VDC
   b. Binary outputs shall provide a SPST Triac output rated for 500mA at 24 VAC.
   c. For noise immunity, the outputs shall be internally isolated from power, communications, and other output circuits.

23. Application Configuration
   a. The VAV Modular Assembly shall be configured with a software tool that provides a simple Question/Answer format for developing applications and downloading.

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

F. VAV Modular Assembly (ZN 341/141)
1. The VAV Modular Assembly shall provide both standalone and networked direct digital control of pressure-independent, variable air volume terminal units. It shall address both single and dual duct applications.
2. The ZN shall be BACnet Testing Labs (BTL) certified and carry the BTL Label.
   a. The ZN shall be tested and certified as a BACnet Advanced Application Controller (B-AAC).
   b. A BACnet Protocol Implementation Conformance Statement shall be provided for the ZN
   c. The Conformance Statement shall be submitted 10 days prior to bidding.

3. The VAV Modular Assembly shall communicate over the ARCNET Bus using BACnet Standard protocol SSPC-135

4. The VAV Modular Assembly shall have internal electrical isolation for AC power, Universal inputs, and ARCNET communications.

5. The VAV Modular Assembly shall be a configurable digital controller with integral differential pressure transducer and damper actuator. All components shall be connected and mounted as a single assembly that can be removed as one piece.

6. The VAV Modular Assembly shall be assembled in a plenum-rated plastic housing with flammability rated to UL94-5VB.

7. The integral damper actuator shall be Brushless DC motor, torque 35 inch-pounds.

8. The controller shall determine airflow by precision low flow AWM series 0-2” W.C. sensitive down to +/- 0.001” W.C.

9. Each controller shall have the ability to automatically calibrate the flow sensor to eliminate pressure transducer offset error due to ambient temperature / humidity effects.

10. The controller shall utilize a proportional plus integration (PI) algorithm for the space temperature control loops.

11. The controller shall provide the ability to download and upload programming files, both locally and via the communications network. Controllers shall be able to be loaded individually or as a group.

12. Control setpoint changes initiated over the network shall be written to non-volatile memory to prevent loss of setpoint changes and to provide consistent operation in the event of communication failure.

13. The controller firmware shall be flash-upgradeable remotely via the communications bus to minimize costs of feature enhancements.

14. The controller shall provide fail-soft operation if the airflow signal becomes unreliable, by automatically reverting to a pressure-dependent control mode.

15. The controller shall interface with balancer tools that allow automatic recalculation of box flow pickup gain (“K” factor), and the ability to directly command the airflow control loop to the box minimum and maximum airflow setpoints.

16. The controller shall provide a compliant interface for ASHRAE Standard 62-1989 (indoor air quality), and shall be capable of resetting the box minimum airflow based on the percent of outdoor air in the primary air stream.

17. The controller shall comply with ASHRAE Standard 90.1 (energy efficiency) by preventing simultaneous heating and cooling, and where the control strategy requires reset of airflow while in reheat, by modulating the box reheat device fully open prior to increasing the airflow in the heating sequence.

18. Inputs:
a. Analog inputs with user defined ranges shall monitor the following analog signals, without the addition of equipment outside the terminal controller cabinet:
   ◊ 0-5 VDC Sensors
   ◊ Type II Thermistors
b. Binary inputs shall monitor dry contact closures. Input shall provide filtering to eliminate false signals resulting from input “bouncing.”
c. For noise immunity, the inputs shall be internally isolated from power, communications, and output circuits.

19. Outputs
   a. Analog outputs shall provide the following control outputs:
      ◊ 0-10 VDC
   b. Binary outputs shall provide a Relay contact rated at 1A max @ 24V-ac/dc
   c. For noise immunity, the outputs shall be internally isolated from power, communications, and other output circuits.

20. Application Configuration
   a. The VAV Modular Assembly shall be configured with Eikon Graphical Software.

21. Sensor Support
   a. The VAV Modular Assembly shall communicate over the Rnet Bus with a Network Sensor.
   b. The ZN shall support an LCD display room sensor.
   c. The ZN shall also support standard room sensors as defined by analog input requirements.
   d. The ZN shall support humidity sensors.

G. Network Sensors (NS-XXX700X)
   1. The Network Sensors (NS) shall have the ability to monitor the following variables as required by the systems sequence of operations:
      a. Zone Temperature
      b. Zone Humidity
      c. Zone Setpoint
      d. Discharge Air Temperature
   3. The NS shall be BACnet Testing Labs (BTL) certified and carry the BTL Label.
      a. The NS shall be tested and certified as a BACnet Smart Sensors (B-SS).
      b. A BACnet Protocol Implementation Conformance Statement shall be provided for the NS.
      c. The Conformance Statement shall be submitted 10 days prior to bidding.
   4. The Network Zone Sensors shall include the following items:
      a. A backlit Liquid Crystal Display (LCD) to indicate the Temperature, Humidity and Setpoint
      b. An LED to indicate the status of the Override feature
      c. A button to toggle the temperature display between Fahrenheit and Celsius
      d. A button to initiate a timed override command
e. Available in either surface mount or wall mount
f. Available with either screw terminals or phone jack

5. The Network Discharge Air Sensors shall include the following:
   a. 4 inch or 8 inch duct insertion probe
   b. 10 foot pigtail lead
   c. Dip Switches for programmable address selection
   d. Ability to provide an averaging temperature from multiple locations
   e. Ability to provide a selectable temperature from multiple locations

H. Network Sensors (RS-BASE/PLUS/PRO/PROF)
   1. The Network Sensors (NS) shall have the ability to monitor the following variables
      as required by the systems sequence of operations:
         a. Zone Temperature
         b. Zone Humidity
         c. Zone Setpoint
         d. Zone CO2
   2. The NS shall transmit the information back to the controller on the Sensor-Rnet using BACnet Standard protocol SSPC-135.
   3. The NS shall be BACnet Testing Labs (BTL) certified and carry the BTL Label.
      a. The NS shall be tested and certified as a BACnet Smart Sensors (B-SS).
      b. A BACnet Protocol Implementation Conformance Statement shall be provided for the NS.
      c. The Conformance Statement shall be submitted 10 days prior to bidding.
   4. The Network Zone Sensors shall include the following items:
      a. A backlit Liquid Crystal Display (LCD) to indicate the Temperature, Humidity and Setpoint
      b. An LED to indicate the status of the Override feature
      c. A button to toggle the temperature display between Fahrenheit and Celsius
      d. A button to initiate a timed override command
      e. Available for wall mount
      f. Available with either screw terminals

2.7 System Tools
   A. System Configuration Tool (SCT).
      1. The Configuration Tool software is existing and shall be utilized for the development of software on this project.

2.8 Input Devices
   A. General Requirements
      1. Installation, testing, and calibration of all sensors, transmitters, and other input devices shall be provided to meet the system requirements.
   B. Temperature Sensors
      1. General Requirements:
         a. Sensors and transmitters shall be provided, as outlined in the input/output summary and sequence of operations.
b. The temperature sensor shall be of the resistance type, and shall be either two-wire 1000 ohm nickel RTD, two-wire 1000 ohm platinum RTD; or Type II Thermistor.

c. The following point types (and the accuracy of each) are required, and their associated accuracy values include errors associated with the sensor, lead wire, and A to D conversion:

<table>
<thead>
<tr>
<th>Point Type</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chilled Water</td>
<td>± .5°F.</td>
</tr>
<tr>
<td>Room Temp</td>
<td>± .5°F.</td>
</tr>
<tr>
<td>Duct Temperature</td>
<td>± .5°F.</td>
</tr>
<tr>
<td>All Others</td>
<td>± .75°F.</td>
</tr>
</tbody>
</table>

2. Room Temperature Sensors
a. Room sensors shall be constructed for either surface or wall box mounting.
b. Room sensors shall have the following options when specified:
   ◊ Setpoint reset slide switch providing a ±3 degree (adjustable) range.
   ◊ Individual heating/cooling setpoint slide switches.
   ◊ A momentary override request push button for activation of after-hours operation.
   ◊ Analog thermometer.

3. Room Temperature Sensors with Integral Display
a. Room sensors shall be constructed for either surface or wall box mounting.
b. Room sensors shall have an integral LCD display and four button keypad with the following capabilities:
   ◊ Display room and outside air temperatures.
   ◊ Display and adjust room comfort setpoint.
   ◊ Display and adjust fan operation status.
   ◊ Timed override request push button with LED status for activation of after-hours operation.
   ◊ Display controller mode.
   ◊ Password selectable adjustment of setpoint and override modes.

4. Thermo wells
a. When thermo wells are required, the sensor and well shall be supplied as a complete assembly, including wellhead and Greenfield fitting.
b. Thermo wells shall be pressure rated and constructed in accordance with the system working pressure.
c. Thermo wells and sensors shall be mounted in a threadolet or 1/2” NFT saddle and allow easy access to the sensor for repair or replacement.
d. Thermo wells shall be constructed of 326 stainless steel.

5. Outside Air Sensors
a. Outside air sensors shall be designed to withstand the environmental conditions to which they will be exposed. They shall also be provided with a solar shield.
b. Sensors exposed to wind velocity pressures shall be shielded by a perforated plate that surrounds the sensor element.
c. Temperature transmitters shall be of NEMA 3R construction and rated for ambient temperatures.

6. Duct Mount Sensors
   a. Duct mount sensors shall mount in an electrical box through a hole in the duct, and be positioned so as to be easily accessible for repair or replacement.
   b. Duct sensors shall be insertion type and constructed as a complete assembly, including lock nut and mounting plate.
   c. For outdoor air duct applications, a weatherproof mounting box with weatherproof cover and gasket shall be used.

7. Averaging Sensors
   a. For ductwork greater in any dimension that 48 inches and/or where air temperature stratification exists, an averaging sensor with multiple sensing points shall be used.
   b. For plenum applications, such as mixed air temperature measurements, a string of sensors mounted across the plenum shall be used to account for stratification and/or air turbulence. The averaging string shall have a minimum of 4 sensing points per 12-foot long segment.
   c. Capillary supports at the sides of the duct shall be provided to support the sensing string.


C. Humidity Sensors
   1. The sensor shall be a solid-state type, relative humidity sensor of the Bulk Polymer Design. The sensor element shall resist service contamination.
   2. The humidity transmitter shall be equipped with non-interactive span and zero adjustments, a 2-wire isolated loop powered, 4-20 mA, 0-100% linear proportional output.
   3. The humidity transmitter shall meet the following overall accuracy, including lead loss and Analog to Digital conversion. 3% between 20% and 80% RH @ 77 Deg F unless specified elsewhere.
   4. Outside air relative humidity sensors shall be installed with a rain proof, perforated cover. The transmitter shall be installed in a NEMA 3R enclosure with sealite fittings and stainless steel bushings.
   5. A single point humidity calibrator shall be provided, if required, for field calibration. Transmitters shall be shipped factory pre-calibrated.
   6. Duct type sensing probes shall be constructed of 304 stainless steel, and shall be equipped with a neoprene grommet, bushings, and a mounting bracket.

D. Differential Pressure Transmitters
   1. General Air and Water Pressure Transmitter Requirements:
      a. Pressure transmitters shall be constructed to withstand 100% pressure over-range without damage, and to hold calibrated accuracy when subject to a momentary 40% over-range input.
      b. Pressure transmitters shall transmit a 0 to 5 VDC, 0 to 10 VDC, or 4 to 20 mA output signal.
      c. Differential pressure transmitters used for flow measurement shall be sized to the flow sensing device, and shall be supplied with Tee fittings and shut-
off valves in the high and low sensing pick-up lines to allow the balancing Contractor and Owner permanent, easy-to-use connection.

d. A minimum of a NEMA 1 housing shall be provided for the transmitter. Transmitters shall be located in accessible local control panels wherever possible.

2. Low Differential Water Pressure Applications (0” - 20” w.c.)
   a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of flow meter differential pressure or water pressure sensing points.
   b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
      ◊ .01-20” w.c. input differential pressure range.
      ◊ 4-20 mA output.
      ◊ Maintain accuracy up to 20 to 1 ratio turndown.
      ◊ Reference Accuracy: +0.2% of full span.

3. Medium to High Differential Water Pressure Applications (Over 21” w.c.)
   a. The differential pressure transmitter shall meet the low pressure transmitter specifications with the following exceptions:
      ◊ Differential pressure range 10” w.c. to 300 PSI.
      ◊ Reference Accuracy: ±1% of full span (includes non-linearity, hysteresis, and repeatability).
   b. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.

4. Building Differential Air Pressure Applications (-1” to +1” w.c.)
   a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.
   b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
      ◊ -1.00 to +1.00 w.c. input differential pressure ranges. (Select range appropriate for system application)
      ◊ 4-20 mA output.
      ◊ Maintain accuracy up to 20 to 1 ratio turndown.
      ◊ Reference Accuracy: ±0.2% of full span.
   c. Acceptable Manufacturers: Johnson Controls and Setra.

5. Low Differential Air Pressure Applications (0” to 5” w.c.)
   a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.
b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:

◊ (0.00 - 1.00” to 5.00”) w.c. input differential pressure ranges. (Select range appropriate for system application.)
◊ 4-20 mA output.
◊ Maintain accuracy up to 20 to 1 ratio turndown.
◊ Reference Accuracy: +0.2% of full span.

c. Acceptable Manufacturers: Johnson Controls and Setra.

6. Medium Differential Air Pressure Applications (5” to 21” w.c.)

a. The pressure transmitter shall be similar to the Low Air Pressure Transmitter, except that the performance specifications are not as severe. Differential pressure transmitters shall be provided that meet the following performance requirements:

◊ Zero & span: (c/o F.S./Deg. F): .04% including linearity, hysteresis and repeatability.
◊ Accuracy: 1% F.S. (best straight line) Static Pressure Effect: 0.5% F.S. (to 100 PSIG.
◊ Thermal Effects: <-.033 F.S./Deg. F. over 40°F to 100°F. (calibrated at 70°F.)

b. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.

c. Acceptable manufacturers: Johnson Controls and Setra.

E. Flow Monitoring

1. Air Flow Monitoring

a. Fan Inlet Air Flow Measuring Stations

◊ At the inlet of each fan and near the exit of the inlet sound trap, airflow traverse probes shall be provided that shall continuously monitor the fan air volumes and system velocity pressure.
◊ Each traverse probe shall be of a dual manifoldered, cylindrical, type 3003 extruded aluminum configuration, having an anodized finish to eliminate surface pitting and unnecessary air friction. The multiple total pressure manifold shall have sensors located along the stagnation plane of the approaching airflow. The manifold should not have forward projecting sensors into the air stream. The static pressure manifold shall incorporate dual offset static tops on the opposing sides of the averaging manifold so as to be insensitive to flow-angle variations of as much as ±20° in the approaching air stream.
◊ The airflow traverse probe shall not induce a measurable pressure drop, nor shall the sound level within the duct be amplified by its singular or multiple presence in the air stream. Each airflow-measuring probe shall contain multiple total and static pressure sensors placed at equal distances along the probe length. The number of sensors on each probe and the quantity of probes utilized at each installation shall comply with the ASHRAE Standards for duct traversing.
Airflow measuring stations shall be manufactured by Air Monitor Corp., Tek-Air Systems, Inc., Ebtron, or Dietrich Standard.

b. Single Probe Air Flow Measuring Sensor

The single probe airflow-measuring sensor shall be duct mounted with an adjustable sensor insertion length of up to eight inches. The transmitter shall produce a 4-20 mA or 0-10 VDC signal linear to air velocity. The sensor shall be a hot wire anemometer and utilize two temperature sensors and a heater element temperature. The other sensor shall measure the downstream air temperature. The temperature differential shall be directly related to airflow velocity.

c. Duct Air Flow Measuring Stations

Each device shall be designed and built to comply with, and provide results in accordance with, accepted practice as defined for system testing in the ASHRAE Handbook of Fundamentals, as well as in the Industrial Ventilation Handbook.

Airflow measuring stations shall be fabricated of 14-gauge galvanized steel welded casing with 90 Deg. connecting flanges in configuration and size equal to that of the duct into which it is mounted. Each station shall be complete with an air directionalizer and parallel cell profile suppressor (3/4” maximum cell) across the entering air stream and mechanically fastened to the casing in such a way to withstand velocities up to 6000 feet per minute. This air directionalizer and parallel cell honeycomb suppressor shall provide 98% free area, equalize the velocity profile, and eliminate turbulent and rotational flow from the air stream prior to the measuring point.

The total pressure measurement side (high side) will be designed and spaced to the Industrial Ventilation Manual 26th Edition, Page 9-5. The self-averaging manifolding will be manufactured of brass and copper components.


The main take-off point from both the total pressure and the static pressure manifolds must be symmetrical.

Total and static pressure manifolds shall terminate with external ports for connection to control tubing. An identification label shall be placed on each unit casing, listing model number, size, area, and specified airflow capacity.

Installation Considerations

(i) The maximum allowable pressure loss through the Flow and Static Pressure elements shall not exceed .065” w.c. at 1000 feet per minute, or .23” w.c. at 2000 feet per minute. Each unit shall measure the airflow rate within an accuracy of plus 2% as determined by U.S. – GSA certification tests, and shall contain a minimum of one total pressure sensor per 36 square inches of unit measuring area.

(ii) The units shall have a self-generated sound rating of less than NC40, and the sound level within the duct shall not be amplified nor shall additional sound be generated.
(iii) Where the stations are installed in insulated ducts, the airflow passage of the station shall be the same size as the inside airflow dimension of the duct. Station flanges shall be two inch to three inch to facilitate matching connecting ductwork.

(iv) Where control dampers are shown as part of the airflow measuring station, opposed blade precision controlled volume dampers integral to the station and complete with actuator, pilot positioner, and linkage shall be provided.

(v) Stations shall be installed in strict accordance with the manufacturer’s published requirements, and in accordance with ASME Guidelines affecting non-standard approach conditions.

◊ Acceptable manufacturers: Air Monitor Corp., Tek-Air, Ebtron, and Johnson Controls.

d. Static Pressure Traverse Probe

◊ Duct static traverse probes shall be provided where required to monitor duct static pressure. The probe shall contain multiple static pressure sensors located along exterior surface of the cylindrical probe.

◊ Acceptable manufacturers: Cleveland Controls

e. Shielded Static Air Probe

◊ A shielded static pressure probe shall be provided at each end of the building. The probe shall have multiple sensing ports, an impulse suppression chamber, and airflow shielding. A suitable probe for indoor and outdoor locations shall be provided.

2. Water Flow Monitoring

◊ Water flow meters shall be electromagnetic type with integral microprocessor-Based electronics. The meter shall have an accuracy of 0.25%.

◊ Acceptable manufacturers: Onicon

F. Power Monitoring Devices

1. Current Measurement (Amps)

a. Current measurement shall be by a combination current transformer and a current transducer. The current transformer shall be sized to reduce the full amperage of the monitored circuit to a maximum 5 Amp signal, which will be converted to a 4-20 mA DDC compatible signal for use by the Facility Management System.

b. Current Transformer – A split core current transformer shall be provided to monitor motor amps.

◊ Operating frequency – 50 - 400 Hz.
◊ Insulation – 0.6 Kv class 10Kv BIL.
◊ UL recognized.
◊ Five amp secondary.
◊ Select current ration as appropriate for application.

◊ Acceptable manufacturers: Veris Industries

c. Current Transducer – A current to voltage or current to mA transducer shall be provided. The current transducer shall include:

◊ 6X input over amp rating for AC inrushes of up to 120 amps.
Manufactured to UL 1244.

Accuracy: +.5%, Ripple +1%.

Minimum load resistance 30kOhm.

Input 0-20 Amps.

Output 4-20 mA.

Transducer shall be powered by a 24VDC regulated power supply (24 VDC +5%).

Acceptable manufacturers: Veris Industries

G. Smoke Detectors

1. Ionization type air duct detectors shall be furnished as specified elsewhere in Division 26 for installation under Division 23. All wiring for air duct detectors shall be provided under Division 26, Fire Alarm System.

H. Status and Safety Switches

1. General Requirements

   a. Switches shall be provided to monitor equipment status, safety conditions, and generate alarms at the BACS when a failure or abnormal condition occurs. Safety switches shall be provided with two sets of contacts and shall be interlock wired to shut down respective equipment.

2. Current Sensing Switches

   a. The current sensing switch shall be self-powered with solid-state circuitry and a dry contact output. It shall consist of a current transformer, a solid state current sensing circuit, adjustable trip point, solid state switch, SPDT relay, and an LED indicating the on or off status. A conductor of the load shall be passed through the window of the device. It shall accept over-current up to twice its trip point range.

   b. Current sensing switches shall be used for run status for fans, pumps, and other miscellaneous motor loads.

   c. Current sensing switches shall be calibrated to show a positive run status only when the motor is operating under load. A motor running with a broken belt or coupling shall indicate a negative run status.

   d. Acceptable manufacturers: Veris Industries

3. Air Filter Status Switches

   a. Differential pressure switches used to monitor air filter status shall be of the automatic reset type with SPDT contacts rated for 2 amps at 120VAC.

   b. A complete installation kit shall be provided, including: static pressure tops, tubing, fittings, and air filters.

   c. Provide appropriate scale range and differential adjustment for intended service.

   d. Acceptable manufacturers: Johnson Controls, Cleveland Controls

4. Air Flow Switches

   a. Differential pressure flow switches shall be bellows actuated mercury switches or snap acting micro-switches with appropriate scale range and differential adjustment for intended service.

   b. Acceptable manufacturers: Johnson Controls, Cleveland Controls

5. Air Pressure Safety Switches
a. Air pressure safety switches shall be of the manual reset type with SPDT contacts rated for 2 amps at 120VAC.
b. Pressure range shall be adjustable with appropriate scale range and differential adjustment for intended service.
c. Acceptable manufacturers: Johnson Controls, Cleveland Controls

6. Water Flow Switches
   a. Water flow switches shall be equal to the Johnson Controls P74.

7. Low Temperature Limit Switches
   a. The low temperature limit switch shall be of the manual reset type with Double Pole/Single Throw snap acting contacts rated for 26 amps at 120VAC.
   b. The sensing element shall be a minimum of 23 feet in length and shall react to the coldest 18-inch section. Element shall be mounted horizontally across duct in accordance with manufacturers recommended installation procedures.
   c. For large duct areas where the sensing element does not provide full coverage of the air stream, additional switches shall be provided as required to provide full protection of the air stream.
   d. The low temperature limit switch shall be equal to Johnson Controls A70.

2.9 Output Devices

A. Actuators
   1. General Requirements
      a. Damper and valve actuators shall be electronic and/or pneumatic, as specified in the System Description section.
   2. Electronic Damper Actuators
      a. Electronic damper actuators shall be direct shaft mount.
      b. Modulating and two-position actuators shall be provided as required by the sequence of operations. Damper sections shall be sized Based on actuator manufacturer’s recommendations for face velocity, differential pressure and damper type. The actuator mounting arrangement and spring return feature shall permit normally open or normally closed positions of the dampers, as required. All actuators (except terminal units) shall be furnished with mechanical spring return unless otherwise specified in the sequences of operations. All actuators shall have external adjustable stops to limit the travel in either direction, and a gear release to allow manual positioning.
      c. Modulating actuators shall accept 24 VAC or VDC power supply, consume no more than 23 VA, and be UL listed. The control signal shall be 2-10 VDC or 4-20 mA, and the actuator shall provide a clamp position feedback signal of 2-10 VDC. The feedback signal shall be independent of the input signal and may be used to parallel other actuators and provide true position indication. The feedback signal of one damper actuator for each separately controlled damper shall be wired back to a terminal strip in the control panel for trouble-shooting purposes.
      d. Two-position or open/closed actuators shall accept 24 or 120 VAC power supply and be UL listed. Isolation, smoke, exhaust fan, and other dampers, as specified in the sequence of operations, shall be furnished with adjustable end switches to indicate open/closed position or be hard wired to
start/stop associated fan. Two-position actuators, as specified in sequences of operations as “quick acting,” shall move full stroke within 20 seconds. All smoke damper actuators shall be quick acting.

e. Acceptable manufacturers: Johnson Controls, Mamac, Belimo

3. Electronic Valve Actuators

a. Electronic valve actuators shall be manufactured by the valve manufacturer.
b. Each actuator shall have current limiting circuitry incorporated in its design to prevent damage to the actuator.
c. Modulating and two-position actuators shall be provided as required by the sequence of operations. Actuators shall provide the minimum torque required for proper valve close-off against the system pressure for the required application. The valve actuator shall be sized based on valve manufacturer’s recommendations for flow and pressure differential. All actuators shall fail in the last position unless specified with mechanical spring return in the sequence of operations. The spring return feature shall permit normally open or normally closed positions of the valves, as required. All direct shaft mount rotational actuators shall have external adjustable stops to limit the travel in either direction.
d. Modulating Actuators shall accept 24 VAC or VDC and 120 VAC power supply and be UL listed. The control signal shall be 2-10 VDC or 4-20 mA and the actuator shall provide a clamp position feedback signal of 2-10 VDC. The feedback signal shall be independent of the input signal, and may be used to parallel other actuators and provide true position indication. The feedback signal of each valve actuator (except terminal valves) shall be wired back to a terminal strip in the control panel for trouble-shooting purposes.
e. Two-position or open/closed actuators shall accept 24 or 120 VAC power supply and be UL listed. Butterfly isolation and other valves, as specified in the sequence of operations, shall be furnished with adjustable end switches to indicate open/closed position or be hard wired to start/stop the associated pump or chiller.
f. Acceptable manufacturers: Johnson Controls or Belimo

B. Control Dampers

1. The BACS Contractor shall furnish all automatic dampers. All automatic dampers shall be sized for the application by the BACS Contractor or as specifically indicated on the Drawings.

2. All dampers used for throttling airflow shall be of the opposed blade type arranged for normally open or normally closed operation, as required. The damper is to be sized so that, when wide open, the pressure drop is a sufficient amount of its close-off pressure drop to shift the characteristic curve to near linear.

3. All dampers used for two-position, open/close control shall be parallel blade type arranged for normally open or closed operation, as required.

4. Damper frames and blades shall be constructed of either galvanized steel or aluminum. Maximum blade length in any section shall be 60”. Damper blades shall be 26-gauge minimum and shall not exceed eight (8) inches in width. Damper frames shall be 26-gauge minimum hat channel type with corner bracing. All damper bearings shall be made of reinforced nylon, stainless steel or oil-impregnated bronze. Dampers shall be tight closing, low leakage type, with synthetic elastomer seals on the blade edges and flexible stainless steel side seals.
Dampers of 48”x48” size shall not leak in excess of 8.0 cfm per square foot when closed against 4” w.g. static pressure when tested in accordance with AMCA Std. 500.

5. Airfoil blade dampers of double skin construction with linkage out of the air stream shall be used whenever the damper face velocity exceeds 2300 FPM or system pressure exceeds 2.5” w.g., but no more than 4000 FPM or 6” w.g. Acceptable manufacturers are Johnson Controls D-7250 D-1250 or D-1300, Ruskin CD50, and Vent Products 5650.

6. One piece rolled blade dampers with exposed or concealed linkage may be used with face velocities of 2300 FPM or below. Acceptable manufacturers are: Johnson Controls D-2600, Ruskin CD36, and Vent Products 5800.

7. Multiple section dampers may be jack-shafted to allow mounting of piston pneumatic actuators and direct connect electronic actuators. Each end of the jackshaft shall receive at least one actuator to reduce jackshaft twist.

C. Control Relays

1. Control Pilot Relays
   a. Control pilot relays shall be of a modular plug-in design with retaining springs or clips.
   b. Mounting Bases shall be snap-mount.
   c. DPDT, 3PDT, or 4PDT relays shall be provided, as appropriate for application.
   d. Contacts shall be rated for 10 amps at 120VAC.
   e. Relays shall have an integral indicator light and check button.
   f. Acceptable manufacturers: Johnson Controls, Lectro

2. Lighting Control Relays
   a. Lighting control relays shall be latching with integral status contacts.
   b. Contacts shall be rated for 20 amps at 277 VAC.
   c. The coil shall be a split low-voltage coil that moves the line voltage contact armature to the ON or OFF latched position.
   d. Lighting control relays shall be controlled by:
      ◊ Pulsed Tri-state Output – Preferred method.
      ◊ Pulsed Paired Binary Outputs.
      ◊ A Binary Input to the Facility Management System shall monitor integral status contacts on the lighting control relay. Relay status contacts shall be of the “dry-contact” type.
   e. The relay shall be designed so that power outages do not result in a change-of-state, and so that multiple same state commands will simply maintain the commanded state. Example: Multiple OFF command pulses shall simply keep the contacts in the OFF position.

D. Control Valves

1. All automatic control valves shall be fully proportioning and provide near linear heat transfer control. The valves shall be quiet in operation and fail-safe open, closed, or in their last position. All valves shall operate in sequence with another valve when required by the sequence of operations. All control valves shall be sized by the control manufacturer, and shall be guaranteed to meet the heating and cooling loads, as specified. All control valves shall be suitable for the system flow conditions and close against the differential pressures involved. Body pressure
rating and connection type (sweat, screwed, or flanged) shall conform to the pipe schedule elsewhere in this Specification.

2. Chilled water control valves shall be modulating plug, ball, and/or butterfly, as required by the specific application. Modulating water valves shall be sized per manufacturer’s recommendations for the given application. In general, valves (2 or 3-way) serving variable flow air handling unit coils shall be sized for a pressure drop equal to the actual coil pressure drop, but no less than 5 PSI. Valves (3-way) serving constant flow air handling unit coils with secondary circuit pumps shall be sized for a pressure drop equal to 25% the actual coil pressure drop, but no less than 2 PSI. Mixing valves (3-way) serving secondary water circuits shall be sized for a pressure drop of no less than 5 PSI. Valves for terminal reheat coils shall be sized for a 2 PSIG pressure drop, but no more than a 5 PSI drop.

3. Ball valves shall be used for hot and chilled water applications, water terminal reheat coils, radiant panels, unit heaters, package air conditioning units, and fan coil units except those described hereinafter.

4. Modulating plug water valves of the single-seat type with equal percentage flow characteristics shall be used for all special applications as indicated on the valve schedule. Valve discs shall be composition type. Valve stems shall be stainless steel.

5. Butterfly valves shall be acceptable for modulating large flow applications greater than modulating plug valves, and for all two-position, open/close applications. In-line and/or three-way butterfly valves shall be heavy-duty pattern with a body rating comparable to the pipe rating, replaceable lining suitable for temperature of system, and a stainless steel vane. Valves for modulating service shall be sized and travel limited to 50 degrees of full open. Valves for isolation service shall be the same as the pipe. Valves in the closed position shall be bubble-tight.

6. Pressure independent delta-p valves may be used for hydronic heating applications.

E. External Manual Override Stations

1. External manual override stations shall provide the following:
   a. An integral HAND/OFF/AUTO switch shall override the controlled device pilot relay.
   b. A status input to the Facility Management System shall indicate whenever the switch is not in the automatic position.
   c. A Status LED shall illuminate whenever the output is ON.
   d. An Override LED shall illuminate whenever the HOA switch is in either the HAND or OFF position.
   e. Contacts shall be rated for a minimum of 1 amp at 24 VAC.

F. Electronic/Pneumatic Transducers

1. Electronic to Pneumatic transducers shall provide:
   a. Output: 3-23 PSIG.
   b. Input: 4-20 mA or 0-10 VDC.
   d. Pressure gauge.
   e. External replaceable supply air filter.
   f. Acceptable manufacturers: Johnson Controls, Mamac, ACT

2.10 Miscellaneous Devices
A. Variable Frequency Motor Speed Control Drives
   1. Variable frequency drives shall be Danfoss, supplied by the BACS or Electrical Contractor. Provide 3-contactor bypass with integral disconnect.

B. Local Control Panels
   1. All control panels shall be factory constructed, incorporating the BACS manufacturer’s standard designs and layouts. All control panels shall be UL inspected and listed as an assembly and carry a UL 508 label listing compliance. Control panels shall be fully enclosed, with perforated sub-panel, hinged door, and slotted flush latch.
   2. In general, the control panels shall consist of the DDC controller(s), display module as specified and indicated on the plans, and I/O devices—such as relays, transducers, and so forth—that are not required to be located external to the control panel due to function. Where specified the display module shall be flush mounted in the panel face unless otherwise noted.
   3. All I/O connections on the DDC controller shall be provide via removable or fixed screw terminals.
   4. Low and line voltage wiring shall be segregated. All provided terminal strips and wiring shall be UL listed, 300-volt service and provide adequate clearance for field wiring.
   5. All wiring shall be neatly installed in plastic trays or tie-wrapped.
   6. A convenience 120 VAC duplex receptacle shall be provided in each enclosure, fused on/off power switch, and required transformers.

C. Power Supplies
   1. DC power supplies shall be sized for the connected device load. Total rated load shall not exceed 75% of the rated capacity of the power supply.
   2. Input: 120 VAC +10%, 60Hz.
   3. Output: 24 VDC.
   4. Line Regulation: +0.05% for 10% line change.
   5. Load Regulation: +0.05% for 50% load change.
   6. Ripple and Noise: 1 mV rms, 5 mV peak to peak.
   7. An appropriately sized fuse and fuse block shall be provided and located next to the power supply.
   8. A power disconnect switch shall be provided next to the power supply.
   9. When the application is life safety or mission critical, provide an uninterruptible power supply of capacity and duration sufficient to maintain operation of system.

D. Thermostats
   1. Electric room thermostats of the heavy-duty type shall be provided for unit heaters, cabinet unit heaters, and ventilation fans, where required. All these items shall be provided with concealed adjustment. Finish of covers for all room-type instruments shall match and, unless otherwise indicated or specified, covers shall be manufacturer’s standard finish.

3. Part 3 – Execution

3.1 BACS Specific Requirements
A. Graphic Displays
   1. Graphics will be developed for the project will be representative of the systems
      controlled by the BACS. Floor plans will be provided by the project
      Architect/Engineer and will be used to develop floor-level graphics to speed
      recognition and response for operation of BACS. Level of graphics capability will
      be based on the type of system controlled.
         a. Provide floor plan(s) defining spaces (with University approved
            numbering) that are served by each air handling unit.
         b. Provide schematic drawing showing the unit configuration and
            control devices for each air handling unit.

B. Custom Reports:
   1. As required.

C. Actuation / Control Type
   1. Primary Equipment
      a. Controls shall be provided by equipment manufacturer as specified herein.
      b. All damper and valve actuation shall be electric.
   2. Air Handling Equipment
      a. All air handers shall be controlled with a HVAC-DDC Controller
      b. All damper and valve actuation shall be electric.
   3. Terminal Equipment:
      a. Terminal Units (VAV, UV, etc.) shall have electric damper and valve
         actuation.
      b. All Terminal Units shall be controlled with HVAC-DDC Controller

3.2 Installation Practices
A. BACS Wiring
   1. All conduit, wiring, accessories and wiring connections required for the installation
      of the Building Automation Controls System, as herein specified, shall be provided
      by the BACS Contractor unless specifically shown on the Electrical Drawings
      under Division 26 Electrical. All wiring shall comply with the requirements of
      applicable portions of Division 26 and all local and national electric codes, unless
      specified otherwise in this section.
   2. All BACS wiring materials and installation methods shall comply with BACS
      manufacturer recommendations.
   3. The sizing, type and provision of cable, conduit, cable trays, and raceways shall be
      the design responsibility of the BACS Contractor. If complications arise, however,
      due to the incorrect selection of cable, cable trays, raceways and/or conduit by the
      BACS Contractor, the Contractor shall be responsible for all costs incurred in
      replacing the selected components.
   4. Class 2 Wiring
      a. All Class 2 (24VAC or less) wiring shall be installed in conduit unless
         otherwise specified.
      b. Conduit is not required for Class 2 wiring in concealed accessible locations.
         Class 2 wiring not installed in conduit shall be supported every 5’ from the
         building structure utilizing metal hangers designed for this application.
BUILDING AUTOMATION CONTROLS SYSTEM

Wiring shall be installed parallel to the building structural lines. All wiring shall be installed in accordance with local code requirements.

5. Class 2 signal wiring and 24VAC power can be run in the same conduit. Power wiring 120VAC and greater cannot share the same conduit with Class 2 signal wiring.

6. Provide for complete grounding of all applicable signal and communications cables, panels and equipment so as to ensure system integrity of operation. Ground cabling and conduit at the panel terminations. Avoid grounding loops.

7. Remove all cabling this has been abandoned or is no longer in service.

8. Color code wiring in accordance with KU standards.

B. BACS Line Voltage Power Source

1. 120-volt AC circuits used for the Building Automation Controls System shall be taken from panel boards and circuit breakers provided by Division 26.

2. Circuits used for the BACS shall be dedicated to the BACS and shall not be used for any other purposes.

3. DDC terminal unit controllers may use AC power from motor power circuits.

C. BACS Raceway

1. All wiring shall be installed in conduit or raceway except as noted elsewhere in this specification. Minimum control wiring conduit size 1/2”.

2. Where it is not possible to conceal raceways in finished locations, surface raceway (Wiremold) may be used as approved by the Architect.

3. All conduits and raceways shall be installed level, plumb, at right angles to the building lines and shall follow the contours of the surface to which they are attached.

4. Flexible Metal Conduit shall be used for vibration isolation and shall be limited to 3 feet in length when terminating to vibrating equipment. Flexible Metal Conduit may be used within partition walls. Flexible Metal Conduit shall be UL listed.

D. Penetrations

1. Provide fire stopping for all penetrations used by dedicated BACS conduits and raceways.

2. All openings in fire proofed or fire stopped components shall be closed by using UL approved fire resistive sealant and/or system.

3. All wiring passing through penetrations, including walls shall be in conduit or enclosed raceway.

4. Penetrations of floor slabs shall be by core drilling. All penetrations shall be plumb, true, and square.

E. BACS Identification Standards

1. Node Identification. All nodes shall be identified by a permanent label fastened to the enclosure. Labels shall be suitable for the node location.

   Cable types specified in Item A shall be color coded for easy identification and troubleshooting.

F. BACS Panel Installation

1. The BACS panels and cabinets shall be located as indicated at an elevation of not less than 2 feet from the bottom edge of the panel to the finished floor. Each cabinet shall be anchored per the manufacturer’s recommendations.
2. The BACS contractor shall be responsible for coordinating panel locations with other trades and electrical and mechanical contractors.

G. Input Devices
1. All Input devices shall be installed per the manufacturer recommendation
2. Locate components of the BACS in accessible local control panels wherever possible.

H. HVAC Input Devices – General
1. All Input devices shall be installed per the manufacturer recommendation
2. Locate components of the BACS in accessible local control panels wherever possible.
3. The mechanical contractor shall install all in-line devices such as temperature wells, pressure taps, airflow stations, etc.
5. Outside Air Sensors
   a. Sensors shall be mounted on the North wall to minimize solar radiant heat impact or located in a continuous intake flow adequate to monitor outside air conditions accurately.
   b. Sensors shall be installed with a rain proof, perforated cover.

6. Water Differential Pressure Sensors
   a. Differential pressure transmitters used for flow measurement shall be sized to the flow-sensing device.
   b. Differential pressure transmitters shall be supplied with tee fittings and shut-off valves in the high and low sensing pick-up lines.
   c. The transmitters shall be installed in an accessible location wherever possible.

7. Medium to High Differential Water Pressure Applications (Over 21” w.c.):
   a. Air bleed units, bypass valves and compression fittings shall be provided.

8. Building Differential Air Pressure Applications (-1” to +1” w.c.):
   a. Transmitters exterior sensing tip shall be installed with a shielded static air probe to reduce pressure fluctuations caused by wind.
   b. The interior tip shall be inconspicuous and located as shown on the drawings.

9. Air Flow Measuring Stations:
   a. Where the stations are installed in insulated ducts, the airflow passage of the station shall be the same size as the inside airflow dimension of the duct.
   b. Station flanges shall be two inch to three inch to facilitate matching connecting ductwork.

10. Duct Temperature Sensors:
    a. Duct mount sensors shall mount in an electrical box through a hole in the duct and be positioned so as to be easily accessible for repair or replacement.
    b. The sensors shall be insertion type and constructed as a complete assembly including lock nut and mounting plate.
c. For ductwork greater in any dimension than 48 inches or where air temperature stratification exists such as a mixed air plenum, utilize an averaging sensor.
d. The sensor shall be mounted to suitable supports using factory approved element holders.

11. Space Sensors:
a. Shall be mounted per ADA requirements, or as stated on project drawings.
b. Provide lockable tamper-proof covers in public areas and/or where indicated on the plans.

12. Low Temperature Limit Switches:
a. Install on the discharge side of the first water or steam coil in the air stream.
b. Mount element horizontally across duct in a serpentine pattern insuring each square foot of coil is protected by 1 foot of sensor.
c. For large duct areas where the sensing element does not provide full coverage of the air stream, provide additional switches as required to provide full protection of the air stream.

13. Air Differential Pressure Status Switches:
a. Install with static pressure tips, tubing, fittings, and air filter.

14. Water Differential Pressure Status Switches:
a. Install with shut off valves for isolation.

I. HVAC Output Devices
1. All output devices shall be installed per the manufacturers recommendation. The mechanical contractor shall install all in-line devices such as control valves, dampers, airflow stations, pressure wells, etc.
2. Actuators: All control actuators shall be sized capable of closing against the maximum system shut-off pressure. The actuator shall modulate in a smooth fashion through the entire stroke. When any pneumatic actuator is sequenced with another device, pilot positioners shall be installed to allow for proper sequencing.
3. Control Dampers: Shall be opposed blade for modulating control of airflow. Parallel blade dampers shall be installed for two position applications.
4. Control Valves: Shall be sized for proper flow control with equal percentage valve plugs. The maximum pressure drop for water applications shall be 5 PSI. The maximum pressure drop for steam applications shall be 7 PSI.
5. Electronic Signal Isolation Transducers: Whenever an analog output signal from the Building Automation Controls System is to be connected to an external control system as an input (such as a chiller control panel), or is to receive as an input a signal from a remote system, provide a signal isolation transducer. Signal isolation transducer shall provide ground plane isolation between systems. Signals shall provide optical isolation between systems.

3.3 Project Acceptance
A. The BACS contractor shall have all control points operating and viewable on the campus Metasys system at substantial completion:
1. Provide a document containing “screen captures” of all the Metasys views of every piece of HVAC equipment including, but not limited to, chillers, cooling towers, pumps, air handling units, and terminal boxes. Two hard copies and one electronic copy shall be provided to Owner.
2. Provide “first draft” of current as-built submittals to the Owner no later than substantial completion date. One hard copy and one electronic copy. Final comprehensive as-built submittals shall be routed per the usual project process.

3. Complete graphics in timely fashion to facilitate building maintenance. Deliver to Owner at the same time as the project Cx report (by others).

3.4 Training
A. The BACS contractor shall provide the following training services:
   1. One day (8 hours or as determined by project requirements) of on-site orientation by a system technician who is fully knowledgeable of the specific installation details of the project. This orientation shall, at a minimum, consist of a review of the project as-built drawings, the BACS software layout and naming conventions, and a walk through of the facility to identify panel and device locations.
      a. System technician shall demonstrate the operation of each air handling unit control device and conformance to the project sequence of operation.
      b. Demonstration shall be coordinated with project commissioning agent.

3.5 Commissioning
A. Fully test all aspects of the Building Automation Controls System work.
B. Acceptance Check Sheet
   1. Prepare a check sheet that includes all points for all functions of the BACS as indicated on the point list included in the contract documents.
   2. Submit the check sheet to the Engineer for approval
   3. The Engineer will use the check sheet or other means as the basis for acceptance of the BACS system.
C. VAV box performance verification and documentation:
   1. The BACS Contractor shall test each VAV box for operation and correct flow.
D. Promptly rectify all listed deficiencies and submit to the Engineer that this has been done.
E. Coordination with project commissioning (Cx) agent:
   1. Provide allowance for assistance with project Cx agent.
   2. Provide copies of all acceptance check sheets and VAV box verification.
   3. Provide “first draft” of current as-built submittals to the Cx agent no later than substantial completion date.

3.6 Sequences of operation and points lists
A. Per construction documents.
B. Zone setpoints shall be 69 degrees (winter) and 76 degrees (summer) (adjustable) for non-research spaces. Winter and Summer zone setpoints shall be created for all systems.
C. The A/E shall consult with Owner for zone setpoints in research or other specialized occupancies.

END OF SECTION 230900