KCTCS Using Agency Project Requirements For Building Automation Systems

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Revision History

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1. Introduction

a. KCTCS has two Enterprise Building Automation Systems. One is Tridium/Niagara based and one is Automated Logic based. We achieve similar operational results with each system, and both are considered primary systems.
b. This document will help describe the minimum requirements that both systems must meet to be considered for each installation.
c. The "KCTCS Agency Project Requirements for BAS" is intended to communicate the KCTCS project requirements for building automation systems (BAS) to the design team. These requirements are to be adapted into the project design and specifications as appropriate for the application. These do not modify the project design and contracting team's responsibility for project design, specification, and construction.
d. For the purposes of maintaining the security and reporting integrity of its enterprise BAS network, KCTCS has established a BAS Standards and Compliance Team. This team's primary responsibility, related to new and renovation construction projects, is to assure that the building automation systems are designed and installed consistent with the quality and performance requirements of the current KCTCS Information Technology and BAS Network Standards and Policies.
e. To accomplish these objectives, KCTCS requires several changes to the traditional delineation of responsibilities in implementing building automation systems. The designer is cautioned to make note of these departures from previous BAS project requirements.
f. The Designer shall make every attempt to allow competitive bidding of the BAS and controls systems without compromising the project requirements defined in this document. When adjustments are required to achieve this end, such adjustments must be approved by the Division of Engineering and Contract Administration (DECA) Project Manager and the KCTCS Capital Project Manager.

2. Definition of Terms

a. BACnet: a communications protocol, defined by ANSI / ASHRAE™ Standard 135-2004
b. BAS: Building Automation System
c. CEMCS: Commonwealth Energy Management and Control System
d. CLAN: Controls System Local Area Network
e. DECA: Division of Engineering and Contract Administration
f. DDC: Direct Digital Controls
g. GUI: Graphical User Interface
h. IPsec: Internet Protocol Security
i. JACE: Java Application Control Engine
j. KCTCS: Kentucky Community and Technical College System
k. WAN: KCTCS Enterprise Wide Area Network
l. Lon: a communications protocol, defined by EIA standard 709.1 protocol (LonTalk™), components referred to as LonMark™ or LonWorks™ compliant.
m. Modbus: a communications protocol, managed by the Modbus Organization
n. MSTP: Master Slave Token Passing Protocol
o. NiCS: Niagara^{AX} Compatibility Statement
p. OFCI: Owner Furnished, Contractor Installed
q. PES: Portable Engineering Station

r. S/C Team: KCTCS BAS Standards and Compliance Team
s. SNVT: Standard Network Variables Type
t. TCP/IP: Transmission Control Protocol/Internet Protocol
u. UAPR: User Agency Project Requirements
v. UNC: Universal Network Controller
w. VPN: Virtual Private Network

3. KCTCS BAS Standards and Compliance Team - Coordination Requirements

The primary areas where the KCTCS Capital Project Manager's role will impact the design and construction process include but are not limited to:

a. Design Phase
   i. Design Deliverables Checklist Review
   ii. Incremental Design Reviews
   iii. Incremental Design Phase Approvals
b. Construction
   i. BAS Supplier Pre-Bid Conference
   ii. HVAC Instrumentation and Controls Scheduling Meeting
   iii. Pre-Submittal Meeting
   iv. Submittal Review
   v. Controls Standard Object Palettes for Controls Suppliers
   vi. Building and Building System Graphics Generation
   vii. Building Controls to College Server Integration
   viii. Controls Implementation & Commissioning Acceptance
   ix. Owner Proficiency Meeting
   x. Warranty Phase Operations
   xi. Warranty Transition

4. KCTCS Building Automation System Description

A typical controls system architecture in the existing KCTCS inventory is comprised of multiple tiers of communication; the most fundamental being the local equipment controller (BAS Level 1) at the bottom rung, up to the Building Controller Level (BAS Level 2) which manages the multiple equipment controllers and passes information up to the Server/BACnet router level (BAS Level 3) which manages the human interface and reporting functions. It is a KCTCS requirement that the BAS architecture implementation and any expansion be accomplished with open protocols / all vendor engineering tools (including database, programming and graph creating applications) shall be included in all projects installed at KCTCS facilities, and shall not be limited in anyway, nor should there be any additional charges for use or distribution within the KCTCS facilities division.

a. This has been difficult to accomplish due to the complexity and proprietary nature of the many control suppliers that have been utilized at the sixteen (16) colleges.

b. To take full advantage of the existing BAS investment and avoid adding to the BAS complexity, two (2) enterprise level software platforms are currently deployed to implement the KCTCS BAS network. These platforms are Niagara Tridium Web Supervisor and Automated Logic WebCTRL. The intent is to accommodate the existing BAS networks while maintaining the ability to competitively bid construction projects without compromising the BAS standards and operations. The open nature of these enterprise platforms will enable this plan.

c. To enable competitive bidding of construction projects, without compromising the BAS standards and operations, the controls supplier/vendor/contractor shall install the Level 2 or 3 controller in the form of a (owner furnished) Tridium Vykon JACE network controller or a vendor furnished Automated Logic BACnet/IP router. They shall also provide all Level 1 Application Specific and Custom Application Controllers, as well as all control sensing, actuation, and similar devices. The preferred protocol for Level 1 controllers will be BACnet/MSTP, however, LON devices will be considered subject to Building Automation System / Control Product Requirements (paragraph 6 below) and applicable provisions of these agency requirements.

   The enterprise BAS architecture must also be implemented in a manner that will maintain the integrity and security of BAS and other KCTCS networks. These provisions are detailed within KCTCS reference documentation. This document is updated as technology and security developments occur; the design team should request the most current version at the concept development stage of a project. BACnet/IP networking standards, including the standardized definition/assignments of BACnet Network Numbers and Device Instance Numbers, will be provided by KCTCS and be a requirement for all installing controls contractors to implement on any new controls system being installed. The control system communications shall be transparent, meaning that the user or control programmer does not need to know the details of system architecture and operation.

d. The project design shall provide for all labor, materials, equipment programming, and service necessary for a complete and operating control system, utilizing a high-speed peer to peer network of interoperable Direct Digital Controls (DDC), electronic sensing and actuation devices, and Graphical User Interface (GUI) with color graphic displays available to the Enterprise network user.

e. The Controls System Local Area Network (CLAN) for dedicated controllers shall be at least 100 Mpbs Ethernet furnished by the control system supplier and shall support BACnet IP, BACnet MSTP, Lon, Modbus TCP, and Modbus Async for maximum flexibility for integration of building data with Universal Network Controllers (UNCs) to control system supplier's Application Specific Controllers, Custom Application Controllers, and control devices.

f. The Enterprise Ethernet (IEEE 802.3) shall utilize the Wide Area Network (WAN) furnished and maintained by KCTCS.

g. The control system shall consist of an open architecture with capability to utilize EIA standard 709.1 (LonTalk™) protocol, as a common communication protocol between controllers and integral ANSI / ASHRAE™ Standard 135-2XXX (BACnet- current release) functionality to assure interoperability among all system components. Both the Lon protocol and the BACnet protocol are required to assure that the project be fully supported by the two leading HVAC open protocols to reduce future building maintenance, upgrade, and expansion costs. Where specific products are not Lon or BACnet compatible, the Modbus protocol is an acceptable communication protocol to that specific device only.

h. The products used in constructing the control system shall be LonMark™ certified and complaint.

i. The software tools including cables and connectors required to manage all the open protocols must be provided with the system, and these tools shall include a perpetual license. Minimum BACnet compliance is at Level 2 and 3; and all output points (AO,AV, MSO, BO, BV, etc.) must support data read and write functionality, and all points must be enabled. Physical connection of BACnet devices shall be via Ethernet/Ethernet IP.

j. All work described in this section shall be installed, circuit tested, and calibrated by factory certified technicians qualified for this work and in the regular employment of the Control System Supplier.

k. Provide Portable Engineering Station (PES) software, and interfaces to provide uploading/downloading of Custom Application Controller and Application Specific Controllers databases, monitoring of all Lon Standard Network Variable Types (SNVTs) including display of all bound SNVTs, monitoring and overrides of all controllers physical input/output points, and editing of controller resident time schedules. PES connectivity shall be via digital wall sensor connected to controller. This software must include a perpetual license.

l. All provided software and applications for a project will be hosted on KCTCS provided college level servers and maybe utilized for current and future controls projects at that college exclusively. These resources will not be shared between college servers.

5. Building Automation System Design Requirements

a. Design Deliverables
   i. Phase A - Conceptual Design Requirements
      1) Submit MEP Deliverables Checklist including BAS/Controls Design Deliverables
      2) MEP System Control Description including:
         a. Preliminary Controlled Systems Sequence Descriptions
         b. Conceptual MEP Flow Schematics
         c. Preliminary Electrical Riser Diagram with sub-metering strategy to measure HVAC, lighting, receptacle, and instructional power energy usage.

   ii. Phase B - Design Development Requirements
      1) 95% MEP system flow schematics
      2) Controls Specifications Draft
      3) 95% Control Sequences and KCTCS-CEMCS compatible Points List (obtain current standard objects point list from the KCTCS Capital Project Manager or DECA Project Manager during Phase A Design).
      4) 95% Controls Specification
      5) 75% Entry to Distribution Panel Electrical Riser Diagram
      6) Room Numbering Methodology Defined
      7) BAS Standards & Compliance Team Coordination Meeting
         a. Custom Graphics Definition
         b. OFCI Component & Services Decisions
      8) Phase B Design Review shall also include the:
         a. BAS Standards & Compliance Team
         b. HVAC Service Contract Provider

9) Training scope requirements will be provided to the Design Team by the BAS Standards & Compliance Team during the Phase B Design Review

iii. Phase C - Construction Documents Requirements
1) Phase C 50% Review
a. Room Numbering Firmly Established
b. BAS / Controls on Emergency Power
c. Unique Equipment Identification
d. HVAC Equipment schedules include fields which indicate system component relationships where such exist, for instance:
i. Air Terminal Unit's to upstream Air Handling Unit
ii. Air Handling Unit to upstream pumps
iii. Etc.
e. Electrical Panel schedules include fields which indicate feed source identification
f. BAS Standards & Compliance Team Review Meeting

2) Phase C 100% Review
a. Control Sequence Set-points Defined
b. Control Sequence Schedules Defined
c. Sub-contractor's bid form listing:
i. Identification of the Controls Provider
ii. Identification of the Niagara AX Certified Technician
d. Materials (Equipment) bid form listing:
i. Controls Manufacturer

b. Submittal Requirements
i. Include manufacturer's technical literature for each control device.

ii. Bill of materials of equipment indicating quantity, manufacturer, and model number, cross referenced to Component Tag on Plans.

iii. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and all other control devices.

iv. Wiring Diagrams: Power, signal, and control wiring, with wire number identification.

v. Written description of sequence of operation, and either: 1) programming ladder logic diagrams, or 2) control logic block diagrams, fully populated with initial set- point and control values.

vi. Schedule of dampers and valves including size, leakage, torque requirements and flow characteristics.

vii. DDC System Hardware:
1) Wiring diagrams for control units with termination numbers.
2) Schematic diagrams and scaled floor plans for field sensors and control hardware.
3) Schematic diagrams for control, communication, and power wiring, showing trunk data conductors and wiring between operator workstation and control unit locations.
4) Points list.

viii. Control System Software:
   1) Summary List of "Standard Objects" Graphic Palettes being utilized. (Required for Niagara Web Supervisor integration only)
   2) Summary List of points to be displayed on each "Standard Object" Graphic. (Required for Niagara Web Supervisor integration only)
   3) Summary List of all Custom Graphics to be developed by the KCTCS Capital Project Team.
      a. Floor Plans
      b. System Schematics
      c. Custom Equipment
      d. Etc.
   4) Summary list of points to be displayed on these custom graphics.
   5) Other graphic requirements as outlined in paragraph 8.b. BAS Graphics Coordination below and as defined during the Pre-Submittal meeting.

ix. Data Communications Protocol Certificates: Certify that each proposed DDC system component complies with Lon, Modbus and BACnet standards.

x. Qualification Data: For installer, manufacturer, and Niagara 4 Certified Technician. The certification is dependent upon the existing architecture version of the KCTCS College.

xi. Project Work Schedule: Provide a Gantt or Critical Path Work Schedule developed in conjunction with the General Contractor, Divisions 23, 26, 27, and 28 Sub-contractors demonstrating the plan to have the HVAC systems installed and operational in ample time to complete functional performance tests prior to the substantial completion deadline; and ample time between substantial and final completion for the KCTCS Capital Project Team to complete a compliance review.

xii. Operation and Maintenance Data: For instrumentation and control system components to include in emergency, operation, and maintenance manuals. Include the following:
   1) Maintenance instructions and lists of spare parts for each type of control device and / or compressed-air station.
   2) Interconnection wiring diagrams with identified and numbered system components and devices.
   3) Keyboard illustrations and step-by-step procedures indexed for each operator function.
   4) Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
   5) Calibration records and list of set points.

xiii. Field quality-control checklists.

c. Quality Assurance Requirements
In addition to device listing, labeling and conformance to industry standards; the following quality assurance provisions are required:

i. Controls Provider Qualifications: The control systems provider shall be the controls manufacturer's authorized representative, who is trained and approved for installation of the system components required for this Project. The Controls Provider will be responsible for the installation quality and warranty.

1) The Controls Provider shall have a minimum rated qualification of five (5) years of installation experience with the manufacturer and shall provide documentation in the submittal package verifying longevity of the installing company's relationship with the manufacturer.
2) Supervision, calibration, and checkout of the system shall be by the employees of the Controls Provider.
3) The Controls Provider shall have a full-service facility within Kentucky or surrounding States that is staffed with engineers/technicians trained in integrating interoperable systems and fully capable of providing Lon, Modbus and BACnet programming and instruction.
4) The Controls Provider shall have support within 200 statute miles of the site with technical staff, spare parts inventory and all necessary test and diagnostic equipment to perform routine and emergency maintenance service on all system components.
5) The Controls Provider shall utilize a Niagara 4 Framework Certified Technician with a minimum of three (3) years programming experience of Niagara 4 systems to program the Vykon JACE networked controllers and to configure all attributes of the controlled devices being served up to the College Level Niagara 4 Supervisor. Programming shall be implemented in a manner that there are no restrictions on which brands or tools can interact with the system, except for integral factory installed equipment controllers.
6) The Controls Provider's Project Manager and the Niagara Framework Certified Technician shall complete a publicly accessible training and orientation session on the implementation requirements for the KCTCS Building Automation System that will be offered by the KCTCS BAS Manager.
    a. A Certification Statement will be issued upon completion of the session.
    b. It is strongly encouraged but not mandatory that the Controls Provider complete this certification prior to bidding the project. It is a requirement that evidence of successful certification be presented with the BAS / Controls submittals.
    c. The design team shall not approve the BAS / Controls submittals without this certification.

ii. Where DDCs are specified as factory mounted equipment, it is a requirement that the Contractor and the Controls System Supplier be responsible for coordinating all controls, actuators, valve assemblies, and sensors specified are fully compatible and shall be capable of seamless interfacing with all Lon, Modbus and BACnet protocol requirements specified.

iii. User / Operator Proficiency: The Design Team shall make provisions for a training program conducted by the Controls Provider which includes three (3) progressive levels of training based on the access permissions granted to the User / Operators of the BAS.
   1) The objectives for the three (3) levels of training will be furnished by the KCTCS Capital Project Manager, as a component of the Phase B Design Review feedback, based on the complexity of the project's Building Systems, its BAS and the capabilities of the college's operating staff.
   2) The three (3) levels of training will be organized as follows:
      a. User Access - designed for those needing read only access to building system information, with minimal set-point adjustment authorization.
      b. Operator Access - designed for those authorized to make limited write adjustments to set-points and schedules.
      c. Engineer Access - designed for those authorized to make substantial write and invoke level adjustments to the BAS.
   3) KCTCS Capital Project Manager will recommend the duration of the training with this Phase B review feedback.

iv. Controls Implementation and Commissioning Final Completion Acceptance Report
   1) The KCTCS Capital Project Team will perform a compliance review of the BAS between substantial and final completion.
   2) Prior to final acceptance the KCTCS Capital Project Team must issue an Acceptance Report confirming acceptable completion of the BAS and receipt of the following BAS related items:
      a. Software & Tools
      b. Documentation
      c. Licenses and Programming Niagara Compatibility Statement (NiCS).
      d. Owner Training / Proficiency Report

d. Coordination Meeting Requirements
   i. BAS Pre-bid Conference: Prior to the project Pre-bid Conference, the Design Team shall schedule or advertise a BAS Pre-bid Conference hosted either in person or on Microsoft Teams by the KCTCS Capital Project Team.
      1) The purpose of the BAS Pre-Bid (Web) Conference is to familiarize the Controls Provider with the provisions of the Standard Objects Palettes being utilized by KCTCS.
      2) The KCTCS – BAS Implementation Guide will be made available to the Controls Provider.
      3) An understanding of these provisions will help the Controls Provider accurately estimate the programming time savings available with these palettes and services.
      4) Attendance to the BAS Pre-bid Conference shall be optional.

   ii. HVAC Instrumentation and Controls Scheduling Meeting: This meeting shall be arranged between the General Contractor, Division 23, Division 26, Division 27, Division 28 Sub-contractor, Commissioning Authority, and the Controls System Supplier to establish a Project Work Schedule. This Project Work Schedule is a requirement for Submittal Approval.

iii. Pre-submittal Meeting: This meeting shall be scheduled through the Design Team. The Control Systems Supplier representation shall include the Control System Designer, the System Programmer, and Project Supervisor. A KCTCS Capital Project Manager representative, Design Engineer representative, and a Commissioning Authority representative shall participate in this meeting. The intent is to:
   1) Coordinate location of thermostats, humidistats, and other exposed control sensors with plans and room details before installation.
   2) Coordinate locations for UNC's, Ethernet communication cabling and secure open ports and TCP/IP addresses.
   3) Coordinate Point Naming, Graphics, Alarms and System Navigation with the KCTCS Capital Project Manager.

iv. Submittal Review Meeting: At the discretion of the Engineer and/or the Commissioning Authority, the Control System Supplier's Programmer and Project Supervisor shall meet to review and/or adjust the programming or other portions of the submittal prior to approving or returning the Control System Supplier's submittals. The intent is to reconcile any uncertainties so that the control submittal(s) can be approved as a complete set rather than incrementally.

e. Ownership of Proprietary Materials
   i. Controller Software / Toolkits / Licenses – Ownership
      1) It is a requirement that the ownership of all BAS controllers, software and licenses be in the name of KCTCS.
      2) All programming intellectual property associated with the KCTCS BAS software shall be tendered to and owned by KCTCS with full disclosure.
      3) KCTCS shall be provided a copy of all the tool kits required to operate, adjust, and program all BAS products.
      4) All software shall include a perpetual license and will be hosted on the college supervisor.

   ii. Warranties of all BAS Hardware shall be in the name of KCTCS.

   iii. KCTCS shall sign a copy of the manufacturer's standard software and firmware licensing agreement as a condition of this contract. Such license shall grant use of all programs and application software to KCTCS as defined by the manufacturer's license agreement but shall protect manufacturer's rights to disclosure of trade secrets contained within such software. All project developed software and documentation shall become the property of KCTCS. These include, but are not limited to project graphic images, record drawings, project database, project specific application programming code, and all other associated documentation.

f. BAS / IT Network Requirements
   i. KCTCS IT Standards apply to all elements of BAS installation where the BAS / Control device is networked on the KCTCS IT network.

   ii. Where sub-networks are established for communication between the networked controllers and lower-level controllers or devices; the Division 26 low voltage cabling, identification, pathways, and other applicable specifications shall apply.

iii. The coordination of IP addresses, porting and other networking requirements shall be through the KCTCS project manager or KCTCS Capital Project Manager representative as designated by the project manager.

iv. Controls Provider Access
   1) An authorized Controls Provider Technician / Engineer will be granted VPN access only to the building(s) under contract. Username and Password credentials will be provided to the appropriate service technicians.
   2) The Controls Provider's network must meet certain IPsec requirements, access outside this IPsec network will be denied.
   3) Password strength must meet certain minimum requirements and will be updated on a schedule per KCTCS.
   4) Access will only be available until the Contract warranty period expires.

g. Warranty and Maintenance Requirements
   i. All components, system software, and parts furnished and installed by the Control Systems Supplier shall be guaranteed against defects in materials and workmanship for one (1) year of substantial completion unless extended warranty by owner or manufacturer is greater than one (1) year. Labor to repair, re-program, or replace these components shall be furnished by the Control Systems Supplier at no charge during normal working hours during the warranty period.

   ii. Materials furnished but not installed by the Control Systems Supplier shall be covered by warranty to the extent of the product only. Installation labor shall be the responsibility of the trade contractor performing the installation.

   iii. All corrective software modifications made during warranty periods shall be updated on all user documentation and on user and manufacturer archived software disks.

   iv. The Control Systems Supplier shall respond to the owner's request for warranty service within forty-eight (48) standard working hours. Emergency service shall be available within twenty-four (24) hours.

   v. Any changes made to the control system, including set-points, programming, schedules, or calibrations shall be documented on the Owner's work order to clarify the adjustments made in addition to updating user documentation.

   vi. Service Contract Provider Transition Acceptance Report: After project Final Completion, KCTCS will transition preventative maintenance responsibilities to their current Service Contract Provider (outside the project contract). Prior to acceptance of these responsibilities the Service Contract Provider will inspect the facility and issue a Service Contract Provider Transition Acceptance Report. The design team shall review the findings of this report and work with the commissioning and contracting teams to resolve appropriate project warranty related issues.

h. Building Automation System Warranty Transition Requirements; The design team shall add the following to the project closeout provisions:
   i. The BAS Standards & Compliance Team will be provided a copy of the:
      1) Commissioning Report
      2) Design Team Final Warranty/ Closeout Report
      3) Service Contractor Transition Acceptance Report

ii. As a provision of the project closeout, the BAS Standards & Compliance Team will issue a Project Closeout Acceptance Report indicating the BAS is performing consistent with the project requirements.

6. Building Automation Performance Requirements

a. Graphic Display: Display graphic with minimum twenty (20) dynamic points with current data within ten (10) seconds.

b. Graphic Refresh: Update graphic with minimum twenty (20) dynamic points with current data within eight (8) seconds.

c. Object Command: Reaction time of less than two (2) seconds between operator command of a binary object and device reaction.

d. Object Scan: Transmit change of state and change of analog values to control units or workstation within six (6) seconds.

e. Alarm Response Time: Annunciate alarm at workstation within forty-five (45) seconds. Multiple workstations must receive alarms within five (5) seconds of each other.

f. Program Execution Frequency: Run capability of applications as often as five (5) seconds, but selected consistent with mechanical process under control.

g. Performance: Programmable controllers shall execute DDC PID control loops, and scan and update process values and outputs at least once per second.

h. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows:

Reporting Accuracy and Stability of Control Tolerances

Variable	Report Range	Control Range
Water Temperature	+/- .5ºF (0.25ºC)	+/- 2ºF
Water Flow	+/- 2% of full scale	+/- 5% of full scale
Water Pressure	+/- 1% of full scale	+/- 2% of full scale
Space Temperature	+/- 1ºF (0.5ºC)	+/- 3ºF
Ducted Air Temperature	+/- .5ºF (0.25ºC)	+/- 1˚F – 2˚F
Outside Air Temperature	+/- 1ºF (.5ºC)	N/A
Dew Point Temperature	+/- 1ºF (.5ºC)	+/- 3ºF
Temperature Differential	+/- 0.25ºF (0.15ºC)	N/A
Relative Humidity	+/- 1%	+/- 3%
Airflow (Pressurized Spaces)	+/- 1% of full scale	+/- 3% of full scale
Airflow (Measuring Stations)	+/- 2% of full scale	+/- 5% of full scale
Airflow (Terminal)	+/- 2% of full scale	+/- 10% of full scale
Air Pressure (Space)	+/- 0.01" wg (2.5 Pa)	+/- 0.05" wg
Air Pressure (Supply Duct)	+/- 0.1" wg (25 Pa)	+/- 0.2" wg
Air Pressure (Return Duct)	+/- 0.01" wg (2.5 Pa)	+/- 0.05" wg
Electrical Power	+/- 1% of reading	N/A

7. Building Automation System / Control Product Requirements

The following BAS / Control Product Requirements are intended to communicate the product specific BAS and Controls Project Requirements to the Design Team. These requirements are to be adapted into the project design and specifications as appropriate for the application. They do not modify the design and contracting team's responsibility for project design, specification, construction and functionality.

a. Network Controller Standards (BAS Level 2 Field Cabinets)
The BAS Network Controllers shall be an open protocol / open distribution controller. For existing buildings, the current BAS Level 2 Devices are to remain unless requiring replacement. In such cases, the Vykon JACE with open Niagara Compatibility Statements (NiCS) or an Automated Logic BACnet/IP router (Optiflex) model G5CE, or G5RE, or newer product will be used. Where existing conditions warrant an exception and with written approval from the KCTCS Capital Project Manager an existing non-Vykon JACE may be considered. As long as the existing JACE has the required BACnet Server/Client license installed and functioning on the device.

b. Custom Application Controllers
   i. Custom Application Controllers applied to specific equipment shall include a standard open communications interface of either BACnet-IP, BACnet-MSTP, Modbus TCP, Modbus-Async (Serial), or Lon (EIA Standard 709.1) protocol.

   ii. Mechanical and Electric Equipment with integrated factory controllers shall include a standard open communications interface of either BACnet-IP, BACnet- MSTP, Modbus TCP, Modbus-Async (Serial), or Lon (EIA Standard 709.1) protocol.

   iii. Modular and Custom Air Handling Unit Controls may be factory mounted as directed by the design team, but in such cases, the Custom Application Controller shall be furnished and programmed by Controls Provider and of the same manufacturer as other Custom Application Controllers and Application Specific Controllers used for the project.

   iv. Variable Frequency Drives shall include a standard open communications interface of either BACnet-IP, BACnet-MSTP, Modbus TCP, Modbus-Async (Serial), or Lon (EIA Standard 709.1) protocol.

c. Zone Control Standards (BAS Level 1)
   i. Application Specific Controllers
      1) Application Specific Controllers shall be of the same manufacturer for a given building (mixed controls manufacturers within a given building requires written approval by the KCTCS project manager).
      2) Application Specific Controllers shall include a standard open communications interface of either BACnet-IP, BACnet-MSTP, or Lon (EIA Standard 709.1) protocol.

d. Control Devices
   i. Sensing Devices shall be of high quality and perform to the functionality specified under Building Automation Performance Requirements.

ii. Actuating Devices shall be of high quality and perform to the functionality specified under Building Automation Performance Requirements. Except for very large assemblies or devices, electronic actuation is preferred over pneumatic. The actuators shall have torque ratings sufficient to drive the connected devices without shortening the life of the actuator.

8. Building Automation System Execution Phase Requirements

a. BAS Installation Requirements

i. It is intended that the HVAC Instrumentation and Controls wiring be installed and terminated in accordance with Division 26 Requirements, with the following guidelines for signal and communication cable management:

1) Conceal cable, except in mechanical rooms and areas where other conduit and piping are exposed.
2) Install exposed cable in raceway.
3) Install concealed cable in raceway.
4) Existing building cable tray raceways may be utilized, but control cabling shall be of a different jacket color than existing cabling and shall be secured and bundled within the tray separately of other cables.
5) Bundle and harness multi-conductor instrument cable in place of single cables where several cables follow a common path.
6) Fasten flexible conductors, bridging cabinets and doors, along hinge side; protect against abrasion. Tie and support conductors.
7) Number-code conductors for future identification and service of control system, except local individual room control cables may be color coded.
8) Install wire and cable with sufficient slack and flexible connections to allow for vibration of piping and equipment.

ii. Install labels and nameplates to identify control components according to Division 26, Section Identification for Electrical Systems

b. BAS Graphics Coordination, Niagara Web Supervisor Integration projects

i. BAS Graphics for KCTCS building automation systems generally fall into three (3) categories:

1) Typical Equipment types: Typical MEP equipment types have had "Standard Object" palettes developed by the KCTCS Capital Project Manager.
   a. The palettes include the graphics for this equipment.
   b. These Owner-furnished palettes will be provided to the Controls Provider after project award.
   c. These types include fan coils, VAV boxes, heat pumps, and similar equipment.
2) Custom Equipment types: Custom MEP equipment graphical requirements shall be coordinated during the design phase with the KCTCS Capital Project Manager.
   a. In most instances, these will be developed by the KCTCS Capital Project Manager and will be Owner-furnished palettes provided to the Controls Provider after project award.
   b. There may be circumstances where the design team is instructed to have these custom graphics developed by the BAS Supplier. In such cases, the BAS Supplier shall utilize widely available Tridium/ Niagara workplace graphic tools (specifically the kit Px Graphics Palette) to maintain consistency with those developed in the Standard Object palettes and must be approved by the KCTCS Capital Project Manager during the submittal process.

3) Building and Building System level graphics: Building and Building System level graphical requirements shall be coordinated during the design phase with the KCTCS Capital Project Manager.
   a. In most instances, these will be developed by the Team and will be added to the College Level Server by the Team.
   b. There may be circumstances where the design team is instructed to have these custom graphics developed by the BAS Supplier. In such cases, the BAS Supplier shall utilize widely available Tridium/ Niagara workplace graphic tools (specifically the kit Px Graphics Palette) to maintain consistency with those developed in the Standard Object palettes and must be approved by the KCTCS Capital Project Manager during the submittal process.
4) The specifications shall instruct the Controls Provider to map and integrate control points from the devices and equipment onto the graphics provided by the KCTCS Capital Project Manager.

ii. Controls Provider's BAS Graphics Responsibility
1) The Controls Provider will be responsible for linking the building-level control points to the JACE level Standard Object modules using the KCTCS Standards Objects palette. The Controls Provider will need to support the integration of the networked JACE's into the college-level Niagara AX or Niagara 4 Supervisor server. This includes, but is not limited to, responsiveness to the JACE commissioning review, communication to confirm networking, availability to review custom systems that do not meet standard configuration.

c. BAS Graphics Coordination – Automated Logic WebCTRL Integration projects (WC8.0 or later) WebCTRL software minimum, features and add-ons include:
   i. Security. The web server application shall support Transport Layer Security (TLS) with a capability of 256-bit encryption for transmitting private information over the Internet using HTTPS. Additionally, the web server shall have SHA-2 certificate support.

   ii. Advanced Security: The ability to setup Operator access to the system to be location-dependent. This type of operator access lets one to assign privileges to an operator only at locations in the system where he needs them. For example, you could assign an operator mechanic privileges in one building in a system, view-only privileges in another building, and no privileges in a third building. In addition, this feature provides support for 21 CFR Part 11. With this feature enabled, the WebCTRL® application can require an operator to record a reason for changing an equipment property before it accepts the change. The WebCTRL® Audit Log report then displays the operator's name and the recorded reason for making the change.

   iii. Trend Export: The Trend Export add-on allows the operator to specify, manage, and export:

   - Trend source data to .csv files
   - Trend source data into zipped folders of multiple .csv files
   - Trend source data into an external database

   Operator can export the files on-demand at any time or at scheduled intervals allowing you to process or analyze trend data outside of your building automation system.

iv. Operator Interface. The web server shall reside on a high-speed network with the building controllers. Web pages generated by this server shall be compatible with the latest versions of Microsoft Internet Explorer or Edge, Google Chrome, Mozilla Firefox, and Apple Safari browsers. Any of these supported browsers connected to the server shall be able to access all system information. Mobile devices shall be recognized by the web server and shall supply the appropriate system content as needed. The Operator Interface (web server with client devices) shall conform to the BACnet Operator Workstation (B-OWS) or BACnet Advanced Workstation (B-AWS) device profile as specified in ASHRAE/ANSI 135 BACnet Annex L. This includes the ability to configure and/or reconfigure the system from the client device (change programs, graphics, labels, etc.).

v. Communication. Web server and controllers shall communicate using BACnet protocol. Web server and control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing as specified in ANSI/ASHRAE 135, BACnet Annex J. Communication between the web server and client (workstation) shall be HTTP or HTTPS protocol utilizing HTML5 language. Use of Adobe Flash in any part of the communication infrastructure is not acceptable.

vi. Database. System shall support any JDBC (Java DataBase Connectivity) compliant engine. This includes MS SQL, My SQL, PostgreSQL and Oracle.

vii. Graphics

1) System Graphics. The operator interface software shall be graphically based and shall include at least one graphic per piece of equipment or occupied zone, graphics for each chilled water and hot water system, and graphics that summarize conditions on each floor of each building included in this contract. Indicate thermal comfort on floor plan summary graphics using dynamic colors to represent zone temperature relative to zone setpoint.
   a. Minimum graphics resolution shall be 1920 x1080 for display of detailed system graphics.
   b. Functionality. Graphics shall allow operator to monitor system status, to view a summary of the most important data for each controlled zone or piece of equipment, to use point-and-click navigation between zones or equipment, and to edit setpoints and other specified parameters.
   c. Animation. Graphics shall be able to animate by displaying different image files for changed object status.
   d. Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.
   e. Format. Graphics shall be saved in an industry-standard format such as BMP, JPEG, PNG, or GIF. Web-based system graphics shall be viewable on browsers compatible with World Wide Web Consortium browser standards. Web graphic format shall require no plug-in) or shall only require widely available no-cost plug-ins (such as Active-X or Adobe Flash).
2) Custom Graphics. Custom graphic files shall be created with the use of a graphics generation package furnished with the system. The graphics generation package shall be a graphically based system to create and modify graphics that are saved in the same formats as are used for system graphics.

3) Graphics Library. Furnish a complete library of standard HVAC equipment graphics such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. This library also shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. The library shall be furnished in a file format compatible with the graphics generation package program.

viii. System Applications. System shall provide the following functionality to authorized operators as an integral part of the operator interface or as stand- alone software programs. If furnished as part of the interface, the tool shall be available from each workstation or web browser interface. If furnished as a stand- alone program, software shall be installable on standard IBM-compatible PCs with no limit on the number of copies that can be installed under the system license.

ix. Automatic System Database Configuration. Each workstation or web server shall store on its hard disk a copy of the current system database, including controller firmware and software. Stored database shall be automatically updated with each system configuration or controller firmware or software change.

x. Manual Controller Memory Download. Operators shall be able to download memory from the system database to each controller.

xi. System Configuration. The workstation software shall provide a method of configuring the system. This shall allow for future system changes or additions by users under proper password.

xii. On-Line Help. Provide a context-sensitive, on-line help system to assist the operator in operating and editing the system. On-line help shall be available for all applications and shall provide the relevant data for that particular screen. Additional help information shall be available through the use of hypertext.

xiii. Video Training. Provide online video support to supplement on-line help assistance. Video content shall be relevant and support existing system documentation.

xiv. Security. Each operator shall be required to log on to the system with a username and password in order to view, edit, add, or delete data.

1) Operator Access. The username and password combination shall define accessible viewing, editing, adding, and deleting privileges for that operator. Users with system administrator rights shall be able to create new users and edit the privileges of all existing users. System Administrators shall also be able to vary and deny each operator's privileges based on the geographic location, such as the ability to edit operating parameters in Building A, to view but not edit parameters in Building B, and to not even see equipment in Building C.
2) Password Policy Rules. System administrator shall invoke policies for minimum password strength, including number of characters, special characters and numbers, upper and lower case, etc.

3) Automatic Log Out. Automatically log out each operator if no keyboard or mouse activity is detected. This auto logoff time shall be user adjustable.
4) Encrypted Security Data. Store system security data including operator passwords in an encrypted format. System shall not display operator passwords.

xv. System Diagnostics. The system shall automatically monitor the operation of all building management panels and controllers. The failure of any device shall be annunciated to the operator.

xvi. Alarms
1) Processing. System input and status objects shall be configurable to alarm on departing from and on returning to normal state. Operator shall be able to enable or disable each alarm and to configure alarm limits, alarm limit differentials, alarm states, and alarm reactions for each system object. Configure and enable alarm points as specified in Sequences of Operation. Alarms shall be BACnet alarm objects and shall use BACnet alarm services.
2) Alarm Messages. Alarm messages shall use the English language descriptor for the object in alarm in such a way that the operator will be able to recognize the source, location, and nature of the alarm without relying on acronyms or mnemonics.
3) Alarm Reactions. Operator shall be able to configure (by object) what, if any actions are to be taken during an alarm. As a minimum, the workstation or webserver shall be able to log, print, start programs, display messages, send e-mail, send SMS text, and audibly annunciate.
4) Alarm and Event log. Operators shall be able to view all system alarms and changes of state from any location in the system. Events shall be listed chronologically. An operator with the proper security level may acknowledge and delete alarms and archive closed alarms to the workstation or web server hard drive.

xvii. Trend Logs. The operator shall be able to configure trend sample or change of value (COV) interval, start time, and stop time for each system data object and shall be able to retrieve data for use in spreadsheets and standard database programs. Controller shall sample and store trend data and shall be able to archive data to the hard disk. Configure trends as specified in Sequences of Operation or in project points listing. Trends shall be BACnet trend objects. As a minimum, all physical points in the system shall be trended within the local controller (AAC, ASC, BC) for at least 277 samples per point. Selected points, as desired, shall be available for historical archiving within the server. The historical archiving capability cannot be less than 2 years.

xviii. Object and Property Status and Control. Provide a method for the operator to view, and edit if applicable, the status of any object or property in the system. The status shall be available by menu, on graphics, or through custom programs.

xix. Reports and Logs. Operator shall be able to select, to modify, to create, and to print reports and logs. Operator shall be able to store report data in a format accessible by standard spreadsheet and word processing programs.

xx. Audit and Security Detail. All users accessing the system shall have their actions recorded. Information recorded shall include login/logout time and date; system modifications – with before and after values; ability to report user activity based on individual and/or date and time.

xxi. Standard Reports. Furnish the following standard system reports:

xxii. Objects. System objects and current values filtered by object type, by status (in alarm, locked, normal), by equipment, by geographic location, or by combination of filter criteria.

xxiii. Alarm Summary. Current alarms and closed alarms. System shall retain closed alarms for an adjustable period.

xxiv. Logs. System shall log the following to a database or text file and shall retain data for an adjustable period:

1) Alarm History.

2) Trend Data. Operator shall be able to select trends to be logged.

xxv. Custom Reports. Operator shall be able to create custom reports that retrieve data, including archived trend data, from the system, that analyze data using common algebraic calculations, and that present results in tabular or graphical format. Reports shall be launched from the operator interface.

xxvi. Time Lapse Graphic Replay. Operator shall be able to "replay" any graphic in the system to see how key values changed over an operator-selected period of time. Operator shall be able to select the starting date/time for this display and the end date/time or the display period. System shall then display the graphic as it would have looked at the beginning of that period, displaying key data, dynamic colors, etc. based upon values recorded at the start time. When the operator starts the replay the graphics and key values shall dynamically change to produce the effect of "fast forwarding" through the designated period of time. Once the system has been operational for at least 30 days, the contractor shall demonstrate that up to 24 hours of data from within the last 30 days can be replayed on any graphic page. Owner's representative shall choose the graphic pages for this demonstration at the time of the demonstration.

xxvii. Workstation Application Editors. Each PC or browser workstation shall support editing of all system applications. The applications shall be downloaded and executed at one or more of the controller panels.

xxviii. Controller. Provide a full-screen editor for each type of application that shall allow the operator to view and change the configuration, name, control parameters, and set points for all controllers.

xxix. Scheduling. An editor for the scheduling application shall be provided at each workstation. Provide a method of selecting the desired schedule and schedule type. Exception schedules and holidays shall be shown clearly on the calendar. The start and stop times for each object shall be adjustable from this interface.

xxx. Custom Application Programming. Provide the tools to create, edit, debug, and download custom programs. System shall be fully operable while custom programs are edited, compiled, and downloaded. Programming language shall have the following features:

1) Language. Language shall be graphically based and shall use function blocks arranged in a logic diagram that clearly shows control logic flow. Function blocks shall directly provide functions listed below, and operators shall be able to create custom or compound function blocks.
2) Programming Environment. Tool shall provide a full-screen, cursor-and- mouse-driven programming environment that incorporates word processing features such as cut and paste. Operators shall be able to insert, add, modify, and delete custom programming code, and to copy blocks of code to a file library for reuse in other control programs.
3) Independent Program Modules. Operator shall be able to develop independently executing program modules that can disable, enable and exchange data with other program modules.
4) Debugging and Simulation. Operator shall be able to step through the program observing intermediate values and results. Operator shall be able to adjust input variables to simulate actual operating conditions. Operator shall be able to adjust each step's time increment to observe operation of delays, integrators, and other time-sensitive control logic. Debugger shall provide error messages for syntax and for execution errors.
5) Conditional Statements. Operator shall be able to program conditional logic using compound Boolean (AND, OR, and NOT) and relational (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.
6) Mathematical Functions. Language shall support floating-point addition, subtraction, multiplication, division, and square root operations, as well as absolute value calculation and programmatic selection of minimum and maximum values from a list of values.

xxxi. Variables. Operator shall be able to use variable values in program conditional statements and mathematical functions.

1) Time Variables. Operator shall be able to use predefined variables to represent time of day, day of the week, month of the year, and date. Other predefined variables or simple control logic shall provide elapsed time in seconds, minutes, hours, and days. Operator shall be able to start, stop, and reset elapsed time variables using the program language.
2) System Variables. Operator shall be able to use predefined variables to represent status and results of Controller Software and shall be able to enable, disable, and change setpoints of Controller Software.

xxxii. Controllers:

1) General. Provide an adequate number of Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), Smart Actuators (SA), and Smart Sensors (SS) as required to achieve performance specified in Section 23 09 23 Article 1.9 (System Performance). Every device in the system which executes control logic and directly controls HVAC equipment must conform to a standard BACnet Device profile as specified in ANSI/ASHRAE 135, BACnet Annex L. Unless otherwise specified, hardwired actuators and sensors may be used in lieu of BACnet Smart Actuators and Smart Sensors BACnet.
2) Building Controllers (BCs): Each BC shall conform to BACnet Building Controller (B-BC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L, and shall be listed as a certified B-BC in the BACnet Testing Laboratories (BTL) Product Listing.
3) Advanced Application Controllers (AACs): Each AAC shall conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-AAC in the BACnet Testing Laboratories (BTL) Product Listing.
4) Application Specific Controllers (ASCs): Each ASC shall conform to BACnet Application Specific Controller (B-ASC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B- ASC in the BACnet Testing Laboratories (BTL) Product Listing.
5) Smart Actuators (SAs): An actuator which is controlled by a network connection rather than a binary or analog signal (0-10v, 4-20mA, relay, etc.). Each SA shall conform to BACnet Smart Actuator (B-SA) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-SA in the BACnet Testing Laboratories (BTL) Product Listing.
6) Smart Sensors (SSs): A sensor which provides information to the BAS via network connection rather than a binary or analog signal (0-10000 ohm, 4-20mA, dry contact, etc.). Each SS shall conform to BACnet Smart Sensor (B-SS) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-SS in the BACnet Testing Laboratories (BTL) Product Listing.

xxxiii. BACnet Communication.

1) Each BC shall reside on or be connected to a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing.
2) BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.
3) Each AAC shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
4) Each ASC shall reside on a BACnet network using the MS/TP Data Link/Physical layer protocol.

5) Each SA shall reside on a BACnet network using the MS/TP Data Link/Physical layer protocol.
6) Each SS shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using ARCNET or MS/TP Data Link/Physical layer protocol.
7) Security. Provide BACnet firewall capability, as defined in the BACnet standard, for controllers that are IP capable.

xxxiv. Communication.
1) Service Port. Each controller shall provide a service communication port for connection to a Portable Operator's Terminal. Connection shall be extended to space temperature sensor ports where shown on drawings.
2) Signal Management. BC and ASC operating systems shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.
3) Data Sharing. Each BC and AAC shall share data as required with each networked BC and AAC.
4) Stand-Alone Operation. Each piece of equipment shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All I/O points specified for a piece of equipment shall be integral to its controller. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network such as outdoor air conditions, supply air or water temperature coming from source equipment, etc.

xxxv. Environment. Controller hardware shall be suitable for anticipated ambient conditions.
1) Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -29°C to 60°C (-20°F to 140°F).
2) Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).

xxxvi. Local graphical keypad and display (where applicable). Provide a local graphical keypad and display for each BC and AAC. Operator shall be able to use keypad to view and edit data. The local interface shall be customizable with graphics particular the equipment and function. Real-Time Clock. Controllers that perform scheduling shall have a real-time clock.

xxxvii. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to a field-removable modular terminal strip or to a termination card connected by a ribbon cable. Each BC and AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.

xxxviii. Memory.

1) Controller memory shall support operating system, database, and programming requirements.
2) Each BC and AAC shall retain BIOS and application programming for at least 72 hours in the event of power loss.
3) Each ASC and SA shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

xxxix. Immunity to Power and Noise. Controllers shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).

xl. Transformer. ASC power supply shall be fused or current limiting and shall be rated at a minimum of 125% of ASC power consumption.

d. Calibration Requirements

i. Application Specific Controllers

1) Calibrate instruments.
   a. Make three-point calibration test for both linearity and accuracy for each analog instrument.
   b. Calibrate equipment and procedures using manufacturer's written recommendations and instruction manuals. Use test equipment with accuracy at least double that of instrument being calibrated.
2) Control system inputs and outputs:
   a. Check analog inputs at 0, 50, and 100 percent of span.
   b. Check analog outputs using milliampere meter at 0, 50, and 100 percent output.
   c. Check digital inputs using jumper wire.
   d. Check digital outputs using ohmmeter to test for contact making or breaking.
   e. Check resistance temperature inputs at 0, 50, and 100 percent of span using a precision-resistant source.
3) Flow:
   a. Set differential pressure flow transmitters for 0 and 100 percent values with three-point calibration accomplished at 50, 90, and 100 percent of span.
   b. Manually operate flow switches to verify that they make or break contact.
4) Pressure:
   a. Calibrate pressure transmitters at 0, 50, and 100 percent of span.
   b. Calibrate pressure switches to make or break contacts, with adjustable differential set at minimum.

5) Temperature:
   a. Calibrate resistance temperature transmitters at 0, 50, and 100 percent of span using a precision-resistance source.
   b. Calibrate temperature switches to make or break contacts.
6) Stroke and adjust control valves and dampers without positioners, following the manufacturer's recommended procedure, so that valve or damper is 100 percent open and closed.
7) Stroke and adjust control valves and dampers with positioners, following manufacturer's recommended procedure, so that valve and damper is 0, 50, and 100 percent closed.
8) Provide diagnostic and test instruments for calibration and adjustment of system.
9) Provide written description of procedures and equipment for calibrating each type of instrument. Submit procedures for review and approval before initiating startup procedures, per the Commissioning Plan.
10) Adjust initial pressure, temperature and humidity set points.

e. Software and Firmware Operational Documentation:
   i. Include the following:
      1) Software operating and upgrade manuals.
      2) Program Software Backup: On a magnetic media or compact disc, complete with data files.
      3) Device address list.
      4) Printout of software application and graphic screens.

   ii. Software license required by and installed for DDC workstations and control systems, with a licensed copy left at the Campus.

   iii. Software Upgrade Kit: For Owner to use in modifying software to suit future systems revisions or monitoring and control revisions.

f. On-site Assistance
   i. Occupancy Adjustments: Within one (1) year of date of Substantial Completion, provide up to three (3) project site visits, when requested by Owner, to adjust and calibrate components and to assist Owner's personnel in making program changes and in adjusting sensors and controls to suit actual condition.

g. Training
   i. The initial training session shall be scheduled and completed prior to project Final Completion date. The remaining hours allocated for training (dependent on recommendation from SC Team during Phase B review) shall be scheduled and completed at Owner designated intervals during the Warranty period.

   ii. Training shall be performed in a controlled classroom environment where Owners' Representatives can access the BAS through workstations or PCs. The user service, prototypes, and permissions shall be set up prior to training to provide appropriate access and visual information to the trainees.

iii. Train the designated staff of Owner and Owner's Representatives to achieve the objectives of the User / Operator Proficiency requirements outlined in the Quality Assurance section, paragraph 5.c.iv above.

iv. Present & Document content in digital format for each level of training, in modular format. The three (3) levels of training will generally be organized around:
   1) User Access - designed for those needing read only access to building system information, with minimal set-point adjustment authorization.
   2) Operator Access (low to medium) - designed for those authorized to make limited write adjustments to set-points and schedules.
   3) Operator Access (medium to high) - designed for those authorized to make substantial write and invoke level adjustments to the BAS.

v. Make digital content accessible at the Read-Only user level through the BAS browser.

END OF SECTION