

SECTION 23 09 23 – BUILDING AUTOMATION SYSTEM

PART 1 - GENERAL

1.1.1.1 SUMMARY

- A.** This Section includes control equipment and installation for HVAC systems and components, including control components for terminal heating and cooling units not supplied with factory-furnished controls.
- B.** The control system shall be an extension of the existing Siemens Building Automation System and all controllers and software shall match the existing or be the latest version of the existing.
- C.** This Section includes an Energy Reporting and Data Analytics software package.
- D.** See "Sequences of Operation" for requirements that relate to this Section.

1.1.1.2 RELATED DOCUMENTS

- A.** Drawings and Specification Sections of the Contract, including General and Supplementary Conditions, apply to this Section.
 - 1. Division 01 – General and Special Requirements
 - 2. Division 01 – Submittal Requirements
 - 3. Division 01 – Materials and Equipment
 - 4. Division 11 – Equipment
 - 5. Division 11 40 00 - Food Service Equipment
 - 6. Division 11 50 00 – Educational and Scientific Equipment
 - 7. Division 23 – Common Work Results for HVAC
 - 8. Section 23 – Variable Frequency Drives
 - 9. Division 23 – Sequences of Operation
 - 10. Division 23 – Testing, Adjusting, and Balancing for HVAC
 - 11. Division 26 – General Electrical Provisions for Electrical Work
 - 12. Division 26 – Common Work Results for Electrical
 - 13. Division 26 – Low Voltage Electrical Power Conductors and Cables
 - 14. Division 26 – Hangers and Supports for Electrical Systems
 - 15. Division 26 – Raceway and Boxes for Electrical Systems
 - 16. Division 26 – Identification for Electrical Systems
 - 17. Division 26 – Wiring Devices
 - 18. Division 26 – Network Lighting Controls
 - 19. Division 27

20. CSU and Cal Poly Campus ITS Department Requirements

1.1.1.3 ABBREVIATIONS

- A.** AAC: Advanced Application Controller
- B.** AHU: Air Handling Unit.
- C.** ALN: Automation Level Network
- D.** ASC: Application-Specific Controller
- E.** ASHRAE: American Society of Heating Refrigerating and Air-Conditioning Engineers
- F.** BACnet SC: Building Automation Control Network Secure Connect
- G.** BAS: Building Automation System
- H.** BC: Building Controller
- I.** BIBB: BACnet Interoperability Building Blocks
- J.** BIM: Building Information Modeling
- K.** BMS: Building Management System.
- L.** CFM: Cubic Feet per Minute.
- M.** DCIM: Data Center Infrastructure Management
- N.** DCV: Demand Controlled Ventilation
- O.** DDC: Direct digital controls
- P.** EIA: Electronics Industries Alliance
- Q.** EMI: Electro-Magnetic Interference
- R.** EP: Electric-to-Pneumatic
- S.** EPMS: Electrical Power Monitoring System
- T.** FAS: Fire Alarm System.
- U.** FLN: Floor Level Network

- V.** FCU: Fan Coil Unit
- W.** HMI: Human Machine Interface
- X.** HVAC: Heating, Ventilating, and Air Conditioning.
- Y.** IEEE: Institute of Electrical and Electronic Engineers
- Z.** I/O: Input/Output
- AA.** IP: Internet Protocol
- BB.** IT: Information Technology
- CC.** LAN: Local area network.
- DD.** LCD: Liquid Crystal Display
- EE.** LED: Light Emitting Diode
- FF.** MER: Mechanical Equipment Room.
- GG.** MLN: Management Level Network
- HH.** MS/TP: Master-slave/token-passing.
- II.** NEMA: National Electric Manufacturers' Association
- JJ.** NFPA: National Fire Protection Association
- KK.** OEM: Operator Equipment Manufacturer
- LL.** PC: Personal Computer
- MM.** PICS: Protocol Implementation Conformance Statement
- NN.** PID: Proportional Integral Derivative.
- OO.** POT: Portable Operators Terminal.
- PP.** RAM: Random Access Memory
- QQ.** RFI: Radio Frequency Interference
- RR.** RTD: Resistance Temperature Device
- SS.** SNMP: Simple Network Management Protocol

- TT.** TAB: Testing and Balancing
- UU.** TCP: Transfer Control Protocol
- VV.** UDP: User Datagram Protocol
- WW.** UL: Underwriters Laboratories
- XX.** UPS: Uninterruptable Power Supply
- YY.** VAV: Variable Air Volume
- ZZ.** VFD: Variable Frequency Drive.
- AAA.** WAN: Wide Area Network.

1.1.1.4 DEFINITIONS

- A.** BACnet: An industry standard data communication protocol for Building Automation and Control Networks. Refer to the latest version of ASHRAE standard 135.
- B.** BACnet Secure Connect: As an addendum to the BACnet protocol, it is a secure, encrypted datalink layer that is specifically designed to meet the requirements of managed IP infrastructures.
- C.** Scope Terminology
 1. Provide = Furnish equipment, engineer, program, and install
 2. Furnish = Furnish equipment, engineer, and program
 3. Mount = securely fasten or pipe
 4. Install = mount and wire
 5. Wire = wire only

1.1.1.5 WORK INCLUDED

- A.** The BAS Contractor shall provide a complete and operational system that will perform the sequences of operation as described herein.
- B.** Furnish a complete distributed direct digital control system in accordance with this specification section. This includes all system controllers, logic controllers, and all input/output devices. Items of work included are as follows:
 1. Provide a submittal that meets the requirements below for approval.
 2. Coordinate installation schedule with the mechanical contractor and general contractor.
 3. Provide installation of all panels and devices unless otherwise stated.

4. Provide power for panels and control devices unless otherwise stated.
 5. Provide all low-voltage control wiring for the DDC system.
 6. Provide miscellaneous control wiring for HVAC and related systems regardless of voltage.
 7. Provide engineering and technician labor to program and commission software for each system and operator interface. Submit commissioning reports for approval.
 8. Provide testing, demonstration, and training as specified below.
- C.** The installation of the control system shall be performed under the direct supervision of the controls manufacturer with the shop drawings, flow diagrams, bill of materials, component designation, or identification number and sequence of operation all bearing the name of the manufacturer.
- D.** Provide data generated and trended shall be stored in a SQL server that can be used by other reporting applications, such as EcovoX. Coordinate requirements with Cal Poly Representative and CxA.

1.1.1.6 SUBMITTALS

- A.** Provide submittals for fast-track items that need to be approved and released to meet the schedule of the project. Provide submittals for the following items separately upon request:
1. Project Specific Graphics
 2. Complete Point Listing
 3. Device List with MAC address that requires Campus IT to issue an IP Address
 4. Provide Equipment names, and description locations that require dedicated IP. Provide MAC address for the assignment of IP.
 5. DDC controls that interact with other BacNet devices, coordinate with such equipment, and provide a BACnet mapped point list (e.g., VRF units, Heat Recovery Chillers, Central Plant Chillers and Boilers, Heat Pumps, Kitchen Controls, Fume Hood controllers)
 6. Valve schedule and product data
 7. Damper schedule and product data
 8. Mounting and wiring diagrams for factory-installed control components
 9. Thermostat locations
- B.** Provide a complete submittal with all control system information for approval before construction starts. Include the following:
1. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
 2. Wiring Diagrams: Power, signal, and control wiring. Detail the wiring of the control devices and the panels. Show point-to-point wiring from field devices to the control panel. Show point-to-point wiring of hardwired interlocks. Show a ladder

- diagram or schematic of wiring internal to the panels, including numbered terminals. Clearly designate wiring that is done at a factory, at a panel shop, or in the field.
3. Details of control panel faces, including sizes, controls, instruments, and labeling.
 4. Schedule of dampers and actuators including size, leakage, and flow characteristics. If dampers are furnished by others, submit a damper actuator schedule coordinating actuator sizes with the damper schedule.
 5. Schedule of valves including leakage and flow characteristics.
 6. A written description of the Sequence of Operations.
 7. Network riser diagram showing wiring types, network protocols, locations of floor penetrations, and the number of control panels. Label control panels with network addresses and BACnet device instance numbers. Show all routers, switches, hubs, and repeaters.
 8. Point list for each system controller including both inputs and outputs (I/O), point numbers, the controlled device associated with each I/O point, and the location of the I/O device.
 9. Starter and variable frequency drive wiring details of all automatically controlled motors.
 10. Reduced size floor plan drawings showing locations of control panels, thermostats, and any devices mounted in occupied space.
 11. Product Data: Include the manufacturer's technical literature for each control device indicated, labeled with a setting or adjustable range of control. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated. Submit a write-up of the application software that will be used on the operator workstation including revision level, functionality, and software applications required to meet the specifications.
 12. Submit BACnet Protocol Implementation Conformance Statements (PICS) for all direct digital controllers, software, and other system components that will communicate on the BAS utilizing BACnet. The Manufacturer's Product Data submittal for each piece of DDC Hardware must include the Protocol Implementation Conformance Statement (PICS) for that hardware
- C.** Submit a description of the application software that will be used on the operator workstation including revision level, functionality, and software applications required to meet the specifications.
- D.** Submit blank field check-out and commissioning test reports, customized for each panel or system, which will be filled out by the technician during start-up.
- E.** Variance letter: Submit a letter detailing each item in the submission that varies from the contract specification or sequence of operation in any way.

- F.** After the BAS system is approved for construction, submit sample operator workstation graphics for typical systems for approval. Print and submit the graphics that the operator will use to view the systems, change setpoints, modify parameters, and issue manual commands. Programming shall not commence until typical graphics are approved.
- G.** Operation and Maintenance Data: In addition to items specified in Division 1 Section "Operation and Maintenance Data," include the following:
 - 1. Product data with installation details, maintenance instructions, and lists of spare parts for each type of control device.
 - 2. Keyboard illustrations and step-by-step procedures indexed for each operator function.
 - 3. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
 - 4. Calibration records and list of set points.

1.1.1.7 PROJECT RECORD DOCUMENTS

- A.** Project Record Documents: Submit three (3) copies of record (as-built) documents upon completion of installation. Submittal shall consist of:
 - 1. Project Record Drawings. As-built versions of the submittal shop drawings are provided as AutoCAD-compatible files in electronic format and as 11 x 17-inch prints.
 - 2. Testing and Commissioning Reports and Checklists. Completed versions of reports, checklists, and trend logs used to meet requirements in the Control System Demonstration and Acceptance section of this specification.
 - 3. Operation and Maintenance (O & M) Manual.
 - a. As-built versions of the submittal product data.
 - b. Names, addresses, and 24-hour telephone numbers of installing contractors and service representatives for equipment and control systems.
 - c. Operator's Manual with procedures for operating control systems, logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing setpoints and variables.
 - d. Programming manual or set of manuals with a description of programming language and of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
 - e. Engineering, installation, and maintenance manual or set of manuals that explain how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.
 - f. Documentation of all programs created using custom programming language, including setpoints, tuning parameters, and object database.

- g. Graphic files, programs, and databases on electronic media.
 - h. List of recommended spare parts with part numbers and suppliers.
 - i. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware, including computer equipment and sensors.
 - j. Complete original original-issue copies of furnished software, including operating systems, custom programming language, operator workstation software, and graphics software.
 - k. Licenses, guarantees, and warranty documents for equipment and systems.
- B.** Operating manual to serve as training and reference manual for all aspects of the day-to-day operation of the system. As a minimum include the following:
- 1. The sequence of operation for automatic and manual operating modes for all building systems. The sequences shall cross-reference the system point names.
 - 2. Description of manual override operation of all control points in the system.
 - 3. BMS system manufacturers complete operating manuals.
- C.** Provide maintenance manual to serve as training and reference manual for all aspects of day-to-day maintenance and major system repairs. As a minimum include the following:
- 1. Complete as-built installation drawings for each building system.
 - 2. Overall system electrical power supply schematic indicating source of electrical power for each system component. Indicate all battery backup provisions.
 - 3. Photographs and/or drawings showing installation details and locations of equipment.
 - 4. Routine preventive maintenance procedures, corrective diagnostics troubleshooting procedures, and calibration procedures.
 - 5. Parts list with manufacturer's catalog numbers and ordering information.
 - 6. Lists of ordinary and special tools, operating materials supplies, and test equipment recommended for operation and servicing.
 - 7. Manufacturer's operation, set-up, maintenance, and catalog literature for each piece of equipment.
 - 8. Maintenance and repair instructions.
 - 9. Recommended spare parts.
- D.** Provide a Programming Manual to serve as training and reference manual for all aspects of system programming. As a minimum include the following:
- 1. Complete programming manuals, and reference guides.
 - 2. Details of any custom software packages and compilers supplied with the system.
 - 3. Information and access are required for independent programming of the system.

1.1.1.8 QUALITY ASSURANCE

A. Codes

1. Perform all wiring in accordance with Division 26, NEC, local codes, and Owner's requirements.
2. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
3. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilation Systems."
4. Comply with ASHRAE 135-2010 BACnet: A Data Communication Protocol for Building Automation and Control Networks.
5. Comply with BACnet Secure Connect Communication: A secure, encrypted datalink layer that is specifically designed to meet the requirements of managed IP infrastructures.
6. Comply with ASHRAE 90.1- Energy Standard for Buildings Except Low-Rise Residential Buildings.
7. Comply with the current version of the State of California's Building Energy Efficiency Standards for Residential and Non-Residential Buildings (Title 24).
8. All equipment shall be UL listed and approved and shall meet all applicable NFPA standards, including UL 916 - PAZX Energy Management Systems,
 - a. Provide written approvals and certifications after the installation has been completed.
9. All electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Governing Radio Frequency Electromagnetic Interference, and be so labeled.
10. The manufacturer of the building automation system shall provide documentation supporting compliance with ISO-9002 (Model for Quality Assurance in Production, Installation, and Servicing) and ISO-140001 (The application of well-accepted business management principles to the environment). The intent of this specification requirement is to ensure that the products from the manufacturer are delivered through a Quality System and Framework that will assure consistency in the products delivered for this project.

B. Qualifications

1. Installing contractor shall be in the business of installing and servicing DDC controls for mechanical systems, temperature and ventilation control, environmental control, lighting control, access and security, life safety, and energy management as their primary business.
2. Installer Qualifications: An experienced installer who is the authorized representative of the automatic control system manufacturer for both installation and maintenance of controls required for this Project.
3. Engineering, drafting, programming, and graphics generation shall be performed by Siemens-qualified engineers and technicians directly employed by the Building Automation System Contractor.
4. Supervision, checkout, and commissioning of the system shall be by the local branch engineers and technicians directly employed by the Building Automation

System Contractor. They shall perform commissioning and complete testing of the BAS system.

5. Character of Workers

(a) If a BAS contractor worker or management personnel appears to the Owner to be incompetent or acts disorderly or improperly, discharge the worker or management personnel immediately upon request by Cal Poly, at no cost to the Owner. Do not employ or assign this BAS Contractor worker or management personnel again on the project or on any future projects at Cal Poly.

- C. The BAS contractor shall maintain a service organization consisting of factory-trained service personnel and provide a list of ten (10) projects, similar in size and scope to this project, completed within the last five years.
- D. The final determination of compliance with these specifications shall rest solely with the Engineers and the University/Owner who will require proof of prior satisfactory performance.
- E. For any BAS system and equipment submitted for approval, the BAS contractor shall state what, if any, specific points of system operation differ from these specifications.
- F. All portions of the system must be designed, furnished, installed, commissioned, and serviced by manufacturer-approved, factory-trained employees.
- G. The system shall have a documented history of compatibility by design for a minimum of 15 years. Future compatibility shall be supported for no less than 10 years. Compatibility shall be defined as the ability for any existing control system component including but not limited to building controllers, advanced application controllers, application-specific, personal operator workstations, and portable operator's terminals, to be connected and directly communicate with any new BAS system equipment without bridges, routers or protocol converters.

1.1.1.9 DELIVERY, STORAGE, AND HANDLING

- A. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping of control devices to the unit manufacturer.
- B. Deliver, store, protect, and handle products to the site under provisions of the contract Documents. Coordinate all site deliveries with the General Contractor/Construction Manager's Project Manager.

- C.** Protect products from construction operations, dust, and debris, by storing materials inside, protected from the weather in a conditioned space.

1.1.1.10 COORDINATION

- A.** Ease of Maintenance / Operation: Building Automation systems shall be designed to be easily maintained and operated. Access and service space shall be key considerations of the design. All Fixtures, Equipment, and Valves locations shall be designed and Installed to be Accessible, Readily (Readily Accessible). Capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to take actions such as to use tools (other than keys), to climb over or under, to remove obstacles, or to resort to portable ladders, and so forth.
- B.** Coordinate and obtain formal approval from the Owner representative and the Campus ITS, for IP drops, network diagrams, network connections, user interfaces, firewalls, etc.
- C.** Coordinate and obtain formal approval for the location of thermostats, humidistats, panels, and other exposed control components with plans and room details, with the Owner representative, before installation.
- D.** Coordinate equipment with Division 28 "Fire Alarm" to achieve compatibility with equipment that interfaces with that system.
- E.** Coordinate equipment with Division 27 "Communications" to achieve compatibility with equipment that interfaces with that system.
- F.** Coordinate equipment with Division 11: Equipment (e.g. Kitchen controller)
- G.** Coordinate with Battery/UPS requirements for EMS controllers, especially where downtime of the controller is not advisable in critical applications such as classroom lab exhaust fans, kitchen exhaust fans, etc. where controllers may require rebooting of the controllers.
- H.** Coordinate power for control units and operator workstation with the electrical contractor.
- I.** Coordinate equipment with the provider of starters and drives to achieve compatibility with motor starter control coils and VFD control wiring.
- J.** Coordinate scheduling with the electrical contractor, the mechanical contractor, and the general contractor. Submit a schedule for approval based upon the installation schedule of the mechanical equipment.
- K.** Coordinate installation of taps, valves, airflow stations, etc. with the mechanical contractor.

- L.** Products Furnished but Not Installed Under This Section
 - 1. Hydronic and Refrigerant Piping accessories:
 - a. Control Valves
 - b. Temperature Sensor Wells and Sockets
 - c. Pressure Sensor Wells and Sockets
 - d. Flow Switches
 - e. Flow Meters
 - f. Differential Pressure Transmitters
 - 2. Sheet metal accessories
 - a. Dampers
 - b. Airflow Stations
 - c. Terminal Unit Controls

- M.** Products Installed but Not Furnished Under This Section
 - 1. Refrigeration Equipment:
 - a. Refrigerant Leak Detection System
 - b. Proof of flow pressure switches
 - 2. Rooftop Air Handling Equipment:
 - a. Thermostats
 - b. Duct Static Pressure Sensors

- N.** Products Integrated To but Not Furnished or Installed Under This Section
 - 1. Lighting Control panels
 - 2. Kitchen Controls

1.1.1.11 WARRANTY

- A.** Provide warranty per Division 01 - General Requirements and as supplemented in this section.
- B.** The warranty shall cover all costs for parts, labor, associated travel, and expenses for 12 months from the project completion.
- C.** Hardware and software personnel supporting this warranty agreement shall provide on-site or off-site service in a timely manner after failure notification to the vendor. The maximum acceptable response time to provide this service at the site shall be 24 hours.
- D.** During normal building-occupied hours, failure of items that are critical for system operation shall be provided within 4 hours of notification from the Owner's Representative.
- E.** This warranty shall apply equally to both hardware and software.

PART 2 - PRODUCTS

2.1.1.1 SYSTEM DESCRIPTION

- A.** The Building Automation System (BAS) contractor shall furnish and install a networked system of HVAC controls. The contractor shall incorporate direct digital control (DDC) for central plant equipment, building ventilation equipment, supplemental heating and cooling equipment, and terminal units.
- B.** The control system for this project shall be an extension of the Owner's existing Siemens Building Automation System and all controllers and software shall match the existing or be the latest version of the existing.
- C.** Provide networking to new DDC equipment using industry-accepted communication standards. The system shall utilize BACnet communication according to ANSI/ASHRAE standard 135-2010 for interoperability with smart equipment, for the main IP communication trunk to the BAS Server, and peer-to-peer communication between DDC panels and devices. The system shall not be limited to only standard protocols, but shall also be able to integrate to a wide variety of third-party devices and applications via drivers and gateways.
- D.** Provide standalone controls where called for on the drawings or sequences.
- E.** Provide Energy Reporting and Data Analytics packages described herein.
- F.** It must be BACnet Testing Laboratory (BTL) Listed.
- G.** The BAS shall be the Siemens APOGEE system as manufactured by Siemens Industry, Inc.

2.1.1.2 BUILDING AUTOMATION SYSTEM NETWORK

- A.** All networked control products provided for this project shall be comprised of industry-standard open protocol internetwork. Communication involving control components (i.e. all types of controllers and operator interfaces) shall conform to ASHRAE 135-2010 BACnet standard. Networks and protocols proprietary to one company or distributed by one company are prohibited.
- B.** Access to system data shall not be restricted by the hardware configuration of the building management system. The hardware configuration of the BMS network shall be transparent to the user when accessing data or developing control programs.

1. Software applications, features, and functionality, including administrative configurations, shall not be separated into several network control engines working together.
- C. BAS Server shall be capable of simultaneous direct connection and communication with BACnet/SC, BACnet/IP, OPC, and TCP/IP corporate-level networks without the use of interposing devices.
- D. Any break in Ethernet communication from the server to the controllers on the Primary Network shall result in a notification at the server.
- E. Any break in Ethernet communication between the server and standard client workstations on the Primary Network shall result in a notification at each workstation.
- F. The network architecture shall consist of three levels of networks:
 1. The Management Level Network (MLN) shall utilize BACnet/IP over Ethernet along with other standardized protocols, such as web services, HTML, JAVA, SOAP, XML, etc., to transmit data to non-BAS software applications and databases. The BAS Server and Operator Workstations shall reside on this level of the network architecture.
 2. The Automation Level Network (ALN) shall utilize BACnet/IP over Ethernet. It shall connect BACnet Building Controllers to the BAS Server and Operator Workstations. Controllers for central plant equipment and large infrastructure air handlers shall reside on the ALN backbone BACnet/IP network. The building's Ethernet LAN shall be utilized for the ALN backbone and all ALN devices shall be connected to the building's LAN. Coordinate and obtain formal approval for all IP drops with the Owner and Campus ITS. All ALN devices shall support BACnet/SC or be BACnet/SC-ready at minimum.
 3. The Floor Level Network shall utilize BACnet/IP over Ethernet or BACnet MS/TP over RS-485 to connect all of the DDC-controlled terminal heating and cooling equipment on a floor or in a system that are controlled with BACnet Advanced Application Controllers or BACnet Application Specific Controllers. FLN devices are networked to a router that connects to the Automaton Level Network backbone.
- G. BAS controllers utilizing BACnet/SC and that reside on a BACnet/SC network shall support the following:
 1. System controllers shall be native-BACnet/SC or shall be BACnet/SC-ready by future firmware upgrade to provide data encryption utilizing secure WebSocket protocol with TLS V1.3 (WSS) functioning on TCP/IP.
 2. System controllers shall be native-BACnet/SC or shall be BACnet/SC-ready by future firmware upgrade to provide device authentication of those BACnet/SC

devices by utilizing the X.509 International Telecommunication Union standard defining the format of PKI certificates.

3. System controllers shall utilize two (2) BACnet/SC hubs per BACnet network for logical function. A primary hub is required for communication to occur on the BACnet/SC network. A secondary failover hub shall be required to ensure communication can resume in the case of a primary hub failure.
 - a. BACnet/SC hubs shall be embedded devices on the BACnet/SC network.
 - b. BACnet/SC hub-capable controllers shall support routing between different BACnet data link types such as BACnet/SC-to-BACnet/IP routing.
 - c. BACnet/SC controllers with BACnet/SC hub functionality must support a minimum of 100 node connections per hub.
4. System controllers shall support BACnet/SC node, or BACnet/SC hub+node functionality (natively or with future firmware upgrades) for the system to function.
5. BACnet/SC must support Certificate Authority (CA) and Certificate Management
 - a. BAS provider must provide software tools for Certificate Authority and Certificate Management.
 - b. The software tool must be made available to interact with the customer's IT department infrastructure by exchanging certificates and CSR (certificate signing request) for certificate management of the BACnet/SC system for the life of the building automation system.
 - c. The BACnet/SC solution must allow for an internal-to-the-organization Certificate Authority (self-signed certificates) utilizing a software tool method capable of generating, signing, and provisioning certificates to the BAS vendor's devices, and revoking certificates completely on its own.
 - d. The BACnet/SC Certificate Management must allow for interaction with a trusted 3rd party Certificate Authority (CA) for customers. The BAS vendor provided software tool for generating certificates and provisioning them to the vendor's devices must be able to generate a CSR (Certificate Signing Request) and be able to export the required common Root Certificate (aka Issuer Certificate) on a file level to be signed by a trusted 3rd party certificate authority of the customer's preference as well as be able to import the signed certificate and provision it to the vendor's devices along with the required unique Operational Certificates (aka Client Certificates).

- e. Certificate Management must allow for interoperability with 3rd party vendor BACnet/SC certificate management methods and allow for CA migration (CA1 -> CA2).
 - f. The certificate's validity period shall be configurable in the vendor's certificate management tool to comply with customer security requirements. This shall be configurable for a minimum of 1 week or years to a maximum of 25 years.
 - g. The vendor-specific BACnet/SC configuration and management tool from each BACnet/SC vendor on the project as well as the corresponding project database containing the Root Certificate must be provided to the customer for ongoing certificate management as well as vendor coordination on the project.
- H.** Provide a router for each RS-485 subnetwork to connect them to the base building backbone level network. The router shall connect BACnet MS/TP subnetworks to BACnet over Ethernet. Routers shall be capable of handling all of the BACnet BIBBs that are listed for the controller that resides on the subnetwork.
- I.** The Building Level Controllers shall be able to support subnetwork protocols that may be needed depending on the type of equipment or application. Subnetworks shall be limited to :
- 1. BACnet MS/TP
 - 2. Apogee FLN
 - 3. Modbus
- J.** BACnet MSTP Setup rules
- 1. Addressing for the MSTP devices shall start at 00 and continue sequentially for the number of devices on the subnetwork.
 - 2. No gaps shall be allowed in the addresses.
 - 3. Set the MaxMaster property to the highest address of the connected device.
 - 4. MaxMaster property shall be adjusted when devices are added to the subnetwork.
- K.** Provide all communication media, connectors, repeaters, bridges, switches, and routers necessary for the internetwork.
- L.** 3 Controllers and software shall be BTL listed at the time of installation.
- M.** The system shall meet a peer-to-peer communication service such that the values in any one BACnet Building Controller or BACnet Advanced Application Controller can be read or changed from all other controllers without the need for intermediary devices. The software shall provide a transparent transfer of all data, control programs, schedules, trends, and alarms from any one controller through the internetwork to any other controller, regardless of subnetwork routers.

- N.** Systems that use variations of BACnet using Point-to-Point (PTP) between controllers, gateways, bridges, or networks that are not peer-to-peer are not allowed.
- O.** Remote Communications: Provide a TCP/IP compatible communication port for connection to the Owner's network for remote communications. Provide coordination with the Owner for addressing and router configuration on both ends of the remote network.
- P.** The system shall be installed with a 10% spare capacity on each subnetwork for the addition of future controllers.
- Q.** On each floor, wing or major mechanical room provide an Ethernet RJ45 connection that allows connection to the BACnet network. An open port shall always be available and shall not require any part of the network to be disconnected. The location shall be accessible to the base building personnel and not in a location where the tenant can restrict access.
- R.** Distributed Control Requirements:
 1. The loss of any one DDC controller shall not affect the operation of other HVAC systems, only for the points connected to the DDC controller.
 2. The system shall be scalable and shall permit the expansion of both capacity and functionality through the addition of sensors, actuators, DDC Controllers, and operator devices.
 3. System architectural design shall eliminate dependence upon any single device for alarm reporting and control execution. Each DDC Controller shall operate independently by performing its own specified control, alarm management, operator I/O, and data collection. The failure of any single component or network connection shall not interrupt the execution of any control strategy, reporting, alarming and trending function, or any function at any operator interface device.
 4. DDC Controllers shall be able to access any data from or send control commands and alarm reports directly to, any other DDC Controller on the network without dependence upon a central processing device. DDC Controllers shall also be able to send alarms to multiple operator workstations without dependence upon a central or intermediate processing device.
 5. Operators shall have the ability to make database changes at the central system server while operator workstations are online without disrupting other system operations.
 6. The DDC control panel shall be mounted in the same mechanical room as the equipment being controlled, or an adjacent utility room.
 7. Multiple systems can be programmed on the same controller as long as they are in the same room. Systems on separate floors shall have separate controllers.
 8. VAV boxes subnetworks shall be connected to the AHU controller that feeds those boxes. If multiple subnetworks are needed, then the VAV shall be grouped into subnetworks in an orderly method, such as per floor, per wing, etc.

9. Remote sensors shall be wired to the control panel of the equipment it is controlling, not across the network.
10. Signals to remote motor control centers shall be hard-wired to the control panel, not across the network.
11. Terminal units shall each have their own controller. The only exceptions are:
 - a. Groups of reheat coils
 - b. Groups of exhaust fans
 - c. Groups of chilled beams serving the same zone or several adjacent zones

2.1.1.3 BUILDING AUTOMATION SYSTEM SERVER HARDWARE

- A.** Provide PC: Provide a formal submittal for the PC for the BAS Server database. Provide the latest model of the nominal speed, RAM, and memory for a commercial office-grade PC from a named brand manufacturer. This section is applicable if the specific project requires the provision of a new server. Coordinate and obtain formal approval from the Owner representative and the Campus ITS. Minimum requirements and accessories shall be:
 1. Processor: Intel Core i7 series or AMD equal
 2. 32GB RAM
 3. 1TB Hard disk space, 7200RPM
 4. Video Card with 2 GB RAM
 5. At least 2 USB Ports
 6. NIC Card
 7. 101 key enhanced keyboard, Mouse, power strip
- B.** Provide monitor: Provide a formal submittal for the widescreen, active matrix LCD, flat panel type monitor that supports a minimum display resolution of no less than 1920 × 1080 pixels, Energy Star compliant 32-bit color. The display shall have a minimum of 21-inch visible area in diagonal measurement. Separate controls shall be provided for color, contrast, and brightness. The screen shall be non-reflective. Coordinate and obtain formal approval from the Owner representative and the Campus ITS.
- C.** Locate the BAS Server in a clean, secure, dry, and temperature-controlled environment. Coordinate and obtain formal approval from the Owner representative and the Campus ITS.
- D.** The server shall reside on the same BACnet/IP protocol network as the System Controllers. Coordinate and obtain formal approval from the Owner representative and the Campus ITS.
- E.** Provide software licenses for interfacing with the BAS.
- F.** Load software, configure, and set up for viewing the BAS system.

- G.** Provide with the PC an operating system, such as Linux and Windows. Coordinate and obtain formal approval from the Owner representative and the Campus ITS.
- H.** Software: Provide the following application software licenses, preloaded on the server for the Owner: MS Office Professional or approved equal, Microsoft Edge or approved equal, Acrobat Reader or approved equal, ACAD Viewer, Microsoft IIS server or approved equal. Set up an icon on the desktop to take the Owner directly to the BAS system login page.
- I.** Provide a copy of the software (or all software if there are multiple) used to program and download sequences to controllers.
- J.** Provide a backup of all of the programs used in the system for storage by the Owner.

2.1.1.4 OPERATOR WORKSTATION HARDWARE

- A.** Provide PC: Provide a formal submittal for the PC for a BAS operator workstation. Provide the latest model of the nominal speed, RAM, and memory for a commercial office-grade PC from a named brand manufacturer. This section is applicable if the specific project requires the provision of an Operator Work Station. Coordinate and obtain formal approval from the Owner representative and the Campus ITS. Minimum requirements and accessories shall be:
 - 1. Processor: Intel Core i7 series or AMD equal
 - 2. 32 GB RAM
 - 3. 1 TB Hard disk space, 7200RPM
 - 4. Video Card with 2 GB RAM
 - 5. At least 2 USB Ports
 - 6. NIC Card
 - 7. 101 key enhanced keyboard, Mouse, power strip
- B.** Locate the operator workstation as located on the plans.
- C.** Provide monitor: Provide a formal submittal for the monitor of flat panel type and shall support a minimum display resolution of no less than 1920 x 1080 pixels. The display shall have a minimum of 21-inch visible area in diagonal measurement. Separate controls shall be provided for color, contrast, and brightness. The screen shall be non-reflective. Coordinate and obtain formal approval from the Owner representative and the Campus ITS.
- D.** Locate the Operator Workstations in a clean, secure, dry, and temperature-controlled environment
- E.** Provide software licenses for interfacing with the BAS.

- F.** Load software, configure, and set up for viewing the BAS system.
 - 1. Provide a spreadsheet view of systems and associated set points and process conditions (e.g., VAV boxes, VRF Units, Split Unit heat pumps, Exhaust Fans).
 - 2. Provide Airflow offsets in areas such as Labs where maintaining a carefully controlled pressure differential is critical. The offset shall be determined based on Total Supply air minus Total exhaust air in a given room (where these are separately metered and reported).
- G.** Provide the PC with an operating system, such as Linux and Windows, or other approved operating systems compatible with the BAS software. Coordinate and obtain formal approval from the Owner representative and the Campus ITS.
- H.** Software: Provide the following application software licenses, preloaded on the client for the Owner: MS Office Professional or approved equal, Microsoft Edge or approved equal, Acrobat Reader or approved equal, CAD Viewer. Set up an icon on the desktop to take the Owner directly to the BAS system login page.

2.1.1.5 BACNET ADVANCED WORKSTATION SOFTWARE

- A.** Interface Description
 - 1. The software shall provide, as a minimum, the following functionality:
 - a. Real-time graphical viewing and control of the BMS environment.
 - b. Reporting of both real-time and historical information.
 - c. Scheduling and override of building operations.
 - d. Collection and analysis of historical data.
 - e. Point database editing, storage, and downloading of controller databases.
 - f. Configuration of and navigation through default and personalized hierarchical "tree" views that include workstation and control system objects.
 - g. Event reporting, routing, messaging, and acknowledgment.
 - h. Definition and construction of dynamic color graphic displays.
 - i. Online, context-sensitive help, including an index, glossary of terms, and the capability to search for help via keyword or phrase.
 - j. On-screen access to User Documentation, via online help or PDF-format electronic file.
 - k. Automatic database backup at the operator interface for database changes initiated at Building Controllers.
 - l. Display dynamic trend data graphical plot.
 - 1) Must be able to run multiple plots simultaneously.
 - 2) Each plot must be capable of supporting 10 pts/plot minimum.
 - 3) Must be able to command points from selection on dynamic trend plots.
 - 4) Must be able to plot real-time data without prior configuration.

- 5) Must be able to plot both real-time and historical trend data simultaneously.
 - m. Program editing
 - n. Transfer trend data to third-party spreadsheet software
 - o. Scheduling reports
 - p. Operator Activity Log
2. Operator interface software shall minimize operator training through the use of user-friendly and interactive graphical applications.
3. Users must be able to build multiple, separate, personalized hierarchical "tree" views that represent the workstation, control systems, geographical facility layouts, and mechanical equipment relationships.
4. 256-character point identification (names) must be supported to provide clear descriptive identification.
5. Online help must be available.
6. The user interface shall display relevant information for a selection in multiple panes of a single window without the need for opening multiple overlapping windows on the desktop
7. Provide a graphical user interface that shall minimize the use of a keyboard through the use of a mouse or similar pointing device, with a "point and click" approach to menu selection and a "drag and drop" approach to inter-application navigation.
8. Software navigation shall be user-friendly by utilizing a "forward & back" capability between screens and embedded links to graphics, documents, drawings, trends, schedules, as well as external documents (.doc, .pdf, .xls, etc.) or web addresses that are related to any selected object.
9. The primary selection of objects in the operator interface software shall be available from user-defined hierarchical Views, from graphics, or from events in an Event List.
10. The secondary selection of objects in the operator interface software shall be available from links to any objects or external documents related to the primary selection.
11. Links to information related to any selected objects shall be displayed in a consistent manner and automatically defined based on where an object is used in the system.
12. The operator workstation shall be capable of displaying web pages and common document formats (.doc, .xls, .pdf) within the operator workstation application.
13. The software shall provide a multi-tasking type environment that allows the user to run several applications simultaneously.
14. System database parameters shall be stored within an object-oriented database.
15. Standard Windows applications shall run simultaneously with the BMS software.
16. The operator shall be able to work in Microsoft Word, Excel, and other Windows-based software packages or approved equals, while concurrently annunciating online BMS alarms and monitoring information.

17. Provide automatic backup and restore of all Building Controller databases on the workstation hard disk.
18. System configuration, programming, editing, and graphics generation shall be performed online from the operator workstation software.
19. The user shall be able to edit the point configuration of any configurable BACnet point that resides in a device that supports external editing.
20. The software shall also allow the user to configure the alarm management strategy for each point.
21. Users shall have the ability to view the program(s) that is\are currently running in a Building Controller. The display shall mark the program lines with the following: disabled, comment, unresolved, and trace bits.

B. Certifications and Approvals

1. BAS software shall have been tested against the following norms and standards:
 - a. BACnet Revision 1.13, certified by BACnet Testing Laboratory as BACnet Advanced Workstation Software (BTL B-AWS)
 - b. IT security compliant with the ISA-99/IEC 62443 Security Level: SL1
 - c. OPC DA V2.05a and V3.0 Server, certified by the OPC Foundation certification program
 - d. UL-listed to UL864 9th edition Standard for Control Units and Accessories (when installed on a UL-approved computer)

C. Client-Server Connectivity

1. Client sessions must be allowed to run on the server and on other devices connected to the server via Intranet, Extranet, or Internet connections.
2. Internet connections, ISP services, as well as necessary firewalls or proxy servers, shall be provided by the owner as required to support remote access features.
3. The following client options must be supported
 - a. Installed Client.
 - 1) Software application installed from installation media onto the client machine.
 - 2) Installed client software must be configurable to allow it to run in a Closed Mode such that the BAS software can lock down the client machine and prevent users without permission from minimizing the application or running other Windows applications that might cover the BAS software interface.
 - 3) Communication between the server and Installed Clients must be monitored so that any break in communication between the server and an installed client results in a notification at the Server and Installed Client machine
 - 4) Installed client machines to communicate directly with the BAS server
 - b. Web Client.

- 1) Software that runs in a browser on the client machine as a Full Trust client application.
- 2) Connected to the BAS software server via Microsoft IIS Server or approved equal.
- c. Windows App.
 - 1) Software applications downloaded from the BAS server to run on the client machine like an installed application
 - 2) The application must be automatically updated whenever new apps are available on the server.
 - 3) Connected to the BAS software server via Microsoft IIS Server or approved equal.
4. Each of the client options shall provide the same functionalities including operation and configuration capabilities.

D. Access Rights and User Privileges

1. Access to any client user session must be password protected.
2. Users shall be able to create local user accounts specific to the application software.
3. Users shall be able to link application user accounts to Active Directory user accounts for consistent management with domain user accounts.
4. Operator-specific password access protection shall be provided to allow the administrator/manager to limit users' workstation control, display, and database manipulation capabilities as deemed appropriate for each user, based upon an assigned user name and password.
5. Operator privileges shall follow the operator to any workstation logged onto.
6. The administrator or manager shall be able to further limit operator privileges based on which console an operator is logged on to.
7. The administrator or manager shall be able to grant discrete levels of access and privileges, per user, for each point, graphic, report, schedule, and BMS workstation application.

E. Activity Logging

1. The operator interface software shall maintain a log of the actions of each individual operator.
2. The software shall provide an application that allows querying based on object name, operator, action, or time range.
3. The software shall provide the ability to generate reports showing operator activity based on object name, operator, action, or time range.

F. Graphics Application

1. All graphics shall be available with the same look and functionality whether they are displayed at an installed client console or in a browser.
2. User shall be able to add/delete/modify system graphics for floor plan displays and system schematics for each piece of mechanical equipment (including, air handling units, chilled water systems, hot water boiler systems, and room level terminal

- units) from standard user interface without the need of any external or specialized tools.
3. The software shall include all necessary tools and procedures for the user to create their own graphics.
 4. The software shall provide the user the ability to display real-time point values by animated motion or custom picture control visual representation.
 5. The software shall provide an animation that depicts the movement of mechanical equipment, or air or fluid flow.
 6. The software shall provide users the ability to depict various positions in relation to assigned point values or ranges.
 7. The software shall provide the ability to add custom gauges and charts to graphic pages.
 8. The software must include a library of at least 400 standard control application graphics and symbols for visualizing common mechanical systems, including fans, valves, motors, chillers, AHU systems, standard ductwork diagrams, piping, and laboratory symbols.
 9. The Graphics application shall include a set of standard Terminal Equipment controller application-specific background graphic templates. Templates shall provide the automatic display of a selected Terminal Equipment controller's control values and parameters, without the need to create separate and individual graphic files for each controller.
 10. The Graphics application shall be capable of automatically assigning the appropriate symbol for an object (point) selected to be displayed on the graphic based on what the object represents (fan, duct sensor, damper, etc.) when the object is placed on a graphic.
 11. The Graphics application shall allow a user to manually override the automatically assigned symbol for an object when a different symbol is desired.
 12. The user shall have the ability to add custom symbols to the symbol library.
 13. The software shall permit the importing of AutoCAD or scanned pictures for use in graphics.
 14. Graphics must be automatically associated to any points or system objects that are rendered on the graphic, so that selection of a system object will allow a user to simply navigate to any associated graphic, without the need for manual association.
 15. The software must allow users to command points directly off the graphics application.
 16. The graphic display shall include the ability to depict real-time point values dynamically with text or animation.
 17. Navigation through various graphic screens shall be optionally achieved through a hierarchical "tree" structure
 18. Graphics viewing shall include dynamic pan zoom capabilities.
 19. Graphics viewing shall include the ability to switch between multiple layers with different information on each layer.

20. Graphics shall include a decluttering capability that allows layers to be programmatically hidden and displayed based on zoom level.
21. Graphics shall be capable of displaying the status of points that have been overridden by a field HAND switch, for points that have been designed to provide a field HAND override capability.
22. The software must provide the ability to create dashboard views consisting of gauges and charts that graphically display system and/ or energy performance.

G. System Performance

1. Comply with the following performance requirements:
 - a. Graphic Display: Display a graphic with minimum 20 dynamic points with current data within 5 seconds.
 - b. Graphic Refresh: Update the graphic with minimum 20 dynamic points with current data within 5 seconds.
 - c. Object Command: Reaction time of less than 5 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 5 seconds.
 - e. Alarm Response Time: Annunciate the alarm at the workstation within 2 seconds. Multiple workstations must receive alarms within five seconds of each other.
 - f. Program Execution Frequency: Programmable controllers shall execute DDC PI control loops, and scan and update process values and outputs at least once per second.
 - g. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows:
 - 1) Water Temperature: Plus or minus 1 deg F.
 - 2) Water Flow: Plus or minus 5 percent of full scale.
 - 3) Water Pressure: Plus or minus 2 percent of full scale.
 - 4) Space Temperature: Plus or minus 1 deg F.
 - 5) Ducted Air Temperature: Plus or minus 1 deg F.
 - 6) Outside Air Temperature: Plus or minus 2 deg F.
 - 7) Dew Point Temperature: Plus or minus 3 deg F.
 - 8) Temperature Differential: Plus or minus 0.25 deg F.
 - 9) Relative Humidity: Plus or minus 2 percent.
 - 10) Airflow (Pressurized Spaces): Plus or minus 3 percent of full scale.
 - 11) Airflow (Measuring Stations): Plus or minus 5 percent of full scale.
 - 12) Airflow (Terminal): Plus or minus 10 percent of full scale.
 - 13) Air Pressure (Space): Plus or minus 0.01-inch wg.
 - 14) Air Pressure (Ducts): Plus or minus 0.1-inch wg.
 - 15) Carbon Monoxide: Plus or minus 5 percent of reading.
 - 16) Carbon Dioxide: Plus or minus 50 ppm.
 - 17) Electrical: Plus or minus 5 percent of reading.

H. Reports

1. The software must allow reports shall be executed on demand.
2. The software must allow reports shall be executed via the pre-defined schedule.
3. As a minimum, the system shall allow the user to easily obtain the following types of reports:
 - a. A general listing of all or selected points in the network
 - b. A status report showing present value and alarm status
 - c. List of all points currently in alarm
 - d. List of all points currently in override status
 - e. List of all disabled points
 - f. System diagnostic reports including, list of Building panels online and communicating, the status of all Building terminal unit device points
 - g. List of alarm strategy definitions
 - h. List of Building Control panels
 - i. Point totalization report
 - j. Point Trend data listings
 - k. Initial Values report
 - l. User activity report
 - m. Event history reports

I. Scheduling

1. The software shall provide a calendar-type format for simplification of time and date scheduling and overrides of building operations.
2. The software shall support the definition of BACnet schedules that are defined at the workstation and are downloaded to the Building Controller to ensure time equipment scheduling when the PC is off-line, such that the operating software is not required to execute time scheduling. The software must provide the following capabilities for BACnet scheduling capabilities as a minimum:
 - a. Fully support all BACnet Schedule, Calendar, and Command objects.
 - b. Daily and Weekly schedules
 - c. Ability to combine multiple points into logical Command Groups for ease of scheduling (e.g., all Building 1 lights)
 - d. Ability to schedule for a minimum of up to ten (10) years in advance.
3. The software shall support the definition of schedules that are configured and executed to run at the workstation, support the scheduling of workstation software activities, and support field systems that do not include internal scheduling mechanisms. The software must provide the following capabilities for BACnet scheduling capabilities as a minimum:
 - a. Schedule predefined reports
 - b. Schedule Trend collections
 - c. Schedule automated system backups
 - d. Schedule commands to be sent to field panels
 - e. Daily and weekly schedules

- f. Setting up and executing Holiday schedules
- g. Ability to combine multiple points into logical Command Groups for ease of scheduling (e.g., all Building 1 lights)
- h. Ability to schedule for a minimum of up to ten (10) years in advance.
4. The software shall support the definition of Apogee Equipment Schedules Objects that are defined at the workstation and are downloaded to the Building Controller to ensure time equipment scheduling when the PC is off-line, such that the operating software is not required to execute time scheduling. The software must provide the following capabilities for BACnet scheduling capabilities as a minimum:
 - a. Apogee equipment schedule Zones
 - b. Apogee equipment schedule Events
 - c. Configuration of Daily, Weekly, and Monthly schedules
 - d. Configuration of Replacement Days
5. The software shall provide the ability for users to override regular weekly schedules through menu selection, graphical mouse action, or function keys.
6. The software shall provide a timeline view, showing the results of any number of combined selected workstation and field panel controller schedules for an overview of facility operation.

J. Trending

1. Provide trending capabilities that allow the user to easily monitor and preserve records of system activity over an extended period of time.
2. Any system point may be trended automatically at time-based intervals or change of value, both of which shall be user-definable.
3. Trend data shall be collected and stored on a hard disk for future diagnostics and reporting.
4. Automatic Trend collection may be scheduled at regular intervals through the same scheduling interface as used for scheduling of equipment.
5. The system shall support trending in the same device as the monitor point or in an external device.
6. The software must support the configuration of panels that have a trending level threshold, above which the data will be automatically uploaded to the BMS server to prevent overwriting the data in the field panel. The trending level will be user defined in % of available space (e.g., automatically upload when the trend buffer is at 75% of allocated space).
7. Trend data reports shall be provided to allow the user to view all trended point data.
8. Trend data reports may be customized to include individual points or predefined groups of selected points.
9. Provide 5-minute trending of all points for 1 year from start-up through the warranty period.
10. Migrate to 15-minute trending following 1 year of operation.

11. The software shall allow the user to view real-time trend data on trend graphical plot displays.
 - a. A minimum of ten points may be plotted
 - b. A combination of real-time and historical data may be plotted
 - c. Dynamic graphs shall continuously update point values
 - d. At any time the user may redefine sampling times or range scales for any point
 - e. The user may pause the display and take "snapshots" of plot screens to be stored on the workstation disk for future recall and analysis
 - f. Exact point values may be viewed on the Trend plot
 - g. Trend graphs may be printed
 - h. The operator shall be able to command points by selecting them on the trend plot. The operator shall be able to zoom in on a specific time range within a plot.
 - i. The Trend Viewer must allow users to configure separate left and right axis for easier differentiation of point values.
 - j. The Trend Viewer must allow users to display historical data for the same group of points at different times simultaneously for easy comparison of system behavior over time.

K. Event Management

1. Event Notification shall be presented to each workstation in a tabular format application, and shall include the following information for each event: name, value, event time and date, event status, priority, acknowledgment information, and alarm count.
2. Only events for which the logged-on user has privileges to view shall be displayed on each workstation.
3. The software shall provide the ability to users to limit the list of events displayed at each workstation (e.g. only show fire events at this workstation, no matter who is logged on)
4. Each event shall have the ability to sound an audible notification based on the category of the event.
5. Event List shall have the ability to list and sort the events based on event status, point name, and ascending or descending activation time.
6. Directly from the Event List, the user shall have the ability to acknowledge, silence the event sound, print, or erase each event.
7. The interface shall provide the option to inhibit the erasing of active acknowledged events until they have returned to normal status.
8. The user shall have the ability to navigate to all information related to a selected point to command, launch an associated graphic or trended graphical plot, or run a report on a selected point directly from the Event List.
9. Each event shall have a direct link from the Event List to further user-defined point informational data.

10. The user shall have the ability to also associate real-time electronic annotations or notes to each event.
11. Software shall provide the option to configure detailed operating procedures that guide a user through predetermined standard operating procedures for handling critical events. Users shall be able to log the completion of each operating step as it is performed.

L. Remote Notification (RENO)

1. Workstations shall be configured to send out messages to numeric pagers, alphanumeric pagers, SMS (Simple Messaging Service, text messaging) Devices, and email accounts based on a point's alarm condition.
2. Email notifications must support POP3, IMAP, and SMTP with SSL/TSL
3. Communication with external software must be encrypted.
4. There shall be no limit to the number of points that can be configured for remote notification of alarm conditions and no limit on the number of remote devices which can receive messages from the system.
5. On a per-point basis, the system shall be configurable to send messages to an individual or group and shall be configurable to send different messages to different remote devices based on alarm message priority level.
6. The system must be configurable to send messages to an escalation list so that if the first device does not respond, the message is sent on to the next device after a configurable time has elapsed.
7. Workstation shall have the ability to send manual messages allowing an operator to type in a message to be sent immediately.
8. Workstations shall have a feature to send a heartbeat message to periodically notify users that they have communication with the system.

M. External Data Access

1. The software shall provide the ability to expose configuration properties and real-time values through CSV files, OPC DA, OPC UA, or REST-based Web Services.
2. The software shall provide the ability for external applications to change configuration and real-time values through OPC DA, OPC UA, or REST-based Web Services.
3. The software shall provide the ability for external applications to access historical Trend data through CSV files or REST-based Web Services.
4. External data access must be secured using the level of permissions configured for users and operator workstations.
5. Web service interfaces must allow for exchanging data (object's values, events, and trend series) between workstations and external applications such as facility management systems, enterprise applications, mobile applications, or other value-added services.
6. Documentation describing web services interfaces must be included to allow external developers to write applications that leverage the data exchange.

N. Licensing

1. Software licensing must be allowed to be bound to a dongle or physical PC hardware.
2. User licenses from all client types shall be from a common pool of client licenses. Licenses for installed and browser-based clients shall not be in separate pools.
3. Provide the number of client licenses as called for here or in the Sequence of Operations.

O. Data Security

1. The BAS software must allow all communication paths between clients and the server to be encrypted and protected against replay attacks as well as data manipulation.
2. Any runtime data transfer between the system server and Web Server (IIS) must be allowed to be encrypted by Desigo CC.
3. Communication between any Web Server (IIS) and the Web Clients must be allowed to be encrypted.
4. Passwords must be handled with encrypted storage and transmission
5. The software must support the use of public domain algorithms for cryptographic functions, including AES, Diffie-Hellman, RSA, and SHA-2. No self-coded algorithms shall be allowed.
6. All symmetrical encryption must use 256-bit AES or stronger.
7. All asymmetrical encryption must use 2048 bits or stronger.
8. The software must support the use of commercial certificates for securing client-server communications.
9. The software must support the use of self-signed certificates to allow local deployments without the overhead of obtaining commercial certificates.
10. When using self-signed certificates, the owner of the Desigo CC system is responsible for maintaining their validity status, and for manually adding them to and removing them from the list of trusted certificates.
11. The BAS software shall be compatible with the following Virus Scanners:
 - a. Kaspersky
 - b. Avira
 - c. McAfee
 - d. Bitdefender
 - e. TrendMicro Office Scan

P. Virtualization

1. The BAS software must be compatible with the following Virtualization software packages:
 - a. VMware®:
 - 1) Virtualization platform: VSphere 6.0 or higher
 - 2) Fault-tolerant software: ESXi 6.0b managed by VCenter Server Appliance v6.0.0 or higher

- b. Stratus®:
 - 1) Virtualization platform: KVM for Linux CentOS v7.0 or higher
 - 2) Fault-tolerant software: everRun Enterprise 7.2 or higher
 - 3) Virtualization platform: Citrix XenServer 6.0.2 or higher
 - 4) Fault-tolerant software: everRun MX 6.2 or higher

Q. Subsystem Connectivity

1. The BAS application software must be capable of connecting simultaneously to multiple control systems and data sources.
2. Interface software shall simultaneously communicate with and share data between multiple Ethernet-connected building-level networks.
3. The BAS application software must support the following standard protocols:
 - a. BACnet IP (standard Revision 1.13)
 - b. OPC (OLE for Process Control) OPC DA 2.05, 3.0
 - c. Modbus TCP
 - d. SNMP (Agent V1 and V2)
 - e. Siemens Apogee P2
 - f. Siemens XNET
4. Any break in system controller communication must result in a notification at the server.

R. BACnet

1. The Operator Workstation Software shall be capable of BACnet IP communications.
2. The Operator Workstation Software shall have demonstrated interoperability during at least one BTL Interoperability Workshop.
3. The Operator Workstation Software shall have demonstrated compliance to BTL B-AWS device classification through BTL listing as specified in ANSI/ASHRAE 135 under revision 1.13 or higher.
4. The BAS software shall meet the BACnet device profile of an Advanced Workstation Server (B-AWS) and Operator Workstation (B-OWS) and shall support the following BACnet BIBBs:
 - a. Data Sharing
 - 1) DS-RP-A Data Sharing-ReadProperty-A
 - 2) DS-RP-B Data Sharing-ReadProperty-B
 - 3) DS-RPM-A Data Sharing-ReadPropertyMultiple-A
 - 4) DS-RPM-B Data Sharing-ReadPropertyMultiple-B
 - 5) DS-WP-A Data Sharing-WriteProperty-A
 - 6) DS-WP-B Data Sharing-WriteProperty-B
 - 7) DS-WPM-A Data Sharing-WritePropertyMultiple-A
 - 8) DS-COV-A Data Sharing-ChangeofValue-A
 - 9) DS-COVP-A Data Sharing – ChangeofValueProperty-A
 - 10) DS-V-A Data Sharing - View - A
 - 11) DS-AV-A Data Sharing - Advanced View - A

- 12) DS-M-A Data Sharing - Modify - A
- 13) DS-AM-A Data Sharing - Advanced Modify - A
- b. Scheduling
 - 1) SCHED-VM-A Scheduling-View and Modify-A
 - 2) SCHED-AVM-A Scheduling-Advanced View and Modify-A
 - 3) SCHED-WS-A Scheduling-Weekly Schedule-A
- c. Alarm and Event Management
 - 1) AE-N-A Alarm and Event-Notification-A
 - 2) AE-ACK-A Alarm and Event-ACK-A
 - 3) AE-LS-A Alarm and Event-LifeSafety - A
 - 4) AE-VM-A Alarm and Event Management - View and Modify - A
 - 5) AE-AVM-A Alarm and Event Management - Advanced View and Modify - A
 - 6) AE-VN-A Alarm and Event Management - View Notifications - A
 - 7) AE-AVN-A Alarm and Event Management - Advanced View Notifications - A
- d. Trending
 - 1) T-V-A Trending-Viewing and Modifying Trends-A
 - 2) T-ATR-A Trending-Automated Trend Retrieval-A
 - 3) T-AVM-A Trending-Advanced View and Modify -A
- e. Network Management
 - 1) NM-CE-A Network Management-Connection Establishment-A
- f. Device Management
 - 1) DM-DDB-A Device Management-Dynamic Device Binding-A
 - 2) DM-DDB-B Device Management-Dynamic Device Binding-B
 - 3) DM-DOB-A Device Management-Dynamic Object Binding-A
 - 4) DM-DOB-B Device Management-Dynamic Object Binding-B
 - 5) DM-DCC-A Device Management-DeviceCommunicationControl-A
 - 6) DM-TM-A Device Management-Text Message-A
 - 7) DM-MTS-A Device Management-Manual Time Synchronization-A
 - 8) DM-ATS-A Device Management-Automatic Time Synchronization-A
 - 9) DM-TS-A Device Management-TimeSynchronization-A
 - 10) DM-UTC-A Device Management-UTCTimeSynchronization-A
 - 11) DM-RD-A Device Management-ReinitializeDevice-A
 - 12) DM-BR-A Device Management-Backup and Restore-A
 - 13) DM-LM-A Device Management-List Manipulation-A
 - 14) DM-LM-B Device Management-List Manipulation-B
 - 15) DM-OCD-A Device Management-Object Creation and Deletion-A
 - 16) DM-ANM-A Device Management-Automatic Network Mapping-A
 - 17) DM-ADM-A Device Management-Automatic Device Mapping-A
5. The BAS Server and Workstations shall support the following Data Link Layers:
 - a. BACnet IP Annex J
 - b. BACnet IP Annex J Foreign Device

- c. ISO 8802-3, Ethernet (Clause 7)
6. The BAS Server and Workstations shall be able to interact with all of the BACnet objects in the controllers. In addition, the software shall be able to support the following objects as they relate to features in the workstation software:
 - a. Calendar – Creatable, Deletable
 - b. Command – Creatable, Deletable
 - c. Event Enrollment – Creatable, Deletable
 - d. Notification Class – Creatable, Deletable
 - e. Schedule - Creatable, Deletable
7. The BAS Server and Workstations shall support transmitting and receiving segmented messages.
8. The BAS Server and Workstation shall have the capability to be the BACnet/IP Broadcast Management Device (BBMD) and support foreign devices.

2.1.1.6 ENERGY REPORTING AND DATA ANALYTICS SOFTWARE PLATFORM

- A.** Acceptable Manufacturers
 1. Siemens Industry, Inc – Advantage Navigator Software or approved equal.
- B.** Acceptable Installers
 1. Installers and programmers shall be factory-trained representatives of the manufacturer of the software.
- C.** Provide software to accumulate, log, compile, and display energy consumption data and related parameters and measures. See Section 1.1.1.5, D. Coordinate requirements with Cal Poly Representative and CxA.
- D.** Provide an automated reporting software package that will allow the utilization of data collected from a sub-metering system and data network. The system should address the following areas:
 1. Utility bill tracking
 2. Account tracking
 3. Savings and analysis
 4. Weather Data
 5. Weather Normalization
 6. Reporting
 7. Interval data tracking including meters and equipment data
 8. Automated Energy Star benchmarking and greenhouse gas emissions. Provides a portfolio Comparison and facility ratings trending. Ability to integrate with Energy Star Automated Benchmarking System and generate multi-site Energy Star ranking reports as well as individual site trending of monthly Energy Star score.
 9. Web-based hosted solution

10. Customization and Interfaces

- E.** The software shall integrate into devices provided in other sections of this specification. The contractor shall refer to other sections for the scope of the devices to be integrated into this software, including: [edit to match the project]
1. Division 11: Equipment (Kitchen Controls)
 2. Division 23 Building Automation System
 3. Division 23 Sequences of operations
 4. Division 23 Gas sub-meters
 5. Division 23 Water sub meters
 6. Division 23 Utility meters
 7. Division 25 Integrated Automation
 8. Division 26 Electrical panel boards (if specified with smart meters)
 9. Division 26 Lighting controls (based on the network to one location and data available via BACnet/IP protocol)
 10. Division 26 Electric meters
- F.** Coordinate networking, security, and user access to the Web Server interface with the customer's IT representative. Internet connections, ISP services, firewalls, or proxy servers shall be provided by the owner as required to support the Web access feature.
- G.** Functionality Requirements
1. User Functionality
 - a. The system shall support multiple user roles in which permissions and access to functions can be defined on a customer basis as described in User Setup.
 - b. The system shall support a user licensing system.
 2. Reliability
 - a. The system shall have measures in place to ensure reliability. This includes but is not limited to 99.x% uptime, a backup of all databases, and redundant servers.
 - b. The system shall have a staging and quality control environment to ensure system reliability.
 - c. The hosting servers shall be on a UPS power supply for a minimum of 100 minutes.
 - d. The hosting facility shall be monitored by personnel 24/7, including the facility, server hardware, and software applications.
 - e. The hosting facility shall demonstrate strict security access.
 - f. The hosting facility shall demonstrate that the servers operate in a well-controlled and protected environment including temperature and humidity control, fire detection, water protection, and server-safe fire extinguishing.
 3. Development
 - a. The system shall have a continuous development process with ongoing version releases to support continual system enhancements and the addition of new features.

4. Data Quality and Import / Export
 - a. The system must have measures in place to ensure the reliability and quality of data. This includes but is not limited to Automated Meter Reset Adjustment features.
 - b. The system shall have the ability to normalize data for the weather by meeting ASHRAE VBDD (Variable-Based Degree Day) method
 - c. The system shall incorporate a staging environment and have a quality control process to ensure consistency and accuracy of data.
 - d. The system shall be able to support the import of data from external sources. This includes Utility Bill data – which shall be disaggregated and normalized, manual entry of data, and any interval trend data including meters and BAS points.
 - e. The system shall have the ability to receive and monitor data on a 1, 5, 15, 30, and 60-minute resolution.
 - f. The system shall have the ability to import and prorate utility bill data by calendar month.
 - g. The system shall have an interface allowing users to manually enter data.
 - h. The system shall have the ability to import any interval trend data including but not limited to meters and BAS points.
 - i. The system shall provide external data accessibility through a REST (Representational State Transfer) API service.
 - j. The system shall allow users to export data from the system.
 - k. At the termination of the service, all data shall be owned by the customer
5. General Functionality
 - a. Data within the energy management system shall be owned by the customer.
 - b. The system shall have supported at least 1000 buildings to prove the scalability of the system.

H. Security

1. The application and database servers shall operate in a “demilitarized zone” (DMZ), meaning that the application is protected by firewalls from the internet as well as general access by the provider, software maker, and the host’s intranet.
2. Passwords shall be disabled after 5 login attempts with incorrect passwords.
3. Passwords shall require a minimum of 6 characters
4. Data transfers between your PC / browser and Advantage Navigator shall be protected with 256-bit SSL encryption
5. The system shall use e-mail validation to reset a forgotten password
6. The system shall support the use of data validation certificates
7. The system shall support strong authentication via SMS one-time passwords

I. Reporting Requirements

1. Refer to Section 1.1.1.5, D. Coordinate requirements with Cal Poly Representative and CxA.
2. The system shall provide the following ad-hoc reporting capabilities
 - a. The system shall allow data to be displayed in multiple chart types. At a minimum, it shall support the following charts:
 - 1) Line
 - 2) Bar
 - 3) Stepped Area
 - 4) Area
 - 5) Carpet Plot (Ability to show each day on the x-axis and each hour of the day on the y-axis. Each cell provides an automated color coding that indicates the intensity of energy usage of the data point)
 - 6) Stepped line
 - b. The system shall allow multiple data points to be overlaid on a single chart.
 - c. The system shall allow the user to save any pre-configured ad-hoc reporting view.
 - d. The system shall allow the user to compare data sets between user-selectable time frames using multiple meters including a rolling most recent period or a fixed period.
 - e. Data Export
 - 1) The system shall allow the user to export charts in graphical formats including but not limited to PNG, JPG, or PDF.
 - 2) The system shall allow the user to export charts in text format including but not limited to CSV.
 - f. Chart manipulation
 - 1) The system shall allow the user to drag and drop data points.
 - 2) The system shall allow the user to zoom in and zoom out on charts.
 - 3) The system shall allow the user to view data in a tabular format.
 - 4) The system shall allow the user to view at least four charts simultaneously.
 - 5) The system shall allow multiple X or Y axis in a single chart.
 - 6) The system shall allow the user to show/hide the X or Y axis.
 - 7) The system shall allow the user to change the scale on the X or Y axis.
 - 8) The system shall allow the user to select colors displayed on each chart.
 - 9) The system shall allow the user to change the chart type.
 - 10) The system shall allow the user to stack bar and area chart types.
3. The system shall provide the following reporting delivery capabilities:
 - a. Report access via a web-based interface
 - b. E-mailed delivery of standardized reports to the customer via a web-based scheduling interface
 - c. Allow users to schedule recurring automated e-mails of standardized reports to an unlimited number of e-mail addresses
 - d. Allow users to save report parameters for easy access to favorite reports

4. The system shall include the following report types and KPIs as listed in Report Types.
5. The system shall have Environmental Reporting including but not limited to EPA EGRID factors and manual entry of Emission Factors.
6. The system shall allow the user to export data and charts in HTML, XLS, CSV, PDF, and PPT.
7. The system shall provide the ability to automate reporting on data quality issues

J. Technical Requirements

1. Remote Access
 - a. The system shall provide secure remote access that is Certified ISO / IEC 27001.
2. Management Dashboard
 - a. Google Maps with integrated Geo Pin functionality allowing the user to Toggle KPIs Geo Pin Location based on at least three color-coded thresholds definable per individual location
 - b. A site ranking system based on energy use index (EUI), energy cost index (ECI), CO2 per square foot, energy consumption versus prior year, cost versus prior year, CO2 versus prior year, energy consumption versus budget, energy star score ranking
 - c. The dashboard shall provide the ability to trend data over time
3. User Interface
 - a. The system shall be hosted in a centrally located data center.
 - b. The system shall be accessible via a web browser.
 - c. The system shall allow unlimited concurrent users.
 - d. The system shall allow administrators to assign different security access by user role as specified in User Setup.
 - e. The system shall provide a tree view system supporting multiple tree view structures and orientations.
 - f. The system shall support a tree view system at least six levels deep.
 - g. The system shall support property inheritance of tree node properties.
4. Language Requirements
 - a. The system shall support at least 20 languages.
 - b. The system shall support 2-bit (nvar) characters.
 - c. The system shall support languages left to right and right to left as necessary.
5. Unit Requirements
 - a. The system shall support both Imperial and Metric units.
 - b. The system shall allow the user to toggle units for select reports.
6. General Technical Requirements
 - a. The system shall allow the software setup and configuration process to be conducted all through a web-based interface without any non-web-based tools required.

- b. The system shall allow aggregation through property inheritance in a tree structure for knowledge meters.
- c. The system shall support the properties of a building showing both square feet and geo coordinates.
- d. The system shall support the ability to track consumption and cost budgets versus actual.
- e. The system shall support the ability to track consumption and cost baseline versus actual. This provides the ability to compare energy consumption and cost against a baseline
- f. The system shall provide the ability to display on and off-peak usage, day vs. night usage, demand charges, and customer charges based on actual rate tariff.
- g. The system shall provide the average cost of consumption.

K. User Setup

1. The system shall provide the capability to set up specific users with corresponding capabilities according to need or security. At a minimum provide the following setup types:
 - a. Super User
 - 1) The Super User shall have all rights and access to all functions that are offered by the software application. Only one user per customer may have this role. However, the Super User will be able to Add Super User Substitutes who automatically have the same rights as the actual Super User.
 - b. Partner User
 - 1) Super Users may Add Partners. The partner role enables Super Users to delegate entire branches (e.g. a building pool) of their tree view to a partner (e.g. to a regional manager within the same organization, or an external facility management service provider). This gives the Partner User full access rights for the node assigned to him or her, including all of the lower-level nodes and meters it contains.
 - 2) The Partner User has the same rights as the Super User on the delegated node, but can only display the part of the tree view assigned to him or her. The Partner User has its user management facility and is, therefore, able to Add new users (of type Basic User and Advanced User, see next page) and assign nodes to them (within the given part of the tree view).
 - 3) Such Partner Users are invisible to Super Users outside of the partner company. Like the Super User, Partner Users can Add Super User Substitutes but they do not have the authorization to add additional Partners.
 - c. Advanced User

- 1) Each node in the tree view (site, building, etc.) can be assigned to an Advanced User who has the following rights:
 - a) Reading rights - Example: generate and subscribe to reports, display meter lists
 - b) Writing rights - Example: Add new buildings and meters, or enter metering data
 - 2) Deleting rights - Example: delete values, meters, or nodes for which the user is the contact person. Note: When a User deletes a meter, the meter and all entered values are automatically moved to the "deleted meters" node (the Super User's "recycle bin"). Therefore, the Super User can finally delete meters or restore them.
- d. Basic User
- 1) Alternatively, each node can be assigned to a Basic User who has the following rights:
 - a) Reading rights - Example: generate and subscribe to reports, display meter lists
 - b) Writing rights - Enter and edit meter readings only (no meter exchange)
 - c) Deleting rights - Delete individual meter readings only

L. Report Types

1. The software shall support the following report types:
 - a. Load Profiles (Arrangement of all load levels over time)
 - 1) Daily Max kW
 - 2) Monthly Max kW
 - 3) # of Occ. Of peak load
 - 4) The trend of a single KPI
 - 5) Daily Avg kW
 - 6) Demand
 - 7) Monthly Avg kW
 - 8) Daily Total kWh
 - 9) Gas
 - 10) Monthly Total kWh
 - 11) Daily Avg kWh
 - 12) Steam
 - 13) Monthly Avg kWh
 - 14) On Peak
 - 15) Temperatures
 - 16) Off Peak
 - 17) Fuel / Oil
 - 18) % Breakdown by load
 - 19) Chilled Water
 - 20) Flow

- 21) Frequency (Any trend data from a BAS System)
- b. Operational Analysis
 - 1) Daily Max
 - 2) Daily Min
 - 3) Total usage
 - 4) Daily Avg Usage
- c. Performance Indicators
 - 1) Opportunity Score - Ranked by the opportunity to reduce energy use
 - 2) Target Energy Use Intensity
- d. Consumption
 - 1) Daily Max
 - 2) Total portfolio energy usage
 - 3) Total portfolio emissions usage
 - 4) Electricity
 - 5) Absolute and pct breakdown of energy usage (electricity)
 - 6) Spikes
 - 7) Total and Average (electricity)
 - 8) Total
 - 9) Total portfolio cumulative energy usage
 - 10) Daily Min
 - 11) Energy Use Intensity
 - 12) Emissions Use Intensity
 - 13) Demand
 - 14) Gas
 - 15) Average and r-value correlation (Electricity vs. outside air temp)
 - 16) Total usage
 - 17) Average energy usage
 - 18) Average emissions usage
 - 19) Steam
 - 20) Gaps and missing data
 - 21) Daily Avg Usage
 - 22) Fuel
 - 23) Temperatures
 - 24) Fuel / Oil
 - 25) Chilled Water
 - 26) Flow
 - 27) Target Energy Use Intensity
 - 28) Yearly Energy use intensity
 - 29) Prior Yr Abs Deviation
 - 30) Prior Yr Abs Deviation
 - 31) Prior Yr % Deviation
- e. Emissions
 - 1) Total portfolio emissions usage

- 2) Emissions Use Intensity
- 3) Average emissions usage
- f. Chilled Water Reports
 - 1) Daily Max tons
 - 2) Total usage
 - 3) Daily Avg tons
 - 4) Daily Total ton-hr
 - 5) Daily Avg ton-hr
 - 6) On Peak
 - 7) Off Peak
 - 8) % Breakdown by load
- g. Steam Reports
 - 1) Daily Max tons
 - 2) Total usage
 - 3) Daily Avg tons
 - 4) Daily Total ton-hr
 - 5) Daily Avg ton-hr
 - 6) On Peak
 - 7) Off Peak
 - 8) % Breakdown by load
- h. Energy Budgeting
 - 1) Electricity
 - 2) Demand
 - 3) Gas
 - 4) Steam
 - 5) Temperatures
 - 6) Fuel / Oil
 - 7) Chilled Water
 - 8) Budget
 - 9) Deviation absolute
 - 10) Deviation % (Ability to generate a report with multiple sites and rank by % deviation from a budget)
- i. Cost Analysis / Budgeting
 - 1) Total portfolio energy cost
 - 2) Energy cost Intensity
 - 3) Average energy cost
 - 4) Electricity
 - 5) Demand
 - 6) Gas
 - 7) Steam
 - 8) Fuel / Oil
 - 9) Chilled Water
 - 10) Budget

- 11) Deviation absolute
- 12) Deviation %
- j. Energy Star / Weather Normalization
 - 1) Energy Star Score
 - 2) Total consumption (Electricity & Gas)
 - 3) Weather normalized consumption (System shall support a Variable-Base Degree Day Model (VBDD) program to automatically calculate a customized Balance Point Temperature for each site.)
 - 4) absolute deviation from the prior year
 - 5) % deviation from the prior year
- k. Critical Environments (if such as system is included in the project)
 - 1) % of ventilation in occupied mode due to Baseline airflow, cooling, and ventilation
 - 2) % of ventilation in the Unoccupied mode due to baseline airflow, cooling, and ventilation
 - 3) Air Volume and reheat valve position
 - 4) % of Satisfactory Temperature
 - 5) Savings in CFM and currency
 - 6) Statement of Performance Criteria
 - 7) Air volume reduction
 - 8) Target Hood Ratio Benchmark
 - 9) % of Satisfactory Exhaust Volume
 - 10) % of Satisfactory Exhaust Volume
 - 11) % of Satisfactory Directional Airflow
 - 12) % of Satisfactory Ventilation
- l. Chiller Plant Optimization (if such as system is included in the project)
 - 1) Plant Efficiency (kW/Ton)
 - 2) Target Savings
 - 3) Actual Savings
 - 4) Total Operating Hours
 - 5) Total Chilled Water usage
 - 6) Savings: Actual vs. Predicted
- m. Site ranking by customized building attributes
 - 1) Energy use index (EUI)
 - 2) Energy cost index (ECI)
 - 3) Total CO₂
 - 4) Energy consumption versus the prior year
 - 5) Cost versus the prior year
 - 6) Energy consumption versus budget
 - 7) Energy cost versus budget
 - 8) Energy star score

2.1.1.7 DIRECT DIGITAL CONTROLLER SOFTWARE

- A.** Provide a full-capability user license to the owner for the operator to be able to see, modify, create, upload, download, and save control programs to the DDC controllers.
- B.** The software program shall be provided as an integral part of DDC Controllers and shall not be dependent upon any higher-level computer or another controller for execution.
- C.** The software shall be provided with an interactive HELP function to assist operators with syntax, abbreviations, commands, and saving programs.
- D.** Point naming and communication format:
 - 1. All points, panels, and programs shall be identified by a 30-character name. All points shall also be identified by a 16-character point descriptor. The same names shall be displayed at both Building Controller and the Operator Interface.
 - 2. All digital points shall have a consistent, user-defined, two-state status indication with 8 characters minimum (e.g., Summer, Enabled, Disabled, Abnormal).
 - 3. The Building Controller Software shall be capable of BACnet communications. The BACnet Building Controller (B-BC) shall have demonstrated interoperability during at least one BTL Interoperability Workshop, have demonstrated compliance to BTL through BTL listing, and shall substantially conform to BACnet Building Controller (B-BC) device profile as specified in ANSI/ASHRAE 135-2004, Annex L.
- E.** System Security
 - 1. User access shall be secured using individual security passwords and user names.
 - 2. Passwords shall restrict the user to the objects, applications, and system functions as assigned by the system manager.
 - 3. Building Controllers shall be able to assign a minimum of 50 passwords access and control priorities to each point individually. The logon password (at any Operator Interface or portable operator terminal) shall enable the operator to monitor, adjust and control only the points that the operator is authorized for. All other points shall not be displayed at the Operator Interface or portable terminal. Passwords and priorities for every point shall be fully programmable and adjustable.
 - 4. User Log On/Log Off attempts shall be recorded.
 - 5. The system shall protect itself from unauthorized use by automatically logging off following the last keystroke. The delay time shall be user-definable.
 - 6. The use of workstation resident security as the only means of access control is not an acceptable alternative to resident system security in the DDC controller software.
- F.** User-Defined Control Applications: The applications software shall program DDC routines to meet the sequences of operations.

1. Building Controllers shall have the ability to perform energy management routines including but not limited to the time of day scheduling, calendar-based scheduling, holiday scheduling, temporary schedule overrides, start-stop time optimization, automatic daylight savings time switch over, night setback control, enthalpy switch over, peak demand limiting, temperature-compensated duty cycling, heating/cooling interlock, supply temperature reset, priority load shedding, and power failure restart.
 2. The Building Controllers shall have the ability to perform the following pre-tested control algorithms:
 - a. Two position with differential control and time delays
 - b. Floating control
 - c. Proportional control
 - d. Proportional plus integral control
 - e. Proportional, integral, plus derivative control
 - f. Automatic tuning of control loops
 - g. Model-free adaptive control
 - h. Start Stop Time Optimization
 3. Controllers shall be able to execute custom, job-specific processes defined by the user, to automatically perform calculations and special control routines.
 4. Each controller shall support plain language text comment lines in the operating program to allow for quick troubleshooting, documentation, and historical summaries of program development.
- G. Peer-to-peer access to other DDC controllers**
1. It shall be possible to use any actual or virtual point data or status, any system-calculated data, a result from any process, or any user-defined constant in any controller in the system.
 2. Any process shall be able to issue commands to points in all other controllers in the system.
 3. Processes shall be able to generate operator messages and advisories to other operator I/O devices. A process shall be able to directly send a message to a specified device or cause the execution of an advanced annunciation feature, such as:
 - a. Generate a report
 - b. Annunciate an alarm
 - c. Issue a text message or email
- H. Alarm Management**
1. Alarm management shall be provided within the controller software to monitor and direct alarm information to operator devices.
 2. Each Building Controller shall perform distributed, independent alarm analysis, minimize network traffic and prevent alarms from being lost. At no time shall the Building Controllers' ability to report alarms be affected by either operator or

- activity at a PC workstation, local I/O device, or communications with other panels on the network.
3. Conditional alarming shall allow the generation of alarms based upon user-defined multiple criteria.
 4. An Alarm "shelving" feature shall be provided to disable alarms during testing. (Pull the Plug, etc.).
 5. Binary Alarms. Each binary alarm object shall be set to alarm based on the operator-specified state. Provide the capability to automatically and manually disable alarming.
 6. Analog Alarms. Each analog alarm object shall have both high and low alarm limits. Alarming must be able to be automatically and manually disabled.
 7. All alarms shall include the point's user-defined language description and the time and date of occurrence.
 8. Alarm reports and messages shall be routed to a user-defined list of operator workstations, or other devices based on time and other conditions. An alarm shall be able to start programs, print reports, be logged in the event log, generate custom messages, and display graphics.
 9. The user shall be able to add a 200-character alarm message to each alarm point to fully describe the alarm condition or direct operator response. Each Building Controller shall be capable of storing a library of at least 50 alarm messages. Each message may be assigned to any number of points in the Controller.
 10. Operator-selected alarms shall be capable of initiating a trigger to an advanced annunciation, such as text, email, etc.
 11. An alarm history log shall report the start of the alarm condition, acknowledgment by a user, and return of the alarm to normal condition.
- I. Scheduling:
1. Provide a comprehensive menu-driven program to automatically start and stop designated multiple objects or events in the system according to a stored time.
 2. Schedules shall reside in the building controller and shall not rely on external processing or network.
 3. It shall be possible to define a group of objects as a custom event (i.e., meeting, athletic activity, etc.). Events can then be scheduled to operate all necessary equipment automatically.
 4. For points assigned to one common load group, it shall be possible to assign variable time delays between each successive start and/or stop within that group.
 5. The operator shall be able to define the following information:
 - a. Time, day
 - b. Commands such as on, off, auto, etc.
 - c. Time delays between successive commands.
 - d. There shall be provisions for manual overriding of each schedule by an authorized operator.

6. It shall be possible to schedule calendar-based events up to one year in advance based on the following:
 - a. Weekly Schedule. Provide separate schedules for each day of the week. Each of these schedules should include the capability for start, stop, optimal start, optimal stop, and night economizer. When a group of objects are scheduled together as an Event, provide the capability to adjust the start and stop times for each member.
 - b. Exception Schedules. Provide the ability for the operator to designate any day of the year as an exception schedule. Exception schedules may be defined up to a year in advance. Once an exception schedule is executed, it will be discarded and replaced by the standard schedule for that day of the week.

- J.** Peak Demand Limiting (PDL):
 1. The Peak Demand Limiting (PDL) program shall limit the consumption of electricity to prevent electrical peak demand charges.
 2. PDL shall continuously track the amount of electricity being consumed, by monitoring one or more electrical kilowatt-hour/demand meters. These meters may measure the electrical consumption (kWh), electrical demand (kW), or both.
 3. PDL shall sample the meter data to continuously forecast the demand likely to be used during successive time intervals.
 4. If the PDL forecasted demand indicates that electricity usage is likely to exceed a user preset maximum allowable level, then PDL shall automatically shed electrical loads.
 5. Once the demand peak has passed, loads that have been shed shall be restored and returned to normal control.

- K.** Temperature-compensated duty cycling
 1. User-defined conditions shall be able to initiate a Duty Cycle Control Program.
 2. The Duty Cycle Control Program (DCCP) shall be configured to periodically stop and start loads according to various patterns.
 3. The loads shall be cycled such that there is a net reduction in both the electrical demands and the energy consumed.

- L.** Automatic Daylight Savings Time Switchover. The system shall provide automatic time adjustment for switching to/from Daylight Savings Time.

- M.** Night setback control. The system shall provide the ability to automatically adjust setpoints for night control.

- N.** Enthalpy switchover (economizer). The Building Controller Software (BCS) shall control the position of the air handler relief, return, and outside air dampers. If the outside air dry bulb temperature falls below the changeover setpoint the BCS will modulate the dampers to provide 100 percent outside air. The user will be able to quickly change

over to an economizer system based on dry bulb temperature and will be able to override the economizer cycle and return to minimum outside air operation at any time.

O. Control Loop Algorithm

1. Provide a PID (proportional-integral-derivative) closed-loop control algorithm with direct or reverse action and anti-windup. The algorithm shall calculate a time-varying analog value that is used to position an output or stage a series of outputs. The controlled variable, setpoint, and weighting parameters shall be accessible from the operator workstation.

P. Adaptive Loop Tuning

1. Building Controllers shall also provide high-resolution sampling capability for verification of DDC control loop performance. Documented evidence of tuned control loop performance shall be provided on a monthly, seasonal, quarterly, and annual period.
2. For Model-Free Adaptive Control loops, evidence of tuned control loop performance shall be provided via graphical plots or trended data logs. Graphical plots shall minimally include depictions of setpoint, process variable (output), and control variable (e.g., temperature). Other parameters that may influence loop control shall also be included in the plot (e.g., fan on/off, mixed-air temp).
3. For PID control loops, operator-initiated automatic and manual loop tuning algorithms shall be provided for all operator-selected PID control loops. Evidence of tuned control loop performance shall be provided via graphical plots or trended data logs for all loops.
 - a. In automatic mode, the controller shall perform a step response test with a minimum one-second resolution, evaluate the trend data, calculate the new PID gains, and input these values into the selected LOOP statement.
 - b. Loop tuning shall be capable of being initiated either locally at the Building Controller, from a network workstation or remotely using dial-in modems. For all loop tuning functions, access shall be limited to authorized personnel through password protection.

Q. Logic programming: Provide a software routine that can build ladder logic to control using many conditional statements.

1. The logic programming syntax shall be able to combine ladder logic with other software features, such as combining status, scheduling, PDL, and alarm conditions into one conditional decision.
2. Logic programming shall be able to reference conditions in any other controller in the system.

R. Staggered Start:

1. This application shall prevent all controlled equipment from simultaneously restarting after a power outage. The order in which equipment (or groups of

equipment) is started, along with the time delay between starts, shall be user definable in an application and shall not require written scripts or ladder logic.

2. Upon the resumption of power, each Building Controller shall analyze the status of all controlled equipment, compare it with normal occupancy scheduling, and turn equipment on or off as necessary to resume normal operations.

S. Totalization Features:

1. Run-Time Totalization. Building Controllers shall automatically accumulate and store run-time hours for all digital input and output points. A high runtime alarm shall be assigned, if required, by the operator.
2. Consumption totalization. Building Controllers shall automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis for all analog and digital pulse input type points.
3. Event totalization. Building Controllers shall have the ability to count events such as the number of times a pump or fan system is cycled on and off. Event totalization shall be performed on a daily, weekly, or monthly basis for all points. The event totalization feature shall be able to store the records associated with events before reset.

T. Data Collection:

1. A variety of historical data collection utilities shall be provided to manually or automatically sample, store, and display system data for all points.
2. Building Controllers shall store point history data for selected analog and digital inputs and outputs:
3. Any point, physical or calculated may be designated for trending. Any point, regardless of physical location in the network, may be collected and stored in each Building controller's point group.
4. Two methods of collection shall be allowed: either by up to four pre-defined time intervals or upon a pre-defined change of value. Sample intervals of 1 minute to 7 days shall be provided.
5. Each Building Controller shall have a dedicated RAM-based buffer for trend data and shall be capable of storing a minimum of 10,000 data samples.
6. Trend data shall be stored at the Building Controllers and uploaded to the workstation when retrieval is desired. Uploads shall occur based upon either user-defined interval, manual command, or when the trend buffers are full. All trend data shall be available for use in third-party personal computer applications.

2.1.1.8 BACNET BUILDING CONTROLLERS

- A.** Provide all necessary hardware for a complete operating system as required. The Building Controller shall be able to operate as a standalone panel and shall not be dependent upon any higher-level computer or another controller for operation.

- B.** The basis of design is Siemens PX Modular and Compact Controllers (PXC).
- C.** This controller shall have the BTL listing and meet the BACnet device profile of a Building Controller (B-BC) and shall support the following BACnet BIBBs:
 - 1. Data Sharing
 - a. Data Sharing-Read Property-Initiate, Execute (DS-RP-A, B)
 - b. Data Sharing-Read Property Multiple- Initiate, Execute (DS-RPM-A, B)
 - c. Data Sharing-Write Property- Initiate, Execute (DS-WP-A, B)
 - d. Data Sharing-Write Property Multiple- Execute (DS-WPM-B)
 - e. Data Sharing-COV- Initiate, Execute (DS-COV-A, B)
 - f. Data Sharing-COV-Unsolicited- Initiate, Execute (DS-COVU-A,B)
 - 2. Scheduling
 - a. Scheduling-Internal- Execute (SCHED-I-B)
 - b. Scheduling-External- Execute (SCHED-E-B)
 - 3. Trending
 - a. Trending-Viewing and Modifying Trends - Initiate (T-VMT-A)
 - b. Trending-Viewing and Modifying Trends Internal- Execute (T-VMT-I-B)
 - c. Trending-Viewing and Modifying Trends-External- Execute (T-VMT-E-B)
 - d. Trending-Automated Trend Retrieval- Execute (T-ATR-B)
 - 4. Network Management
 - a. Network Management-Connection Establishment- Initiate (NM-CE-A)
 - 5. Alarming
 - a. Alarm and Event-Notification- Initiate (AE-N-A)
 - b. Alarm and Event-Notification Internal- Execute (AE-N-E-B)
 - c. Alarm and Event-Notification External- Execute (AE-N-E-B)
 - d. Alarm and Event-ACK- Initiate, Execute (AE-ACK-A, B)
 - e. Alarm and Event –Alarm Summary- Execute (AE-ASUM-B)
 - f. Alarm and Event –Enrollment Summary- Execute (AE-ESUM-A, B)
 - g. Alarm and Event –Information- Initiate, Execute (AE-ESUM-A, B)
 - 6. Device Management
 - a. Device Management-Dynamic Device Binding- Initiate, Execute (DM-DDB-A, B)
 - b. Device Management-Dynamic Object Binding- Initiate, Execute (DM-DOB-A, B)
 - c. Device Management-Device Communication Control- Execute (DM-DCC-B)
 - d. Device Management-Private Transfer- Initiate, Execute (DM-PT-A, B)
 - e. Device Management-Text Message- Initiate, Execute (DM-TM-A, B)
 - f. Device Management-Time Synchronization- Execute (DM-TS-B)
 - g. Device Management-Reinitialize Device- Execute (DM-RD-B)
 - h. Device Management-Backup and Restore- Execute (DM-RD-B)
 - i. Device Management-List Manipulation- Execute (DM-RD-B)
 - j. Device Management-Object Creation and Deletion- Execute (DM-OCD-B)
 - 7. The Building Level Controller shall support the following Data Link Layers:

- a. BACnet IP Annex J
 - b. BACnet IP Annex J Foreign Device
 - c. MS/TP Master (Claus 9)
8. The Building Level Controller shall be able to interact with all of the BACnet objects in the controllers. In addition, the software shall be able to support the following objects as they relate to features in the workstation software:
 - a. Calendar – Creatable, Deletable
 - b. Command – Creatable, Deletable
 - c. Event Enrollment – Creatable, Deletable
 - d. Notification Class – Creatable, Deletable
 - e. Schedule - Creatable, Deletable
 9. The Building Level Controller shall support transmitting and receiving segmented messages.
 10. The Building Level Controller shall have the capability to be the BACnet/IP Broadcast Management Device (BBMD) and support foreign devices.
 11. The Building Level Controller shall have the capability to act as a BACnet router between MS/TP subnetworks and BACnet/IP.
- D.** This level of controller shall be used for the following types of systems:
1. Chiller plant systems
 2. Heating plant systems
 3. Cooling Towers
 4. Pumping systems
 5. VAV air handlers
 6. Air handlers over 15,000 cfm
 7. Systems with over 24 input/output points
 8. Rooftop systems
- E.** Computing power and memory minimum:
1. A 32-bit, stand-alone, multi-tasking, multi-user, real-time 100MHz digital control microprocessor module.
 2. Inputs shall be a 16-bit minimum analog-to-digital resolution
 3. Outputs shall be 10-bit minimum digital-to-analog resolution
 4. Memory module (24 Megabytes, minimum) to accommodate all Primary Control Panel software requirements, including but not limited to, its own operating system and databases (see Controllers Software section), including control processes, energy management applications, alarm management applications, historical/trend data for points specified, maintenance support applications, custom processes, operator I/O, dial-up communications.
 5. Real-time clock and battery
 6. Data collection/ Data Trend module sized for 10,000 data samples.
 7. Flash Memory Firmware: Each Building Level Control Panel shall support firmware upgrades without the need to replace hardware.

- F.** Onboard or Modular hardware and connections:
 - 1. Primary Network communication module, if needed for primary network communications.
 - 2. Secondary Network communication module, if needed for secondary network communications.
 - 3. RJ45 port 10/100Mbaud
 - 4. RS485 ports for subnetworks and point expansion
 - 5. Man to Machine Interface port (MMI)
 - 6. USB Port

- G.** Input and Output Points Hardware
 - 1. Input/output point modules as required including spare capacity.
 - 2. Input/output point modules shall have removable terminal blocks.
 - 3. Monitoring of the status of all hand-off-auto switches.
 - 4. Monitoring of all industry-standard types of analog and digital inputs and outputs, without the addition of equipment to the primary control panel.
 - 5. Local status indication for each digital input and output for constant, up-to-date verification of all point conditions without the need for an operator I/O device. Each primary control panel shall perform diagnostics on all inputs and outputs and a failure of any input or output shall be indicated both locally and at the operator workstation.
 - 6. Graduated intensity LEDs or analog indication of value for each analog output.
 - 7. Optional HOA (hand-off-auto module) with software configurability and LED status indicators.

- H.** Code Compliance
 - 1. Approvals and standards: UL916; CE; FCC
 - 2. Provide UL864-UUKL where called for in the sequences of operations.

- I.** Accessories:
 - 1. Appropriate NEMA-rated metal enclosure.
 - 2. Power supplies as required for all associated modules, sensors, actuators, etc.

- J.** The operator shall have the ability to manually override automatic or centrally executed commands at the primary control panels via local, point discrete, onboard hand/off/auto operator override switches. If onboard switches are not available, provide separate control panels with HOA switches. Mount the panel adjacent to the primary control panel. Provide hand/off/auto switch for each digital output, including spares.

- K.** Each Building Level Control Panel shall continuously perform self-diagnostics on all hardware modules and network communications. The System Level Control Panel shall provide both local and remote annunciation of any detected component failures, low battery conditions, or repeated failure to establish communication with any system.

- L.** Panel setup, point definitions, and sequencing diagrams shall be backed up on EEPROM memory.
- M.** Power loss. In the event of the loss of power, there shall be an orderly shutdown of all Building Controllers to prevent the loss of database or operating system software. Non-volatile memory shall be incorporated for all critical controller configuration data and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 30 days.
- N.** Building Level control panels shall provide at least two serial data communication ports for the operation of operator I/O devices such as industry standard printers, operator terminals, modems, and portable laptop operator's terminals. Primary control panels shall allow temporary use of portable devices without interrupting the normal communications, and operation of permanently connected modems, printers, or terminals.
- O.** Building Level Controllers shall have the capability to serve as a gateway between Modbus subnetworks and BACnet objects. Provide software, drives, and programming.
- P.** Isolation shall be provided at all primary control panel terminations, as well as all field point terminations to suppress induced voltage transients consistent with IEEE Standards 587-1980.
- Q.** Spare Capacity: Provide enough inputs and outputs to handle the equipment shown to be "future" on drawings and 10% more of each point type. Provide all hardware modules, software modules, processors, power supplies, communication controllers, etc. required to ensure adding a point to the spare point location only requires the addition of the appropriate sensor/actuator and field wiring/tubing.
- R.** Environment.
 - 1. Controller hardware shall be suitable for the anticipated ambient conditions.
 - 2. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures and shall be rated for operation at 0°C to 49°C (32°F to 120°F). For enclosures located outdoors, provide enclosures meeting NEMA 250 NEMA 4X Rating requirements.
 - 3. Controllers used in conditioned space shall be mounted in dust-proof enclosures and shall be rated for operation at 0°C to 49°C (32°F to 120°F).
 - 4. For enclosures located in mechanical or electrical rooms, provide enclosures meeting NEMA 250 NEMA 4X Rating requirements.
 - 5. For enclosures in other locations including but not limited to occupied spaces, above ceilings, and in plenum returns, provide enclosures meeting NEMA 250 Type 1 requirements.
 - 6. Controller hardware shall be optionally suitable for rooftop environments.

- S.** Immunity to power and noise.
 - 1. The controller shall be able to operate at 90% to 110% of the nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage.
 - 2. 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).
 - 3. Isolation shall be provided at all primary network terminations, as well as all field point terminations to suppress induced voltage transients consistent with:
 - a. RF-Conducted Immunity (RFI) per ENV 50141 (IEC 1000-4-6) at 3V.
 - b. Electro Static Discharge (ESD) Immunity per EN 61000-4-2 (IEC 1000-4-2) at 8 kV air discharge, 4 kV contact.
 - c. Electrical Fast Transient (EFT) per EN 61000-4-4 (IEC 1000-4-4) at 500V signal, 1 kV power.
 - d. Output Circuit Transients per UL 864 (2,400V, 10A, 1.2 Joule max).
 - 4. Isolation shall be provided at all Building Controller's AC input terminals to suppress induced voltage transients consistent with:
 - a. IEEE Standard 587 1980
 - b. UL 864 Supply Line Transients
 - c. Voltage Sags, Surge, and Dropout per EN 61000-4-11 (EN 1000-4-11)

2.1.1.9 BACNET ADVANCED APPLICATION CONTROLLERS

- A.** Provide all necessary hardware for a complete operating system as required. The Advanced Application level control panel shall be able to operate as a standalone panel and shall not be dependent upon any higher-level computer or another controller for operation.
- B.** The basis of design is Unitary Equipment Controller (PXCxx-UCM).
- C.** The Advanced Application Controller Software shall be capable of BACnet communications. The BACnet Advanced Application Controller (B-AAC) shall have demonstrated compliance to BTL through BTL listing and shall substantially conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ANSI/ASHRAE 135-2004 or ANSI/ASHRAE 135-2008. Supported BIBBS shall include:
 - 1. Data Sharing
 - a. Data Sharing-Read Property-Initiate, Execute (DS-RP-A, B)
 - b. Data Sharing-Read Property Multiple- Initiate, Execute (DS-RPM-A, B)
 - c. Data Sharing-Write Property- Initiate, Execute (DS-WP-A, B)
 - d. Data Sharing-Write Property Multiple- Execute (DS-WPM-B)
 - e. Data Sharing-COV- Initiate, Execute (DS-COV-A, B)
 - 2. Scheduling
 - a. Scheduling-Internal- Execute (SCHED-I-B)

3. Trending
 - a. Trending-Viewing and Modifying Trends Internal- Execute (T-VMT-I-B)
 - b. Trending-Automated Trend Retrieval- Execute (T-ATR-B)
4. Network Management
 - a. Network Management-Connection Establishment- Initiate (NM-CE-A)
5. Alarming
 - a. Alarm and Event-Notification Internal- Execute (AE-N-I-B)
 - b. Alarm and Event-ACK- Initiate, Execute (AE-ACK-A, B)
 - c. Alarm and Event –Enrollment Summary- Execute (AE-ESUM-B)
 - d. Alarm and Event –Information- Execute (AE-INFO-B)
6. Device Management
 - a. Device Management-Dynamic Device Binding- Initiate, Execute (DM-DDB-A, B)
 - b. Device Management-Dynamic Object Binding- Initiate, Execute (DM-DOB-A, B)
 - c. Device Management-Device Communication Control- Execute (DM-DCC-B)
 - d. Device Management-Time Synchronization- Execute (DM-TS-B)
 - e. Device Management-Reinitialize Device- Execute (DM-RD-B)
 - f. Device Management-Backup and Restore- Execute (DM-BR-B)
 - g. Device Management-List Manipulation- Execute (DM-LM-B)
 - h. Device Management-Object Creation and Deletion- Execute (DM-OCD-B)
7. The Advanced Application Controller shall be able to interact with all of the BACnet objects in the controllers. In addition, the software shall be able to support the following objects as they relate to features in the workstation software:
 - a. Calendar – Creatable, Deletable
 - b. Command – Creatable, Deletable
 - c. Event Enrollment – Creatable, Deletable
 - d. Notification Class – Creatable, Deletable
 - e. Schedule - Creatable, Deletable
8. The Advanced Application Controller shall support transmitting and receiving segmented messages.

D. Communication:

1. BAS Network: The Advanced Application Controller shall support the following Data Link Layers:
 - a. MS/TP Master
2. Serial Communication: Temporary use of portable devices shall not interrupt the BAS communication, nor the normal operation of permanently connected printers or terminals.
 - a. Provide at least one EIA-232C serial data communication port for the operation of operator I/O devices such as industry standard printers, operator terminals, and portable laptop operator terminals.

- b. A USB port shall alternatively be available to support local HMI tools connection.

E. Software

1. The software programs specified in this section shall be provided as an integral part of Advanced Application Controllers and shall not be dependent upon any higher-level computer or another controller for execution.
2. Advanced Application Controllers shall have the ability to perform energy management routines including but not limited to
 - a. scheduling, calendar-based scheduling, holiday scheduling, temporary schedule overrides
 - b. automatic daylight savings time switch over
 - c. night setback control
 - d. economizer switch over using enthalpy, dry bulb, or a combination
 - e. peak demand limiting,
 - f. temperature-compensated duty cycling
 - g. heating/cooling interlock
 - h. supply temperature reset
 - i. priority load shedding
 - j. power failure restart
3. The software shall have a routine for the automatic tuning of control loops
4. System Security in the Field Panel
 - a. User access shall be secured using individual security passwords and user names.
 - b. Passwords shall restrict the user to the objects, applications, and system functions as assigned by the system manager.
 - c. The system shall protect itself from unauthorized use by automatically logging off following the last keystroke. The delay time shall be user-definable.
 - d. The use of workstation resident security as the only means of access control is not an acceptable alternative to resident system security in the field panel.
5. User-Defined Control Applications:
 - a. Controllers shall be fully-programmable. Controllers shall execute custom, job-specific sequences to automatically perform calculations and special control routines. Factory-installed or pre-configured sequences shall only be allowed if they exactly match the sequence specified herein.
 - b. Programs shall combine control logic, control loop algorithms, and energy management routines
 - c. Each controller shall support plain language text comment lines in the operating program to allow for quick troubleshooting, documentation, and historical summaries of program development.

- d. The controller shall provide a HELP function key, providing enhanced context-sensitive online help with task-oriented information from the user manual.
- F. Adaptive Loop Control.**
1. Each AAC controller shall come standard with an Adaptive Control Loop Algorithm
 - a. Tuning parameters shall automatically adjust for non-linear applications
 2. Model-Free Adaptive (MFA) algorithm
 - a. The algorithm shall not require modeling of the non-linear system to maintain control at all points of the non-linear load.
 - b. The controlled variable, setpoint, and weighting parameters shall be user-selectable.
 3. Output shall be analog or shall stage a series of outputs.
 4. Adaptive Control shall take the place of Proportional, Proportional + Integral, and PID-type algorithms for non-linear applications. Adaptive Control routines shall :
 - a. Improve response time
 - b. Improve System Efficiency
 - c. Improve Stability
 - d. Result in Consistent outputs
 - e. Reduce cycling and repositioning
 - f. Reduce wear and tear on actuators
 5. Adaptive control shall auto-adjust to compensate for
 - a. mode changes
 - b. load changes
 - c. seasonal changes
 - d. Heating and cooling changeover
 - e. Heating or cooling capacity changes on the primary side
 - f. Flow changes on the primary or secondary side
 - g. Airflow changes across the coil
 - h. Flow across a heat exchanger
 6. Adaptive control shall auto-adjust to compensate for
 - a. Non-linear coils and heat exchangers
 - b. Hot water and chilled water reset routines
 - c. Water flow reset routines
 - d. Duct Static reset routines
 7. Auto-Tune PID loops are not acceptable substitutions.
 8. If Adaptive Loop Control is not available, then the BAS contractor shall provide re-tuning of the control loops for coils and heat exchangers for each of the following conditions:
 - a. Low heating supply water, high heating supply water
 - b. Low load on the steam coil, high load on the steam coil
 - c. Chilled water coil, non-dehumidification, and condensing
 - d. Chilled water coil, low airflow, high airflow, economizer

- e. Dual temperature systems tune for heating and cooling modes
 - f. Each of the 4 seasons
- G.** This level of controller shall be used for the following types of systems:
- 1. Systems with custom sequences that meet all of the criteria below:
 - 2. No primary pumping systems
 - 3. Secondary Pumping systems that are remote from Central Plants
 - 4. Air handlers up to 15,000 cfm
 - 5. Systems up to 20 input/output points
 - 6. Room control sequences that cannot be achieved with an application-specific controller
 - 7. BAS Network or Architecture or Sequences do not require the system to be on an IP network
 - 8. No systems that require integration into meters, VFDs, or other smart equipment
 - 9. Integration to smart thermostats is allowed
- H.** Input/Outputs
- 1. Inputs shall be a 16-bit minimum digital resolution
 - 2. Outputs shall be a 10-bit minimum digital resolution
 - 3. The following I/O port types shall be available on the controller
 - a. Universal Input (software configurable):
 - 1) Digital Input Choices:
 - a) Pulse Accumulator
 - b) Contact Closure Sensing
 - c) Dry Contact/Potential Free inputs only
 - d) Digital Input (10 ms settling time)
 - e) Counter inputs up to 20 Hz, minimum pulse duration 20 ms (open or closed)
 - 2) Analog Input Choices:
 - a) 0-10 Vdc
 - b) 4-20 mA
 - c) 1K Ni RTD @ 32°F (Siemens, JCI, DIN Ni 1K)
 - d) 1K Pt RTD (375 or 385 alpha) @ 32°F
 - e) 10K NTC Type 2 or Type 3 Thermistor
 - f) 100K NTC Type 2 Thermistor
 - b. Universal Input or Output (software configurable):
 - 1) All of the above input types
 - 2) Analog Output Types:
 - a) 0 to 10 Vdc @ 1 mA max
 - c. Super Universal Input or Output (software configurable):
 - 1) All of the above input types
 - 2) All of the above output types
 - 3) Super digital output type:

- a) 0 to 24 Vdc, 22 mA max. (for controlling pilot relay)
 - 4) Super Analog Output Choices:
 - a) 0 to 20 mA @ 650 Ω max.
 4. Provide software configurable I/O ports such that a programmer make a port either an input or an output
- I.** Each System Level Control Panel shall, at a minimum, be provided with:
1. Appropriate NEMA-rated metal enclosure.
 2. A 32-bit, multitasking, real-time 100 MHz digital control microprocessor with plug-in, enclosed processors.
 3. Each Advanced Application Controller shall have sufficient memory, a minimum of 24 megabytes, to support its own operating system and databases, including control processes, energy management applications, alarm management applications, historical/trend data for points specified, maintenance support applications, custom processes, and operator I/O.
 4. Real-time clock and battery
 5. Data collection/ Data Trend module sized for 10,000 data samples.
 6. Power supplies as required for all associated modules, sensors, actuators, etc.
 7. Monitoring of all industry-standard types of analog and digital inputs and outputs, without the addition of equipment to the primary control panel.
 8. Local status indication for each digital input and output for constant, up-to-date verification of all point conditions without the need for an operator I/O device.
 9. Each control panel shall perform diagnostics on all inputs and outputs and a failure of any input or output shall be indicated both locally and at the operator workstation.
 10. Graduated intensity LEDs or analog indication of value for each analog output.
- J.** Power loss. In the event of the loss of power, there shall be an orderly shutdown of all controllers to prevent the loss of database or operating system software. Non-volatile memory shall be incorporated into the operating system software and firmware.
1. The controller shall be able to operate at 90% to 110% of the nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage.
 2. Brownout protection and power recovery circuitry protects the controller board from power fluctuations.
 3. Battery backup shall be provided to support the real-time clock for 10 years
 4. The program and database information stored in SDRAM memory shall be battery-backed for a minimum of 30 days and up to 60 days. This eliminates the need for time-consuming program and database re-entry in the event of an extended power failure.
- K.** Database Restore: Each AAC controller shall automatically save the latest programmed database. The controller shall be able to automatically restore a lost or corrupt database without involvement from the operator.

- L.** Each System Level Control Panel shall continuously perform self-diagnostics on all hardware modules and network communications. The System Level Control Panel shall provide both local and remote annunciation of any detected component failures, low battery conditions, or repeated failure to establish communication with any system.
- M.** Each Control Panel shall support firmware upgrades without the need to replace hardware.
- N.** System Level control panels shall provide at least two RS-232C serial data communication ports for operation of operator I/O devices such as operator terminals, and additional memory. Control panels shall allow temporary use of portable operator interface devices without interrupting normal communications.
- O.** Immunity to noise.
 - 1. 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).
 - 2. Isolation shall be provided at all primary network terminations, as well as all field point terminations to suppress induced voltage transients consistent with:
 - a. RF-Conducted Immunity (RFCl) per ENV 50141 (IEC 1000-4-6) at 3V.
 - b. Electro Static Discharge (ESD) Immunity per EN 61000-4-2 (IEC 1000-4-2) at 8 kV air discharge, 4 kV contact.
 - c. Electrical Fast Transient (EFT) per EN 61000-4-4 (IEC 1000-4-4) at 500V signal, 1 kV power.
 - d. Output Circuit Transients per UL 864 (2,400V, 10A, 1.2 Joule max).
 - 3. Isolation shall be provided at all Advanced Application Controller's AC input terminals to suppress induced voltage transients consistent with:
 - a. IEEE Standard 587 1980
 - b. Voltage Sags, Surge, and Dropout per EN 61000-4-11 (EN 1000-4-11)
- P.** Agency Compliance
 - 1. UL UL916 PAZX (all models)
 - 2. UL916 PAZX7 (all models)
 - 3. FCC Compliance CFR47 Part 15, Subpart B, Class B
- Q.** Spare Capacity: Provide enough inputs and outputs to handle the equipment shown to be "future" on drawings and 10% more of each point type. Provide all hardware modules, software modules, processors, power supplies, communication controllers, etc. required to ensure adding a point to the spare point location only requires the addition of the appropriate sensor/actuator and field wiring/tubing.

2.1.1.10 CONTROL PANELS

- A.** Controllers in mechanical rooms or electrical rooms shall be mounted in NEMA 4X rating enclosures.

- B.** Controllers in areas where moisture is a concern shall be mounted in NEMA 12 enclosures.
- C.** Controllers installed outdoors shall be mounted in NEMA 4X enclosures. Provide heaters where freezing temperatures are normally experienced.
- D.** UPS is required for Controllers. Critical areas shall be confirmed by the Division 23 contractor with the Cal Poly Representative and the design team that require zero downtime of the controllers (e.g., Classroom lab exhaust fans).
- E.** Mount on walls at an approved location or provide a free-standing rack.
- F.** Panels shall be constructed of 16 gauge, furniture-quality steel, or extruded-aluminum alloy, totally enclosed, with hinged doors and keyed lock and with ANSI 61 gray polyester-powder painted finish, UL listed. Provide common keying for all panels.
- G.** Provide power supplies for control voltage power.
- H.** Dedicate 1 power supply to the DDC controller. Other devices shall be on a separate power supply unless the power for the control device is derived from the controller terminations.
- I.** Power supplies for controllers shall be a transformer with a fuse or circuit breaker. Power supplies for other devices can be plain transformers.
- J.** All power supplies for 24V low voltage wiring shall be class 2 rated and less than 100VA. If low-voltage devices require more amps, then provide multiple power supplies. If a single device requires more amps, then provide a dedicated power supply in a separate enclosure and run a separate, non-class 2 conduit to the device.
- K.** Surge transient protection shall be incorporated in the design of the system to protect electrical components in all DDC Controllers and operators' workstations.
- L.** All devices in a panel shall be permanently mounted, including network switches, modems, media converters, etc.
- M.** Provide a pocket to hold documentation.

2.1.1.11 SENSORS

- A.** General
 1. Provide mounting hardware for all devices, including actuator linkages, wells, installation kits for insertion devices, wall boxes and fudge plates, brackets, etc.
 2. If a special tool is required to mount a device, provide that tool.

B. Terminal Unit Space Thermostats

1. Each controller performing space temperature control shall be provided with a matching room temperature sensor.
 - a. Plain Space Temperature Sensors – Wired: Where called for in the sequences or on the drawings, provide sensors with plain covers.
 - b. The sensing element for the space temperature sensor shall be thermistor type providing the following.
 - 1) Element Accuracy: + /- 1.0°F
 - 2) Operating Range: 55 to 95°F
 - 3) Set Point Adjustment Range: 55 to 95°F
 - 4) Calibration Adjustments: None required
 - 5) Installation: Up to 100 ft. from the controller
 - 6) Auxiliary Communications Port: as required
 - 7) Local LCD Temperature Display: as required
 - 8) Setpoint Adjustment Dial as required
 - 9) Occupancy Override Switch as required
 - c. Auxiliary Communication Port. Each room temperature sensor shall include a terminal jack integral to the sensor assembly. The terminal jack shall be used to connect a portable operator's terminal to control and monitor all hardware and software points associated with the controller. RS-232 communications port shall allow the operator to query and modify the operating parameters of the local room terminal unit from the portable operator's terminal.
2. Digital Display temperature sensor specifications – Wired:
 - a. As called for in the sequences of operations or on the drawings, provide temperature sensors with digital displays.
 - b. The sensing element for the space temperature sensor must be IC-based and provide the following.
 - 1) Digitally communicating with the Application Specific Controller.
 - 2) Mountable to and fully covering a 2 x 4 electrical junction box without the need for an adapter wall plate.
 - 3) IC Element Accuracy: + /- 0.9°F
 - 4) Operating Range: 55 to 95°F
 - 5) Setpoint Adjustment Range: User limiting, selectable range between 55 and 95°F
 - 6) Display of temperature setpoint with numerical temperature values
 - 7) Display of temperature setpoint graphically, with a visual Hotter/Colder setpoint indication
 - 8) Calibration: Single point, field adjustable at the space sensor to + /- 5°F
 - 9) Installation: Up to 100 ft. from the controller
 - 10) Auxiliary Communications Port: to be included

- 11) Local OLED Temperature Display: to be included
 - 12) Display of Temperature to one decimal place
 - 13) Temperature Setpoint Adjustment to be included.
 - 14) The occupancy Override Function is to be included.
- c. Auxiliary Communication Port. Each room temperature sensor shall include a terminal jack integral to the sensor assembly. The terminal jack shall be used to connect a portable operator's terminal to control and monitor all hardware and software points associated with the controller. RS-232 communications port shall allow the operator to query and modify the operating parameters of the local room terminal unit from the portable operator's terminal.
3. Provide the following options as they are called for in the sequences or on the drawings:
- a. Setpoint Adjustment. The setpoint adjustment function shall allow for modification of the temperature by the building operators. Setpoint adjustment may be locked out, overridden, or limited as to time or temperature through software by an authorized operator at any central workstation, Building Controller, room sensor two-line display, or via the portable operator's terminal.
 - b. Override Switch. An override button shall initiate the override of the night setback mode to normal (day) operation when activated by the occupant and enabled by building operators. The override shall be limited to two (2) hours (adjustable.) The override function may be locked out, overridden, or limited through software by an authorized operator at the operator interface, Building Controller, room sensor two-line display, or via the portable operator's terminal.
 - c. Space Combination Temperature and Humidity Sensors. Each controller performing space temperature control shall be provided with a matching room temperature sensor, which also includes the ability to measure humidity for either monitoring or control purposes. The combination of temperature and humidity sensors shall have the same appearance as the space temperature sensors. Humidity elements shall measure relative humidity with a +/- 2% accuracy over the range of 10 to 90% relative humidity. The humidity element shall be an IC (integrated circuit) sensing element. Humidity sensing elements shall be removable and field replaceable if needed.

C. Temperature Sensors

1. All temperature sensors shall meet the following specifications:
 - a. Accuracy: Plus or minus 0.2 percent at the calibration point.
 - b. Wire: Twisted, shielded-pair cable.
 - c. Vibration and corrosion resistant

2. Space temperature sensors shall meet the following specifications:
 - a. 10k ohm type 2 thermistors
 3. Insertion Elements in Ducts shall meet the following specifications:
 - a. Single point 10k ohm thermistor
 - b. Use where not affected by temperature stratification
 - c. The sensor shall reach more than 1/3 the distance from the duct wall
 - d. Junction box for wire splices
 4. Averaging Elements in Ducts shall meet the following specifications:
 - a. 72 inches (183 cm) long
 - b. Flexible
 - c. Use where prone to temperature stratification, in front of coils, or where ducts are larger than 9 sq. ft.
 - d. Junction box for wire splices
 5. Insertion Elements for Liquids shall meet the following specifications:
 - a. Platinum RTD with 4-20mA transmitter
 - b. Threaded mounting with matching well
 - c. Brass well with a minimum insertion length of 2-1/2 inches for pipes up to 4" diameter
 - d. Brass well with an insertion length of 6 inches for pipes up to 10" diameter
 - e. Junction box for wire splices
 6. Outside-Air Sensors Platinum RTD with 4-20mA transmitter:
 - a. Watertight enclosure, shielded from direct sunlight
 - b. Circulation fan
 - c. Watertight conduit fitting
- D.** Where called for in the sequences of operations, provide the following feature on space sensors and thermostats:
1. Security Sensors: Stainless-steel cover plate with insulated back and security screws
 2. Space sensors with setpoint adjust: Plain white plastic cover with slide potentiometer to signal a setpoint adjustment to the DDC
 3. Space Sensors with LCD display:
 - a. Operator buttons for adjusting setpoints, setting fans speeds, and overriding unit to on/off
 - b. Graphical LCD icons for signaling heating/cooling mode, fans speed, schedule mode, actual temperature, and current setpoint
- E.** Humidity Sensors shall meet the following specifications:
1. A bulk polymer sensor element
 2. Accuracy: 2 percent full range with linear output
 3. Room Sensors: With locking cover matching room thermostats, a span of 0 to 100 percent relative humidity

4. Duct and Outside-Air Sensors: With element guard and mounting plate, range of 0 to 100 percent relative humidity
- F.** Air Static Pressure Transmitter shall meet the following specifications:
1. Non-directional sensor with suitable range for expected input, and temperature compensated.
 2. Accuracy: 2 percent of full scale with repeatability of 0.5 percent.
 3. Output: 4 to 20 mA.
 4. Building Static-Pressure Range: 0 to 0.25 inches wg.
 5. Duct Static-Pressure Range: 0 to 5 inches wg.
- G.** Pressure Transmitters: Direct acting for gas, liquid, or steam service; range suitable for the system; proportional output 4 to 20 mA.
- H.** Equipment operation sensors are as follows:
1. Status Inputs for Fans: Differential-pressure switch with an adjustable range of 0 to 5 inches wg.
 2. Status Inputs for Pumps: Differential-pressure switch piped across pump with an adjustable pressure-differential range of 8 to 60 psig.
 3. Status Inputs for direct drive electric motors: Current-sensing relay with current transformers, adjustable and sized for 175 percent of rated motor current.
 4. Status inputs for belt drive electric motors: Current sensing transmitter with linear 4-20mA output
- I.** Electronic Valve/Damper Position indication: Visual scale indicating percent of travel and 0 to 10 V dc, feedback signal.
- J.** Water-Flow Switches: Pressure-flow switches of bellows-actuated mercury or snap-acting type, with appropriate scale range and differential adjustment, with stainless-steel or bronze paddle. For chilled-water applications, provide a vapor-proof type.
- K.** Air Differential Pressure Switches: Diaphragm-type air differential pressure switches with die-cast aluminum housing, adjustable setpoint, minimum 5 amp switch rating at 120VAC, SPDT switches, and the switch pressure range shall be suited for the application. Provide Dwyer or equal. These switches shall be utilized for filter status.
- L.** Leak detectors: Provide spot leak detectors that can be secured to the floor or secured to a drain pan. The detection shall use microchip-controlled energized probes. The detector shall operate on 24V or less. Provide a way to adjust the height of the leak probes. The SPDT contacts shall be inside a watertight enclosure.

2.1.1.12 ELECTRO-MECHANICAL THERMOSTATS

- A.** Fire-Protection Thermostats: UL listed with fixed or adjustable settings to operate at not less than 75 deg F above normal maximum operating temperature, with the following:
 - 1. Reset: Automatic with control circuit arranged to require manual reset at the central control panel, with pilot light and reset switch on the panel labeled to indicate operation.
- B.** Electric Low-Limit Duct Thermostat: Snap-acting, single-pole, single-throw, manual- or automatic-reset switch that trips if the temperature sensed across any 12 inches of bulb length is equal to or below the set point. The setpoint shall be adjustable.
 - 1. Bulb Length: Minimum 20 feet.
 - 2. Quantity: One thermostat for every 20 sq. ft. of coil surface.
- C.** Electric space thermostats: Provide a charged element type stat with a snap-acting SPDT switch. The switch shall be rated for 16A or 1HP at 120V.
- D.** Aquastat: Provide a charged element type stat with a snap-acting SPDT switch. The switch shall be rated for 16A or 1HP at 120V.

2.1.1.13 AUTOMATIC CONTROL VALVES

- A.** General:
 - 1. All automatic control valves shall be fully proportioning unless specified otherwise. The valves shall be quiet in operation and fail-safe in the either normally open or normally closed position in the event of control air failure. All valves shall be capable of operating at varying rates of speed to correspond to the exact dictates of the controllers and variable load requirements. The valves shall be capable of operating in sequence with other valves and/or dampers when required by the sequence of operation. All control valves shall be sized by the control vendor and shall be guaranteed to accommodate the flow rates as scheduled. All control valves shall be suitable for the pressure conditions and shall close against the differential pressures involved. Body pressure rating and connection type construction shall conform to fitting and valve schedules. Control valve operators shall be sized to close against a differential pressure equal to the design pump heads plus 10 percent.
 - 2. Cold water, hot water, steam valves, throttling type, and bypass valves shall have equal percentage flow characteristics.
 - 3. Unless otherwise specified, control valves 2 inches and smaller shall have cast iron or bronze bodies with screwed NPT connections.
 - 4. Valves between 2-1/2 inches and 4 inches shall have cast iron bodies with flanged connections.
 - 5. All automatic control valves installed exposed to the elements shall be provided with electric actuators with operating characteristics and accessories as described

herein. Coordinate with the Division 26 electrical contractor for power availability and point of connection.

6. All automatic control valves controlled by the BAS shall be furnished by the controls contractor unless noted otherwise in these documents.
7. All automatic control valves shall be installed by the mechanical trade.
8. The controls contractor shall provide wiring as follows:
 - a. All line voltage power for electric valve actuators shall be wired by the controls contractor from the nearest available power panel. Coordinate with the Division 26 electrical contractor
 - b. All wiring between the central control system (ATC/BMS) and the valve actuator shall be wired by the controls contractor.
 - c. All wiring between the valve actuator and their associated thermostats, pressure switches, control devices, etc. shall be wired by the controls contractor.
 - d. All wiring shall comply with code requirements and per Cal Poly Construction Standards Division 26 - Electrical and Division 27 – Communications. Segregate high and low-voltage wiring & circuits and segregate the FAS and controls (BMS) terminals.

B. Characterized Ball Valves

1. All control valves shall be sized by the control vendor. All control valve bodies shall be suitable for the static and dynamic pressures of the system. Control valve operators shall be sized to close against a differential pressure equal to the design pump head plus 10 percent.
2. Body pressure rating and connection type construction shall conform to fitting and valve schedules.
 - a. Design body pressure shall be determined by adding the static pressure due to the height of the system plus the compression tank charge plus the maximum head of the system pump at cut-off. Provide a 10% design factor.
3. The valve seat differential pressure rating shall exceed the pump dynamic head design pressure.
4. All automatic control valves controlled by the BAS shall be furnished by the controls contractor unless otherwise noted in these documents.
5. All automatic control valves shall be installed by the mechanical trade.
6. The controls contractor shall provide wiring as follows:
 - a. All line voltage power for electric valve actuators shall be wired by the controls contractor from the nearest available power panel. Coordinate with the electrical trade.
 - b. All low-voltage wiring between the controller and the valve actuator shall be wired by the control contractor.
 - c. All wiring between safeties and the valve actuator shall be wired by the control contractor.

- d. All wiring shall comply with code requirements and per Cal Poly Construction Standards Division 26 - Electrical and Division 27 – Communications. Segregate high and low voltage wiring and circuits and segregate the Fire Alarm (FACS) and BAS controls wiring.
- C. Manufacturer**
1. Siemens 599 series valves bodies, SSD, SAX, SQV Actuators, Series 230, 231, 232, 233, 238, 239, 371, and 373 assemblies, or approved equal.
- D. Threaded Valves, line size ½" to 2"**
1. Controlled Media-Specific Items
 - a. The control valve shall be suitable for chilled water to a minimum of 35°F (2°C) and hot water to a maximum temperature of 250°F (121°C). 3-way 1-1/2 inch and 2-inch valves shall be suitable for chilled water to a minimum of 35°F (2°C) and hot water to a maximum temperature of 230°F (110°C).
 - b. The control valve shall be suitable for up to 50% ethylene or propylene glycol solutions, chilled glycol/water solutions to a minimum of 35°F (2°C), and hot glycol/water solutions to a maximum temperature of 250°F (121°C). 3-way 1-1/2 inch and 2-inch valves shall be suitable for up to 50% ethylene or propylene glycol solutions, chilled glycol/water solutions to a minimum of 35°F (2°C), and hot glycol/water solutions to a maximum temperature of 230°F (110°C).
 2. General Construction Materials/Applicable Standards
 - a. Control valve bodies shall be constructed of forged brass according to ASTM B283 (C37700, CuZn39Pb2 or equivalent), and shall meet requirements of ANSI 250 and 600WOG pressure classes.
 - b. Inlets and outlets shall be clearly marked on the valve bodies.
 - c. The valve ball shall consist of nickel-plated brass, chrome-plated brass, or stainless steel.
 - d. End connections shall be NPT internally threaded according to ANSI B1.20.1.
 - e. The control valve flow rate (Cv) shall meet the requirements of ANSI/ISA S75.02.
 - f. The control valve shall have an equal percentage flow characteristic, according to ANSI/ISA S75.11. A single glass-filled PTFE V port insert shall provide both the ball seal and shall establish the flow coefficient of the valve. The V port insert shall be retained by the valve body itself, not requiring additional retaining components. Flow coefficient adapters requiring a retainer clip, or installed after final assembly of the valve or as inserts in the ball shall not be allowed.
 - g. 2-way valves and the A-AB path on 3-way valves shall meet the requirements of ANSI Class IV (0.01% of rated Cv) seat leakage, or better, according to ANSI/FCI 70.2, at the specified close-off pressure. Bypass path (B-AB) on 3-

way valves shall meet the requirements of ANSI Class III (0.1% of rated Cv) seat leakage, or better, according to ANSI/FCI 70.2.

- h. The chilled and Hot water valve shall have a blow-out proof stem with two EPDM (peroxide-cured) O-rings. External stem retainers will not be allowed.
- i. The valve stem shall be made of brass or stainless steel.
- j. The valve shall have the ability to be manually operated in the event of a power failure.

E. Actuators - Electric

- 1. The valves shall be provided with an actuator by the same manufacturer, and factory installed.
- 2. All actuators shall have visual position indications.
- 3. No external programming device shall be required.
- 4. The actuator shall be electric motor driving, microprocessor signal controlled.
- 5. Modulating valves shall be positive positioning, responding to a 0-10VDC, 2-10VDC, or 4-20mA signal. Floating modulating signals are acceptable for modulation on terminal units and radiation units. There shall be a visual valve position indicator.
- 6. Power: All actuators shall be 24VAC power and less than 100VA draw. Power shall be via Class 2 wiring. Actuators requiring more than 100VA shall have a dedicated conduit for power wiring, not mixed with the signal wiring.
- 7. Fail-Safe: Valves actuators shall position the valve in a fail-safe position when the power supply is disrupted or the signal goes to 0. Fail-safe according to the following guidelines unless otherwise stated in the sequence of operations
 - a. Power fail-safe shall be via spring-loaded mechanical means
 - b. Any AHU hot water exposed to ventilation air shall fail open
 - c. AHU Chilled water coils exposed to ventilation air in possible freezing conditions shall be fail open
 - d. AHU Chilled water coils that are drained in winter months or are in climate zones without freezing conditions shall be fail-in-place
 - e. Terminal unit valves shall fail-in-place
- 8. Fail in Safe valves on primary equipment such as chilled water systems, hot water systems, and condenser water systems shall have a means to manually open the valve when power is not available, such as a hand wheel or a geared crank with a clutch.
- 9. The actuator shall be designed with a current limiting motor protection. A release button (clutch) or handle on the actuator shall be provided to allow for manual override (except when the actuator is spring return type).
- 10. The actuator shall provide the minimum torque required for proper valve close-off. The close-off differential pressure rating of the valve shall exceed the highest possible head pressure available at the pump plus 10%, and still be rated for a Class IV leakage.

11. The actuator shall have the capability of adding auxiliary switches or feedback potentiometers if specified.
12. All automatic control valves installed in locations exposed to the elements shall be provided with weather-resistant housings and heaters for climates that reach below freezing.
13. Actuators shall be UL and CSA listed.

F. Hot Water / Condenser Water / Control Valves

1. Single-seated.
2. Fully proportioning with modulating plug or V-port inner valves.
3. Body pressure rating and connection type construction shall conform to fitting and valve schedules. The ANSI rating of the valve shall match the ANSI rating of the piping in which the valve is installed. The minimum ANSI rating shall be ANSI 125.
4. Stainless steel stems and trim.
5. Spring-loaded Teflon packing
6. Quiet in operation.
7. Fail-safe in either normally open or normally closed position in the event of power failure.
8. Capable of operating in sequence with other valves and/or dampers when required by the sequence of operation.
9. Capable of operating at varying rates of speed to correspond to the exact dictates of the controller and variable load requirements.

G. Differential Pressure Control Valves :

1. Provide for all water systems where modulating water flow conditions are required to prevent excessive pump pressure build-up. Provide a valve for each closed-loop water system. Valve to be globe type. Provide valves 2" and smaller with screwed end bodies and provide valves 2-1/2" and larger with flanged ends.

H. Steam Valves:

1. Steam control valves shall be of linear flow characteristics for modulating service.
2. Sizing Criteria:
 - a. 15 psig or less; pressure drop 80% of inlet psig.
 - b. 16 to 50 psig; pressure drop 50% of inlet psig.
 - c. Over 50 psig; pressure drop as scheduled on plans.
 - d. Steam valves shall fail normally open or closed, as scheduled on plans, or as follows:
 - 1) Heating coils in air handlers: normally open.
 - 2) Steam to hot water heat exchanger: normally closed.
 - 3) Other applications: as required by sequences of operation.

2.1.1.14 ELECTRONIC ACTUATOR SPECIFICATION

A. ELECTRONIC VALVE ACTUATORS

1. The actuator shall be fully modulating, floating (tri-state), two positions, and/or spring return as indicated in the control sequences. Specified fail-safe actuators shall require mechanical spring return.
2. Modulating valves shall be positive positioning, responding to a 2-10VDC or 4-20mA signal. There shall be a visual valve position indicator.
3. The actuator shall have the capability of adding auxiliary switches or feedback potentiometers if specified.
4. The actuator shall provide the minimum torque required for proper valve close-off. The actuator shall be designed with a current limiting motor protection. A release button (clutch) or handle on the actuator shall be provided to allow for manual override (except when the actuator is spring return type).
5. Actuators shall be UL listed.

B. ELECTRONIC DAMPER ACTUATORS

1. The actuator shall be directly coupled (over the shaft), enabling it to be mounted directly to the damper shaft without the need for connecting linkage. The actuator-to-shaft clamp shall use a "V" bolt and a "V" shaped, toothed cradle to attach to the damper shaft for maximum holding strength. Single bolt or set screw-type fasteners are not acceptable.
2. The actuator shall have electronic overload or digital rotation sensing circuitry to prevent damage to the actuator throughout the rotation of the actuator. End switches to deactivate the actuator at the end of the rotation or the magnetic clutch are not acceptable.
3. For power-failure/safety applications, a mechanical, spring return mechanism shall be used.
4. Actuators with spring return mechanisms shall be capable of either clockwise or counterclockwise spring return operation by simply changing the mounting orientation.
5. Proportional actuators shall accept a 2-10VDC, 4-20mA signal, or be of the 2-point floating type and provide a 2-10VDC actuator position feedback signal.
6. All actuators shall have an external manual gear release (clutch) or manual crank to aid in installation and for allowing manual positioning when the actuator is not powered.
7. All actuators shall have an external direction of rotation switch to aid in installation and to allow proper control response.
8. Actuators shall be provided with a factory-mounted 3-foot electrical cable and conduit fitting to provide easy hook-up to an electrical junction box.
9. Actuators shall be listed under Underwriters Laboratories Standard 873 and Canadian Standards Association. They must be manufactured under ISO 9001.

PART 3 - EXECUTION

3.1.1.1 EXAMINATION

- A.** The project plans shall be thoroughly examined for control device and equipment locations. Any discrepancies, conflicts, or omissions shall be reported to the architect/engineer for resolution before rough-in work is started.
- B.** The contractor shall inspect the site to verify that equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to the engineer for resolution before rough-in work is started.
- C.** The contractor shall examine the drawings and specifications for other parts of the work. If headroom or space conditions appear inadequate—or if any discrepancies occur between the plans and the contractor’s work and the plans and the work of others—the contractor shall report these discrepancies to the engineer and shall obtain written instructions for any changes necessary to accommodate the contractor’s work with the work of others.

3.1.1.2 INSTALLATION

- A.** Provide all relays, switches, and all other auxiliaries, accessories, and connections necessary to make a complete operable system in accordance with the sequences specified. All field wiring shall be done by the Division 23 contractor.
- B.** Install controls so that adjustments and calibrations can be readily made. Controls are to be installed by the control equipment manufacturer.
- C.** Mount surface-mounted control devices on brackets to clear the final finished surface on insulation.
- D.** Install equipment level and plumb.
- E.** Install control valves horizontally with the power unit up.
- F.** Unless otherwise noted, install wall-mounted thermostats and humidistats 60” above the floor measured to the center line of the instrument, or as otherwise directed by the Architect.
- G.** Install averaging elements in ducts and plenums in horizontal crossing or zigzag patterns.
- H.** Install outdoor sensors in perforated tubes and sun-shield.

- I. Install damper motors on the outside of the duct in protected areas, not in locations exposed to outdoor temperatures.
- J. Install labels and nameplates on each control panel listing the name of the panel referenced in the graphics and a list of equipment numbers served by that panel.
- K. Furnish hydronic instrument wells, valves, and other accessories to the mechanical contractor for installation.
- L. Furnish automatic dampers to the mechanical contractor for installation.

3.1.1.3 GRAPHIC DISPLAY GENERATION

- A. All software shall be capable of providing color graphics. All software shall include a graphical viewing and control environment and the definition and construction of dynamic color graphic displays.
- B. Provide a main default screen showing the basic layout of the building. Each color graphic screen shall have transfer links to allow the building operator to transfer between system-associated screens (both forward and backward), as well as a transfer link back to the main default screen.
- C. Basic CAD floor plans with layers for walls, windows, low-pressure ductwork only, supply diffusers, and room numbers shall be provided for all CV, VAV, and FPVAV terminal units. Floor plans shall show the location of each space temperature sensor with a dashed line to the associated terminal unit. Display in real time the difference between the space temperature and the current setpoint.
 - 1. Display the
 - a. cooling %,
 - b. heating % (if applicable)
 - c. current CFM of each terminal unit.
 - 2. Provide a transfer link for each terminal unit to allow the operator to access the flow graphic for each terminal unit. Use a different color to shade the background area for each part of a floor plan graphic served by a different air handling unit.
- D. All control set points shall be easily adjustable from the system's color graphic screen by operators with the proper access level. Each controlled point on the BAS operator workstation color graphic screens shall have the set point indicated along with the actual controlled variable reading (preferred set point on top and actual reading on bottom). All points shall indicate the associated engineering unit. All analog output points shall indicate engineering units such as "%-open" or "%-closed" as required by the application. All normally-closed or normally-open points shall indicate the normal position (such as "N.C." or "N.O." next to the controlled device).

- E.** Provide system color graphics for each HVAC system and for each electrical, plumbing, and/or piping system that is monitored and/or controlled by the BMS. Provide scaled floor plans indicating equipment location, service, and system data as required.
- F.** Provide color graphic floor plan displays and system schematics for each piece of mechanical equipment, including but not limited to air handling units, chilled water systems, and hot water systems to optimize system performance analysis and speed alarm recognition.
- G.** The operator interface shall allow the users to access the various system schematics and floor plans via a graphical penetration scheme, menu selection, or text-based commands.
- H.** Dynamic temperature values, humidity values, flow values, and status indications shall be shown in their actual respective locations and shall automatically update to represent current conditions without operator intervention.
- I.** The windowing environment of the operator interface shall allow the user to simultaneously view several graphics at a time to analyze total building operation or to allow the display of a graphic associated with an alarm to be viewed without interrupting work in progress.
 - 1. Provide libraries of pre-engineered screens and symbols depicting standard air handling unit components (e.g., fans, cooling coils, filters, dampers, etc.), complete mechanical systems (e.g., constant volume-terminal reheat, VAV, etc.), and electrical symbols.
 - 2. Graphical displays can be created to represent any logical grouping of system points or calculated data based on building function, mechanical system, building layout, or any other logical grouping of points which aids the operator in the analysis of the facility.
- J.** Provide an automatically updated, dynamic display of the site-specific BMS architecture indicating the status of primary and secondary controllers.
- K.** Provide a separate dynamic display page for each HVAC (AHU, AC, chiller, cooling tower, fuel oil, etc.), electrical, and/or plumbing system connected to the BMS.
- L.** Provide a separate dynamic display page for each piece of terminal equipment (VAV box, fan coil unit, etc.) connected to the BMS.
- M.** Provide additional dynamic, graphic display pages as required by the operating staff to further assist in daily system operations.
- N.** Graphics shall incorporate all system integration points communicated via hardware or software gateways and/or interfaces. The origin of information shall be transparent to

the operator and shall be controlled, displayed, trended, etc. as if the points were hardwired to the BMS.

- O.** Each graphic shall have a "BACK" button and a "HOME" or "MAIN" button located in the same location on all graphics.
- P.** The operator shall be able to clearly distinguish the difference between the following types of points on a graphic either by color, shape, icon, or text label:
 - 1. Real-time sensor reading
 - 2. Setpoint
 - 3. Manually set vs. program set Setpoint
 - 4. Real-time output reading
 - 5. Manually Overridden or commanded output vs program set output
 - 6. Status feedback from a piece of equipment vs the output command
- Q.** Make appear links to additional information associated with the system on the graphic, such as:
 - a. Controls as-built schematics and wiring diagrams
 - b. As-built Sequence of Operation
 - c. Mechanical drawings
 - d. Electrical drawings
- R.** Integration graphics shall be representative of personnel standing in front of the equipment. The graphics for equipment specified in the Building Systems Integration paragraph shall be representative of the manufacturers' local display panel and each shall be completely operable from the computer workstation.
- S.** Lighting Control System User Interface:
 - 1. Floor plan Graphics: Provide an interface for area-level lights status, level, occupancy mode, preset scene, and ability to override all.
 - 2. Room Graphics: Provide an interface for zone-level lights status, level, occupancy mode, preset scene, light level (photocell), light level setpoint, and ability to override all.
 - 3. Schedule Interface: Time clock schedule commands to the Lighting Control System shall be managed by the BAS System. Provide an interface for schedule mode input for each time clock area, with mode feedback.
 - 4. Alarm Management: BAS System shall manage the collection and distribution of alarms from the Lighting Control System. Provide an interface for any system or device alarm, including lamp or ballast failures (as available), panel failures, or network failures.
 - 5. Trend/History Management: BAS System shall collect and manage historical trend logs for Lighting Control System points.

3.1.1.4 ELECTRICAL WIRING SCOPE

- A.** The Division 23 contractor shall be responsible for power that is not shown on the electrical drawings, to controls furnished by this contractor. If power circuits are shown on the electrical drawings, this contractor shall continue the power run to the control device. If power circuits are not shown, this contractor shall coordinate with the electrical contractor to provide breakers at distribution panels for power to controls. This contractor is then responsible for power from the distribution panel.
 - 1. Coordinate panel locations with the design team. The final acceptance of the location is to be reviewed by Cal Poly Representative. If enclosures for panels are shown on the electrical drawings, furnish the enclosures according to the electrician's installation schedule.
- B.** The Division 23 contractor shall not be responsible for power to control panels and control devices that are furnished by others unless it is part of the control interlock wiring. Power to control panels and control devices shall be provided by the Division 26 contractor. All routing of conduits and wiring shall be coordinated by Division 23 and the Division 26 contractor. Any rework required due to a lack of coordination by the Construction Manager/General Contractor shall be corrected at no cost to the owner.
- C.** Refer to the Coordination section for what devices this contractor is responsible to mount and which are turned over to others to mount.
- D.** This contractor shall be responsible for the wiring of any control device that is furnished as part of this section of the specification at no additional cost to the owner.
- E.** Interlock wiring shall be run in separate conduits from BAS-associated wiring.
- F.** Provide network wiring for equipment that is called to be integrated into the BAS. Network wiring shall be per Cal Poly Construction Standards Division 27 – Communications.

3.1.1.5 ELECTRICAL WIRING AND CONNECTION INSTALLATION

- A.** Installation shall be per Cal Poly Construction Standards Division 26 - Electrical and Division 27 – Communications. All low voltage control wiring shall be class 2. Control wiring that is not class 2 shall be run in separate conduits from class 2 wiring.
- B.** Floor-level network wiring between terminal units can be combined with thermostats and other low-voltage wiring in the same conduit. All other network wiring shall be in dedicated conduits and per Cal Poly Construction Standards Division 26 - Electrical and Division 27 – Communications.

- C.** Install raceways, boxes, and cabinets according to Division 26 Section "Raceways and Boxes and Cal Poly Construction Standards Division 26 - Electrical and Division 27 – Communications.
- D.** Install building wire and cable according to Division 26 Section "Conductors and Cables, and Cal Poly Construction Standards Division 26 - Electrical and Division 27 – Communications.
- E.** Installation shall meet the following requirements:
 - 1. Conceal cable and conduit, except in mechanical rooms and areas where other conduits and piping are exposed.
 - 2. Install exposed cable in the raceway or conduit.
 - 3. Install concealed cable using a plenum-rated cable.
 - 4. Bundle and harness multiconductor instrument cables in place of single cables where several cables follow a common path.
 - 5. Fasten flexible conductors, bridging cabinets and doors, along the hinge side; protect against abrasion. Tie and support conductors.
 - 6. Number-code or color-code conductors for future identification and service of the control system, except local individual room control cables.
 - 7. All wiring in lab areas shall be in conduit.
 - 8. All unsupported risers shall be rigid steel conduit. Supported risers shall be EMTs.
- F.** Rigid conduit shall be steel, hot dip galvanized, threaded with couplings, $\frac{3}{4}$ inch minimum size, manufactured in accordance with ANSI C-80-1. Electrical metallic tubing (EMT) with compression fittings or intermediate metallic conduit (IMC) may be used as a conduit or raceway where permitted by the NEC and per Cal Poly Construction Standards Division 26 – Electrical.
- G.** Concealed control conduit and wiring shall be provided in all spaces except in the Mechanical Equipment Rooms and unfinished spaces. Install in parallel banks with all changes in directions made at 90-degree angles and per Cal Poly Construction Standards Division 26 – Electrical.
- H.** Install conduit adjacent to the machine to allow service and maintenance per Cal Poly Construction Standards Division 26 - Electrical.
- I.** Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in the interlock circuit of power controllers.
- J.** Connect hand-off-auto selector switches to override automatic interlock controls when the switch is in hand position.
- K.** Ground equipment.

3.1.1.6 COMMUNICATION WIRING

- A.** All cabling shall be installed in a neat and workmanlike manner. Follow the manufacturer's installation recommendations for all communication cabling and Cal Poly Construction Standards Division 27 – Communications.
- B.** Do not install communication wiring in the raceway and enclosures containing Class 1 wiring.
- C.** Maximum pulling, tension, and bend radius for cable installation, as specified by the cable manufacturer, shall not be exceeded during installation.
- D.** The contractor shall verify the integrity of the entire network following the cable installation. Use appropriate test measures for each particular cable.
- E.** Cable bundling:
 - 1. Per Cal Poly Construction Standards Division 27 – Communications.
 - 2. RS485 cabling run open-air inaccessible areas and can be bundled with other class 2 low-voltage cabling if approved by the Campus ITS department.
 - 3. RS485 cabling run between terminal units in conduits above ceilings or under floors or in inaccessible areas can be bundled with other class 2 low voltage cabling.
 - 4. RS485 cabling run between floors shall be in a communication-only conduit.
 - 5. RS485 conduit runs long distances between utility rooms or between buildings shall be in a communication-only conduit.
 - 6. Ethernet cabling shall be in a communication-only conduit.
 - 7. Ethernet and RS485 can be run together.
 - 8. Fiber optics can be run with Ethernet and RS485 cabling as long as the conduit is bent to fiber optic standards and junction boxes are sized for fiber optic use.
- F.** RS485 Cabling
 - 1. Per Cal Poly Construction Standards Division 27 – Communications.
 - 2. RS485 cabling shall be used for BACnet MS/TP networks.
 - 3. RS485 shall use low capacitance, 20-24 gauge, twisted shielded pair.
 - 4. The shields shall be tied together at each device.
 - 5. The shield shall be grounded at one end only and capped at the other end.
 - 6. Provide end-of-line (EOL) termination devices at each end of the RS485 network or subnetwork run, to match the impedance of the cable, 100 to 120ohm.
- G.** Ethernet Cabling
 - 1. Per Cal Poly Construction Standards Division 27 – Communications.
 - 2. Ethernet shall not be run with any Class 1 or low voltage Class 2 wiring.
 - 3. CAT6, unshielded twisted pair (UTP) cable shall be used for BAS Ethernet.

4. Solid wire shall be used for long runs, between mechanical rooms and between floors. Stranded cables can be used for patch cables and between panels in the same mechanical room up to 50 feet away.
5. When the BAS Ethernet connects to an Owner's network switch, document the port number on the BAS As-builts.

H. Fiber-Optic Cabling

1. Per Cal Poly Construction Standards Division 27 – Communications.
2. Maximum pulling tensions as specified by the cable manufacturer shall not be exceeded during installation. Post-installation residual cable tension shall be within the cable manufacturer's specifications.
3. All cabling and associated components shall be installed in accordance with the manufacturers' instructions. Minimum cable and unjacketed fiber bend radii, as specified by the cable manufacturer, shall be maintained.
4. All terminations shall be made into a patch panel, designed for such use. Free air terminations with patch panels are prohibited.

- I.** When a cable enters or exits a building, a lightning arrestor must be installed between the lines and the ground, and per Cal Poly Construction Standards Division 26 - Electrical. The lightning arrestor shall be installed according to the manufacturer's instructions and Cal Poly Construction Standards Division 26 - Electrical.

- J.** All runs of communication wiring shall be unspliced length when that length is commercially available.

- K.** All communication wiring shall be labeled to indicate origination and destination data per Cal Poly Construction Standards Division 27 – Communications.

- L.** Grounding of the coaxial cable shall be in accordance with NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

3.1.1.7 IDENTIFICATION

- A.** Permanent warning labels shall be affixed to all equipment that can be automatically started by the DDC system.

1. Labels shall use white lettering (12-point type or larger) on a red background.
2. Warning labels shall read as follows: C A U T I O N This equipment is operating under automatic control and may start or stop at any time without warning. Switch disconnect to the "Off" position before servicing.

- B.** Permanent warning labels shall be affixed to all motor starters and all control panels that are connected to multiple power sources utilizing separate disconnects.

1. Labels shall use white lettering (12-point type or larger) on a red background.

2. Warning labels shall read as follows: **C A U T I O N** This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing.
- C. Control Equipment and Device labeling:**
1. Labels and tags shall match the unique identifiers shown on the as-built drawings.
 2. All Enclosures shall be labeled to match the as-built drawing by either the control panel name or the names of the DDC controllers inside.
 3. All sensors and actuators not in occupied areas shall be tagged.
 4. Airflow measurement arrays shall be tagged to show the flow rate range for a signal output range, duct size, and pitot tube AFMS flow coefficient.
 5. Duct static pressure taps shall be tagged at the location of the pressure tap.
 6. Each device inside enclosures shall be tagged.
 7. Terminal equipment needs only to have a tag for the unique terminal number, not for each device. Match the unique number on:
 - a. First, the design drawings, or
 - b. Second, the control as-builts, or
 - c. Third, the DDC addressing scheme
 8. Tags on the terminal units shall be displayed on the Operator Workstation Graphics.
- D.** Tags shall be mechanically printed on permanent adhesive-backed labeling strips, 12-point height minimum.
- E.** Manufacturers' nameplates and UL or CSA labels are to be visible and legible after the equipment is installed.
- F. Identification of Wires**
1. Per Cal Poly Construction Standards Division 26 - Electrical and Division 27 – Communications.
 2. Tag each wire with a common identifier on each end of the wire, such as in the control panel and at the device termination.
 3. Tag each network wire with a common identifier on each end.
 4. Tag each 120V power source with the panel and breaker number it is fed by.
- G. Identification of Conduits:**
1. Per Cal Poly Construction Standards Division 26 - Electrical and Division 27 – Communications.
 2. Identify the low voltage conduit runs as BAS conduit, power feeds are not included.
 3. Identify each electric box, junction box, utility box, and wiring tray with a blue paint mark or blue permanent adhesive sticker.
 4. For conduit runs that run more than 8 ft between junction boxes in 1 room, place a blue identifier at least every 8 feet.

5. Place a blue identifier on each side of where a conduit passed through a wall or other inaccessible path.
6. Identify all BAS communication conduits the same as above.

3.1.1.8 FIELD QUALITY CONTROL

- A.** Manufacturer's Field Service: Engage a factory-authorized service representative to inspect field-assembled components and equipment installation, including piping and electrical connections. Report results in writing.
 1. Operational Test: After electrical circuitry has been energized, start units to confirm the proper unit operation. Remove malfunctioning units, replace them with new units, and retest.
 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment, and retest.
 3. Calibration test controllers by disconnecting input sensors and stimulating operation with a compatible signal generator.
- B.** Engage a factory-authorized service representative to perform startup service.
- C.** Replace damaged or malfunctioning controls and equipment.
 1. Start, test, and adjust control systems.
 2. Demonstrate compliance with requirements, including calibration and testing, and control sequences.
 3. Adjust, calibrate, and fine-tune circuits and equipment to achieve the sequence of operation specified.

3.1.1.9 SYSTEM CHECKOUT AND STARTUP

- A.** Inspect each termination in the MER control panels and devices to make sure all wires are connected according to the wiring diagrams and all terminations are tight.
- B.** After the controls devices and panels are installed and power is available to the controls, perform a static checkout of all the points, including the following:
 1. Inspect the setup and reading on each temperature sensor against a thermometer to verify its accuracy.
 2. Inspect the setup and reading on each humidity sensor against a hygrometer to verify its accuracy.
 3. Inspect the reading on each CO2 sensor using a calibration kit to verify the sensor range accuracy matches the DDC setup.
 4. Inspect the reading of each status switch to verify the DDC reads the open and close correctly.
 5. Command each relay to open and close to verify its operation.
 6. Command each 2-position damper actuator to open and close to verify operation.

7. Command each 2-position valve to open and close to verify operation.
 8. Ramp each modulating actuator to 0%, 25%, 50%, 75%, and 100% to verify its operation.
 9. Ramp each modulating output signal, such as a VFD speed, to verify its operation.
 10. Test each safety device with a real-life simulation, for instance, check low-temperature detectors with ice water, water detectors with water, etc.
- C.** Document that each point was verified and operating correctly. Correct each failed point before proceeding to the dynamic startup.
- D.** Verify that each DDC controller communicates on its respective network correctly.
- E.** After all of the points are verified, and power is available to the mechanical system, coordinate a startup of each system with the mechanical contractor. Include the following tests:
1. Start systems from DDC.
 2. Verify that each setpoint can be met by the system.
 3. Change setpoints and verify system response.
 4. Change sensor readings to verify system response.
 5. Test safety shutdowns.
 6. Verify time delays.
 7. Verify mode changes.
 8. Adjust filter switches and current switches for proper reactions.
 9. Adjust proportional bands and integration times to stabilize control loops.
- F.** Perform all program changes and debugging of the system for a fully operational system.
- G.** Verify that all graphics at the operator workstations correspond to the systems as installed. Verify that the points on the screens appear and react properly. Verify that all adjustable setpoints and manual commands operate from the operator workstations.
- H.** After the sequence of operations is verified, set up the trends that are listed in the sequence of operations for logging and archiving for the commissioning procedure.

3.1.1.10 SYSTEM COMMISSIONING, DEMONSTRATION, AND TURNOVER

- A.** The BAS Contractor shall prepare and submit for approval a complete acceptance test procedure including submittal data relevant to point index, functions, sequence, interlocks, and associated parameters, and other pertinent information for the operating system. Prior to acceptance of the BAS by the Owner and Engineer, the BAS contractor shall completely test the BAS using the approved test procedure.

- B. Work with Commissioning Agent to provide all required commissioning services during the start-up and testing phase and the warranty phase of the building;
- C. Based on input from the commissioning agent, provide sequence adjustments as necessary to correct deficiencies found during testing and operation;
- D. Provide lap-top with required software licenses to the TAB subcontractor and Commissioning agent to enable review of controls during start-up and testing phases of the project
- E. After the BAS contractor has completed the tests and certified the BAS is 100% complete, the Engineer shall be requested, in writing, to approve the satisfactory operation of the system, sub-systems, and accessories. The BAS contractor shall submit Maintenance and Operating manuals at this time for approval. An acceptance test in the presence of the Engineer and Owner's representative shall be performed. The Owner will then shake down the system for a fixed period of time (30 days).
- F. The BAS contractor shall fix punch list items within 30 days of acceptance.
- G. When the system performance is deemed satisfactory in whole or in part by these observers, the system parts will be accepted for beneficial use and placed under warranty.
- H. Emergency Service: The University will initiate service calls when the system is not functioning properly. Qualified personnel must be available to provide service to the system. A telephone number where the service supervisor can be reached at all times must be provided. Service personnel must be at the site within 24 hours of receiving a service request. The control system must be restored to proper operating condition

3.1.1.11 TRAINING

NOTE: Training requirements should be coordinated with the relevant campus shop organization at the project site. The extent of training should be based on the needs of the installation personnel.

- A. During System commissioning and at such time as the acceptable performance of the Building Automation System hardware and software has been established, the BAS contractor shall provide on-site operator instruction to the owner's operating

personnel. Operator instruction during normal working hours shall be performed by a competent building automation contractor representative familiar with the Building Automation System's software, hardware, and accessories.

- B.** At a time mutually agreed upon, during System commissioning as stated above, the BAS contractor shall give 40 hours of onsite training on the operation of all BAS equipment. The contractor shall make audio and visual recordings of the training sessions for later use. Provide audiovisual equipment and other training materials and supplies required to conduct training. A training day is defined as 8 hours of classroom instruction, including two 15-minute breaks and excluding lunchtime, Monday through Friday, during the daytime shift in effect at the training facility. Describe its intended use for the programmed functions specified. Operator orientation of the automation system shall include, but not be limited to:
 - 1. Explanation of drawings and operator's maintenance manuals.
 - 2. Walk-through of the job to locate all control components.
 - 3. Operator workstation and peripherals.
 - 4. DDC Controller and ASC operation/sequence.
 - 5. Operator control functions including scheduling, alarming, and trending.
 - 6. Explanation of adjustment, calibration, and replacement procedures.
- C.** Additional 8 hours of training shall be given after the 30-day shakedown period.
- D.** Since the Owner may require personnel to have a more comprehensive understanding of the hardware and software, additional training must be available from the Contractor. If the Owner requires such training, it will be contracted at a later date. Describe available local and factory customer training. Provide costs associated with performing training at an off-site classroom facility and detail what is included in the manufacturer's standard pricing such as transportation, meals, etc.

3.1.1.12 TRAINING DOCUMENTATION

Prepare training documentation consisting of:

- A.** Course Attendee List: Develop the list, of course attendees in coordination with and signed by the Controls, HVAC, and Electrical shop supervisor.
- B.** When the system performance is deemed satisfactory in whole or in part by these observers, the system parts will be accepted for beneficial use and placed under warranty.
- C.** Training Manuals: Provide training manuals that include an agenda, defined objectives for each lesson, and a detailed description of the subject matter for each lesson. When

presenting portions of the course material by audiovisuals, deliver copies of those audiovisuals as a part of the printed training manuals.

3.11.2 Training Course Content

For guidance in planning the required instruction, assume that attendees are familiar with HVAC systems. During the training course, cover all of the material contained in the Operating and Maintenance Instructions, the layout and location of each controller enclosure, the layout of one of each type of equipment and the locations of each, the location of each control device external to the panels, the location of the compressed air station, preventive maintenance, troubleshooting, diagnostics, calibration, adjustment, commissioning, tuning, and repair procedures. Typical systems and similar systems may be treated as a group, with instruction on the physical layout of one such system. Present the results of the performance verification test and the Start-Up Testing Report as benchmarks of the HVAC control system performance by which to measure operation and maintenance effectiveness.

3.11.3 Training Documentation Submittal Requirements

Submit hardcopy training manuals and all training materials on CD-ROM. Provide one hardcopy manual for each trainee on the Course Attendee List and 2 additional copies for the archive at the project site. Provide 2 copies of the Course Attendee List with the archival copies. service training Documentation may be submitted as a Technical Data Package.

Points List

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