Specify factory controlled equipment in other sections to include BACnet protocol connections for interfacing with the BAS.

Note in mechanical terminal unit section: Use of “plunger” type VAV boxes is prohibited.

PART I. GENERAL

1.01 SECTION INCLUDES
A. General Requirements
B. Description of Work
C. Quality Assurance
D. System Architecture
E. Distributed Processing Units/Quantity and Location
F. Demolition and Reuse of Existing Materials and Equipment
G. Sequence of Work

1.02 RELATED DOCUMENTS
A. Section “Basic Mechanical Requirements.”
B. Section “BAS Basic Materials and Devices”
C. Section “BAS Field Panels”
D. Section “BAS Communication Devices.”
E. Section “BAS Software and Programming”
F. Section “BAS Sequence of Operation”
G. Section “BAS Commissioning”

1.03 DESCRIPTION OF WORK
A. Contractor shall furnish and install a distributed digital control (DDC) system to replace portions of the existing pneumatic BAS system and Energy Monitoring and Control System (BAS). The new BAS shall utilize electronic sensing, microprocessor based digital control, and electronic and pneumatic actuation of dampers and valves to perform control sequences and functions specified. The BAS for this project will generally consist of monitoring and control of air handling systems, pumps and other miscellaneous equipment. Refer to control drawings, sequences of operation, and points lists.

B. The Contractor shall assist the Owner and Engineer as needed for LEED credit qualification including utility metering trends, IAQ and OA delivery monitoring.

The following paragraph only applies to add-on or partial renovation work in buildings with an existing BAS.
C. The proposed system must be entirely compatible with the existing building BAS. No system, even if supplied by the same manufacturer, may be installed as sole source if gateways or other means are required to interface with the existing system. In the exclusion of sole source, the project will be open bid to vendors with similar interface capabilities.

1.04 QUALITY ASSURANCE

A. Manufacturer's Qualifications: Firms regularly engaged in manufacture of pneumatic, electric, and direct digital control equipment, of types and sizes required, and whose products have been in satisfactory use in similar service for not less than 10 years.

B. Installer's Qualifications: Firms specializing and experienced in control system installations for not less than 5 years. Firms with experience in DDC installation projects with point counts equal to this project. If installer is a Value Added Reseller (VAR) of a manufacturers product, installer must demonstrate at least 3 years prior experience with the manufacturer products.

C. BAS System Qualifications: System shall be based on Manufacturer's standard integrated hardware and software product offering, which has been installed and fully operational in similar service for not less than 2 years.

A. Installer's Field Coordinator and Sequence Programmer Qualifications: Individual(s) shall specialize in and be experienced with control system installation for not less than 3 years. Proposed field coordinator shall have experience with the installation of the proposed product line for not less than 2 projects of similar size and complexity. Installer shall submit the names of the proposed individual and at least one alternate for each duty. Submittals shall document this experience with references. The proposed individuals must show proof of the following training:

1. Product Line Training: Individuals overseeing the installation and configuration of the proposed product line must provide evidence of the most advanced training offered by the Manufacturer on that product line for installation and configuration.

2. Programming Training: Individuals involved with programming the site-specific sequences shall provide evidence of the most advanced programming training offered by the vendor of the programming application offered by the Manufacturer.

B. Installer’s Service Qualifications: The installer must be experienced in control system operation, maintenance and service. Installer must document a minimum 5 year history of servicing installations of similar size and complexity. Installer must also document at least a 2 year history of servicing the proposed product line.

C. Codes and Standards:

1. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)
   a) ASHRAE 135-2001: BACnet - Building Automation and Control Networking Protocol

2. Underwriters Laboratories
   a) UL 916: Energy management Systems.
   b) UL 864 UUKL Supervised Smoke Control

3. NEMA Compliance:
a) NEMA 250 Enclosure for Electrical Equipment  
b) NEMA ICS 1: General Standards for Industrial Controls.

4. NFPA Compliance:
   a) NFPA 90A "Standard for the Installation of Air Conditioning and Ventilating Systems" where applicable to controls and control sequences.
   b) NFPA 70 National Electrical Code (NEC)

5. Institute of Electrical and Electronics Engineers (IEEE)
   a) IEEE 142 Recommended Practice for Grounding of Industrial and Commercial Power Systems

6. Electronics Industries Associations
   b) EIA-232 Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange.

1.05 DEFINITIONS

A. **Advanced Application Controller (AAC):** A device with limited resources relative to the Building Controller (BC). It may support a level of programming and may also be intended for application specific applications.

B. **Application Specific Controller (ASC):** A device with limited resources relative to the Advanced Application Controller (AAC). It may support a level of programming and may also be intended for application-specific applications.

C. **Building Automation System (BAS):** The entire integrated management and control system.

D. **Building Controller (BC):** A fully programmable device capable of carrying out a number of tasks including control and monitoring via direct digital control (DDC) of specific systems, acting as a communications router between the LAN backbone and sub-LANs, and data storage for trend information, time schedules, and alarm data.

E. **Controller or Control Unit (CU):** Intelligent stand-alone control panel. Controller is a generic reference and shall include BCs, AACs, and ASCs as appropriate.

F. **Control Systems Server (CSS):** This shall be a computer (or computers) that maintains the systems configuration, historical trend data and programming database.

G. **Gateway:** A device, which contains two or more dissimilar networks/protocols, permitting information exchange between them (ASHRAE/ANSI 135).

H. **Local Area Network (LAN):** General term for a network segment within the architecture. Various types and functions of LANs are defined herein.

I. **Master-Slave/Token Passing (MS/TP):** Data link protocol as defined by the BACnet standard. (ASHRAE/ANSI 135).

J. **Operator Interface (OI):** A device used by the operator to manage the BAS including operator workstations, portable operator terminals and hand held devices.
1.06 FUNCTIONAL INTENT

A. Throughout these Division 25 Sections, detailed requirements are specified, some of which indicate a means, method or configuration acceptable to meet that requirement.

B. Contractor may submit products that utilize alternate means, methods, and configurations that meet the functional intent. However these will only be allowed with prior approval. Therefore, Contractor shall submit an Exception List with bid.

C. Exception List: Contractor shall submit a listing of all items for which the Contractor cannot explicitly conform to a requirement of this specification. Listing shall be indexed to match the structure of these specifications. List shall include the section, part, item, and subparagraph number, the specification requirement to which the exception is taken, and a description of the alternate method of meeting the functional intent. The exception list shall be submitted with the bid.

D. Contractor shall meet all requirements as specified that are not indicated on the approved Exception List.

1.07 SUBMITTALS

A. Submit under provisions of Division 01.

B. Exception List: as specified above.

C. Electronic Submittals: Control submittals and O&M information shall be provided as one hard copy and electronically in Adobe PDF format. Control drawings shall be electronically provided in Adobe PDF in a size no less than 11"x17". Documents will be converted from their native electronic format directly to Adobe PDF format. Any text documents scanned as images must be converted to a searchable text format using OCR (Optical Character Recognition) and reduced in size prior to submission.

D. Qualifications: Manufacturer, Installer, and Key personnel qualifications as described in Quality Assurance paragraph above.

E. Product Data: Submit manufacturer's technical product data for each control device, panel, and accessory furnished, indicating dimensions, capacities, performance and electrical characteristics, and material finishes. Also include installation and start-up instructions.

F. Shop Drawings: Submit shop drawings for each control system. Submit a completed drawing for each air handling unit, system, pump, device, etc. with all point descriptors, addresses and point names indicated. Shop drawings shall be submitted both on paper and electronic media. Each shop drawing shall contain the following information:

1. System architecture one-line diagram indicating schematic location of all control units, workstations, gateways, etc. Indicate address and type for each control unit. Indicate protocol and type of each LAN. The entire schematic shall be updated, maintained and submitted with each project.

2. Schematic flow diagram of each air and water system showing fans, coils, dampers, valves, pumps, heat exchange equipment and control devices. Include verbal description of sequence of operation. Where applicable indicate equipment and devices operating via factory controller and details of BAS interface to factory controller.

3. All physical points shall be indicated with names, descriptors, and point addresses identified.
4. With each schematic, provide a detailed points list on the drawings with all physical and virtual points included and functionally grouped. Include names, descriptors, addresses and point types with applicable range as a minimum.

5. Label each control device with setting or adjustable range of control.

6. Label each input and output with the appropriate range.

7. Provide a Bill of Materials with each schematic. Indicate device identification to match schematic and actual field labeling, quantity, actual product ordering number, manufacturer, description, size, voltage range, pressure range, temperature range, etc. as applicable.

8. Provide a Control Valve Schedule listing valve and actuator information including: size, Cv, design flow, design pressure drop, manufacturer, model number, close off rating, control signal, etc. Indicate normal positions of valves with fail positions.

9. Provide a Control Damper Schedule listing damper and actuator information including: size, material, blade arrangement, manufacturer, model number, control signal, close off rating, etc. Indicate normal positions of automatic return dampers.

10. Provide an Air Flow Monitoring Station Schedule listing the following information: size, manufacturer, model number, control signal, CFM range, etc.

11. Indicate all required electrical wiring. Electrical wiring diagrams shall include both ladder logic type diagram for motor starter, control, and safety circuits and detailed digital interface panel point termination diagrams with all wire numbers and terminal block numbers identified. Provide panel termination drawings on separate drawings. Ladder diagrams shall appear on system schematic. Clearly differentiate between portions of wiring that are existing, factory-installed and portions to be field-installed.

12. Provide details of control panels, including controls, instruments, and labeling shown in plan or elevation indicating the installed locations and allocated service clearances.

13. Points list including all physical I/O and virtual points. Points list shall be provided in electronic format (Quote and Comma Delimited, ACCESS data table, or EXCEL spreadsheet formats are acceptable formats)

14. Sheets shall be consecutively numbered.

15. Each sheet shall have a title indicating the type of information included and the HVAC system controlled.

16. Table of Contents listing sheet titles and sheet numbers.

17. Legend and list of abbreviations.

G. Laminated Control Drawings: Provide laminated control drawings within each control panel for the CUs and devices controlled from that panel. System control schematics shall be mounted adjacent to key pieces of equipment for that system. Panel termination drawings shall be mounted in or adjacent to respective panels.

Include the following Control Logic Documentation requirement when a 3rd party CxA or the University Controls Engineer has this within their scope to review. Coordinate with AU PM and AU BAS department.

H. Control Logic Documentation:
1. Submit control logic graphical flow diagrams (for block type programs) or program listings and logic flow charts (for line type programs) to document the control software of all control units.

2. Control logic shall be annotated to describe how it accomplishes the sequence of operation. Annotations shall be sufficient to allow an operator to relate each program component (block or line) to corresponding portions of the specified Sequence of Operation. Logic flow charts for line type programs shall graphically show the logic flow of each application program.

3. Include written description of each control sequence.

4. Include control response, settings, setpoints, throttling ranges, gains, reset schedules, adjustable parameters and limits.

5. Sheets shall be consecutively numbered.

6. Each sheet shall have a title indicating the controller designations and the HVAC system controlled.

7. Include Table of Contents listing sheet titles and sheet numbers.

8. For block type programs, any two interconnected blocks that are shown on one sheet shall be shown with an interconnecting line, with limited use of references. Any two interconnected blocks that are shown on separate sheets shall include references to the connected block and the sheet number where the connected block is located. For line type programs, any program that calls a subroutine located on a separate sheet shall reference the line number where the subroutine is located.

9. Submit one complete set of programming and operating manuals for all digital controllers concurrently with control logic documentation. This set will count toward the required number of Operation and Maintenance materials.

I. BAS Start-Up Test Report:
1. Submit Agenda, which shall consist of all required test sheets and checklists as required for the Pre-commissioning Test Report as specified in Section “BAS Commissioning”.

2. Submit Final Test Report documenting that the BAS has been fully tested, adjusted and calibrated and is ready for demonstration and commissioning. Report shall include, but shall not be limited to, completed test sheets and checklists. Required details of the report shall be as specified in Section “BAS Commissioning”.

J. Operation and Maintenance Materials:
1. Submit documents electronically under provisions of Division 01.

2. Submit maintenance instructions and spare parts lists for each type of control device, control unit, and accessory.

3. Include all submittals (product data, shop drawings, control logic documentation, hardware manuals, software manuals, installation guides or manuals, maintenance instructions and spare parts lists) in maintenance manual; in accordance with requirements of Division 01.

K. Manufacturers Certificates: For all listed and/or labeled products, provide certificate of conformance.
L. Product Warrante Certificate: submit manufacturers product warrantee certificates covering the hardware provided.

1.08 PROJECT RECORD DOCUMENTS
A. Submit documents under provisions of Division 01.
B. Electronic copies of product data and control shop drawings updated to reflect the final installed condition.
C. Record copies of approved control logic programming and database will be provided to the AU BAS Supervisor. Accurately record actual setpoints and settings of controls, all BACnet objects and their properties, and actual sequence of operation, including changes to programs made after submission and approval of shop drawings and including changes to programs made during specified testing.
D. Record copies of approved project specific graphic software stored with CSS backup.
E. Maintain project record documents throughout the warrantee period and submit final documents at the end of the warrantee period.

1.09 SYSTEM ARCHITECTURE
A. The system provided shall incorporate hardware resources sufficient to meet the functional requirements of these Specifications. The Contractor shall include all items not specifically itemized in these Specifications that are necessary to implement, maintain, and operate the system in compliance with the functional intent of these Specifications.
B. The system shall be configured as a distributed processing network(s) capable of expansion as specified below.

*As part of the AU BAS Master Plan the BAS server is moving to a virtual machine and a VLAN is being established for all BAS network traffic. Coordinate updates to the section below with AU BAS and OIT.*

C. The system architecture shall consist of a single Local Area Network (LAN) or multi-leveled LANs all which support control units (CUs), both local and remote operator interfaces (OIs), and gateways. The following indicates a functional description of the system structure.

1. Campus Ethernet: University network generally used for supervision, and communication between primary controlling LANs. Coordinate with University for assignment of required IP addresses. Contractor may not extend this network without prior approval from the University.
2. Primary Controller LAN: High-speed peer-peer LAN generally used to connect Building Controllers (BCs) and Gateways/Routers. Acceptable technologies include: Ethernet (IEEE802.3)
3. Secondary Controller LAN: polling or peer-peer LAN to support connection of ASCs, AACs and terminal network devices. Acceptable technologies include: Arcnet (IEEE8802.4), Ethernet (IEEE802.3), and MS/TP.
D. Dynamic Data Access: Any data throughout any level of the network shall be available to and accessible by all other devices, CUs, Gateways, and OIs, whether directly connected or connected remotely.
E. Remote Data Access: Coordinate remote access connectivity with the University. The system shall support the following methods of remote access to the building data.

1. Browser-based access: A remote user using a standard browser shall be able access all control system facilities and graphics with a proper username and password. The following paradigms are acceptable for browser-based access:
   a) Native Internet-based user interfaces (HTML, Java, XML, etc.) that do not require a plug-in. The user interface must be compatible with the most current stable version of the supporting software (Java, etc.) without requiring the user to downgrade to a lesser version.
   b) Terminal emulation software that works across the Internet and requires licensing and an installed program on the remote machine. Licenses shall be provided for at least 10 simultaneous remote connections. Contractor shall configure and test all 10 machines as requested by the University.

The below paragraph regarding communications speed shall apply at the discretion of the AU BAS Supervisor.

F. The communication speed between the CUs, Gateways, and operator interface devices shall be sufficient to ensure fast system response time under any loading condition. In no case shall delay times between an event, request, or command initiation and its completion be greater than the following. Contractor shall reconfigure LAN as necessary to accomplish these performance requirements.

1. 5 seconds between a Level 1 (critical) alarm occurrence and enunciation at operator workstation
2. 10 seconds between a Level 2 alarm occurrence and enunciation at operator workstation
3. 20 seconds between and a Level 3-5 alarm occurrence and enunciation at operator workstation
4. 10 seconds between an operator command via the operator interface to change a setpoint and the subsequent change in the controlling CU
5. 5 seconds between an operator command via the operator interface to start/stop a device and the subsequent command to be received at the controlling CU
6. 10 seconds between a change of value or state of an input and it being updated on the operator interface
7. 10 seconds between an operator selection of a graphic and it completely painting the screen and updating at least 10 points

G. The operator interface shall provide for overall system supervision, operator interface, management report generation, alarm annunciation, remote monitoring and back up and loading of software and data to be stored in control unit volatile memory.

H. The BCs, AACs, and ASCs shall monitor, control, and provide the field interface for all points specified. Each BC, AAC, or ASC shall be capable of performing all specified energy management functions, and all DDC functions, independent of other BCs, AACs, or ASCs. Operator interface devices as more fully specified in Section “BAS Field Panels”.

I. Interruptions or fault at any point on any Primary Controller LAN shall not interrupt communications between other nodes on the network. If a LAN is severed, separate
networks shall be formed and communications within each network shall continue uninterrupted.

J. All line drivers, signal boosters, and signal conditioners etc. shall be provided as necessary for proper data communication.

1.10 WARRANTY MAINTENANCE

A. Contractor shall warrant all products and labor for a period of 18 months after Final Acceptance. Make warranty period 24 months on “critical” (i.e. research buildings) projects with complicated (or new to AU) systems. Coordinate with AU PM.

B. At no cost to the Owner, during the warranty period, the Contractor shall provide maintenance services for software and hardware components as specified below:

1. Maintenance services shall be provided for all devices and hardware specified in Division 25 Sections. Service all equipment per the manufacturer’s recommendations. All devices shall be calibrated within the last month of the warrantee period.

2. Emergency Service: Any malfunction, failure, or defect in any hardware component or failure of any control programming that would result in property damage or loss of comfort control shall be corrected and repaired following telephonic notification by the Owner to the Contractor.
   a) Response to any request for service shall be provided within two (2) hours of the Owner's initial telephone request for service.
   b) In the event that the malfunction, failure, or defect is not corrected through the telephonic communication, at least one (1) hardware and software technician, trained in the system to be serviced, shall be dispatched to the Owner's site within eight (8) hours of the Owner's initial telephone request for such services, as specified.

3. Normal Service: Any malfunction, failure, or defect in any hardware component or failure of any control programming that would not result in property damage or loss of comfort control shall be corrected and repaired following telephonic notification by the Owner to the Contractor.
   a) Response to any request for service shall be provided within eight (8) working hours (contractor specified 40 hr per week normal working period) of the Owner's initial telephone request for service.
   b) In the event that the malfunction, failure, or defect is not corrected through the telephonic communication, at least one (1) hardware and software technician, trained in the system to be serviced, shall be dispatched to the Owner's site within three (3) working days of the Owner's initial telephone request for such services, as specified.

4. Owners Request for Service: Contractor shall specify a maximum of three telephone numbers and email addresses for the Owner to use in the event of a need for service. The AU BAS department will be the Owner’s authorized representative for all service requests.

5. Technical Support: Contractor shall provide remote technical support throughout the warrantee period.

6. Preventive maintenance shall be provided throughout the warrantee period in accordance with the hardware component manufacturer's requirements.
1.11 DELIVERY, STORAGE, AND HANDLING
   A. Provide factory shipping cartons for each piece of equipment and control device. Maintain cartons during shipping, storage and handling as required to prevent equipment damage, and to eliminate dirt and moisture from equipment. Store equipment and materials inside and protect from weather.

1.12 LISTING AND LABELING
   A. The BAS and components shall be listed by Underwriters Laboratories (UL 916) as an Energy Management System.  
      Include the following only when required by code:
   B. The BAS shall be listed by Underwriters Laboratories (864) UUKL for supervised smoke control

PART II. PRODUCTS

2.01 MATERIALS AND EQUIPMENT
   A. Materials shall be new, the best of their respective kinds without imperfections or blemishes and shall not be damaged in any way. Used equipment shall not used in any way for the permanent installation except where drawings or specs specifically allow existing materials to remain in place.

2.02 UNIFORMITY
   A. To the extent practical, all equipment of the same type serving the same function shall be identical and from the same manufacturer
PART III.  EXECUTION

3.01 INSPECTION
   A. Examine areas and conditions under which control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3.02 INSTALLATION OF CONTROL SYSTEMS
   A. General: Install systems and materials in accordance with manufacturer's instructions, roughing-in drawings and details shown on drawings.
   B. Refer to additional requirements in other sections of this specification.

3.03 CU QUANTITY AND LOCATION
   A. Each control panel shall consist of one or multiple CUs to meet requirements of this specification.
   B. Contractor shall provide at least one (1) CU, and additional CUs as required, in sufficient quantity to meet the requirements of this Specification. Restrictions in applying CUs are specified in Section “BAS Field Panels”. This contractor shall extend power to the control panel from an acceptable power panel. If the control contractor wishes to further distribute panels to other locations, control contractor is responsible for extending power to that location. Furthermore, contractor is responsible for ensuring adequate locations for the panels that do not interfere with other requirements of the project and maintain adequate clearance for maintenance access.
   C. Each Application Category 2 or higher CU shall be installed with 20% spare points for each point type provided with the CU. Example: Design calls for 10 binary outputs, module shall be provided with 12 binary outputs.
   D. Stand Alone Functionality: Provide CUs so that all points associated with and common to one air handling unit or other complete stand-alone system/equipment shall reside within a single control unit. See related restriction in Section “BAS Field Panels”. When referring to the CU as pertains to the standalone functionality, reference is specifically made to the processor. One processor shall execute all the related functions. I/O point expander boards may be added to expand the point capacity of the CU. Where any I/O point expansion devices are connected to the main controller board via communication, that communication sub LAN shall be dedicated to that controller and include no other devices including secondary controllers.
   E. Contractor shall locate control panels as referenced. It is the Contractor's responsibility to provide enough CUs to ensure a completely functioning system, according to the point list and sequence of operations.
   F. Contractor shall provide a minimum of the following:
      1. One control panel (including at least one BC) in the central mechanical room.
      2. One CU for each air handler located in applicable mechanical room.
      3. One CU shall be provided for each terminal unit unless indicated otherwise.
3.04 SURGE PROTECTION

A. The Contractor shall furnish and install any power supply surge protection, filters, etc. as necessary for proper operation and protection of all BCs, AAC/ASCs, operator interfaces, and other hardware and interface devices. All equipment shall be capable of handling voltage variations 10% above or below measured nominal value, with no affect on hardware, software, communications, and data storage.

3.05 DEMOLITION AND REUSE OF EXISTING MATERIALS AND EQUIPMENT

A. Contractor shall assume that existing equipment that is specifically indicated to be reused is in good condition and is operable. Contractor during the course of work, shall inspect these devices and determine if any devices are in need of replacement or repair. Contractor shall prepare an itemized list of suggested repairs/replacement. This repair/replacement will be at the discretion of the Owner and will be accomplished under separate contract.

B. Existing wire, conduit, and control panel cabinets may be reused at the contractors discretion, but only if such materials or equipment comply with the applicable specification for new materials and equipment. Such materials shall not be reused if visibly damaged or otherwise unsuitable for the intended service. Materials shall not be reused if visibly damaged or otherwise unsuitable for the intended service. The University does not guarantee the suitability of any such existing materials or equipment for reuse in accordance with the requirements for new materials and equipment.

C. Where such materials are reused, the contractor’s shop drawings shall reflect the existing wiring designation. If existing labeling is illegible or otherwise does not comply with the applicable specification for labeling, wiring runs shall be relabeled in accordance with the requirements specified elsewhere.

D. Existing MBC and SCU control modules that will be replaced as part of this project are to be turned over to AU BAS department. All other existing control devices and panels that will not be reused are to be removed from the site.

E. Existing electrical service to control panels or devices that will not be reused must be properly terminated and secured per NEC requirements. Label wire with the panel and circuit breaker it is served by. Label wire as “HOT” if circuit cannot be deenergized.

F. Existing pneumatic tubing located between the existing BAS panels and the pneumatic operators shall not be reused; however, conduit for such tubing may be reused. All other pneumatic tubing may be reused, but only if such materials comply with the applicable specification for new materials. Materials shall not be reused if visibly damaged or otherwise unsuitable for the intended service.

G. The existing pneumatic main air supply system shall be modified as required and reused to serve existing pneumatic controls that are to remain, and shall be extended as necessary to serve new pneumatic controls. Where existing pneumatic controls are removed, main air piping shall be removed back to the point of connection to the main air supply which remains in use, and shall be capped or plugged.

H. Existing valves and dampers and their operators shall be reused, except where noted to be removed or provided as new. If an existing valve or damper actuator is not serviceable the actuator will be replaced with an equivalent electronic model. If an electronic model is not available the entire assembly, valve and actuator must be replaced. Contractor shall lubricate all damper linkages of dampers being controlled under this project.
I. Other materials and equipment not specifically mentioned herein may be reused only if specifically allowed by indications on the drawings.

J. For HVAC systems which are indicated to receive a new BAS, all existing materials and equipment associated with the existing pneumatic system and BAS shall be removed unless otherwise specified or indicated to remain, or unless reused in accordance with the above requirements, except for the following: 1) conduit and electrical boxes (but not wiring within conduit) may remain in place if not reused; 2) inaccessible pneumatic tubing may remain in place if not reused. Existing materials and equipment to be removed shall be removed subject to the requirements in paragraph “Sequence of Work”. For systems that are not to receive new BAS, the existing system shall remain fully functional.

K. Where existing wall mounted devices are removed in finished spaces, comply with the requirements of Division 01.

L. Removed materials and equipment shall be subject to the requirements of Division 01.

M. For systems with existing workstation graphics, the existing graphic must be entirely removed from the system including all links and references and replaced with a new graphic meeting all requirements of these BAS Sections. If renovation is only partial, the entire system graphic must be replaced including devices and equipment that will be reused.

N. Existing system points shall be released. Partial system renovations shall not be split between old and new points. All points shall be created or recreated to meet the requirements of these BAS Sections.

3.06 SEQUENCE OF WORK

A. General: All work involving changeover of control functions from existing systems to the new BAS shall be performed in accordance with the following sequence in order to minimize the duration of equipment outages. The following descriptions are intended to indicate the sequence in which the work shall be performed, not to define fully the scope of the work.

B. Install construction server, operator’s terminal, peripherals, graphic software, and LAN prior to placing any equipment under the control of the new BAS.

C. Work which requires shutting down a pump motor, fan motor, or chiller shall be considered a utility shutdown and shall be subject to the restrictions specified in Division 01.

D. The following sequence applies to an individually controlled HVAC subsystem, such as an air handling unit. Only one such system shall be placed under manual control (as described below) at any given time.

1. Install CUs adjacent to (or within) existing control panel. Programming shall be complete (except for loading and debugging) prior to installation. Install all field devices which do not require interruption of the existing system.

2. Install all conduit, wiring, and pneumatic tubing which does not require interruption of the existing system.

3. Remove existing controls including wiring, conduit, and tubing (except materials to be reused in accordance with provisions specified elsewhere) which must be removed to facilitate installation of new BAS materials and equipment.
4. Remove existing digital points. Install and calibrate remainder of new BAS materials and equipment for this subsystem. Load CU software. Connect CU(s) to LAN.

5. Perform all field testing and calibration that does not require connection of permanent pneumatic outputs.

6. Notify the contracting officer prior to this step. Place the system under the control of the new BAS equipment. Conclude field testing and submit field testing report prior to placing the next subsystem under control. The owner shall be given a password with a priority level that allows monitoring (but not control until notification of substantial completion has been approved).

7. Remove remaining existing materials and equipment (except materials to be reused in accordance with provisions specified elsewhere). All existing equipment for those subsystems that have not yet been converted shall remain intact, on-line, and fully functional.

3.07 CONTROL POWER SOURCE AND SUPPLY

A. Division 25 Contractor shall extend all power source wiring required for operation of all equipment and devices provided under Division 25.

B. General requirements for obtaining power include the following:

1. To the extent practical obtain power from a dedicated circuit from the same source that feeds the equipment being controlled such that both the control component and the equipment are powered from the same panel. Where equipment is powered from a 460V source, obtain power from the electrically most proximate 120v source fed from a common origin, or provide a control transformer fed from the equipment’s panel.

2. Where control equipment is located inside a new equipment enclosure, coordinate with the equipment manufacturer and feed the control with the same source as the equipment. If the equipment’s control transformer is large enough and of the correct voltage to supply the controls, use it. If not either request a larger control transformer from the equipment manufacturer or provide separate transformer.

3. Regardless of power source, whenever the controlled equipment is scheduled to operate on emergency/standby power the BAS control panel and devices must be served by emergency/standby power.

3.08 SYSTEM COMMISSIONING AND ACCEPTANCE

A. Refer to Section “BAS Commissioning”.

3.09 SEQUENCE OF OPERATION

A. Refer to Section “BAS Sequence of Operation” and to Control Drawings
PART I. GENERAL

1.01 SECTION INCLUDES
   A. BAS and equipment testing and start-up.
   B. Validation of proper and thorough installation of BAS and equipment.
   C. Functional testing of control systems.
   D. Documentation of tests, procedures, and installations.
   E. Coordination of BAS training.
   F. Documentation of BAS Operation and Maintenance materials.

1.02 RELATED SECTIONS:
   A. Section “Basic Mechanical Requirements.”
   B. Section “Building Automation System (BAS) General.”
   C. Section “BAS Basic Materials and Devices.”
   D. Section “BAS Field Panels.”
   E. Section “BAS Communication Devices.”
   F. Section “BAS Software and Programming.”
   G. Section “BAS Sequence of Operations.”

1.03 GENERAL DESCRIPTION
   A. This section defines responsibilities of the BAS Contractor to facilitate the Commissioning process for the Building Automation System (BAS).
   B. Owner, at Owner's expense, shall retain a Commissioning Authority (CA) who shall work with the Contractor to ensure that the systems, equipment, and interfaces are installed, tested, and operate per the design intent; that the systems are adequately documented; and that the Owner is adequately trained on system intent, operation, and maintenance.

1.04 CONTRACTOR RESPONSIBILITIES
   A. Completely install and thoroughly inspect, startup, test, adjust, balance, and document all systems and equipment.
   B. Assist Commissioning Authority in verification and performance testing. Assistance will generally include the following:
      1. Attend Commissioning (Cx) progress and coordination meetings.
      2. Prepare and submit required draft forms and systems information.
      3. Establish trend logs of system operation as specified herein.
      4. Demonstrate system operation.
5. Manipulate systems and equipment to facilitate testing.
6. Provide instrumentation necessary for verification and performance testing.
7. Manipulate control systems to facilitate verification and performance testing.
8. Train Owners Representatives in both systems operation and control equipment use, operation, maintenance, and repair. Training shall be conducted as follows:
   a) Control system training shall be conducted by the Control Subcontractor. Control system training shall be as specified in Part 3 of this section.

C. Provide a Control technician to work at the direction of Commissioning Authority for software optimization assistance for a minimum of 80 hours for Scope 1 and 40 hours for Scope 2. Refer to Part 3 for a description of the software optimization.

D. **Compensation for Re-testing:** Compensate the University for site time necessitated by incompleteness of systems or equipment at time of functional performance testing. All testing failures which require on-site time for re-testing will be considered actual damages to the owner. The contract sum shall be reduced by contract modification at a rate of $160 per person-hour of on-site time necessary to retest failures. All parties under contract with the Owner who are affected by the re-testing shall be included in the contract modification.

**1.05 SEQUENCING:**

A. The following list outlines the general sequence of events for submittals and commissioning.
1. Submit Product data and Shop Drawings, and receive approval.
2. Submit Control Logic Documentation, and receive approval.
3. Submit Start Up checklists and manufacturers start up procedures for all equipment provided by the BAS contractor.
4. Install controls.
5. Submit BAS Start Up Test Agenda/schedule for review.
6. Receive BAS Start Up Test Agenda/schedule approval.
7. Submit Training Plan.
8. Simulate sequencing and debug program off-line to the extent practical.
9. Place systems under BAS control where applicable during a scheduled outage.
10. Perform BAS system start up where applicable during a scheduled outage.
11. Prepare and initiate Trend Log data storage and format trend graphs.
12. Submit completed BAS Start Up Reports and Initial draft of the O&M Manuals.
13. Receive BAS Start Up Report approval and approval to schedule Demonstrations and Commissioning.
14. Demonstrate systems to Commissioning Authority and Owner.
15. Submit trend logs in format specified.
16. Receive Demonstration approval and approval to schedule Acceptance Period.
17. Train Owner on control system operation and maintenance.
18. Substantial Completion.
20. Two week Operational Test.
22. Receive Acceptance Period approval, which is Functional Completion for the BAS.
23. Train Owner on final Sequences and modes of operation.
24. Install Framed Control Drawings.
25. Provide Level 1 password access to the University.
26. Revise and Re-Submit Record drawings and O&M manuals.
27. Final Acceptance.
29. Schedule and begin Opposite Season Acceptance Period.
30. Receive Opposite Season Acceptance Period approval.
31. Submit As-Built drawings and O&M manuals.
32. Update Framed Control Drawings.
33. Complete owner training.
34. End of Warranty Period.

PART II. PRODUCTS

2.01 INSTRUMENTATION
A. Instrumentation required to verify readings and test system and equipment performance shall be provided by Contractor and made available to Commissioning Authority. Generally, no testing equipment will be required beyond that required to perform Contractors work under these Contract Documents. All equipment used for testing and calibration shall be NIST/NBS traceable and calibrated within the preceding 12-month period. Certificates of calibration shall be submitted.

2.02 TAB & COMMISSIONING PORTABLE OPERATORS TERMINAL
A. For new projects, Contractor shall provide a portable operator’s terminal or hand held device to facilitate TAB and calibration. This device shall support all functions and allow querying and editing of all parameters required for proper calibration and start up.
B. Connections shall be provided local to the device being calibrated. For instance, for VAV boxes, connection of the operator’s terminal shall be either at the sensor or at the box.

PART III. EXECUTION

3.01 BAS START-UP TESTING, ADJUSTING, CALIBRATION
A. Work and/or systems installed under this Division shall be fully functioning prior to Demonstration and Acceptance Phase. Contractor shall start, test, adjust, and calibrate all work and/or systems under this Contract, as described below:
1. Inspect the installation of all devices. Review the manufacturer’s installation instructions and validate that the device is installed in accordance with them.
2. Verify proper electrical voltages and amperages, and verify that all circuits are free from faults.
3. Verify integrity/safety of all electrical connections.
4. For the following control settings, initially use the control setting that was used by existing control system, unless otherwise indicated. For AHUs that use a throttled outside air damper position when minimum outside air is required, contractor shall mark existing minimum outside air damper position to allow replication by new controls.

5. Coordinate with TAB subcontractor to obtain and with CA to fine tune control settings that are determined from balancing procedures. Record the following control settings as obtained from TAB contractor, and note any TAB deficiencies in the BAS Start-Up Report:
   a) Optimum duct static pressure setpoints for VAV air handling units.
   b) Minimum outside air damper settings for air handling units.
   c) Optimum differential pressure setpoints for variable speed pumping systems.
   d) Calibration parameters for flow control devices such as VAV boxes and flow measuring stations.
      1) BAS contractor shall provide hand held device as a minimum to the TAB and CA to facilitate calibration. Connection for any given device shall be local to it (i.e. at the VAV box or at the thermostat). Portable operator’s terminal shall allow querying and editing of parameters required for proper calibration and start up.

6. Test, calibrate, and set all digital and analog sensing and actuating devices. Calibrate each instrumentation device by making a comparison between the BAS display and the reading at the device, using an instrument traceable to the National Bureau of Standards, which shall be at least twice as accurate as the device to be calibrated (e.g., if field device is +/-0.5% accurate, test equipment shall be +/-0.25% accurate over same range). Record the measured value and displayed value for each device in the BAS Start Up Report.

7. Check and set zero and span adjustments for all transducers and transmitters.

8. For dampers and valves:
   a) Check for adequate installation including free travel throughout range and adequate seal.
   b) Where loops are sequenced, check for proper control without overlap.

9. For actuators:
   a) Check to insure that device seals tightly when the appropriate signal is applied to the operator.
   b) Check for appropriate fail position, and that the stroke and range is as required.
   c) For sequenced electronic actuators, calibrate per manufacturer’s instructions to required ranges.

10. Check each digital control point by making a comparison between the control command at the CU and the status of the controlled device. Check each digital input point by making a comparison of the state of the sensing device and the OI display. Record the results for each device in the BAS Start Up Report.

11. For outputs to reset other manufacturers devices (VFDs) and feedback from them, calibrate ranges to establish proper parameters. Coordinate with representative of the respective manufacturer and obtain their approval of the installation.
12. Verify proper sequences by using the approved checklists to record results and submit with BAS Start Up Report. Verify proper sequence and operation of all specified functions.

13. Verify that all safety devices trip at appropriate conditions. Adjust setpoints accordingly.

14. Tune all control loops to obtain the fastest stable response without hunting, offset or overshoot. Where auto-tuning software is used record the final operating parameters. Auto-tuning software shall not be allowed to continuously adjust parameters as this may lead to masking other device or system problems. Record tuning parameters and response test results for each control loop in the BAS Start Up Report. Except from a startup, maximum allowable variance from set point for controlled variables under normal load fluctuations shall be as follows. Within 3 minutes of any upset (for which the system has the capability to respond) in the control loop, tolerances shall be maintained (exceptions noted):
   a) Duct air temperature: ± 1°F.
   b) Space Temperature: ± 2°F.
   c) Chilled Water: ± 1°F.
   d) Hot water temperature: ± 3°F.
   e) Duct pressure: ± 0.25” w.g.
   f) Water pressure: ± 1 psid.
   g) Duct or space Humidity: ± 5%.
   h) Air flow control: ± 5% of setpoint velocity. For min OA flow loops being reset from CO₂, response to upset max time is one hour.
   i) Space Pressurization (on active control systems): ± 0.05” w.g. with no door or window movements.

15. For interface and DDC control panels:
   a) Ensure devices are properly installed with adequate clearance for maintenance and with clear labels in accordance with the record drawings.
   b) Ensure that terminations are safe, secure and labeled in accordance with the record drawings.
   c) Check power supplies for proper voltage ranges and loading. Test all BC uninterruptible power supplies.
   d) Ensure that wiring and tubing are run in a neat and skillful manner, either bound or enclosed in trough.
   e) Check for adequate signal strength on communication networks.
   f) Check for stand-alone performance of controllers by disconnecting the controller from the LAN. Verify the event is annunciated at OIs. Verify that the controlling LAN reconfigures as specified in the event of a LAN disconnection.
   g) Ensure that all outputs and devices fail to their proper positions/states.
   h) Ensure that buffered and/or volatile information is held through power outage.
   i) With all system and communications operating normally, sample and record update/annunciation times for critical alarms fed from the panel to the OI.
   j) Check for adequate grounding of all DDC panels and devices.
16. For Operator Interfaces:
   a) Verify that all elements on the graphics are functional and are properly bound to physical devices and/or virtual points, and that hot links or page jumps are functional and logical.
   b) Output all specified BAS reports for review and approval.
   c) Verify that the alarm logging is functional and per requirements.
   d) Verify that trend archiving to disk and provide a sample to the CA for review.
   e) Verify that alarm annunciation is functional.
   f) Verify the functionality of remote OIs and that a robust connection can be established consistently.
   g) Verify that required third party software applications required with the bid are installed and are functional.

17. Verify proper interface with fire alarm system.

B. Submit Start Up Test Report. Report shall be completed, submitted, and approved prior to Substantial Completion.

3.02 SENSOR CHECKOUT AND CALIBRATION

A. General Checkout: Verify that all sensor locations are appropriate and are away from causes of erratic operation. Verify that sensors with shielded cable are grounded only at one end. For sensor pairs that are used to determine a temperature or pressure difference, make sure they are reading within 0.2°F of each other for temperature and within a tolerance equal to 2% of the reading of each other for pressure. Tolerances for critical applications may be tighter.

B. Calibration: Calibrate all sensors using one of the following procedures:

1. Sensors Without Transmitters – Standard Application. Make a reading with a calibrated test instrument within 6 inches of the site sensor at various points across the range. Verify that the sensor reading (via the permanent thermostat, gage or BAS) is within the tolerances specified for the sensor. If not, adjust offset and range, or replace sensor. Where sensors are subject to wide variations in the sensed variable, calibrate sensor within the highest and lowest 20% of the expected range.

2. Sensors With Transmitters – Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer’s resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature mBAShing 20 mA to the potentiometer span or maximum and verify at the OI. Record all values and recalibrate controller as necessary to conform to tolerances. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or BAS) is within the tolerances specified. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.

C. Sensor Tolerance: Sensors shall be within the tolerances specified for the device. Refer to Section “BAS Basic Materials and Devices.”
3.03 COIL VALVE LEAK CHECK
A. Verify proper close off of the valves. Ensure the valve seats properly by simulating the maximum anticipated pressure difference across the circuit. Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Via the OI, command the valve to close. Energize fans. After 5 minutes observe air temperature difference across coil. If a temperature difference is indicated, and the piping surface temperature entering the coil is within 3°F of the water supply temp, leakage is probably occurring. If it appears that it is occurring, close the isolation valves to the coil to ensure the conditions change. If they do, this validates the valve is not closing. Remedy the condition by adjusting the stroke and range, increasing the actuator size/torque, replacing the seat, or replacing the valve as applicable.

3.04 VALVE STROKE SETUP AND CHECK
A. For all valve and actuator positions checked (does not include terminal equipment), verify the actual position against the OI readout.
B. Set pumps to normal operating mode. Command valve closed, verify that valve is closed, and adjust output zero signal as required. Command valve open, verify position is full open and adjust output signal as required. Command valve to a few intermediate positions. If actual valve position doesn’t reasonably correspond, replace actuator.

3.05 BAS DEMONSTRATION
A. Demonstrate the operation of the BAS hardware, software, and all related components and systems to the satisfaction of the Commissioning Authority and Owner. Schedule the demonstration with the Owner’s representative 1 week in advance. Demonstration shall not be scheduled until all hardware and software submittals, and the Start Up Test Report are approved. If the Work fails to be demonstrated to conform to Contract specifications, so as to require scheduling of additional site visits by the Commissioning Authority for re-demonstration, Contractor shall reimburse Owner for costs of subsequent Commissioning Authority site visits.
B. The Contractor shall supply all personnel and equipment for the demonstration, including, but not limited to, instruments, ladders, etc. Contractor supplied personnel must be competent with and knowledgeable of all project-specific hardware, software, and the HVAC systems. All training documentation and submittals shall be at the job site.
C. Demonstration shall typically involve small representative samples of systems/equipment randomly selected by the University and the CA.
D. The system shall be demonstrated following the same procedures used in the Start Up Test by using the approved Commissioning Checklists. Demonstration shall include, but not necessarily be limited to, the following:
   1. Demonstrate that required software is installed on BAS workstations. Demonstrate that graphic screens, alarms, trends, and reports are installed as submitted and approved.
   2. Demonstrate that points specified and shown can be interrogated and/or commanded (as applicable) from all workstations, as specified.
   3. Demonstrate correct calibration of input/output devices using the same methods specified for the Start Up tests. A maximum of 10 percent of I/O points shall be selected at random by Commissioning Authority and/or Owner for demonstration. Upon failure of any device to meet the specified end-to-end accuracy, an
additional 10 percent of I/O points shall be selected at random by Commissioning Authority for demonstration. This process shall be repeated until 100 percent of randomly selected I/O points have been demonstrated to meet specified end-to-end accuracy.

4. Demonstrate that all DDC and other software programs exist at respective field panels. The Direct Digital Control (DDC) programming and point database shall be as submitted and approved.

5. Demonstrate that all DDC programs accomplish the specified sequences of operation.

6. Demonstrate that the panels automatically recover from power failures, as specified.

7. Demonstrate that the stand-alone operation of panels meets the requirements of these Specifications. Demonstrate that the panels’ response to LAN communication failures meets the requirements of these Specifications.

8. Identify access to equipment selected by Commissioning Authority. Demonstrate that access is sufficient to perform required maintenance.

9. Demonstrate that required trend graphs and trend logs are set up per the requirements. Provide a sample of the data archive. Indicate the file names and locations.

10. Demonstrate proper sequencing of the Campus Shutdown command.

E. BAS Demonstration shall be completed and approved prior to Substantial Completion.

F. Any tests successfully completed during the demonstration will be recorded as passed for the functional performance testing and will not have to be re-accomplished.

3.06 **BAS ACCEPTANCE PERIOD**

A. After approval of the BAS Demonstration and prior to Contract Close-Out Acceptance Phase shall commence. Acceptance Period shall not be scheduled until all HVAC systems are in operation and have been accepted, all required cleaning and lubrication has been completed (i.e. filters changed, piping flushed, strainers cleaned, etc.), and TAB report has been submitted and approved.

B. **Operational Test**: At the beginning of the Acceptance Phase, the system shall operate properly for two weeks without malfunction, without alarm caused by control action or device failure, and with smooth and stable control of systems and equipment in conformance with these specifications. At the end of the two weeks, contractor shall forward the trend logs to the CA for review. CA shall determine if the system is ready for functional performance testing and document any problems requiring contractor attention.

1. If the systems are not ready for functional performance testing, Contractor shall correct problems and provide notification to the Owner’s representative that all problems have been corrected. The Acceptance Period shall be restarted at a mutually scheduled time for an additional one-week period. This process shall be repeated until Commissioning Authority issues notice that the BAS is ready for functional performance testing.

C. During the Acceptance Period, the contractor shall maintain a hard copy log of all alarms generated by the BAS. For each alarm received, contractor shall diagnose the cause of the alarm, and shall list on the log for each alarm, the diagnosed cause of the alarm, and the corrective action taken. If in the contractor’s opinion, the cause of the
alarm is not the responsibility of the contractor, contractor shall immediately notify the Owner’s representative.

3.07 TREND LOGS

A. CA will analyze trend logs of the system operating parameters to evaluate normal system functionality. Contractor shall establish trends, ensure that they are being stored properly, and forward the data in electronic format to the CA.

B. Data shall include a single row of field headings and the data thereafter shall be contiguous. Each record shall include a date and time field. Recorded parameters for a given piece of equipment or component shall be trended at the same intervals and be presented in a maximum of two separate two dimensional formats with time being the vertical axis and field name being the horizontal axis. Data shall be forwarded in one of the following formats.

2. Microsoft ACCESS Database (*.mdb).
4. Comma Separated Value (*.csv or *.txt), preferably with quotes delimiting text fields and # delimiting date/time fields.

C. Sample times indicated as COV (±) or change of value mean that the changed parameter only needs to be recorded after the value changes by the amount listed. When output to the trending file, the latest recorded value shall be listed with any given time increment record. If the BAS does not have the capability to record based on COV, the parameter shall be recorded based on the interval common to the unit.

3.08 TREND GRAPHS

A. Trend graphs shall generally be used during the Acceptance Phase to facilitate and document testing. Prepare controller and workstation software to display graphical format trends during the Acceptance Period. Trend graphs shall demonstrate compliance with contract documents. Trended values and intervals shall be the same as those specified for the functional performance tests.

B. Lines shall be labeled and shall be distinguishable from each other by using either different line types, or different line colors.

C. Indicate engineering units of the y-axis values; e.g. °F., in. w.g., Btu/lb, percent wide open, etc.

D. The y-axis scale shall be chosen so that all trended values are in a readable range. Do not mix trended values on one graph if their unit ranges are incompatible.

E. Trend outside air temperature, humidity, and enthalpy during each period in which any other points are trended.

F. All points trended for one HVAC subsystem (e.g. air handling unit, chilled water system, etc.) shall be trended during the same trend period.

G. Each graph shall be clearly labeled with HVAC subsystem title, date, and times.

3.09 WARRANTY PHASE BAS OPPOSITE SEASON TRENDING AND TESTING:

A. **Trending:** Throughout the Warranty Phase, trend logs shall be maintained as required for the Acceptance Period. Contractor shall forward archived trend logs to the CA for
review upon CA’s request. CA will review these and notify contractor of any warranty work required.

B. **Opposite Season Testing**: Within 6 months of completion of the Acceptance Phase, CA shall schedule and conduct Opposite Season functional performance testing. Contractor shall participate in this testing and remedy any deficiencies identified.

### 3.10 SOFTWARE OPTIMIZATION ASSISTANCE

A. The contractor shall provide the services of a controls technician as specified above at the project site to be at the disposal of the CA. The purpose of this requirement is to make changes, enhancements and additions to control unit and/or workstation software that have been identified by the CA during the construction and commissioning of the project and that are beyond the specified Contract requirements. The cost for this service shall be included with the bid. Requests for assistance shall be for contiguous or non-contiguous 8-hour days, unless otherwise mutually agreed upon by contractor, Commissioning Authority, and Owner. The Owner’s representative shall notify contractor 2 days in advance of each day of requested assistance.

B. The controls technician provided shall be thoroughly trained in the programming and operation of the controller and workstation software. If the controls technician provided cannot perform every software task requested by the Commissioning Authority in a timely fashion, contractor shall provide additional qualified personnel at the project site as requested by the Commissioning Authority, to meet the total specified requirement per building on-site.

### 3.11 BAS OPERATOR TRAINING:

A. Provide services of controls contractor’s qualified technical personnel for three 6-hour days to instruct Owner's personnel in operation and maintenance of BAS. CA shall witness selected sessions. Instruction shall be in classroom setting at the project site for appropriate portions of the training. Training may be in non-contiguous days at the request of the Commissioning Authority or Owner. The Owner’s representative shall notify contractor 1 week in advance of each day of requested training.

B. Provide up to 6 complete sets of the approved Operations and Maintenance Manual to be used for training.

C. Contractor shall submit a Training Plan as outlined in the Cx plan for the scope of training for which he is responsible. Training Plan shall be forwarded to the Division 15 contractor who will compile, organize, format, and forward to the CA.

D. The contractor’s designated training personnel shall meet with the Commissioning Authority and owner’s representative for the purpose of discussing and fine-tuning the training agenda prior to the first training session. Training agenda shall generally be as follows:

1. **Day 1:**
   a) Brief walk-through of systems, including identification of all controlled equipment and condensed demonstration of CU portable and built-in operator interface device display capabilities where applicable.
   b) Brief overview of the various parts of the O&M manual, including hardware and software programming and operating publications, catalog data, controls installation drawings, and DDC programming documentation.
   c) Review of workstation login/logout procedures, password setup, and exception reporting.
d) Review of workstation menu penetration and broad overview of the various
workstation features.

2. Day 2:
   a) Review of CU programming.
   b) Review of sequence of operation, CU programming, standalone modes, fail
      modes and graphic workstation screen for each HVAC subsystem.

3. Day 3:
   a) Review of alarm features.
   b) Review of diagnostics features.
   c) Review of I/O hardware testing, calibration, and replacement.
   d) Review of trend features.
   e) Review of workstation reports.
   f) Review of setpoint optimization and fine-tuning concepts.
   g) Review of all remaining miscellaneous workstation features.
   h) Question and answer period.

E. Advanced Training: Advanced Training shall be provided for [one] individual and be
   provided at an off-site training facility containing installations of the proposed system.
   Contractor shall pay training registration and materials fee and the University shall pay
   all employee expenses (travel, per diem, salary).
   a) Contractor shall provide the standard, certified advanced training offering on
      all Control Programming Applications.
   b) Contractor shall provide the standard, certified advanced training offering on
      Advanced Installation, Configuration, Maintenance, and Network
      Administration.

END OF SECTION
SECTION 25 1200 BAS COMMUNICATION DEVICES

INSTRUCTIONS FOR USE AND MODIFICATION

COMMENTS THAT REQUIRE MODIFICATION ARE ITALICIZED AND BLUE.

1. WHEN EDITING IS COMPLETE, DELETE THIS BLOCK AND SAVE THE FILE AS A NEW NAME
2. THIS SECTION IS SPECIFIC TO THE AU STANDARDS. ALL CHANGES AND VARIANCES MUST BE APPROVED BY AU.

PART I. GENERAL

1.01 SECTION INCLUDES
   A. LAN Interface Devices
   B. System Interface Devices

1.02 RELATED DOCUMENTS:
   A. Section “Basic Mechanical Requirements.”
   B. Section “Building Automation System (BAS) General”
   C. Section “BAS Basic Materials and Devices.”
   D. Section “BAS Operator Interfaces.”
   E. Section “BAS Field Panels.”
   F. Section “BAS Software and Programming.”
   G. Section “BAS Commissioning.”

1.03 DESCRIPTION OF WORK
   A. Contractor shall provide all interface devices and software to provide an integrated system connecting BCs, AACs, ASCs and Gateways to the University network.

PART II. PRODUCTS

2.01 CONTROLLER LOCAL AREA NETWORK GATEWAYS
   A. The Supervisory Gateway shall be a microprocessor-based communications device that acts as a gateway/router between the Supervisory LAN CSSs or OWS and the Primary LAN. The Gateway must be able to receive an IP address from a Dynamic Host Configuration Protocol (DHCP) Server or be configured with a fixed IP address. Any loss of communication between the Supervisory Gateway and Primary LAN shall be reported at the workstation without disrupting any BAS functions.

   B. The Gateway shall perform information translation between the Primary LAN and the Local Supervisory LAN, which is 100/1000 Mbps Ethernet TCP/IP, and shall use BACnet/IP, OPC and/or APOGEE MLN protocols.

   C. The gateway shall contain its own microprocessor, RAM, battery, real-time clock, communication ports, and power supply as specified for a BC in Section “BAS Field Panels.”. Each gateway/router shall be mounted in a lockable enclosure.
D. The gateway/router shall allow centralized overall system supervision, operator interface, management report generation, alarm annunciation, acquisition of trend data, and communication with control units. It shall allow system operators to perform the following functions from the CSS, and OWSs:
   1. Configure systems.
   2. Monitor and supervise control of all points.
   3. Change control setpoints.
   4. Override input values.
   5. Override output values.
   6. Enter programmed start/stop time schedules.
   7. View and acknowledge alarms and messages.
   8. Receive, store and display trend logs and management reports.
   9. Upload/Download programs, databases, etc. as specified.

E. Upon loss of power to the Gateway, the battery shall provide for minimum 100 hour backup of all programs and data in RAM. The battery shall be sealed and self-charging.

F. The Gateway shall be transparent to control functions and shall not be required to control information routing on the Primary LAN.

2.02 CONTROLS INTERFACE DEVICE (CID)
A. The CID shall be a microprocessor-based communications device that acts as a gateway between the control protocol and the applicable factory controller protocol.
B. The CID shall contain its own microprocessor, RAM, battery, communication ports and, power supply.
C. Each CID shall support full bi-directional communications translation as more fully specified in Section BAS Software.

*Edit the following list(s) as necessary to meet the needs of the University based on equipment size and application.*

D. The following Chilled Water System points shall be mapped as a minimum:
   1. CHW Supply and Return Temperatures
   2. CW Supply and Return Temperatures
   3. Power Consumption (kW)
   4. Percent of Power Consumption (compared to maximum)
   5. Bearing Temperature
   6. Suction and Head Pressures
   7. Suction and Head Temperatures
   8. All available alarms; common alarm as minimum
   9. Chiller Status
   10. Enable/Disable
   11. Current Limit Percent
   12. CHW Setpoint and Setpoint Reset
E. The following Hot Water System points shall be mapped as a minimum:
1. Boiler Supply Temperatures
2. Boiler Pressure
3. Call for Heat
4. Boiler Ignition On
5. All available alarms; common alarm as minimum
6. Boiler Status
7. Firing Rate
8. Enable/Disable
9. HW Setpoint and Setpoint Reset

F. The following Variable Frequency Drive points shall be mapped at a minimum:
1. Output Frequency
2. Motor Speed (RPM, %, or Engineering units)
3. Motor Current
4. Calculated Motor Torque
5. Calculated Motor Power (kW)
6. DC Bus Voltage
7. Output Voltage
8. kWh meter (resettable)
9. mWh meter

G. The following Computer Room Air Conditioner points shall be mapped as a minimum:
1. Space Temperature and Humidity
2. Change Filter
3. Humidifier Status
4. Unit Off Local / Off Remote
5. All available alarms; common alarm as minimum
6. Unit Status
7. Enable/Disable
8. Space Temperature and Humidity Setpoints.

PART III. EXECUTION

3.01 INSPECTION:
A. Examine areas and conditions under which control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3.02 INSTALLATION OF CONTROL SYSTEMS:
A. General: Install systems and materials in accordance with manufacturer's instructions, roughing-in drawings and details shown on drawings.
3.03 COMMUNICATION DEVICE REQUIREMENTS

A. Provide gateways as required to support manufacturer’s configuration.

END OF SECTION
SECTION 25 1400 – BAS FIELD PANELS

INSTRUCTIONS FOR USE AND MODIFICATION
COMMENTS THAT REQUIRE MODIFICATION ARE ITALICIZED AND BLUE.
1. WHEN EDITING IS COMPLETE, DELETE THIS BLOCK AND SAVE THE FILE AS A NEW NAME
2. THIS SECTION IS SPECIFIC TO THE AU STANDARDS. ALL CHANGES AND VARIANCES MUST BE APPROVED BY AU.

PART I. GENERAL

1.01 SECTION INCLUDES:
   A. Building Controller (BC).
   B. Advance Application Specific Controller (AAC).
   C. Application Specific Controller (ASC).
   D. Application Requirements of CUs.

1.02 RELATED DOCUMENTS:
   A. Section “Basic Mechanical Requirements”
   B. Section “Building Automation System (BAS) General”
   C. Section “BAS Basic Materials and Devices”
   D. Section “BAS Communication Devices.”
   E. Section “BAS Software and Programming.”
   F. Section “BAS Commissioning.”

1.03 DESCRIPTION OF WORK:
   A. Furnish and install DDC Control Units required to support specified building automation system functions.
   B. Refer to Section “Building Automation System (BAS) General” for general requirements.

PART II. PRODUCTS

2.01 BUILDING CONTROLLER (BC)
   A. General Requirements:
      1. The BC(s) shall provide fully distributed control independent of the operational status of the OWSs and CSS. All necessary calculations required to achieve control shall be executed within the BC independent of any other device. All control strategies performed by the BC(s) shall be both operator definable and modifiable through the Operator Interfaces.
      2. BCs shall perform overall system coordination, accept control programs, perform automated system functions, control peripheral devices and perform all necessary mathematical and logical functions. BCs shall share information with the entire network of BCs and AACs/ASCs for full global control. Each controller shall permit multi-user operation from multiple workstations and portable operator terminals connected either locally or over the Primary Controller LAN. Each unit shall have its own internal RAM, non-volatile memory, microprocessor, battery backup, regulated power supply, power conditioning equipment, ports for
connection of operating interface devices, and control enclosure. BCs shall be programmable from an operator workstation, portable operators terminal, or handheld operating device. BC shall contain sufficient memory for all specified global control strategies, user defined reports and trending, communication programs, and central alarming.

3. BCs shall be connected to a controller network that qualifies as a Primary Controlling LAN.

4. All BCs shall be protected from any memory and/or operational loss with a network capable (coordinate network connectivity and monitoring with AU OIT) uninterruptable power supply and a battery backup using a lithium battery with a rated service life of fifty (50) hours, and a rated shelf life of at least five years. *Self-diagnostic routine shall report an alarm for a low battery condition.*
   a) EEPROM, EPROM, or NOVROM non-volatile memory

5. BCs may provide intelligent, standalone control of system or equipment functions. Each BC may be capable of standalone direct digital operation utilizing its own processor, non-volatile memory, input/output, wiring terminal strips, A/D converters, real-time clock/calendar and voltage transient and lightning protection devices. Refer to standalone functionality specified above.

6. The BC may provide for point (AI, DO, DI, AO) mix flexibility and expandability. This requirement may be met with a family of expander boards, modular input/output configuration, or a combination thereof. Refer to stand alone functionality specified above.

7. All BC point data, algorithms and application software shall be modifiable from the Operator Workstation.

8. Each BC shall execute application programs, calculations, and commands via a microprocessor resident in the BC. The database and all application programs for each BC shall be stored in non-volatile or battery backed volatile memory within the BC and will be able to upload/download to/from the OWS and/or CSS.

9. BC shall provide memory buffer for holding alarms, messages, trends etc.

10. Each BC shall include self-test diagnostics, which allow the BC to automatically alarm any malfunctions, or alarm conditions that exceed desired parameters as determined by programming input.

11. Each BC shall contain software to perform full DDC/PID control loops.

12. For systems requiring end-of-line resistors those resistors shall be located in the BC.

13. Input-Output Processing
   a) Digital Outputs (DO): Outputs shall be rated for a minimum 24 Vac or Vdc, 1 amp maximum current. Each shall be configurable as normally open or normally closed. Each DO shall be discrete outputs from the BC’s board (multiplexing to a separate manufacturer’s board is unacceptable). Provide suppression to limit transients to acceptable levels.
   b) Analog Inputs (AI): AI shall be 0-5 Vdc, 0-10 Vdc, and 0-20 mA. Provide signal conditioning, and zero and span calibration for each input. Each input shall be a discrete input to the BC’s board (multiplexing to a separate manufacturers board is unacceptable unless specifically indicated otherwise). A/D converters shall have a minimum resolution of 12 bits.
c) Digital Inputs (DI): Monitor dry contact closures. Accept pulsed inputs of at least one per second. Source voltage for sensing shall be supplied by the BC and shall be isolated from the main board.

d) Universal Inputs (UI-AI or DI): To serve as either AI or DI as specified above.

e) Electronic Analog Outputs (AO): Voltage mode: 0-5 Vdc and 0-10 Vdc; Current mode: 4-20 mA. Provide zero and span calibration and circuit protection. Pulse Width Modulated (PWM) analog via a DO [and transducer] is acceptable only with University approval (Generally these will not be allowed on loops with a short time constant such as discharge temperature loops, economizer loops, pressure control loops and the like. They are generally acceptable for standard room temperature control loops.). Where these are allowed, transducer/actuator shall be programmable for normally open, normally closed, or hold last position and shall allow adjustable timing. Each DO shall be discrete outputs from the BC’s board (multiplexing to a separate manufacturers board is unacceptable). D/A converters shall have a minimum resolution of 10 bits.

f) Pulsed Inputs: Capable of counting up to 8 pulses per second with buffer to accumulate pulse count. Pulses shall be counted at all times.

14. A communication port for operator interface through a terminal shall be provided in each BC. It shall be possible to perform all program and database back-up, system monitoring, control functions, and BC diagnostics through this port. Standalone BC panels shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers, or workstations.

15. Each BC shall be equipped with loop tuning algorithm for precise proportional, integral, derivative (PID) control. Loop tuning tools provided with the Operator Workstation software is acceptable. Tools to support loop tuning must be provided such that P, I, and D gains are automatically calculated.

16. All analog output points shall have a selectable out of range alarm. The BC shall be capable of maintaining this failure setpoint in the event of a system malfunction, which causes loss of BC control, or loss of output signal, as long as power is available at the BC. The failure setpoint shall be selectable on a per point basis.

17. Slope intercepts and gain adjustments shall be available on a per-point basis.

18. BC Power Loss:
   a) Upon a loss of power to any BC, the other units on the primary controlling network shall not in any way be affected.
   b) Upon a loss of power to any BC, the battery backup shall ensure that the energy management control software, the Direct Digital Control software, the database parameters, and all other programs and data stored in the RAM are retained for a minimum of three days (72 hours). An alarm diagnostic message shall indicate that the BC is under battery power.
   c) Upon restoration of power within the specified battery backup period, the BC shall resume full operation without operator intervention. The BC shall automatically reset its clock such that proper operation of any time dependent function is possible without manual reset of the clock. All monitored functions shall be updated.
d) Should the duration of a loss of power exceed the specified battery back-up period or BC panel memory be lost for any reason, the panel shall automatically report the condition (upon resumption of power) and be capable of receiving a download via the network, and connected computer. PU shall be able to upload the most current versions of all energy management control programs, Direct Digital Control programs, database parameters, and all other data and programs in the memory of each BC from the operator workstation via the local area network, or the local communications port.

19. BC Failure:
   a) Building Controller LAN Data Transmission Failure: BC shall continue to operate in stand-alone mode. BC shall store loss of communication alarm along with the time of the event. All control functions shall continue with the global values programmable to either last value or a specified value. Peer BCs shall recognize the loss, report alarm and reconfigure the LAN.
   b) BC Hardware Failure: BC shall cease operation and terminate communication with other devices. All outputs shall go to their specified fail position.

20. Each BC shall be equipped with firmware resident self-diagnostics for sensors and be capable of assessing an open or shorted sensor circuit and taking an appropriate control action (close valve, damper, etc.).

21. BCs may include LAN communications interface functions for controlling secondary controlling LANs Refer to Section “BAS Communications Devices” for requirements if this function is packaged with the BC.

22. BCs shall be mounted on equipment, in packaged equipment enclosures, or in locking wall mounted enclosure, as specified elsewhere.

2.02 ADVANCED APPLICATION SPECIFIC CONTROLLER (AAC) AND APPLICATION SPECIFIC CONTROLLER (ASC)

A. General Requirements:
   1. AACs and ASCs shall provide intelligent, standalone control of systems and equipment. Each unit shall have its own internal RAM, non-volatile memory and will continue to operate all local control functions in the event of a loss of communications on the ASC LAN or sub-LAN. Refer to standalone requirements by application specified in Part 3 of this section. It shall be able to share information with every other BC and AAC /ASC on the entire network.
   2. Each AAC and ASC shall include self-test diagnostics that allow the AAC /ASC to automatically relay to the BC, LAN Interface Device or workstation, any malfunctions or abnormal conditions within the AAC /ASC or alarm conditions of inputs that exceed desired parameters as determined by programming input.
   3. AACs and ASCs shall include sufficient memory to perform the specific control functions required for its application and to communicate with other devices.
   4. Each AAC and ASC must be capable of stand-alone direct digital operation utilizing its own processor, non-volatile memory, input/output, minimum 8 bit A to D conversion, voltage transient and lightning protection devices. All volatile memory shall have a battery backup of at least fifty (50) hrs with a battery life of five years.
5. All point data, algorithms and application software within an AAC/ASC shall be modifiable from the Operator Workstation.

6. AAC and ASC Input-Output Processing
   a) Digital Outputs (DO): Outputs shall be rated for a minimum 24 VAC or VDC, 1 amp maximum current. Each shall be configurable as normally open or normally closed. Each DO shall be discrete outputs from the AAC/ASC’s board (multiplexing to a separate manufacturer’s board is unacceptable). Provide suppression to limit transients to acceptable levels.
   b) Analog Inputs (AI): AI shall be 0-5 Vdc, 0-10Vdc, 0-20Vdc, and 0-20 mA. Provide signal conditioning, and zero and span calibration for each input. Each input shall be a discrete input to the BC’s board (multiplexing to a separate manufacturers board is unacceptable unless specifically indicated otherwise). A/D converters shall have a minimum resolution of 8-10 bits depending on application.
   c) Digital Inputs (DI): Monitor dry contact closures. Accept pulsed inputs of at least one per second. Source voltage for sensing shall be supplied by the BC and shall be isolated from the main board. Software multiplexing of an AI and resistors may only be done in non-critical applications and only with prior approval of Engineer.
   d) Universal Inputs (UI-AI or DI): To serve as either AI or DI as specified above.
   e) Electronic Analog Outputs (AO) as required by application: voltage mode, 0-5VDC and 0-10VDC; current mode (4-20 mA). Provide zero and span calibration and circuit protection. D/A converters shall have a minimum resolution of 8 bits.
   f) Analog Output Pneumatic (AOP), 0-20 psi: Pneumatic outputs via an I/P transducer or 0-10vdc to pneumatic transducer are acceptable. Multiplexed pneumatic outputs of a separate manufacturer are unacceptable.

PART III. EXECUTION

3.01 INSPECTION:
   A. Examine areas and conditions under which control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3.02 INSTALLATION OF CONTROL SYSTEMS:
   A. General: Install systems and materials in accordance with manufacturer's instructions, roughing-in drawings and details shown on drawings.

3.03 HARDWARE APPLICATION REQUIREMENTS
   A. General: The functional intent of this specification is to allow cost-effective application of manufacturer’s standard products while maintaining the integrity and reliability of the control functions. A Primary Control Unit as specified above is generally fully featured and customizable whereas the Secondary Control Unit refers to a more cost-effective unit designed for lower end applications. Specific requirements indicated below are required for the respective application. Manufacturer may apply the most cost-effective unit that meets the requirement of that application.
B. Standalone Capability: Each Control Unit (CU) shall be capable of performing the required sequence of operation for the associated equipment. All physical point data and calculated values required to accomplish the Sequence of Operation shall originate within the associated CU with only the exceptions enumerated below. Listed below are physical point data and calculated values that shall be allowed to be obtained from or stored by other CUs via LAN.

C. Where associated control functions involve functions from different categories identified below, the requirements for the most restrictive category shall be met.

D. Application Category 1 (Terminal Units and Small Unitary Equipment):

1. Applications in this category include the following:
   a) Fan Coil Units.
   b) Airflow control Boxes (VAV and Constant Volume Boxes).
   c) Unit Ventilators.
   d) Miscellaneous Heaters.
   e) Multizonal Dampers.
   f) Unitary equipment <15 tons (Split System AC’s and HP’s).

2. ASCs or BCs may be used in these applications.

3. Standalone Capability: Provide ability to execute space temperature control functions for the application for a given setpoint or mode, which shall generally be occupied mode control. Only the following data (as applicable) may be acquired from other CUs via LANs. In the event of a loss of communications with any other CUs, or any fault in any system hardware that interrupts the acquisition of any of these values, the CU shall use the last value obtained before the fault occurred. If such fault has not been corrected after the specified default delay time, specified default value(s) shall then be substituted until such fault has been corrected.

<table>
<thead>
<tr>
<th>physical/virtual point</th>
<th>default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheduling Period</td>
<td>Normal</td>
</tr>
<tr>
<td>Morning Warm-Up</td>
<td>Off (cold discharge air)</td>
</tr>
<tr>
<td>Load Shed</td>
<td>Off (no shedding)</td>
</tr>
</tbody>
</table>

4. Mounting:
   a) CUs that control equipment located above accessible ceilings shall be mounted on/in the equipment and shall be rated for plenum use.
   b) CUs that control equipment mounted in a mechanical room may either be mounted in or on the equipment or on the wall of the mechanical room at an adjacent, accessible location.
   c) CUs that control equipment mounted outside shall either be located in the unit or in a proximate mechanical/utility space.

5. For new installations of terminal equipment, BAS contractor shall furnish CUs and associated peripheral devices to the terminal unit manufacturer for factory mounting. Peripheral devices shall be furnished as follows
   a) Fan Coil Units: Provide temperature sensors and control valves.
   b) VAV or Constant Volume Boxes: Provide integral actuator/CU where possible, and control valves where reheat is used.
   c) Unitary Equipment: Provide temperature sensors and status monitoring devices.
d) Single zone air handlers less than 2,500 CFM: Provide all sensors, status devices, and control valves.

6. For existing terminal equipment, BAS contractor shall field install CUs and peripheral devices.

7. Programmability: Operator shall be able to modify all setpoints (temperature and airflow), scheduling parameters associated with the unit, tuning and set up parameters, interstage timing parameters, and mode settings. Application specific block control algorithms may be used provided they satisfy the Sequence of Operations. The ability to customize the control algorithm is not required unless specifically indicated otherwise.

8. Network Restrictions: Limit the number of nodes on the network to the maximum recommended by the manufacturer.

E. Application Category 2 (General Purpose Terminal Controller)

1. Applications in this category include the following:
   a) Unitary Equipment ≥ 15 tons (Air Conditioners, Heat Pumps, Packaged Heating/Cooling Units, etc.).
   b) Constant Volume Single Zone Air Handling Units less than 5,000 CFM.
   c) Constant Volume Pump Start/Stop.
   d) Miscellaneous Equipment (Exhaust Fan) Start/Stop.
   e) Miscellaneous Monitoring (not directly associated with a control sequence and where trending is not critical).
   f) Converter Control.

2. BCs may be used in these applications

3. ASCs may be used in these applications provided the ASC meets all requirements specified below. This category requires a general purpose ASC to which the contractor can attach application specific control algorithms.

4. Stand alone Capability: Only the following data (as applicable) may be acquired from other CUs via LANs. In the event of a loss of communications with any other CU, or any fault in any system hardware that interrupts the acquisition of any of these values, the CU shall use the last value obtained before the fault occurred. If such fault has not been corrected after the specified default delay time, specified default value(s) shall then be substituted until such fault has been corrected.

<table>
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<tr>
<th>physical/virtual point</th>
<th>default delay time</th>
<th>default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside Air Temperature</td>
<td>3 minutes</td>
<td>80°F</td>
</tr>
<tr>
<td>Outside Air Humidity</td>
<td>3 minutes</td>
<td>60%RH</td>
</tr>
<tr>
<td>Outside Air Enthalpy</td>
<td>3 minutes</td>
<td>30 Btu/lb</td>
</tr>
</tbody>
</table>

5. Mounting:
   a) CUs that control equipment located above accessible ceilings shall be mounted on the equipment and shall be rated for plenum use.
   b) CUs that control equipment located in occupied spaces or outside shall either be mounted within the equipment enclosure (responsibility for physical fit remains with the contractor) or in a nearby mechanical/utility room in which case it shall be enclosed in a locking NEMA 1 enclosure.

6. Programmability: Operator shall be able to modify all setpoints (temperature and airflow), scheduling parameters associated with the unit, tuning and set up
parameters, interstage timing parameters, and mode settings. Operator shall be able to address and configure spare inputs for monitoring. Operator shall be able to address and configure spare outputs for simple single loop control actions or event initiated actions. Application specific block control algorithms may be used provided they meet the sequence of operations. The ability to customize the control algorithm is not required unless specifically indicated otherwise.

7. Network Restrictions: Limit the number of nodes on the network to the maximum recommended by the manufacturer.

F. Application Category 3 (Advanced Applications)

1. Applications in this category include the following:
   a) VAV Air Handlers {generally <10,000 cfm}.
   b) Dual Duct Air Handlers {generally <10,000 cfm}.
   c) Cooling Towers.
   d) Sequenced or Variable Speed Pump Control.
   e) Local Chiller Control (unit specific).
   f) Local Free Cooling Heat Exchanger Control.
   g) Self-Contained VAV Units.

2. BCs may be used in these applications.

3. AACs may be used in these applications provided:
   a) The AAC meets all requirements specified below.
   b) All control functions and physical I/O associated with a given unit reside in one AAC.
   c) Input A/D is 10 bit. Exception: 8 Bit input A/D can be used when matched with high accuracy sensors, the range of which meets the resolution requirements specified for the applicable sensor in Section “BAS Basic Materials and Devices”.
   d) Pulsed inputs required for the application can be monitored and accumulated effectively.
   e) Unit has the capability to have all points in trend and upload these to the BC and/or the CSS.

4. Standalone Capability: Only the following data (as applicable) may be acquired from other CUs via LANs. In the event of a loss of communications with any other CU, or any fault in any system hardware that interrupts the acquisition of any of these values, the AAC shall use the last value obtained before the fault occurred. If such fault has not been corrected after the specified default delay time, specified default value(s) shall then be substituted until such fault has been corrected.

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<td>3 minutes</td>
<td>30 Btu/lb</td>
</tr>
</tbody>
</table>

5. Mounting:
   a) CUs that control equipment located above accessible ceilings shall be mounted on the equipment and shall be rated for plenum use.
b) CU's that control equipment located in occupied spaces or outside shall either be mounted within the equipment enclosure (responsibility for physical fit remains with the contractor) or in a nearby mechanical/utility room in which case it shall be enclosed in a locking enclosure.

6. Programmability: Operator shall be able to modify all setpoints (temperature and airflow), scheduling parameters associated with the unit, tuning and set up parameters, interstage timing parameters, and mode settings. Operator shall be able to address and configure spare inputs for monitoring. Operator shall be able to program custom DDC control algorithms and specify trending parameters which will be retained in memory in the event of a loss of communications. Application specific block control algorithms may be used provided they meet the sequence of operations. The control algorithms shall be completely customizable.

7. Network Restrictions: Each LAN which participates in the transfer of data between the CU and the CSS shall be subject to the following criteria:
   a) Trending capability shall allow all points on all air handlers to be able to be trended and archived at minimum 15 minute intervals.

G. Application Category 4 (Central Plant)
   1. Applications in this category include all other applications not specifically indicated in the other three application categories.
   2. BCs shall be used in these applications.

3.04 CONTROL UNIT REQUIREMENTS
   A. Refer to Section “Building Automation System (BAS) General” for requirements pertaining to control unit quantity and location.

END OF SECTION
PART I. GENERAL

1.01 SECTION INCLUDES

A. System Software.
B. Programming Description.
C. Control Algorithms.
D. Energy Management Applications.
E. Password Protection.
F. Alarm Reporting.
G. Trending.
H. Dynamic Color Graphics.
I. Management Reporting.

1.02 RELATED DOCUMENTS:

A. Section “Basic Mechanical Requirements.”
B. Section “Building Automation System (BAS) General”
C. Section “BAS Basic Materials and Devices.”
D. Section “BAS Field Panels.”
E. Section “BAS Communication Devices.”
F. Section “Sequence of Operation.”
G. Section “BAS Commissioning.”

1.03 DESCRIPTION OF WORK:

A. Furnish and provide all software, programming, and dynamic color graphics for a complete and fully functioning system as specified.
B. Refer to Section “Building Automation System (BAS) General” for general requirements.
C. Refer to Section “Sequence of Operation” for Sequences of Operation for controlled equipment.

1.04 LICENSING

A. Include licensing for all software packages at all required workstations.
B. Include licensing for workstation operating systems, and for all required third party software.
C. Upgrade all software packages to the release (version) in effect at the end of the Warranty Period at no additional cost to the University.
D. All licensing shall be perpetual for the life of the system (no renewal requirement).
PART II. PRODUCTS

2.01 SYSTEM SOFTWARE – GENERAL

A. Functionality and Completeness: The Contractor shall furnish and install all software and programming necessary to provide a complete and functioning system as specified. The Contractor shall include all software and programming not specifically itemized in these Specifications that is necessary to implement, maintain, operate, and diagnose the system in compliance with these Specifications.

B. Configuration: The software shall support the system as a distributed processing network configuration.

C. Software Rights: No aspect of the control programming that executes the sequence of operations shall be considered proprietary. The University and its representatives shall have full and unlimited access to all programming manuals, site specific programming at all levels, updates to all manuals, etc. Advanced programming training is specified. Properly trained individuals will be given applicable password access to view and modify control programming without consent or notification of the contractor. Any system in which control sequence programming is considered proprietary in any way will not be considered.

D. Custom Software: Contractor shall be required to retain backup copies of custom software drivers and documentation of same for no less than ten years with free access to AU for the same period. If the backup is not available within the specified timeframe, Contractor shall recreate the custom software at no charge to AU.

2.02 CONTROLLER SOFTWARE

A. BC Software Residency: Each BC shall be capable of control and monitoring of all points physically connected to it. All software including the following shall reside and execute at the BC:

1. Real-Time Operating System software
2. Real-Time Clock/Calendar and network time synchronization
3. BC diagnostic software
4. LAN Communication software/firmware
5. Direct Digital Control software
6. Alarm Processing and Buffering software
7. Energy Management software
8. Data Trending, Reporting, and Buffering software
9. I/O (physical and virtual) database
10. Remote Communication software

B. AAC/ASC Software Residency: Each AAC/ASC shall be capable of control and monitoring of all points physically connected to it. As a minimum, software including the following shall reside and execute at the AAC/ASC. Other software to support other required functions of the AAC/ASC may reside at the BC or LAN interface device (specified in Section 15954) with the restrictions/exceptions per application provided in Section 15953:

1. Real-Time Operating System software
2. AAC/ASC diagnostic software
3. LAN Communication software
4. Control software applicable to the unit it serves that will support a single mode of operation
5. I/O (physical and virtual) database to support one mode of operation.

C. **Stand Alone Capability**: BC shall continue to perform all functions independent of a failure in other BC/AAC/ASC or other communication links to other BCs/AACs/ASCs. Trends and runtime totalization shall be retained in memory. Runtime totalization shall be available on all digital input points that monitor electric motor status. Refer also to Section 15953 for other aspects of stand-alone functionality.

D. **Operating System**: Controllers shall include a real-time operating system resident in ROM. This software shall execute independently from any other devices in the system. It shall support all specified functions. It shall provide a command prioritization scheme to allow functional override of control functions.

E. **Network Communications**: Each controller shall include software/firmware that supports the networking of CUs on a common communications trunk that forms the respective LAN. Network support shall include the following:
   1. Building Controller/Primary LAN shall be a high-speed network designed and optimized for control system communication. If a Primary LAN communications trunk is severed, BCs shall reconfigure into two separate LANs and continue operations without interruption or Operator intervention.
   2. Controller communication software shall include error detection, correction, and re-transmission to ensure data integrity.
   3. Operator/System communication software shall facilitate communications between other BCs, all subordinate AACS/ASCs, Gateways and Operator Workstations. Software shall allow point interrogation, adjustment, addition/deletion, and programming while the controller is on line and functioning without disruption to unaffected points. The software architecture shall allow networked controllers to share selected physical and virtual point information throughout the entire system.

F. **Diagnostic Software**: Controller software shall include diagnostic software that checks memory and communications and reports any malfunctions

G. **Alarm/Messaging Software**: Controller software shall support alarm/message processing and buffering software as more fully specified below.

H. **Application Programs**: Controllers shall support and execute application programs as specified:
   1. All Direct Digital Control software, Energy Management Control software, and functional block application programming software templates shall be provided in a ‘ready-to-use’ state, and shall not require (but shall allow) Owner programming.

I. **Security**: Controller software shall support multiple level password access restriction as specified.

J. **Direct Digital Control**: Controller shall support application of Direct Digital Control Logic. All logic modules shall be provided pre-programmed with written documentation to support their application. Provide the following logic modules as a minimum:
1. Proportional-Integral-Derivative (PID) Control with analog, PWM, and floating output.
2. Two Position Control (High or Low crossing with dead band).
4. Delay Timer (delay on make, delay on break, and interval).
5. Hi/Low Selection.
6. Reset or Scaling Module.
7. Logical Operators (And, Or, Not, Xor).
8. Misc. floating point arithmetic calculations.

K. **Psychrometric Parameters**: Controller software shall provide preprogrammed functions in accordance with the current edition of ASHRAE “Handbook of Fundamentals”, to calculate and report psychrometric parameters (given temperature and relative humidity) including the following as a minimum: Enthalpy, Wet Bulb Temperature, Humidity Ratio, Dew Point, and Specific Volume.

L. **Updating/Storing Application Data**: Site-specific programming residing in volatile memory shall be uploadable/downloadable from an OWS or CSS connected locally, to the Primary LAN, to the Local Supervisory LAN and remotely via the internet. Initiation of an upload or download shall include the following methods, Manually and Automatically upon detection of a loss or change.

M. **Restart**: System software shall provide for orderly shut down upon loss of power and automatic restart upon power restoration. Volatile memory shall be retained, outputs shall go to programmed fail (open, closed, or last) position. Equipment restart shall include a user definable time delay on each piece of equipment to stagger the restart. Loss of power shall be alarmed at operator interface indicating date and time.

N. **Miscellaneous Calculations**: System software shall automate calculation of psychrometric functions, calendar functions, kwh/kw and flow determination and totalization from pulsed or analog inputs, curve-fitting, look-up table, input/output scaling, time averaging of inputs and A/D conversion coefficients.

**2.03 PROGRAMMING DESCRIPTION**

A. The application software shall be user programmable.

B. This specification generally requires a programming convention that is logical, easy to learn, use, and diagnose. General approaches to application programming shall be provided by one, or a combination, of the following conventions:

1. **Point Definition**: Provide templates customized for point type, to support input of individual point information.

2. **Graphical Block Programming**: Manipulation of graphic icon “blocks,” each of which represents a subroutine, in a functional/logical manner forming a control logic diagram. Blocks shall allow entry of adjustable settings and parameters via pop-up windows. Provide a utility that shall allow the graphic logic diagrams to
be directly compiled into application programs. Logic diagrams shall be viewable either off-line, or on-line with real-time block output values.

3. **Functional Application Programming**: Pre-programmed application specific programs that allow/require limited customization via “fill in the blanks” edit fields. Typical values would be setpoints, gains, associated point names, alarm limits, etc.

4. **Line Programming**: Textual syntax-based programming in a language similar to BASIC designed specifically for HVAC control. Subroutines or functions for energy management applications, set points, and adjustable parameters shall be customizable, but shall be provided preprogrammed and documented.

C. Provide a means for testing and/or debugging the control programs both off-line and on-line. All input values shall be able to be placed in a test mode or an override mode to facilitate testing.

### 2.04 ENERGY MANAGEMENT APPLICATIONS

A. System shall have the ability to perform all of the following energy management routines via preprogrammed function blocks or template programs. As a minimum provide the following whether or not required in the software:

1. Time of Day Scheduling.
2. Calendar Based Scheduling.
3. Holiday Scheduling.
4. Temporary Schedule Overrides.
5. Optimal Start/Optimal Stop - based on space temperature offset, outdoor air temperature, and building heating and cooling capacitance factors as a minimum.
6. Night Setback and Morning Recovery Control with ventilation only during occupancy.
7. Night Purge ventilation cycle to use the cool night/morning air to pre-cool the space prior to occupancy.
8. Economizer Control (enthalpy or dry bulb).
9. Peak Demand Limiting / Load Shedding.
10. Duty Cycling.
11. Dead Band Control.

B. All programs shall be executed automatically without the need for operator intervention, and shall be flexible enough to allow operator customization. Programs shall be applied to building equipment as described in the Section “Sequence of Operation.”

### 2.05 PASSWORD PROTECTION

A. Multiple-level password access protection shall be provided to allow the University’s authorized BAS Administrator to limit workstation control, display and database manipulation capabilities as he deems appropriate for each user, based upon an assigned user name with a unique password.

B. All passwords for the system shall be provided to the University including administrator, dealer, or factory level passwords for the systems provided under this project.
C. Passwords shall restrict access to all control units.
D. Each user name shall be assigned to a discrete access level. A minimum of five levels of access shall be supported. Alternatively, a comprehensive list of accessibility/functionality items shall be provided which can be enabled or disabled for each user.
E. A minimum of 50 user names shall be supported.
F. Operators shall be able to perform only those commands available for the access level assigned to their user name.
G. User-definable, automatic log-off timers of from 1 to 60 minutes shall be provided to prevent operators from inadvertently leaving interface device software on-line.

2.06 ALARM AND MESSAGE REPORTING
A. Alarm management shall be integrated with the existing AU RENO service or provided via approved substitution to monitor, buffer, and direct alarms and messages to operator devices and memory files. The CSS shall perform distributed, independent alarm analysis and filtering to minimize operator interruptions due to non-critical alarms, minimize network traffic, and prevent alarms from being lost. At no time shall a BC’s ability to report alarms be affected by either operator activity at an Operator Workstation or local handheld device, or by communications with other panels on the network.

1. **Alarm Descriptor**: Each alarm or point change shall include the point’s English language description, and the time and date of occurrence. In addition to the alarm’s descriptor and the time and date, the user shall be able to print, display and store an alarm message to more fully describe the alarm condition or direct operator response.

2. **Alarm Prioritization**: The software shall allow users to define the handling and routing of each alarm by their assignment to discrete priority levels. A minimum of five priority levels shall be provided. For each priority level, users shall have the ability to enable or disable an audible tone whenever an alarm is reported and whenever an alarm returns to normal condition. Users shall have the ability to manually inhibit alarm reporting for each individual alarm and for each priority level. Recommended prioritization: Alarm Level 1 Life Safety (i.e. smoke detector), Level 2 Critical (i.e. controller failure), Level 3 Abnormal (i.e. out-of-range temperature), Level 4 Energy Waste (i.e. fighting valves), Level 5 Maintenance Message (i.e. runtime monitor, filter status).

3. **Alarm Report Routing**: Each alarm priority level shall be associated with a unique user-defined list of operator devices including any combination of local or remote workstations, email and SMS accounts. All alarms associated with a given priority level shall be routed to all operator devices on the user-defined list associated with that priority level. For each priority level, alarms shall be automatically routed to a default operator device in the event that alarms are unable to be routed to any operator device assigned to the priority level.

4. **Alarm Acknowledgment**: For alarm priority levels that are directed to a workstation screen, an indication of alarm receipt shall be displayed immediately regardless of the application in use at the workstation, and shall remain on the screen until acknowledged by a user having a password that allows alarm acknowledgment. Upon acknowledgment, the complete alarm message string
5. **Alarm Recording & Storage:** All alarms shall be stored in an alarm database.

### 2.07 TRENDING

**A.** The software shall be capable of displaying historical data in both a tabular or graphical format. The requirements of this trending capability shall include the following:

1. All physical points and calculated variables shall be available for trending.
2. In the graphical format, the trend shall plot at least 4 different values for a given time period superimposed on the same graph. The 4 values shall be distinguishable by using unique colors. In printed form the 4 lines shall be distinguishable by different line symbology. Displayed trend graphs shall indicate the engineering units for each trended value.
3. The time period for each trend shall be user selectable.
4. The trended value range shall be user selectable.
5. Date and time stamps shall be associated with each sample. For related multiple trend samples taken at common intervals (all points for an air handler for example), common time stamps shall be used to allow displaying data in parallel (all values at that instant on one record of a table).

**B.** **Control Loop Performance Trends:** Controllers incorporating PID control loops shall also provide high resolution sampling capability in less than 2 second increments for verification of control loop performance.

**C.** **Data Storage and Archiving:** Trend data shall be stored at the BC, and uploaded to CSS when archiving is desired. Uploads shall occur based upon user-defined interval, manual command, or when the trend buffers become full. Trended data shall include one row of descriptive column headings with all subsequent data in a contiguous stream. Up to 20 values shall be presented in one record for a common time stamp. For data output for dissimilar methods for recording data (such as COV and time interval), data for all fields in all records shall be populated (COV variables shall be filled in). All trend data shall be available one of the following file formats:

1. Quote and/or Comma separated text.
2. Microsoft ACCESS database.
3. Microsoft EXCEL spreadsheets.

### 2.08 TOTALIZATION

**A.** The software shall support totalizing analog, digital, and pulsed inputs and be capable of accumulating, storing, and converting these totals to engineering units used in the documents. These values shall generally be accessible to the Operator Interfaces to support management reporting functions.

**B.** Totalization of electricity use/demand (hourly, daily & monthly) shall allow application of totals to different utility tariff rate periods, which shall be user definable.

**C.** When specified to provide electrical or utility Use/Demand, the Contractor shall obtain from the local utility all information required to obtain meter data, including k factors, conversion constants, and the like.

**D.** Detailed energy consumption reports for campus utilities, including but not limited to Chilled Water Flow, EWT/LWT, Tons (hourly, daily & monthly), Ton-Hours, Steam
Flow, and Condensate Flow shall be stored as their final calculated value on a daily, monthly and yearly basis. Archive of this data shall be for no less than one year.

2.09 SCHEDULING

A. Provide a graphic utility for user-friendly operator interface to adjust equipment operating schedules.

B. Scheduling feature shall include multiple seven-day master schedules, plus holiday schedule, each with start time and stop time. Master schedules shall be individually editable for each day and holiday.

C. Scheduling feature shall allow for each individual equipment unit to be assigned to one of the master schedules.

D. Timed override feature shall allow an operator to temporarily change the state of scheduled equipment. An override command shall be selectable to apply to an individual unit, all units assigned to a given master schedule, or to all units in a building. Timed override shall terminate at the end of an operator selectable time, or at the end of the scheduled occupied/unoccupied period, whichever comes first. Timed override feature shall be allowed by a password level that does not allow assignment of master schedules.

E. A yearly calendar feature shall allow assignment of holidays, as well as automatic reset of system real time clocks for transitions between daylight savings time and standard time.

2.10 POINT STRUCTURING AND NAMING

2.11 OBJECT NAMING CONVENTION

A. General:

1. All objects shall conform to the following convention;
   a) CAMPUSNAME.BUILDINGNAME.SYSTEMNAME.DEVICENAME

2. Each object name segment delimited by the period (.) character of the object name shall conform to the specific requirements defined herein.

3. The maximum character limit is 30 characters including all period (.) characters.

4. All object names shall be defined using all capital characters.

5. Only the period (.) character shall be used to delimit the segments of the object name.

2.12 CHANGE CONTROL

A. General:

1. When adding new list objects to this standard object naming convention the standard format in the list is:
   a) OBJECTLISTITEMTEXT; Description
   b) The semi-colon is not part of the object list item text.

2. Update the Revision Number at the beginning of this document by one for each new version of the document published to the FCE Standards Library.

3. All modifications shall be in place alphabetically correct based upon the first character of the list item.
2.13 OBJECT NAME SEGMENTS

A. CAMPUSNAME Segment:
   1. The first segment of the object name
   2. This should not be more than 3 characters in length

B. BUILDINGNAME Segment:
   1. The second segment of the object name
   2. This segment should not be more than 3 characters in length.
   3. This segment can be a number, text or alphanumeric.
   4. For first consideration, the numeric portion of the address of the building is used.
   5. For second consideration and in cases where the address number is deemed too long by FCE Operations, a substituted alphanumeric or text name can be applied. All such cases must be approved prior to implementation.

C. SYSTEMNAME Segment:
   1. The third segment of the object name
   2. This segment is to describe the system or macro level components that when combined comprise a system in the building.
   3. This segment should not be more than 10 characters in length.
   4. Only SYSTEMNAMES contained in the SYSTEMNAMES List are permitted.
   5. Any SYSTEMNAME can be succeeded by a numeral to indicate the sequence number for the system being given the name. The numeral is not delimited with a period (.)
   6. Combining multiple SYSTEMNAMES is permitted and each must be delimited with a period (.) character.
   7. The pound character (#) is used to indicate the number of the SYSTEMNAME when multiple are used in a building. It is not necessary to always populate the pound character.

D. DEVICENAME Segment:
   1. The fourth and last segment of the object name
   2. This segment is to describe the devices that are contained within a system in the building.
   3. This segment should not be more than 10 characters in length.
   4. Only DEVICENAMES contained in the DEVICENAMES List are permitted.
   5. Any DEVICENAME can be succeeded by a numeral to indicate the sequence number for the system being given the name. The numeral is not delimited with a period (.)
   6. Combining multiple DEVICENAMES is permitted and shall not be delimited with a period (.) character.
   7. When combining DEVICENAMES it is expected the order of combining be dictated by the actual real English Language pronunciation of the device. Approve all device names during project application of the object naming convention and prior to any implementation.
   8. The pound character (#) is used to indicate the number of the DEVICENAME when multiple are used in a building. It is not necessary to always populate the
pound character. When there is more than one device of the same type required than all devices must use the number including the first device.

2.14 **CAMPUSNAME LIST:**

A. MAN; Main Campus
B. TEN; Tenley Campus

2.15 **BUILDINGNAME LIST:**

<table>
<thead>
<tr>
<th>Building Code</th>
<th>Building Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH</td>
<td>Anderson Hall</td>
</tr>
<tr>
<td>ASB</td>
<td>Asbury Building</td>
</tr>
<tr>
<td>BCC</td>
<td>Media Production Center</td>
</tr>
<tr>
<td>BE</td>
<td>Beeghly Building</td>
</tr>
<tr>
<td>BL</td>
<td>Bender Library</td>
</tr>
<tr>
<td>BP</td>
<td>Butler Pavilion &amp; Arcade</td>
</tr>
<tr>
<td>BT</td>
<td>BATTELINE-TOMPKINS</td>
</tr>
<tr>
<td>BW</td>
<td>Brandywine Building</td>
</tr>
<tr>
<td>CB</td>
<td>Constitution Bldg.</td>
</tr>
<tr>
<td>CDC</td>
<td>Child Development Ctr.</td>
</tr>
<tr>
<td>CH</td>
<td>Capital Hall</td>
</tr>
<tr>
<td>CK</td>
<td>Clark</td>
</tr>
<tr>
<td>CN</td>
<td>Centennial Hall</td>
</tr>
<tr>
<td>CO</td>
<td>Congressional Hall</td>
</tr>
<tr>
<td>CS</td>
<td>Costume Shop</td>
</tr>
<tr>
<td>DH</td>
<td>Dunblane House</td>
</tr>
<tr>
<td>FA</td>
<td>Financial Aid Bldg.</td>
</tr>
<tr>
<td>FH</td>
<td>Federal Hall</td>
</tr>
<tr>
<td>GR</td>
<td>Gray Hall</td>
</tr>
<tr>
<td>HA</td>
<td>Hamilton</td>
</tr>
<tr>
<td>HF</td>
<td>Hockey Field</td>
</tr>
<tr>
<td>HH</td>
<td>Hughes Hall</td>
</tr>
<tr>
<td>HU</td>
<td>Hurst</td>
</tr>
<tr>
<td>KA</td>
<td>Katzen Art Center</td>
</tr>
<tr>
<td>KB</td>
<td>Kogod School of Business</td>
</tr>
<tr>
<td>KR</td>
<td>Kreeger</td>
</tr>
<tr>
<td>KS</td>
<td>Kay Spiritual Life Ctr.</td>
</tr>
<tr>
<td>LTH</td>
<td>Letts Hall</td>
</tr>
<tr>
<td>LH</td>
<td>Leonard Hall</td>
</tr>
<tr>
<td>MCB</td>
<td>McCabe</td>
</tr>
<tr>
<td>MGC</td>
<td>Mary Graydon Center</td>
</tr>
<tr>
<td>MH</td>
<td>McDowell Hall</td>
</tr>
<tr>
<td>MK</td>
<td>McKinley</td>
</tr>
<tr>
<td>MPF</td>
<td>Multi-Purpose Field</td>
</tr>
<tr>
<td>MS</td>
<td>Tenley Maintenance Shop</td>
</tr>
</tbody>
</table>
### 2.16 SYSTEM NAME LIST

1. **AHU#;** Air Handling Unit
2. **AHA#;** Animal Holding Area Systems Points
3. **ALN#;** Automation Level Network
4. **AQA#;** Aquatics Animal Holding Areas
5. **BLR#;** Boiler System
6. **BLDG#;** Building Systems
7. **BLN#;** Building Level Network
8. **BSL#;** Biohazard Labs Systems
9. **CAIR#;** Control Air System
10. **CAV#;** Constant Air Volume Terminal Box Control Systems
11. **CHL#;** Chiller System
12. **CHW#;** Chill Water System
13. **COR#;** Corridor/Hallway Control Points
14. **CLT#;** Cooling Tower System
15. **CLG#;** Cooling Plant System
16. **COLD#;** Cold Room or Laboratory Refrigerator System Points
17. **CW#;** Condenser Water System
18. **CGW#;** Cage Wash Systems
19. **CSG#;** Clean Steam Generation Systems
20. **CND#;** Condensate Pump Systems
21. **CVD#;** Domestic Hot Water with Converter Systems
22. **CVH#;** Heating Converter System
23. CVR#: Radiation Converter System
24. CVG#: Glycol Converter Preheat System
25. DX#: Direct Expansion Systems
26. DCW#: Domestic Cold Water Systems
27. DHW#: Domestic Hot Water System without Converter Systems (Electric)
28. EF#: Exhaust Fan
29. EXH#: Exhaust Fan Systems (# is a number; used in multiple fans to a common plenum)
30. EMG#: Emergency Generator System
31. FCU#: Fan Coil Units
32. FAN#: Miscellaneous and General Purpose Fans
33. FIR#: Fire Alarm System
34. FLN#: Floor Level Network
35. FRM#: Fermentation Exhaust Systems
36. FUL#: Fuel Oil System
37. FUM#: Fume Hood Control Points
38. HTR#: Unit Heaters, Cabinet Heaters, Duct Heaters, Gas Fired Heaters
39. HOT#: Hot Room System Points
40. HRC#: Heat Recovery Systems
41. HX#: Heat Exchanger System
42. ISO#: Infectious Isolation Systems
43. INTR#: Interstitial Space Control Points (Where # indicates floor, room, or zone)
44. KW#: Electric and Electric Metering Systems
45. LAB#: Laboratory Area Control Points
46. LABAIR#: Laboratory Compressed Air Systems
47. LABGAS#: Laboratory Gas Systems (Use gas type in device name)
48. MER#: Mechanical Equipment Room Systems
49. MEDGAS#: Medical Gas Systems (Use gas type in device name)
50. PNL#: Siemens Field Panel Resident Objects (# is the panel number, all panels shall have a number)
51. OR#: Surgical Operating Rooms
52. RM#: Room Objects (Where # is the room number)
53. RSR#: Duct/ Pipe Riser Objects (Where # is the Riser number)
54. RO#: Reverse Osmosis Systems
55. SAS#: Supply Air Systems (# is a number; used in multiple fans to a common plenum)
56. SUMP#: Sump Pump Systems
57. ATS#: Transfer Switch Systems
58. TNK#: Tank Systems
59. VACAIR#: Vacuum Compressed Air Systems
60. VAV#: Variable Air Volume Terminal Box Control Systems
61. VIR#: Virology System Points (where # is system number)
62. ZN#: Zone Systems

2.17 DEVICENAME LIST

A. General List

1. ALARM#: ALARM
2. ALN#: AUTOMATION LEVEL NETWORK
3. AMP#: AMPERAGE
4. AVG#: AVERAGE
5. AFM#: AIR FLOW METERING DEVICES
6. BYP#: BYPASS DEVICES
7. BRG#: BEARINGS
8. BLN#: BUILDING LEVEL NETWORK
9. BELL#: HORNS AND BELLS
10. CFM#: CUBIC FEET PER MINUTE
11. CD#: COLDDECK
12. CHW#: CHILL WATER DEVICES
13. CLG#: COOLING DEVICES
14. CLN#: CLEAN DEVICES (e.g. Cage washes)
15. CO#: CARBON MONOXIDE
16. COND#: CONDUCTIVITY
17. CO2#: CARBON DIOXIDE
18. CW#: CONDENSER WATER DEVICES
19. D#: DISSOLVED (To Be Used with Gases)
20. DAY#: DAILY
21. DEHUM#: DEHUMIDIFIER DEVICES
22. DD#: DOWN DUCT DEVICES
23. DP#: DIFFERENTIAL PRESSURE DEVICES
24. DA#: DISCHARGE AIR DEVICES
25. DEWPT#: DEWPOINT
26. DMPR#: DAMPER
27. DTY#: DIRTY DEVICES (e.g. Cage washes)
28. EAST#: EAST
29. ENT#: ENTHALPY
30. EP#: ELECTRIC/PNEUMATIC COIL
31. ETO#: ETHYLENE OXIDE
32. EXH#: EXHAUST DEVICES
33. ECON#: ECONOMIZER DEVICES
34. EMER#: EMERGENCY DEVICES
35. ESW#: END SWITCH
36. EH#: ELECTRIC HEAT DEVICES
37. ENABLE#: ENABLE/DISABLE Points (NOT Based on a Schedule)
38. FAULT#; FAULT
39. FAST#; FAST SPEED
40. FB#; FACE BYPASS
41. FF#; FINAL FILTER STATUS (use State Text)
42. FS#; HIGH LIMIT SUPPLY
43. FR#; HIGH LIMIT RETURN
44. FZ#; LOW LIMIT
45. FLR#; FLOOR SPECIFICATION (Where # is B3, B2, B1, 1….10, 11…, PH)
46. FLN#; FLOOR LEVEL NETWORK
47. FLO#; FLOW
48. FUM#; FUME HOOD CONTROLLER
49. GPM#; GALLONS PER MINUTE
50. H2#; HYDROGEN
51. HE#; HELIUM
52. HOA#; HAND-OFF-AUTO (Use state text)
53. HP#; HIGH PRESSURE DEVICES
54. HD#; HOTDECK DEVICES
55. HW#; HOT WATER DEVICES
56. HR#; HOURLY
57. HUM#; HUMIDITY DEVICES
58. HTRC#; HEAT TRACE TAPE
59. HOUR#; TIME HOURS
60. HI#; HIGH
61. ISO#; ISOLATION DEVICES
62. LOW#; LOW
63. LVL#; LEVEL INDICATION
64. LL#; LEAD/LAG TOGGLE (Use Lenumerator)
65. LIT#; LIGHTS
66. LPO#; LOOP OUTPUT
67. LOAD#; LOAD (Used for Chillers, Electrical…)
68. LOC#; LOCAL CONTROL POINT (Use Panel System Name & PPCL-Local Statement)
69. LRC#; LABORATORY ROOM CONTROLLER
70. LCN#; LOCATION (EG PANEL RESIDENCE)
71. MA#; MIXED AIR DEVICES
72. METR#; METERS (FLOW, KW)
73. MED#; MEDIUM OR MEDIAN
74. MODE#; Reserved for Operating Modes and Enhanced Alarming
75. MON#; MONTHLY
76. MIN#; MINIMUM
77. MAX#; MAXIMUM
78. NORTH#; NORTH
79. N2#; NITROGEN
80. O2#; OXYGEN
81. OA#; OUTSIDE AIR DEVICES
82. OCC#; OCCUPANCY (Based on a Schedule)
83. ON#; ON
84. OFF#; OFF
85. OVLD#; OVERLOAD DEVICES
86. OVRD#; OVERIDE DEVICES
87. PMP#; PUMP DEVICES OR NUMBER
88. PF#; PREFILTER DEVICES (use State Text)
89. PPM#; PARTS PER MILLION
90. PSI#; PRESSURE
91. POS#; POSITION
92. PCT#; PERCENT
93. PRI#; PRIMARY
94. PRF#; PROOF
95. PRC#; PRESSURIZED ROOM CONTROLLER
96. PHT#; PREHEAT DEVICES
97. PH#; ACID/BASE LEVEL
98. PPCL; Pwr Process Control Language (See Special Cases section)
99. PWR#; POWER
100. PWRFAIL#; ON POWER RETURN POWERFAIL POINT FOR PANELS
101. RCL#; RECOOL DEVICES
102. RHT#; REHEAT DEVICES
103. RA#; RETURN AIR DEVICES
104. RAF#; RETURN AIR FAN (SUPPLY/RETURN SYSTEMS ONLY)
105. R#; RETURN DEVICES
106. RPC#; ROOM PRESSURIZATION CONTROLLER
107. RPM#; REVOLUTIONS PER MINUTE
108. RESET#; RESET (COMMAND ONLY)
109. SAF#; SUPPLY AIR FAN (SUPPLY/RETURN SYS ONLY)
110. SEC#; SECONDS (Counters for program control)
111. SP#; STATIC PRESSURE (Where # is for multiple sensors)
112. SIG#; SIGNAL
113. STAT#; STATUS
114. S#; SUPPLY DEVICES
115. SS#; START/STOP
116. SEAS#; SUMMER/WINTER OR SEASON POINT
117. SMK#; SMOKE CONTROL DEVICES
118. SOUTH#; SOUTH
119. START#; START (COMMAND ONLY)
120. STOP#; STOP (COMMAND ONLY)
121. STBY#; STANDBY DEVICES
122. STPT#; SET POINT (Used as a suffix to any other device name)
123. STM#; STEAM DEVICES
124. TEC#; TERMINAL EQUIPMENT CONTROLLER
125. TEMP#; TEMPERATURE
126. TIME#; TIME CONTROL UNIT
127. TRAQ#; AHU TRACK DRIVE
128. TECUP#; TEC UPDATE TRIGGER (used with MBC system name)
129. TOT#; TOTALIZED VALUE OR TOTAL
130. VEN#; VENTURI
131. VP#; VELOCITY PRESSURE
132. VFD#; VARIABLE FREQUENCY DRIVE OUTPUT SIGNAL
133. VTX#; VORTEX
134. VLV#; VALVE
135. WEST#; WEST
136. WD#; WATER DETECTOR
137. #; NUMBERS
138. ZN#; ZONE

B. Animal Holding Areas
   1. RMHUM#; ROOM EXHAUST HUMIDITY
   2. DAHUM#; DISCHARGE HUMIDITY
   3. EXHCFM#; EXHAUST CFM
   4. DACFM#; DISCHARGE CFM
   5. RMTEMP #; ROOM EXHAUST TEMPERATURE
   6. AIRX#; AIR CHANGES
   7. LITPRF#; LIGHT PROOF (Photo Cell)
   8. LITON#; LIGHT ON TIME
   9. LITOFF#; LIGHT OFF TIME
  10. LIT#; LIGHTS (Command)
  11. RMSTPT#; TEMPERATURE SETPT
  12. HUMSTPT#; HUMIDITY SETPT

2.18 SPECIAL CASES

A. **Network Naming Conventions**
   1. All MLN, ALN’s, FLN’s and BLN’s will follow the object naming convention.
   2. The Siemens System Name for the ALN shall be as follows;
      a) CAMPUSNAME.BUILDINGCODE.ALN#
   3. All Networks shall have a full English Language description defined in Apogee.

B. **Siemens Program (PPCL) Naming Convention**
1. PPCL naming shall STRICTLY follow the object naming.
2. All PPCL names shall be of the format convention;
   a) PANELNAME.PPCL
   b) PANELNAME is defined below and will be strictly adhered to.

C. Field Panel Naming Convention
1. Field Panels shall always be Ethernet connected devices to the FCE provided WAN/LAN.
2. The HostName and IP parameters of the device on the TCP/IP network shall be provided by the FCE IT Department. See the General BAS Specification for details.
3. The Siemens System Name for the Field Panel shall follow the object naming standard as follows with the except of limited to 25 characters;
   a) CAMPUSNAME.BUILDINGNAME.RM#.PNL#
   b) RM# can also be MER# if the panel is located in a Mechanical Space as opposed to a Room with a number.

D. Terminal Equipment Controllers Naming Convention
1. All TEC equipment types (air boxes, fume hoods, lab controllers, etc. essentially all devices that reside on a floor level network) shall follow the object naming convention as detailed herein.

E. Graphic Naming Convention
1. All graphic names shall follow the object naming convention.
2. SYSTEMNAME is equal to the SYSTEMNAME used by the majority of the objects the graphic contains.
3. All background graphic files shall be named as follows;
   a) CAMPUSNAME.BUILDINGNAME.SYSTEMNAME.dsf
4. All Dynamic Graphics shall be named as follows, where (?) is variable;
   a) CAMPUSNAME.BUILDINGNAME.SYSTEMNAME.?.GRA
5. It is worthy to note here; the name of the graphic is not the name that Siemens would necessarily use when linking to the graphic as defined in the graphic specification of the Master BAS Specification. Graphic linking shall be descriptive and easily navigated.

F. Report Naming Convention
1. All reports created by Siemens shall follow the object naming convention
2. All reports shall be named as follows, where (?) is variable;
   a) CAMPUSNAME.BUILDINGNAME.SYSTEMNAME.?.RPT

G. Zone and Event Naming Convention
1. All zones and events created by Siemens shall follow the object naming convention
2. All zones and events shall be named as follows;
   a) CAMPUSNAME.BUILDINGNAME.SYSTEMNAME.ZN#
   b) CAMPUSNAME.BUILDINGNAME.SYSTEMNAME.EV#

H. General: Name points consistently across all AU facilities. Contractor shall configure the systems from the perspective of the entire AU BAS network, not solely the local project. The following requirement establishes a standard for naming points and
addressing Buildings, Networks, Devices, and the like. The convention shall be implemented as much as practical, and any deviations from this naming convention shall be pre-approved by AU. Contractor must obtain the latest System Point Name and Building numbering documents prior to developing their point summary table. See BAS Standard Point List Drawings for point name details.

I. **Point Summary Table**

1. The term ‘Point’ is a generic description for the class of object represented by analog and binary inputs, outputs, and values.

2. With each schematic, Contractor shall provide a Point Summary Table listing:
   a) Building number and abbreviation
   b) System type
   c) Equipment type
   d) Point suffix
   e) Full point name (see Point Naming Convention paragraph)
   f) Point description
   g) Network number
   h) Engineering units.

3. Point Summary Table shall be provided in electronic format (ODBC-compliant).

4. Point Summary Table shall illustrate Network Variables and Data Link Bindings.

5. The BAS Contractor shall coordinate with AU and compile and submit a proposed Point Summary Table for review prior to any object programming or project startup.

6. The Point Summary Table shall be kept current throughout the duration of the project by the Contractor as the Master List of all points for the project. Project closeout documents shall include an up-to-date Point Summary Table. The Point Summary Table shall be used as a reference and guide during the commissioning process.

7. The Point Summary Table shall contain all data fields on a single row per point. The Point Summary Table is to have a single master source for all point information in the building that is easily sorted and kept up-to-date. The point description shall be an easily understandable English-language description of the point.

J. **Point Naming Convention**

1. All point names shall adhere to the established format. Said objects shall include all physical I/O points, calculated points used for standard reports, and all application program parameters.

2. AU has designated the Building codes in the above table. The System descriptor shall further define the object in terms of air handling, cooling, heating, or other system. The Equipment descriptor shall define the equipment category; e.g., Chiller, Air Handler, or other equipment. The Point descriptor shall define the hardware or software type or function associated with the equipment; e.g., supply temperature, water pressure, alarm, mixed air temperature setpoint, etc. and shall
contain any numbering conventions for multiples of equipment; e.g., CHLR1KW (Chiller 1 kW), CHLR2KW (Chiller 2 kW), BLR2AL (Boiler 2 Alarm), HWP1ST (Hot Water Pump 1 Status).

3. Examples: Within each object name, the descriptors shall be bound by a period. Within each descriptor, words shall not be separated by spaces as follows:
   a) Main.HUR.First.COOLING.CHILLER.CHWP1ST
   b) Main.KOG.Pent.AIRHANDLING.AHU8.SAT

See BAS Standard Drawing Point Lists for additional examples.

K. Device Addressing Convention:
   1. All assignment of network numbers shall be coordinated with AU.
   2. Each Network number shall be unique throughout all facilities.
   3. The BAS Contractor shall coordinate with AU to ensure that no duplicate Device Object IDs occur.
   4. Alternative Device ID schemes or cross project Device ID duplication if allowed shall be approved before project commencement by AU.

2.19 OPERATOR INTERFACE GRAPHIC SOFTWARE

A. Graphic software shall facilitate user-friendly interface to all aspects of the System Software specified above. The intent of this specification is to require a graphic package that provides for intuitive operation of the systems without extensive training and experience. It shall facilitate logical and simple system interrogation, modification, configuration, and diagnosis.

B. Graphic software shall provide for multitasking such that third party programs can be used while the Operator Workstation Software is on line. Provide the ability to alarm graphically even when operator is in another software package.

C. The software shall allow for Owner creation of user defined, color graphic displays of geographic maps, building plans, floor plans, and mechanical and electrical system schematics. These graphics shall be capable of displaying all point information from the database including any attributes associated with each point (e.g., engineering units, etc.). In addition, operators shall be able to command equipment or change setpoints from a graphic through the use of the mouse.

D. Screen Penetration: The operator interface shall allow users to access the various system graphic screens via a graphical penetration scheme by using the mouse to select from menus or “button” icons. Each graphic screen shall be capable of having a unique list of other graphic screens that are directly “linked” through the selection of a menu item or button icon.

E. Dynamic Data Displays: Dynamic physical point values shall automatically be updated at a minimum frequency of 5 updates per minute without operator intervention. Point value fields shall be displayed with a color code depicting normal, abnormal, override and alarm conditions.

F. Point Override Feature: Each displayed point shall be individually enabled/disabled to allow mouse driven override of digital points or changing of analog points. Such overrides or changes shall occur in the control unit, not just in the workstation software. The graphic point override feature shall be subject to password level protection. Points that are overridden shall be reported as an alarm, and shall be displayed in a coded
color. The alarm message shall include the operator’s user name. A list of points that are currently in an override state shall be available through menu selection.

G. **Dynamic Symbols**: Provide a selection of standard symbols that change in appearance based on the value of an associated point.

1. Analog symbol: Provide a symbol that represents the value of an analog point as the length of a line or linear bar.

2. Digital symbol: Provide symbols such as switches, pilot lights, rotating fan wheels, etc. to represent the value of digital input and output points.

3. Point Status Color: Graphic presentations shall indicate different colors for different point statuses (e.g. green = normal, red = alarm, gray = non-response).

H. **Graphics Definition Package**: Graphic generation software shall be provided to allow the user to add, modify, or delete system graphic displays.

1. The contractor shall provide libraries of pre-engineered screens and symbols depicting standard air handling unit components (e.g. fans, cooling coils, filters, dampers, etc.), mechanical system components (e.g., pumps, chillers, cooling towers, boilers, etc.), complete mechanical systems (e.g. constant volume-terminal reheat, VAV, etc.) and electrical symbols. At a minimum provide all symbols used by the graphics required by this solicitation.

2. The graphic development package shall use a mouse, touch or similar pointing device to allow the user to perform the following:
   
   a) Define symbols.
   
   b) Position items on graphic screens.
   
   c) Attach physical or virtual points to a graphic.
   
   d) Define background screens.
   
   e) Define connecting lines and curves.
   
   f) Locate, orient and size descriptive text.
   
   g) Define and display colors for all elements.
   
   h) Establish correlation between symbols or text and associated system points or other displays.
   
   i) Create hot spots or link triggers to other graphic displays or other functions in the software.

**PART III. EXECUTION**

3.01 **SYSTEM CONFIGURATION**

A. Contractor shall thoroughly and completely configure BAS system software, supplemental software, network communications, CSS, OWS, portable operators terminal and remote communications.

3.02 **SITE SPECIFIC APPLICATION PROGRAMMING**

A. Provide all database creation and site-specific application control programming as required by these specifications, national and local standards and for a fully functioning system. Contractor shall provide all initial site-specific application programming and thoroughly document programming. Generally meet the intent of the written sequences
of operation. It is Contractor’s responsibility to request clarification on sequence issues that require such clarification.

B. All site specific programming shall be fully documented and submitted for review and approval, both prior to downloading into the panel, at the completion of functional performance testing, and at the end of the warranty period.

3.03 PASSWORD SETUP

A. Set up the following password levels to include the specified capabilities. The following are general minimum guidelines and will be more fully specified after award:

1. Level 1: (University’s BAS Administrator)
   a) Level 2 capabilities.
   b) View, add, change and delete user names, passwords, password levels.
   c) All unrestricted system capabilities including all network management functions.

2. Level 2: (Programmer)
   a) Level 3 capabilities.
   b) Configure system software.
   c) Modify control unit programs.
   d) Modify graphic software.
   e) Essentially unrestricted except for viewing or modifying user names, passwords, password levels.

3. Level 3: (Senior HVAC Technician)
   a) Level 4 capabilities.
   b) Override output points.
   c) Change setpoints.
   d) Change equipment schedules.
   e) Exit BAS software to use third party programs.

4. Level 4: (Junior HVAC Technician)
   a) Level 5 capabilities.
   b) Acknowledge alarms.
   c) Temporarily override equipment schedules.

5. Level 5: (Read Only)
   a) Display all graphic data.
   b) Trend point data.

B. Assist the University’s operators with assigning user names, passwords and password levels.

3.04 POINT PARAMETERS

A. Provide the following minimum programming for each analog input:

1. Name.
2. Address.
3. Scanning frequency or COV threshold.
4. Engineering units.
5. Offset calibration and scaling factor for engineering units.
6. High and low alarm values and alarm differentials for return to normal condition.
7. High and low value reporting limits (reasonableness values) which shall prevent control logic from using shorted or open circuit values.
8. Default value to be used when the actual measured value is not reporting. This is required only for points that are transferred across the primary and/or secondary networks and used in control programs residing in control units other than the one in which the point resides. Events causing the default value to be used shall include failure of the control unit in which the point resides, or failure of any network over which the point value is transferred.
9. Selectable averaging function which shall average the measured value over a user-selected number of scans for reporting.

B. Provide the following minimum programming for each analog output:
   1. Name.
   2. Address.
   3. Output updating frequency.
   4. Engineering units.
   5. Offset calibration and scaling factor for engineering units.
   6. Output Range.
   7. Default value to be used when the normal controlling value is not reporting.

C. Provide the following minimum programming for each digital input:
   1. Name.
   2. Address.
   3. Scanning frequency.
   4. Engineering units (on/off, open/closed, freeze/normal, etc.).
   5. Debounce time delay.
   6. Message and alarm reporting as specified.
   7. Reporting of each change of state, and memory storage of the time of the last change of state.
   8. Totalization of run (on) time (for all motorized equipment status points), and accumulated number of off-to-on transitions.

D. Provide the following minimum programming for each digital output:
   1. Name.
   2. Address.
   3. Output updating frequency.
   4. Engineering units (on/off, open/closed, freeze/normal, etc.).
   5. Direct or Reverse action selection.
   6. Minimum on time.
   7. Minimum off time.
   8. Status association with a DI and failure alarming (as applicable).
   9. Reporting of each change of state, and memory storage of the time of the last change of state.
10. Totalization of run (on) time (for all motorized equipment status points), and accumulated number of off-to-on transitions.

11. Default value to be used when the normal controlling value is not reporting.

**3.05 ALARMS**

**A. Alarm Priority Levels:** Alarm messages specified throughout Section “Sequence of Operation” shall be assigned to a priority level. Level 1 is the most critical. Level 5 is the least critical. Unless otherwise specified, alarm messages shall be assigned to priority level 5. Return to normal conditions for all alarms shall be reported at the same priority level.

**B. Override alarms:** Any point that is overridden through the override feature of the graphic workstation software shall be reported as a Level 3 alarm.

**C. Analog Input Alarms:** For each analog input, program an alarm message for reporting whenever the analog value is outside of the programmed alarm limits. Report a return to normal message after the analog value returns to the normal range, using a programmed alarm differential and an adjustable time delay. The alarm limits shall be individually selected by the contractor based on the following criteria:

1. Space temperature, except as otherwise stated in sequence of operation: (Level 3)
   a) Low alarm: 55°F.
   b) Low return to normal: 58°F.
   c) High alarm: 85°F.
   d) High return to normal: 80°F.

2. Controlled media temperature other than space temperature (e.g. AHU discharge air temperature, converter leaving water temperature, condenser water supply, chilled water supply): If controlled media temperature setpoint is reset, alarm setpoints shall be programmed to follow setpoint (Level 3)
   a) Low alarm: 5°F below setpoint.
   b) Low return to normal: 3°F below setpoint.
   c) High alarm: 5°F above setpoint.
   d) High return to normal: 3°F above setpoint.

3. AHU mixed air temperature (Level 4)
   a) Low alarm: 45°F.
   b) Low return to normal: 46°F.
   c) High alarm: 90°F.
   d) High return to normal: 87°F.

4. Duct Pressure:
   a) Low alarm: 0.5” w.g. below setpoint.
   b) Low return to normal: 0.25” w.g. below setpoint.
   c) High alarm: 0.5” w.g. above setpoint.
   d) High return to normal: 0.25” w.g. above setpoint.

5. Air quality CO2:
   a) Low alarm: 300 ppm.
   b) Low return to normal: 350 ppm.
c) High alarm: 1,300 ppm.

d) High return to normal: 1,000 ppm.

D. **HOA Switch Tampering Alarms:** The sequences of operation are based on the presumption that motor starter Hand-Off-Auto (HOA) switches are in the auto position. If a motorized equipment unit starts without a prior start command from the BAS, (as sensed by status sensing device), then BAS shall perform the remaining sequence as specified. BAS shall also enunciate the following Level 5 alarm message if status indicates a unit is operational when the run command is not present:

1. **DEVICE XXXX FAILURE:** Status is indicated on the device even though it has been commanded to stop. Check the HOA switch, control relay, status-sensing device, contactors, etc. involved in starting the unit. Acknowledge this alarm when the problem has been corrected.

E. **Maintenance Alarms:** Enunciate Level 5 alarms when runtime accumulation exceeds a value specified by the operator.

1. **DEVICE XXXX REQUIRES MAINTENANCE:** Run time has exceeded specified value since last reset.

F. **Filter Maintenance Alarms:** Enunciate Level 5 alarms when filter differential pressure exceeds a value specified by the operator.

1. **FILTER XXXX REQUIRES CHANGING:** Pressure drop has exceeded specified loaded value.

G. See requirements for additional equipment-specific alarms specified in Section “Sequence of Operation.”

### 3.06 SITE SPECIFIC TRENDING

A. Establish trends of the following values:

1. All inputs.
2. All outputs.
3. Outside Air Enthalpy.
4. Calculated airflows where there are airflow measuring stations (provide in lieu of the sensed input velocity pressure).
5. Return Air Enthalpy where temperature and humidity are sensed.

B. For each system, default trend templates shall be developed for each primary control variable and setpoint. The template shall display this data graphical with a common time base. Operator shall be able to select hourly, daily and weekly time base formats.

C. See requirements for additional trends specified in Section “Sequence of Operation.”

D. See additional trending requirements for commissioning purposes specified in Section “BAS Commissioning.”

### 3.07 GRAPHIC SCREENS

A. **Floor Plan Screens:** The contract document drawings will be made available to the contractor in AutoCAD format upon request. These drawings may be used only for developing backgrounds for specified graphic screens; however the Owner does not guarantee the suitability of these drawings for the contractor’s purpose.

1. Provide graphic floor plan screens for each floor, wing, etc. of the building. Indicate the location of all equipment that is not located on the equipment room screens. Indicate the location of temperature sensors associated with each
temperature-controlled zone (i.e., VAV terminals, fan-coils, single-zone AHU’s etc.) on the floor plan screens. Alternatively, change zone background color based on the temperature offset from setpoint. Display the space temperature point adjacent to each temperature sensor symbol. Use a distinct line symbol to demarcate each terminal unit zone boundary. Use distinct colors to demarcate each air handling unit zone. Mechanical floor plan drawings will be made available to the contractor upon request for the purpose of determining zone boundaries. Indicate room numbers as provided by the University. Provide a drawing link from each space temperature sensor symbol and equipment symbol shown on the graphic floor plan screens to each corresponding equipment schematic graphic screen.

2. Provide graphic floor plan screens for each mechanical equipment room and a plan screen of the roof. Indicate the location of each item of mechanical equipment. Provide a drawing link from each equipment symbol shown on the graphic plan view screen to each corresponding mechanical system schematic graphic screen.

3. If multiple floor plans are necessary to show all areas, provide a graphic building key plan. Use elevation views and/or plan views as necessary to graphically indicate the location of all of the larger scale floor plans. Link graphic building key plan to larger scale partial floor plans. Provide links from each larger scale graphic floor plan screen to the building key plan and to each of the other graphic floor plan screens.

4. Provide a graphic site plan with links to and from each building plan.

B. System Schematic Screens: Provide graphic system schematic screen for each HVAC subsystem controlled, with each I/O point in the project appearing on at least one graphic screen. System graphics shall include flow diagrams with status, setpoints, current analog input and output values, operator commands, etc. as applicable. General layout of the system shall be schematically correct. Input/output devices shall be shown in their schematically correct locations. Include appropriate engineering units for each displayed point value. Verbose names (English language descriptors) shall be included for each point on all graphics; this may be accomplished by the use of a pop-up window accessed by selecting the displayed point with the mouse. Indicate all adjustable setpoints on the applicable system schematic graphic screen or, if space does not allow, on a supplemental linked setpoint screen. Include a link from each system graphic to the as-built sequence of operation for that system.

1. Provide graphic screens for each air handling system. Indicate outside air temperature and enthalpy, and mode of operation as applicable (i.e., occupied, unoccupied, warm-up, cool-down). Link screens for air handlers to the heating system and cooling system graphics. Link screens for supply and exhaust systems if they are not combined onto one screen. Include external links to sequence of operations, as-built control drawing, as-built electrical schematic and approved shop drawings.

2. Provide a graphic screen for each terminal unit. In addition to points associated with the unit, indicate mode of operation as applicable (i.e., normal occupied, unoccupied, warm-up, maximum heating, maximum cooling). Provide links between the applicable floor plan screen and this screen. Provide links to the associated graphic air handling unit screen.

3. Provide a cooling system graphic screen showing all points associated with the chillers, cooling towers and pumps. Indicate outside air dry-bulb temperature and calculated wet-bulb temperature. The cooling plant graphic screen shall display
the supervisory messages for start/stop of lead and lag chillers (see sequences of operation). After the recommended chiller start or stop sequence has been manually initiated (from the graphic screen), and registered at the field panel, the message shall be removed from the graphic screen. Link the cooling plant graphic screen to the supervisory chiller start/stop messages so that the screen appears automatically whenever a chiller supervisory start or stop message is reported. Link screens for chilled water and condenser water systems if they cannot fit onto one cooling plant graphic screen.

4. Provide a heating system graphic screen showing all points associated with the heat exchangers and pumps. Indicate outside air dry-bulb temperature and relative humidity.

5. Link screens for heating and cooling system graphics to utility history reports showing current and monthly electric uses, demands, peak values, etc.

C. **Alarms:** Each programmed alarm shall appear on at least one graphic screen. In general, alarms shall be displayed on the graphic system schematic screen for the system that the alarm is associated with (e.g., chiller alarm shall be shown on graphic cooling system schematic screen). For all graphic screens, display analog values that are in a “high alarm” condition in a red color, “low alarm” condition in a blue color. Indicate digital values that are in alarm condition in a red color.

**END OF SECTION**
SECTION 25 3500 - BAS BASIC MATERIALS AND DEVICES

INSTRUCTIONS FOR USE AND MODIFICATION

COMMENTS THAT REQUIRE MODIFICATION ARE ITALICIZED AND BLUE.
1. WHEN EDITING IS COMPLETE, DELETE THIS BLOCK AND SAVE THE FILE AS A NEW NAME
2. THIS SECTION IS SPECIFIC TO THE AU STANDARDS. ALL CHANGES AND VARIANCES MUST BE APPROVED BY AU.

PART I. GENERAL ................................................................................................................................................. 2
1.01 SECTION INCLUDES ........................................................................................................................................ 2
1.02 RELATED DOCUMENTS ............................................................................................................................ 2
1.03 DESCRIPTION OF WORK ......................................................................................................................... 2
1.04 WORK BY OTHERS .................................................................................................................................. 3

PART II. PRODUCTS ............................................................................................................................................. 3
2.01 MATERIALS AND EQUIPMENT ................................................................................................................... 3
2.02 CONTROL VALVES .................................................................................................................................. 4
2.03 CONTROL DAMPERS .................................................................................................................................. 7
2.04 ACTUATORS ............................................................................................................................................... 10
2.05 GENERAL FIELD DEVICES ...................................................................................................................... 11
2.06 TEMPERATURE SENSORS (TS) ................................................................................................................ 12
2.07 TEMPERATURE TRANSMITTERS ............................................................................................................... 13
2.08 HUMIDITY TRANSMITTERS (H) ............................................................................................................... 13
2.09 DIFFERENTIAL PRESSURE TRANSMITTERS (DP) .................................................................................. 13
2.10 VALVE BYPASS FOR DIFFERENTIAL PRESSURE SENSORS ................................................................ 14
2.11 DIFFERENTIAL PRESSURE SWITCHES (DPS) ....................................................................................... 14
2.12 PRESSURE SWITCHES (PS) ...................................................................................................................... 15
2.13 TRANSDUCERS ........................................................................................................................................ 15
2.14 CURRENT SWITCHES ............................................................................................................................... 15
2.15 CURRENT TRANSFORMERS (CT) .............................................................................................................. 15
2.16 OUTDOOR AIR STATIC PRESSURE SENSING TIP ............................................................................... 16
2.17 CONTINUOUS LEVEL TRANSMITTERS .................................................................................................... 16
2.18 FLOW METERS (FMS) ............................................................................................................................. 17
2.19 AIRFLOW MEASURING STATIONS (AFM): ............................................................................................... 17
2.20 AIR VELOCITY PRESSURE SENSORS (INSERTION TYPE) ................................................................. 17
2.21 CO2 SENSORS/TRANSMITTERS (CO2) ................................................................................................. 17
2.22 ELECTRIC CONTROL COMPONENTS ................................................................................................. 18
2.23 REFRIGERANT MONITOR ....................................................................................................................... 19
2.24 NAMEPLATES ......................................................................................................................................... 21
2.25 TESTING EQUIPMENT ........................................................................................................................... 21

PART III. EXECUTION ....................................................................................................................................... 22
3.01 INSPECTION ............................................................................................................................................ 22
3.02 INSTALLATION OF CONTROL SYSTEMS ............................................................................................. 22
3.03 REFRIGERANT MONITORS ....................................................................................................................... 24
3.04 SYSTEM COMMISSIONING AND ACCEPTANCE ...................................................................................... 24
PART I. GENERAL

1.01 SECTION INCLUDES
A. Pneumatic Tubing.
B. Wiring.
C. Control Valves and Actuators.
D. Control Dampers and Actuators.
E. Control Panels.
F. Sensors.
G. Flow Meters.
H. Pneumatic Control Components (Gauges, switches, relays, etc.).
I. Electric Control Components (Switches, EP valves, thermostats, relays, smoke detectors, etc.).
J. Transducers.
L. Current Switches.
M. Nameplates.
N. Testing Equipment.

1.02 RELATED DOCUMENTS
A. Section “Basic Mechanical Requirements”
B. Section “Building Automation System (BAS) General.”
C. Section “BAS Field Panel.”
D. Section “BAS Communication Devices.”
E. Section “BAS Software and Programming.”
F. Section “BAS Commissioning.”

1.03 DESCRIPTION OF WORK
A. Refer to Section “Building Automation System (BAS) General” for general requirements.
B. Refer to other mechanical sections for installation of instrument wells, valve bodies, and dampers in mechanical systems; not work of this section.
C. Provide the following electrical work as work of this section:
   1. Control wiring between field-installed controls, indicating devices, and unit control panels.
   2. Interlock wiring between electrically interlocked devices, sensors, and between a hand or auto position of motor starters as indicated.
   3. Wiring associated with indicating and alarm panels (remote alarm panels) and connections to their associated field devices.
   4. All other necessary wiring for a fully complete and functional control system as specified.
1.04 WORK BY OTHERS

A. New Control Valves furnished under this section shall be installed by others at the direction of BAS Contractor who will be fully responsible for the proper operation of the valves.

B. New Control Dampers furnished under this section shall be installed by others at the direction of BAS Contractor who will be fully responsible for the proper operation of the dampers.

C. Water Pressure Taps, Thermal Wells, Flow Switches, Flow Meters, etc. that will have wet surfaces, shall be installed by others at the direction of the BAS Contractor who will be fully responsible for proper installation and application. Contractor shall specify locations where such devices are to be installed.

D. On control installations for new equipment, controlled equipment power wiring shall be furnished and installed under Division 26. Where control involves 120V control devices controlling 120V equipment, Division 26 Contractor shall extend power wiring to the equipment. BAS Contractor shall extend wiring from the equipment to the control device.

PART II. PRODUCTS

2.01 MATERIALS AND EQUIPMENT

A. General: Provide control products in sizes and capacities indicated, consisting of valves, dampers, thermostats, clocks, controllers, sensors, and other components as required for complete installation. Except as otherwise indicated, provide manufacturer's standard materials and components as published in their product information; designed and constructed as recommended by manufacturer, and as required for application indicated.

B. Communication Wiring: All wiring shall be in accordance with National Electrical Codes and electrical specifications of this project.

1. The University shall supply all network drops to the campus Ethernet.

2. Contractor shall supply all communication wiring between Building Controllers, Routers, Gateways, AAC’s, ASC’s and local and remote devices.

3. Primary and Secondary Controller LANs: Communication wiring shall be individual 100% shielded pairs per manufacturers recommendations for distances installed, with overall PVC cover, Class 2, plenum-rated run with no splices and separate from any other wiring. Shielding shall be terminated and wiring shall be grounded as recommended by BC manufacturer. At the point of exit within any control panel, communication wiring shall be tagged with the destination panel or device ID. All primary communication wiring shall be installed in EMT conduit. Secondary communications wiring shall be installed in EMT conduit unless routed over accessible ceiling spaces. Plenum rated wire used above ceilings will be bundled with wire ties every 24 inches and fastened to the structure or hung through bridle rings at least every 6 feet in a workmanlike manner to avoid a conflict with electrical mechanical or plumbing installations.

C. Signal Wiring: Contractor shall run all signal wiring in accordance with National Electric Codes and electrical specifications of this project.

1. Signal wiring to all field devices, including, but not limited to, all sensors, transducers, transmitters, switches, etc. shall be per manufacturer's requirements.
Signal wiring shall be run with no splices and separate from all other wiring above thirty (30) volts.

D. **Low Voltage Analog Output Wiring:** Contractor shall run all low voltage control wiring in accordance with National Electric Codes and electrical specifications of this project.
   1. Low voltage control wiring shall be per manufacturer’s requirements. Low voltage control wiring shall be run with no splices separate from any wiring above thirty (30) volts.

E. **Control Panels:** Provide control panels with suitable brackets for wall mounting for each control system. Locate panel adjacent to systems served.
   1. Fabricate panels of 16-gage furniture-grade steel, totally enclosed on four sides, with piano hinged door and keyed lock, with manufacturer's standard shop-painted finish and color.
   2. Provide UL-listed cabinets for use with line voltage devices.
   3. Control panel shall be completely factory wired and piped, and all electrical connections made to a terminal strip. Control panel shall have standard manufacturer's color.
   4. All gauges and control components shall be identified by means of nameplates.
   5. All control tubing and wiring shall be run neatly and in an orderly fashion in open slot wiring ducts with cover.
   6. Complete wiring and tubing termination drawings shall be mounted in or adjacent to each panel.

2.02 **CONTROL VALVES**

A. **General:** Provide factory fabricated control valves of type, body material and pressure class indicated. Where type or body material is not indicated, provide selection as determined by manufacturer for installation requirements and pressure class, based on maximum pressure and temperature in piping system. The control valves shall be sized by the controls engineer and shall be guaranteed to meet the heating and cooling loads. Provide valve size in accordance with scheduled or specified maximum pressure drop across control valve. Control valves shall be equipped with heavy-duty actuators, stainless steel trim, and with proper close-off rating for each individual application. Minimum close-off rating shall be as scheduled and adequate for each application, and shall generally be considered at dead head rating of the pump. Control valves used for the primary (from central plant) chilled water system shall have a minimum close-off rating of 100 psi unless otherwise shown or specified and these valves will be Pressure Independent Flow Control Valves. All valves shall be fully modulating unless noted otherwise. Valves shall be sized for quiet operation, be equipped with throttling plugs, stainless steel trim, renewable composition discs and be capable of operating at varying rates of speed to correspond with the exact dictates of the controller. Install with stem within 50 degrees of vertical position in horizontal pipe.

B. **Plug-Type Globe Pattern for Water Service:**
   1. **Valve Sizing:** Modulating valves shall be sized for maximum full flow pressure drop between 50% and 100% of the branch circuits. They are controlling unless scheduled otherwise. Two-position valves shall be same size as connecting piping.
2. **Single Seated (Two-way) Valves**: Equal percentage characteristics for typical heat exchanger service and linear for building loop connections to campus systems unless otherwise scheduled on the drawings. Cage type trim, providing seating and guiding surfaces for plug on "top and bottom" guided plugs.

3. **Double Seated (Three-way) Valves**: Linear characteristics. Balanced plug type, with cage type trim providing seating and guiding surfaces on "top and bottom" guided plugs.

4. **Temperature Rating**: 25°F minimum, 250°F maximum

5. **Body**: Bronze, screwed, 250 psi maximum working pressure for 1/2” to 2”; Cast Iron, flanged, 125 or 175psi maximum working pressure for 2-1/2” and larger as required for project conditions.

6. **Valve Trim**: Bronze; Stem - Polished stainless steel.

7. **Packing**: Spring Loaded Teflon or Synthetic Elastomer U-cups; self-adjusting.

8. **Plug**: Brass, bronze or stainless steel; Seat - Brass

9. **Disc**: Replaceable Composition or Stainless Steel Filled PTFE.

10. **Ambient Operating Temperature Limits**: -10 to 150°F (-12.2 to 66°C)

11. **Acceptable Manufacturers**: Subject to compliance with requirements, approved manufacturers are as follows:
   a) Siemens
   b) Johnson Controls.
   c) Belimo.
   d) Substitutions: As provided under Division 01.

C. **Plug-Type Globe Pattern for Steam Service**:

1. **Valve Sizing**: Modulating valves for applications of 15 psig or less shall be sized for 80% of inlet gage pressure unless scheduled otherwise. Modulating valves for applications of greater than 15 psig shall be sized for 42% of inlet absolute pressure unless scheduled otherwise. Two-position valves shall be same size as connecting piping.

2. **Characteristics**: Linear characteristics. Cage type trim, providing seating and guiding surfaces for plug on "top and bottom" guided plugs.

3. **Temperature Rating**: 250°F maximum for applications of 15 psig or less; 366°F maximum for applications of greater than 15 psig up to 150 psig.

4. **Body**: Bronze, screwed, 250 psig steam maximum working pressure for 1/2” to 2”; Cast Iron, flanged, 100 psig steam maximum working pressure for 2-1/2” and larger for applications of 50 psig or less.

5. **Valve Trim**: Plug, Seat and Stem: Polished stainless steel.

6. **Packing**: Spring Loaded Teflon.

7. **Disc**: Replaceable Composition or Stainless Steel Filled PTFE.

8. **Acceptable Manufacturers**: Subject to compliance with requirements, approved manufacturers are as follows:
   a) Siemens
   b) Johnson Controls.
   c) Belimo.
   d) Substitutions: As provided under Division 01.
D. **Butterfly Type:**
1. **Body:** Extended neck epoxy coated cast or ductile iron with full lug pattern, ANSI Class 125 or 250 bolt pattern to match specified flanges.
2. **Seat:** EPDM.
3. **Disc:** Bronze or stainless steel, pinned or mechanically locked to shaft.
4. **Bearings:** Bronze or stainless steel
5. **Shaft:** 416 stainless steel.
6. **Cold Service Pressure:** 175 psi.
7. **Bubble-tight shutoff to 150 psi.**
8. **Acceptable Manufacturers:** Subject to compliance with requirements, approved manufacturers are as follows:
   a) Siemens.
   b) Bray.
   c) Belimo.
   d) Substitutions: As provided under Division 01.

E. **Ball Type:**
1. **Body:** Brass or Bronze; one, two, or three piece design; threaded ends.
2. **Seat:** Reinforced Teflon.
3. **Ball:** Stainless steel.
4. **Port:** Standard or ‘V’ style.
5. **Stem:** Stainless steel, blow-out proof design, extended to match thickness of insulation.
6. **Cold Service Pressure:** 600 psi WOG.
7. **Steam working Pressure:** 150 psi.
8. **Acceptable Manufacturers:** Subject to compliance with requirements, approved manufacturers are as follows:
   a) Siemens.
   b) Belimo.
   c) **Substitutions:** As provided under Division 01.

F. **Segmented/Characterized Ball Type:**
1. **Body:** Carbon Steel (ASTM 216), one piece design with wafer style ends.
2. **Seat:** Reinforced Teflon (PTFE).
3. **Ball:** Stainless steel ASTM A351.
4. **Port:** Segmented design with equal percentage for typical heat exchanger duty or linear characteristic for building loop connections or where specified.
5. **Stem:** Stainless steel.
6. **Cold Service Pressure:** 200 psi WOG.
7. **Cavitation Trim:** Provide cavitation trim where indicated and/or required, designed to eliminate cavitation and noise while maintaining an equal percentage
characteristic. Trim shall be a series of plates with orifices to break the pressure drop into multiple stages.

8. **Acceptable Manufacturers**: Subject to compliance with requirements, approved manufacturers are as follows:
   a) Siemens.
   b) Belimo.
   c) Substitutions: As provided under Division 01.

G. **Pressure Independent Characterized Control Valve**
   1. **Body**: De-zincificated hot-pressed brass OR forged brass, nickel plated
   2. **Seat**: brass OR PTFE
   3. **Seals**: EPDM 281 OR Viton
   4. **Valve characteristic**: Linear
   5. **Stem**: Stainless steel
   6. **Body pressure rating**: 400 psi
   7. **Acceptable Manufacturers**: Subject to compliance with requirements approved manufacturers are as follows:
      a) Belimo
      b) Siemens
      c) Substitutions: As provided under Division 01.

2.03 **CONTROL DAMPERS**

A. **General**: Provide factory fabricated automatic control dampers of sizes, velocity and pressure classes as required for smooth, stable, and controllable air flow. Provide parallel or opposed blade dampers as indicated on drawings or as recommended by manufacturers sizing techniques. For dampers located near fan outlets, provide dampers rated for fan outlet velocity and close-off pressure, and as recommended by damper manufacturer for fan discharge damper service. Control dampers used for outside air or exhaust air service shall have insulated blades. Control dampers used for smoke dampers shall comply with UL 555S. Control Dampers used for fire dampers shall comply with UL 55. Furnish all automatic control dampers and smoke dampers required except for specific dampers that will be provided by the equipment manufacturers where so noted on Drawings. Coordinate sizes of all dampers with duct sub-contractor prior to ordering and delivery to job site.

B. General Isolation and Modulating Control Service in rectangular ducts at velocities not greater than 1500 fpm (7.62 m/s), differential pressure not greater than 2.5” w.c. (622 Pa):
   1. **Performance**: Test in accordance with AMCA 500.
   2. **Frames**: Galvanized steel, 16 gauge minimum thickness, welded or riveted with corner reinforcement.
   3. **Blades**: Stainless steel in lab exhausts and galvanized steel elsewhere, maximum blade size 8 inches (200 mm) wide by 48 inches (1219 mm) long, attached to minimum 1/2 inch (12.7 mm) shafts with set screws, 16 gauge minimum thickness.
   4. **Blade Seals**: Synthetic elastomer, mechanically attached, field replaceable.
   5. **Jamb Seals**: Stainless steel.
6. **Shaft Bearings**: Oil impregnated sintered bronze, graphite impregnated nylon sleeve or other molded synthetic sleeve, with thrust washers at bearings.
7. **Linkage**: Concealed in frame.
8. **Linkage Bearings**: Graphite impregnated nylon.
9. **Leakage**: Less than one percent based on approach velocity of 1500 ft./min. (7.62 m/s) and 1” w.c. (249 Pa).
10. **Maximum Pressure Differential**: 2.5” w.c. (622 Pa)
11. **Temperature Limits**: -40 to 200 °F (-40 to 93 °C).
12. Where opening size is larger than 48 inches (1219 mm) wide, or 72 inches (1829 mm) high, provide dampers in multiple sections, with appropriately intermediate frames, and jackshafts.

C. General Isolation and Modulating Control Service in rectangular ducts in excess of item B but at velocities not greater than 4000 fpm (20.3 m/s), differential pressure not greater than 6” w.c. (1493 Pa):
1. **Performance**: Test in accordance with AMCA 500.
2. **Frames**: Galvanized steel, 16 gauge minimum thickness, welded or riveted with corner reinforcement.
3. **Blades**: Extruded aluminum hollow airfoil shape, maximum blade size 8 inches (200 mm) wide by 48 inches (1219 mm) long, attached to minimum 1/2 inch (12.7 mm) shafts, 14 gauge minimum extrusion thickness.
4. **Blade Seals**: Synthetic elastomeric, mechanically attached, field replaceable.
5. **Jamb Seals**: Stainless steel.
6. **Shaft Bearings**: Oil impregnated sintered bronze sleeve, graphite impregnated nylon sleeve, molded synthetic sleeve, or stainless steel sleeve, with thrust washers at bearings.
7. **Linkage**: Concealed in frame.
8. **Linkage Bearings**: Oil impregnated sintered bronze or graphite impregnated nylon.
9. **Leakage**: Less than 0.1 percent based on approach velocity of 4000 ft./min. (20.3 m/s) and 1” w.c. (249 Pa).
10. **Maximum Pressure Differential**: 6” w.c. (1493 Pa).
11. **Temperature Limits**: -40 to 200 °F (-40 to 93 °C).
12. Where opening size is larger than 48 inches (1219 mm) wide, or 72 inches (1829 mm) high, provide dampers in multiple sections, with appropriately intermediate frames, and jackshafts.

D. General Isolation and Modulating Control Service in rectangular ducts at velocities in excess of item B but not greater than 4000 fpm, differential pressure in excess of item C but not greater than 12” w.c. (2984 Pa). Provide parallel or opposed blade dampers as indicated on drawings or as recommended by manufacturers sizing techniques, typically for mixing applications. Provide opposed blade dampers as indicated on drawings or as recommended by manufacturers sizing techniques, typically for throttling applications:
1. **Performance**: Test in accordance with AMCA 500.
2. **Frames**: Galvanized steel, 12 gauge minimum thickness, welded or riveted with corner reinforcement.
3. **Blades**: Extruded aluminum hollow airfoil shape, maximum blade size 8 inches (200 mm) wide by 48 inches (1219 mm) long, attached to minimum 3/4 inch (19 mm) shafts with set screws.

4. **Shaft Bearings**: Oil impregnated sintered bronze or stainless steel, pressed into frame, with thrust washers at bearings.

5. **Linkage**: 10 gauge minimum thickness galvanized steel clevis type crank arms, 3\(\frac{1}{16}\)” x 3\(\frac{3}{4}\)” (4.76 mm x 19 mm) minimum thickness tie rods.

6. **Linkage Bearings**: Oil impregnated sintered bronze or graphite impregnated nylon.

7. **Leakage**: Less than 0.2 percent based on approach velocity of 4000 ft./min. (20.3 m/s) and 1” w.c. (249 Pa) differential pressure.

8. **Maximum Pressure Differential**: 12” w.c. (2984 Pa).

9. **Temperature Limits**: -40 to 300 °F (-40 to 149 °C).

10. Where opening size is larger than 48 inches (1219 mm) wide, or 72 inches (1829 mm) high, provide dampers in multiple sections, with appropriately intermediate frames, and jackshafts.

**E. General Isolation and Modulating Control Service in round ducts up to 40 inches in size at velocities not greater than 2500 fpm (12.7 m/s), differential pressure not greater than 4” w.c. (994 Pa):**

1. **Performance**: Test in accordance with AMCA 500.

2. **Frames**: Rolled 12 gauge steel strip for sizes 6 inch and smaller, rolled 14 gauge steel channel for larger sizes; galvanized or aluminum finish.

3. **Blades**: Steel construction, 12 gauge minimum thickness for dampers less than 18 inches (457 mm) in size, 10 gauge minimum thickness for larger dampers.

4. **Blade Seals**: Full circumference neoprene.

5. **Shaft**: ½ inch (12.7 mm) diameter zinc or cadmium plated steel.

6. **Shaft Bearings**: Oil impregnated sintered bronze or stainless steel, pressed into frame, with thrust washers at bearings.

7. **Leakage**: Less than 0.2 percent based on approach velocity of 4000 ft./min. (20.3 m/s) and 1” w.c. (249 Pa) differential pressure.

8. **Maximum Pressure Differential**: 4” w.c. (994 Pa).

9. **Temperature Limits**: -40 to 300 °F (-40 to 149 °C).

**F. General Isolation and Modulating Control Service in round ducts in excess of item E up to 60 inches in size at velocities not greater than 4000 fpm (20.3 m/s), differential pressure not greater than 6” w.c. (1492 Pa):**

1. **Performance**: Test in accordance with AMCA 500.

2. **Frames**: Rolled 10 gauge steel channel for sizes 48 inch and smaller, rolled 3/16 inch (4.76 mm) thick steel channel for larger sizes, galvanized or aluminum finish.

3. **Blades**: Steel construction, 10 gauge minimum thickness for dampers not greater than 48 inches in size, 1/4 inch (6.35 mm) minimum thickness for larger dampers.

4. **Blade stops**: ½ inch x ¼ inch (12.7 mm x 6.35 mm) full circumference steel bar.

5. **Blade Seals**: Full circumference neoprene.

6. **Shaft**: Zinc or cadmium plated steel, with angle reinforcing as necessary.

7. **Shaft Bearings**: Oil impregnated sintered bronze or stainless steel, pressed into frame, with thrust washers at bearings.
8. **Leakage:** Less than 0.4 percent based on approach velocity of 4000 ft./min. (20.3 m/s) and 1” w.c. (249 Pa) differential pressure.

9. **Maximum Pressure Differential:** 6” w.c. (1492 Pa).

10. **Temperature Limits:** -40 to 250 °F (-40 to 121 °C).

### 2.04 ACTUATORS

**A. General:** Size actuators and linkages to operate their appropriate dampers or valves with sufficient reserve torque or force to provide smooth modulating action or 2-position action as specified. Select spring-return actuators with manual override to provide positive shut-off of devices. Actuators relying on batteries for any operation are not acceptable.

**B. Damper Actuators**

1. **Ambient Operating Temperature Limits:** -10 to 150°F (-12.2 to 66 °C).
2. **Two Position Electric Actuators:** Line voltage with spring return.
3. **Pneumatic Actuators:** Provide heavy-duty actuators with stroke indication and spring return. When so indicated, and where more than 2 actuators are to be operated in sequence with each other, provide position feedback positive positioners with adjustable start point and operating range. Also provide positive positioners on all modulating pneumatic valves larger than 1” in variable flow systems.
4. **Electronic Actuators:** Provide actuators for two position (24V), 0-5 VDC, 0-10 VDC, 2-10 VDC, or 4-20 mA input as required. Actuators shall travel full stroke in less than 90 seconds. Actuators shall be designed for a minimum of 60,000 full cycles at full torque and be UL 873 listed. Provide stroke indicator. Actuators shall have positive positioning circuit. Where two actuators are required in parallel or in sequence provide an auxiliary actuator driver. Actuators shall have current limiting motor protection. Actuators shall have manual override where indicated. Modulating valves shall have minimum rangeability of 40 to 1.

   a) **Close Off Pressure:** Provide the minimum torque required, and spring return for fail positioning sized for required close off pressure (unless otherwise specifically indicated). Required close off pressure for water valve applications shall be the shutoff head of associated pump. Required close off rating of steam valve applications shall be design inlet steam pressure. Required close off rating of air damper applications shall be shut off pressure of associated fan.
   
   b) **Acceptable Manufacturers:** Subject to compliance with requirements, approved manufacturers are as follows:

      1) Siemens.
      2) Johnson Controls.
      3) Belimo.
      4) Substitutions: As provided under Division 01.

**C. Quarter turn actuators for ball and butterfly valves:**

1. **Electric:**
   
   a) **Motor:** Suitable for 120 or 240 volt single phase power supply. Insulation shall be NEMA Class F or better. Motor shall be rated for 100 percent duty cycle. Motors shall have inherent overload protection.
b) **Gear Train**: Motor output shall be directed to a self-locking gear drive mechanism. Gears shall be rated for torque input exceeding motor locked rotor torque.

c) **Wiring**: Power and control wiring shall be wired to a terminal strip in the actuator enclosure.

d) **Enclosure**: Actuator Enclosure shall be NEMA 4 rated, and shall have a minimum of two-threaded conduit entries. Provide an enclosure heater for actuators located outside of buildings.

e) **Limit Switches**: Travel limit switches shall be UL and CSA approved. Switches shall limit actuator in both open and closed positions.

f) **Mechanical Travel Stops**: The actuator shall include mechanical travel stops of stainless steel construction to limit actuator to specific degrees of rotation.

g) **Manual override**: Actuators shall have manual actuator override to allow operation of the valve when power is off. For valves 4 inches and smaller the override may be a removable wrench or lever or geared hand wheel type. For larger valves, the override shall be a fixed geared hand wheel type. An automatic power cut off switch shall be provided to disconnect power from the motor when the hand wheel is engaged for manual operation.

h) **Valve position indicator**: A valve position indicator with arrow and open and closed position marks shall be provided to indicate valve position.

i) **Torque Limit Switches**: Provide torque limit switches to interrupt motor power when torque limit is exceeded in either direction of rotation.

j) **Position Controller**: For valves used for modulating control, provide an electronic positioner capable of accepting 4-20 mA, 0-10 VDC, 2-10 VDC, and 135 Ω potentiometer.

k) **Ambient Conditions**: Actuator shall be designed for operation from –140 to 150 °F ambient temperature, with 0-100 percent relative humidity.

### 2.05 GENERAL FIELD DEVICES

A. Provide field devices for input and output of digital (binary) and analog signals into controllers (BCs, AACs, ASCs). Provide signal conditioning for all field devices as recommended by field device manufacturers, and as required for proper operation in the system.

B. It shall be the Contractor's responsibility to assure that all field devices are compatible with CU hardware and software.

C. Field devices specified herein are generally "two-wire" type transmitters, with power for the device expected to be supplied from the respective CU. If 1) the CU provided is not equipped to provide this power, or 2) the CU is not designed to work with "two-wire" type transmitters, or 3) if field device is to serve as input to more than one CU, or 4) the wiring lengths will result in a voltage drop in excess of those recommended by the manufacturer or of that which will allow the accuracies specified, the Contractor shall provide "four-wire" type equal transmitter and necessary regulated DC power supply or 120 VAC power supply, as required.

D. For field devices specified hereinafter that require signal conditioners, signal boosters, signal repeaters, or other devices for proper interface to CUs, Contractor shall furnish and install proper device, including 120V power as required. Such devices shall have accuracy equal to, or better than, the accuracy listed for respective field devices.
E. Accuracy: Shall include combined effects of nonlinearity, non-repeatability and hysteresis.

2.06 TEMPERATURE SENSORS (TS)

A. Sensor range: When matched with A/D converter of PCU or SCU, sensor range shall provide a resolution of no worse than $0.3^\circ F$ ($0.16^\circ C$) (unless noted otherwise). Where thermistors are used, the stability shall be better than $0.25^\circ F$ over 5 years.

B. Matched Sensors: The following applications shall require matched sensors:
   1. Building Loop Connections: Provide matched loop and building supply sensors where control sequence requires controlling to a temperature rise.
   2. Hydronic Temperature Difference Calculations: Provide matched supply and return temperature sensors where the pair is used for calculating temperature difference for use in load calculations or sequencing.

C. Room temperature sensor shall be an element contained within a ventilated cover, suitable for wall mounting. Provide insulated base. The following sensing elements are acceptable:
   1. Sensing element - Platinum RTD, Thermistor, or integrated circuit, $\pm 0.4^\circ F$ accuracy at calibration point.
   2. Provide setpoint adjustment only where indicated. The setpoint adjustment shall be a warmer/cooler indication that shall be scalable via the DDC system
   3. Provide an occupancy override button on the room sensor enclosure where indicated. This shall be a momentary contact closure
   4. Provide current temperature indication via LED readout only where indicated.

D. Single point duct temperature sensor shall consist of sensing element, junction box for wiring connections and gasket to prevent air leakage or vibration noise. Temperature range as required for resolution indicated in paragraph A. Sensor probe shall be 316 stainless steel.
   1. Sensing element - Platinum RTD, Thermistor, or integrated circuit, $\pm 0.2^\circ F$ accuracy at calibration point.

E. Averaging duct temperature sensor shall consist of an averaging element, junction box for wiring connections and gasket to prevent air leakage. Provide sensor lengths and quantities to result in one lineal foot of sensing element for each three square feet of cooling coil/duct face area. Temperature range as required for resolution indicated in paragraph A.
   1. Sensing element - Platinum RTD, or Thermistor, $\pm 0.2^\circ F$ accuracy at calibration point.

F. Liquid immersion temperature sensor shall include thermowell, sensor and connection head for wiring connections.
   1. Sensing element (chilled water/glycol systems)- Platinum RTD $\pm 0.2^\circ F$ accuracy at calibration point. Temperature range shall be as required for resolution of $0.15^\circ F$.
   2. Sensing element (other systems) - Platinum RTD, Thermistor, or integrated circuit, $\pm 0.4^\circ F$ accuracy at calibration point. Temperature range shall be as required for resolution of $0.3^\circ F$.

G. Pipe Surface Mount temperature sensor shall include metal junction box and clamps and shall be suitable for sensing pipe surface temperature and installation under insulation. Provide thermally conductive paste at pipe contact point. Temperature range
shall be as required for resolution indicated in paragraph A. These may only be used where specifically indicated, typically on a temporary basis.

1. Sensing element - Platinum RTD, Thermistor, or integrated circuit, ± 0.4° F accuracy at calibration point.

H. **Outside air sensors** shall consist of a sensor, sun shield, utility box, and watertight gasket to prevent water seepage. Temperature range shall be as required for resolution indicated in paragraph A.

1. Sensing element - Platinum RTD, Thermistor, or integrated circuit, ± 0.4° F accuracy at calibration point.

### 2.07 TEMPERATURE TRANSMITTERS

A. Where required by BC or AAC/ASC, sensors as specified above may be matched with transmitters outputting 4-20 mA linearly across the specified temperature range. Transmitters shall have zero and span adjustments, an accuracy of .1° F when applied to the sensor range.

### 2.08 HUMIDITY TRANSMITTERS (H)

A. Units shall be suitable for duct, wall (room), or outdoor mounting. Unit shall be two-wire transmitter utilizing bulk polymer resistance change or thin film capacitance change humidity sensor. Unit shall produce linear continuous output of 4-20 mA for percent relative humidity (% rH). Sensors shall have the following minimum performance and application criteria:

1. **Input Range:** 0 to 100% rH.

2. **Accuracy (% rH):** ±2% (when used for enthalpy calculation, dewpoint calculation or humidifier control) or ±3% (monitoring only) between 20-90% rH at 77° F, including hysteresis, linearity, and repeatability.

3. **Sensor Operating Range:** As required by application.

4. **Long Term Stability:** Less than 1% drift per year.

B. Units shall be Veris, Vaisala HM Series, or approved equal.

### 2.09 DIFFERENTIAL PRESSURE TRANSMITTERS (DP)

A. **General Purpose Water:** Two wire transmitter, 4-20 mA output with zero and span adjustments. Plus or minus 0.5% overall accuracy, 450 psig (3103 KPa) maximum static pressure rating, 200 psid maximum overpressure rating for 6 through 60 psid range, 450 psid for 100 through 300 psid range. Kele & Associates Model 360 C or approved equal.

B. **Industrial Application, Liquid, Steam, and Gas:**

1. **General:** Two wire smart d/p cell type transmitter, 4-20 mA or 1 to 5 volt user selectable linear or square root output, adjustable span and zero, stainless steel wetted parts.

2. **Environmental limits:** –40 to 250 °F (-40 to 121°C), 0 to 100% RH.

3. **Accuracy:** Less than 0.1 percent of span.

4. **Output Damping:** Time constant user selectable from 0 to 36 seconds.

5. **Vibration Effect:** Less than ± 0.1% of upper range limit from 15 to 2000 Hz in any axis relative to pipe mounted process conditions.

6. **Electrical Enclosure:** NEMA 4, 4X, 7, 9.

7. **Approvals:** FM, CSA.
8. **Manufacturer:** Setra, Veris, or approved equal.

**C. General Purpose Low Pressure Air:** Generally for use in static measurement of duct pressure or constant volume air velocity pressure measurement where the range is applicable.

1. Loop powered two wire differential capacitance cell type transmitter.
2. Output: Two-wire 4-20 mA output with zero adjustment.
3. Overall accuracy: Plus or minus 1%.
4. Minimum range: 0.1” w.c.
5. Maximum range: 10” w.c.
6. Housing: Polymer housing suitable for surface mounting.
7. Manufacturer: Modus T30 or approved equal.
8. Static sensing element: Pitot type static pressure sensing tips similar to Dwyer model A-301 and connecting tubing.
9. Range: Select for specified setpoint to be between 25% and 75% full scale.

**D. General Purpose Low Pressure/Low Differential Air:** Generally for use in static measurement of space pressure or constant volume air velocity pressure measurement where the range is applicable.

1. Loop powered two-wire differential capacitance cell type transmitter.
2. Output: Two-wire 4-20 mA output with zero adjustment.
3. Overall accuracy: Plus or minus 1%.
4. Minimum range: 0” w.c.
5. Maximum range: 0.1”, 0.25”, or 0.5” w.c.
6. Housing: Polymer housing suitable for surface mounting.
7. Manufacturer: Modus T30 or approved equal.
8. Static sensing element: Pitot type static pressure sensing tips similar to Dwyer model A-301 and connecting tubing.
9. Range: Select for specified setpoint to be between 25% and 75% full scale.

**2.10 VALVE BYPASS FOR DIFFERENTIAL PRESSURE SENSORS**

A. **Provide** a five valve bypass kit for protection of DP sensors where the static on the pipe can cause on over pressure when connected to one port with the other at atmospheric pressure. **Kit** shall include high and low pressure isolation valves, high and low pressure vent valves and a bypass valve contained in a NEMA-1 enclosure. **Enclosure** shall be mounted no higher than 6 feet above floor level.

**2.11 DIFFERENTIAL PRESSURE SWITCHES (DPS)**

A. General Service Air: Diaphragm with adjustable setpoint and differential and snap acting form C contacts rated for the application. Provide manufacturer's recommended static pressure sensing tips and connecting tubing.

B. General Service Water: Diaphragm with adjustable setpoint, 2 psig or adjustable differential, and snap acting form C contacts rated for the application. 60 psid minimum pressure differential range. 0 °F to 160 °F operating temperature range. Provide manufacturer’s recommended connecting tubing.
2.12 PRESSURE SWITCHES (PS)
A. Diaphragm or bourdon tube with adjustable setpoint and differential and snap acting form C contacts rated for the application. PS shall be capable of withstanding 150% of rated pressure.
B. Acceptable manufacturers subject to meeting the specified requirements: Square D, Setra, ASCO, Penn, Johnson or approved equal.

2.13 TRANSDUCERS
A. Electronic to Electronic (Voltage or Current to Current or Voltage):
   1. Adjustable zero and span.
   2. Failure Mode on Power Loss: Memory feature to allow the transducer to return to last value on power failure.
   3. Accuracy: ± 1% of span.
   4. Output Span: 4-20 mA, 0-5 V, 1-5 V, 0-10V, 2-10V, 0-15V, 3-15V.
   5. Input: 0-20 VDC, 0-20 mA, 0-10 k.
   7. Enclosure: Polymer designed for surface or panel mount.
   8. Manufacturer: RE Technologies Model UAT series (or approved equal).

2.14 CURRENT SWITCHES
A. Clamp-On Design Current Operated Switch for Motor Status Indication
   1. Range: 1.5 to 150 amps.
   2. Trip Point: Adjustable.
   3. Switch: Solid state, normally open, 1 to 135 VAC or VDC, 0.3 Amps. Zero off state leakage.
   4. Lower Frequency Limit: 6 Hz.
   5. Trip Indication: LED.
   6. Approvals: UL, CSA.
   7. Max. Cable Size: 350 MCM.
   8. Manufacturer: Veris Industries; Inc., RE Technologies or approved equal.
B. Wire Through Current Switch (CS/CR) shall consist of 0 to 200 A continuous amperage rating, adjustable trip set-point to ± 1 % of range, 8 A @ 240 VAC resistive, 4 A @ 120 VAC tungsten, 2A @ 240 VAC inductive (1/2 hp). Load control contact power shall be induced from monitored conductor (minimum conductor current required to energize relay 5 A, max. rating of 135A). Veris Industries, Inc., Model # 715; RE Technologies RCS 1150 or approved equal.
   1. Where used for single-phase devices, provide the CS/CR in a self contained unit with override switch in housing similar to Kele RIBX or approved equal.

2.15 CURRENT TRANSFORMERS (CT)
A. Clamp-On Design Current Transformer for Motor Current Sensing
   1. Range: 1-10 A minimum, 20-200 A maximum.
   2. Trip Point: Adjustable.
   3. Output: 0-5 VDC.
4. Accuracy: ±0.2% from 20 to 100 Hz.
5. For variable frequency drive pump and fan applications, CT should have Volt-amp (VA) memory to distinguish at no load, full motor speed.
6. Manufacturer: KELE, Veris, or approved equal.

2.16 OUTDOOR AIR STATIC PRESSURE SENSING TIP
A. Pressure sensor: Pressure sensing tip design to minimize the effects of wind and resulting velocity pressure. Dampen effects of wind up to 80 mph. Dwyer or approved equal.
B. Low Air Pressure Surge Dampener: 30 second time constant. Modus SD030 or approved equal.

2.17 CONTINUOUS LEVEL TRANSMITTERS
A. Capacitance Type
1. Provide a loop powered, continuous capacitance type level transmitter with adjustable span and zero.
2. Output: 4-20 mA.
3. Probe: Fluoropolymer coated stainless steel rod or cable. Provide cable probe with end attachment hardware or weight.
5. Approvals: UL or CSA.
6. Accuracy: ±1% of calibrated span.
7. Process Connection: MPT or ANSI Flange as required.
8. Manufacturer: Drexelbrook, Endress & Hauser, or approved equal.
B. Hydrostatic Pressure
1. Two wire smart d/p cell type transmitter.
2. 4-20 mA or 1 to 5 V user selectable linear or square root output.
3. Adjustable span and zero.
4. Stainless steel wetted parts.
5. Environmental limits: –40 to 250 °F (-40 to 121 °C), 0 to 100% rH.
6. Accuracy: Less than 0.1% of span.
7. Output Damping: Time constant user selectable from 0 to 36 seconds.
8. Vibration Effect: Less than ±0.1% of upper range limit from 15 to 2000 Hz in any axis relative to pipe mounted process conditions.
10. Approvals: FM, CSA.
11. Manufacturer: Rosemount Inc. 3051 Series, Foxboro, Johnson-Yokagawa, or approved equal.
C. Ultrasonic Type
1. Provide a non-contacting, temperature compensating, narrow beam, ultrasonic type level transmitter with adjustable span and zero.
2. Output: 4-20 mA.
3. Transducer Materials: PC/ABS, Polypropylene, PVC and/or Teflon.
5. Approvals: UL, CE or CSA.
6. Accuracy: ± 0.5% of calibrated span.
7. Manufacturer: Flowline, Princo Instruments & Greyline, or approved equal.

2.18 FLOW METERS (FMs)
A. Clamp-On Ultrasonic Flow Meter: The ultrasonic flow meter shall be a transit-time non-invasive clamp-on type in which transducers clamp on the exterior surface of the pipe. The flow meter shall use Time-Domain Expansion Technology that allows for extremely accurate measurement of upstream and downstream arrival time differentials. The achievable field accuracy shall be 1% of rate or better. The repeatability of the flow meter shall be 0.5% of rate. The flow meter shall be able to measure bi-directional velocities.
   1. Manufacturer: Flexim FLUXUS ADM 7407 or approved equal.

2.19 AIRFLOW MEASURING STATIONS (AFM):
A. Thermal Dispersion Grid: Provide a high density thermistor array for thermal dispersion airflow reading. Provide the electronics to output an linear analog signal (0-5/0-10 VDC or 4-20mA) of airflow with a resolution of 0.025% of full scale.
   1. Sensor Accuracy: ±2%
   2. Electronics Accuracy: ±3%, repeatability ±0.25%
   3. Range: Select minimum range to accommodate the expected flow range of the project
   4. Temperature Limits: -20-160°F
B. Vortex Shedding Grid: Provide an array of vortex shedding elements designed to produce stable “Karmen Vortices” that are linear with air velocity. Provide the electronics to totalize the pulses and output average velocity proportional to an output signal of 4-20 mA.
   1. Sensor Accuracy: ± 1.5%.
   2. Electronics Accuracy: ± 0.5%.
   3. Range: Select minimum range to accommodate the expected flow range of the project.
   4. Temperature Limits: 20-140 °F

2.20 AIR VELOCITY PRESSURE SENSORS (INSERTION TYPE)
A. Single or Multi-Point Averaging (as indicated): Sensing tip shall be for insertion into duct with mounting flange and push on tube connections. Material shall be suitable to the application.

2.21 CO2 SENSORS/TRANSMITTERS (CO2)
A. CO2 sensors shall use silicon based, diffusion aspirated, infrared single beam, Dual Wavelength Sensor.
B. Accuracy: ± 36 ppm at 800 ppm and 68 °F.
C. Stability: 5% over 5 years.
D. Output: 4-20 mA, 0-10 V or relay.
E. Mounting: Duct or Wall as indicated. Provide LED readout of current CO2 levels on wall mounted units.
F. Manufacturer: Vaisala, Inc., Siemens, or Veris.

2.22 ELECTRIC CONTROL COMPONENTS

A. Limit Switches (LS): Limit switches shall be UL listed, with adjustable trim arm. Limit switches shall be as manufactured by Square “D,” Allen Bradley, or approved equal; SPDT or DPDT type.

B. Low Temperature Detector (Freezestat) (FZ): Low temperature detector shall consist of a “cold spot” element which responds only to the lowest temperature along any one foot of entire element, minimum bulb size of 1/8” x 20' (3.2mm x 6.1m), junction box for wiring connections and gasket to prevent air leakage or vibration noise, DPST (4 wire, 2 circuit) with manual reset. Temperature range 15 to 55 °F (-9.4 to 12.8 °C), factory set at 38 °F.

C. High Temperature Detectors (Firestat) (FS): High temperature detector shall consist of 3 pole contacts, a single point sensor, junction box for wiring connections and gasket to prevent air leakage of vibration noise, triple pole, with manual reset. Temperature range 25 to 215 °F (-4 to 102 °C).

D. Control Relays: All control relays shall be UL listed, with contacts rated for the application, and mounted in minimum NEMA 1 enclosure for indoor locations, NEMA 4 for outdoor locations.
   1. Control relays for use on electrical systems of 120 volts or less shall have, as a minimum, the following:
      a) AC coil pull-in voltage range of + 10%, - 15% or nominal voltage.
      b) Coil sealed volt amperes (VA) not greater than four (4) VA.
      c) Silver cadmium Form C (SPDT) contacts in a dust proof enclosure, with 8 or 11 pin type plug.
      d) Pilot light indication of power-to-coil, and coil retainer clips.
      e) Coil rated for 50 and 60 Hz service.
      f) Relays shall be Potter Brumfield, Model KRPA, RIB or approved equal.
   2. Relays used for across-the-line control (start/stop) of 120V motors, 1/4 HP, and 1/3 HP, shall be rated to break minimum 10 Amps inductive load. Relays shall be IDEC, or approved equal.
   3. Relays used for stop/start control shall have low voltage coils (30 VAC or less), and shall be provided with transient and surge suppression devices at the CU interface.

E. General Purpose Power Contactors: NEMA ICS 2, AC general-purpose magnetic contactor. ANSI/NEMA ICS 6, NEMA Type 1 enclosure. Manufacturer shall be Square “D,” Cutler Hammer, or Westinghouse.

F. Control Transformers: Furnish and install control transformers as required. Control transformers shall be machine tool type, and shall be US and CSA listed. Primary and secondary sides shall be fused in accordance with the NEC. Transformer shall be proper size for application, and mounted in minimum NEMA 1 enclosure.
   1. Transformers shall be manufactured by Westinghouse, Square "D," Jefferson, or approved equal.

G. Time Delay Relays (TDRs): TDRs shall be capable of on or off delayed functions, with adjustable timing periods and cycle timing light. Contacts shall be rated for the
application with a minimum of two (2) sets of Form C contacts, enclosed in a dust proof enclosure.

1. TDRs shall have silver cadmium contacts with a minimum life span rating of one million operations. TDRs shall have solid state, plug-in type coils with transient suppression devices.

2. TDRs shall be UL and CSA listed, Crouzet type, or approved equal.

H. Electric Push Button Switch: Switch shall be momentary contact, oil tight, push button, with number of N.O. and/or N.C. contacts as required. Contacts shall be snap-action type, and rated for minimum 120 VAC operation. Switch shall be 800T type, as manufactured by Allen Bradley, or approved equal.

I. Pilot Light: Panel-mounted pilot light shall be NEMA ICS 2 oil-tight, transformer type, with screw terminals, push-to-test unit, LED type, rated for 120 VAC. Unit shall be 800T type, as manufactured by Allen Bradley, or approved equal.

J. Alarm Horn: Panel-mounted audible alarm horn shall be continuous tone, 120 VAC Sonalert solid state electronic signal, as manufactured by Mallory, or approved equal.

K. Electric Selector Switch (SS): Switch shall be maintained contact, NEMA ICS 2, oil-tight selector switch with contact arrangement, as required. Contacts shall be rated for minimum 120 VAC operation. Switch shall be 800T type, as manufactured by Allen Bradley, or approved equal.

2.23 REFRIGERANT MONITOR

A. General: Contractor shall provide a refrigerant sensitive infrared based stationary refrigerant gas leak monitor system designed to continuously measure the specified refrigerant in the designated mechanical rooms or storage areas where refrigerants are used and stored. The alarm system shall comply with ANSI/ASHRAE 15 and local code requirements.

B. The refrigerant monitor shall be capable of monitoring the specified refrigerant or multiple refrigerant gas compounds at multiple locations in concentrations of 0 PPM to a minimum of 1000 PPM. The Monitor shall have a low range resolution of 1 PPM in the range of 1 PPM through 100 PPM. Readings above 100 PPM must be accurate to within ± 5% of reading. Accuracy shall be maintained within ambient environmental ranges of 0 °C through 50 °C, (32 °F. through 122 °F) and 5% through 90% relative humidity, non-condensing.

C. The refrigerant monitor shall automatically and continuously monitor the areas through a sample draw type tubular pick up system with an internal pump and filter. The installation of the monitoring control and the tubing shall be in strict accordance with the manufacturer’s instructions. The location, routing, and final position of the sample tubes shall be submitted to the engineer with all necessary shop drawings and monitor specifications and installation instructions. Tubing size, tubing material, and tube length limitations shall be within the specifications of the monitor manufacture. The location and method of tube support and hangers must be identified on the shop drawings. Each of the sampling tubes shall have end of line filters.

D. The analyzer will be based on infrared detection technology, and will be factory tested and calibrated for the specified refrigerant or refrigerants. Factory certification of the calibrations shall be provided with the O&M manuals. The analyzer shall provide a menu driven or automatic method of checking both zero and span calibration for each sensor, and shall allow for adjustment.

E. The monitor shall be equipped with 4 outputs. Three relays shall energize at an adjustable user defined set point based on refrigerant concentration levels. The relay
threshold adjustment shall be protected by keyed or password access controls. Adjustments and observations shall be made at the front panel operator interface. The relay threshold values can be viewed without a password. The digital display will continuously display the refrigerant concentration level and alarm status. The fourth output shall indicate a monitor malfunction alarm. The monitor shall also have an analog output that will provide a linear scaled reference to the refrigerant concentration in parts per million. The analog output signal shall be an industry standard DC voltage, or mA current signal.

F. The monitor shall have a NEMA-4 moisture resistant enclosure with a gasketed, hinged front cover. Conduits and tube connections shall be located on the bottom of the enclosure. The enclosure shall have a rust and corrosion resistant finish.

G. The following alarm modes will be provided by the refrigerant monitor:

1. ALARM LEVEL ONE – Low level of refrigerant concentration at one of the sampling points has detected the presence of a possible refrigerant leak. The initial alarm threshold shall be set to 5 PPM (adjustable) and increased if there are nuisance alarms. This alarm level shall be displayed on the refrigerant monitor interface panel, indicating which sensor has triggered the alarm, and the associated concentration of refrigerant in PPM. This event will also send an Alarm Level One signal to the BAS through a digital output from the monitor relay. This alarm will remain active until the refrigerant concentration is reduced below set point.

2. ALARM LEVEL TWO – This alarm shall indicate that one of the sensors has detected a refrigerant concentration that is approaching dangerous levels in the area being monitored. This alarm shall be set to 25% below the maximum calculated refrigerant level specified in ANSI/ASHRAE 15-1994 and ASHRAE 34-1992. This alarm will be displayed on the monitor interface, and will indicate which of the sensors has caused the alarm, and the highest concentration in PPM. This event will also activate the beacon and audible alarm mounted on the refrigerant monitoring enclosure. This alarm will also be sent to the BAS through the digital output of the relay. In this mode the audible alarm can be silenced, but the beacon shall remain active until the fault is cleared.

3. ALARM LEVEL THREE – This alarm shall be set at the maximum calculated refrigerant level specified in ANSI/ASHRAE 15 and ASHRAE 34; whichever is the lowest concentration. The refrigerant monitor interface will display which sensor has caused the alarm, and the associated concentration in PPM. This event will also activate the beacon and audible alarm mounted on the refrigerant monitoring enclosure. If the audible alarm had been silenced by an earlier alarm, the activation of this level three alarm will cause the audible alarm to be activated again. The relay in the refrigerant monitoring panel shall activate the space ventilation system, and will disable all combustion or flame producing equipment via hard wired control interlocks. In addition, this event will de-energize the energy source for any hot surface (850 °F or 454 °C) located in the space. Interlocks must also be provided to close any normally open doors or openings to the space for proper ventilation and isolation during this alarm condition. This alarm level will also signal the BAS through the digital output through the same relay. In this mode, the audible alarm can be silenced, but the beacon shall remain active until the fault is cleared.

H. All alarm conditions shall be report to the BAS system as follows:

1. ALARM LEVEL ONE – The lowest refrigerant alarm level shall detect the presence of refrigerant in low concentrations and energize a relay to signal a low-level alarm to the BAS operator terminal(s). The alarm shall display an alarm message stating that there is a potential refrigerant leak in the designated area.
2. ALARM LEVELS TWO AND THREE – The second and third refrigerant level alarms shall be high refrigerant alarm alerts. These alarm shall energize relays to signal the BAS system indicating a high level alarm on the BAS operator terminal(s). The BAS alarms shall state that high levels of refrigerant have been detected in the designated area.

3. FAULT ALARM – Reports a high level alarm to the BAS operator terminal(s) that there is a fault in the refrigerant monitoring alarm system.

I. Manufacturer: MSA Chillgard RT.

2.24 NAMEPLATES

A. Provide engraved phenolic or micarta nameplates for all equipment, components, and field devices furnished. Nameplates shall be 1/8 thick, black, with white center core, and shall be minimum 1" x 3", with minimum 1/4" high block lettering. Nameplates for devices smaller than 1" x 3" shall be attached to adjacent surface.

B. Each nameplate shall identify the function for each device using the approved AU naming convention. Nameplates for control panels shall clearly indicate name, LAN segment, what equipment the panel is controlling, and number and model of DDC components in the panel.

2.25 TESTING EQUIPMENT

A. Contractor shall test and calibrate all signaling circuits of all field devices to ascertain that required digital and accurate analog signals are transmitted, received, and displayed at system operator terminals, and make all repairs and recalibrations required to complete test. Contractor shall be responsible for test equipment required to perform these tests and calibrations. Test equipment used for testing and calibration of field devices shall be at least twice as accurate as respective field device (e.g., if field device is +/-0.5% accurate, test equipment shall be +/-0.25% accurate over same range). Current NIST traceable certificate of calibration shall be made available when requested for all test equipment used.
PART III. EXECUTION

3.01 INSPECTION

A. Examine areas and conditions under which control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3.02 INSTALLATION OF CONTROL SYSTEMS

A. General: Install systems and materials in accordance with manufacturer's instructions, roughing-in drawings and details shown on drawings. Install electrical components and use electrical products complying with requirements of National Electric Code and all local codes.

B. Control Wiring: The term "control wiring" is defined to include providing of wire, conduit, and miscellaneous materials as required for mounting and connection of electric control devices. During the bid phase, contractor shall inspect the wiring at representative locations such as at panels and at field devices. Contractor shall assess the type and size and determine adequacy. This wiring may generally be reused where it meets the specifications and/or manufacturer's requirements and is to be assumed to be in good condition and of adequate size. During the Construction period, Contractor shall inspect and test the wiring and identify any deficiencies. Deficiencies shall be corrected outside the scope of the existing contract.

1. Where extensions are required to existing systems, extend wiring in kind.
   a) Exception: Where extension would require splicing of any wiring new wire shall be pulled.

2. For New Systems or branches:
   a) Wiring System: Install complete wiring system for electric control systems. Wiring shall be run in EMT conduit for all mechanical rooms, vertical risers, research/laboratory spaces and horizontal runs in exposed ceilings. All other wiring installations shall be concealed except in areas where other conduit and piping are exposed. Installation of wiring shall generally follow building lines. Install in accordance with National Electrical Code and Division 26 of this Specification. Fasten flexible conductors bridging cabinets and doors, neatly along hinge side, and protect against abrasion. Tie and support conductors every 24 inches, fasten to the structure every 6 feet in a workman like manner to avoid a conflict with electrical or HVAC installations. Provide pull wire through each conduit installed under this section for future use. Any conduit run inside equipment exposed to outside air conditions shall be sealed tight / weather tight conduit.

   b) Control Wiring Conductors: Install control wiring conductors, without splices between terminal points, color-coded. Install in neat, skilful manner, securely fastened. Install in accordance with National Electrical Code.

3. Communication wiring, signal wiring and low voltage control wiring shall be installed separate from any wiring over thirty (30) volts. Signal wiring shield shall be grounded at CU end only, unless otherwise recommended by the CU manufacturer.

4. Primary LAN Communication wiring shield shall be terminated as recommended by CU manufacturer.

5. Install all control wiring external to panels in electric metallic tubing or raceway. However, communication wiring, signal wiring, and low voltage control wiring may
be run without conduit in concealed, inaccessible locations. Contractor will be fully responsible for noise immunity and rewire with conduit if electrical or RF noise affects performance.

a) Communication and signal wiring may be run without conduit above suspended ceilings provided it is run in a neat and orderly fashion, bundled where applicable, and completely suspended (strapped to rigid elements or routed through wiring rings) away from areas of normal access. Wiring shall not be laid on the ceiling or duct. Communication wiring shall not be run in the same conduit with other wiring.

6. Number-code or color-code conductors appropriately for future identification and servicing of control system. Code shall be as indicated on approved installation drawings.

C. Control Valves: Install so that actuators, wiring, and tubing connections are accessible for maintenance. Where possible for non-steam applications, install with valve stem axis vertical, with operator side up. For steam applications, install at 45 degree angle from vertical with extended stem. Where stem position are not possible, or would result in poor access, valves may be installed with stem horizontal. Do not install valves with stem below horizontal, or down.

D. Freezestats (FZs): Install in a serpentine fashion where shown on drawing. Provide one foot of element for each three square foot of coil face area. Where coil face area exceeds required length of element, provide multiple devices wired in parallel for normally open, closed on trip application; wired in series for normally closed, open on trip application. Adequately support with coil clips.

E. Pipe Surface Mount Temperature Sensor: Install with thermally conductive paste at pipe contact point. Pipe insulation shall be replaced in kind and adequately joined to existing undisturbed insulation. Maintain vapor barrier and finish to match. These should be temporary applications only, until a well may be installed for proper in flow measurement of temperature.

F. Averaging Temperature Sensors: Where existing sensors are in good operating condition and properly installed and applied, they may be reused. Cover no more than three square feet per linear foot of sensor length.

G. General Sensor Locations: Locate sensors in positions that most accurately represent the sensed medium. Ensure that single point sensors are positioned in a well-mixed medium position. Ensure that flow sensors are located in areas with minimal turbulence. Ensure that temperature and humidity sensors are located in a position that is remote from humidifiers and sufficiently downstream to ensure full moisture absorption.

H. Air flow measuring stations: Where these are existing and properly installed and applied, they may be reused. For new installations, install per manufacturer’s recommendations in an unobstructed straight length of duct (except those installations specifically designed for installation in fan inlet). For installations in fan inlets, provide on both inlets of double inlet fans and provide inlet cone adapter as recommended by AFM station manufacturer.

I. Relative humidity sensors: Provide element guard as recommended by manufacturer for high velocity installations. For high limit sensors, position remote enough to allow full moisture absorption into the air stream before reaching the sensor.

J. Differential Pressure Transmitters: Provide valve bypass arrangement to protect against overpressure damaging the transmitter.

K. Flow Switches: Where possible, install in a straight run of pipe at least 15 diameters in length to minimize false indications.
L. **Current Switches for Motor Status Monitoring:** Adjust so that setpoint is below minimum operating current and above motor no-load current.

M. **Supply Duct Pressure Transmitters:**
   1. General: Install pressure tips with at least 4 “round equivalent” duct diameters of straight duct with no takeoffs upstream. Install pressure tips securely fastened with tip facing upstream in accordance with manufacturer’s installation instructions. Locate the transmitter in an accessible location to facilitate calibration.
   2. VAV System ‘Down-Duct’ Transmitters: Locate pressure tips at least 2/3 of the way to the most remote terminal in the air system.

N. **Cutting and Patching Insulation:** Repair insulation to maintain integrity of insulation and vapor barrier jacket. Use hydraulic insulating cement to fill voids and finish with material matching, or compatible with, adjacent jacket material.

3.03 **REFRIGERANT MONITORS**
   A. Install in accordance with the manufacturer’s instructions. Place sensing tips in locations to maximize effectiveness.
   B. Hard wire interlocks to the emergency ventilation and shutdown of combustion devices.

3.04 **SYSTEM COMMISSIONING AND ACCEPTANCE**
   A. Refer to Section “BAS Commissioning”.

**END OF SECTION**
SECTION 25 9000 – SEQUENCE OF OPERATION

INSTRUCTIONS FOR USE AND MODIFICATION
COMMENTS THAT REQUIRE MODIFICATION ARE ITALICIZED AND BLUE.
1. WHEN EDITING IS COMPLETE, DELETE THIS BLOCK AND SAVE THE FILE AS A NEW NAME
2. THIS SECTION IS SPECIFIC TO THE AU STANDARDS. ALL CHANGES AND VARIANCES MUST BE APPROVED BY AU.

Table of Contents

PART I. GENERAL ....................................................................................................................................................................................... 1
  1.01 SECTION INCLUDES ..................................................................................................................................................................................... 1
  1.02 SYSTEM DESCRIPTION ................................................................................................................................................................................. 1
  1.03 SUBMITTALS ................................................................................................................................................................................................ 1
  1.04 PROJECT RECORD DOCUMENTS .................................................................................................................................................................. 1
  1.05 DEFINITIONS/ABBREVIATIONS .................................................................................................................................................................... 1

PART II. PRODUCTS ........................................................................................................................................... 2

PART III. EXECUTION ......................................................................................................................................... 3
  3.01 GENERAL .................................................................................................................................................................................................. 3
  3.02 ENERGY CURTAILMENT CONTROL: ..................................................................................................................................................... 6
  3.03 AIR HANDLING UNITS - GENERAL ........................................................................................................................................................................ 6
  3.04 AIR HANDLING UNIT DIAGNOSTICS - GENERAL ...................................................................................................................................................... 10
  3.05 AIR HANDLER MONITORING AND MANAGEMENT ................................................................................................................................................................ 10
  3.06 GENERAL PRIMARY/SECONDARY CHW SYSTEMS CONTROL ........................................................................................................................................ 11
  3.07 CHILLER STAGING (T ON L OFF): ........................................................................................................................................................................... 12
  3.08 CHILLER STAGING (LOAD): ............................................................................................................................................................................. 12
  3.09 CHILLER STAGING (CHILLER AMPS): .................................................................................................................................................................... 13
  3.10 PRIMARY CHW PUMP CONTROL (ONE PUMP/CHILLER) ............................................................................................................................................. 13
  3.11 SECONDARY CHW PUMP (WITH VFD) CONTROL ...................................................................................................................................................... 13
  3.12 CONDENSER WATER PUMP CONTROL (ONE PUMP/CHILLER) ............................................................................................................................................ 14
  3.13 COOLING TOWER BYPASS VALVE CONTROL ...................................................................................................................................................... 14
  3.14 CHILLER PRIORITY SELECTION (EQUAL SIZE AND EFFICIENCY CHILLERS) .......................................................................................................................... 14
  3.15 CHILLER START SEQUENCE ........................................................................................................................................................................... 14
  3.16 CHILLER STOP SEQUENCE ........................................................................................................................................................................... 15
  3.17 GENERAL HEATING WATER SYSTEMS CONTROL .................................................................................................................................................. 15
  3.18 CENTRAL PLANT MONITORING AND MANAGEMENT ........................................................................................................................................... 16
SECTION 25 9000 – SEQUENCE OF OPERATION

PART I. GENERAL

1.01 SECTION INCLUDES
A. Air Handling Units.
B. Terminal Units.
C. Chilled Water Systems.
D. Hot Water Converters.
E. Chillers.
F. Pumps.
G. Cooling Towers.

1.02 SYSTEM DESCRIPTION
A. This Section defines the manner and method by which controls operate and sequence the controlled equipment. Included in this section are general requirements and logic strategies that expand on the specific sequences shown on the drawings. Specific drawing sequences generally refer to this section and reference the logic strategies.
B. Refer to the control drawings for specific sequences for individual systems.

1.03 SUBMITTALS
A. Refer to Section “Building Automation System (BAS) General” and Division 01 for requirements for control shop drawings, product data, Users Manual, etc.

1.04 PROJECT RECORD DOCUMENTS
A. Within two weeks of the completion of commissioning, provide record documents to represent the final control configuration with actual setpoints and tuning parameters as existing at acceptance.
B. Record documents shall be modified control drawings with the actual installed information. Drawings shall be delivered in both reproducible hard copy and electronic format.
C. Provide final points list in electronic format.
D. Provide final detailed wiring diagrams with all wire numbers and termination points indicated.
E. Accurately record final sequences and control logic made after submission of shop drawings.

1.05 DEFINITIONS/ABBREVIATIONS
A. AH: Air Handler.
B. AHU: Air Handling Unit.
C. CHW: Chilled Water.
D. CHWS: Chilled Water Supply.
E. CHWR: Chilled Water Return.
F. DDC: Direct Digital Control.
G. DTW: Dual-temperature Water
I. HW: Hot Water.
J. MVR: Minimum required ventilation rate (ASHRAE 62).
K. OA: Outdoor Air.
L. PCHW: Primary chilled water.
M. SCHW: Secondary chilled water referring to the secondary systems that are used for cooling in the H/C mode (Pumps SC-1,2,3).
N. Physical Point: A point on the BAS that is physically connected to an I/O device such that a hardware point exists.
O. Virtual Point: A point to store values (i.e. a setpoint) that does not represent a physical device.

PART II. PRODUCTS

Not Used
PART III. EXECUTION

3.01 GENERAL

A. Campus Shutdown is a special software switch that when activated must command all air moving equipment OFF and exterior dampers (OA, EA, Relief) CLOSED. Coordinate integration of this network point with all fans and dampers under BAS control for this project.

B. Sequences specified herein and on the drawings indicate the functional intent of the systems operation and may not fully detail every aspect of the programming that may be required to obtain the indicated operation. Furthermore, logic diagrams provided on the drawings are provided to more fully communicate the intended sequence and may not fully detail every aspect of the programming that may be required to obtain the indicated operation. Contractor shall provide all programming necessary to obtain the sequences/system operation indicated.

C. When an air handling unit is not in operation, control devices shall remain in their “off” positions. “Off” positions may differ from the “normal” (meaning failed) position. Except as specified otherwise, “off” and “normal” positions of control devices shall be as follows:

<table>
<thead>
<tr>
<th>Device</th>
<th>“Off” Position</th>
<th>“Normal” Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating coil valves</td>
<td>Closed/controlling</td>
<td>Open</td>
</tr>
<tr>
<td>Cooling coil valves</td>
<td>Closed</td>
<td>Closed</td>
</tr>
<tr>
<td>Outside air damper</td>
<td>Closed</td>
<td>Closed</td>
</tr>
<tr>
<td>Return air damper (Mixed air damper)</td>
<td>Open</td>
<td>Open</td>
</tr>
<tr>
<td>Exhaust/relief air damper</td>
<td>Closed</td>
<td>Closed</td>
</tr>
<tr>
<td>Var. Freq. Drive</td>
<td>Off</td>
<td>Min. Speed</td>
</tr>
</tbody>
</table>

D. Except as specified otherwise, throttling ranges, proportional bands, and cycle differentials shall be centered on the associated setpoint. All modulating feedback control loops shall include the capability of having proportional, integral, and derivative action. Unless the loop is specified “proportional only” or “P+I”, Contractor shall apply appropriate elements of integral and derivative gain to each control loop which shall result in stable operation, minimum settling time, and shall maintain the primary variable within the specified maximum allowable variance.

E. Scheduling Terminology: When air handlers are scheduled throughout the day, the following defines the terminology used:

1. **Occupied Period**: Period of time when the building is in use and occupied. Unless indicated otherwise, this period is defined as 7:00 AM - 5:00 PM weekdays and 7:00 AM to 12:00 noon Saturdays. Exclude all federal holidays. Generally systems will be fully operational throughout this period and ventilation air shall be continuously introduced. Space temperature set points will be applied per American Universities Temperature Policy.

2. **Unoccupied period**: Period of time when the building or zone is not in use and is unoccupied. Ventilation air shall not be introduced.

3. **Preoccupancy Period**: Time prior to the Occupied period when the systems are returning the space temperatures from setback to “normal” or occupied.
setpoints (warm-up and cool-down). Ventilation air shall not be introduced unless outside air conditions permit free cooling. Time period shall be determined by an optimum start strategy unless otherwise specified.

4. **Setback Period:** Setback start will typically coincide with the end of the occupied period and will end with the start of the preoccupancy period, however it shall be provided with its own schedule. Generally systems will be off except to maintain a “setback” temperature.

F. Wherever a value is indicated as adjustable (adj.), it shall be modifiable, with the proper password level, from the operator interface or via a function block menu. For these points, it is unacceptable to have to modify programming statements to change the setpoint.

G. Where any sequence or occupancy schedule calls for more than one motorized unit to start simultaneously, the BAS start commands shall be staggered by 5 second (adj.) intervals to minimize inrush current.

H. Alarm messages specified throughout the sequences are assigned to discrete priority levels. Priority levels dictate the handling and destination of alarm reports, and are defined in Section “BAS Software and Programming.”

I. When a power failure is detected in any phase, the BAS start commands shall be retracted immediately from all electrically powered units served by the failed power source. If the associated BC is powered by normal or emergency power, it may monitor its own power source as an indication of power status. If the BC is powered by uninterruptible power supply (UPS), or if the BC is not capable of monitoring its own power for use in sequences, Contractor shall provide at least one voltage monitor (three phase when applicable) per control panel. When the BAS detects that power has been restored, all equipment for which the BAS start command had been retracted shall be automatically restarted on staggered 5-second intervals to minimize inrush current. When loss of equipment status coincides with a power failure, system shall not alarm individual equipment failures. Instead, only a single Level 2 alarm shall be enunciated as follows:

1. **BUILDING XXXX POWER FAILURE:** Notify electric shop. Acknowledge alarm when power is restored.

J. Where reset action is specified in a sequence of operation, but a reset schedule is not indicated on the drawings, one of the following methods shall be employed:

1. Contractor shall determine a fixed reset schedule that shall result in stable operation and shall maintain the primary variable within the specified maximum allowable variance.

2. A floating reset algorithm shall be used which increments the secondary variable setpoint (setpoint of control loop being reset) on a periodic basis to maintain primary variable setpoint. The recalculation time and reset increment shall be chosen to maintain the primary variable within the specified maximum allowable variance.
K. Where a supply air temperature or duct pressure setpoint is specified to be reset by the space temperature of the zones calling for the most cooling/heating, the following method shall be employed:

1. A floating reset algorithm shall be used which increments the secondary variable (e.g., supply air temperature or duct pressure) setpoint on a periodic basis to maintain primary variable (e.g. space temperature) setpoint. The reset increment shall be determined by the quantity of “need heat” or “need cool” requests from individual CUs. A CU’s “need heat” virtual point shall activate whenever the zone’s space temperature falls below the currently applicable (occupied or unoccupied) heating setpoint throttling range. A CU’s “need cool” virtual point shall activate whenever the zone’s space temperature rises above the currently applicable (occupied, unoccupied, or economy) cooling setpoint throttling range. The recalculation time and reset increment shall be chosen to maintain the primary variable within the specified maximum allowable variance while minimizing overshoot and settling time. Reset range maximum and minimum values shall limit the setpoint range.

L. Where a supply air temperature, duct pressure, or differential water pressure setpoint is specified to be reset by valve or damper position of the zone or zones calling for the most cooling/heating, the following method shall be employed:

1. A floating reset algorithm shall be used which increments the secondary variable (e.g., supply air temperature, pipe or duct pressure) setpoint on a periodic basis to maintain primary variable (e.g. cooling valve, heating valve, damper position) setpoint of 85% open. The reset increment shall be calculated based on the average position of the quantity of the worst (most open valve/damper) zone(s) as specified. The recalculation time, reset increment and control device position influence shall be chosen to maintain the primary variable within the specified maximum allowable variance while minimizing overshoot and settling time. The BAS analog output value shall be acceptable as indicating the position of the control device.

2. Alternatively to continuously calculating the average of the quantity of worst valve/damper positions, a method similar to the one described above may be employed whereby the “need heat” or “need cool” virtual point shall increment by one unit each time a zone’s valve/damper position rises to greater than 95%. The quantity of “need heat” or “need cool” points shall then be the basis for reset.

M. Where “prove operation” of a device (generally controlled by a digital output) is indicated in the sequence, it shall require that the BAS shall, after an adjustable time delay after the device is commanded to operate (feedback delay), confirm that the device is operational via the status input. If the status point does not confirm operation after the time delay or anytime thereafter for an adjustable time delay (debounce delay) while the device is commanded to run, an alarm shall be enunciated audibly and via an alarm message at the operator interface and print at the alarm printers. A descriptive message shall be attached to the alarm message indicating the nature of the alarm and actions to be taken. Contractor shall provide messages to meet this intent. Upon failure, run command shall be removed and the device shall be locked out until the alarm is manually acknowledged unless specified otherwise.
N. BAS shall provide for adjustable maximum rates of change for increasing and decreasing output from the following analog output points:
1. Speed control of variable speed drives.
2. Any temperature setpoint reset.
3. Chiller demand limit.
4. Travel rate of tower isolation and chiller isolation valves.

O. Wherever a value is indicated to be dependent on another value (i.e. setpoint plus 5°F) BAS shall use that equation to determine the value. Simply providing a virtual point that the operator must set is unacceptable. In this case three virtual points shall be provided. One to store the parameter (5°F), one to store the setpoint, and one to store the value which is the result of the equation.

Coordinate use of Curtailment Control with AU on a per project basis. Implementation requires development of a per building, per system plan limiting impact on critical systems and curtailing public, non-critical areas as a first step.

3.02 ENERGY CURTAILMENT CONTROL:

A. BAS shall monitor kW demand over a 15-minute sliding window period.
B. Demand limiting shall be manually enabled by the operator (with appropriate password level) at the OWS. Demand limiting shall remain enabled until manually disabled by the operator at the OWS.
C. On a rise in kW to within 200 kW (adj.) of setpoint, a Level 4 alarm shall be enunciated and BAS shall begin to make one “load shed” command every 3 minutes (adj.). On a fall in kW to 200 kW less than the demand setpoint, BAS shall begin to broadcast one “load restore” command every 3 (adj.) minutes on a first shed, first restored basis. If demand exceeds the demand setpoint and there are no more loads left to shed, the demand setpoint shall be increased to the maximum demand experienced. Demand setpoint shall be automatically reset to an adjustable value at the beginning of each billing period.
D. “Loads” available for shedding are defined elsewhere in this specification section.
E. On a rise in kW to within 50 kW (adj.) of setpoint, a Level 3 and Level 4 alarm shall be enunciated.

3.03 AIR HANDLING UNITS - GENERAL

A. Logic Strategies: The BAS shall fully control the air handlers. Generally the BAS shall energize the AH (start the fans and activate control loops) as dictated for each air handler. The following indicates when and how the BAS shall energize the AHs and control various common aspects of them. The following “logic strategies” shall be included by reference with each air handler with any specific clarifications required:

1. Scheduled Occupancy: BAS shall determine the occupancy periods (occupied, unoccupied, preoccupancy, and setback) as defined above. The following details the common control aspects related to the scheduled occupancy.
a) **Occupied Period**: BAS shall energize the AH during all occupied periods. Note that the beginning of the occupancy period shall be set sufficiently before the actual start of occupancy to obtain the required building component of ventilation per ASHRAE 62. Specific times shall be as directed by the University. Minimum OA flow setpoint shall be specified after award. “Normal” setpoints shall apply.

b) **Unoccupied Period**: Minimum OA flow shall be 0 CFM or the minimum OA damper position shall be 0%. If during the unoccupied period there is a request for occupancy override, the occupancy mode shall become active for an adjustable period. The unoccupied period and the preoccupancy period will typically overlap.

c) **Setback Period**: The BAS shall deenergize the unit except as required to maintain a setback temperature as indicated in the individual sequences with a 5°F cycle differential. Generally, where setback temperatures apply in multiple zones, the worst zone shall control the system. Setback setpoints generally apply except during preoccupancy. If during the unoccupied period there is a request for occupancy override, the occupancy mode shall become active for an adjustable period.

d) **Preoccupancy**: BAS shall energize the AH continuously during the preoccupancy period. Minimum OA flow shall be 0 CFM or the minimum OA damper position shall be 0%. “Normal” setpoints shall apply. Preoccupancy duration shall be one of the following as specified by reference:

1) **Fixed**: The duration of the preoccupancy period shall be fixed as scheduled by the operator.

2) **Optimum**: The duration of the morning warm-up period shall vary according to outside air temperature and space temperature such that the space temperature rises to occupied period heating setpoint at the beginning of, but not before, the scheduled occupied period. The duration of the cool-down period shall vary according to outside air temperature and space temperature such that the space temperature falls to the occupied period cooling setpoint at the beginning of, but not before, the scheduled occupied period.

2. **Minimum OA Control**: BAS shall maintain minimum ventilation during the occupied period. The following strategies may apply:

a) **Balanced Position**: During the occupied period, applicable mixing and OA dampers shall never be positioned less than the position set for the required minimum OA ventilation rate. If the air handler has a single OA damper that is capable of economizer, the minimum position output shall be determined by the TAB contractor on new projects and shall be the previously set value for existing projects. If the AH has a two position minimum OA damper, that position shall be fully open to its balanced position. This logic strategy is only applicable to constant volume AHs or units with flow tracking return fan controls.

b) **Reset Balanced Position**: During the occupied period, applicable mixing and OA dampers shall never be positioned at less than the minimum position. Minimum position shall be reset between limits of a
position delivering system exhaust make-up air CFM and the design minimum position delivering design minimum CFM to maintain a CO₂ setpoint of 900 ppm (adj.). Loop shall be a “sample and bump” or dynamic proportional only loop tuned for slow response. The balancer shall determine the minimum position outputs at both extreme points. This logic strategy is only applicable to constant volume AHs.

c) Damper Controlled Fixed: During the occupied period, applicable mixing dampers shall be modulated to maintain an OA flow rate of no less than the MVR as dictated in the design and required by ASHRAE 62. Setpoint flow rates shall be provided by the University. Flow rate shall be determined in any of the following ways as specified for the particular AH:

1) Measured directly by an OA flow station.
2) As determined by CO₂ mixing equations using the SA, OA, and RA CO₂ sensors.

d) Damper Controlled Reset: During the occupied period, applicable mixing dampers shall be modulated to maintain an OA flow rate setpoint. Setpoint shall be reset between limits of system exhaust make-up air CFM and the design minimum CFM to maintain a RA CO₂ setpoint of 900 ppm (adj.). Loop shall be a “sample and bump” or dynamic proportional only loop tuned for slow response. Setpoint flow rates shall be provided by the A/E. Flow rate shall be determined in any of the following ways as specified for the particular AH:

1) Measured directly by an OA flow station.
2) As determined by CO₂ mixing equations using the SA, OA, and RA CO₂ sensors.

e) Mixed Air Plenum Pressure Control: Minimum position of the OA damper shall be set to obtain the design required minimum OA. This balanced position shall remain fixed whenever the minimum loop is active. BAS shall control the return air damper to maintain a mixed air plenum pressure (relative to outside) setpoint which will be specified by the balancer (-0.5”). Ensure the OA reference pressure is adequately dampened against wind fluctuations using a wind resistance static tip, restrictors, and air volume capacitance.

3. VAV Return Fan Capacity Control: BAS shall control the output of the return fan as follows:

a) Flow Tracking: The return air fan shall run to maintain a return flow setpoint of the supply flow minus an offset value. The offset value shall be determined as follows:

1) Fixed Differential: It shall be fixed at the design minimum OA value.
2) Differential Reset From RA CO₂: It shall be reset between limits of system exhaust make-up air CFM and the design minimum CFM to maintain a RA CO₂ setpoint of 900 ppm (adj.). Loop shall be a “sample and bump” or dynamic proportional only loop tuned for slow response. Setpoint flow rates shall be provided by the University.
3) Differential Reset From Measured OA to Maintain Fixed OA: The differential shall be reset to maintain the measured minimum OA flow at the design value any time the economizer mode is inactive. Whenever economizer is inactive, the offset valve shall be set to the value that existed when the unit became active.

4) Differential Reset From Measured OA to Maintain Reset OA: When the economizer mode is inactive, offset valve shall be reset to maintain the measured OA flow setpoint. The OA setpoint shall be reset between limits of system exhaust make-up air CFM and the design minimum CFM to maintain a RA CO2 setpoint of 900 ppm (adj.). Loop shall be a “sample and bump” or dynamic proportional only loop tuned for the slow response. Setpoint flow rates shall be provided by the University. Whenever the economizer is active, offset valve shall be set to the value that existed when the unit became active.

b) Rescaled Output Capacity Control: The output for the return fan capacity control shall be rescaled from the output of the to the supply device such that the design minimum OA temperature is maintained at both maximum and 50% flow conditions. The balancing contractor shall determine the coordinated output.

4. Airside Economizer: BAS shall modulate the mixing dampers to provide “free cooling” when conditions merit. The free cooling shall generally be staged before any mechanical cooling. While conditions merit, dampers shall be modulated in a DA PID loop to maintain mixed air temperature at a setpoint as specified for the individual unit. Economizer logic shall remain enabled during setback cooling where applicable. The following strategy shall be used to enable the economizer mode:

a) Dry Bulb Switch: Economizer mode shall be active while the unit is energized AND when outside air temperature falls below the switching setpoint of 55°F (adj.) (with 5°F cycle differential). Economizer mode shall be inactive when outside air temperature rises above switching setpoint, dampers shall return to their scheduled minimum positions as specified above.

5. Sequenced Heating and Cooling: BAS shall control the heating and cooling coils and air side economizer as detailed for the particular AH. Program logic shall directly prohibit the heating and cooling valves as well as the heating valve and economizer damper to be open (or above minimum) simultaneously. This does not apply to cooling and reheat valves that are used simultaneously for dehumidification.

6. Mixed Air Low Limit Override: BAS shall override the signal to the OA damper via a proportional only loop to maintain a minimum mixed air temperature of 45°F (adj.) (loop shall output 0% at 45°F which shall be passed to the output via a low selector).

7. Smoke Pressurization Cycle: When pressurization is commanded by the interface to the fire alarm system, supply fan shall start and deliver 100% outside air to the space. Return fan shall remain off. Hardwired interlock from safeties may still interrupt fan operation. (See damper and heating valve sequences for additional sequences associated with pressurization.)
8. **Smoke Exhaust Cycle**: when exhaust is commanded by the interface to the fire alarm system, return fan shall start and shall exhaust 100% return air from the space. Supply fan shall remain off. (See damper and heating valve sequences for additional sequences associated with pressurization.)

9. **Freeze Safety**: Upon operation of a freezestat, unit shall be de-energized with the exception of the heating loops. Typically supply and return fans, where applicable shall be de-energized via a hardwired interlock, and an indication of the operation shall be sensed by the BAS. BAS shall enunciate appropriate alarm and remove and lock out the start command, which shall initiate "fan failure" alarms. OA dampers shall close and heating loops shall remain active.

10. **Smoke Safety**: Upon indication of smoke by a smoke detector, BAS shall de-energize the AH. Smoke detector shall notify the fire alarm system, shut down the fans, and close the smoke dampers via hard-wired interlock.

11. **High or Low Pressure Safety**: Upon activation of a high or low pressure safety switch, AH shall be de-energized, fans shall be de-energized via a hard-wired interlock, and an indication of the operation shall be sensed by the BAS. BAS shall annunciate appropriate alarm and remove and lock out the start command, which shall initiate "fan failure" alarms.

B. The detailed “logic strategies” above shall be required by reference to them in each of the individual sequences specified below.

### 3.04 AIR HANDLING UNIT DIAGNOSTICS - GENERAL

A. **Diagnostic Strategies**: In addition to the standard alarm limits specified for all sensed variables, the BAS shall monitor and diagnose anomalies in the operation of the air handlers. The following “diagnostic strategies” shall be included by reference with each air handler with any specific clarifications required:

1. **Run Time Limit**: BAS shall accumulate the runtime of the status of associated rotating equipment and annunciate a level 5 alarm to indicate that the unit is in need of service.

2. **Filter Monitoring**: BAS shall monitor the differential pressure switch across the filter bank(s). A level 5 alarm shall be reported when pressure drop exceeds the switch’s setting.

3. **Start Monitoring**: BAS shall accumulate the starts of cycling equipment. BAS shall further annunciate a level 5 alarm when the number of starts exceeds the specified value within the specified time period (i.e. more than 3 starts in a 30-min. period).

### 3.05 AIR HANDLER MONITORING AND MANAGEMENT

A. **General**: The BAS shall monitor various aspects of the air handling systems and calculate parameters as specified below to facilitate operations and management.

1. **Trending**: The BAS shall continuously monitor, calculate, and display the following parameters at the intervals indicated. These values shall be stored initially in the buffer of the controlling control unit, and then be uploaded periodically and stored on a specified historical trend server. Trend intervals shall be set per LEED credit requirements or 15 minutes whichever period has a higher frequency.

2. Parameters to be Tended:
a) All temperature sensors at 15-minute intervals.
b) All relative humidity sensors at 15-minute intervals.
c) All pressure sensors at 15-minute intervals.
d) All run requests and statuses on a change in value.
e) All analog loop outputs on 15-minute intervals.
f) Calculated enthalpies in 15-minute intervals.
g) Summed cooling and heating requests on 15-minute intervals.

3.06 GENERAL PRIMARY/SECONDARY CHW SYSTEMS CONTROL

A. General: BAS shall fully control the chilled water systems and equipment and shall provide monitoring and diagnostic information for management purposes. The following logic strategies are referenced in the individual sequences and expand on the requirements.

B. Cooling Enable: As indicated on the drawings for the specific system.

C. Chilled Water Load Determination:
   1. Chilled water load shall be calculated instantaneously from the flow and temperature difference of the following loops:
      a) Primary loop total.
      b) Individual chiller circuits.
      c) Individual secondary circuits (as applicable).
   2. Chilled water load for the purposes of the staging the chillers shall be calculated as the 10 min average of the secondary circuit loads.

D. Chiller Staging: Chiller shall be staged as specified below.

E. Proof Of Chiller Operation: BAS shall prove the operation of the chillers via chiller status and alarm points. When a chiller is assessed as failed, the run command shall be locked out and shall require manual acknowledgment at the operator interface before it is restarted. BAS shall then start the next chiller in rotation. The following conditions shall result in the assessment that the chiller has failed:
   1. Loss of chiller status for more than 15s (adj.) while it is requested.
   2. Closure of chiller failure input.
   3. Leaving chilled water temperature exceeds chiller setpoint plus 8°F for 10 min. continuously.
   4. Chiller environment is unacceptable for 10 min. as specified below.

F. Chiller Environment Monitoring: BAS shall monitor the “environment” of all active (not starting or stopping) chillers and remove the run command when the environment is assessed as unacceptable. An unacceptable environment will include any of the following:
   1. Loss of status on the associated primary pump (pump proof debounce time shall not apply).
   2. Condenser water entering temperature below CHW supply plus 12°F or above 100°F.
   3. Condenser water flow below a minimum setpoint GPM where such flow is measured.
   4. Chilled water flow below a minimum setpoint GPM.
G. In the event that the environment is assessed as unacceptable BAS shall enunciate an alarm, remove chiller run command (not the chiller request; all supporting equipment shall continue to operate) and start a timer. If the environment is still unacceptable after 10 min. (adj.), fail the chiller.

H. **Chiller Request:** A chiller request is the request for a chiller and the associated equipment. A chiller request is issued before the actual run command to the chiller, which is the closure of the physical point that enables the chiller.

I. **Chilled Water Temperature Control:** The chilled water temperature shall be controlled as specified below.

### 3.07 CHILLER STAGING (T ON L OFF):

A. BAS shall control the starting and stopping of chillers to meet the demands of the secondary chilled water systems (SCHW). Whenever cooling is requested, a minimum of one chiller shall be requested. Chillers shall be started per the chiller start sequence and stopped per the chiller stop sequence specified below. Once the conditions merit starting or stopping a chiller, BAS shall complete the starting or stopping sequence regardless of temperature fluctuations during the sequence. Additional chillers shall be started based on SCHW supply temperature as follows:

1. For the purposes of chiller staging control, a virtual point called “average secondary chilled water supply temperature” (ASCHWST) shall be continuously calculated and displayed. This value shall be the 10 minute average of the instantaneously sensed secondary chilled water supply temperature.

2. An additional chiller shall be requested and started per the chiller start sequence specified below when:
   a) The ASCHWST rises more than 4°F above the secondary chilled water supply setpoint for 5 min. (adj.) continuously, AND
   b) More than 30 min. (adj.) has elapsed since the start of the last chiller.

3. Chillers shall be stopped, per the chiller stop sequence specified below, based on the averaged cooling load as follows:
   a) One chiller shall be stopped when the load falls below (Total Nominal Capacity-(Nominal Capacity of Last Chiller) * 1.2), AND
   b) A minimum of 15 min. has elapsed since a chiller has been stopped, AND
   c) A minimum of 30 min. has elapsed since this chiller has been started.

### 3.08 CHILLER STAGING (LOAD):

A. BAS shall control the starting and stopping of chillers to meet the demands of the secondary chilled water systems. Whenever cooling is requested, a minimum of one chiller shall be requested. Chillers shall be started per the chiller start sequence and stopped per the chiller stop sequence specified below. Once the conditions merit starting or stopping a chiller, BAS shall complete the starting or stopping sequence regardless of temperature fluctuations during the sequence. Additional chillers shall be started based on SCHW load as follows:

1. An additional chiller shall be requested and started per the chiller start sequence specified below when:
a) The average cooling load rises above 90% of the nominal capacity of
the active chillers for 5 min. (adj.) continuously, AND
b) More than 30 min. (adj.) has elapsed since the start of the last chiller.

2. Chillers shall be stopped, per the chiller stop sequence specified below,
    based on the averaged cooling load as follows:
   a) One chiller shall be stopped when the load falls below
      (Total Nominal Capacity-(Nominal Capacity of Last Chiller) * 1.2), AND
   b) A minimum of 15 min. has elapsed since a chiller has been stopped,
      AND
   c) A minimum of 30 min. has elapsed since this chiller has been started.

3.09 CHILLER STAGING (CHILLER AMPS):
   A. BAS shall control the starting and stopping of chillers to meet the demands of the
      secondary chilled water systems. Whenever cooling is requested, a minimum of
      one chiller shall be requested. Chillers shall be started per the chiller start
      sequence and stopped per the chiller stop sequence specified below.
      Once the conditions merit starting or stopping a chiller, BAS shall complete the
      starting or stopping sequence regardless of temperature fluctuations during the
      sequence. Additional chillers shall be started based the amperage drawn by the
      chiller as follows:
      1. An additional chiller shall be requested and started per the chiller start
         sequence specified below when:
            a) The average percent amperage drawn by the active chillers rises above
               95% of the nominal full load amperage of the active chillers for 5 min.
               (adj.) continuously, AND
            b) More than 30 min. (adj.) has elapsed since the start of the last chiller.
      2. Chillers shall be stopped, per the chiller stop sequence specified below,
         based on the averaged cooling load as follows:
         a) One chiller shall be stopped when the load falls below
            (Total Nominal Amperage-(Nominal Amperage of Last Chiller) * 1.2), AND
         b) A minimum of 15 min. has elapsed since a chiller has been stopped,
            AND
         c) A minimum of 30 min. has elapsed since this chiller has been started.

3.10 PRIMARY CHW PUMP CONTROL (ONE PUMP/CHILLER)
   A. Primary pumps shall be started to serve their respective chiller when it is
      requested to run per the chiller start and stop sequences specified below. Pumps
      shall run continuously when the respective chiller is requested. BAS shall prove
      operation of the pump.

3.11 SECONDARY CHW PUMP (WITH VFD) CONTROL
   A. Secondary pumps shall run continuously whenever cooling is requested from the
      system it is serving or when system is enabled by the operator. BAS shall prove
      operation of the pump. BAS shall vary the speed of the pumps to maintain the
      lowest differential pressure setpoint across any of the applicable differential
      pressure sensors. The differential pressure setpoint shall either be fixed at 10 psi
(adj.) or reset between 5 psi (adj.) and 15 psi (adj.) based on one of the following as indicated specifically on the drawing sequences:
1. Valve position, OR
2. Cooling requests from the applicable secondary terminals

3.12 CONDENSER WATER PUMP CONTROL (One Pump/Chiller)
A. Pumps shall be started per the chiller start and stop sequences specified below to serve their respective chiller when the chiller is requested to run. Pumps shall run continuously when their chiller is requested. BAS shall prove operation of the pumps.

3.13 COOLING TOWER BYPASS VALVE CONTROL
A. BAS shall control the bypass valve via a PID control loop to maintain a minimum mixed condenser water temperature of 65°F when systems are in mechanical cooling mode.

3.14 CHILLER PRIORITY SELECTION (EQUAL SIZE AND EFFICIENCY CHILLERS)
A. BAS shall automatically prioritize the chillers for starting order. One of the following methods shall be employed to rotate and re-prioritize the chillers.
   1. The chiller with the least run time shall be started first and the chiller with the greatest runtime shall be stopped first.
   2. The BAS shall provide a graphic screen to support the manual selection of chiller priorities.
   3. The chiller priorities shall be rotated based on a predetermined schedule. Owner shall dictate a regular schedule for the priorities to be switched.
B. Operators shall be able to lock out chillers in “Maintenance Mode. This means that the requests for this chiller and associated appurtenances shall be bypassed. This shall be done through a graphic icon associated with a virtual point indicating whether the maintenance mode is active or via a property associated with the chiller icon.

3.15 CHILLER START SEQUENCE
A. On a request for a chiller to start as specified above under “Chiller Staging,” the following sequence shall occur:
   1. Wait thirty seconds (adj.).
   2. Enable additional cooling towers as specified above (if applicable). This shall enable the bypass valve control loop if it is not already enabled. Then command the isolation valves to open. The travel rate of the tower isolation valves shall be limited so as to ease the shock on the tower water system leaving temperature during cold weather. For systems that allow tower piping to drain when the system is off, upon start up fully close bypass valve for 30 seconds (adj.) to prime the system and eject air when the system is first started.
   3. Gradually reset the demand limit to all active chillers from 100% to 50% (adj.) of maximum amps.
4. Request the start of the applicable condenser water pump and prove operation.
5. After condenser pump operation is proven, BAS shall start the applicable primary chilled water pump and prove operation. Concurrently with the starting of the chilled water pumps, BAS shall open the chiller isolation valve (if applicable) at a limited rate of travel to minimize the shock to other operational chillers.
6. Wait a maximum of 5 min. after the command to start the condenser pump for the chiller environment as specified above to be acceptable. As soon as the environment is assessed as acceptable, continue the start sequence. If after 5 min. the environment is not acceptable, fail the chiller and start the next chiller.
7. Command the chiller to start under its own control.
8. Monitor chiller status and prove operation. If status is not indicated within 3 minutes (adj.) of a command to start, announce an alarm, disable and lock out chiller.
9. After status is proven, gradually reset current limit to all active chillers to 100%.

3.16 CHILLER STOP SEQUENCE
A. When a chiller is no longer needed as specified in chiller staging, the following sequence shall occur:
   1. Remove chiller run command.
   2. Wait for status to clear and for the chiller to stop under control.
   3. Wait 1 min. (adj.). Then, where applicable, begin to modulate closed the isolation valve. At mid-stroke stop associated PCHW pump.
   4. Where applicable, begin to stroke the condenser isolation valve closed and at mid stroke, stop the condenser pump.
   5. Close applicable tower isolation valves and, if this is the last chiller running on the circuit, close the applicable bypass valve.

3.17 GENERAL HEATING WATER SYSTEMS CONTROL
A. General: BAS shall fully control the hot water systems and equipment and provide monitoring and diagnostic information for management purposes. The following logic strategies are referenced in the individual sequences and expand on the requirements.
   B. Heating Enable: Heating shall be enabled as indicated on the drawing sequence.
   C. Hot Water Load Determination
      1. Hot water load shall be calculated instantaneously from the flow and temperature difference of the following loops:
         a) Primary loop total.
         b) Individual boiler circuits.
         c) Individual secondary circuits.
      2. Hot water load for the purposes of the staging the chillers shall be calculated as the 10 min average of the secondary circuit loads.
3.18 CENTRAL PLANT MONITORING AND MANAGEMENT

A. General: The BAS shall monitor various aspects of the heating and cooling systems and calculate parameters as specified below to facilitate plant operations and management.

B. Trending: The BAS shall continuously monitor, calculate, and display the following parameters at the intervals indicated. These values shall be stored initially in the buffer of the controlling control unit, and then be uploaded periodically and stored on a specified hard disc. Contractor shall format reports from this data to support one of the following data formats:
   1. Quote (text strings) and Comma delimited.
   2. Microsoft EXCEL.
   3. Microsoft ACCESS.

C. Parameters to be Trended:
   1. Load on the secondary systems in MBH per the following equation: (Return Temp-Supply Temp) * (GPM) / .5. This shows cooling as a positive heat load and heating as a negative heat load. Note that multipliers on this value to accommodate the BAS processors are acceptable as long as they are clearly indicated. This value shall be trended and stored every two hours.
   2. All temperature sensors at 15-minute intervals.
   3. All relative humidity sensors at 15-minute intervals.
   4. All pressure sensors at 15-minute intervals.
   5. All run requests and statuses on a change in value.
   6. All analog loop outputs on 15-minute intervals.
   7. Calculated enthalpies in 2-hour intervals.
   8. Summed cooling and heating requests on 2-hour intervals.

END OF SECTION