

SECTION 23 09 23 - BUILDING AUTOMATION SYSTEM (BAS) FOR HVAC

PART I - GENERAL

1.1 SECTION INCLUDES

- A. Standalone Digital Controllers
- B. Network Interface Modules
- C. Application Specific Controllers
- D. Integrating Subsystem Controllers
- E. Control Devices, Components, Wiring and Material
- F. Instructions for Owners

1.2 RELATED SECTIONS *[Note to PSC: List additional sections as required by project.]*

- A. *Section 01 91 13 - General Commissioning Requirements*
- B. *Section 23 08 00 - Commissioning of HVAC*
- C. *Section 23 09 13 - Instrumentation and Control Devices for HVAC*
- D. *Section 23 09 13.33 – Control Valves*
- E. *Section 23 09 13.34 – Control Valve Actuators*
- F. *Section 23 09 13.43 – Control Dampers*
- G. *Section 26 29 23 – Variable Frequency Motor Controllers*
- H. *Section 28 30 00 - Fire and Smoke Detection System*

1.3 RELATED DRAWINGS *[Note to PSC: Include as appropriate and edit to be specific to the project.]*

- A. *Drawing 23 09 05-01, Controls Symbols*
- B. *Drawing 23 09 05-02, Type VAV AHU, Minimum OA, Steam Preheat*
- C. *Drawing 23 09 05-03, Type VAV AHU, Minimum OA, HW Preheat*
- D. *Drawing 23 09 05-04, Type CV AHU, Minimum OA, Steam Preheat*
- E. *Drawing 23 09 05-05, Type CV AHU, Minimum OA, HW Preheat*
- F. *Drawing 23 09 05-06, Type CV AHU, 100%OA, Steam Preheat*
- G. *Drawing 23 09 05-07, Type CV AHU, 100%OA, HW Preheat*
- H. *Drawing 23 09 05-08, Type CV AHU, 100%OA, HW Preheat, Heat Recovery Loop*
- I. *Drawing 23 09 05-09, Type CV AHU, 100%OA, HW Preheat, Heat Wheel*
- J. *Drawing 23 09 05-10, Pressure Independent VAV Box with HW Reheat and Perimeter Radiation*
- K. *Drawing 23 09 05-11, Steam to Hot Water Heat Exchanger HW System Controls*
- L. *Drawing 23 09 05-12, Chilled Water Bldg Entrance Valve Flow Control Valve*
- M. *Drawing 23 09 13-1, Pressure Differential Instrumentation Piping*
- N. *Drawing 23 09 13-2, Static Pressure Instrumentation Detail*
- O. *Drawing 23 09 13-3, Central Chilled Water System Metering Station Detail*
- P. *Drawing 23 09 23-1, 40 Deg Freezestat-Elect CHW Valve Override*

- Q. *Drawing 23 09 23-2, 40 Deg Freezestat Pneumatic CHW Valve Override*
- R. *Drawing 23 09 23-3, Typical BAS Network Architecture*
- S. *Drawing 23 09 23-4, DDC Panel Installation Detail*
- T. *Drawing 23 09 23-5, General Safety Circuit*
- U. *Drawing 23 09 23 -7 Across the line starter (FVNR) Damper /Fan Motor Application*
- V. *Drawing 23 09 23 -8 Isolation Damper with VFD*
- W. *Drawing 23 09 23 -9 Air Flow Monitoring Stations (AFMS) Placement Details*
- X. *Drawing 23 09 43-1, Temperature Control Air Compressor Installation*
- Y. *Drawing 26 29 23 -01 Configured VFD control wiring from VFD supplier*
- Z. *Drawing 26 29 23-02 , Factory VFD wiring to field wiring terminal strip*

1.4 RELATED EXHIBITS

- A. *Exhibits 23 09 23-01a and 23 09 23-01b, Example Building Main Navigation Screen*
- B. *Exhibits 23 09 23-02a and 23 09 23-02b, Example AHU Graphics Screen*
- C. *Exhibit 23 09 23-03, Example AHU Zone Plan*
- D. *Exhibits 23 09 23-04a and 23 09 23-04b, Example VAV Navigation Screen*
- E. *Exhibits 23 09 23-05a and 23 09 23 05b, Example VAV Summary Table*
- F. *Exhibit 23 09 23-06, Example VAV Small Scale Zone Plan*
- G. *Exhibits 23 09 23-07a and 23 09 23-07b, Example VAV Graphics Screen*
- H. *Exhibit 23 09 23 -08a VAV Box Sequence of Operation*
- I. *Exhibit 23 09 23-09 AHU Standard VAV AHU Sequence of Operation*
- J. *Exhibits 23 09 23-09a and 23 09 23-10a System Graphics Wheel Presentation Example*
- K. *Exhibits 23 09 23 -11 and 23 09 23-12 IO Point Naming Convention*
- L. *Exhibit 23 09 23-14 Energy Recovery Wheel Standard Sequence of Operation*
- M. *Exhibit 23 09 23-15 Energy Recovery Run Around Coil Standard Sequence of Operation*
- N. *Exhibit 23 09 23-16 Two Pump HTX Sequence of Operation*

1.5 REFERENCES

- A. UL508A – Standard for Industrial Control Panels
- B. NEMA 250 Enclosures for Electrical Equipment (1000 volts Maximum)
- C. ASHRAE 85 Automatic Control Terminology for Heating, Ventilating, Air Conditioning
- D. NFPA 70
- E. National Electrical Code
- F. UL 864 - Standard For Safety For Control Units For Fire Protective Signaling Systems

1.6 ACRONYMS

- A. Acronyms used in this specification are as follows:
 1. ASD Application Specific Device
 2. ALN Area Level Network
 3. BAS Building Automation System
 4. BLN Building Level Network

- 5. CER Communication Equipment Room
- 6. *Technology Services*
- 7. CSMA/CD Carrier Sense Multiple Access / Collision Detect
- 8. DDC Direct Digital Control
- 9. HHOT Hand Held Operator's Terminal
- 10. IP Internet Protocol
- 11. FLN Field Level Network
- 12. LAN Local Area Network
- 13. LEED Leadership in Energy and Environmental Design
- 14. NEC National Electric Code
- 15. NCU Network Control Unit
- 16. NIM Network Interface Module
- 17. P&ID Piping & Instrument Diagrams
- 18. PID Proportional, Integral, Derivative
- 19. SDC Stand-alone Digital Controller

1.7 DEFINITIONS

- A. BAS (Building Automation System)
 - a. Devices, conduit, wire, programming and protocols required for operation of a building's environmental control systems. Major systems and units controlled include items such as Chilled Water Distribution, Air Handling Units, DOA units, Chillers, Boilers, Heat Exchangers, and Hot Water Distribution.

- B. Networks: in order of speed / hierarchy.
 - 1. LAN (Local Area Network) Ethernet Communications Network by *Technology Services*
 - 2. BLN (Building Level Network) / ALN (Area Level Network)
 - a. Communication Network between SDC's inside the building.
 - b. Acceptable Protocols used for communication include:
 - (a) Siemens: APOGEE P2 ALN (preferred) or BACnet I/P
 - (b) Siemens: BACnet I/P
 - (c) Schneider Electric Building Systems I/A Series: BACnet I/P
 - c. Used to communicate between BAS devices installed within the building.
 - d. Higher Speed
 - 3. FLN – Field Level Network
 - a. Communications network between ASD's, SDC's
 - b. Acceptable Protocols used for communication include:
 - (d) Siemens: APOGEE P1 FLN
 - (e) Siemens: BACnet MS/TP
 - (f) Schneider Electric Building Systems I/A Series: BACnet MS/TP

- C. Specific Control Component Devices
 - 1. ASD (Application Specific Device)
 - a. Communicates on the FLN
 - b. Contains Analog / Digital I/O points.
 - c. Typically used on Terminal Units such as VAV's, Fan Coils.
 - d. Can "Fully Load", e.g. does not need spare I/O Point capacity.
 - 2. NCU (Network Control Unit)
 - a. Device which communicates between LAN and BLN
 - b. May have capability to directly control Analog / Digital I/O points.

3. NIM (Network Interface Module)
 - a. Device which communicates between LAN and BLN.
 - b. Has no capability to directly control Analog / Digital I/O points.
4. SDC (Stand-alone Digital Controller)
 - a. Device which communicates between LAN and BLN
 - b. May also communicate to devices on FLN.
 - c. Has capability to directly control Analog / Digital I/O points.
 - d. Design so that unit uses only 80% of total I/O capacity to allow for future expansion without immediate need for an additional I/O module.

1.8 LEED REQUIREMENTS

- A. This project shall meet the requirements of the current U.S. Green Building Council Leadership in Energy and Environmental Design (LEED) program.
- B. Carefully examine the LEED portion of the Project Specification for full compliance with the following applicable LEED points. Note that these Prerequisite and Credit descriptions are taken from the 2009 edition of LEED. *[Note to PSC: Descriptions may vary for future editions of LEED. This section needs editing to meet specific requirements of project.]*
 1. "Energy & Atmosphere": Prerequisite 1, "Fundamental Commissioning of Building Energy Systems", Prerequisite 2, "Minimum Energy Performance," Credit 3 - "Enhanced Commissioning", and Credit 5 - "Measurement and Verification", as described by LEED. *[Note to PSC: A complete and total re-commissioning of the temperature control system may be required at one- and two-year intervals. This portion needs removed or revised to give specific requirements to the Building Automation Systems (BAS) Contractor. For LEED platinum projects, the requirement is re-commissioning at one and two year intervals, thus this requirement must be left in. However, it is not reasonable to expect the Contractor to have involvement beyond warranty period nor to bid to 'open ended' / undefined requirements so these contract documents must do a thorough job of defining the work to be done.]*
 2. "Indoor Environmental Quality": Prerequisite 1 - "Minimum Indoor Air Quality Performance", Credit 1 - "Outdoor Air Delivery Monitoring", Credit 2 – "Increased Ventilation", Credit 6.1 - "Controllability of Systems – Lighting", and Credit 6.2 - "Controllability of Systems - Thermal Comfort."
 3. All labor and materials required for these and any other LEED initiatives shall be provided without additional cost to the Owner.

1.9 SYSTEM DESCRIPTION

- A. DDC System: The BAS-Building Automation System shall be a direct digital control (DDC) system which can, without additional equipment, perform all of the automatic temperature control and energy management functions as required in this specification. DDC shall be defined as a control technique through which the process is continuously monitored by a digital computer that accomplishes loop control by calculating a control solution for output to a control device. Each DDC building automation system for HVAC shall be network of independent stand-alone digital controllers (SDC's). Each SDC shall be capable of full control either as a completely independent unit or as a part of a building wide control system. Each SDC shall be capable of communicating with each other without the use of a central host computer within the building level network. Each SDC shall directly communicate to a building Network Interface Module (NIM) which shall be connected to the campus Ethernet. Each SDC shall be provided with two *Technology Services* Ethernet connections, one for the controller (native Ethernet protocol) and other for a portable laptop computer. The system, as specified, shall independently control the building's HVAC equipment to maintain a comfortable environment in an energy efficient manner. Each DDC system shall accommodate internet enabled viewing of the control system. All building level network controllers shall be native Ethernet peer to peer architecture. Floor level network devices shall be DDC devices as well provided with native manufacturer's protocols specified in this standard. System components shall be fully compatible with

existing systems from the same vendor on the campus of the University of Illinois at Urbana-Champaign.

- B. Site License: Approved vendors have systems at this campus with a site license covering all system software which has been documented, approved and signed by all parties. The site license shall be maintained by the University with the vendor in contracts negotiated outside of this project contract. Client Licenses shall be utilized and provided by vendor under this contract where required by this project's system.
- C. Client License: Where required by the system architecture, the vendor shall provide a Client License for utilization at the project site. In addition, a client license shall also be provided to the Owner with each new project added to the system.

1.10 SUBMITTALS

- A. General: Submit documents under provisions of Division 01. Two (2) printed copies of the materials shall be delivered directly to the Owner, in addition to the copies required by other Sections. In addition, an electronic version of the completed materials shall be provided on CD or DVD. Refer to *Section 01 91 13 – General Commissioning Requirements* and *Section 23 08 00 – Commissioning of HVAC* for additional Commissioning submittal requirements.
- B. Electronic Submittals: While all requirements for hard copy submittal apply, control submittals and operation and maintenance (O&M) information shall also be provided in electronic format as follows:
 - 1. Drawings and Diagrams: Shop Drawings shall be provided on electronic media as an AutoCAD drawing per Owner's CAD standards. All 'x reference' and font files must be provided with AutoCAD files.
 - 2. Other Submittals: All other submittals shall be provided in Adobe Portable Document Format.
- C. Equipment Coordination:
 - 1. The Building Automation Systems (BAS) Contractor shall obtain approved equipment submittals from other contractors to determine equipment wiring connections, to choose appropriate controllers, and to provide programming.
 - 2. Control valve selections shall be based on control valve schedule and flow rates shown in Construction Documents.
 - 3. Coordinate the control interface of all equipment with the equipment manufacturers prior to submittal submission.
- D. Shop Drawings Grouped into Separately Phased Submissions: Submit Shop Drawings in groups to be reviewed at appropriate phases of the construction execution. Groups shall be established and submitted such that components and equipment requiring the longest lead time and/or greater coordination efforts are reviewed and approved first. A suggested grouping and order of submission is as follows:
 - 1. First Submission:
 - a. Proposed point names (prior to beginning any programming effort.) Do not begin programming effort until the Owner has approved the point names. *[Note to PSC: All TAB- terminal air boxes controllers including VAV, FCU controllers etc. will be **numbered per room number**. If there are multiple rooms serving as one zone then TAB controllers will be numbered per thermostat room location. *Early in the design process, request a copy of the University's most current point naming convention from the Owner, and incorporate the correct point names into the project. Also, include in documents/drawings and following Exhibits: 23 09 23-11 Siemens IO Point Naming Convention and 23 09 23-12 Alpha Controls IO Point Naming Convention.]**
 - b. Main Valves and their actuators
 - c. Boilers, Chillers

- d. AHU's, Heat Recovery Units
 - e. System Architecture and System Layout
 - 2. Second Submission
 - a. Unitary Controllers, VAV's
 - b. Dampers and their actuators
 - c. Air Flow Measuring Stations
 - d. Schematic Flow Diagrams
 - e. Schematic Diagrams
 - f. Points List
 - g. Sequences
 - h. Product Data of all control devices, panels and accessories
 - 3. Third Submission
 - a. Graphics Pages
 - b. Programming, Block Diagram format and native program language with annotation and documentation.
 - c. Schematic Wiring Diagrams
- E. Shop Drawings: Submit Shop Drawings electronically on AutoCAD software for each control system, including a complete drawing for each air handling unit, system, pump, device, etc. with all point descriptors, addresses and point names indicated. Shop Drawings shall contain the following information:
1. Cross-reference all control components and point names in a single table located at the beginning of the submittal with the identical nomenclature used in this section.
 2. Submittal shall include a trunk cable schematic diagram depicting operator workstations, control panel locations and a description of the communication type, media and protocol.
 3. System Architecture and System Layout: Provide One-line diagram indicating schematic locations of all control units, workstations, LAN interface devices, gateways, etc. Indicate Ethernet backbone number, network number, device ID, address, device instance, MAC address, object ID (object type, instance number), drawing reference number, and controller type for each control unit. Indicate media, protocol, baud rate, and type of each LAN. All optical isolators, repeaters, end-of-line resistors, junctions, ground locations etc. shall be located on the diagram. Include interface requirements with other systems, including but not limited to, security and surveillance systems, lighting control, elevator status, power monitoring systems and door access systems.
 - a. Provide floor plans locating all control units, workstations, servers, LAN interface devices, gateways, etc. Include all WAN and LAN communication wiring routing, power wiring, power originating sources, and low voltage power wiring. Indicate Ethernet network number, network number, device ID, address, device instance, MAC address, drawing reference number, and controller type for each control unit. Indicate media, protocol, baud rate, and type of each LAN. All optical isolators, repeaters, end-of-line resistors, junctions, ground locations etc. shall be located on the floor plans. Wiring routing as-built conditions shall be maintained accurately throughout the construction period and the drawing shall be updated to accurately reflect accurate, actual installed conditions.
 4. Diagrams shall include:
 - a. Wiring diagrams and layouts for each control panel showing all termination numbers.
 - b. Schematic diagrams for all control, communication and power wiring. Provide a schematic drawing of the central system installation. Label all cables and ports with computer manufacturers' model numbers and functions. Show all interface wiring to the control system.
 - c. Identification of all control components connected to emergency power.

- d. Schematic diagrams for all field sensors and controllers.
 - e. A schematic diagram of each controlled system. The schematics shall have all control points labeled. The schematics shall graphically show the location of all control elements in the system.
 - f. A schematic *wiring* diagram for each controlled system. Each schematic shall have all elements labeled. Where a control element is the same as that shown on the control system schematic, label it with the same name. Label all terminals.
 - g. A tabular instrumentation list for each controlled system. The table shall show element name, type of device, manufacturer, model number and product data sheet number.
 - h. All installation details and any other details required to demonstrate that the system will function properly.
 - i. All interface requirements with other systems.
5. With each schematic, provide a point summary table listing building number and abbreviation, system type, equipment type, full point name, point description, If this information is not available at the time of Shop Drawings submittals, furnish with O&M manual documentation for Owner review and approval. See *Section 01 33 23 – Shop Drawings, Product Data, and Samples* and *Section 01 78 23 – Operation and Maintenance Data* for additional requirements.
 6. The network infrastructure shall conform to the published guidelines for wire type, length, number of nodes per channel, termination, and other relevant wiring and infrastructure criteria as published. The number of nodes per channel shall be no more than 80% of the defined segment (logical or physical) limit in order to provide future system enhancement with minimal infrastructure modifications.
 7. Sequences: Submit a complete description of the operation of the control system, including sequences of operation. The description shall include and reference a schematic diagram of the controlled system. **The wording of the control sequences in the submittal shall match verbatim that included in the construction documents to ensure there are no sequence deviations from that intended by the PSC. Clearly highlight any deviations from the specified sequences on the submittals.**
 8. Points List Schedule: Submit a complete points list of all points to be connected to the BAS. The points list for each system controller shall include both inputs and outputs (I/O), point number, the controlled device associated with the I/O point, the location of the I/O device, and reference drawings. Where a control point is the same as that shown on the control system schematic, label it with the same name. Points list shall specifically identify alarms, trends, event history, archive, totalization, graphic points, and all mapped points from other systems (security systems, lighting control, fire alarm, etc.). Provide ~~point's lists~~ points list, point naming convention, and factory support information for systems provided and integrated into the BAS.
 9. Schematic flow diagram of each air and water system showing fans, coils, dampers, valves, pumps, heat exchange equipment and control devices.
 - a. Include written description of sequence of operation on the Schematic Flow diagram to match components and system shown.
 - b. All physical points on the schematic flow diagram shall be indicated with names, descriptors, and point addresses identified as listed in the point summary table
 10. Damper Schedule: Schedule shall include a separate line for each damper and a column for each of the damper attributes:
 - a. Damper Identification Tag.
 - b. Location.
 - c. Damper Type.

- d. Damper Size & Quantity.
 - e. Duct Size.
 - f. Arrangement.
 - g. Blade Type.
 - h. Velocity Pressure Drop.
 - i. Fail Position
 - j. Actuator Identification Tag
 - k. Actuator Type & Quantity.
 - l. Mounting.
11. Valve Schedule: PSC shall create a valve schedule. BAS Contractor shall size the control valves and provide Cv. Schedule shall include a separate line for each valve and a column for each of the valve attributes:
- a. Valve Identification Tag.
 - b. Location.
 - c. Valve Type.
 - d. Valve Size.
 - e. Pipe Size.
 - f. Configuration.
 - g. Flow Characteristics.
 - h. Capacity.
 - i. Valve Cv.
 - j. Design Pressure Drop.
 - k. Pressure Drop at Design Flow.
 - l. Fail Position.
 - m. Close-off Pressure.
 - n. Valve and Actuator Model Number and Type.
12. Airflow Measuring Station (AFMS) Schedule: *[Note to PSC: Consider specifying this for installation by Ventilation Contractor. BAS Contractor shall wire and terminate to the AFMS's Transmitter DP. This would be similar to requirements for Damper Installation.]*
- a. The manufacturer's authorized representative shall prepare the airflow measuring station submittal, or review and approve in writing the submittal prepared by the BAS Contractor prior to submission to the PSC and prior to installation. The representative shall review air handling equipment submittals and duct fabrication drawings to ensure that all AFMS locations meet the appropriate parameters to achieve proper installation and the specified accuracy. Comply with all manufacturer's installation requirements including straight up and downstream duct lengths. Install airflow straighteners if required by the manufacturer based on installation constraints. The PSC shall be notified for approval of any deviations.
 - b. Submit product data sheets for airflow measuring devices indicating minimum placement requirements, sensor density, sensor distribution, and installed accuracy to the host control system.
 - c. Submit installation, operation, and maintenance documentation.
13. Product Data: Submit manufacturer's engineering and technical product data for each control device, panel, and accessory furnished, indicating dimensions, capacities, performance and electrical characteristics, and material finishes. Include installation and start-up instructions for each BAS system component.
14. Provide Graphics Pages to be utilized on Operator Work Stations and Web Access. Sample shall be submitted and approved prior to deployment to system components. See Part 2 of this specification for requirements.
15. Provide copy of program to be utilized in each device for approval by the Owner prior to deployment. Submit information in block diagram format (VISIO) as well as in native program language. Submittal shall include all appropriate documentation, commenting and notation to facilitate understanding and troubleshooting the system.

16. Label each control device with setting or adjustable range of control.
 17. Label each input and output with the appropriate range.
 18. 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.
 19. With each schematic, provide valve and actuator information including size, Cv, design flow, design pressure drop, manufacturer, model number, close off rating, etc. Indicate normal positions of spring return valves and dampers.
 20. 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.
 21. Details of control panels, including controls, instruments, and labeling shown in plan or elevation indicating the installed locations.
 22. Sheets shall be consecutively numbered.
 23. Each sheet shall have a title indicating the type of information included and the HVAC system controlled.
 24. Table of Contents listing sheet titles and sheet numbers.
 25. Legend and list of abbreviations.
- F. Training Manual:
1. Provide Course Outline and training manuals for each class. Refer to the paragraph entitled "Training" in Part 3 of this section.
- G. Record Documents:
1. Update and include all information noted in the Shop Drawing section.
 2. Record copies of product data, as built control Shop Drawings and final sequence of operation updated to reflect the final installed condition.
- H. Provide as-built network architecture Drawings showing all nodes including a description field with specific controller identification, description and location information.
- I. As-Built Control Diagram: Provide complete operating data, system drawings, wiring diagrams, and written detailed descriptions of sequences. One copy of the as-built control diagram shall be placed inside each control panel. Provide metallic pocket inside the door large enough to hold complete drawings. Electronic set to be provided to the Owner commencing with start of Warranty period.
- J. Operation and Maintenance Data:
1. Submit maintenance instructions and spare parts lists for each type of control device, control unit, and accessory.
 - a. Include systems descriptions, setpoints, and controls settings and adjustments.
 - b. Include inspection period, cleaning methods, recommended cleaning materials, and calibration tolerances.
 2. Submit BAS User's Guides (Operating Manuals) for each controller type and for all workstation hardware and software and workstation peripherals.

3. Submit BAS advanced Programming Manuals for each controller type and for all workstation software.
 4. Manufacturer's Certificates: For all listed and/or labeled products, provide certificate of conformance.
 5. Product Warranty Certificates: Submit manufacturer's product warranty certificates covering the hardware provided.
- K. Actual Locations: Include actual location of control components, including panels, thermostats, and sensors, not already included in as-built drawings. Include revised shop drawings to reflect actual installation and operating sequences.
 - L. Calibration Report: The BAS Contractor shall submit to the Owner a calibration report of all final slopes, intercepts and/or offsets for all devices prior to final witnessing by the Owner. See Part 3 of this specification for requirements.
 - M. Commissioning Report: At completion of Work, submit commissioning report of automatic control system.

1.11 QUALIFICATIONS

- A. Manufacturer: *[Note to PSC: Approved companies must specialize in manufacturing the products specified in this Section with minimum 5 years experience.]*

1.12 WARRANTY

- A. Components: Provide one-year warranty on all materials and labor, after commissioning is complete and accepted by Owner.
- B. Software Upgrades: Requirements shall include furnishing and installing all BAS software upgrades issued by the manufacturer for one year beyond the warranty period.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

- A. Siemens Apogee / Siemens BACnet and Siemens Desigo graphical interface (unless specified differently by the Owner)
- B. Schneider SmartStruxure Building Systems, I/A Series or pre-approved successor
 - *Note to PSC: 1. Existing Buildings that have R2 UNCs devices.—The University will not approve expansion of these systems. 2. Buildings that have G3 ENC's devices --- The University will approve to expand on these systems adding new devices to the existing ENC's. If it is going to be a large expansion or require a new ENC then SmartStruxure shall be used. (Caution should be used not to overload existing ENC's) 3. Buildings that do not have G3 or R2--- These buildings shall use SmartStruxure.*
- C. DeltaV Control System

Any component that is part of HVAC air handling system, including: ERW- energy recovery wheels, filters, fan arrays, fans, coils and heat recovery coils, control valves, etc., shall be controlled by SDC- standalone digital controller I/P level DDC device manufactured by approved vendors as listed in section 2.1 Acceptable Manufacturers. *Note to PSC: If any controls component deviates from this standard, a variance request shall be submitted to the Owner.*

Fan Arrays Controllers – shall not be allowed as part of HVAC AHU equipment which includes PLC Programmable Logic Controllers. The Architect & Engineer shall provide Non – proprietary sequence of operation for the Fan Array equipment controls as part of AHU system sequence of operation. Standard UIUC approved controller, and instrumentation shall be provided by Temperature Controls Contractor as listed in section 2.1 of this document and VFD- Variable Frequency Drive provided by Electrical Contractor as listed in division 26.

Fan Array specifics – The number of Variable Frequency Drives in a given fan array/fan wall shall not exceed six (6). Exception: motor size above 10 HP. Other VFD and motor combination may be applied through the variance process and UIUC approval. Standard UIUC approved Variable Frequency Drive shall be specified and shall comply with the UIUC division 26 standard.

Packaged Exhaust controls systems will not be allowed. Exhaust fans shall be controlled via Variable Frequency drives and shall comply with the UIUC division 26 standard.

If Equipment Controllers including: Chillers controllers, , Boilers controllers, , Humidifiers controllers are provided on a project, then those controllers and associated peripherals will be commissioned, and functionally tested per project application and sequence of operation by the “factory representative. Temperature Control Contractor will be responsible to **fully integrate and map** associated peripherals physical and virtual control IO points, and shall comply with UIUC standards and UIUC point naming convention per project application. Temperature Control contractor shall be responsible to provide all necessary drivers and integration components to fully integrate these controllers.

Also, minimum of four hard wired points shall be provided on VFD including Equipment START/STOP, ALARM, Set point, Speed reference, and Serial Communication (Data Connection) shall be included as well.

Laboratory Equipment Controllers – Fume Hood Controls System shall be designed to be part of larger building network, and shall communicate directly with all make up air handling DDC controls system. Acceptable Manufacturers are: A.Siemens Apogee/BACnet laboratory controllers with Siemens main head-end, and B. Schneider main head-end with Accutroll and /or Phoenix fume hood air valves integrated via Schneider SmartStruxure building automation system. Network Integration of laboratory fume hood controllers **will not** be allowed via LON based system.

Energy Recovery Wheel Specifics – Energy Recovery Wheels shall be controlled from main air handling unit DDC controller and by DDC approved manufacturers as listed in paragraph 2.1 Building Automation System Acceptable manufacturers. Standard UIUC approved Variable frequency Drive division 26 shall be provided with each energy recovery wheel. Energy recovery Wheel freeze protection sequence shall be provided and incorporated in a control sequence. Purging and crawling operation modes shall be designed based on project needs and manufacturers recommendations.. Also, the UIUC standard four hard wired points shall be provided on the Energy Recovery Wheel VFD drives which include Start/Stop, Alarm, Speed Reference, VFD status, and serial communication shall be provided on all VFD’s.

2.2 SYSTEM ARCHITECTURE

- A. SDC: The system shall be a network of independent stand-alone digital controllers (SDCs). Each SDC shall provide full control either as a completely independent unit or as a part of a building-wide control system. Each SDC shall be capable of and provide peer-to-peer communication without the use of a central host computer within the building level network. Systems that use a master/slave arrangement shall have all master units communicating with each other. New systems shall communicate directly to existing SDCs, application specific devices (ASDs), network interface modules (NIMs), or network control units (NCUs) within the building. They shall be backward compatible with existing systems of the same manufacturer, or they shall provide a new network interface and all associated hardware.
- B. Communication: Each NCU shall directly communicate to the campus Ethernet via an IEEE 802.3 compliant Ethernet connection. Each NCU or NIM shall communicate with the central host computer located at the U of I Physical Plant Service Building (PPSB) and other NIMs on the system via an Ethernet connection. Communication to all primary SDCs within the building shall be via native Ethernet network interfaces using TCP/IP protocols and manufacturer’s native UDP protocols to exchange information in a peer to peer network. All communications shall be complete and fully operational before the

commissioning is started. Location of all NCU's and NIM's shall be coordinated with the U of I Campus Information Technologies (F&S) and the Educational Services (*Technology Services*) network design engineer. Two network connections shall be provided at each NCU or NIM. No locations may be presumed acceptable. The building control network architecture provided by the BAS Contractor on the project shall meet and satisfy all LEED project requirements for reporting and trending as per project documents. . Two network jacks shall be installed at each panel containing a NCU or NIM unless a variance is granted by the Variance Approval Committee.

- C. NCU's shall connect SDC's or floor level ASD devices via a manufacturer's approved native RS-485 protocol or via a BACnet MSTP (Master-Slave Token Passing Bus).
- D. Programming: A single control programming language shall be used and shall be fully programmable from the central host computer, which shall also function as the database server. The system shall utilize client/server architecture, with all points and program databases stored on the server central host computer. All operator workstations shall serve as clients.
- E. **Licensing**: Provide additional client licenses, programming and engineering tools for the installed Systems to the Owner. A Project Variance Request shall be approved by the Variance Approval Committee prior to deviation from this requirement.
- F. **BBMD (BACnet Broadcast management Devices)** :New *Technology Services* networking model for campus is a building routed subnet network instead of the older core routed subnet network. This change has resulted in a growing need for installing more BBMD devices (BACnet Broadcast Management Devices) than were previously installed under the older core routed model. A BBMD "BACnet Broadcast Management device" shall be installed, if required as determined by F&S Systems and Controls Department, on each new project and new buildings where BACnet controls are installed in order to deliver the global BACnet broadcast messages to all BACnet/IP devices on all subnets in the campus BACnet Internetwork.

The F&S UIUC department shall specify and provide a BBMD "BACnet Broadcast Management device" if required for all new buildings on campus. The TC contractor shall install the device and provide power (24 VAc or DC) and data connection to it. The BBMD device can be installed in new dedicated control panel and/or an existing panel on a controller low voltage area side. The specified BBMD device requires 40 VA of 24 VAC power or 25W of 24 VDC power as the device may be AC or Dc powered.

Also, the TC contractor shall follow a special procedure for all projects that involve BACnet.: The vendors must submit a network architecture drawing of their system and an excel spreadsheet documenting controllers and controller BACnet names to the Owner as part of TC drawing submittal package. The owner will issue instance number assignments, IP address assignments and the determination if an additional BBMD device is required.

2.3 BAS CONTROLLERS AND ACCESSORIES

A. General

1. Multiple Building Functions: BAS Contractor shall furnish and install a BAS capable of integrating multiple building functions, including equipment supervision and control, alarm management, energy management, and historical data collection and archiving.
2. System Components: BAS shall consist of, but not be limited to, the following:
 - a. Standalone DDC Panel(s). See definition of SDC, ASD, NIM, and NCU.
3. Future Expansion: System shall be modular in nature, and permit expansion of both capacity and functions through addition of sensors, actuators, panels, and operator devices. System architecture shall support expansion capacity of all types of DDC panels, and all point types included in the initial installation. There shall be a minimum of 10 percent of each type of I/O point available for expansion on each of the SDCs. If

multiple SDCs are mounted in a single location, 10 percent of each type of I/O point type must be available in the group.

4. Primary Operator's Workstation: Primary Operator's Workstation shall be a client machine to the database server located at the Physical Plant Services Building.
5. Self-Diagnostics: The BAS shall contain self-diagnostics that continuously monitor the integrity of the system. Any malfunction of the system shall be reported to the Central Host Computer to inform the operator of the nature of the malfunction and the NIMs, NCUs, or SDCs affected.
6. Battery: Each SDC shall include its own microprocessor-based controller, power supply, input/output modules, termination modules and a rechargeable Lithium battery. The battery shall be capable of supporting all memory and the real time clock within the control unit for a minimum of 72 hours if the external power to the unit is interrupted or lost.
7. 72 Hour Memory: Upon loss of external power to any SDC, the other units within the network shall not be affected, and the loss of operation of that unit shall be reported at the designated operator's terminal. All control strategies and energy management routines defined for the SDC shall be retained during a power failure via the battery within the unit for a minimum of 72 hours. Upon resumption of commercial power, the SDC shall resume operation without operator intervention. The unit shall automatically reset its clock such that proper operation of timed sequences is possible without the need for manual reset of the clock.
8. Local Operator Interface: All SDCs and NCUs shall contain the necessary equipment for direct interface to the sensors and actuators connected to it from a portable operator's terminal.
9. Safety: The control unit shall be listed by Underwriters Laboratories (UL KK864) against fire, smoke control, and shock hazard as a signal system appliance unit. All SDCs, NIMs, and NCUs shall be enclosed in a hinged metal enclosure. All control panels shall be located away from sources of heat and humidity and away from the primary equipment room entry and exit paths.
10. Power Conditioner: Each SDC, NCU, and NIM shall receive isolated conditioned power from a 120 volt power conditioning constant voltage transformer manufactured by Sola/Hevi-Duty. Unit shall be a hevi-duty CVS series unit or pre-approved equal. One power conditioner may be used to power multiple controllers. The power conditioner shall be sized to allow for the addition of at least 1 controller, but sized no greater than 150% of the connected load. Isolated/un-isolated power shall not be mixed in the same conduit or raceway. The Line side of the conditioner shall be protected by a Class RK1 fuse, Bussmann model LPN or equivalent, sized per manufacturers requirements. The Load side of the conditioner shall be protected by a Class CC fuse, Bussmann model KTK, or equivalent. Load side fuse holder shall be Bussmann Model CHCC, or equivalent.
11. Wiring by BAS Contractor: All wiring for the BAS panels, including power and sensor wiring, shall be by the BAS Contractor. All internal control panel wiring shall conform to the UL508A standard. All external wiring entering BAS panels shall terminate on a terminal strip within the panel and be labeled appropriately. All internal wiring within panel shall be labeled on both ends.
12. NEC Compliant Wiring: All wiring shall be installed in conduit and shall conform to *Division 26 - Electrical* of these specifications and the National Electrical Code. Conduits shall not be filled more than 75 percent of the NEC rating to allow for future expansion. Rigid Conduit shall be used in Utility Plants.
13. Standard Non-Proprietary Components: System shall include all hardware, software, equipment, accessories, wiring, piping, relays, sensors, power supplies, and instrumentation required for a complete and operational system. All materials and equipment shall be standard non-proprietary components regularly manufactured for

this and/or other systems and not custom-designed specifically for this project. All components shall have been thoroughly tested and proven in actual use.

14. Graphical Representation: The BAS shall monitor and control equipment as called for by the "Sequence of Operation" including, but not limited to, the points list. Any additional system components required for proper operation but not necessarily mentioned shall also be included. A graphical representation of each system shall be made available on all operator workstations displaying all control and monitoring points and alarms. Graphical representation shall be web accessible. See paragraph entitled "GRAPHICAL REPRESENTATION" below for specific requirements.
15. Independent Panel Operation: System design shall eliminate dependence on any single device for alarm reporting and control execution.
 - a. Each BAS panel shall operate independently in performing its own specified control, alarm management, operator I/O, and historical data collection. The failure of any single component or network connection shall not interrupt execution of control strategies.
 - b. Critical Loop I/O Control Functions shall have the devices wired directly to the controller. Owner shall have final authority regarding definition of what constitutes a Critical Loop. *[Note to PSC: Ensure that program information is communicated through shop drawing submittals so that this item can be appropriately reviewed.]*

B. Programmability

1. Point Termination: All primary inputs and outputs of control loops shall be terminated on the SDC performing the loop calculations. Secondary inputs, such as reset inputs, may be shared via the RS-485 bus. The control action taken by the SDC upon loss of communications to the source of the shared input shall be clearly defined if these points are not terminated on the SDC.
2. SDC Fully Programmable: All SDCs shall be fully programmable from any operator workstation and from the Central Host Computer located in the Physical Plant Services Building.

C. Network Interface Modules (NIMs)

1. NIM: The BAS Contractor shall provide a minimum of 1 high speed Network Interface Module (NIM) for each building which supports both of the following types of communication standards between SDCs and other NIMs on the network: Two IEEE 802.3 compliant Ethernet network connections shall be provided at each NIM allowing campus Ethernet connection. Each Building Network Controller, CPU memory usage shall remain 80 percent of its total capacity. *[Note to PSC: Include language in the Contract Documents to notify the BAS Contractor that if project LEED requirements cannot be met through the use of one NIM, then each top level primary controller shall be equipped with a NIM.]*
 - a. Ethernet: The BAS-LAN shall employ Carrier Sense Multiple Access/Collision Detect (CSMA/CD) contention type protocol, which adheres to the industry standard format IEEE 802.3. The content of messages shall be the manufacturer's standard. The BAS-LAN components shall be manufacturer's standard or available from third party vendors that utilize the same chip implementation as used by the manufacturer. In addition Ethernet NIMs shall be fully Internet Protocol (IP) compliant allowing connection to currently installed IEEE 802.3 compliant Ethernet Networks. Ethernet NIMs shall directly support connectivity to 10/100 twisted pair RJ-45 terminated UTP category 6 cabling.
2. RS-485: At data rates of up to 19.2 Kbaud, the trunk distance shall be extendible to distances of up to 20,000 feet using RS-485 communication wire or fiber optic repeaters. A repeater shall be used each 4,000 feet of linear distance for wire or every 6,500 feet for fiber optics or at intervals as required by the manufacturer for proper system operation. Repeating devices shall contain separate LED indication for each

communication interface trunk to indicate proper operation of the repeater as well as the communication trunks. Contractors shall provide devices that are of the BAS control system manufacturer's design, and shall provide a trunk riser diagram showing end to end distances and locations of system topology necessary to meet the trunk diagram shown on the plans. Each multi-drop shall support a minimum of 24 SDCs. Systems that communicate on a current loop or any other industry standard communication link will be accepted.

3. Transient Surge Protection: The manufacturer's catalog data sheet shall provide evidence that all BAS products offered by the manufacturer are tested and comply with the standard for Transient Surge, and can withstand capabilities for electrical devices ANSI C62.41, IEEE-587-1980, Categories A and B. Such testing shall have included power and communication trunk wiring. Compliance with IEEE-587 shall imply conformance with IEEE-472 transient standards based on the stated position of ANSI and IEEE regarding applicability of the rated standards. In addition, at each building entry and exit point, the wire communications trunk wiring shall be protected with a transient surge protection device providing the minimal protection specifications of the General semiconductor, Model #422E device. Transient surge protection is not necessary if the communication trunk, external to the building, is fiber optic in nature. The communications circuitry, including phone, and input/output circuitry, of the SDCs shall provide protection against a 1000 volt, 3 amp transient signal, directly applied to the communication or input/output terminations. The manufacturer's catalog data sheet shall provide evidence of conformance with this requirement. Systems not complying with this requirement shall provide equivalent protection external to the BAS controller. Protection shall be provided for the individual communications and input/output terminations for each BAS controller. Submittal documentation shall clearly define how this requirement will be met and how the external protection will not affect the performance of the controllers.

D. Standalone Digital Controllers (SDC)

1. Independent SDC at All Times: Standalone Digital Controllers (SDCs) shall be minimum 16 bit microprocessor based, utilizing a multi-tasking, multi-user operating system. The SDCs shall permit the simultaneous operation of all control, communication facilities management and operator interface software, as programmed by the Contractor or Owner. Modification of the on-board SDC controller database shall be performed on-line using a laptop computer connected via a local RS-232 port or Ethernet via Host System.
2. True Floating Point Arithmetic Capabilities: SDCs shall utilize true floating point arithmetic capabilities. To accommodate totalization of large totalized values, SDCs with reporting capability shall support the calculation, accumulation and display of values within the range of +/-10 to the 10th power.
3. Operator Service Port: SDCs shall be equipped with an operator service port for the connection of a laptop computer. The service ports shall be a built-in RS-232 data terminal port. An optional RJ-11 type jack that connects to the manufacturer's standard HHOT may be included in addition to the RS-232. Connection of a service device to a service port shall not cause the SDC controller to lose communications with its peers or other networked device controllers. The service ports shall allow utilization of the same laptop computer program or HHOT (hand held operator's terminal) from any location. The same laptop computer program or HHOT shall be utilized for any SDC or NIM. Systems that utilize more than one variety of laptop computer program or HHOT are not acceptable.
4. Override Capability: The SDC shall provide commanded override capability from the laptop computer or HHOT. Such overrides shall be annunciated to the Central Host Computer. Such overrides shall be valid as long as power is applied to the controller. SDC indication of such manual override actions shall be provided as feedback status indication points shown on the Drawings, in conjunction with the application programs

within the SDC. H/O/A switches remotely located at the SDC controller shall be behind a locked panel or capable of being disabled through the control program.

5. Adjustments: Every SDC shall provide adjustments for the functions specified. In general, adjustments shall be provided for all setpoints used by controllers within each control panel, or adjustments to other parameters as specified. Adjustments shall be integral to each individual SDC. From a single SDC user interface, any other SDC on the network shall be accessible and full adjustment capabilities shall be provided.
6. Metal Enclosures: All SDCs, or any device not classified as an ASD controller, shall be enclosed in metal enclosures with suitable brackets for either wall or floor mounting and shall be furnished and installed with each system. They shall be fabricated from either steel or extruded aluminum and shall be equipped with hinged door and lock. Panels shall not be secured to any item of equipment. Metal enclosures shall be provided to all SDCs and ASD controllers on all new projects and any upgrade/ retrofit projects as well.

E. Network Control Unit (NCU)

1. A Network Control Unit (NCU) is a SDC incorporating a built-in NIM. The NCU shall incorporate all of the features of the SDCs and NIMs as outlined above.

F. Application Specific Devices (ASD)

1. Independent ASD Operation At All Times: Application Specific Devices (ASD) shall utilize a multi-tasking, multi-user operating system. The ASDs shall permit the simultaneous operation of all control, communication facilities management and operator interface software, as programmed by the Contractor or Owner. Modification of the on-board ASD controller database shall be performed on-line using a laptop computer connected via a local port or from an Operator Workstation. Systems that require the ASD to be removed from service while BAS control sequences are modified are not acceptable.
2. Power Loss Protection: All programming defining the functions to be performed by the ASD, including but not limited to application programs and point database within each ASD, shall be protected from loss due to power failure. Systems providing non-volatile memory for these functions are preferred. Systems not providing non-volatile memory shall provide a system rechargeable battery backup system sufficient to provide protection. Systems not in compliance shall provide for uninterrupted power to each ASD.
3. Operator Service Port: ASDs shall be equipped with an operator service port for the connection of a laptop computer. The service ports shall be a built-in data terminal port. Connection of a service device, to a service port, shall not cause the ASD controller to lose communications with its peers or other networked device controllers. The service ports shall allow utilization of the same laptop computer program or HHOT from any location. The same laptop computer program or HHOT shall be utilized for any ASD or NIM.
4. Adjustments: Every ASD shall provide adjustments for the functions specified. In general, adjustments shall be provided for all setpoints used by controllers within each control panel, or adjustments to other parameters as specified. Adjustments shall be integral to each individual ASD. From a single ASD user interface, any other ASD on the network shall be accessible and full adjustment capabilities shall be provided.

G. Communications

1. NIMs and NCUs: NIMs and NCUs shall communicate to the central server at the physical plant. NIMs and NCUs shall be capable of peer-to-peer communications to all other controllers from the same manufacturer connected to the campus Ethernet system.
2. SDCs and ASDs: SDCs and ASDs shall be capable of peer-to-peer communications at the building network level. Primary SDC's shall be capable of peer-to-peer

communications at the building network level and have capability to communicate to the central server at the physical plant via campus Ethernet system.

3. Sensor Input Signals

- a. Each SDC and ASD shall be capable of direct interface to industry standard sensors and input signals. All signal inputs shall be compatible with the controllers used, and with the requirements for readout of variables in true scaled engineering units as specified. Temperature, humidity, differential pressure signals, and other signal inputs shall be one of the following types:
 - (a) 0-20 mA
 - (b) 4-20 mA
 - (c) 0-5 VDC
 - (d) 0-10 VDC
 - (e) 1000 ohm platinum (at 0° C, 2.62 ohms/ °C)
 - (f) 10 k ohm Thermistor (at 25°C/77°F)
 - (g) Custom, definable input signals (accept sensor inputs from RTD devices, other than those of the manufacturer).
- b. The SDC and ASD shall also be capable of monitoring 2 and 3 state status of starters, fans, H-O-A switches, etc. Isolation relays with bifurcated gold contacts shall be used on all digital or binary inputs (Tyco KHAU17A16 or pre-approved equal).
- c. The SDC and ASD shall also be capable of monitoring pulse accumulator inputs from sources such as power meters and flow meters which provide a scaled pulse output.
- d. Each electronic analog input shall have the capability of accepting 2 wire inputs and shall be terminated on screw type terminals.
- e. Sensors based on proprietary equipment shall not be acceptable.
- f. Thermocouples are not acceptable.

4. Actuators Output Signals

- a. Each SDC shall directly control electronic actuators and controlled devices. Standard analog output signals that shall be provided are:
 - (a) 4-20 mA
 - (b) 0-10 VDC
- b. Pneumatic devices shall be controlled through an E/P Device. The E/P Device shall have output scaled to 0-15 psi. The E/P device shall utilize 4-20 mA / 0-10 VDC.
- c. The SDC shall be capable of performing 2 and 3 state output functions to emulate H-O-A switches, contact closures, etc. Isolation relays shall be used to drive fan and pump starters piloted by the digital outputs of the SDC. See *Section 23 09 13 - Instrumentation and Control Devices for HVAC* for device specifications.
- d. Modulating outputs shall be industry standard 0-5 VDC, or 0-12 VDC with definable output spans, to adapt to industry available control products. Milliamp outputs of 0-20 mA or 4-20 mA are also acceptable. Drive open/Drive closed type modulating outputs are acceptable provided that they also comply with the following requirements. All modulating outputs shall provide within the control panel, a meter gauge, or display indication via on board display or HHOT, the commanded position signal for the actuating device. This meter, gauge, or display shall provide either a 0-100 percent position indication, or read out directly in the

engineering units of the signal being used. Drive open/drive closed type controllers shall include sufficient components and control algorithms to comply with this requirement. In the case of drive open/closed technology, position feedback or a software calibration sequence shall ensure that the controlled device is at the commanded position.

- e. Pilot positioners shall be installed on all valve and damper actuators serving primary mechanical equipment such as AHUs, heat exchangers, etc.

H. Proprietary Software

1. If the BAS Contractor wants a signed licensing agreement for proprietary software, he shall develop one that is mutually agreeable to both parties, prior to requesting its execution. Failure to initiate this process in a timely fashion shall not interfere with progress and completion.

2.4 GRAPHICAL REPRESENTATION

A. General Requirements:

1. Graphics Title: Provide a prominent, descriptive title on each graphics page.
2. System Status: To facilitate the debugging / testing phase and final delivery of graphics screens to the Owner, each graphics screen shall indicate system function as follows:
 - a. UNDER CONSTRUCTION.
 - b. INSTALLATION AND START-UP.
 - c. SYSTEM OFF-LINE.
3. SYSTEM ON-LINE.Dynamic Update: When the workstation is on-line, all graphic I/O object values shall be updated with change-of-value services, or by operator selected discrete intervals.
4. Graphic Linking: Forward and backward linking shall be provided between floor plans, sub-plans, summaries and equipment down to application-specific screen.
5. Resolution and Color Representation: Graphics shall be clear and legible to a screen resolution of 1280 x 1024 pixels. Background shall be teal; RGB value 0/128/128.

B. Building Main Navigation Screen:

1. Provide at least one Building Main Navigation Screen that contains links to all mechanical systems including Air Handling Units, Heat Exchangers, Heat Recovery Systems, and Central Systems (like Chilled Water Load, Condensate Flow, Utility Consumption, etc.) in the building. The Building Main Navigation Screen shall show system mode and alarm status. See *Exhibits 23 09 23-1a* and *23 0923-1b* for *Example Building Main Navigation Screens*.
2. A link shall be provided from the Building Main Navigation Screen to an accurate AHU zone plan (floor plan). See paragraph below for AHU zone plan requirements.
3. A link shall be provided from the Building Main Navigation Screen to the VAV Navigation Screen. See paragraph below for the VAV Navigation Screen requirements.
4. The upper right hand corner of this Building Main Navigation Screen shall contain a dynamic display of the following information:
 - a. Global Outside Air Temperature.
 - b. Global Outdoor Air Humidity.
 - c. Global Outdoor Air Dew Point.
 - d. Global Outdoor Air Enthalpy.

5. The top middle of the page shall list the Building Name and Building Number. Also, a link shall be provided to the main "Illinois" BAS home page, which contains a list of active links to all the campus buildings.
- C. AHU and Other Mechanical Equipment Graphics Screens (Heat Exchangers, Enthalpy Wheels, Boilers, Chillers, etc.)
- (Graphic details provided for AHU as an example).
1. Provide at least one Graphic display for each Air Handling Unit. Indicate in the top of the screen (above the graphics): Building Name, Building Number, Air Handling Unit Name, Air Handling Unit Number, and Unit Location (mechanical room number). See *Exhibits 23 09 23-2a* and *23 09 23-2b* for *Example AHU Graphics Screens*. Graphically show the mechanical systems in as-built condition (i.e. do not use generic drop-in graphics). Include a standard AHU graphics library with all of the controls instruments and mechanical devices and associated set points. Locate all instruments and control objects on the drawing (e.g. By-Pass Dampers, Control Dampers, Control Valves, Freeze-Stats, etc.) as they are installed in the field.
 2. Control Set Points shall be clearly listed and exposed in a box above each instrument.
 3. Each control set point shall have override capability.
 4. Show all Controls Inputs and Controls Outputs (AO, DO) on the screen.
 5. The Owner shall be able to perform troubleshooting from this graphics screen.
 6. The upper right hand corner of this screen shall contain information related to following: AHU scheduling, AHU start-up, and any mode change such as cooling lock out, economizer lock out, etc.
 7. This graphics screen shall have a link to the most current version of the written Sequence of Operations. The Sequence of Operations shall be updated at the end of the Project to reflect as-built conditions. A printable version of the Sequence of Operations shall be supplied as part of the graphics.
 8. Provide color-coded floor (zone) plan with AHU service zones including hallways, etc. Multiple floor plans shall have a consistent color-code among floor plans. Distinct colors shall be used to clearly differentiate between zones, and a legend shall be provided if needed for clarity. If used, indicate and provide links to sub-plan areas. Emulate the project's drawings for the zone plan backgrounds. Where applicable, include the mechanical room, HVAC equipment and control components locations, with corresponding links to the main mechanical pieces of equipment and AHU. Links to these zone plans shall be provided from the Building Main Navigation Screen. These floor plans (zone drawings) shall reside in the control system database. See *Exhibit 23 09 23-3, Example AHU Zone Plan*.
- D. VAV / Terminal Units, Fan Coil Units and/or other HVAC Equipment Graphics Screens:
- (Graphic details provided for VAV Boxes as an example.)
1. A VAV Main Navigation Screen shall be provided, containing links to all VAV Summary Tables and VAV Small Scale Zone Plans. A link to this VAV Main Navigation Screen shall be provided from the Building Navigation Screen. See *Exhibits 23 09 23-04a* and *23 09 23-04b* for *Example VAV Navigation Screens*.
 2. VAV box and other HVAC equipment listing shall be provided in a form of a matrix or table on a summary table page. The table header shall include the following: Building number, AHU number servicing the associated VAV boxes, Room Number (location of VAV box), and all main performance parameters including VAV Flow (CFM), Room Set Point, Room Temperature, VAV Discharge Air Temperature (Auxiliary Temp), and Occupancy Mode. On this same page, provide an AHU operation information box which displays the AHU discharge (supply) air temperature, occupancy mode and supply static. A link to each VAV Summary Table shall be provided from the VAV

Navigation Screen. See *Exhibits 23 09 23-5a* and *23 09 23-5b* for *Example VAV Summary Tables*.

3. In addition, small scale floor plans shall be provided to show a graphical presentation of AHU locations and service areas. A link to each VAV small scale zone plan shall be provided from the VAV Navigation Screen See *Exhibit 23 09 23-6, Example VAV Small Scale Zone Plan*.
4. A link (from both the VAV summary table and the VAV small scale zone plan) to each individual VAV box shall be provided, showing a two or three dimensional drawing (i.e. a zoomed in view of the VAV /Terminal Unit controls detailed drawing). This detailed VAV / Terminal Unit graphic screen shall have all control details including control set points, alarm condition, and signals going IN and OUT of VAV box /Terminal Unit. Each set point shall have override capability (dampers modulation, re-heat valve, etc.). See *Exhibits 23 09 23-7a* and *23 09 23-7b* for *Example VAV Graphic Screens*.

E. Trends:

1. Trending will be determined based on project needs. As a minimum, fan operation, control valve actuation, dampers actuation, safeties and system temperatures shall be trended. All physical IN and OUT points shall be trended.

2.5 EXTENDED BAS SYSTEM COMPONENTS

- A. Extended to Database Server: The BAS system described in this Section shall be extended to the database server in the Physical Plant Building via the campus Ethernet system. The system shall be fully Internet Protocol (IP) compliant allowing connection to currently installed IEEE 802.3 compliant Ethernet Networks.
- B. Complete Operating System: The Contractor shall provide all hardware, cards, network controllers, transducers, software, programs, communications wiring, modems, devices and any other components required to make a complete operating system.

PART 3 - EXECUTION

3.1 COORDINATION WITH U of I *Technology Services* PLANT DESIGN SERVICES

- A. The Contractor shall contact Plant Design of the Campus Information and *Technology Services* Department and provide them with the location of their control panels requiring the installation of network interface jacks.
- B. Plant Design will assign an engineer to review the proposed panel location and determine if network connections can be provided.
- C. The Contractor shall install the necessary conduit for the installation of network interface jacks as per the instructions of the Plant Design engineer.
- D. Following conduit installation, the Contractor shall notify *Technology Services* that the conduit is completed. The *Technology Services* Department will install cabling and terminate the jacks.
- E. The Contractor shall forward the installed jack numbers to the Control System Manager at the Facilities and Services Division.
- F. The Control System Manager shall make arrangements to have the network jacks activated.
- G. The Control System Manager will notify the Contractor when the jacks are activated and assign IP addresses and host names.

3.2 CONFIRMATION OF POINT NAMES

- A. The Contractor shall submit their proposed point names to the Owner for review and approval prior to beginning any programming. The Contractor shall not begin their programming effort until the Owner has approved the point names.

3.3 EXAMINATION

- A. Acceptance of Conditions: Verify that systems are ready to receive Work. Beginning of installation means Installer accepts existing conditions.
- B. Integrate Existing System: Identify existing BAS controllers within the building and include an integration plan to utilize the existing system if it is from the current approved vendor list.

3.4 INSTALLATION

- A. Manufacturers Instruction: Install in accordance with manufacturers instruction.
- B. Verify Locations: Verify locations of thermostats, humidistats, and other exposed sensors with Drawings and room details before installation. Locate top of each room thermostat a maximum of 48 inches above the floor.
- C. Controller Installation: Mount controllers on freestanding angle iron or uni-strut supports in areas away from direct sources of heat or water and out of high traffic areas. One rack may be expanded to accommodate multiple controllers in the same equipment room.
- D. Adjacent to Associated Equipment: Mount controllers and control panels adjacent to associated equipment on vibration free walls or free standing angle iron supports. One cabinet may accommodate more than one system in the same equipment room.
- E. NEC Compliant: Provide NEC compliant conduit and electrical wiring for all temperature control wiring per *Division 26 – Electrical* of these specifications. All low voltage wiring (0-40 Volts), control/power wiring (110 - 120 Volts), and pneumatic tubing shall be run in their own separate raceways. Rigid conduit shall be used in Utility Plants.
- F. Test and Adjust: After completion of installation, test and adjust control equipment and programming.
- G. Calibration: Check calibration of instruments. Recalibrate or replace noncompliant equipment.
- H. All Low voltage cable shall be installed per Division 26 requirements.

3.5 COMMISSIONING

- A. Utility metering systems shall be in place, functional, and commissioned prior to start-up of utility services by the University. The utility service shall not be activated until the University has the means to measure the utility. The DDC Controls System shall be functional, the utility signals trended, and its operation validated to accurately meter the Utility service by the University prior to the utility service being activated. This can be accomplished by means of a functional permanent panel or, at a minimum, with a temporary meter.
- B. Calibration Report: The BAS Contractor shall submit to the Owner a calibration report of all final slopes, intercepts and/or offsets for all devices prior to final witnessing by the Owner. Documentation shall include all Contractor notes and verifications such as point-to-point checkout sheets and shall be appended to contractor-completed Functional Performance Procedures (FPPs). The calibration report shall include all real and virtual points, including energy calculations when included in vendor's equipment (such as for energy recovery wheels). Follow this specification and coordinate with all Commissioning Specification Sections in the Project.

3.6 TRAINING

- A. Upon completion of the work and after User acceptance of Functional Performance testing, on-site training shall be provided by an instructor thoroughly familiar with the installed system. Training will be provided to the Owner's operating personnel who have responsibility for the mechanical and control systems. The training shall focus on operation and maintenance of the installed system. *[Note to PSC: The amount of training shall be provided and shall match the size of the project (e.g., no less than eight hours for small projects and up to 40 hours for large projects). Specify exact hours in the Contract Documents].*

- B. [Note to PSC: Upon completion of the work and after User acceptance of Functional Performance testing, on-site training shall be provided by an instructor thoroughly familiar with the installed system tailored specifically for the Laboratory equipment and controls, and any other unique systems on project. Training will be provided to the Laboratory personnel and simultaneously to the Owner's operating personnel who have responsibility for the mechanical and controls systems. The training shall focus on operation and maintenance of the installed systems for the Laboratory and Systems that support it. The amount of training shall be 40 hours.]
- C. [Note to PSC: Personnel factory training shall be provided for User if an approved manufacturer is new to the University or if User deems necessary during project design phase.] Personnel Factory training shall be provided for User- F&S DDC programmers. This training shall be scheduled after substantial completion. The project shall include training for 4 programmers for one week at a level necessary to successfully operate the BAS supplied. The Contractor will not bear the cost of transportation, meals and lodging of the University's personal. .

END OF SECTION 23 09 23

This section of the *U of I Facilities Standards* establishes minimum requirements only.
It should not be used as a complete specification.