

## **23 09 00 Instrumentation and Control for HVAC**

1. All controls to be corporate Trane, Honeywell or Johnson Controls; no substitutes.
2. Factory Mounted controls to be Trane only, otherwise provide terminal strips for TC Contractor.
3. All designs shall include sequence of operation, listing of all component inputs/outputs, representation of the front-end graphics, and listing of all field adjustable temperature settings.
4. Energy Management Control System, EMCS as specified within, system shall be guaranteed for a period of two years from final approval by CMU, unless approved by CMU.
5. The sequence of operations along with a DDC communication-wiring diagram shall be located on the construction drawings.
6. All occupancy sensors and space temperature sensors illustrated as to which HVAC component they control.
7. Projects involving the major remodeling, or installation of new HVAC equipment, will include a full review of the entire systems controls. Designers shall coordinate review meetings with corporate Trane, Honeywell, or Johnson Control and CMU at the beginning of Construction Documents and implement changes to ensure a complete control design. This review process will include a listing of all sensors, switches, transducers, automatic dampers, AHU's, terminal units, etc., and the names of the manufacturers allowed for the project.
8. The review meeting mentioned above will include a review of the software and hardware requirements for the building management system with CMU.
9. Designs will ensure controls compatibility of each HVAC component, up to and including, the interface with CMU main control panel located in the Powerhouse. The use of secondary communication protocols (LON, Modbus, N2) will not be used without the prior written acceptance by CMU.
10. All product submittals must be reviewed and approved by the successful controls bidder (corporate Trane, corporate Honeywell, or corporate Johnson Control) prior to any material being ordered.
11. HVAC communication wiring will NOT be installed with electrical wiring. If conduit is required i.e. roof penetration or into an electrical box, then the communication wiring will be kept separate and isolated in its own conduit.
12. All Direct Current systems shall be in compliance with the National Electric Code (NEC) refer to sections 250.162 & 250.164 and all parts of the NEC.
13. Freeze stats are to be located on all AHU coils, serpentine across the face and measure temperatures at every 1 inch of tubing, and set at 40 degrees. Only manual resets are allowed.
14. If supply air from AHU is less than 45 degrees (field adjustable) then a minimum alarm will be sent thru DDC.
15. All temperature settings need to be user friendly and field adjustable on the front end and not "nested" or buried into component controls.
16. The high humidity sensor must be a minimum of 15' from the humidifier coil and controlled by the outside temperature and field adjustable.
17. All sensor locations will be clearly identified and marked on the record drawings.
18. DDC panels, and associated communication devices, shall be connected to the back-up generator, with properly sized battery backup for DDC controllers.
19. Controls Contractor shall provide a full backup copy of all HVAC programming. This shall be a complete functional copy of programs, files and settings for each system installed. To be provided at the end of the warranty period.
20. Any device connected to the EMCS that is also controlled by some local device (e.g.: light switch, P.E., high limit stat, twist timer, etc.) must be defined as a DI point, device input point. Provide dry contract from local device to digital input at controller and programming necessary to accomplish sequence of operation.
21. Contractor to provide a spare parts list detailing any items that require lead time for replacement.

---

## **23 09 13 Instrumentation and Control Devices for HVAC**

### **23 09 13 13 Electronic Actuators**

1. Unless approved otherwise by CMU, all actuation shall be electronic with capacitive return or spring return (critical applications).

- A. Manufacturers: Belimo

### **23 09 13 23 Sensors and Transmitters**

1. Current Sensors (Transformers)
  - A. Current sensors used for monitoring motor operation shall be sized according to motor horsepower. The output shall be compatible with the EMCS field device with necessary interfacing transducers provided.
  - B. The current sensor shall have mounting brackets for attachment to the motor starter enclosure.
  - C. Manufacturers: Functional Devices, Inc. (RIB) or approved equal.
2. Current Sensing Relays
  - A. Current sensing relays shall be used for monitoring motor operation, sized according to motor HP.
  - B. Manufacturers: Functional Devices, Inc. (RIB) or approved equal.
3. Temperature Detectors
  - A. Temperature detectors shall be wire wound or thin film platinum resistance type sensors, or 10K ohm thermistor type, reference at 77°F, either having a minimum accuracy of+ .5 Degree F over the noted range. All sensors of a particular category shall be of the same type and manufacturer.
  - B. Resistance Temperature Detectors (RTD) shall be two-wire type, and shall be provided with local 4-20 MA signal conditioning transducers shall be provided where necessary. The minimum temperature range for all sensors will be 20°F to 120°F. Sensors shall have a maximum time constant of three seconds per degree change. Sensors shall not require recalibration at any time. Where required, linearizing, ranging, and resistance change versus temperature curve interpretations shall be made by software programming at the CPU or Controller. Minimum room temperature sensor range is 40°-90°F. Wider range may be required for special applications.
  - C. Temperature detectors shall be either stem or tip sensitive types. Sensors installed outdoors, in piping systems, and in corrosive environments shall be hermetically sealed in type 316 stainless steel enclosures, with all joints and closures Heli arc welded. Soldering or brazing is not approved. Entire assembly, including external trim, shall be a watertight, vibration proof, heat resistant unit.
  - D. Sensing elements installed in piping systems shall be provided with separable wells constructed of type 316 stainless steel. Elements shall be inserted into the wells with appropriate heat transfer compound.
  - E. Sensors installed outdoors shall be of weatherproof construction, protected.
  - F. All duct mounted temperature sensors shall be of the averaging type, with 17' or 25' long sensing elements. Averaging elements shall be installed across the full airflow area in a serpentine fashion, on rigid supports designed specifically for mounting of such elements. The averaging elements shall be protected against vibrations and wear at each point of contact with the element supports. Strain on the element shall be relieved at the junction box to prevent tension on the internal electrical connections
  - G. Rigid stem averaging sensors will be allowed where duct size is smaller than 3' square.
4. Static Pressure Transmitter
  - A. Static pressure transmitters shall be industrial quality, capable of transmitting 4-20mA analog output signal proportional to differential (static) pressure input signals. Transmitter shall have

- a minimum 1% accuracy rating over the range of the device, zero and span adjustment, and stainless steel case.
- B. Manufactures: Approved by CMU.
5. Electronic To Pneumatic Transducers
    - A. Accessories: In-line filter, dual valve and gauge.
    - B. Manufactures: Approved by CMU.
  6. Damper End Switches
    - A. Damper end switches shall be two positions, encapsulated non-mercury style mounted on the shaft arm, SPDT, unless noted otherwise. Where electronic actuators are used and switches provided with actuator will be allowed.
  7. EMCS Cable
    - A. All EMCS cable shall be installed in conduit in mechanical rooms. Free air is allowed with proper cable management. EMCS cable shall comply with manufacture's recommendations. Separate raceway systems shall be supplied for Class I and Class II circuits.
    - B. Data transmission trunk cables and equipment grounding procedures shall meet the latest FCC guidelines (FCC rules, part 15, subpart J) for electromagnetic field generations.
    - C. No splicing of RS-485 or RS-232 data cabling shall be allowed. Communication trunk shall be installed per manufactures recommendation for operation at 19,200 baud or higher, continuous daisy chain with no tees and trunk terminators installed where appropriate. All communication and analog input wiring shall be AWG size as recommended by manufacturer with plenum rated jacket.
    - D. Sleeves are required for wall penetrations.
    - E. Splicing of temperature sensor cable is not allowed.
    - F. Splicing of binary status or command cable shall take place at the field cabinet or motor starter only.

**23 09 13 33 Control Valves**

- A. Globe for steam
- B. Characterized Control (ball) for hot and chilled water.
- C. Manufactures: Belimo

**23 09 13 53 Controllers**

1. DDC Controllers
  - A. Controllers shall be complete assemblies consisting of modular hardware including power supply, microcomputer, input/output modules, and termination modules. Controllers should NOT loose data with a power loss.
  - B. Controllers shall be furnished as newest revision level with largest available memory configuration unless prior approval by CMU. Verify controller type to be used in design with CMU. Most recent revision firmware shall be supplied unless otherwise noted. Each controller shall be provided with 20% spare point capacity. All controllers shall be provided with floor level (MS/TP) network capability and H-O-A switches at the output points unless approved otherwise by CMU.
  - C. All points from a given mechanical system shall reside in the same controller.
  - D. Each Controller cabinet shall be able to monitor the following types of inputs:
 

<u>Analog Inputs</u>	<u>Digital [Binary] Inputs</u>
4-20 mA	Dry contact closure
0-10 VDC	Pulse accumulator
Resistive	
  - E. Controller cabinets shall directly control pneumatic and electronic actuators and control devices. Each control unit shall be capable of providing the following control outputs:
 

<u>Analog Outputs</u>	<u>Digital [Binary] Outputs</u>
4-20 mA	
0-10 VDC	

- F. All temperature control functions shall be executed within the same DDC Controller. Loop control shall be executed via direct digital control algorithms. The user shall be able to customize control strategies and sequences of control, and shall be able to define appropriate control loop algorithms and choose the optimum loop parameters for loop control. Upon CMU request the EMCS shall demonstrate stable loop control by utilizing test cabinet simulation program and trending the data. Control loops shall support any of the following control modes:
  - 1) Two position (on-off, slow-fast, etc.)
  - 2) Proportional (P)
  - 3) Proportional plus integral (PI)
  - 4) Proportional, integral, plus derivative (PID)
- G. It shall be possible to fully create, modify, or remove control algorithms within a specific DDC Controller while it is operating and performing other control functions. Input for these changes may be made directly into the DDC Controller or via the network. Each control loop shall be fully user definable in terms of:
  - 1) Sensors/actuators that are part of the control strategy.
  - 2) Control mode.
  - 3) Gain.
  - 4) Sampling time.
- H. DDC Controllers shall be able to share point information such that control sequences or control loops executed at one control unit may receive input signals from sensors connected to other DDC Controllers within the network. If the network communication link fails or the other DDC Controller malfunctions, the control loop shall continue to function using the last value received from the Controller.
- I. The system shall permit the generation of job-specific control strategies that can be activated in any of the following ways:
  - 1) Continuously.
  - 2) At a particular time of day.
  - 3) On a pre-defined date.
  - 4) When a specific measured or controlled variable reads a selected value or state.
  - 5) When a piece of equipment has run for a certain period of time.
- J. Upon a loss of commercial power to any DDC Controller, 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 DDC Controller shall be retained during power failure via the internal battery for a minimum of eight (8) hours. Upon resumption of commercial power the control unit shall resume full operation without operator intervention. The unit shall also automatically reset its clock such that proper operation of timed sequences is possible without the need for manual reset of the clock.
- K. Location of DDC Controller cabinets shall be approved by CMU prior to installation, and documented on as-build drawings.
- L. Enclose and install control devices and equipment such that they will not be subject to vibration, excessive temperature, dirt, moisture, or other harmful effects or conditions beyond their rated limitations. If devices must be located to be subjected to conditions beyond their recommended or rated limitations, provide the necessary protective enclosures or furnish the equipment constructed of materials and features capable of withstanding the adverse conditions. Controls and devices subject to moisture or to the weather shall be corrosion resistant weather tight enclosures.
- M. DDC programs shall follow CMU standard form and shall include discrete sections of code that are not intermingled with other sections of control.
  - 1) Each DDC program shall include the alarm indicators code in Section A. Each DDC program shall include code in Section E that initialize the run time totals on all equipment defined for totalization.

- 2) Any air handling unit with a heating coil controlled through DDC shall include programming which places the unit in special operation on discharge sensor failure to prevent freezing of the heating and cooling coils.
- 3) Each controller cabinet shall include only as many programs as is necessary for programming modularity and ease of troubleshooting. If device operation is such that the existence of multiple programs within a single control has an effect on system performance or control timing, the presence of these multiple programs must receive prior approval by CMU. Multiple programs, if present, shall be independent in functionality and shall not perform similar or identical functions (i.e. Start/Stop, Time of Day, etc.). Each program shall be tested utilizing a test cabinet simulation to verify program functions properly, prior to loading in field cabinet.
- N. Hot Water Heating Systems designed with 100% backup shall alternate pump/converter operation based on Odd/Even month. If a pump fails to operate, the backup pump shall be commanded on and a critical messaging output shall be sent to the appropriate destination.
- O. Point entry shall follow these conventions:
  - 1) Descriptors: AI: use range of device, e.g. 20-120; AO: use range of device and normal position of device, e.g. NC 3-15 (normally closed 3 to 15 PSI); DO: use valid commands, e.g. ON OFF: DI use word STATUS.
  - 2) General Alarms: All alarmable points shall be displayed on EMCS graphics.
  - 3) Critical Alarming: All critical alarm points shall trigger an audible alarm at CMU Central Energy Facility.
  - 4) Change of Value Limit: No less than 2% and no greater than 10% of range of device.
  - 5) Engineering Units: DEG F, AMPS, PPM, IN WC, PCT RH, PSI, CFM, GPM, etc.
  - 6) Command String and State Descriptors: These two shall typically match each other. Some common entries are ON/OFF, ENABLE/OFF, OPEN/CLOSE, FAST/OFF/SLOW, ON/OFF/AUTO.
  - 7) Totalization: All points that indicate the run-time of a piece of equipment shall be included in this summary with time totalized per hour.
  - 8) Contact State Descriptor: Fire alarm and fire trouble points: use a period for both states. Control air compressor: use a period for the normal state and LOW for the off-normal state. Avoid using the words NORMAL and ALARM as state descriptors for alarmable points. Return to Normal Printouts: Yes, in all instances. Critical Alarms shall not report their return to normal state to via a message to the critical messaging output device unless approved by CMU.
  - 9) Naming convention shall follow CMU Standard and approved. Standard is Building Initials Controller Point Descriptor. (RO\_AHU11D\_SpaceTemperatureLocal)
8. Advanced Application Controllers
  - A. Each DDC controller shall be able to extend its performance and capacity through the use of floor level (subnet), advanced application controllers (AAC). See Appendix 2.
  - B. Each AAC shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each AAC shall be a microprocessor-based, multi-tasking, real-time digital control processor, and fully programmable.
  - C. Terminal Box Controllers - Provide control of individual pieces of equipment including, but not limited to, the following:
    - 1) Variable air volume (VAV) boxes.
    - 2) Constant air volume (CAV) boxes.
    - 3) Unit Conditioners.
    - 4) Unit Ventilators.
  - D. Controllers shall include all point inputs and outputs necessary to perform the specified control sequences.
  - E. Each controller performing space temperature control shall be provided with a matching room temperature sensor.

- F. A dedicated power circuit and separate isolation transformer for each AAC Power Trunk shall be provided. Transformer shall be mounted in a separate auxiliary enclosure.
- 9. Application Specific Controllers
  - A. Application specific controllers (ASCs) shall NOT be utilized unless approved by the CMU prior to project bid.
- 10. Field Quality Control
  - A. Upon completion of the work, the EMCS Contractor shall instruct CMU and acquaint with all of the operating characteristics of all equipment installed including the EMCS and all other systems, at the same time operating each and every system individually for a period of two days, unless otherwise specified. During this two-day period, the building's Operations Manual shall be used for reference.
  - B. During system commissioning and at such time acceptable performance of the installed system hardware and software has been established, the Contractor shall provide on-site operator instruction to CMU's operating personnel. A competent representative, familiar with the equipment, will perform instruction during normal working hours.
  - C. At a time mutually agreed upon during system commissioning as stated above, the EMCS Contractor shall give an absolute minimum 4 hours of instruction, max of 16 hours in 4 sessions, to CMU's designated personnel on the operation of all equipment included in the project. Operator orientation of the automation system will include, but not be limited to equipment functions, commands, advisories, appropriate operator intervention required in responding to the system's operation, and any other training needed in the operation of the system. A manual prepared for this project by the Contractor will be used in addition to the instruction. Manuals shall be provided and electronic copy for file.
  - D. The Contractor as an extra service shall provide additional instruction time as deemed necessary by CMU.
- 11. Acceptance Procedure
  - A. SUBMITTALS data relevant to point index, functions limits, sequences, interlocks, power fail/restarts, logs, software routines and associated parameters, and other pertinent information for the operating system and database shall be forwarded from the EMCS contractor to CMU.
  - B. All points shall be verified prior to "punch-out" for correct and accurate correspondence between the CRT data display and actual field location and equipment operation.
  - C. The Contractor shall maintain dated and initialed calibration and verification sheets and provide a copy to CMU. Include verification of enhanced alarming with messages for all points selected by CMU. Typical points with messages include control air compressors, 24 hour fans and pumps, critical systems and animal areas. Point verification sheets shall be submitted to CMU.
  - D. Upon successful completion of system installation, CMU shall be requested in writing to inspect and approve the satisfactory operation of the EMCS, sub-systems, and accessories.
- 12. Demonstration
  - A. A factory-authorized service representative to train CMU's maintenance personnel to adjust, operate, and maintain HVAC instrumentation and controls.

## **23 09 23 Direct-Digital Control**

- 1. Summary
  - A. This Section includes a complete and functional direct digital Energy Management Control System (EMCS) as specified herein. The EMCS Contractor shall have total system responsibility for the installation including the following:
    - 1) Non-BACnet Installations: Furnish and install all software, hardware, data base, conduit, wire, cable, building level network control units, floor level network control units and required connections for a complete and functional system to monitor and

- control points as specified, including software and data base generation, loading, debugging, and start-up.
- 2) BACnet Installations: Furnish and install a totally native BACnet-based system including applicable software to be installed on a CMU provided operator workstation (OWS) in accordance with this specification. All building controllers, application controllers, and input/output devices shall communicate using the protocols and network standards as defined by ANSI/ASHRAE Standard 135-2001, BACnet. Provide all software, hardware, database, conduit, wire, cable, building level (supervisor) controllers, floor (unit) level controllers and required connections for a complete and functional system to monitor and control points as specified, including software and database generation, loading, debugging and startup. Third party controllers to be connected on the MS/TP Link if possible. If other communications type is needed, CMU must approve. Provide all necessary BACnet-compliant hardware and software to meet the systems functional specifications.
  - 3) Operator Workstation Software:
    - a. All applicable software to facilitate direct connection to the building EMCS.
    - b. Any necessary software/hardware "keys" required for EMCS communication software.
    - c. Any additional hardware cabling or equipment that may be required to facilitate direct connection to EMCS field devices (Serial Communication adapters, etc.)
  - 4) IP Addresses, Subnet Mask and Gateway Addresses to be provided by CMU. Standard mode of connection shall be BACnet over IP unless approved otherwise by CMU. Network registration is required of Ethernet connected devices. Owner will be notified of all Ethernet connected devices, physical hardware locations and MAC addressing. CMU will provide one UDP port per building. Use of default BACnet UDP ports not allowed.
  - 5) Generation of color graphic displays at the existing graphic terminal for each mechanical system connected to the system. Graphics to include all dynamic point data information associated with each major mechanical system and set points.
  - 6) Provide complete hardware and software documents, controller backups, shop drawings, operating and maintenance manuals and classroom training of operators and maintenance personnel at the site. Provide as-built control drawings in electronic PDF and CAD format to CMU.
  - 7) Provide a dedicated power circuit to each controller cabinet and communications interface. Provide manufacturers recommended grounding to each controller cabinet, and dedicated 120V, 20A circuit with locking clip on breaker. Clearly label circuit in panel.
  - 8) Accomplish acceptance tests, including point-to-point verification, with alarming verification including messages for all critical alarm and life safety points. Typical points requiring messaged alarming include but are not limited to:
    - a. Control air compressor
    - b. 24 hour fans and pumps (i.e. Freeze Protection)
    - c. Critical temperature and humidity control areas (i.e. Archiving/Museum)
    - d. Critical pressure control areas and systems (i.e. Laboratories and Lab Systems)
  - 9) Critical systems (i.e. Fire and Security)
  - 10) State/Federally regulated areas (i.e. Animal Areas)
  - 11) Provide connections for all electrical devices provided by the EMCS contractor to the controllers.
  - 12) Provide proper marking and identification of all devices, wiring, and controls. Equipment labels should indicate device name, address, room location, etc.

- 13) Schedule all non-24 hour equipment in accordance with generally approved CMU's guidelines for energy usage. Non-24 hour equipment shall be scheduled as soon as practical to avoid excessive use of resources prior to turnover to the CMU.
- 14) Provide any additional support that may be required to facilitate full integration of all control devices, including hardware communication troubleshooting with 3rd party devices (Variable Frequency Drives, packaged controllers, etc.).
- 15) Demolition Requirements: Demolition shall include removal of all associated control components (sensors, switches, etc.), wiring, and database at the front end (point definitions, programming, etc.)
- 16) Guarantee.

### 13. System Description

- A. The temperature control system shall be of the DDC type, connected to CMU's Energy Monitoring and Control System.
- B. Include item C below only for BACnet installations.
- C. BACnet implementations shall be functionally verified on EMCS.
- D. BACnet implementation shall be completely based on ANSI/ASHRAE Standard 135-2001, BACnet, and is to control all listed equipment using native BACnet-compliant components. Non BACnet-compliant or proprietary equipment or systems (including gateways) shall not be acceptable and are specifically prohibited. Any device designated to act as a BACnet Broadcast Management Device (BBMD) shall be designed for and dedicated to that purpose.
- E. System controllers (Supervisor) connected to floor level (Unit level)(via BACnet MS/TP) devices shall perform all necessary MS/TP network routing to facilitate network efficiency and reduce communication and control lag.
- F. For communication system layout, see Appendix 2.
- G. All materials and equipment used shall be standard components, regularly manufactured for Control Systems and shall not be custom designed especially for this project. All components shall have been thoroughly tested and proven in actual use

### 14. Submittals

- A. Product Data: Include manufacturer's technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated.
- B. Shop Drawings:
  - 1) Submit complete shop drawings of the proposed EMCS for approval including sequence of operation, valve ranges, DDC logical points and physical addresses, typical system information such as fan CFM, voltage, FLA, HP, GPM, etc.
  - 2) Submit complete shop drawings of the proposed EMCS system for approval including, but not be limited to the following:
    - a. I/O point summary with recommended set points, start/stop times, time delays, etc.
    - b. Operator and hardware point numbers, logical names and user names.
    - c. Controller unit schematic wiring, layout sheet including logical point names, valve ranges, etc.
    - d. Fan and mechanical system schematic diagrams showing EMCS sensor locations, including valve ranges, CFM, voltage, FLA, GPM and areas served.
    - e. One-line diagrams for sensors, control points, and terminations, including labeling to controller cabinets, with all components, signal values, and cables.
    - f. Terminal cabinets, including labeled terminal blocks.
    - g. Connections to existing loops, controls, and panels.
    - h. Internal and external wiring of relays and contacts.



- i. Schematic of all major equipment provided.
    - j. Operator, maintenance, and software programming manuals.
    - k. Spare parts list and prices.
    - l. Complete sequence of operation, description, control logic flow diagrams, and completed programming sheets in manual form for each mechanical system controlled.
  - 3) All manufacturer's drawings, catalog cuts, and specifications shall be properly identified with the Engineer's project number and title. Each piece of equipment shall be properly identified as to its location and equipment number. Verify Equipment numbering with CMU.
- C. As-built Drawings:
  - 1) At the completion of the project as-built drawings shall be submitted to CMU, cable and wire identification, panel and sensor locations, and device layouts with panels, branch circuit numbers, and wiring diagrams for each type of typical field point wiring and for each specific variation, and data trunk riser diagram.
  - 2) Furnish 3 sets of neatly drawn as-built diagrams of the temperature control systems, complete with sequence of operations, valve ranges, cabinet layout sheets, point logical names and physical addresses. One set to be mounted in plastic covers located in control cabinets in the field. One electronic set to be delivered to CMU. One set of electronic AutoCAD as-built drawings shall be furnished to CMU.
  - 3) EMCS Contractor is to keep a current marked-up copy of as-built drawings on site at all times once installation started.
- D. Operations and Maintenance Manuals:
  - 1) The system shall be provided with complete maintenance and operation instructions including, but not limited to the following:
    - a. Complete electronic schematic wiring diagrams for printed circuit boards, DDC Controller cabinets and other equipment included in these specifications.
    - b. Complete instruction set in manual form for operation of the system.
    - c. Complete instruction set in manual form for adding and deleting of points and interface device panels including all relevant parameters such as descriptor inputs, point types, change-of-state type, functions, etc.
    - d. Complete diagnostic and troubleshooting procedures set in manual form.
    - e. Complete instruction set in manual form for all software and firmware.
  - 2) Any updates to firmware, software, and hardware shall be fully documented at or before the time of delivery.

## **23 09 33 Graphic Display**

- 1. Provide the following graphic displays as a minimum at the operator workstations, arranged in logical penetration paths:
  - A. Overall campus layout which shows all of the buildings on CMU's campus.
  - B. Individual building layout or isometric for each building connected to the system.
  - C. Floor plans for each floor within each building, with display of present values of space conditions sensed by connected space sensors, display of the name of the air handler associated with each space sensor, display of the room number in which the sensor is located and color coding to indicate whether the sensed space condition is within the acceptable range, is too high, or is too low. Contractor shall confirm CMU desired room names/numbers prior to graphics generation which may differ from the room names/numbers indicated on construction documents.
  - D. Schematic diagram for each HVAC system. Each system schematic display shall include at least the following:

- 1) Schematic arrangement of ductwork, fans, dampers, coils, valves, piping, pumps, equipment etc.
  - 2) System name.
  - 3) Area served.
  - 4) Present value or status of all inputs, along with present set point.
  - 5) Present percent open for each damper, valve, etc. based on commanded position.
  - 6) Reset schedule parameters for all points, where applicable.
  - 7) Present occupancy mode.
  - 8) Present economizer mode, where applicable.
  - 9) Present outside air temperature.
  - 10) Associated space conditions and set points, where applicable.
  - 11) Status of application programs (e.g., warm-up, night cycle, duty cycle, etc.).
  - 12) Color coding to indicate normal and abnormal values, alarms, etc.
2. Contractor will submit graphic display package to CMU for review and approval prior to commencing implementation.

### **23 09 93 Sequence of Operation for HVAC Controls**

The following guidelines are to be incorporated in to the project documents. Sequence of operation shall be included on the 95% Design Development drawings. Modifications are to be reviewed with CMU. Refer to Division 23 and 26 standards for additional information.

1. Hot Water Heating System (Heat Exchangers)
2. Hot Water Heating System (Boilers)
3. Snow Melt System
4. Chilled Water System
5. Air Handling Units (Mixed Air)
  - A. General
    - 1) A complete functional system with all required components is to be provided.
    - 2) All set points, dead bands, and time delays shall be adjustable by the system operators through the front end.
    - 3) All points identified will be displayed on the user's graphic interface.
    - 4) All variable speed drives to be manual reset.
    - 5) Each fan and pump shall totalize the runtime hours for the maintenance service period and grand total. Both are displayed and resettable on the graphics.
  - B. Scheduling
    - 1) The air handling unit runs continuously during the occupied mode.
    - 2) The air handling unit shall have scheduling functionality through the DDC system.
    - 3) If communication is lost to the BAS, the unit shall continue to operate per the last schedule sent.
  - C. Occupied Start Up Mode
    - 1) All sensors alarms are disabled at startup for 300 seconds.
    - 2) Open the supply and return smoke isolation dampers (if applicable).
    - 3) The return air damper remains fully open. The outside air and relief air dampers remain closed.
    - 4) Energize the supply fan per sequence.
    - 5) Energize the return fan per sequence.
    - 6) The outside air damper, return air damper, and relief air damper are controlled per the ventilation sequence.
    - 7) Remote exhaust fans that are interlocked are controlled per their sequence.
  - D. Unoccupied Start Up Mode
    - 1) All sensors alarms are disabled at startup for 300 seconds.
    - 2) Open the supply and return smoke isolation dampers (if applicable).

- 3) The return air damper remains full open. The outside air and relief air dampers remain closed.
  - 4) Energize the supply fan per sequence.
  - 5) Energize the return fan per sequence.
  - 6) Remote exhaust fans that are interlocked remain disabled.
- E. Supply Fan Control
- 1) The supply fan is controlled to maintain the duct static pressure set point. The sensor is located approximately 2/3 of the distance in the duct system. Initial set point is 1.5 in-wc. Final set point is verified and documented by the balancer.
  - 2) Upon start, the supply fan is modulated to a minimum speed of 20%.
  - 3) Upon reaching minimum speed, the return fan starts.
  - 4) Both the supply fan and return fan modulate in unison to the duct static set point.
  - 5) Upon reaching stable operation, the outside air damper opens and begins ventilation control.
  - 6) The supply duct static set point shall be reset based on the most demanding terminal unit controller. Once the critical zone damper position is 100%, downward reset is adjusted upward 0.1 in-wc. every five minutes until the critical zone damper position is less than 90%. The most demanding terminal unit is to be identified on the graphic page.
  - 7) Upon a loss of the static pressure signal, the unit shall command to the last reported speed. An alarm is to be sent to the BAS after 30 seconds.
  - 8) The fan status is monitored through the respective variable frequency drive. Improper status shall issue a BAS alarm after a 120 second delay.
- F. Return Fan Control
- 1) During occupied mode, the return fan is controlled to maintain the scheduled offset from the supply airflow. This is accomplished through a bias offset and not through airflow measuring stations.
  - 2) The offset is disabled during unoccupied mode.
  - 3) The return fan is interlocked to the supply fan.
  - 4) Upon start, the return fan is modulated to a minimum speed of 20%.
  - 5) Upon stable operation, the supply and return fan modulate to maintain set point.
  - 6) The fan status is monitored through the respective variable frequency drive. Improper status shall issue a BAS alarm after a 120 second delay.
- G. Remote Exhaust Fan Control
- 1) If the sum of the remote exhaust fans is less than 3-5% of the total system airflow, the fans shall be interlocked with the air handling unit.
  - 2) Higher quantities of airflow are to be controlled through the DDC system.
  - 3) Process exhaust fans shall be hardwired to the respective make up air unit.
  - 4) The fan status is monitored by a go-no-go current sensor. Improper status shall issue a BAS alarm after a 120 second delay.
- H. Ventilation Control
- 1) During the occupied mode, DDC modulates the outside air, return air, and relief air dampers to maintain the code required outside airflow rate.
  - 2) The relief air damper tracks the same as the outside air damper.
  - 3) DDC monitors the outside airflow rate through the outside airflow station.
  - 4) If the outside airflow station fails, the outside air damper position remains at the last commanded position. An alarm is issued to the BAS after a 120 second delay.
  - 5) During economizer, the outside airflow rate is allowed to rise above the code required outside airflow rate to the maximum unit supply airflow rate.
- I. Demand Control Ventilation (If Applicable)
- 1) After a 180 second delay, DDC shall reset the outside airflow set point between the code required outside airflow rate and the demand control ventilation outside airflow rate.

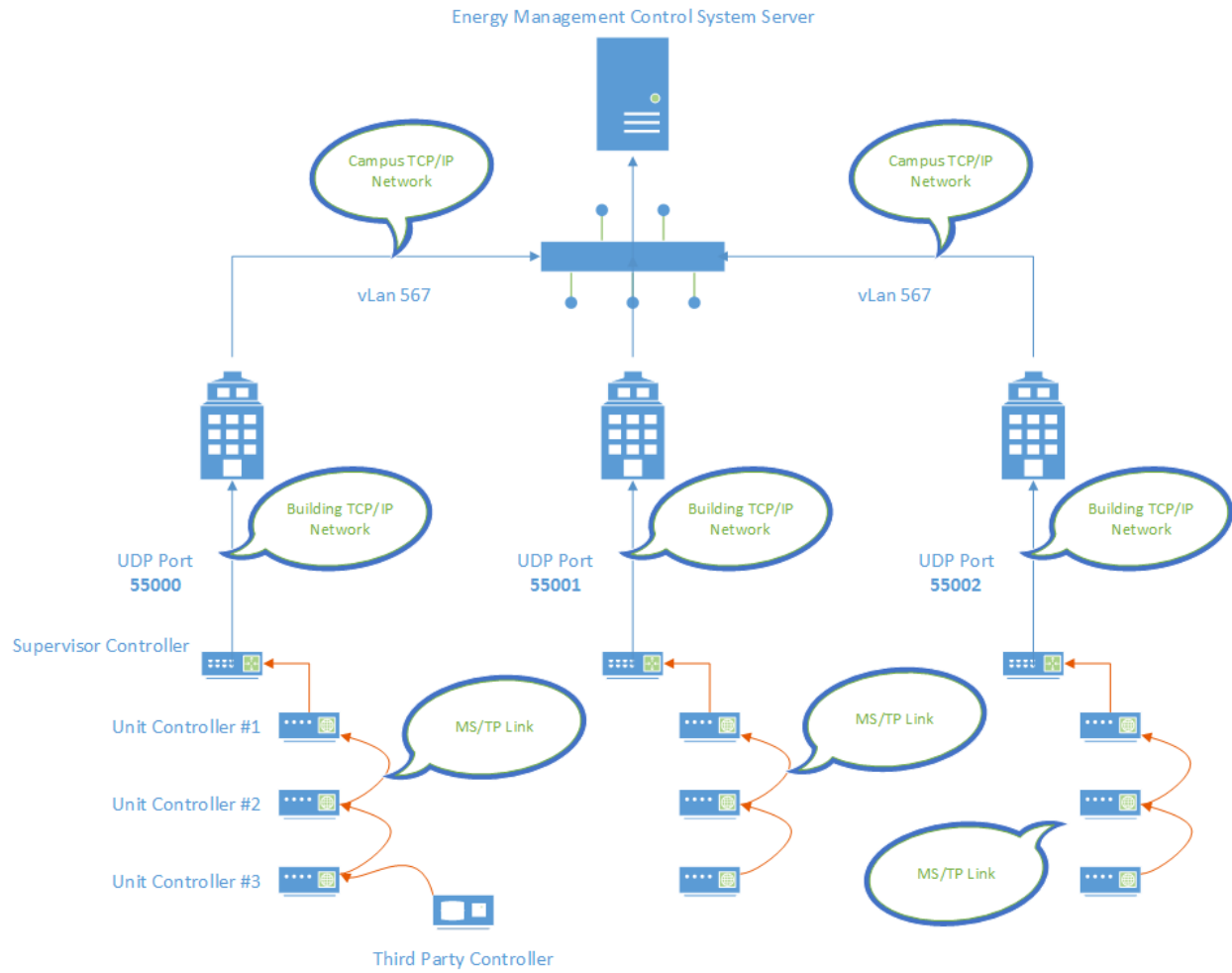
- 2) Space CO2 sensors are connected to the air terminal units and shall first increase the supply airflow rate to the space. Refer to the air terminal unit sequence of operation.
  - 3) When the return air CO2 sensor rises above 1,100 ppm, DDC modulates the mixed air dampers toward the code required outside airflow rate to maintain CO2 control.
  - 4) When the return air CO2 sensor falls below 700 ppm, DDC modulates the mixed air dampers toward the reset ventilation rate.
  - 5) Ventilation optimization shall only operate in the occupied mode when outdoor air can be controlled.
- J. Economizer Control
- 1) When the outside air temperature is less than the return air temperature, the mixed air dampers modulate to maintain discharge air temperature set point.
  - 2) Dampers may exceed the code require outside airflow rate. The heating coil and cooling coil control valves remain closed.
  - 3) Once the outside airflow rate matches the unit airflow rate and the discharge air temperature cannot be maintained, the cooling coil may be used.
  - 4) When the outdoor air enthalpy is greater than 28 btu/lb or 65 degrees, DDC disables the economizer mode and performs the ventilation control and demand control ventilation (if applicable).
- K. Filter Monitoring
- 1) Filters are manually monitored at the magnehelic gauges.
- L. Heating Mode
- 1) DDC modulates the heating coil control valve to maintain the cooling discharge air set point.
  - 2) The cooling coil control valve remains closed.
  - 3) If more than half of the connected air terminal units are at minimum airflow and in heating mode, DDC increases toward the heating discharge set point.
  - 4) Once an air terminal unit cannot maintain space temperature set point, DDC resets to the cooling discharge air set point.
- M. Heating Coil Pump Control
- 1) DDC shall start and stop the heating coil circulation pump.
  - 2) The pump runs continuously whenever the outside air temperature is below 40 degrees, or the heating coil control valve is modulated to an open position.
  - 3) The pump status is monitored by a current relay sensor. Improper status shall issue a BAS alarm after a 120 second delay.
- N. Cooling Mode
- 1) DDC modulates the cooling coil control valve to maintain the cooling discharge air set point.
  - 2) The heating coil control valve remains closed.
- O. Optimal Start
- 1) The unit shall be commanded to start prior to the scheduled occupancy to achieve occupied heating or cooling set point at scheduled occupancy.
  - 2) During optimal start, the unit operates in the unoccupied mode.
  - 3) The discharge air temperature set point for warmup may reset up to a high limit of 80 degrees.
- P. Remote Start & Temporary Occupancy.
- 1) The unit shall have capability to start upon a call from one of the air terminal units.
  - 2) The functionality of remote start shall be able to be deactivated through the user graphical interface. Status of the remote start device shall be visible on the graphics.
  - 3) Upon activation of an air terminal unit push button over ride, the unit enters the occupied mode for 2 hours.
- Q. Night Cycling

- 1) The first stage of heating is perimeter heating. After a 10-minute delay, the air handling unit may start as the second stage of heating.
  - 2) The unit shall run until the air terminal unit's zone temperature is 2 degrees above unoccupied heating set point or 2 degrees below unoccupied cooling setpoint.
- R. Safety Controls
- 1) If smoke is detected in by the duct smoke detector or from the fire alarm zone module, the unit shuts down.
  - 2) A freeze stat set point of 40 degrees shall shut the unit down.
  - 3) A supply air high duct static limit of 5.5 in. wc. or a return air low duct static limit of negative 3.5 in. wc. shall shut the unit down.
  - 4) If the discharge air temperature falls below 45 degrees, the unit shuts down.
  - 5) A failure of the variable frequency drives or unit controller shall shut the unit down.
- S. Shutdown Mode
- 1) A shutdown command from the DDC or a safety device shall shut the unit down.
  - 2) The cooling mode cycles off.
  - 3) The supply, return, and remote exhaust fans are commanded off.
  - 4) The return air damper opens and the outside air and relief air damper close.
  - 5) After a 5-minute delay, the smoke isolation dampers close (if applicable).
  - 6) The heating coil valve modulates to maintain an air handling unit plenum temperature of 50 degrees.
- T. Set point
- 1) Unoccupied Heating Discharge Air = 60°F
  - 2) Occupied Heating Discharge Air = 60°F
  - 3) Occupied Cooling Discharge Air = 55°F
  - 4) Unoccupied Cooling Discharge Air = 55°F
- U. Alarms
- 1) Mission critical alarms reported to the campus Powerhouse.
    - a. Freeze stat.
  - 2) BAS alarms reported HVAC staff.
    - a. Airflow differential pressure.
    - b. Freeze stat.
    - c. Heating coil pump run status.
    - d. Return air low static pressure.
    - e. Return fan run status/alarm.
    - f. Supply fan run status/alarm.
    - g. Supply air high static pressure.
    - h. Supply air temperature.
6. Air Handling Units (100% Outside Air)
  7. Air Terminal Units
  8. Miscellaneous Systems

**APPENDIX 1**

SPACE	TIME	WINTER		SUMMER		COMMENTS
		TEMP (°F)	RELATIVE HUMIDITY (%)	TEMP (°F)	RELATIVE HUMIDITY (%)	
LABORATORIES	OCCUPIED	68	30-70	73	30-70	
LABORATORIES	UNOCCUPIED	65	30-70	76	30-70	
NON-LAB (OFFICES, GYMS, CONF. ROOMS)	OCCUPIED	70	30-70	75	30-70	+/- 2 °F ADJUSTMENT
NON-LAB (OFFICES, GYMS, CONF. ROOMS)	UNOCCUPIED	67	30-70	78	30-70	
LARGE INSTRUMENT ROOMS	24/7	70 +/- 2°	40-60	70 +/- 2°	40-60	4% RH RATE OF CHANGE PER MONTH
SMALL INSTRUMENT ROOMS	24/7	70 +/- 2°	40-60	70 +/- 2°	40-60	4% RH RATE OF CHANGE PER MONTH
ANIMAL HOLDING ROOMS	24/7	68	30-70	73	30-70	SAME AS LABS WITH NO SETBACK
HERBARIUM	24/7	68	30-70	73	30-70	USER DESIRES LESS THAN 50% RH. NO SPECIAL SYSTEMS IN PLACE
MECH./ELEC. ROOMS	24/7	55	N/A	90	N/A	
IDF ROOMS	24/7	70	20	75	80	
MISC	24/7	55	N/A	90	N/A	

**APPENDIX 2**



**DOCUMENT CONTROL PAGE:**

<b>Document Published:</b>	October 8, 2018
<b>Prepared By:</b>	Robert Francisco
<b>Reviewed By:</b>	Mike Walton, Linda Slater, Chris Paseka, Dan Methner, Steve Esch, Jesse Reed
<b>Approved By:</b>	Jonathan Webb

**Revision History:**

Date	Revision	Approved By:
10.26.18	Added Section 23 09 1333 – Control Valves	J. Webb
5.20.19	Added Johnson Control, Inc. as a third control vender, Added language addressing UDP ports in section 23.09.23, sub section 1.A.4.	J. Webb