Basis of Design

University of Washington Specific Controls Features

The following items are specific to the University of Washington:

- The goal is to move from pneumatic to DDC controls. This goal shall be evaluated by the consultant against limitations in project budget and schedule. Work with Engineering Services on a project-by-project basis to determine how these goals are to be balanced on a given project.
- Hard-wired fan high-limit pressure switches and low-limit freeze stats provided as back-up to software-based freeze-protection algorithms.
- Control system return to normal operation unmanned in stages after a power outage or fire alarm.
- Access to control system provided from both local and remote sites.
- On new construction, coordinate with Architect to provide a dedicated, ventilated, well-lit, and secure control room to house the environmental control system’s main terminal, operating manuals, and mechanical drawings.
- On retrofit projects, work with Engineering Services to decide what type of space and front-end equipment the control shop will need to operate the system.
- Coordinate with electrical to provide appropriate power to the Local Operators Station (LOS), an Ethernet connection for remote communication on the UW Facility Network, and phone for remote access by the control shop.
- On remodels and expansion projects, consult with Engineering Services on how to coordinate new and existing controls.
- In project specifications, coordinate with piping specialties to assure there is a test port at each piping sensor.
- Much of the labor required for commissioning is provided by the Control Contractor. Coordinate control specifications with commissioning requirements in other specification sections so that the control system is operated by the Control Contractor for all commissioning tests that require the control system.

Interfacing the DDC with Equipment Built-In Controls

- Indicate the relationship between the environmental control system and the dedicated (built-in) controls for specific HVAC equipment such as chillers, heat pumps, furnaces, and boilers.
- Use built-in controls provided under other sections of the project specifications to handle staging and coordination of parts within each major piece of equipment. This provides a sole source of responsibility for the equipment’s performance to avoid damage to the equipment, to increase safety, and to increase Contractor and manufacturer responsiveness during problem solving.
- The building’s environmental control system may offer monitoring and enable the local controls for “on/off.” Review with Engineering Services which parameters should be monitored by the environmental control system.
- Operation of multiple supply terminal boxes in a single zone presents special problems. Discuss with Engineering Services.
- Make sure any equipment submittals and on-site testing cover the interface between built-in controls and the building’s environmental control system.
Interfacing the DDC with Fire Alarm

- Only the fire alarm system should control life safety fans such as those serving atrium, elevator shaft, and dedicated smoke control. Likewise, only the fire alarm system should control the smoke dampers at air handler inlet and discharge. Fire smoke damper position is not monitored by the environmental controls so the fire alarm system should not release the fans to run until those dampers are open. The fire alarm system should directly shut down all environmental fans over 2,000 cfm and that shut down authority should be effective for all positions of the local HOA or VFD controls. The environmental control system shall not control fans after shutdown by the fire alarm system until after reset of the fire alarm system. Toilet and other non-recirculating exhaust fans shall remain on unless this creates a problem of excessive pressure on exit doors. Fume hood fans shall remain operating. Consult with EH&S for further information.

- Smoke/fire dampers and smoke/fire damper actuators are to be specified under the air distribution system, not under control specifications. The University of Washington promotes use of pneumatic actuators and copper pneumatic lines for smoke/fire dampers. Coordinate control specifications to provide pneumatic lines to any pneumatic smoke/fire damper actuators specified under other sections.

- Specify provision for a current switch for fire alarm system “run status.”

Interfacing the DDC with Emergency Power

- In buildings where mechanical systems operate under DDC control in emergency power conditions, the environmental control system shall monitor the fire alarm panel to determine when the building is under a fire alarm condition. The Environmental Control System shall monitor the appropriate emergency power transfer switch to determine when there is loss of normal power and restoration of normal power.

- Specify a restart schedule indicating equipment start-up priority.

PART 1 - INSTALLATION, FABRICATION AND CONSTRUCTION

1.01 SCOPE

Specify provision for an operational, distributed processing control system, including all software, licensing, and equipment necessary for stand-alone operation of each system. Specify provision for all software, licensing, and hardware necessary for communication among controllers and Local Operator’s Stations (LOS) via local building LAN provided by the DDC vendor. Specify provision for all software, licensing, and hardware necessary for communication between building and Remote Operator's Stations (vendor's central campus server) via campus Ethernet. Vendor is required to provide all parts and labor required in establishing a complete and workable system.

1.02 GENERAL

This section includes controls for heating, ventilation, air conditioning systems, laboratory ventilation systems, metering and interfaces to other systems such as fire alarm systems, as well as other interfaces to other mechanical systems, plumbing systems, electrical systems, etc. for miscellaneous control and monitoring. All materials and equipment used shall be new, standard components,
regularly manufactured and not custom-designed or fabricated specifically for this project. All components and software shall have been previously tested and proven in regular use. The HVAC control system shall possess a modular architecture, permitting expansion through the addition of more distributed processing units, input/output units, sensors, actuators and operator stations. Vendor shall submit and receive approval for all submittals including materials, floor plan, schematics, programming, and mechanical equipment/systems graphics prior to installation.

1.03 APPROVED MANUFACTURERS

Specify provision for an HVAC control system by Siemens Industry Building Technologies Issaquah Branch, Johnson Controls Bothell Branch or Alerton by ATS Automation (no substitutions). New equipment and software shall be selected for compatibility with systems presently installed on campus. Specify that the controls vendor shall provide all software, hardware, and licensing upgrades to allow new controls to work with both old and new control systems. Design, component selection, installation, project specific programming, technical checkout/startup documentation, testing, training and warranty service shall be the direct responsibility of the controls vendor. These services shall be provided from a business address located within 50 miles of the project site. HVAC control system components purchased and installed by a third-party contractor, that is not the selected controls vendor for the project as chosen from the three allowable control vendors, shall not be allowed. When providing additional controls in a building that has an existing DDC system, specify that the additional controls shall be the same as the existing DDC system. More than one control vendor in the same building is not acceptable.

1.04 SUBMITTALS

Schedule of Prerequisite Submittals: Specify provision for the submittal of the proposed graphics, the point-to-point (PTP) and sequence-of-operation verification test plans at least 90 days prior to the scheduled beginning of testing. PTP testing shall be part of the construction schedule.

- Resubmit all materials which, in the Owner’s opinion, have become substantially changed as a result of the review process.

Programming Code: Specify provision for a print-out of the programming code (Algorithm).

- Show initial setpoints.

- Specify provision for all documentation and software necessary to interpret programming related submittals.

Sequences of Operation: Specify provision for project specific highly detailed prose sequences of operation detailing all control strategies, including initial setpoints and referencing all points by the point name used in the DDC controls programming. (These sequences of operation will also be provided in the construction and record drawings.)

Controls Drawings: Specify provision for a complete set of reproducible control drawings using computer aided design and drafting (CADD) technology. Include the following information:

- Show general physical arrangement of component devices installed in the panels. Indicate applicable detailed drawing reference.

- Specify provision for a typical schematic drawing of each control circuit.
• Identify equipment and devices by the reference designations shown on the drawings and by unique point identification used in system software. Provide material list with or on each drawing.

• Supply block diagrams and schematics showing riser diagrams, the layout of equipment, communication cabling, and wire type.

• Specify provision for electric ladder diagrams that coordinate with each system’s sequence of operation and systems diagram.

• Specify provision for schematics showing the general mechanical system layout with all sensors/devices of each mechanical system.

• Specify provision for floor plan drawings showing the general location of all controlled equipment and devices used for sensing and control.

• Specify provision for a schematic drawing of each control circuit, complete with individual wire identifications. Typical drawings are acceptable.

• Specify provision for all graphic display designs for Owner’s approval.

• Specify provision for a schematic drawing of each control circuit, complete with individual wire identifications. Typical drawings are acceptable.

Equipment List, Cutsheets, Damper and Valve Schedules: Specify provision for a complete list of equipment to be furnished, which includes a manufacturer’s catalog sheet for each item on the material list. Care shall be taken in the preparation of catalog cut sheets. Digital format is preferred.

- Catalog cut sheets shall be digital and indicate item being submitted.

- Supplement catalog sheets as necessary to fully describe the device being furnished. Include information to aid the Owner in judging the suitability of each device.

- Specify provision for a damper schedule with one line per damper. Provide for each damper: The project TAG, the size, the model of the damper, the model of the actuator, and whether the damper fails open, closed, or in place. Indicate whether the actuator is electronic or pneumatic.

- Specify provision for a valve schedule with one line per valve. Provide for each valve: The project TAG, the size, the model of the valve, the pressure rating, the model of the actuator, the valve Cv, and whether the damper fails open, closed, or in place. Indicate whether the actuator is electronic or pneumatic.

- Submit sizing calculation data for pneumatic air dryer for approval, if used.

Testing Plan: Specify provision for a detailed test plan describing the specific procedures used to complete and document the “Owner-witnessed Testing” described in the Final Acceptance requirement.

- Test plans shall include a complete schedule for tracking each phase of the testing, e.g. zone testing by floor, fan testing by system, chiller interface testing, heating system testing, etc.

- The vendor is required to supplement the planned work effort to meet the progress dates given in the schedule.
As part of the submittal process, the vendors including the engineer assigned to programming the system shall meet with representatives of the Owner’s engineering and operations divisions, giving them a thorough briefing on the DDC programming design. This briefing shall describe in detail the methods the control programmer has used to meet the requirements of the sequence of operations.

1.05 SYSTEM STARTUP AND COMMISSIONING

**Startup**: Specify that the controls vendor shall provide complete and documented startup services for the controls systems, including verification of interfaces to other equipment and systems as specified.

- The Contractor shall provide complete startup services of the DDC controls systems to provide a fully functioning system to meet the design requirements. The Contractor shall then demonstrate compliance of the system installation, setup, operation, stability, and documentation via the Owner-Witnessed point to point testing and then through the commissioning process as demonstrated to the Owner and the Commissioning Authority for the project.

- Specify that controls vendor shall provide staff and materials to conduct the point-to-point testing, also referred to as Owner-Witnessed Testing and then for the commissioning process.

- The Contractor shall perform their own preliminary point-to-point, and commissioning functional performance “pretests” before the witnessed tests, and shall fill out data sheets during pretests, as a prerequisite, to demonstrate successful performance prior to witnessed tests.

**Owner-Witnessed Point to Point Testing Demonstration**: Demonstration of the point to point testing shall be conducted by commanding system points via the graphics screens and witnessing that the actual component, in the field, responds appropriately to the command and the actual state of the point is accurately reflected in the controls system. Physical verification or commanding from other software tools shall be allowed as a substitute verification method only where the control point is not available on the graphics or where the test function cannot be completed through the graphics.

- Verify operation, location and identification of power sources, including circuit breakers and control power transformers.

- Start/stop points: Issue start and stop commands. Verify that controlled equipment responds appropriately and that the start/stop status is indicated.

- Analog points: Analog inputs and outputs shall be verified at both extremes of their ranges and at the midpoint. Verify tight shutoff and full opening of dampers and valves.

- Binary points: Verify that both commanded conditions (on/off, open/closed, etc.) are achieved.

- Fan and pump run status points: Test fan and pump run status feedback by turning off the motor at the HOA switch and observing the run-state indication at the operator station. For motors controlled by variable frequency drives, verify that the motor speed matches the speed signal sent from the controls system, and that minimum speed is coordinated between the controls signal and the VFD’s minimum speed setpoint, such that the “%” speed signal from the controls system matches the “%” speed signal displayed at the VFD throughout the entire speed range.

- Temperature points: Verify accuracy of sensors by comparing displayed temperature values with the reading of an independent measuring device located in the same flow. Test liquid temperature sensors as installed in piping thermowells to verify effectiveness of heat conducting compound. [NOTE: Specify within the piping specialties section the requirement for self-healing-type pressure/temperature test ports to be located near all pipe sensors for the purpose of verifying the controls system temperature sensor calibration].
- Relative humidity points: Verify accuracy of sensors by comparing displayed RH with the reading of an independent measuring device located in the same flow stream.

- Gas concentration points: Verify accuracy of sensors by comparing displayed gas concentration level; (CO2, CO, NOx, etc.) with the reading of an independent measuring device located in the same flow stream. Alternately, the reading through the controls system can be compared to the known, pre-mixed gas concentration of a calibration bottle kit, made specifically for calibration verification of that sensor model when hooked up to that sensor.

- Pressure points: Verify accuracy of sensors by comparing displayed pressure with the reading of an independent measuring device located in the same flow stream. Retain the services of the balancer as required to confirm readings. [NOTE: Specify within the piping specialties section the requirement for self-healing-type pressure/temperature test ports to be located near all pipe sensors for the purpose of verifying the controls system pressure sensor calibration]

- Flow points: Verify that the sensor meets at least the manufacturer's minimum installation direction requirements to ensure proper and accurate operation. Verify accuracy of sensors by comparing displayed flow with the reading of an independent measuring device located in the same flow stream. Confirm that the flow units are displayed correctly through the controls system. Retain the services of the balancer as required to confirm readings.

- Control valves and dampers: Verify that the controlled device operates in the direction per the command (open and close), has full range of commanded stroke, and has tight shutoff. For control valves, verify tight shutoff by comparing water or air temperatures entering and leaving the heat transfer device. For pneumatic actuators used in modulating applications, verify that the pilot positioners are set up to achieve the full range of commanded positions with tight shutoff. Ensure that the position of multiple operators provides simultaneous modulation of damper or valve assemblies.

- Safety switches: Safety switches, such as freezestats and pressure limit switches, shall be tested by simulating fault condition at the sensor (i.e. – applying pressure to the high pressure port of a high pressure limit switch using a hand squeeze bulb and magnehelic pressure gauge, or dipping the last 24” of a freezeastat bulb into an ice water bath). Confirm that the switch makes as expected and that it is properly interlocked to the associated equipment to shut it down whether the equipment is in its HAND, OFF, OR AUTO operating mode. Also verify that the status of the switch is correctly identified through the controls system.

Commissioning Functional Performance Testing: Specify that the controls vendor shall provide assistance, staff, and materials to support all of the commissioning activities, including functional performance testing.

- This includes all testing apparatus in use by the vendor to test and calibrate or verify calibration of the control system and all other apparatus for which the vendor has control or calibration responsibility.

- Assistance includes but is not limited to reviewing test procedures and providing software enhancements to accommodate testing methods.

- Controls vendor shall operate the control system for any commissioning tests specified in other specification sections. Testing shall be performed by the manufacturer or its local representative, witnessed by the Owner and demonstrated to the Commissioning Authority.

- The procedure for the test must provide a format for documenting the results, comments, vendor repair activity, vendor’s initials, and retest witnessing. Specify provision for data sheets with one
line for each physical point on the system, and columns to record the results, dates, and initials of witnesses for both pretests and witness tests.

- The complete local operator station, including all controls software and programming development, shall be installed and made available to support the point-to-point testing and commissioning activities.

- Demonstrate the capability of the controls system to execute the complete sequence of operation as given in the mechanical design documents, including all modes of operation, all alarm and failure responses, all interfaces to other equipment and building systems, and all enhancements necessary, as found during the functional performance testing, to make the systems function properly and to meet the design intent.

- Control signal stability, general: Demonstrate that control loops are tuned so that the output does not change until the controlled system has had time to respond to the last output signal.

- Control signal stability, response to step input: Demonstrate that control loops are tuned so that they are stable without excessive hunting following a step input of not less than 20% of the operating/reset range of the controlled variable.

- Control signal stability, floating point devices: Verify that minimum pulse output duration is no less than the value required to assure repositioning of the controlled device. For each floating point actuator, ensure that the control system parameters are set up to conduct “command/position synchronization” routines on a regular basis, or as needed to meet the sequence of operation and without losing control of the basic HVAC functions, such as zone temperature control, pressurization control, or causing the central fan or pump equipment to operate at a falsely-loaded capacity.

- LOS Point override test: Verify manual override capability for start/stop and modulated point types.

- Control logic test: Exercise all control logic packages. Check response to upset, change in setpoint.

- Supervisory functions: Verify content and operation of time clock schedules. Also, verify alarm’s reporting capabilities and setup.

- Failure modes: Verify all stand-alone operation by disconnecting communication lines between stand-alone control units and verifying continued operation. Disconnect and reapply 120 VAC Local Operator Station (LOS) power to confirm proper recovery from power failure. Disconnect and reconnect controller power to confirm proper recovery from power failure.

- Remote server tests: Verify communication with each field device installed. Verify transmission and reporting of alarms. Verify acquisition of data. Verify trend logging functions. Verify report generation functions. Verify remote access to the server through the campus Facnet internet gateway and also from the vendor’s other local operator stations on campus

- Test the ability of the control system to automatically restart all the connected systems which are scheduled to run following a power restoration and fire alarm recovery.

Refer to the commissioning section—“General Commissioning Requirements”, section—“Commissioning of Plumbing”, section—“Commissioning of HVAC”, and section—“Commissioning of Electronic Safety and Security” for additional requirements relating to commissioning support.

1.06 FINAL ACCEPTANCE REQUIREMENTS
As Built Documentation: Specify that controls vendor is required to provide corrected documentation to show changes made to correct deficiencies discovered during commissioning tests. Vendor shall reassemble manuals and drawing packages to reflect corrected documentation records.

- Submit shop drawings reflecting final "as-built" condition.
- Specify provision for 3 copies of drawings and programming database.
- Specify provision for 1 copies of reproducible record drawings and 1 on computer disk for the latest edition of AutoCAD as well as .pdf file format.
- These record drawings shall accurately depict the final as-built conditions and the floor plan portions shall be on Architectural/Mechanical backgrounds provided by the A/E.
- These drawings shall include accurate depiction of location of sensors and controlled equipment (motor starters, valves, chillers, dampers, AHUs, etc.)
- Insert one copy of applicable shop drawings, panel layout drawing, and points list at each enclosure’s documentation holder.
- Furnish one original set of application software on original media as well as printed and .pdf file media. Disks shall bear the manufacturer's label. Field copies are not acceptable. Application software includes operating system, controls application generation, graphic support, maintenance support and all other utilities provided in support of the installed system.

Operation and Maintenance (O&M) Manuals: Specify provision for three paper copies. Also, refer to section—“O&M Documentation” for submittal schedule as well as requirements for electronic O&M formats. Describe operation, maintenance and servicing requirements of the HVAC control system and associated equipment. Specify provision for the following information with an index.

- Technical literature for all equipment, including catalog sheets, calibration, adjustments and operation instructions, and installation instructions.
- Hardware and software manuals, including information supplied by the original product developer, on the application programs and on the computers and controllers provided by vendor.
- System description and complete sequence of operation.
- Reduced size (11" x 17") copies of record drawings.
- Input/output (I/O) summary forms for the system, listing all connected analog and binary input and output functions and the number and types of points. Indicate spare input/output capacity control programs specific to this system.
- Integrated points summary forms, listing all integrated points by equipment/system. Where the purpose of the point is not obvious, include a description for the point. For each integrated equipment, specify the network address and version of the firmware file for the integrated equipment.
- Completed point-to-point checkout plan used in Owner-witnessed testing, and the completed data sheets showing the results of the point-to-point testing.
- One copy of the preliminary as-builts (site drawings) shall be provided to support the point to point testing.
Owner Demonstration and Training: Specify provisions for Owner training and demonstration within the specification section—"Demonstration and Training". The requirements for that specification, relating to controls system training, are noted here for reference.

Specify provision for a minimum of 32 hours of classroom and on-site training in the operation and maintenance of the installed system. For the first training session, hold eight hours of this training prior to point to point testing. This shall be an introductory session. Provide each trainee with a copy of the sequence of operations and the graphics during each training session. Training shall address the following subjects:

- System log-on procedures
- Review of sequence of operations
- System troubleshooting
- Emergency service support
- Fire alarm interface
- System restart after power failure
- System backup and restoration procedures
- Replacement procedures of each system component
- Calibration and initialization procedures
- Regeneration procedures on all installed programming at operator’s control stations
- Operation of maintenance service programs
- Any building systems interface
- Conduct site walk-thru to familiarize the staff with locations of major controllers and components as well as the equipment controlled by the system.

Specify provision for an additional 4 hour training session just prior to turnover of the facility for Owner operation. The subjects from the initial training session shall be reviewed and the trainer will also emphasize system characteristics that would be helpful for the staff in managing and operating the systems. Many of these characteristics will be learned from the startup and commissioning processes.

Specify provision for on-site training in system operation and programming for the Owner’s staff on 4 separate occasions during the year following final system acceptance.

- The combined total of this training shall be no less than 20 hours.
- This training shall focus on preparing new personnel in the basic operation of the system.

Specify provision for the standard manufacturer’s training (at minimum, 80 classroom hours) to prepare the Owner’s staff to write and maintain the control system programming.

- This training shall be provided for 2 employees of the Owner at the manufacturing facility or (at the Owner’s option) by the manufacturer’s regularly employed trainer(s) at the Owner’s location for up to 4 employees of the Owner.
• Included are all travel and lodging expenses for trainer and Owner’s employees.

• Training shall prepare the Owner’s maintenance staff to generate and maintain the control system programming logic.

• Personnel shall be capable of making changes to the control system, transferring programming between controllers and server, understanding how backups are secured in the system as well as how programming and parameters are automatically downloaded by controllers, expanding the control system by adding logic and hardware devices, performing troubleshooting, and how to obtain technical support.

Specify provision for one set of the special tools, reference materials (manuals), test instruments, and software manufactured or modified by the manufacturer for use in the installation, troubleshooting, and repair of installed devices. Include portable test terminal, test boxes, circuit card extenders, and calibration modules. Specify provision for software for the portable operator’s station as required to perform system maintenance and operation functions.

Owner will provide computer support for the generation of backup database records. Actual use of computer support is during Owner training for generation of backup database records.

1.07 SERVICE AND GUARANTEE

The complete control system shall be warranted to be free of defects in manufacturing, workmanship and materials for one year. Temperature sensor accuracy shall be warranted for 3 years. Software and documentation shall be revised to reflect system changes required to meet warranty obligations.

During the warranty period, specify provision for a 24-hour emergency service telephone number where a qualified service technician, familiar with the installed system, may be reached.

• This technician shall have the capability of remote communication with the control system for troubleshooting and program alterations.

• The vendor shall pay all costs to provide communications for remote access via owner provided static IP address.

• A fully equipped, qualified repair technician shall be at the job site within 4 hours of a request for emergency service.

Specify provision for free of charge during the warranty period 2 DDC software sequence modifications as instructed by the Owner. Modification shall be in software only.

PART 2 - SYSTEM DESCRIPTION

2.01 GENERAL

Specify provision for all software, licensing, hardware, input/output devices, wiring and control power not shown in electrical bid documents, actuated dampers, actuated valves, actuators, operation and maintenance training, special maintenance tools and aids, supervision of labor, and warranty.

The system shall be built only of standard components kept in stock by the supplier.
• All replacement parts shall be available on site within 48 hours.

• The components shall not require customizing other than setting jumpers and switches, or adding firmware or software modules, or on-site software programming to do required functions.

System display should meet the following requirements:

• All system titles, prompts, and instructions are to be in the English language.

• All values shall be in actual control unit, i.e., a setpoint such as 74°F.

The primary means of information display, mechanical systems management and monitoring functions shall be by graphic display.

• System shall be controlled and monitored through a color Graphical User Interface (GUI).

• Graphical presentation shall group all elements of a system in a clear and logical manner and present on-screen display of system status.

• Each display will contain comment sections to indicate building area served (if area-specific) and also contain a graphical presentation for all other interlocked systems.

The system shall include all standard software applications needed to fully service, edit, set up, configure, manage, trend, and troubleshoot all of the controls systems software, network, components, and controllers. The software required to manipulate the graphics overlays, backgrounds, and active components shall also be included, along with the associated licensing. Control system management shall generally occur at a dedicated computer, the local operator station. However, the system shall also be managed through the remote connection to the vendor’s campus server as well as connection of a laptop (portable operator’s station) to individual controllers. Provide all software, special cables, and interface modules necessary to perform all direct-controller interface troubleshooting, setup, and monitoring from the portable operator station.

2.02 SYSTEM ARCHITECTURE

The environmental control system shall consist of a distributed network of controllers providing full stand-alone operation of the building. The controllers shall contain the necessary programming to accomplish the sequence of operations for building control.

Controllers shall normally execute the control strategy to use peer-to-peer communication capabilities. Upon loss of communication, the stand-alone control unit shall be able to execute its own stand-alone programming. This distribution of control authority is mandated so that the lost communications capability shall not cause a complete loss of control for affected systems. All points required to implement the sequence of operation for a particular equipment or system shall be connected to a common controller to allow for stand-alone operation in the event of communication failure to the rest of the control system. Exceptions will be made for global points that are passed to all of the controllers, such as outside air temperature, changes to occupancy schedules from the server, etc. or for programming that is required to interlock operation of equipment/system, each of which has its own, stand-alone controller already. Remote sensors, for example duct static pressure sensors mounted 2/3 down the main trunk, shall be hard-wired back to the controller for the associated air handling unit. All programming for a particular system shall reside within that common controller and shall not require programming from a different controller, with communications over the system networks, in order to implement the full sequence of operation for that system. The vendor shall utilize controllers with sufficient programming capabilities and capacity to accomplish this requirement.
Specify provision for all equipment and hardware necessary for communication among the main distributed processing units within the facility using TCP/IP or BacNet over IP. Specify provision for a single point of connection per building from the DDC system to the campus Ethernet for communication to remote operator’s stations and the vendor’s server for the campus. The port for the campus Ethernet connection shall be installed inside a 12x12x6 inch, lockable enclosure similar to Milbank series 12126-LC1. The Ethernet port shall allow the operators to connect to the UW Facility Network subnet (“FACNET”). Coordinate communication and power requirements with the electrical consultant. The owner will provide the static IP address for all the Ethernet-connected controllers and operator stations.

Operator station shall not be necessary to sustain building operation.

2.03 SPECIFIC SYSTEM FEATURES

Zone-by-zone control of space temperature, usage scheduling, and equipment failure reporting (A zone is the area served by one HVAC terminal unit, fan coil, heat pump, air terminal, etc.)

Specify provision for UPS (Un-interruptible Power Supply) having 5 year battery life and battery hot swappable capability for all cabinets containing controllers. Discuss the requirement for UPS backup power with Engineering Services. These cabinets shall be provided with a fused duplex receptacle to be used as a source for UPS power. Cabinet shall draw power from the UPS. Specify provision for a shelf for the UPS. Where a UPS is used, the UPS shall have an output contact that shall be monitored by the BAS as a summary alarm point for the UPS. The contact should be normally closed so that if the point is disconnected, the BAS will indicate an alarm for it. The purpose of this summary alarm is to notify the operator of malfunctions of the UPS and more importantly, to monitor battery life and impending need for battery replacement.

Totally tamper-proof room sensors installed with Allen, Bristol or similar hardware with no local setpoints. All temperatures are to be set from an operator’s station or portable terminal. (Note to Consultant: Modify this statement when it is appropriate to include a limited adjustment capability by the occupant.)

Specify individually assignable priority password security system to prevent unauthorized use. Specify provision for at least 4 levels including the following: Information only, change of setpoint & ON/OFF, programmer, and a fourth master level for assigning appropriate local access.

Auto-restart, without operator intervention, the operator stations and all controlled equipment to the control state that would be in effect if the power failure or fire alarm event had not occurred. Start/stop outputs shall continue to command the affected device while motor power is unavailable and allow for equipment restart, as previously commanded or scheduled, upon restoration of motor power.

Equipment run-time totalization of motor driven equipment.

Interactive displays of all input and output points: As a minimum, each of the screens on the display monitor shall be able to display all of the interactive points and custom text for that screen.

Operator may, through keyboard interface, disable any control logic for any output or setpoint, temporarily substitute the value for any input/output, and introduce a different value or state for all inputs, outputs and setpoints.

Individual controllers will be programmed with nonvolatile stand-alone control logic necessary to maintain appropriate HVAC equipment operation. While in temporary stand-alone mode, energy efficiency can be
sacrificed to maintain temperature control and operational conditions that will not damage equipment or compromise health and safety.

The control system shall only control equipment while the HOA switch is in the Auto position. Where equipment is controlled by both the fire alarm system and DDC controls, the fire alarm system shall provide separate start/stop relays. The fire alarm system shall always override the DDC controls. The controls contractor shall engineer and provide the integrated wiring diagram to coordinate this priority of controls as well as indicate how the wiring is terminated to the equipment to provide positive start and positive stop from the fire alarm commands regardless of the motor starter HAND, AUTO, OFF, or BYPASS positions. The fire alarm commands shall not override electrical disconnect functions.

Controllers shall, upon loss of valid programming, be capable of requesting and receiving a programming download of all required program code from the local operator control station. The controllers shall not automatically download programming upon loss of power or cold start of panel in order to prevent inadvertent override of controller programming or parameter setup to earlier versions of the backups on the server.

UW personnel shall be able to create and modify control software with an MS Windows (current version in use by UW) compatible computer utilizing menu-driven programming. UW personnel shall be able to store the programming on a removable computer disk and preprogram a nonvolatile, transportable memory storage device, which can be used for replacement of the programming in system controllers.

2.04 OPERATOR STATIONS

Operator stations shall be Microsoft Windows® based personal computers or servers selected to meet the specification requirements of the vendor-provided control system software.

All operator station hardware and software shall be provided, installed and made operational by the control vendor.

Stations will provide complete facilities for local printing on laser type printers.

Stations will provide complete facilities for loading and archival storage of computer software as well as provide CD/DVD Drive.

Specification for processor type, speed and memory shall be consistent with those recommended by the software manufacturer.

Station will provide all hardware and software to communicate with remote operator stations over the campus Ethernet system using TCP/IP protocol.

Remote Operator Station (ROS): The contractor shall provide all hardware, software, and licensing to provide secure communication, over the campus FACNET using TCP/IP, from the LOS or POS within the facility to the vendor’s campus server for their system (ROS).

Local Operator Station (LOS): Specify provision for a computer selected to meet all specifications for operation of control system software and provide additional unused disk store space for operational requirements such as trending and totalization. Disk storage space shall be no more than 20% utilized by the initial installation.
Portable Operator Station (POS): Specify provision for one “lap top” computer capable of operating all vendor-supplied field maintenance programs. Provide all special cables and interface devices required to interface directly with all controllers to the POS

2.05  CONTROLLERS

Each controller shall operate as part of the building-wide control system and as an independent unit when not in communication with other controllers or an operator station. Global controllers shall be able to share Global information on a peer-to-peer basis without relying on an operator station.

It shall be possible to define control strategies at each controller from any operator station. Each controller shall be able to interface directly with an operator station.

Each controller shall include its own microprocessor, power supply, and, if necessary, battery with automatic charger. Upon loss of system power, the controller memory shall be maintained for a minimum of 60 hours with no external source of power. Upon restoration of system power, the control unit shall resume full operation without operator intervention.

Specify provision for control programming logic at each controller for proportional and/or proportional plus integral control capabilities as necessary to assure complete and stable control of each controlled variable.

Controllers shall be either BACNET IP or BACNET MSTP based communication compatible.

2.06  CONTROLLER FUNCTIONALITY

Each controller shall maintain and perform its own stand-alone control strategy upon communications failure. The controller stand-alone control program shall be adequate to maintain the basic control function and specify provision for protection from inappropriate equipment operation. The controller shall retain its programming during a power failure and resume operation without program reloading from another device.

The controllers shall be powered by 24 VAC, one grounded leg.

Each controller shall be isolated (optically or by other means) from communication trunk and have fuse or overload protection.

The controller point monitoring and control capabilities shall include but not be limited to the following:

- Binary inputs (contact closures)
- Analog inputs (use only resistive, 0-10 volt, and 4-20 ma. inputs; provide A/D conversion of 10 bits, minimum)
- Binary output (start/stop or latching and momentary contacts)
- Floating point control
- Analog outputs (must include 4-20 ma. @ 10 VDC minimum, 0-10 VDC; provide A/D conversion of 12 bits, minimum)

2.07  FAILURE MODE
Upon failure of any global controller, the operator station shall display off-line occurrence for each affected point, and provide communication verification to each controller for each I/O channel.

In the event of communication failure, controller shall continue to operate equipment using appropriate backup values for missing global information. If sensor information is necessary for proper stand-alone function, then that sensor shall be attached directly to the appropriate controller. Specify provision for failure mode programming to accomplish safe operation of equipment in case of communications failure on local trunk.

Upon return of primary power after a power failure of up to 72 hours, the system shall automatically return to completely normal operation with no action required from operating personnel.

Unless otherwise indicated in the design documents, provide the following failure modes, (that is, the position that the controlled device attains under failure due to loss of power, loss of air pressure, or loss of communications) for valves and dampers:

- All heating converter steam valves shall fail closed.
- All fan preheat steam valves shall fail closed.
- All fan and unit heating hot water heating valves shall fail open.
- All fan cooling water valves shall fail closed.
- All central cooling water differential pressure control valves shall fail closed.
- All fan exhaust air and outside air dampers shall fail closed.
- All fan recirculation dampers shall fail open.
- All fume exhaust control and fan isolation dampers shall fail open.
- Zone-level air terminal unit hot water valves and dampers, unit heater hot water valves, and perimeter hot water heater valves may fail in place.

EP transducers shall be selected so that valves and dampers go to the above-listed failure positions on loss of power.

2.08 ENERGY REDUCTION AND MONITORING AND SPECIAL OPERATION SOFTWARE

The system shall be designed to control energy-consuming loads. Specify provision for engineering, consulting, and programming to develop and set up the following energy reduction software:

- Time schedules: Software should provide at least 16 time schedules. Each schedule is to be on 7-day type, capable of 6 entries minimum per day. Time program shall provide ON/OFF commands, and reset SETPOINT capabilities.
- Holiday time programs: Specify provision for a holiday time schedule capability.
- Optimal start warmup and cool-down modes: Specify provision for the ability to optimize start times to attain and maintain temperature setpoint only during occupied times. The system shall be self tuning, based on the system’s historic ability to achieve the target occupied temperature by occupied start time as well as outside air temperature and average zone temperature, with compensation for weekends and holidays.
• Setpoint reset: Specify provision for a means of automatically resetting heating water supply air temperature, chilled water supply temperature, condenser water supply temperature, and outside air ventilation air inflows (demand-based ventilation), fan static pressure setpoints, and pump differential pressure setpoints, based on demand.

• Specify provision for a program to automatically restart all DDC controlled equipment upon the resumption of power or return from fire alarm condition. Equipment shall be restarted according to a prearranged, prioritized and staggered restart schedule.

• For loads that have been turned off at the MCC controller, local motor starter, or VFD motor starter, either by positioning of the HOA switch or the line disconnect; provide a restart strategy that automatically restarts load upon the reset of switches to their normal on-line positions.

• Specify provision for global command software to support balancing and commissioning work including, as a minimum, single command authority to command hydronic control valves, for each system independently (including all terminal units and zone reheat valves), to their full open position. For air systems, provide a single command authority to command all terminal units to their maximum airflow setpoints, for each air handling unit system independently. Provide single command authority for return to normal operation. Provide pre-configured reports to indicate valve and damper position reports, independently by system that can be run at any time by single command.

• Specify provision for capability to adjust the setpoints of all mechanical systems from the operator station using simple ‘point and click’ command windows.

2.09 ALARM PROGRAMMING

For each analog input point, assign operator high and low alarm limits according to design data or as Owner requests.

For each alarm input, provide the following assignable alarm responses:

• Display English language point description in addition to system point identification.

• Print out alarm description and operator-created alarm message.

• Require acknowledgment by operator and print occurrence if directed by Owner.

Specify provision for equipment monitoring and alarm function including information for diagnosing equipment problems.

• All system points shall be programmed to report alarm conditions by fully expanded point names that are tailored and specific to this project.

• The consultant shall include a matrix of all expected alarms for the control system and shall include this matrix within the design document sequence of operation. The matrix shall be coordinated with the U.W. Engineering Services, U.W. controls shops, and, where facilities have critical environmental requirements (for example: critical temperature labs, critical relative humidity for museum archive storage, etc.), those alarms for the critical parameters shall also be coordinated with the users for those spaces. The matrix shall also indicate alarm points that are intended to be remotely annunciated via text message, email, phone, or other method, as well as the distribution network and escalation responses.
• Interlock all alarm points to system status so as to lock out alarms when the system is not operational by schedule or operator command.

2.10 LOGS AND TRENDS

As a minimum, specify provision for capacity for 500 trend logs. Store time segments. Allow for review of data on monitor, printer, or exported file. Each trend log shall have assignable individual start/stop times/dates. Trends shall be displayed in tabular format and graphical chart format. Chart trend logs shall have the ability to graph multiple trended points on a common trend chart, including the ability to use two separate value axis. This allows comparison of trended points that have significantly different range values.

Current alarm log: Display all points currently in alarm.

Operator activity log: Record a running log of operator activity by operator account identification and work performed.

2.11 SPECIFIC SENSOR FEATURES

General

• All devices shall be mounted within enclosures. Cable trays and external cabinet services shall not be used as mounting services.

Temperature sensors

• Sensors shall be completely pre-calibrated with no electrical adjustments or calibration required for standard installation conditions, but shall have provisions to adjust sensor output to adjust “calibration” if needed.

• The temperature displayed at an operator terminal shall be accurate to within 1°F. This accuracy shall be warranted (parts and labor) for a minimum of 3 years. Temperature sensors, including room “thermostats” shall read within ±1.5°F of an independent instrument that is rated with an accuracy of ±0.5°F or better. Point-type discharge air sensors from terminal units shall be accurate to within ±2°F. Temperature sensors that do not comply shall be adjusted through the controls system or replaced until compliance with this requirement is achieved.

• Wall sensors shall be housed in tamperproof enclosures installed with Allen, Bristol or similar mounting hardware. Wall sensors for zone controls shall provide jack for operations laptop connection. That connection shall allow communication with system for monitoring and adjusting at least the zone-level equipment serving that zone. Wall-mounted sensors shall be mounted on electrical boxes, not mud rings, and the boxes and electrical penetrations shall be sealed to prevent thermal convection from the inside of the wall from influencing the sensor readings. The wall sensor shall be air tight from the interior wall cavity. Provide thermal blocking back-plates where sensors are mounted to an exterior wall.

• Thermowells shall be bronze, brass, or stainless steel with 1-inch NPT threads. Use heat-conducting compound. Thermowells shall be sized with a length sufficient to ensure that the sensor is within the flow path of the sensed medium in order to achieve the fastest response time and accurate reading of the parameter.
• Specify provisions within the piping specialties specification section to require self-healing type pressure/temperature port fittings (Pete's Plugs®) within 6” of every controls system temperature and pressure sensor tap in piping systems. These shall be used to verify calibration of these control system sensors by directly inserting an independent, calibrated testing instrument in the same location as the controls system sensor.

• Terminal unit discharge air temperature sensors shall not be mounted within 36” of the discharge point of the unit reheat coil.

• Mount and shield outside air sensors so as to avoid solar influence.

• Outside air sensors shall be a waterproof assembly protected from solar radiation. Span shall cover the range of –30°F to 100°F or better and not exceed a 150°F span.

• Provide averaging-type temperature sensors within air handling units on the discharge side of each heat transfer coil. The averaging sensors shall cover the entire cross-sectional area of the coil to provide a true average temperature output from the coil. Averaging elements shall be mounted so as to cross a minimum of 80% of the plenum width and shall be located so as to provide an indication of temperature within ±1°F. Specify provision for support at 36 inches maximum. Where coils are made up of multiple coil sections, a separate averaging sensor shall be used for each coil section and then an average of those sensors shall be written to a common virtual point for real time monitoring and display of one temperature on the system graphics.

Space Air Pressure and Differential Pressure Sensors:

• Mount outside pressure reference sensors with an outdoor sensing port device so as to eliminate wind effect.

• Provide finished terminations for indoor air pressure reference ports. The open end of a controls tube shall not be an acceptable termination method.

Air Velocity and Flow Transmitters:

• Shall provide air velocity information independent of the effects of static pressure. Transmitter shall operate at rated accuracy from 0°F to 120°F. The minimum accuracy of displayed value at an operator terminal shall be within ±3% through the range of 20% to 100% of sensed airflow, with a drift rate no greater than 1% per year. The proportional output shall be 4 to 20 ma.

• Flow transmitters shall be installed per all the manufacturer’s installation instructions to achieve the rated measurement accuracy, including minimum required straight ductwork lengths ahead of and following the sensor to achieve a uniform airflow pattern across the face of the transmitter sensor(s). The Contractor shall work with the balancing contractor to ensure that the output of the transmitter is spanned properly and reads accurately by the controls system.

Relative Humidity Transmitter:
- Sensors shall be of the solid state type using a hygroscopic or thin-film capacitive technology sensing element. The sensor shall operate from 40°F to 100°F. The minimum accuracy, as displayed at an operator terminal, shall be within ±2%RH through the range of 10% to 95% RH, with a drift rate no greater than 1% per year. The proportional output shall be 4 to 20 ma.

Differential and static pressure transmitters:

- Transmitter shall operate from 50% of minimum to 150% of maximum anticipated pressure. The maximum error of displayed value at an operator terminal shall be ±2% through the range of 20% to 150% of the intended maximum setpoint. Minimum pressure tolerance shall be 150% of the maximum pressure expected in normal operation. The maximum drift rate shall be no greater than 1% per year. The proportional output shall be 4 to 20 ma. Specify designed pressure pitot sensor.

Freeze protection thermostats:

- Freezestats shall be mounted upstream of the coil they are intended to protect, typically the cooling coil.

- Specify provision for freeze protection thermostats with DPDT contacts. One set of contacts shall be wired directly to controlled mechanical equipment contactor/VFD in order to affect both automatic and manual (HOA) switch positions. The second set of contacts will be wired to a digital input for annunciation of freeze protection alarm condition. Both contacts shall actuate simultaneously. Differential actuation of the contacts shall not be allowed.

- Manual reset type freeze protection thermostats are required.

- Freezestats used for fan shutdown control shall be wired to stop the fan in both HAND and AUTO positions of the motor starter (including the BYPASS position for VFD’s). Fire alarm controls shall have priority control over freezestat control.

- Averaging bulb freezestats shall not be allowed. The freezestats shall make when any 12” section of its sensing bulb falls to below the setpoint of the device.

- Locate the reset head outside the plenum wall and at the highest point of the assembly. The sensing bulb shall be sloped continuously downward from the reset head.

- Freezestats’ capillary length shall provide 1 foot of capillary length for each 4 square feet of coil face area (provide multiple freezestat units if necessary to meet this requirement). In all cases the coil face shall be completely crossed from corner to corner.

- Freezestats shall be installed with capillaries supported by non-metallic stand-offs. No part of the capillary shall otherwise touch the coil or frame. Specify mounting support at least every 36” and within 6” of the capillary end.

Electrical current transmitters:

- Current sensors shall convert AC to proportional DC (4 to 20 ma). Response time: 300 milliseconds to 99% of final value.
Current sensing relay switches:

- Current switch (AC relay) shall indicate the presence of current flow. Device to be powered by induction from the line being monitored. Use for fire alarm system “run status” monitoring.

- Current sensing relays shall be used to provide positive run status feedback of equipment and motorized fans and pumps.

- Current sensing relays shall be adjusted to ensure reliable operation at the lowest operating loads for the equipment as well as the lowest run speed settings for VFD’s.

2.12 CONTROLLED DEVICES

Actuators

- Actuators for steam valves and actuators located in mechanical rooms shall be pneumatic type. Air distribution system air terminal (zone) box damper and valve actuators and perimeter hot water heater valve actuators may be electronic.

- Specify pneumatic actuators selected from the standard vendor catalog.

- Specify in sufficient size, quantity and type to assure reliable operation throughout the normal aging process of valves and dampers.

- Full stroke actuation of pneumatic actuators shall not be more than 30 seconds unless there are more stringent requirements.

- Large damper assemblies shall be made of individually driven segments that are small enough to ensure reliable operation and uniform closure across the entire damper assembly. The actuators shall be operated independently so that if one damper segment or actuator becomes inoperable, the others remain operable. The use of jackshafts shall not be permitted unless the damper sections can be synchronized to maintain position within 5% stroke of each other through their entire modulation range while at the same time achieve 100% tight shutoff for all damper sections.

- See the failure mode section above for actuator responses under failure due to loss of power, loss of control air, or loss of communication. Where an actuator is to fail open or fail closed, provide spring return. Actuators shall not be dependent on batteries or capacitors to stroke to the power fail position upon loss of power.

- Permanently stamp or scribe position indication on the end of driven shaft unless damper is visible from same location as end of shaft. Use of permanent ink markers shall not be an allowable permanent substitute for stamping or scribing.

- Select electronic actuators from the vendor standard product line.

- All electronic actuators shall be 24 VAC. The use of any other actuator must be approved by the Owner.

- Proportional electronic actuators shall use 0 to 10 VDC, 4 to 20 ma. or floating point control. Floating point actuators shall not be allowed for air terminal units serving spaces that have pressurization direction requirements (i.e. – labs, operating rooms, etc.) unless they have special provisions in their controllers and are provided with accessories to prevent the need to fully open or close the primary air damper for the purpose of airflow sensor calibration (“autozero”) or
damper position/command synchronization and these provisions prevent disruption of pressurization direction control while conducting those functions.

- Multiple electronic actuators may be powered by one separately fused 24 VAC transformer, providing the transformer size does not exceed 100 VA.
- Do not stack electronic actuators.
- Valve actuators shall be installed directly above the controlled valve whenever possible (with the exception of steam control valves where the actuator is rotated approximately 30 degrees to avoid hot zone directly above valve) unless rotation is needed to permit maintenance access. However, in no case shall the operator be rotated to or beyond horizontal.
- All electronic valve actuators shall have field manual positioning capability to allow manual positioning of valve in absence of control power.

**Actuated dampers**

- Outside air and exhaust air dampers that continue the thermal envelope of the building shall be provided with insulated damper blades.
- Specify provision for low leakage control dampers where not furnished with packaged units.
- Damper leakage rate shall not exceed 6 CFM/sq. ft. at 4-inch wg. and 1% of full flow rate.
- Dampers shall have blade seals and stops.
- Specify American Warming and Ventilation, Ruskin, Greenheck or approved equal dampers.
- Install actuators in the orientation recommended, or stated as preferred, in manufacturer’s literature.
- For actuator selection, see “Failure Mode” requirements above.

**Actuated valves**

- Valves shall be selected to meet CV and pressure requirements.
- Valve body and actuator selection shall be sufficient to handle system pressure, and shall close against the system differential pressures.
- Valve service rating shall be 125 psig. or greater (except that valves in the central cooling water piping shall be rated at 250 psig. or greater.)
- The shafts to which the actuators are coupled shall be square or hexagonal or round with one side flattened to permit secure coupling.
- Install valves in the orientation recommended, or stated as preferred, in manufacturer’s literature.
- Use valves and actuators directly marketed and warranted by the controls vendor. Third party and after-market devices will not be accepted where the vendor’s catalog shows appropriate devices.
- Zone valves: Valves shall be constructed with a cast brass body. The valve shall provide for 100% shut-off and silent operation.
AHU valves: Valves shall be constructed with cast brass or iron body and screwed or flanged ends. Specify the valve Cv so that the valve pressure drop at full open position is equal to the pressure drop through the coil's branch circuit pressure loss, where branch circuit is defined as the branch lines going to the coil, all of the piping specialties, including the balancing valves, and the coil itself. For CCW coils refer to section

Steam valves

- Shall have similar construction as AHU valve but with temperature and pressure ratings to match the steam application. Specify the valve Cv so that the valve pressure drop at full open position is equal to the pressure drop through the coil’s branch circuit pressure loss, where branch circuit is defined as the branch lines going to the coil, all of the piping specialties, including the balancing valves, and the coil itself.
- Butterfly valves may only be used for two position applications.
- Butterfly valves with plates attached to the stem with screws, bolts or rivets are not acceptable.

Control relays

- Panel relays shall be plug-in type with contacts rated at twice the amperage rating of circuit requirements: Minimum temperature range –25º C to +70º C.
- Enclosure: Clear dust cover and shock resistant, rated for minimum of 2.5 million mechanical operations and 100,000 electrical operations at full load.

Remote/interposing relays shall be used for all remote switched loads.

- They shall be housed in a NEMA-rated enclosure. Where two or more relays are mounted in the same enclosure, provide a hinged cover.
- Besides meeting panel relay requirements, they shall have 24 VAC coils and form C dry contacts with a minimum rating of 5 amps @ 240 VAC.
- Relays controlling inductive loads shall be equipped with coil transient suppression devices to limit transients to 150% of rated coil voltage.

2.13 ENCLOSURES

All enclosures to be NEMA 1, unless otherwise required for intended service. All controls and instruments shall be logically assembled at one or more panels, have hinged doors and be marked with engraved melamine labels. All enclosures used as a mounting site for control devices shall also contain a documentation holder located on the inside of the door. All enclosures shall be provided with locks with the vendor’s standard core. Label each equipment panel furnished with 120 VAC power with power source label showing identification of power panel and breaker.

Provide weather-proof enclosures for control components located outdoors.

2.14 WIRING AND CONDUIT

All wiring shall be stranded. Exceptions will be made for wiring used in preassembled factory crimped cables, 20 ga. and smaller, where connectors provide support to the insulated cable jacket at the point of connection.
Junction box covers shall be labeled “DDC” or show the vendor logo. Splicing shall not be allowed between the controller and the controlled device.

Conduit shall be cleaned of foreign material just before pulling the wire or cable. Lubricants shall be compounds specifically prepared for cable pulling and shall not contain petroleum or other products that will affect cable insulation.

All wire shall be new and brought on the jobsite in original packages bearing Underwriter’s label and the date of manufacture. Wire that has scrapes, nicks, gouges, or crushed insulation shall not be used and shall be removed when present.

Groups of conductors, where installed in cabinets and wire trays, shall be neatly grouped with wire ties or equal. All wiring contained in metal wireways shall be in wireways dedicated to low voltage service.

Low voltage energy-limited wiring shall not be run in the same wireways with, or closely parallel to, high voltage or switched power wiring. Interposing relays shall be used for all switched power loads and shall be located so that the switched power conductors do not run in the same wireway as the interposing relay coil power or any other energy-limited low voltage conductors.

Aluminum wire is prohibited.

No conduit shall be filled so that the maximum bundled cross sectional dimension exceeds 40 % of conduit inside diameter. No raceway shall be filled to more than 40% and maximum fill for “wiremold” (surface raceway) shall be 20%. No wire run or circuit shall be longer than 80% of the maximum allowable length or power consumption for the wire size and application.

No output circuit shall exceed 80% of the maximum load capacity specified by the manufacturer. The basic wiring method shall be in conduit unless otherwise permitted in this section. Where conduit direct connection is not possible, all permitted open wiring shall be plenum rated.

Permitted open wiring is limited to the following applications:

- Wiring from a zone airflow control unit to a nearby temperature sensor not to exceed 50 feet
- Wiring from a zone airflow terminal control unit to a nearby water control valve not to exceed 6 feet

Open wiring, when permitted, shall be installed in compliance with WAC 296-46B-300 and shall also be installed as follows:

- All open wiring that penetrates through walls and crosses structural ceilings shall do so within 18 inches of the structural ceiling surface.
- Wiring shall be attached to vertical supports at attachment points prepared by a protective wrap of electrical tape around the support. This wrap shall create a surface free of sharp edges.
- Absolutely no wire is to be attached to pipe work or conduit of any kind.
- Wire ties, if used, shall be trimmed so as to reduce sharp edges.
- The vendor shall provide required cabling attachment points for control’s use if the ceiling structure does not provide acceptable attachment points.
Wiring from any controller to a device which has otherwise been approved for installation and cannot accept conduit connection shall meet the following requirements:

- Conduit shall be used to within 12 inches of the device.
- Install in wireway all trunk communication wiring between the operator station and the controllers, and between controllers. Open wiring is not otherwise permitted.

Conduits shall be provided with appropriate bushings and end fittings to protect cabling from sharp conduit edges. Conduit size shall be 1/2-inch minimum. For all wiring groups consisting of 6 or more conductors, conduits shall be 3/4-inch minimum. NEC requirements shall apply as though conductors were used to their full current carrying and thermal capacity.

Wireway runs shall be parallel or perpendicular to walls, pipes and sides of openings. Passageways for access and servicing shall not be blocked.

All trunk or LAN cables shall be in conduit or wireway and 100% backed up with spare conductors.

All conductors that become bundled or pass from an enclosure or into an enclosure shall be identified with typed or machine lettered labels. Tag numbers shall agree with wire numbers assigned on wiring diagrams and the installation drawings as well as the point name. Wires shall be labeled with mechanically prepared labels at their connection point to each apparatus point of connection.

2.15 SPECIAL DESIGN STANDARDS

VAV terminal boxes used in configurations of multiple supply and/or multiple exhaust units need to have their flow rates synchronized to ensure airflow rates are appropriate and repeatable. Control vendor shall accomplish synchronization through positive feedback of the damper position or by commanding the damper position with an analog signal (or other appropriate means).

If alternation of lead-lag motors or services is made possible by design requirements, lead-lag scheduling shall be by operator command.

Specify provision for a minimum 1¼-inch pressure gauge at the output of each I/P and E/P transducer.

2.16 GRAPHIC DISPLAY REQUIREMENTS

Specify provision for a Microsoft Windows-based software package, including necessary licensing, for the preparation of system graphics, including backgrounds, overlays, and dynamic graphics.

Include with this software a library of HVAC symbols such as fans, pumps, chillers, etc.

All graphics screens shall be submitted and approved before implementation.

Graphics shall be arranged and organized to make them as intuitive as possible to read and understand.

This section establishes standards for graphic displays as follows:

- The graphics shall be a set of separate graphics pages with navigation links and a home page. The main graphic page will have links to the major system and equipment graphic screens as well as links to floor plan graphics, miscellaneous systems, and monitoring functions. Each major graphic screen shall have links back to the home page and links to sub screens to navigate to
subsystem graphics. The system will allow navigation backwards and forwards through the navigation history.

- All non-portable operator stations shall be programmed to display dynamic color graphic representations of the mechanical systems and floor areas for which this system has control. All operator stations shall have the ability to access the graphs from the vendor’s campus server through remote connection. Representations of equipment does not need to be exact representations of the actual equipment installed but, at a minimum, be representative of the type of equipment installed so that it accurately represents that equipment. For example, a small condensing hydronic boiler shall not be used on the graphics to represent a large fire tube boiler that is actually installed. Some equipment, such as large air handling units, are typically represented in diagram form, in order to show all of the controlled components and sensors installed in such a complex unit.

- All controlled and monitored equipment shall be displayed within the graphics screens.

- Show the following components (if included on a project) on a single graphic: Hydronic systems (for example, include chilled and condenser water pumps, cooling towers, chillers, etc. for a chilled water system and then provide sub-graphics for the individual equipment) air handling units, hot water heating systems, central cooling water (CCW) differential pressure control valves (header), heat exchangers between the CCW system and the condenser water, and the status indicator for whether the two systems are in their “summer” or “winter” mode of operation.

- Displays shall automatically update with current real time data.

- Floor plan displays are required and shall indicate the approximate positions of controlled mechanical system elements as well as zone sensor locations (temperature, RH, CO2, etc.). Each temperature control zone shall be represented by an outline, filled in with a different color to distinguish it from adjacent, neighboring temperature zones. Thermostat shall be linked “jump-point” to detailed terminal unit information graphic. Room floor plan displays are required if rooms are served from more than one terminal unit. All displays shall show real time data to include temperatures, actuator positions, and motor run status.

- All displays shall show real time data updates. For each graphic page, indicate all controlled devices as well as all sensors and monitored points relating to that system or equipment. Where the graphic has sub-graphics, some of those points may be indicated on the sub-graphics in order to better organize the screens as well as prevent overcrowding of information. For each control loop, the graphic shall indicate the setpoint and update it dynamically if it is reset. For each reset function, the graphic shall indicate pertinent information relating to that reset so that the operator can understand and troubleshoot the current reset setpoint value as appropriate for the current conditions (for example, an outside air reset sequence for AHU discharge temperature setpoint reset shall indicate on the graphics the limit variables for the reset table, but not necessarily allow adjustment of those setpoints form the graphics).

- Where setpoint or parameter values can be adjusted through the graphics screens, the suggested value for that setpoint or parameter shall be noted next to that graphic field.

- For each air handling unit system, include a graphics zone summary page that indicates, in tabular form, each temperature control zone with room parameter setpoints, room parameter real-time values, reheat coil valve position, primary air damper positions, fan status (for fan-powered air terminal units), and any other pertinent parameters for the room sequence of operation or included controlled components or monitored points.

- For each major system, provide a sub-graphic that includes the sequence of operation, including setpoint values (dynamically updated).
• Provide dynamic graphics that indicate animations for fans, pumps, dampers, and compressors such that it is intuitive when they are running or when they are stopped. Additionally, show these components in a different color when they are operating (such as green) than when they are stopped. When a component is in alarm, indicate that component with a color change to flashing red so that it is very obvious when observing that graphic screen.

2.17 SMALL PROJECTS

The requirement for a dedicated computer (as indicated in section Operators Stations), as the point for system management does not apply. It shall be possible to attach a portable computer to the main system controller for the purpose of system management.

Requirements for operator stations do not apply except for the specification on portable operator stations.

Alarm log requirements do not apply except for the current alarm log and a reduced trending requirement of 10 trend logs.

Section POST INSTALLATION INSTRUCTIONS AND MATERIALS - TRAINING is modified as follows:

• Training requirement of 32 hours is reduced to 8 hours.
• Training requirement of 16 hours is reduced from 16 hours on a total of 4 occasions to 4 hours on a single occasion.
• Training requirement for 2 employees is reduced to 1 employee, and the use of a local trainer at the local facility or project is permitted.

Section FINAL ACCEPTANCE REQUIREMENTS makes reference to a Local Operator Station. This reference is amended to be the existing Remote Operator Station.

Section SYSTEM DESCRIPTION, GENERAL is amended to require remote communications to a remote site via campus Ethernet, which can act as a communications relay device. If an existing relay site is used, vendor shall pay all costs to upgrade and configure such site for support of this project.

On small projects building system graphics shall be updated appropriately to indicate the modifications of the project.

2.18 PNEUMATIC AIR SYSTEMS

Pneumatic air piping shall conform to the following:

• Copper tubing: ASTM B88, hard drawn deoxidized copper tubing, type L, with wrought copper solder joint fittings conforming to ANSI B16.22. Copper tubing used to support life safety functions, such as pneumatic actuators on combination fire/smoke dampers, shall be joined with brazed joints, and using a nitrogen purge.
• Plastic tubing: Virgin polyethylene tubing, FR rated, tested in accordance with ASTM D-1693 standards with minimum burst pressure of 600 psig and minimum working pressure of 100 psi at 75°F.
• Plastic tubing is only permitted inside panels and for final connection (not to exceed 6 inches) to devices that are designed with barbed fittings.
• Pneumatic copper tubing shall be run parallel to building lines. Create tubing bends with formed pieces or with the use of a tubing bender.

• Tubing shall be attached to the building structure at no greater than 4-foot intervals (No adhesive type mounts allowed)

• Copper tubing shall be ¼ inch o.d. minimum in all locations. Take special care in sizing pneumatic lines for applications serving pneumatic actuators on fire dampers and fire/smoke dampers. These need to be sized sufficiently large in order to allow the actuators to bleed down fast enough to meet the code-required closing time limits for these devices.

• Specify provision for soldered end caps at all terminations of existing and new copper tubing. Crimped or taped tubing ends or other means are not permitted.

• The pneumatic operator’s air supply system shall be sized and piped to operate the driven load with full stroke time not to exceed 30 seconds unless there is a more stringent requirement.

• The campus tunnel pneumatic control air supply distribution shall be used as the primary source for pneumatic control air. Provide a refrigerated air dryer, sized for the maximum calculated control air load, a filter unit, and a coalescing water separator after the dryer.

PART 3 - SEQUENCE OF OPERATION AND POINTS DESCRIPTION

3.01 DESIGN STATEMENTS

Design Sequence of Operation appears on the mechanical design drawings. Supplement in controls sequence of operation statements to explain how the control system programming and architecture accomplishes the design intent.

3.02 GENERAL

Program as a minimum the following:

- Control of equipment as described in the design sequence of operations
- Time and holiday schedules
- Alarm limits and histories
- Summary of data for each zone
- Trend logs (for every control loop including commanded components, controlled variable(s), and setpoint(s)) and historical data
- All setpoints
- Master menu
- Dynamic color graphic Interface

3.03 SPECIFIC REQUIREMENTS
The following Points Descriptions and Sequences of Operation shall be enhanced as necessary and included as part of the control drawings to expand and clarify information shown in the drawings.

- Point's information shall be displayed and organized by system in dynamic graphic form at the operator stations.
- The energy reduction software and miscellaneous functions shall manage all points.
- It shall be possible to “disconnect” any output or setpoint from the AUTOMATIC control logic and enter a MANUAL value or state from any Operator Station.
- It shall be possible to replace any input with a MANUAL value from any Operator Station.
- All control loop parameters for each loop shall be displayed on one display.

3.04 SPECIFIC DISPLAY AND PROGRAMMING REQUIREMENTS

The following commands, displays and data shall be available at the operator terminal:

- Air handling unit
- Fan status (current sensor proof)
- Outside air temperature
- Mixed air temperature
- Supply air temperature
- Return air temperature
- Coldest and warmest zone, all zones sampled
- Duct and space static pressures
- Freeze protection status
- Alarms (temperature, airflow, pressure)
- VFD (Output)

The following points, numbered 1 through 3, are only required if needed by control strategy:

- Directly measured total supply airflow (CFM)
- Directly measured total return airflow (CFM)
- Directly measured minimum outside airflow (CFM)

The following points shall be displayed using calculated values based upon commanded position unless exact values, as indicated by a feedback signal, are required by control strategy:

- Fan speed (per cent of full speed)
- Damper positions (per cent of full open)
- Heating and cooling valve position (per cent of full open)
Hot water steam converters and pumps

- Status of pumps (current sensor proof)
- Supply and return temperature
- VFD (Output)
- Valve positions (per cent of full open) (A calculated value not requiring feedback)
- Differential pressure (if used)

Air terminals

- Current space temperature
- Discharge air temperature
- Occupied heating/ventilating setpoint
- Unoccupied heating/ventilating setpoints
- Current status (heating/ventilating)
- Current mode (day/night)
- Minimum and maximum airflow setting (CFM)
- Current primary airflow reading (CFM)
- Current primary airflow calculation
- Valve position (per cent of full open) (Water - a calculated value not requiring feedback)
- High/low temperature alarm
- Input and software capacity to add local temperature adjustment and push button timed override from the space temperature sensor

Chilled Water System

- Supply and return temperatures
- Entering and leaving temperatures (if different from above)
- Supply temperature reset
- Pump status (current sensor proof)
- Pump command status
- Chiller status
- High/low temperature alarms
- VFD (Output)
Central Cooling Water (CCW) System

Consultant should refer to the standard drawing under Mechanical - Central Cooling Water for more detail about control of that system.

- Temperature and pressure of CCW supply water coming into the building at the header
- Temperature and pressure of CCW return water leaving the building at the header
- CCW supply pressure at the CCW header discharge
- Summer/winter mode status
- Entering and leaving water temperatures for the heat exchanger between the condenser water to CCW

Metering:

- See Metering section for utilities with meter outputs connected to DDC.

Special monitoring and control: Specify provision for the following DDC I/O points:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire alarm status</td>
<td>Binary Input</td>
</tr>
<tr>
<td>Cascade Lighting Control</td>
<td>Binary Output</td>
</tr>
<tr>
<td>Emergency Power Switch Position</td>
<td>Binary Output</td>
</tr>
</tbody>
</table>

Note: Review on a project-by-project basis whether it is desirable to monitor the lighting controls.

3.05 SEQUENCE OF OPERATION

Refer to mechanical design drawings. Control vendor shall develop a controls version of the sequence to show how the controls programming and contractor-engineered system implements the framework and intent of the sequence provided in the mechanical design. Include controls sequence of operations written in project specific highly detailed prose in submittals.

PART 4 – INTERFACE WITH OTHER SYSTEMS AND EQUIPMENT

4.01 INTERFACING TO FIRE ALARM SYSTEMS

- The building fire alarm system shall shut down fan systems as required by Code. The control system shall monitor a relay from the fire alarm system for the purpose of determining when the fire alarm system has initiated a fire alarm event. The controls contractor shall coordinate with the fire alarm vendor to provide a coordinated shutdown and subsequent restart of fan systems that are shut down by the fire alarm system. Where the fire alarm system has priority control over the control systems for fan start or stop, the control system shall monitor the fire alarm
system to determine which fans it has shut down. This can be accomplished by several methods. For instance, if there is a duct detector associated with a fan for smoke control shutdown purposes, that duct detector will report to the fire alarm system that the detector has activated and the fire alarm system will respond by sending a signal to that fan’s motor starter to force it to stop (and possibly other actions as well). The control system shall have a means of monitoring that the fire alarm system has shut down that particular fan so that the control system can release its run signal to that fan. Otherwise, the control system will see that event as a fan failure and annunciate a nuisance fan failure alarm. Instead, the control system shall monitor that fire alarm action (either by monitoring a discrete relay from the fire alarm system or monitoring a secondary contact from the smoke detector, or monitoring integrated communications point between the fire alarm system and the control system), and respond by initiating its own “complementary shutdown” of the fan system in a manner that prevents nuisance alarms in the control system. The control system shall initiate an alarm event that relays the activation of the fire alarm system action only (such as an alarm for the duct smoke detector point being active). If, for example, a general fire alarm event for the building causes the fire alarm system to shut down all or a group of fan systems in the building, the controls system shall likewise initiate a complimentary shutdown for those same fan systems. After the fire alarm event has cleared, the controls system shall automatically restart the affected fan systems in an orderly manner without the need for operator intervention.

- Shaft pressurization fans and their associated dampers shall be started and stopped by the building fire alarm system via interposing relays to the fan motor starter. The controls contractor shall be responsible for the interconnection wiring from the fire alarm start (and stop) relay to the motor starter terminations. The control system shall monitor the fan for run status only.

- Where the fire alarm system controls a fan under fire alarm response and the control system controls the fan under normal building operation, the fire alarm system shall have priority control over the building control system. This also applies to situations where the two systems control the same damper. The order of priority of controls, from greatest priority to least priority, shall be as follows:
  - Electrical disconnect switch
  - Ductwork high static pressure safety limit switch
  - Manual fan override switches at the fire alarm panel
  - Supply fan ductwork smoke detectors (for pressurization fans that are associated with that fan, not the duct detectors tied to smoke or combination fire/smoke dampers in the distribution ductwork)
  - Automatic active smoke control sequence of operation (for engineered smoke control systems only)
  - Building automation system controls hard-wired safety devices (freezestats typically)
  - Motor start HOA or VFD bypass starter controls
  - Building automation system controls in AUTO

- The controls contractor shall engineer and install the controls interface wiring for all fire alarm interfaces to fan motor starters in a manner to allow for the correct sequence of operation to occur as well as maintain the order of priority for the controls as required by the Codes.

4.02 INTERFACING TO EMERGENCY POWER SYSTEMS

- The control system shall monitor the emergency electrical system automatic transfer switches (ATS’s) that serve equipment that is controlled by the building control systems.
For each ATS monitored, the control system shall monitor the “ATS transferred to Emergency Power Source” and “ATS transferred to Normal Power Source” points. The exact points will vary between ATS manufacturers.

When the ATS has transferred to emergency power source, the DDC shall initiate a complementary shutdown of the affected equipment in order to prevent nuisance alarms such as fan failure, etc. When the ATS transfers back to the normal power source, the DDC shall conduct an orderly restart of the affected equipment, after appropriate delay has expired, and clear any nuisance alarms that are a result of the power loss and restart event.

The controls contractor shall test the effectiveness of the controllers under power loss and restart conditions to ensure that the controllers retain their programming and parameter setups.

END OF DESIGN SECTION