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40 00 00. PROCESS INTERCONNECTIONS

40 90 12 METERS AND GAUGES

PART 1 - GENERAL

.1 DESCRIPTION OF WORK

.1.1 The A/E shall specify that all devices supplied, whether free-standing or provided as part of a packaged equipment unit, shall satisfy the requirements of this Section.

.1.2 This Section provides the specification for thermometers, thermometer wells, pressure gauges, flow meters, and other related accessories.

.2 SUBMITTALS

.2.1 Shop Drawings and Product Data, A/E shall specify that the Contractor submit the following:

.2.1.1 Thermometers and Thermometer Wells

.2.1.1.1 Provide manufacturer's catalog cut sheets for each type of thermometer with range, accuracy, materials, and accessories marked clearly.

.2.1.2 Pressure Gauges

.2.1.2.1 Provide manufacturer's catalog cut sheets for each type of pressure gauge with range, accuracy, materials, and accessories marked clearly.

.2.1.3 Flow Meters: Provide manufacturer's catalog data sheets with range, accuracy, turndown, rating, materials, end connections, dimensions, and accessories marked clearly. Indicate required upstream and downstream pipe diameters of straight pipe to maintain meter accuracy. For pressure and/or temperature measuring devices for compensation, provide data on those devices.

.2.2 Operation and Maintenance Manuals: The A/E shall specify that the Contractor submit the following:

.2.2.1 Thermometers

.3.2.1.1 General maintenance data

.2.2.2 Pressure Gauges

.3.2.2.1 General maintenance data

.2.2.3 Flow Meters

.3 DELIVERY, STORAGE, AND HANDLING

.3.1 Store thermometer, pressure gauges, and flow meters in a dry location, away from the weather, dust, and debris.

.3.2 Retain shipping flange protective covers and protective coatings during storage.

.3.3 Inspect items immediately upon arrival and report any irregularities or damage immediately to the manufacturer/supplier and Engineer.

.4 QUALITY ASSURANCE

.4.1 Comply with applicable portions of American Society of Engineers (ASME) and Instrument Society of America (ISA) standards pertaining to construction and installation of gauges and meters.
.4.2 Conform to ASME B31.1 for all installations.
.4.3 Certification: Provide thermometers, gauges, and meters whose accuracies are certified by the manufacturer for the specified operating conditions.
.4.4 Single-source Responsibility: Specify that the Contractor shall obtain each category of thermometers, pressure gauges, and flow meters, from one source and by a single manufacturer.

.5 IDENTIFICATION
.5.1 Provide an aluminum valve identification tag for each thermometer, and pressure gauge. The tag shall list the area number, device type, and device number, i.e. "PG-8501".

PART 2 - PRODUCTS
.1 THERMOMETER - BIMETAL DIAL
.1.1 Case and Ring: Type 300 Series stainless steel. Case hermetically sealed. Dial size shall be 3-inch diameter.
.1.2 Window: Shatterproof glass.
.1.3 Accuracy: 1% of full scale. An external adjustable screw shall be provided for calibration.
.1.4 Adjustable Joint: Finish to match case, 180 degree adjustment in vertical plane, 360 degree adjustment in horizontal plane, with locking device.
.1.5 Element: Bi-metallic.
.1.6 Stem: Type 300 Series stainless steel, 1/4-inch diameter, of length to suit installation and thermowell length, with consideration given to extension for insulation.
.1.7 Scale: White coated aluminum with permanently marked black etchings.
.1.8 Range: Units shall appear in Fahrenheit only.

.2 THERMOMETER WELLS
.2.1 Construction: Type 304 stainless steel with pressure and temperature rating of 2000 psi at 800°F. All thermowells shall be socket weld connection to service pipe.
.2.2 Stem Length: For piping applications, shall be 1/3 to 1/2 of internal pipe diameter. For combustion air and flue gases, shall be 18 inches long.
.2.3 Extension for Insulated Piping ("T" Length): Provide extended thermowells so that the bottom of the thermometer extends 2 inches minimum beyond the insulation.
.2.4 Threaded Cap Nut: With chain permanently fastened to well and cap.

.3 PRESSURE AND DIFFERENTIAL PRESSURE GAUGES
.3.1 Type: Type 316 stainless steel, 316L stainless steel Bourbon-tube pressure gauge, with bottom stem-mounted connection.
.3.2 Case: Polypropylene case, turret style, direct mounting style.
.3.3 Liquid Fill: Silicone liquid filled cases for all liquid applications.

.3.4 Connector: 316SS with 1/4 inch male NPT.
.3.5 Scale: White coated aluminum with permanently marked black etchings.
.3.6 Range: Units shall appear in PSIG only, or PSID for differential pressure gauges.
.3.7 Accuracy: Per ASME B40.100, accuracy Grade 2A.
.3.8 Acceptable Manufacturers: All gauge pressure gauges (not differential pressure) shall be Ashcroft Duragauge Type 1279 with XLL option (Plus! Performance) which minimizes vibration and pulsation issues. Differential pressure gauges shall be Ashcroft Type 1128 with 0 at the 12 o'clock position, accuracy Grade 1A.

.4 PRESSURE GAUGE ACCESSORIES
.4.1 Isolation Valves: For all pressure gauges, provide 1/2-inch NPS shutoff valves as designed and specified for the specific piping system. Valves shall be located a minimum of 2 inches outside of insulation.
.4.2 Snubber: Not required due to "XLL option" for Ashcroft gauge specified.
.4.3 Syphon: On water systems operating above 120°F and for all steam systems, specify fabricated coil syphon or "pig tail" constructed as specified for the specific piping.

.5 ORIFICE PLATE FLOW METERS
.5.1 Type and Construction: Square edge type made of 1/8-inch thick Type 316 stainless steel with a minimum 15/32-inch roughness finish and with flatness within 0.010 inches per inch of dam height. Concentric bore tolerance shall comply with ASME Fluid Meters Committee Report and the calculation shall be based on the "L.K. Spinks" calculation method. Upstream tab of plate shall be stamped with plate data.
.5.2 Accessories: Specify carbon steel condensate pots for steam service. Specify multi-variable transmitter, including temperature element.
.5.3 Accuracy: The A/E shall specify that the orifice plate flow meter shall have an accuracy of ±1% for a turndown of eight-to-one for the maximum flow listed.

.6 FLOW NOZZLES
.6.1 Type and Construction: Long radius flow nozzle manufactured per ASME MFC-3M with ±2.0% uncertainty of discharge coefficient. Nozzle shall be a fitting that shall be installed between flanges. Nozzle shall be Type 316 stainless steel. Upstream tab of nozzle shall be stamped with design data.
.6.2 Accuracy: The flow nozzle shall have an accuracy of ±1% for a turndown of eight-to-one for the maximum flow listed.
.6.3 Acceptable Products: Specify flow nozzle flow meter by the following manufacturer in accordance with this specification:
.6.3.1 Rosemount (Daniel)
.6.3.2 Yokogawa

.6.4 Accessories: Specify flow transmitter. Provide carbon steel condensate pots for steam service.

.7 VORTEX FLOW METERS

.7.1 Acceptable products: Specify vortex meters by the following manufacturer in accordance with this specification:
- .7.1.1 Johnson Yokogawa
- .7.1.2 Rosemount

.7.2 General: Specify vortex-style flow meter with electronics for the specific conditions of each meter. The meter shall have no moving parts. Isolation valve feature shall not be provided.

.7.3 Materials: Body shall be Type 304 SS with ASTM A105 ANSI Class 300 carbon steel flanges. Shedder bar shall be stainless steel. Sensor gasket shall be designed and rated for specified steam services conditions.

.7.4 Performance:
- .7.4.1 Accuracy for Feedwater Service: Shall be ±1% of reading for flow rates with Reynolds Number of 20,000 or greater, and ±2% of reading for flow rates with Reynolds Number of 5,000 to 20,000. Accuracy shall be corrected for the actual installed upstream and downstream disturbances.
- .7.4.2 Repeatability: ±0.2% of reading
- .7.4.3 Response Time: 0.25 seconds
- .7.4.4 Pressure and Temperature Compensation: Not required.
- .7.4.5 Permanent Pressure Loss: Shall be no more than 1.5 PSIG at specified maximum flow for feedwater service.

.7.5 Electronics:
- .7.5.1 Output signal shall be 4 to 20 mA.
- .7.5.2 Meter shall be configurable and diagnostics shall be performed through the DCS over the 4 to 20 mA signal through a digital signal via the Hart protocol. Meter shall be "Smart."
- .7.5.3 The flow calculation electronics shall incorporate Spectral Signal Processing Technology, Adaptive Filtering, or DSP Converter (depending on manufacturer) which filters signal noise, hydraulic noise, and pipe vibration.
- .7.5.4 Local Display: Required.
- .7.5.5 Remote Electronics Housing: Provide where specified with individual meter specifications. Provide a minimum of 30 feet of wiring.
- .7.5.6 Electronics Housing: Low copper aluminum alloy with epoxy powder-coated finish. Buna-N O-rings or other acceptable material shall be NEMA Type 4X.
- .7.5.7 Housing Temperature Rating: Ensure that electronics will not be affected by process temperature, especially for steam service meters. Provide remote electronics housing if necessary to satisfy this requirement regardless if remote electronics are specified for meter.
- .7.5.8 Calibration: Calibrate electronics in factory. Provide factory calibration certificate for each meter.

PART 3 - EXECUTION

.1 THERMOMETER INSTALLATION
- .1.1 Specify that Contractor shall install thermometers in a vertical, upright position and tilted to be easily read by an operator standing on the floor.
- .1.2 Specify that Contractor shall install where indicated in the Contract Documents.
- .1.3 Thermometer Wells: Install in pipe coupling or tee as required. Install in vertical upright position. Fill well with oil or graphite and secure cap.
- .1.4 Verify that thermowell depth is proper for pipe size.

.2 PRESSURE GAUGE INSTALLATION
- .2.1 Specify that Contractor shall install pressure gauges in pipe coupling or tee as required. Provide shutoff valve, snubber, and/or syphon as specified. Locate pressure gauge in most readable position.
- .2.2 Specify that Contractor shall install where indicated in the Contract Documents.

.3 ADJUSTING AND CLEANING
- .3.1 Calibration Statement: Calibrate meters and gauges according to manufacturer's written instructions, after installation. Contractor shall provide a written and signed statement indicating that all meters and gauges have been calibrated in accordance with the manufacturer's instructions. Calibration devices shall be NIST traceable. Provide documentation of NIST traceable with calibration documentation.
- .3.2 Adjusting: Adjust faces of meters and gauges to proper angle for best visibility.
- .3.3 Cleaning: Clean windows of meters and gauges and factory-finished surfaces. Replace cracked and broken windows and repair scratched and marred surfaces with manufacturer's touchup paint.

.4 METER INSTALLATION
- .4.1 Specify that the Contractor shall provide all process connections in piping systems to accommodate meter and gauge installation. Process connection type shall be selected by the Contractor to match the actual meter and gauge provided.
- .4.2 Locate meters away from upstream and downstream disturbances per manufacturer's requirements.

.5 MAINTENANCE MANUALS
- .5.1 In maintenance manuals for meters and gauges, include calibration requirements.

40 90 00 INSTRUMENT AND CONTROL FOR PROCESS SYSTEMS

PART 1 - OVERVIEW

.1 This section is applicable to the following process systems on The Ohio State University main campus operated and maintained by Utilities:
- .1.1 Power Plant Boilers and auxiliaries
- .1.2 Power Plant Chillers and auxiliaries
- .1.3 Water treatment systems and auxiliaries
- .1.4 Remote chilled water plants
- .1.5 Standby generation facilities

40 90 02 APPLICABLE INDUSTRY STANDARDS

- ISA SP5-Documentation of Measurement and Controls Systems
- ISA S20-Instrument Specification Forms
- ISA SP12- Electrical Equipment for Hazardous Locations
- ISA SP18- Instrument Signals and Alarms
- ISA SP77- Fossil Power Plant Standards
- ISA SP84- Programmable Electronics Systems for Safety Applications
- ISA SP95- Controls Integration
- ISA SP99- Control System Security
- NIST Standard 800-82 Industrial Control System Security
- IEC 61131
- National Electrical Manufacturers' Association (NEMA)
- NFPA 85
- ANSI

.1 Code Conflicts: Code and/or standard conflicts shall be brought to the attention of the University and shall be resolved by the University. In the event of differences between codes and standards, the most stringent code or standard shall apply. Whenever reference is made to a specific code or standard, it shall be understood that the latest edition of such reference, as of the date of the proposal, shall govern.

40 90 03 CONTROLS PROJECT EXECUTION AND DOCUMENTATION REQUIREMENTS

.1 Process Flow Diagram (PFD): A simple process flow diagram shall be generated by the project's A/E or their designated controls integrator. The drawing will contain only general details of the process. Once approved by the University, this drawing will be used to generate the Heat and Material Balance drawing.

.2 Heat and Material Balance Drawing (HMB): The HMB will be similar to the PFD but contain more in depth design detail for the system. Calculated items such heat loads, flow rates, dwell times, throughput, and energy expenditures shall be shown on the document.

.3 Process and Instrumentation Diagrams (P&ID's): The P&IDs shall be a graphical depiction of all instruments, process equipment, and major piping. P&ID's shall follow the ISA S5 standard. Instrument symbols and identifications shall follow ISA-5.1. Graphic symbols on the P&ID that will be for Operator Interface computer display shall follow ISA-5.3.

.4 Detailed Cost Estimate and Project Schedule: The detailed cost estimate shall be completed in MS Excel spreadsheet format. The project schedule shall be submitted in MS Project format.

.5 Drawing List: A Master MS Excel Spreadsheet shall be provided for all drawings used in the project. The spreadsheet shall minimally include the following items: Document Index Number, Associated documents, Document Type, Description, Date Created, OSU Drawing Naming Convention (Reference OSU's Electronic File Drawing and Specification Naming Requirements document located under the Utilities tab at the following web link: https://fod.osu.edu/resources), and Comments. The Document Type field shall contain the following choices: Block Diagram, Cable Schedule, Graphics, Installation

Detail, Instrumentation Data Sheet, Interconnection Drawing, Loop Drawing, Panel Layout, Plan Drawing, Power Plan, SAMA drawing, Termination Drawing, and Wiring Diagram.

.6 Control System Interconnection drawing: This drawing shall show the interconnection between the new system and the plant Distributed Control System.

.7 Master Instruments and I/O List Spreadsheet: This spreadsheet will be created early in the project process. All instruments for the project shall be recorded in this spreadsheet by tag name. Items such as description, location, span information, Vendor, Vendor Part#, Physical location, DCS graphics page(s) and I/O termination point shall be included. This spreadsheet will be used for the Commissioning Plan for the system.

.8 Instrument Specifications: Instrument specification sheets shall follow the ISA S20 standard.

.9 Site Plan and Conduit Routing Drawings: The site plan shall show the location of all new major equipment and control cabinets. A conduit routing plan shall be provided. The conduit routing drawing(s) shall be interference checked. Any interference needing to be relocated shall be noted on the drawing(s) and costs associate with relocating/demolishing interferences shall be included in the project budget.

.10 Termination Drawings

.10.1 Termination drawings will show wiring details at the module level at the controller. Terminal numbers, power source with fuse number, shield terminations, channel number, and polarity will be shown for each analog module. Wire colors will be shown near the termination. Wiring from the terminals will be shown to the field device. Field device will consist of the Tag Number, Description, and associated Loop Sheet number.

.10.2 Digital I/O modules will show power source with fuse number, common, terminal numbers. Field devices will be identified by Tag Number, Description, and Loop Sheet number.

.10.3 All types of I/O modules will be fused per manufacturer’s recommendations.

.11 Instrument Termination Diagrams and Loop Sheets

.11.1 Loop sheets will show both the I/O module and instrument wiring terminations. The I/O module termination will be identified by the Controller Number, Rack Number, Slot Number, and Channel number. The I/O module termination will reference polarity, wire colors, and terminal numbers. Each I/O module termination will also reference the module drawing that it is derived from.

.11.2 The instrument wiring terminations will show terminal numbers, polarity, wire colors, and wire label. Each instrument will be identified by its Tag Number, Description, Location, Manufacturer, Model Number, and range.

.12 Panel Arrangement Drawings: Panel arrangement drawing will include a general power arrangement drawing and a detailed drawing showing all internal items in the panel. Power arrangement drawings will show the main power feeds and sources (24 VDC and 110 VAC) for each device. A separate Cable Schedule drawing will be provided for each panel.

The detailed arrangement drawing shall show the full layout to scale in the panel of all devices, terminal blocks, power supplies, mounting hardware, etc. If space allows, a spreadsheet with a complete bill of material for the panel will be shown. Otherwise the Bill of Materials will need to be shown on a separate drawing. BOM shall include: Quantity, Manufacturer, Manufacturer's Part Number, and Description.

.13 Installation Detail Drawings: A typical installation detail drawing for each type of instrument will be provided. Locations for each instrument shall be field checked for potential interferences. The A/E shall specify that all transmitters be installed no more than 5' off the floor or platform and shall be accessible for routine maintenance without a safety harness. The A/E shall specify that all transmitter manifolds and tubing be constructed of stainless steel appropriate for the process.

Differential transmitters measuring steam flow shall have condensate pots installed on each tap of the flow device. The pots shall be installed level with each other. Tubing shall be installed so there are no air pockets. The horizontal legs of the stainless steel tubing shall fall a minimum of 1" per foot towards the transmitter. The A/E shall provide details on the drawings for differential transmitter and condensate pot installation.

The A/E shall specify that all pneumatic positioners shall be installed with 5 micron oil/air filters and an isolation ball valve. Tubing to positioners and solenoid operated valves will be of hard copper or stainless steel, all which shall be sourced from the plant control air system. If there is no control air available, an automated control air dryer shall be provided as source air for the system.

.14 Bill of Materials: A complete bill of materials (BOM) for each project shall be provided. BOM will include: Quantity, Manufacturer, Part Number, Description, and distributor.

.15 Integrated Design Check: Prior to the A/E submitting a Construction Drawing set to the University for review, the A/E shall perform an integrated design check. The design check will verify the interfacing of controls with the current mechanical and electrical drawings and equipment specifications provided by other disciplines. P & ID drawings and the instrument and drawing databases will be finalized after this check.

.16 Commissioning Plan: Specify a full commissioning plan for the controls system and associated devices. Plan shall include a detailed checklist to commission each controls item installed by the project. Each item shall be specified to be commissioned by factory trained personnel. Each device shall be field verified from the device, to the controller, then to the graphic control screen(s) for the operator. The A/E's control integrator shall be a full time participant in the commissioning of the controls system and lead commissioning in concert with the commissioning agent during instrument and controls startup and commissioning.

.17 Field Calibration Records: The A/E shall specify that all transmitters, pressure switches, and positioners shall be field calibrated by technicians trained in field calibrations. Each calibration shall be documented on a calibration sheet. Calibration sheets shall have as a minimum: Tag Name, Description, Location, Process variable, Range, Calibrator type and model with last date of certified calibration, and calibration data showing As-Found and As-Left checks. Calibration checks shall be 0-25-50-75-100 percent of range recorded on the calibration sheet. Calibrator shall have a NIST traceable calibration certificate no more than 6 months old.

.18 Redlines: Changes to engineering design documents during construction shall be captured and maintained by the contractor. While construction is occurring, a fully

maintained set of redline drawings shall be retained at the construction site, accessible by University personnel.
The design engineer will capture all redline changes and incorporate OSU Utilities Drawing Numbering system on the OSU drawing title block at the end of the project and update the drawings “As-Built”. The design engineer shall do a detailed field review of the installation and wiring to insure it matches the “As-Built” drawings.

.19 Issue for Record Documentation: The following items are required to be submitted to the University in the Close Out documentation of a controls project within 3 months of receiving contractor redlines:
- .19.1 As-Built drawings on a CD in AutoCAD format and 1-11 X 17 printed set
- .19.2 O&M Manuals for all installed devices
- .19.3 Configuration and calibrations sheets for all devices
- .19.4 Final controller/Operator Interface programming on a CD
- .19.5 Bill of Materials
- .19.6 Instrument and drawing database on CD
- .19.7 Operating and Maintenance procedures
- .19.8 Licensed software copy included with each instrument that requires special (Vendor) programming software
- .19.9 Commissioning report
- .19.10 Final PLC and HMI programs

40 90 04 PROJECT DELIVERABLES

.1 Schematic Design phase submittals shall contain the following items from the A/E:
- .1.1 Process flow diagram(s)
- .1.2 Heat and Material Balance Drawing(s) if required
- .1.3 Preliminary Process and Instrumentation Diagrams (P&IDs)
- .1.4 Preliminary Cost Estimate and Schedule
- .1.5 Preliminary Drawing List
- .1.6 Preliminary Control System Interconnection Diagram

.2 Design Development Submittals shall contain the following items from the A/E:
- .2.1 Final Process and Instrumentation Diagrams (P&IDs)
- .2.2 Updated Cost Estimate and Schedule
- .2.3 Updated Drawing List
- .2.4 Final Control System Interconnection Diagram
- .2.5 Preliminary Instrumentation Database
- .2.6 Preliminary Instrument Specification Sheets
- .2.7 Preliminary Site Plant and Conduit Routing Drawing(s)
- .2.8 Preliminary Termination Drawings
- .2.9 Preliminary Loop Sheets
- .2.10 Preliminary Panel Arrangement Drawings
- .2.11 Preliminary Installation Detail Drawings
- .2.12 Preliminary Bill of Materials
- .2.13 Preliminary Operator Interface mock up
- .2.14 Preliminary Bid Documents
- .2.15 Preliminary Commissioning Plan

.2.16 Preliminary Controller Programming

.3 Construction Document Submittals shall contain the following items from the A/E:
.3.1 Final Cost Estimate and Schedule
.3.2 Final for Construction Drawing List
.3.3 Final for Construction Instrumentation Database
.3.4 Final Site Plant and Conduit Routing Drawing(s)
.3.5 Final Termination Drawings
.3.6 Final Loop Sheets
.3.7 Final Panel Arrangement Drawings
.3.8 Final Installation Detail Drawings
.3.9 Final Bill of Materials
.3.10 Final Operator Interface
.3.11 Final Bid Documents
.3.12 Final Commissioning Plan
.3.13 Controller Programming
.3.14 HMI Graphics (both local and DCS graphics)
.3.15 Alarm list

40 91 00 PRIMARY PROCESS MEASURING DEVICES

.1 General Requirements
.1.1 Specified and designed instrumentation shall be industrial grade for harsh plant environments that may include heat, cold, dust, water, and vibration. Instrumentation designed to be installed at the floor or basement level shall be rated for temperatures 0 to 140°F. Instrumentation designed to be mounted in high heat area, such as the upper levels of McCracken Power Plant, shall be rated to 180°F. Instrumentation for outdoor installations shall be rated for -20 to 140°F. All instrumentation shall specified to be NEMA Type 3R enclosure or better.
.1.2 All electronic analog instrumentation shall be Smart HART (Highway Addressable Remote Transducer) protocol. Specify that Vendors shall provide the latest Device Type Manager (DTM) files with their submittals. Configuration, at minimum, shall be accomplished by using a Fisher 475 HART communicator and the Endress & Hauser Fieldcare system. All transmitters will have the instrument tag in HART configuration of the transmitter. Any instrument requiring special programming software shall have a licensed software copy included with the instrument and specified as part of the project to be turned over to the University.
.1.3 Specify that all transmitters shall have a Stainless Steel tag with the manufacturer, model #, tag #, and serial number of the device. Any transmitter connecting to a controller or PLC shall be 2 wire, loop powered, 4-20 ma signal. Transmitters that require external power will be required to use loop power for the 4-20 ma signal. Specify tag numbers shall match the instrumentation tag numbers used on the contract drawing P&IDs.
.1.4 Specify that all transmitters shall be mounted between 4 and 5.5 feet from the floor or operating platform. Transmitters shall be mounted so that the LCD reading is visible for operational use and the tubing and wiring is accessible for maintenance.

.1.5 Specify that all transmitters shall be factory calibrated and have a NIST traceable factory calibration certificate.

.1.6 Flow meters of any type shall be sized for the piping that it is installed. Piping shall not be reduced/increased in size for the flow meter installation. All flow meters shall be installed per the manufacturers' recommendation for straight pipe diameters upstream and downstream of the flow meter. If the upstream/downstream straight pipe diameters cannot be accomplished, and another type of flow meter cannot be installed in the position, then the mechanical engineer shall redesign the piping system to accommodate the flow meter.

40 91 13 CHEMICAL PROPERTIES PROCESS MEASUREMENT DEVICES

.1 pH/ORP Meter/Transmitter

.1.1 pH meters shall have a measuring range of 0-14, with a .01 pH resolution, and repeatability of ±0.01 pH. This will be across a temperature range of 0 to 80°C. pH meters shall have built-in temperature compensation.

.1.2 ORP meters shall have a measuring range of -2000 to 2000 mV, with a 1 mV resolution, and repeatability of ±5 mV.

.1.3 Transmitters for the pH/ORP meters shall be capable of both 2 point automatic calibration and manual calibrations.

.1.4 Approved Vendors: Specify Rosemount and Yokogawa.

40 91 16 ELECTROMAGNETIC PROCESS MEASUREMENT DEVICES

.1 Capacitance Process Level Measurement Devices

.1.1 The 2-WIRE Capacitance type continuous level transmitter shall produce an output of 4-20 mA, and HART protocol that is proportional to level (PVl). It shall be capable of making the measurement independent of changes in material density and not be affected by the presence of material clinging to the sensing element. The measurement shall be free from the effects of changes in temperature, density or acoustic noise in the vapor space above the level. Calibration shall be accomplished from a HART Communication PC software with a modem connected anywhere in the 2-wire loop. Calibration may be entered in user's choice of engineering units and by entering any two level points not necessarily zero and full. There shall be no easily accessible controls that unauthorized persons could tamper with. The output shall be certified compatible with the HART Protocol specification Revision 5 or later.

.1.2 The level measuring system shall be intrinsically safe and suitable for installation in Division 1 hazardous areas when supplied from an approved power supply. The electronic unit shall be mounted in an explosion-proof enclosure and be capable of being either located integrally with the sensor or remotely from the sensor up to 150 feet away.

.1.3 The electronic unit shall be capable of operating in harsh environments with temperature ranges from -40°F to 185°F (-40°C to 85°C) and be protected from corrosion with a NEMA 4X rated housing. The internal circuit boards shall be protected by a conformal (tropicalized) coating.

.1.4 The electronic unit shall be a single device capable of use over a wide range of level applications by having a capacitance tuning range of 1 to 40,000 pF. The electronic unit shall have provision for field changeable fail-safe (mode), damping, and field changeable phasing in the event the measurement requires such changes to optimize the level reading. The reading shall be free from effects of Radio Frequency Interference (RFI) when plant radios (walkie-talkies) are in the vicinity of the level transmitter. Further, the measurement shall be free from harmful effects of static electricity on the sensing element with discharges up to 10 Amperes being tolerated without damage.

.1.5 Approved Vendor: Specify Drexel-Brooks.

.2 Conductivity Process Measurement Devices

.2.1 Conductivity measurement devices shall consist of a remote mounted probe and a 4-20 ma transmitter with HART protocol. Transmitter shall be loop powered. A local LCD display of the conductivity measurement shall be provided at the transmitter. The remote probe shall be made of materials to withstand the process temperature and pressure. The remote probe shall have a ¾" seal tight connection at the head to allow the sensing cable to be protected by seal tight and/or conduit. All measurements shall be in micro Siemens. The probe cell constant shall be chosen to insure the normal measured variable is between 30 and 60% of the device full range.

.2.2 Approved Vendors: Specify ABB, Rosemount, and Yokogawa.

.3 Magnetic Flow Meters

.3.1 Magnetic flow meters shall be installed in horizontal runs of piping and may only be used in processes where the meter tube is fully wetted at all times. Meter materials of construction shall be suitable for use in the intended process. Meters that are 4 to 5.5 feet from the floor or platform may have a permanently mounted transmitter on the unit with a local display. Meters that are not at floor/platform level shall have remote transmitters with display mounted to the nearest wall or panel. Transmitters shall be capable of indicating and measuring reverse flow and be able to show reverse flow in the PLC using only the 4-20 ma signal. Meters requiring external (non-loop) power shall use 120 VAC. The meter shall be able to be a source or sink for the 4-20 ma signal, selectable via an internal dip switch.

.3.2 Approved Magnetic Flow Meter Vendors: Specify Emerson (Rosemount), ABB, and Yamatake.

40 91 19 PHYSICAL PROPERTIES PROCESS MEASUREMENT DEVICES

.1 Gauge Pressure Transmitters

.1.1 Gauge pressure transmitters will be supplied with internal LCD screens to display the Process variable. A stainless steel ball valve will be supplied upstream of the transmitter to isolate it from the process for maintenance purposes. Tubing between the process and the pressure transmitter shall be stainless steel.

.1.2 Approved Vendors: Specify Honeywell, Emerson (Rosemount), Siemens, Yokogawa, and ABB.

.2 Differential Pressure Transmitters

.2.1 Differential pressure (DP) transmitters for steam flow or drum level on boilers shall be installed so that the process fluid in the impulse lines is cooled to ambient conditions. For steam measurement or drum level, condensing pots shall be installed near the root process valves. Where 2 condensing pots are required for one transmitter, the pots shall be installed level with each other. Any horizontal SS tubing runs used shall fall towards the transmitter 1” per foot of horizontal run. All differential pressure transmitters will be supplied with a SS 3-valve manifold that is appropriate for the process pressure and temperature.

.2.2 Any range < 30” WC shall have a draft range transmitter installed. Transmitters advertising large turndowns such as 400:1 shall not be used in draft range applications.

.3 Temperature Transmitters and sensors

.3.1 Temperature transmitters shall be able to use 2-, 3-, or 4-wire RTD’s. Thermocouples may not be used for any applications. All RTD’s will be 3-wire, wire wound, and spring loaded with a thermowell that extends at least 35% into the process line. Thermowell construction shall be designed per ASME PTC 19.3 and per manufacturer’s recommendations for maximum fluid velocity.

.3.2 RTD extension cable shall be shielded #18 AWG, 300 volt, solid conductors in twisted pair triads with PVC insulation, polyester wrapping, and extruded PVC jacket, color coded per ISA standards.

.3.3 All temperature transmitters shall have local LCD indication of the temperature process variable.

.3.4 Approved Transmitter Vendors: Foxboro, Honeywell, Emerson (Rosemount), ABB, and Yokogawa.

.3.5 Approved RTD Vendor: Specify Burns Engineering.

.4 Warranties/Spare Parts

.4.1 All transmitters and sensors shall be specified to come with a 5-year manufacturer’s warranty from date of commissioning. Specifications shall state that the Contractor shall provide one spare of each transmitter type and sensor. The A/E shall be responsible for tracking these items and verifying that the University has received the specified 5-year warranty and spare devices.

40 91 23 FLOW PROCESS MEASUREMENT DEVICES

.1 Vortex shedding flow meters

.1.1 Vortex flow meters may only be used to measure liquid flow. Meters that are 4 to 5.5 feet from the floor or platform may have a permanently mounted transmitter with local display on the unit. Meters that are not at floor level shall have remote transmitters mounted to the nearest wall or panel.

.1.2 Approved Vortex shedding flow meters Vendors: Specify Rosemount and Yokogawa.

.2 Differential Pressure Flow Meters (Orifice plate, V-cone, flow nozzle, pitot tube)

.2.1 Differential pressure flow meters may be used to measure steam, air, oil, and natural gas flows. Steam, gas, and air flows shall be compensated for temperature and pressure conditions by utilizing a Multivariable Transmitter (MVT). If specialized software and computer cables are required to program the MVT, they shall be provided by the project installing the MVT. In cases where compensation is not possible via an MVT, an external flow computer shall be used to compensate for the temperature and pressure conditions and convert the mass flow into a 4-20 mA signal.

.2.2 Approved Multivariable Transmitter Vendors: Emerson (Rosemount).

.3 Coriolis flow meters

.3.1 Coriolis flow meters shall be used to measure fuel oil flow to boilers. Meters shall be ANSI flanged. Meter accuracy will be at ±-0.2% of actual reading or better for liquid flows. If the meter is connected to a PLC, meter power will be sourced from the PLC cabinet. Meter shall have a local display for flow rates. Meter shall be provided with a NIST traceable calibration certificate for fuel oil.

.4 Warranties/Spare Parts

.4.1 All transmitters and sensors shall be specified to come with a 5-year manufacturer's warranty from date of commissioning. Specifications shall state that the Contractor shall provide one spare of each transmitter type and sensor. The A/E shall be responsible for tracking these items and verifying that the University has received the specified 5-year warranty and spare devices.

40 92 29 CURRENT TO PRESSURE CONVERTORS

Current to Pressure converters, also known as I/P devices are not allowed for use. See 40 92 30 for positioner specifications.

40 92 30 VALVE AND DAMPER POSITIONERS

.1 All valve and damper air actuators shall utilize SMART/HART Positioners with 4-20 mA feedback. Positioners will have a local display for position percentage and programming purposes. Positioners will be equipped with a 3-port manifold with pressure gauges, all field airlines into the manifold will be stainless steel tubing conforming to ASTM A 269, Grade TP 316. Positioner shall be able to operate actuators with air pressures between 60 and 100 PSIG. A filter/regulator will be installed on the air supply to the positioner. Filter shall provide ≤ 5 microns filtration for control air. In the event the positioner cannot be installed 4.0 to 5.5 feet from an operating platform or floor level, a remote positioner will be installed between 4.0 and 5.5 feet from the operating level.

.2 Warranty: All positioners shall be provided with a 5-year manufacturer's warranty from date of commissioning. The A/E shall be responsible for tracking these items and verifying that the University has received the specified 5-year warranty.

.3 Approved Positioner Vendors: Specify Siemens PS2 and Fisher-Rosemount DVC 6000 series.

40 92 36 LINEAR ACTUATORS

.1 Linear pneumatic valve actuators shall be sized to fully hold the valve against the maximum process differential pressure and spring rate with air to the actuator. If not explicitly stated maximum process differential pressure is to be determined at an upstream pressure 10 percent above maximum inlet pressure and the downstream pressure at atmospheric. Actuators shall be directly mounted to the valve body.

.2 Single acting (spring return) actuators shall be designed to fail in a safe position on loss of control signal or air pressure. Double-acting actuators shall be designed and specified to fail in last position on loss of control signal or air pressure. On/Off actuators shall be designed and specified with a speed limiting control. Construction shall be rugged type designed for industrial applications, with low sensitivity to vibration and shock.

40 92 43 ROTARY ACTUATORS

.1 Pneumatic rotary actuators will be designed for 150% of torque requirements at 80 PSI instrument air pressure. Actuators shall be sized to fully hold the valve against the maximum process differential pressure and spring rate with air to the actuator. If not explicitly stated maximum process differential pressure is to be determined at an upstream pressure 10 percent above maximum inlet pressure and the downstream pressure at atmospheric. Actuators will be directly mounted to the valve body.

.2 Single acting (spring return) actuators shall be designed and specified to fail in a safe position on loss control signal or air pressure. Double acting actuators shall be designed and specified to fail in last position on loss of control signal or air pressure. On/Off actuators shall be designed and specified with a speed limiting control and position switches with a visible indicator that is visible from the operating floor. Construction shall be rugged type designed for industrial applications, with low sensitivity to vibration and shock.

.3 Rotary actuators shall have a declutchable handwheel to operate the valve should the actuator or positioner fail.

.4 Electric modulating rotary actuators shall only be used when pneumatic actuators are not practical, for example, valves located outdoors. Electric actuators shall be specified to have the following features:

.4.1 4-20 ma control and feedback
.4.2 Operable between -40°F to 185°F
.4.3 120 VAC drive power
.4.4 Configurable action on loss of input signal
.4.5 0.1% repeatability of span
.4.6 HART communications
.4.7 Automatic zero and span calibration
.4.8 Low current draw, continuous duty motor that will not coast, overshoot, or overheat under continuous modulation
.4.9 Stall protection
.4.10 Declutchable handwheel
.4.11 Approved Vendor: Specify Beck.

40 92 49 VARIABLE FREQUENCY DRIVES

.1 Variable Frequency Drives (VFD) controlled by a PLC shall be fully integrated into the PLC utilizing a redundant Controlnet connection. Drives that have integrated bypass starters shall be started via a digital 120VAC output from the PLC. When in VFD mode, automatic speed control will be via the Controlnet connection to the PLC. The following drive data will be communicated back to the PLC via Controlnet for HMI display and historical use in the controls system:

.1.1 Speed feedback in RPM
.1.2 VFD Hertz
.1.3 VFD heat sink temperature
.1.4 VFD alarm/fault codes
.1.5 VFD status

.2 Warranty: Variable frequency drives shall have a 2-year manufacturer's warranty from date of commissioning. The A/E shall be responsible for tracking these items and verifying that the University has received the specified 2-year warranty.

.3 Approved Model: Specify Rockwell Powerflex 750 series.

.4 VFD's mounted inside enclosures shall have an adjustable din rail mountable industrial thermostat to cycle the cooling fans on only when needed per manufacturer specs.

40 94 13 DIGITAL PROCESS CONTROLLER COMPUTERS

.1 Server Class Process Control Computers: Server grade computers should only be provided if vendor software is not able to be virtualized with VMware. Non-VMware servers shall be from Dell and have the following configuration minimums:

.1.1 16 GB of memory
.1.2 Dual 2.5 GHz quad core processors or greater
.1.3 1 TB of Hard disk space utilizing a hardware RAID 5 configuration
.1.4 Dual power supplies
.1.5 Dual Ethernet connections
.1.6 Ethernet Based IDRAC connection
.1.7 Rack mounted 2u chassis
.1.8 Windows 2012 R2 Operating system
.1.9 Microsoft SQL Server 2012 or the software vendor's recommended Microsoft SQL server. (SQL Server Express, Lite, or Embedded is forbidden.)
.1.10 5-year, next business day warranty. Warranty shall be transferred to The Ohio State University-Utilities Division.

.2 Workstation Process Control Computers: Operator workstation computer for process monitoring and control shall have the following minimal configuration:

.2.1 8 GB of memory
.2.2 Dual 500 GB hard drives in a RAID 0 configuration
.2.3 2.5 Ghz quad core processor or better
.2.4 Redundant Ethernet cards
.2.5 Quad monitor video card that meets software vendors specifications
.2.6 Provide Windows 7 or 10-64 bit Operating system depending on software vendor's specifications.
.2.7 5-year, next business day warranty. Warranty shall be transferred to The Ohio State University-Utilities Division.

40 94 33 HUMAN MACHINE INTERFACES (HMIS)

.1 FactoryTalk View SE HMI

.1.1 FactoryTalk View SE will be used for Control Room HMI's. The primary use of the HMI is control and monitoring of plant systems. The servers for the FTSE HMI will be redundant and fail over automatically on loss of communications with the Primary server. Servers will be virtualized utilizing VMware vSphere ESXI 5.5 or greater. Project A/E's will be required to estimate the number of added screens needed and insure each project provides licensing for the screens.

.1.2 P&ID graphics shall be provided that will closely follow the ISA S5 standard. Detailed graphics screens for subsystems shall be provided as required for operator control. Graphic backgrounds will be gray unless otherwise requested. Objects that change state will follow the following color scheme:

- 1.2.1 Gray- Offline and available to start
- 1.2.2 Yellow-Offline in Maintenance Mode or unavailable
- 1.2.3 Blue-Selected to start
- 1.2.4 Flashing Green-Starting
- 1.2.5 Green-Running
- 1.2.6 Red-Faulted

.1.3 Each graphics screen shall have a row of pushbuttons across the bottom to aid the operator in navigating the system. The following pushbuttons will be required:

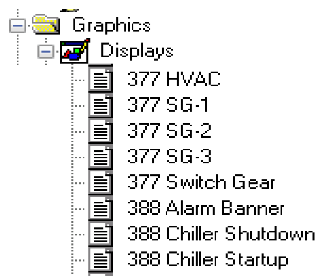
- 1.3.1 Alarm-Opens Current Alarm Screen
- 1.3.2 Main-Opens screen of pushbuttons with all graphics shortcuts for system
- 1.3.3 Trend-Opens screen of Trend pushbuttons
- 1.3.4 Back-Goes back one screen
- 1.3.5 Equipment Overview- Shows state of all equipment in system
- 1.3.6 Equipment Legend-Shows equipment color legend

.1.4 Each graphic screen header shall contain the following: Date, Time, Main Navigation Button, Page Name, Login/Logout buttons, current logged in user, and page close button.

.1.5 Graphic Display Names, Parameter Files, Alarm Names, Trend Templates, and Macros should all have a building number prefix as follows:

- 1.5.1 McCracken – 069
- 1.5.2 West Campus Substation – 134
- 1.5.3 East Regional Chilled Water Plant – 376
- 1.5.4 Central Power Plant Water Treatment Building – 390
- 1.5.5 Smith Substation – 127
- 1.5.6 Generator Building – 377
- 1.5.7 South Campus Central Chilled Water Plant – 388
- 1.5.8 OSU Substation – 079

  i.e.:



.1.6 Key historical data shall be identified for each project. Data will be historicized in FactoryTalk SE Historian. Project A/E's will need to estimate the number of added points needed and insure each project provides licensing for the new points.

.1.7 Trending shall be setup in FactoryTalk SE by each project utilizing the Historian. Trends will logically group data by system and avoid more than 8 pens per trend when practical. Trend Template names will use the building number prefix as shown above. One or more HMI screens will need to be created to provide pushbutton shortcuts to configured trends. Pushbuttons will be grouped logically per system.

.2 Local HMI's

.2.1 Each control cabinet that contains a PLC shall be designed to have a local Panelview Plus 1500 touch connected to the PLC via Ethernet. The Panelview graphics shall match the graphics in Control Room FactoryTalk SE system. Graphics will need to update at 1-second intervals.

.2.2 The Panelview alarm system shall match up with the FactoryTalk SE system alarms. There will be an Alarm Pop up with the latest alarm shown. An alarm history page is required. The Panelview will synchronize its time with the PLC once a day to maintain accurate alarm timestamps. Alarms acknowledged in the Control Room on the FTSE system should also remotely acknowledge alarms on the PanelView.

.2.3 Security shall be configured on the Panelview as View Only, Operator Access, and Administrative Access. View Only access will only allow view of P&ID and overview screens, no control will be allowed from View Only access. Operator Access will allow the same control the operator has in the FTSE system. Administrative Access will allow full access to the Panelview, including Configuration. View Only access will be the default and will not require a password. The PanelView will be configured to automatically log out users after an inactive period of 45 minutes.

40 94 43 PROGRAMMAGLE LOGIC PROCESS CONTROLLERS

.1 Integrator Qualifications and Certifications

.1.1 Controls integrators shall be experienced in the I/O platform they are installing. Experienced is defined as being fully trained and having completed at least 3 other projects utilizing the I/O platform being installed. A fully trained integration engineer shall be onsite at all times when configuration, programming, and commissioning of the I/O platform is occurring. Non OEM integrators shall be members in good standing with the CSIA (Control System Integrators Association) and follow the CSIA's Best Practices and Benchmarks.

.1.2 Any project that integrates controls into the Power Plant Boiler DCS (Honeywell Experion) shall use a Honeywell field service representative for programming, SCADA, and operator graphics. Integrators with experience with Honeywell Experion DCS may do their own integration into the Honeywell system if the engineer has attended the following Honeywell training courses:

1.2.1 EXP02 Experion Server Engineering and Configuration
1.2.2 EXP03 Experion Graphics Design and Building
1.2.3 EXP20 Experion Control Execution Environment Controller

.1.3 The integrator shall also have their own licensed copy of Honeywell Experion for program development.

.1.4 Any project that integrates controls into the Utilities FactoryTalk Site Edition DCS shall use an integrator with FactoryTalk SE training for programming and implementation. Integrators are required to have the following ControlLogix/FactoryTalk SE training:

1.4.1 CCP146 Studio 5000 Logix Designer Level 1: ControlLogix System Fundamentals
1.4.2 CCP151 Studio 5000 Logix Desinger Level 2: Basic Ladder Logic Programming
1.4.3 CCP143 Studio 5000 Logix Designer Level 3: Project Development
1.4.4 CCV207 FactoryTalk View SE Programming
1.4.5 CCV204 FactoryTalk View ME and Panelview Plus Programming

.2 Plant Systems

.2.1 Boiler Steaming controls shall be specified as Rockwell ControlLogix controllers with redundant processors. All Analog I/O modules shall be HART compatible. Each ControlLogix controller shall have an Allen Bradley Panelview 1500 for local viewing and control of the boiler. The ControlLogix controller shall be integrated into the existing McCracken Ethernet network utilizing a 1756-EN2T card. The redundancy module should synchronize its internal clock to the PLC clock once a day to maintain accurate and synchronized time stamps of events.

.2.2 Boiler Burner Management Systems (BMS) shall be separate from the ControlLogix steaming controls. The BMS shall be Allen Bradley ControlLogix with an L61 Processor and redundant power supplies. Each BMS shall meet NFPA 85 standards. The BMS shall be integrated into the steaming controls via Ethernet. All permissive and interlock signals between the BMS and the steaming controls shall be hard wired 110 VAC digital inputs and outputs. The BMS shall have a local AB Panelview 1500 Operator Interface for burner control and monitoring. The BMS shall comply with NFPA 85 and all other applicable safety standards.

.2.3 Chiller, Cooling Tower, and Plant Auxiliary Equipment controls shall use AB Control Logix. Under no circumstances are OPC interfaces allowed to interface controllers to the FactoryTalk SE system. The selected controller shall communicate via Ethernet back to the FactoryTalk SE system.

.2.4 Remote plants shall use AB ControlLogix. Controllers shall be integrated into the

.2.5 FactoryTalk SE system utilizing TCP/IP communications. Networking equipment shall be provided to utilize redundant fiber optic connections back to the McCracken Power Plant controls network. The remote plant shall be fully automated to both start/stop the remote system automatically or manually from the FactoryTalk SE system at the Power Plant.

.3 Input/Output (I/O) Modules

.3.1 All I/O modules shall have DIN rail mounted remote termination panels and cables. Analog modules shall be HART protocol enabled if available from the OEM or OEM approved 3rd party modules.

.4 Configuration Software

.4.1 If the Utilities Division does not possess the software to configure a new PLC or controller, 3 fully licensed copies of the software shall be specified to be provided with the project. Software shall be Windows 7 64-Bit Enterprise compatible. All software registration shall be transferred over to The Ohio State University.

.4.2 All software programs and content become the property of The Ohio State University. All modules within a software program shall be accessible by the University. All software programs shall be submitted free of any Non-Disclosure Agreements.

.5 Spare Parts

.5.1 Each project shall provide one each of the following spare controller parts:

- .5.1.1 Controller CPU
- .5.1.2 Controller Backplane
- .5.1.3 Controller communication module
- .5.1.4 One of each type of I/O module
- .5.1.5 One of each type of remote termination panel and cable
- .5.1.6 One of each type of relay
- .5.1.7 One of each type of power supply
- .5.1.8 One of each type of redundancy module

.6 Warranty and Technical Support

.6.1 Each controller shall be specified to be warranted for 2 years from the date of commissioning. The integrator shall provide a minimum of 2 years technical support for controller programming issues. If the project has provided a controller not made by Honeywell or Rockwell, 2 years of priority telephone technical support from the OEM shall be included as part of the project for controller issues.

40 96 41 PROGRAMMABLE LOGIC PROCESS CONTROLLER PROGRAMMING STANDARDS

PART 1 - Software Design

.1 Control Coding Strategy: The following guidelines are intended to improve PLC operation, aid in the troubleshooting process, and help develop code that can be read and supported once the project is commissioned. They are not intended to inhibit the creativity of programmers. A control strategy is the sequence of steps that must occur within the program to produce the desired output. When developing a control strategy, the programmer should always plan first and program later. The following guidelines should be used when implementing a control strategy.

.1.1 Understand the desired functions of the system. This is accomplished by:

.1.1.1 Reviewing and understanding the Process and Instrumentation Diagrams.

.1.1.2 Reviewing and understanding SAMA diagrams.

.1.1.3 Reviewing and understanding any functional intent documents.

.1.1.4 Reviewing current plant operations with the OSU Automation and Operations team.

.1.2 Review possible control methods.

.1.3 Flowchart the process operation.

.1.4 Translate the flowchart into PLC code.

.2 The larger a project is, the more organization it will require. It is important to document the system throughout its development verses once it is installed. This can be accomplished by being well organized from start to finish.

.2.1 Flowcharting

.2.1.1 Flowcharting is just one of several techniques used when planning a program after a functional understanding of the process has been completed. Flowcharts should outline the operational process in a sequential manner. Each step in the chart should perform an operation. Flowcharts should never be long and complex. If a process is large and complex, a main flowchart should be developed that would indicate the major functions to be performed in the operation. Then several smaller flowcharts can be used to further describe each of the functions in the main flowchart. Flowcharts are the recommended technique because concepts and details, along with their relationship to each other are quickly clear. General descriptions of sequences and relationships that are difficult to breakdown also become obvious after applied to a flowchart. Finally, it is much easier to discuss and explain an operation to an end user in the form of a flow chart than in ladder logic. Once the process has been flowcharted, the programmer can start developing the ladder code based upon the flowcharts.

.2.2 Code Development

.2.2.1 Code development should not begin until an OSU Controls Engineer has reviewed and commented on the flow charts. All review comments shall be, documented, discussed, and agreed to by the programming team and the OSU Automation Team.

.2.2.2 Unless a process is extremely simple, it should be organized into modules or subroutines. The subroutines can then be ordered according to process flow. Before the actual code is started, each programmer should develop a method for assigning memory (addresses). The recommended method would be to use an excel spreadsheet. The addresses should be grouped according to function. When assigning addresses, always leave enough room for future expansion. Always group addresses that are sent to an HMI together. This will help through-put of data between the PLC and the HMI. This memory map or address map should be included in the final documentation, for it could assist in troubleshooting and expansion of the control system. The code should be thoroughly documented. Each task or module should have comments describing the general operation. Abbreviations should be avoided if possible. When a description is too long, familiar abbreviations should be used. The following is a list of guidelines that should be followed for every control program.

.2.2.2.1 Use flowcharts to develop your code
.2.2.2.2 Organize code into functional modules
.2.2.2.3 Order the code according to process flow
.2.2.2.4 Develop a memory (address) map
.2.2.2.5 Group all addresses according to functions
.2.2.2.6 Always group addresses that are sent to an HMI
.2.2.2.7 Document your code thoroughly
.2.2.2.8 Avoid using abbreviations
.2.2.2.9 Values that may need changed should always be coded as variables rather than hard coded constants
.2.2.2.10 Avoid master control relays (MCRs)
.2.2.2.11 The number of elements in a rung should be limited to what can be displayed on one screen of the programming terminal
.2.2.2.12 Avoid the use of latching coils
.2.2.2.13 Each module (subroutine) should have only one entry point, preferably from the main module
.2.2.2.14 Modules (subroutines) should not call other modules
.2.2.2.15 Avoid executing multiple messages at the same time by staggering them to execute on timer and the completion or error of the previous message.

.2.3 General Code Formats

2.3.1 This section provides examples of general rung formats. The following terms will be used in the examples:

- Initiator – Starts or begins the rungs execution
- Permissive – Prevents the rung from initiating but will not drop it out.
- Interlock – Prevents the rung from initiating and will drop it out
- Seal-In – Seals in the output of the rung
- Output – The result of the rung execution

2.3.2 Guidelines

.2.3.2.1 The initiator should always be the first element on the rung
.2.3.2.2 The initiator should normally be momentary

.2.3.2.3 The permissive should be to the right of the initiator
.2.3.2.4 Seal-Ins should be in parallel with the permissives
.2.3.2.5 Interlocks should follow the permissives and go before the output

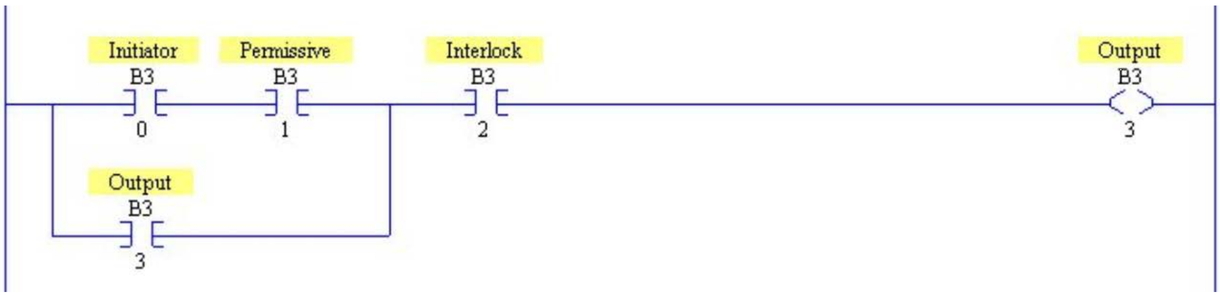


Figure 1.1 - General Rung

Figures 1.2, 1.3, and 1.4 - General Large Rungs
Avoid programming rungs that contain too many elements. Simplify the rung by dividing it into separate components. Figure 1-2 shows a rung with multiple elements. Figures 1-3 and 1-4 show the equivalent logic, but simplified.

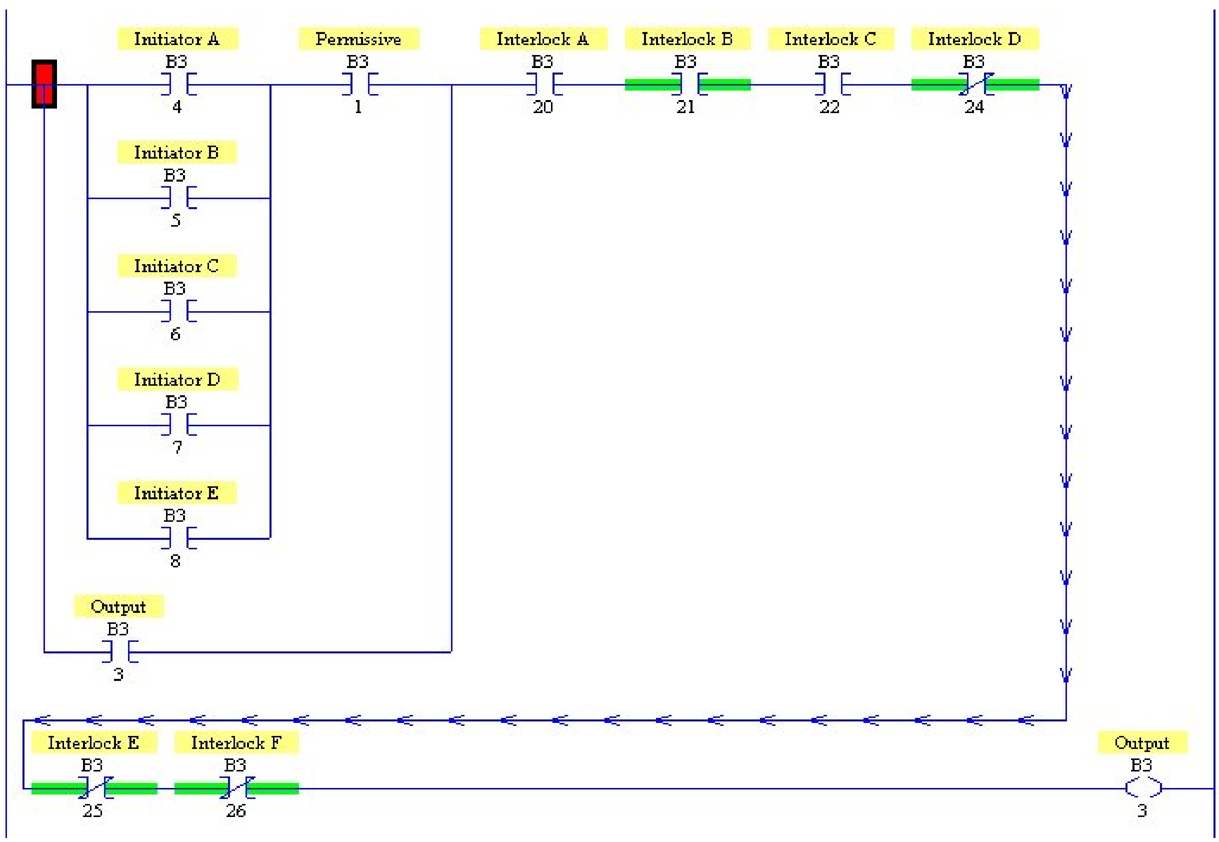


Figure 1.2

Figure 1.3

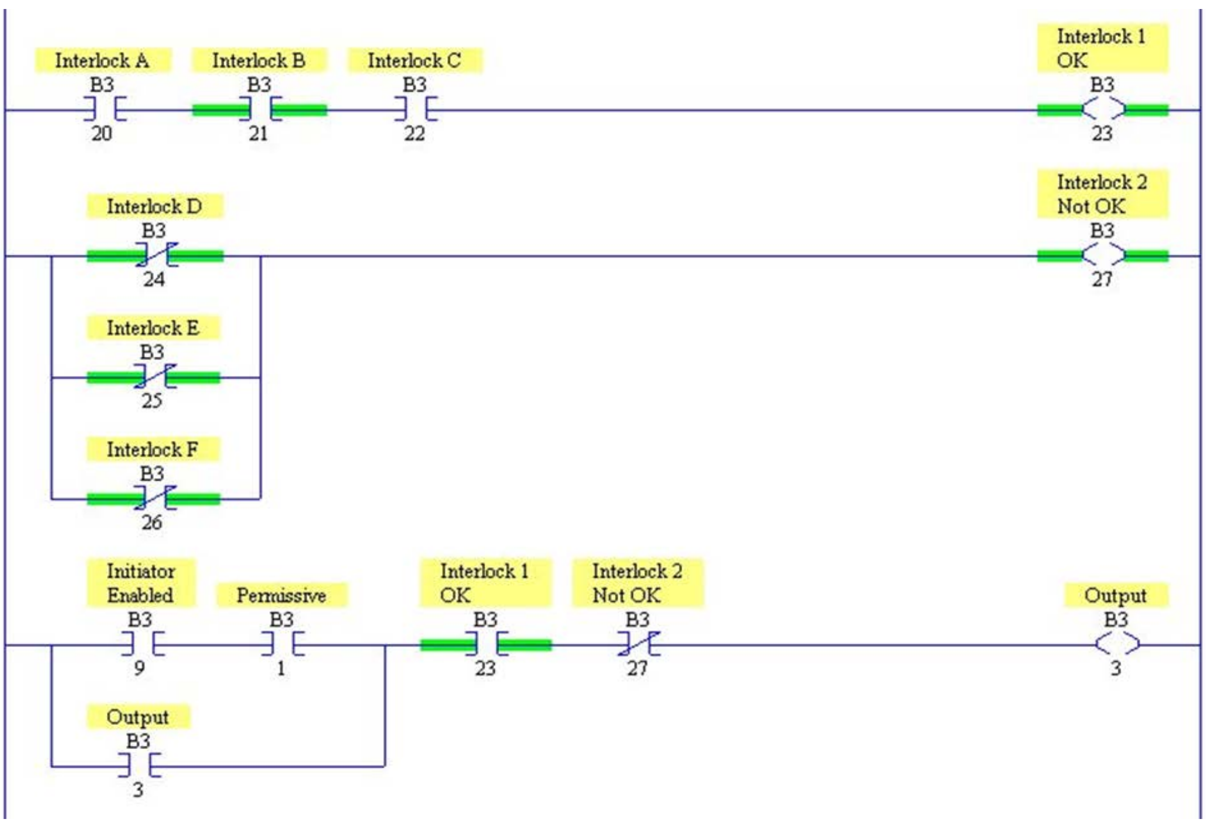


Figure 1.4

.3 Documentation - Documentation is a critical part of any PLC program. To make a program readable to the end user and other engineers in the organization, all programmers should make full use of the programming software's documentation capability. If a program is documented well, the troubleshooting process time can be greatly reduced.

.3.1 Descriptors - Every address in a PLC program shall have a unique descriptor associated to it. Input and Output descriptors should contain information that indicates physical location, device/equipment type and functional meaning. Symbols should match the device identification tag found on the electrical drawing I/O schematics.

.3.1.1 Inputs will always start with physical location followed by equipment type and functional meaning.

Input Example:

Physical Location	North, Lower, Operator Pedestal, etc.
Equipment type	Conveyor, Motor, Reservoir, etc.
Functional Meaning	Start, Stop, Forward, Reverse, Low Level, etc.
Symbol	112PB, 4533LS

.3.1.2 Outputs will always start with functional meaning followed by physical location and equipment type.

Output Example:

Functional Meaning	Start, Stop, Open, Close, etc.
Physical Location	North, Prefill, etc.
Equipment type	Conveyor, Motor, Valve, etc.
Symbol	112MS, 4533SOL

.3.1.3 Internal coils will not be in a specific order. Use as much information as possible to describe the use of the internal coil.

Internal Coil Example #1:	Internal Coil Example #2:
North	Autopurge
Furnace	Step 1
Over Temperature	"Vacuum to
Alarm	1 Torr"

.3.1.4 Internal addresses that interface with a HMI should always contain either of the phrase's "From HMI" or "To HMI" as the last line of their descriptor.

Internal HMI Example #1:	Internal HMI Example #2:
North	Processing
Fluid Pump	Tank 321
Start	Temperature
Pushbutton	Set point
From HMI	From HMI

.3.1.5 All I/O descriptors should be named for the true (On State) condition of the input or output. If an I/O point does not represent a true condition, fail safe devices, the descriptor shall contain "Normally Closed" in the description.

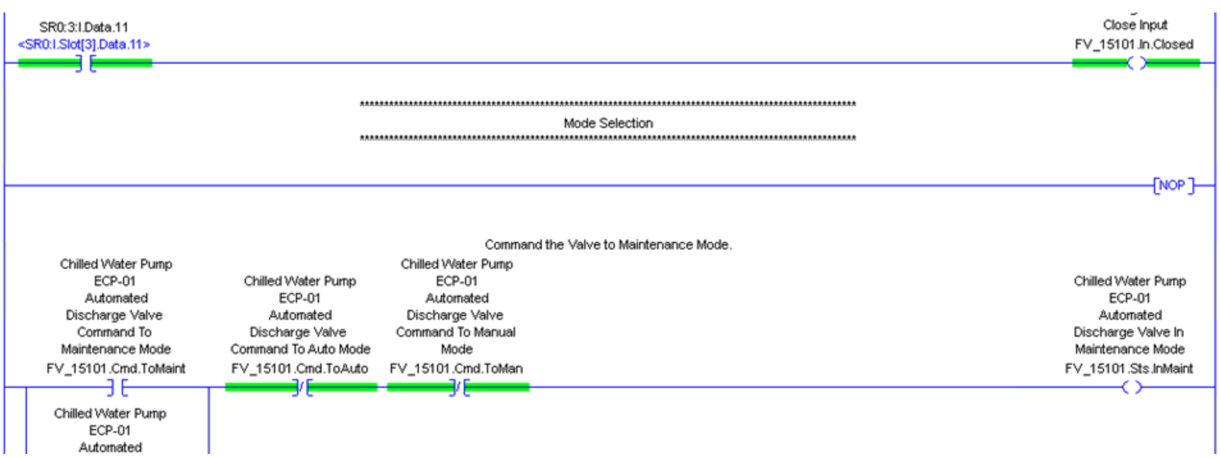
Input Example:

Physical Location	North
Equipment type	Reservoir
Functional Meaning	Low Low Level
	Normally Closed
Symbol	423LVS

In the example above, the input would be on when the level is ok and off when the level goes low. This is a common fail safe situation that would be tied to a pump that would be pumping out of the tank. If the wire is cut or the device fails, the logic would stop a pump from emptying a tank and possible damaging the pump.

.4 Symbols - Symbols are to be used for all Input and Output address only. Symbols can be added to integer or floating point addresses only if the address comes from the BTR or BTW of an analog module.

.5 Rung Comments - Rung Comments should be used to further describe a rung or a group of rungs. It is up to the programmer to decide where to use rung comments. As a rule of thumb, if a rung or group of rungs would benefit from further description than the descriptor provides, a rung comment is required. If using a rung to segment a routine into logical sections for troubleshooting purposes, use the NOP instruction instead of an OTE.



.6 Page Titles - Page titles should be used to summarize and identify the operation and functionality of the code that is below the title.

PART 2 - PLC Tag Structure and Naming

.1 User Defined Tag Group - A UDT is a data structure defined by the programmer. A user-defined data type groups different types of data into a single named entity. Like tags, the members have a name and data type. A UDT is usually used when there is multiple equipment of the same type. A tag is created for each piece of similar equipment with its type being the same UDT. This allows for a common tag structure to be used for all similar equipment. The following are examples of UDT names that were used for a Chiller project.

- Chiller
- TowerMCC
- TowerVFD
- CondWaterPump
- ChillWaterPump

.2 Tag Naming Convention - The tag names that will be created in the OSU Chiller Control System PLC software will follow the convention described below. This convention allows tags to be logically organized and facilitates troubleshooting and maintenance of the application. Each tag name will be made up of several fields. These fields when put together will identify the equipment and describe the tags use. These fields will include either a group or single piece of equipment's identification; an attribute identifier of the equipment and a description of the attribute that further defines its function. This naming convention will be used for tags within a UDT as well as standalone tags.

.2.1 Creating Tag Names - In order to create a tag, you will need to identify and define several items. The first step in creating tags is to organizing the equipment into functional groups. When grouping equipment, try and group equipment that operates as a self-contained system. After a group of equipment is defined it should be assigned an abbreviation that will be used as part of the tag name. Note that only groups that have long descriptions will be abbreviated. Each group of equipment will then be assigned a UDT type. For example, based on the P&ID drawing of the OSU Chillers 8-10, the following groups of equipment can be defined:

Equipment Group Description	Equipment Group Abbreviated Identification	UDT Type
Chiller #8	Chiller8	Chiller
Chiller #9	Chiller9	Chiller
Chiller #10	Chiller10	Chiller
Tower #14	Tower14	TowerMCC
Tower #15	Tower15	TowerVFD
Tower #16	Tower16	TowerMCC
Tower #17	Tower17	TowerVFD
Tower #18	Tower18	TowerMCC
Tower #19	Tower19	TowerVFD
Chilled Water Pump 10	ChilledPump10	ChillWaterPump
Chilled Water Pump 11	ChilledPump11	ChillWaterPump
Chilled Water Pump 12	ChilledPump12	ChillWaterPump
Chilled Water Pump 13	ChilledPump13	ChillWaterPump
Condenser Water Pump 10	CondenserPump10	CondWaterPump

Condenser Water Pump 11	CondenserPump11	CondWaterPump
Condenser Water Pump 12	CondenserPump12	CondWaterPump
Condenser Water Pump 13	CondenserPump13	CondWaterPump

.2.2 Once the different groups of equipment are defined, each piece of equipment that is part of a group should be identified. When identifying this equipment, the P&ID instrument identification tag number should be recorded. This identification number will be used in the tag name to identify the equipment. For example Chiller #8 has the following devices:

Equipment Description	**Instrument Identification Tag Number**
Chiller #8 Chilled Water Flow Present	HS-CH0850
Chiller #8 Chilled Water Inlet Temperature	TIT-CH0801
Chiller #8 Chilled Water Outlet Temperature	TIT-CH0802
Chiller #8 Tower Water Inlet Temperature	TIT-CH0803
Chiller #8 Tower Water Outlet Temperature	TIT-CH0804
Chiller #8 Chilled Water Flow	FIT-CH0801

.2.3 After all of the equipment has been grouped and identified, the functionality of the equipment should be identified and recorded. Note that a group of equipment can perform a function as well as a single piece of equipment that is used as part of a group. Below are some sample functions for Chiller #8.

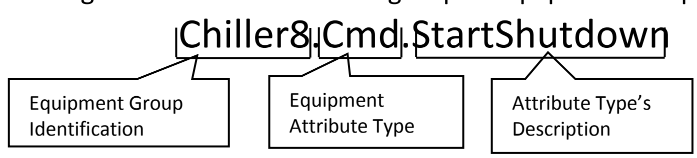
- Start Chiller #8 Shutdown Cycle
- Start Chiller #8 Primary Compressor
- Start Chiller #8 Lag Compressor

.2.4 Finally, before a tag name can be put together, you will need to define the attributes that will be used to characterize the group or single piece of equipment. There are four different categories of attributes that can be used to characterize equipment. The first type of attribute is commands. Commands are used to initiate a function. Typical commands are Start, Stop, Open and Close. All commands will be prefixed with the abbreviation of “Cmd”. The second type of attribute is settings. Settings are modifiable variables that are used to control the equipment. Typical settings are set points and alarm limits. All settings will be prefixed with the abbreviation of “Set”. The third type of attribute is values. Values are used to represent an assigned or computed varying quantity. Typical values are temperatures, pressures and flow totals. All values will be prefixed with the abbreviation of “Val”. The fourth type of attribute is statuses. Statuses are used to represent the state or condition of an object. Typical Statuses are opened, closed, and running. All statuses will be prefixed with the abbreviation of “Sts”. Below is a table that summarizes the attributes that are used to characterize equipment.

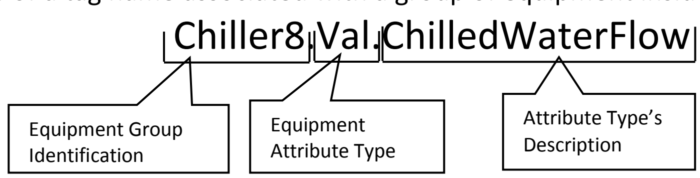
Category	Prefix Abbreviation	Description	Examples
Commands	Cmd	Commands are used to initiate a function.	Start, Stop, Open, Close
Values	Val	Values are used to represent an assigned or computed varying quantity.	Temperatures, Pressures, Flow Totals
Settings	Set	Settings are modifiable variables that are used to control the object.	Set points, Alarm Limits
Statuses	Sts	Statuses are used to represent the state or condition of an object.	Running, Stopped, Opened, Closed

.2.5 Once all of the items above have been completed, you can put them together to form a descriptive tag name. The following diagrams show the location\order of the fields that make up a tag name.

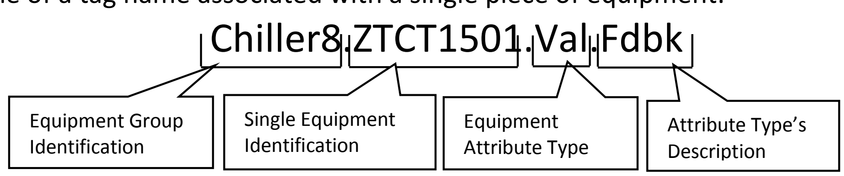
Example of a tag name associated with a group of equipment not part of a UDT:



Example of a tag name associated with a group of equipment inside a UDT:



Example of a tag name associated with a single piece of equipment:



.2.6 The following items summarize the tag naming convention:
- .2.6.1 Tag Names should be organized by grouping equipment based on area and function.
- .2.6.2 Use one of the 4 standard attribute types to further define a tag.
- .2.6.3 The first letter of every word should be capitalized.
- .2.6.4 Spaces should never be used between words.
- .2.6.5 Underscores should only be used between words when upper and lower case text cannot be used.
- .2.6.6 When using abbreviations, the same abbreviation shall be used throughout the application and come from the approved abbreviation table.

.2.6.7 Tag names should be kept as short as possible to minimize controller memory usage.

Table of Abbreviations

Word	Abbreviation	Word	Abbreviation	Word	Abbreviation
Abort	Abrt	Engine	Engn	Pallet	Pal
Aborted	Abrtd	Enter	Entr	Parameter	Param
Accept	Acpt	Error	Err	Position	Pos
Acknowledge	Ack	Exhaust	Exh	Present	Prsnt
Address	Addr	Extend	Ext	Pressed	Prsd
Advance	Adv	Extended	Extd	Pressure	Prsr
Advanced	Advd	Fault	Flt	Process Variable	PV
Advancing	Advg	Feedback	Fdbk	Program	Pgm
Alarm	Alm	Float Switch	Fls	Proof	Prf
Assembly	Assy	Forward	Fwd	Proximity Switch	Prox
Automatic	Auto	Frequency	Freq	Pulse	Pls
Backup	Bkup	Green	Grn	Pushbutton	PB
Block	Blk	Hold	Hld	Raise	Rais
Blocked	Blkd	Horizontal	Horiz	Raised	Raisd
Blue	Blu	Human Machine Interface	HMI	Raising	Raisg
Build	Bld	Immediate	Imed	Ready	Rdy
Calibration	Calib	Input	In	Receive	Rcv
Change	Chng	Interlock	Intlk	Recover	Rcvr
Check	Chk	Leaving	Levg	Reject	Rej
Circuit Breaker	CB	Level	Lvl	Retract	Retr
Clamp	Clmp	Light	Lt	Retracted	Retrd
Clamped	Clmpd	Light Curtain	LtCurt	Return	Ret
Clear	Clr	Limit Switch	LS	Reverse	Rev
Close	Cls	Load	Ld	Rotate	Rot
Closed	Clsd	Lookup	Lkup	Select	Sel
Closing	Clsg	Lower	Lwr	Selector Switch	SS
Command	Cmd	Lowered	Lowrd	Sequence	Seq
Communication	Comm	Lowering	Lowrg	Setpoint	SP
Complete	Cmplt	Machine	Mach	Slide	Sld
Completed	Cmpltd	Maintenance	Maint	Starved	Strvd
Connected	Cnctd	Manifold	Mnfld	Station	Sta
Control	Ctrl	Manual	Man	Status	Sts
Control Variable	CV	Memory	Mem	String	Str
Conveyor	Conv	Message	Msg	Target	Tgt

Word	Abbreviation	Word	Abbreviation	Word	Abbreviation
Counter	Ctr	Motion	Motn	Temperature	Temp
Cycle	Cyc	Motor	Mtr	Text	Txt
Cylinder	Cyl	Normal	Nrml	Timeout	TOut
Deadband	DB				
Delay	Dly	Number	Num	Unload	Unld
Diagnostic	Diag	Okay	OK	Vacuum	Vac
Done	Dn	Opened	Opnd	Vertical	Vert
Downstream	Dnstrm	Opening	Opng	Warning	Wrn
Emergency	Emerg	Operator	Oprtr	Water	Wtr
Emergency Stop	E-stop	Output	Out	Write	Wrt
Enable	Enbl	Overtravel	OTrvl		

PART 3 - Alarming

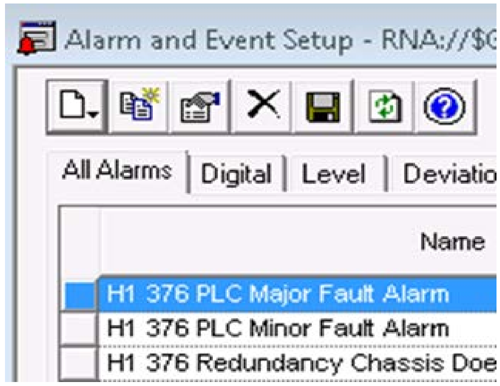
.1 Alarm Rationalization - An alarm rationalization process is required of all projects with HMI's that have operator interaction. Any alarm that an operator will see will require the operator to take an action. Alarm actions shall be documented with Operations and Procedure manual for the system being installed. Alarms that do not require operator action are defined as events and should never be on an alarm screen.

.1.1 All Alarm Names shall have the prefix of the building number as outlined in section 40 94 33.1.5

.1.2 Alarms will have 4 priorities:

- Urgent
  - Operator must respond in 60 seconds or less.
  - Level should only be used for Life-Safety, equipment protection, or equipment shutdown. Example: High High Water level in a boiler.
  - FactoryTalk Alarm and Event Priority: 1000.
- High
  - Operator must respond in 2 minutes or less.
  - Level should be used to warn of an impending Urgent alarm or to escalate a Low priority alarm. Example: High water level alarm in a boiler.
  - FactoryTalk Alarm and Event Priority: 750.
- Low
  - Operator response can be greater than 2 minutes.
  - Level can be used by itself or a as a predecessor to High level alarm. Example: High conductivity in a boiler.
  - FactoryTalk Alarm and Event Priority: 250.
- Diagnostic
  - PLC diagnostic alarms. Example: PLC Major Fault.
  - Level is not seen by operator on alarm screen but an HMI page should show the fault. Diagnostic alarms are emailed to the Plant Automation shop via WIN-911FactoryTalk Alarm and Event Priority: 1

- o Diagnostic items shall have a special prefix of "H1" in the Alarm Name and use the format: H1 [Building Number] [Alarm Name]
  - ▪ i.e.: H1 376 PLC Major Fault Alarm



.1.3 The percentage of alarms per priority should be:

- Urgent <5%
- High <15%
- Low <=80%

.2 Alarm Acknowledgment

.2.1 The Alarm routine shall utilize a single bit from the FactoryTalk SE or Honeywell Experion system to acknowledge and reset alarms per the example below, Figure 3.1. Examples on how to code alarms in the PLC, Figures 3.2 and 3.3.

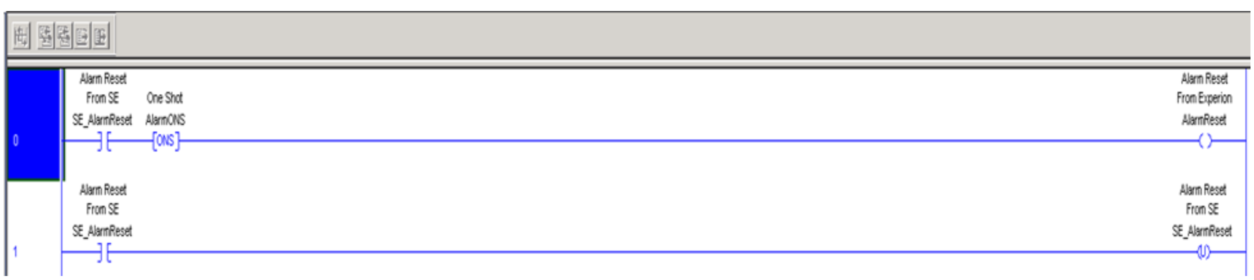


Figure 3.1

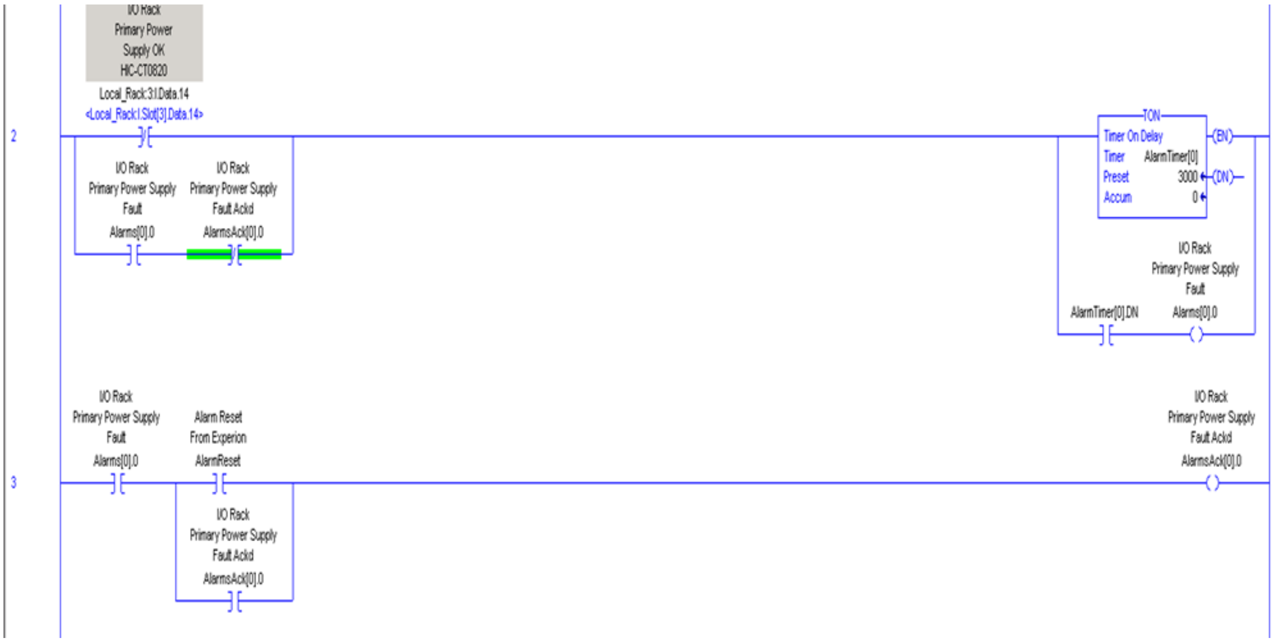


Figure 3.2
Example of a Digital alarm with acknowledge rung

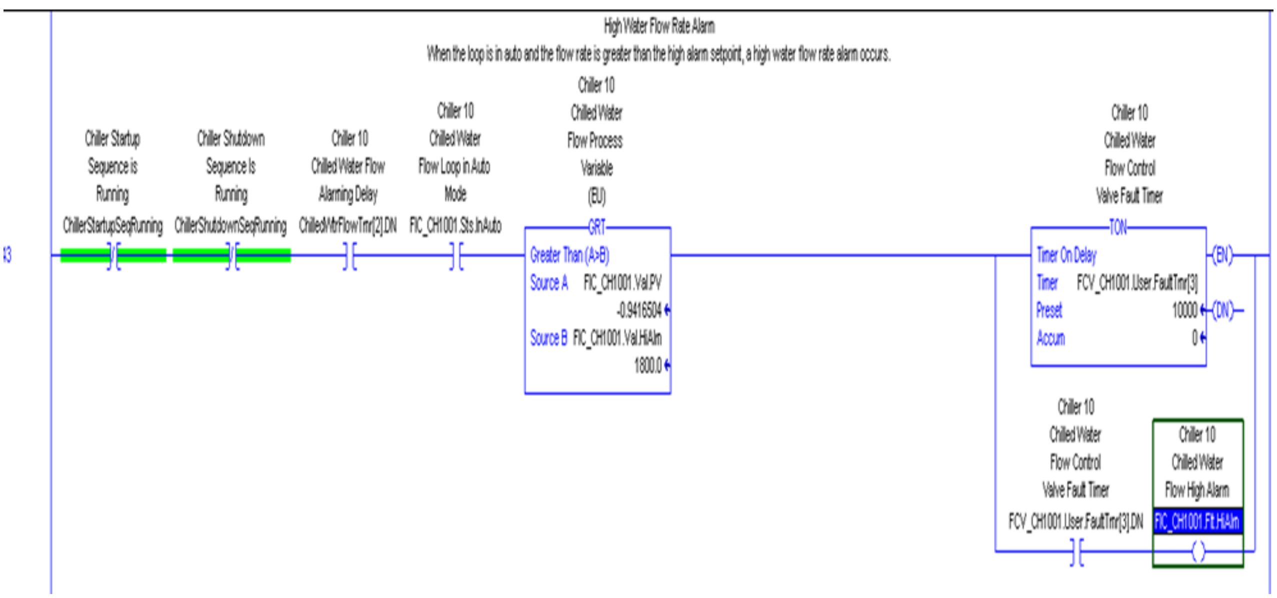
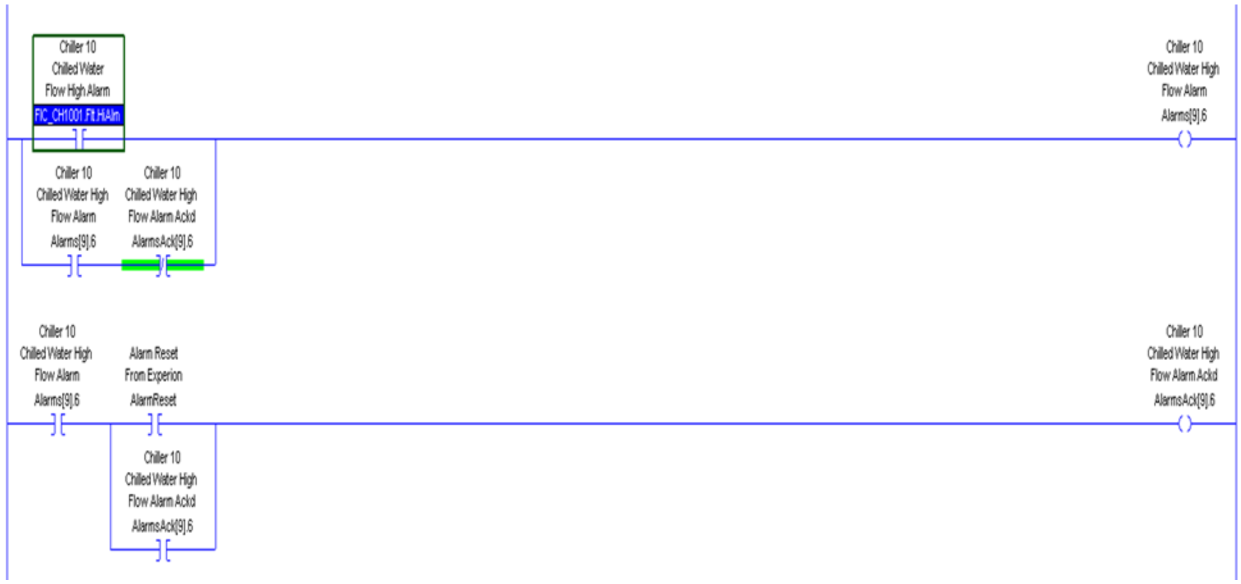


Figure 3.3 (cont. see below)
Example of an analog level alarm with acknowledge rung



PART 4 – Fault routines

.1 The following fault routines are required of every Rockwell PLC project:

.1.1 Controller fault handler-Alarm mapped to HMI server

.1.2 ControlNet media status for the A and B channel

.1.3 Ethernet Ring Fault (if used)

.1.4 Local Rack Communication fault

.1.5 Remote Rack Communication fault

.1.6 VFD Communication fault

.1.7 PLC Minor fault alarm

PART 5 - Data mapping/Totalizers

.1 Projects connecting to the boiler-side Experion system will need to map Rockwell PLC data tags to PLC 5 tags using RSLogix 5000. Real number values will need to be mapped to F registers. Boolean values will need to be mapped to N registers. PLC programmer shall provide a spreadsheet of the data mapping for the HMI programmer with register, data description, and range value of the data if it is an analog or calculated point.

.2 Boiler PLCs will totalize the following data points utilizing the totalizer function block in RSLogix 5000:

.2.1 Gas flow

.2.2 Oil Flow

.2.3 Steam Flow

.2.4 Feedwater flow

.3 Chiller PLCs will totalize the following data points utilizing the totalizer function block in RSLogix 5000:

.3.1 Chiller Tonnage

.3.2 Tower Makeup Flow

.3.3 Tower Blowdown Flow
.3.4 Chilled Water loop Makeup flow

.4 Totalizers shall be programmed to reset daily at 12:01 AM.

PART 6 - Programming software

.1 Projects shall be developed in Rockwell RSLogix 5000 software, version 20.1 or greater. Panelview HMI programs shall be developed in the latest version of software available during the controls engineering phase of the project.

40 95 00 PROCESS CONTROL HARDWARE

Specify that process control hardware shall be industrial grade and able to withstand temperatures between 32 and 160°F.

40 95 13 PROCESS CONTROL PANELS AND HARDWARE

.1 Control Panels

.1.1 The A/E shall specify that all control panels shall be NEMA 12. In areas where there is a likelihood of water splashing on the panel, the panel shall be specified to be NEMA 4X. Panels shall be specified to have a built in hasp to allow locking with a padlock. Panels shall also be provided with an external Ethernet port and 3 amp electrical socket that can be secured via a padlock.

.1.2 The A/E shall specify and design for all conduit and tray entry into control panels to be from the bottom or side. Top penetrations are not allowed.

.2 Panel Hardware

.2.1 The A/E shall design all control panels to be equipped with an isolated copper bus bar to connect to the plant instrument grounding system. This is separate from the panel safety ground. The bar shall be sized to accept a 4-0 grounding cable from the field. All IFM shield grounds shall be wired to the instrument ground bus bar.

.3 Panel wiring

.3.1 All wiring inside the panel going to compression type terminals shall be specified to have ferrules installed at the terminal. If ferruling is not practical, all wires shall be specified to be tinned at the termination. All panel and wiring shall be specified to be labeled per the Termination Drawings.

.3.2 Wire colors shall be as follows:

120 VAC HOT	Red
120 Neutral	White
24 VDC +	Blue
24 VDC Common	White w/ Blue Stripe
Instrument Ground	Green w/ Yellow Stripe
Safety Ground	Green

.3.3 Low power signal and communication wires should not run in the same cable raceway as control and AC power. Separate as much as possible and avoid parallel runs.

.4 Panel Design

.4.1 Panels shall be designed to accept redundant UPS power feeds for 120 VAC power. Power above 120 VAC is prohibited inside a control panel. Incoming power feeds shall be labeled and have lockable circuit breakers inside the control panel to isolate power.

.4.2 Panels shall be sized to dissipate heat loads inside the panel with ambient exterior temperatures at 104°F. PLC CPU's shall be designed to be installed in the bottom 1/3 of the panel.

40 95 23 PROCESS CONTROL INPUT/OUTPUT MODULES

.1 Rockwell 1756 I/O modules

.1.1 1756 series I/O modules shall use 1492 Interface Modules (IFM) for field-side wiring. Digital/Analog input and Digital Output IFMs shall be fused. Digital outputs controlling electric motors with a starter larger than NEMA Size 1 shall have an interposing relay between the digital output and the motor starter. Wiring to IFMs shall follow Rockwell's Industrial Automation Wiring and Grounding Guidelines, publication 1770-4.1.

.1.2 Analog input I/O modules shall be 4-20 mA, HART modules. 1756-IF8H or 1756-IF16H shall be used.

.1.3 Analog output I/O modules shall be 4-20 mA, HART modules. 1756-OF8H shall be used.

.1.4 Digital input and output modules shall be either 120 VAC or 24 VDC, depending on the application. 24 VDC shall not be used in any safety system application. Cards should be the isolated type with no more than 16 points per card.

.2 Honeywell C200 modules

.2.1 Except for specialty cards, such as Modbus interfaces, the Honeywell C200 shall use the same 1756 I/O cards as in Section .1 above. I/O cards shall be purchased from Honeywell due to firmware issues. IFMs can be purchased from Rockwell directly. Module requirements and wiring guidelines are the same as in Section .1 above.

.3 1769 Compact Logix I/O modules

.3.1 1769 series I/O modules shall use 1492 Interface Modules (IFM) for field-side wiring. Digital/Analog input and Digital Output IFMs shall be fused. Digital outputs controlling electric motors with a starter larger than NEMA Size 1 shall have an interposing relay between the digital output and the motor starter. Wiring to IFMs shall follow Rockwell's Industrial Automation Wiring and Grounding Guidelines, publication 1770-4.1.

.3.2 Analog input I/O modules shall be 4-20 ma, HART modules. 1769sc-IF4IH shall be used.

.3.3 Analog output I/O modules shall be 4-20 ma, HART modules. 1769sc-OF4IH shall be used.

.3.4 Digital input and output modules shall be either 120 VAC or 24 VDC, depending on the application. 24 VDC shall not be used in any safety system application. Cards should be the isolated type with no more than 16 points per card.

40 95 26 PROCESS CONTROL INSTRUMENT AIR PIPING AND DEVICES

.1 Instrument Air Lines

.1.1 The A/E shall design and specify that the initial horizontal run shall be a minimum half inch diameter line (with root valve) terminating with a plugged tee and having drop lines from it, unless otherwise shown, sizes as follows:

Number of instruments supplied from one branch line	Branch line size
2 or less	1/4" NPS Pipe or 3/8" OD Tube
5 or less	3/8" NPS Pipe or 1/2" OD Tube
15 or less	1/2" NPS Pipe or 5/8" OD Tube
Over 15	1" NPS Pipe or 1-1/8" OD Tube

Number of control valves supplied from one branch line	Branch line size
1	1/4" NPS Pipe or 3/8" OD Tube
2	3/8" NPS Pipe or 1/2" OD Tube
4	1/2" NPS Pipe or 5/8" OD Tube
more than 4	1" NPS Pipe or 1-1/8" OD Tube

.1.2 Instrument air sub-headers from root valves to individual supplies 1 inch and greater shall be designed by the A/E per OSU Utilities requirements. All control tubing 7/8-inch and smaller shall be in accordance with .2 CONTROL TUBING specified below in this Section.

.1.3 Branch lines shall be connected to the supply headers at the top of the pipe.

.1.4 Individual air filters, air pressure reducing valves with built in relief valve, and 2-inch diameter pressure gauges shall be supplied by the Contractor for each instrument.

.1.5 Main and branch air supply headers shall have blowdown lines and valves at every low point, with a minimum of one blowdown per building elevation. These are to be 1/2-inch nominal pipe with gate valves 48-inches above the floor.

.2 Control tubing

.2.1 All tubing shall be seamless, fully annealed, stainless steel tubing conforming to ASTM A 269, Grade TP 316. The ends shall be plugged before shipment.

.2.2 Fittings shall be flareless compression Type 316 stainless steel. Approved fittings are as follows:

- CPI by Park-Hannifin
- SWAGELOK by Swagelock

- TYLOK by Tylok International

.3 Instrument air

.3.1 Instruments air is defined as compressed air free from contaminants that has a dew point of -40°F.

40 95 33 PROCESS CONTROL NETWORKS

.1 Prior to installing new network equipment, an engineering study shall be completed by the Project's A/E to determine the data load and security impacts of the new networking equipment. The person performing the study shall be Network ++ certified or have an equivalent certificate. Study shall encompass the full controls network with special attention paid to multicasting control (IGMP snooping), vLANing, network loading, ACLs, ring redundancy, firewalling, DMZ's, and routing. Project A/E's study recommendations shall be included in the installing contractor's scope for the project.

.2 The A/E shall specify that Contractors will not be allowed to have direct access to the Utilities network with laptops or any other device. Utilities will provide a laptop when needed for project work. All contractor produced files that are to be used on the Utilities network will be uploaded to a Box account, downloaded by Utilities personnel, and scanned for viruses on a computer that is not on the Controls Network. Limited remote access is available to the Utilities network for technical support. Remote access will not be used for checkout, startup, or commissioning activities. The A/E and Contractors shall refer to the Utilities Remote Network Access Policy for more information.

.3 Cabled Process Control Network

.3.1 Specify that Ethernet cables shall be CAT6 Shielded Industrial with the following properties:

.3.1.1 Industrial grade PVC outer jacket

.3.1.2 Aluminum foil-Polyester Tape shield, 100% coverage with drain wire

.3.1.3 PVC Inner Jacket

.3.1.4 23 AWG solid copper conductors with polypropylene insulation

.3.2 Approved cable: Belden Data Tuff 7953A

.3.3 Cables shall be terminated with a shielded, CAT6 compatible RJ-45 plug on one end only. This end will be the switch end. In the situation where the cable is going from switch to switch, one switch shall have the terminated shield only. The shield drain wire shall be properly installed in this plug. The other end shall be terminated with a standard, CAT6 compatible RJ-45 plug. This end will NOT have the shield terminated. All cables ends shall have proper strain relief devices installed. Cables shall be tested with a Fluke DSX-5000 Cable Analyzer or approved equal. Specify that the contractor shall provide full report on cable testing to the A/E and University.

.4 Fiber Optic Process Control Network

.4.1 OPTICAL FIBER CABLE

.4.1.1 Description: Single mode, 9/125-micrometer, 12-fiber, nonconductive, tight buffer, optical fiber cable. Cable shall be Corning Freedom cable.

.4.1.1.1 Comply with ICEA S-83-596 for mechanical properties.
.4.1.1.2 Comply with TIA/EIA-568-B.3 for performance specifications.
.4.1.1.3 Comply with TIA/EIA-492AAAA-B for detailed specifications.
.4.1.1.3.1 Plenum Rated, Nonconductive: Type OFNP, complying with NFPA 262.

.4.1.1.2 Maximum Attenuation: 3.5 dB/km at 850 nm; 1.5 dB/km at 1300 nm.
.4.1.1.3 Minimum Modal Bandwidth: 160 MHz-km at 850 nm; 500 MHz-km at 1300 nm.

.4.1.2 Jacket:
.4.1.2.1 Jacket Color: Aqua for 9/125-micrometer cable
.4.1.2.2 Cable cordage jacket, fiber, unit, and group color shall be according to TIA/EIA-598-B
.4.1.2.3 Imprinted with fiber count, fiber type, and aggregate length at regular intervals not to exceed 40 inches.

.4.2 OPTICAL FIBER CABLE HARDWARE
.4.2.1 Cable Connecting Hardware: Comply with the Fiber Optic Connector Intermateability Standards (FOCIS) specifications of TIA/EIA-604-2, TIA/EIA-604-3-A, and TIA/EIA-604-12. Comply with TIA/EIA-568-B.3.
.4.2.1.1 Quick-connect, simplex and duplex, Type SC and Type ST connectors. Insertion loss not more than 0.75 dB.

.4.2.2 Approved Manufacturers: Corning Cable Systems InfiniCor SX+ Optical Fiber Cabling, Termination Components, and Enclosures.

.5 Wireless Process Control Network
.5.1 No wireless devices of any kind shall be designed, installed, or allowed access on the process control network.

40 95 49 PROCESS CONTROL ROUTERS AND FIREWALLS

.1 Routers shall be redundant with high availability features that will automatically roll over to the backup router on fault or failure. Router shall be designed to be fed from separate UPS power feeds. Current uplink to the building network uplink is CAT 6 cable with a 1 GB speed. Router shall be capable of routing both public and private IP addresses. Router shall have built in VPN capabilities. Device chosen may be a firewall/router combination device. Device shall be approved by the University's OCIO office as supportable device. Device shall be provided with a 5-year renewable 24/7 support contract.
.1.1 Approved Model, specify Dell NSA 3600.

.2 Firewalls shall be a robust model capable of deep packed inspection without degradation of the 1 GB network throughput. Firewall shall be redundant with high availability features that will automatically roll over to redundant firewall on fault or

failure. Firewall shall be designed to be on separate UPS electrical feeds. The following features shall be included in the firewall:
.2.1 Gateway Antivirus
.2.2 Anti-spyware
.2.3 Intrusion Prevention
.2.4 Botnet Prevention
.2.5 App Control
.2.6 Content filtering
.2.7 SYN flood protection
.2.8 Multicast Snooping
.2.9 Remote log file storage
.2.10 Alert messaging via email

.3 Device chosen may be a firewall/router combination device. Device shall be approved by the University's OCIO office as supportable device. Device shall be provided with a 5-year renewable 24/7 support contract.
.3.1 Approved Model, specify Dell NSA 3600.

40 95 53 PROCESS CONTROL SWITCHES

.1 Control Cabinet Networking Equipment:
.1.1 Industrial Managed Ethernet switch, software Layer 2 Basic, store and forward switching mode 10Mbit/s and 100Mbit/s; Shall be capable of using VLANs, IGMP snooping, https, and ring redundancy.
.1.2 Ports: 10/100BASE-TX RJ-45 ports, auto-crossing, auto-negotiation, auto polarity, 8 ports minimum
.1.3 Voltage: 24 VDC
.1.4 Operating Temperature: 0 to 60°C with a fanless housing
.1.5 Relative Humidity: 10% to 95% (non-condensing)
.1.6 Mounting: 35 mm DIN rail
.1.7 Metal case, IP20 rated
.1.8 Line/star/ring topology
.1.9 Diagnostic LEDs
.1.10 Redundant 24 Vdc power with plug-in terminal block
.1.11 Manufacturer, specify Hirschmann (RS20-0800T1T1SDABHH05.0)

.2 Rack-Mounted Ethernet Networking Equipment:
.2.1 Industrial Managed Ethernet switch, software Layer 2 Basic, store and forward switching mode 10Mbit/s, 100Mbit/s, and 1000Mbit/s; Shall be capable of using VLANs, IGMP snooping, https, and ring redundancy.
.2.2 Ports: 20/1000BASE-TX RJ-45 ports, auto-crossing, auto-negotiation, auto polarity, 8 ports minimum. 4/1000BASE-TX single-mode fiber ports, auto-crossing, auto-negotiation, auto polarity
.2.3 Voltage: 120 VAC
.2.4 Operating Temperature: 0 to 60°C with a fanless housing
.2.5 Relative Humidity: 10% to 95% (non-condensing)
.2.6 Mounting: Standard Rack mounting

.2.7 Metal case, IP20 rated
.2.8 Line/star/ring topology
.2.9 Diagnostic LEDs
.2.10 Redundant 120 VAC power with plug-in terminal blocks
.2.11 Manufacturer, specify Hirschmann (MACH104-20TX-FR)

40 95 73 PROCESS CONTROL WIRING

.1 Process Control Cable

.1.1 Instrumentation Analog Signal Cable shall be No. 18 AWG stranded, tinned copper conductors, polyethylene insulation, twisted pair, 100% coverage aluminum polyester shield, No. 20 AWG stranded, tinned copper drain wire with vinyl outer jacket, UL Listed rated for 300V indoors, above grade, or inside control panels.

.1.1.1 Approved Cable, specify Belden 8760.

.1.2 ControlNet Cable and Connectors:

.1.2.1 Coaxial Cable:

.1.2.1.1 Cable shall be 75-ohm, coaxial cable RG-6 Type, 18 AWG, single conductor, solid.
.1.2.1.2 Conductor material shall be bare copper covered steel.
.1.2.1.3 Insulation material shall be foam polyethylene.
.1.2.1.4 Outer shield shall be Duobond IV quad shield; 100% coverage.
.1.2.1.5 Outer jacket shall be polyvinyl chloride.
.1.2.1.6 Cable shall be specifically designed for use with Allen-Bradley systems; lengths as required.

.1.2.2 Coaxial Tap Kits:

.1.2.2.1 Right angle T-tap, straight T-tap, right angle Y-tap, and straight Y-tap as required
.1.2.2.2 Allen Bradley 1786-TPR, 1786-TPS, 1786-TPYR, and 1786-TPYS

.1.2.3 Coaxial Connectors:

.1.2.3.1 BNC Plugs: Allen Bradley 1786-BNC.
.1.2.3.2 Terminating Resistors:

.1.2.3.2.1 A 75-ohm terminating resistor shall be provided at the each end of a network segment.
.1.2.3.2.2 Allen Bradley 1786-XT
.1.2.3.2.3 Terminations of ControlNet cable shall be done utilizing the Allen Bradley 1786-CTK termination kit.

.1.3 Control Cables:

.1.3.1 No. 14 AWG minimum, type XHHW-2, low smoke zero halogen (LSZH). Nylon conductor jackets and the use of PVC for conductor insulation or jacketing are not acceptable. Multiconductor and jacketed control cable shall conform to ICEA Method 1 Table E2 for individual conductor color coding.

.1.4 Modbus RTU
1.4.1 Approved Cable: Belden 82841

.1.5 Cable installations shall not exceed the manufacturer's recommended minimum bend radius or max pulling tension.

.2 Process Control Conduit, Raceway, and Supports

.2.1 Conduits shall be designed to be rigid with a 1" minimum size. Conduits with more than one conductor shall not be filled more than 40%. A pull wire shall be installed in each conduit and a pull station installed every 30 feet. A junction box shall be installed within 3' of each instrument. The instrument shall be connected to the junction box via Seal Tight. In wet areas, such as cooling towers, there shall be a seal off in the seal tight at the transmitter to protect it from water intrusion. See Division 48 03 04 for detailed installation procedures and requirements.

.3 Process Control Junction Boxes

.3.1 All interior and exterior junction boxes are to be NEMA 3R or better. Junction boxes used on boilers will be NEMA 4X. Conduit entry into junction boxes shall be designed and specified to be from the bottom or the side.

End of Division 40

Table of Contents

48 00 00 ELECTRICAL POWER GENERATION (AND ALLIED FACILITIES)

48 01 01. Operations & Maintenance

.1 INTRODUCTION: To a large extent the success of any great institution depends on the strength and durability of its infrastructure. A key element of the University infrastructure is its utilities. Electricity plays a vital role in almost every aspect of the University experience from housing through academics and sports to research and allied institutions such as the medical center. Our mission in Utility High Voltage Services (UTHVS) is to provide quality of service and continuity of service with a principal focus on public and employee safety.

The Electric utility infrastructure performance relies on ***Maintenance***, ***Equipment Performance*** and ***Human Performance***.

Human Performance relies on training, standards (design consistency), and reliable equipment (good maintenance, sound design).

Equipment performance relies on sound design, quality components, and sound maintenance practices.

Good Maintenance relies on sound planning, quality components, sound design, and reliable human performance.

No element stands alone. No one element can be sustained without the others. No one element can compensate for the absence of another. This Division of the Building Design Standards sets forth unique requirements applied to address the equipment performance, human performance and maintenance needs of the utility high voltage infrastructure of the University. These requirements should be used in conjunction with the remainder of the University BDS to arrive at a design and implementation that meets the full utility performance expectation of the University and its allied institutions.

.2 SCOPE OF APPLICABILIITY: This document provides the requirements and preferred practices of the University as they apply to the McCracken Power Plant and allied facilities such as chemical storage areas, water treatment, standby generation, fuel supply systems and facilities, central chiller and central steam generation facilities and temporary facilities such as portable generation, package boilers etc.

OSU maintains and operates its own utility plants and standby generators. The plants supply steam, chilled water, domestic hot water and compressed air to the University. The scope of application of this document is limited to the above mentioned facilities, and allied facilities. It covers the design and operation of these facilities, for power system equipment and associated controls and protection. Guidance for the design and operation of the electrical systems for the building office space, unless otherwise noted in this document, is contained in Division 26 of the Building Design Standards.

The practices and conventions referenced herein and applied throughout the design of the Medium Voltage Distribution System and its allied facilities are the product of an engineering process directed toward optimizing safe and reliable operations. Compliance with OSHA and National Electric Safety Code requirements is fundamental. Compliance with the National Electric Code is not a design requirement and shall be invoked only on a case by case basis, conformant to the Code applicability statements and where technically useful in obtaining Utilities objectives for overall facility safety and reliability.

A/E and Contractor provisions of this document are intended to promote work practices that:

- Adhere in all their procurement and work practices to the OSU Utilities Project Construction Quality Plan
- Conform their construction practices to the OSU Utilities Project Safety and Health Guide

This Division of the Building Design Standard makes reference to various codes and standards. In all cases where there is an apparent conflict between this document and these other referenced documents the requirements of this document shall govern.

48 02 00 CONFIGURATION MANAGEMENT

48 02 01. Drawing System

.1 INTRODUCTION: Utilities maintains a design drawing system as part of the overall Configuration Management program. The drawing system is used to facilitate maintenance, troubleshooting, and to serve as a resource for planning and engineering upgrades and changes to the power plant, substations, and high voltage distribution system. Keeping the drawings in this system accurate, current, and complete can greatly reduce system downtime and improve power system reliability and availability. It also directly affects personnel training, personnel performance and productivity.

.2 DRAWING PLATFORM: The electrical drawing system is made up of a set of specialized drawing types. The types are designed to document and there by facilitate the control of the configuration of various portions of the electrical power system and related equipment; their protection and their control, and monitoring features. Certain projects may require specialized drawings. In general, the drawings maintained by UTHVS fall into four broad categories: One-lines, Schematics, interconnection, and physical layout. The drawings are maintained in AutoCAD.

Utility High Voltage Services maintains or contributes to the maintenance of: Electrical One Line Diagrams for the bulk power and 13.2 KV Primary power distribution, 480 and 208 VAC, 125 VDC; Quad drawings, circuit schematics (data tables); Manhole diagrams and Circuit Risers for the 13.2 KV feeder pairs, and underground. Elementary Schematic drawings for metering and power equipment control and protection; Interconnection diagrams and logics for integrated control systems and interlocking.

The electrical one line diagrams show power sources, major power equipment, their ratings and connections. They also show metering and protection, instrument transformers, major loads, reactors, capacitors, surge arrestors, fuses, circuit breakers, switches, grounding, phasing, and voltage levels present.

Quad drawings are drawings that show the physical layout of the campus overlaid by a specific Primary Circuit Feeder pair. It is a scaled drawing form that shows each manhole and connecting duct bank routing.

Circuit schematics (data tables) show individual Primary Circuits Pairs as a series of duct bank sections and manholes from the substation power source to the extreme ends of the circuits including all branches. These documents also show cable sizes, cable lengths, duct bank occupancy and cable installation dates.

Manhole diagrams show the manhole conduit contents and status for all four walls in a physical portrayal but not to scale. They also show circuit numbers and building lateral destinations.

Circuit riser diagrams DWG 999 E1015 (GE One-lines) are a form of One line diagram used specifically to show Primary Circuit Taps, their associated manholes and the Primary Select switches and Primary transformers. They show Primary disconnects and the various switching arrangements belonging to the buildings powered from the Primary Circuit pairs. They also contain fuse data for the Primary transformer feeds.

Elementary Schematic drawings show in schematic rather than physical sense, the arrangement and logic involved in both the power connections and switching as well as the logic and components used in design of the control and protection circuitry. They contain the nomenclature used to identify all electrical components as well as the control instruments and interface components such as transmitters, motor operated valves, solenoid valves, positioners, hydraulics, pneumatics etc... They also contain references to vendor supplied drawings, documents and interconnection diagram wire references. Switch and relay contact developments are included on the elementaries to facilitate understanding the control logic.

Interconnection diagrams show how equipment and systems are interconnected (wired and cabled). They may or may not show the relative physical orientation of components. Interconnection, wiring diagrams and or wiring tables give specific information on how equipment is wired on a wire by wire basis and identify physical location and associated reference drawing.

Logic diagrams show the logic used for the control interlocking and protection of equipment and systems. They are primarily schematic and show little or no physical detail other that physical location and elevation.

One lines, elementary/schematics and interconnection/logic diagrams are meant to work as a system, meaning they are cross referenced and contain complimentary information. Duplication of information between drawing types is held to a minimum level needed to facilitate moving between the various drawing types. Each type is designed to assist in accomplishing specific engineering and electrician tasks.

Drawing nomenclature, conventions, and symbology may vary from drawing to drawing. To the extent practical, electrical drawings use nomenclature, conventions, and symbology reflecting general practice in the utility industry.

.3 DRAWING SYSTEM NUMBERING: This drawing numbering system pertains to design, construction and operating drawings documenting designs and as-installed conditions in the Substations and Centralized steam plants and chilled water plants and allied facilities on the Main OSU Campus. The system may be applied after record drawings are submitted at the completion of a project or its utilization may be required of the Design Associate at the beginning of a project, in which case the drawing numbering will carry through from CD throughout the life of the facility. See drawing naming requirements at:

http://fod.osu.edu/proj_del/ref/Electronic_Drawing_Naming_Req.doc

.3.1 Administration:

A master list (data base) shall be maintained current by the Utilities Division and contain the drawing number, the drawing title, the associated project, the revision number, and the organizational unit responsible for the maintenance of the drawing.

.3.2 Effective Date:

The drawing system was placed in force for all projects issuing CD drawings on and after January 1, 2007 and was applied earlier at the discretion of the Director of Utilities as seen fit to facilitate projects already underway at that time.

.4 DRAWING MANAGEMENT

.4.1 CAD file management

The drawing system is managed as CAD files. The files are uniquely named and organized numerically by type of drawing and status (revision and approval). Superseded files are archived along with the current files and are write-protected. Working revisions in development or awaiting approval are password protected. Open revisions are controlled individually. All previous revisions are archived and kept available for reference. All current and active and revision files are maintained on network drives and subject to routine periodic back-up and archival storage.

.4.2 Hard copy access

Current and revision review files are available in electronic and hard copy form on request. Superseded revisions are available on reasonable notice.

.4.3 Inclusion of vendor information

Vendor information in the form of drawings, tables or sketches, when in a compatible format, may be incorporated directly onto the electrical drawings. Project or equipment design specific information should be incorporated into the drawing system. General information should be incorporated into training materials or instruction books and not made part of the drawing system.

.4.4 Inclusion of as-built information

Because the majority of projects are engineered and constructed by other organizations for the university, incorporation of these project files into the utility drawing system is particularly important.

Read-only design drawing files are generally acceptable up until the construction release. Construction drawing release and the release of as-built (as-constructed record drawings) drawings shall be in revisable format compatible with the Universities CAD platform. Construction release drawing files are retained within the drawing system and serve as a reference point for planning and estimating parallel projects. Final project record drawings are incorporated into the drawing system as current drawing revision “0”. An archive copy of these files shall also be retained in the respective project record files (record drawings). These revisions are separately identified and given unique drawing numbers.

.4.5 Incorporation of project drawings

Drawings prepared by an associate or contractor for a project shall be prepared with the understanding that the University may incorporate the drawing contents in their entirety or in part into the University drawing system. Drawing completeness, accuracy and drafting quality shall support this. All drawings produced during the course of a project shall become the property of the University in their native revisable and reproducible form.

.4.6 Drawing numbering and revision management

Drawings maintained in the Drawing System are uniquely identified. Each drawing is coded with its drawing type, a project sequence identifier, a title and a revision number.

.4.7 Design standards and Sketch management

The Drawing System shall maintain a set of Drafting Standards and Design Sketches. Both the Standards and the Sketches are managed like drawings, with unique titles and revision numbering.

.4.8 Drawing Index and drawing lists

The Drawing System shall incorporate a procedure governing drawing types, numbering methodology, standard nomenclature and symbology. It shall also incorporate a series of listings containing all the active (current and archived) drawings along with the current revision date. See drawing naming requirements at:

http://fod.osu.edu/proj_del/ref/Electronic_Drawing_Naming_Req.doc

.4.9 Quality Control

Drawing source material shall be reviewed and accepted for incorporation. All design and drafting work shall be subjected to a rigorous self-checking and independent check for accuracy and completeness. The independent checking shall extend to verifying that all integrated drawings have been properly coordinated, completed or revised.

.4.10 Integrated Design check

Prior to sending out a Construction Drawing set to the University for review, the Engineer shall perform an integrated design check. The design check will verify the interfacing of controls with the current mechanical and electrical drawings and equipment specifications provided.

.4.11 Approval and signature authority

Approval authority for drawings and stamped plans generated external to the University in the execution of projects by the project engineer shall be in conformance with the University process governing the issuance of project drawings.

Approval authority for internally generated drawing additions or revisions of drawings for facilities within the scope of this Standard resides with the Technical Director of Utilities. Signature authority shall be delegated via written form to any qualified member of the Utility staff. The design document shall be initialed by the drafter of record, the reviewer and approved by the Technical Director of Utilities or their designee.

48 02 02. Software, Firmware Control System

.1 INTRODUCTION: Utilities maintains a system for the control of software based information as part of the overall Configuration Management program. This Software and Firmware control system is used to facilitate maintenance, troubleshooting and to serve as a resource for planning and engineering upgrades and changes to the power plant, substations and high voltage distribution system. Included in this class of information are: Program listings, system and component set-up data, protective relay settings files, fault and coordination files, calculation files and failure data recordings. Keeping the information in this system accurate, current and complete can greatly reduce system downtime and improve power system reliability and availability. It also directly affects personnel training, personnel performance and productivity.

.2 PLATFORM: The University Utility Group can support a variety of platforms. It reserves the right to request compatibility to specific platforms when circumstances warrant.

.3 CONFIGURATION SOFTWARE: If the Utilities Division does not possess the software to configure a new PLC or controller, 3 fully licensed copies of the software must be provided with the project. Software must be Windows 7 compatible.

.4 ORGANIZATION (future work item)

Software/firmware types
File content
Standards

.5 MANAGEMENT (future work item)

File management
Hard copy access
Inclusion of vendor information
Inclusion of as-built information
Incorporation of project software, configurations and settings
File identification and revision management
Design standards and Sketch management
Index and listings

.6 QUALITY CONTROL (future work item)

.7 APPROVAL AUTHORITY (future work item)

48 02 03. Change Control

.1 CHANGE AUTHORIZATION: Work that exceeds basic maintenance and repairs or that changes the design, system operation or materials of construction in the power plant, substation, or primary distribution systems requires prior authorization of the Technical Director of Utilities or designee and qualified design oversight and inspection. This requirement applies to systems that are in operation as well as systems that are being installed to approved construction documents. Approval authority may be delegated by the Technical Director of Utilities to the construction authority for projects under construction. Approval authority may be delegated to subordinates in Utilities.

.2 WORK SCOPING AND DOCUMENT IMPACT IDENTIFICATION: The nature of the proposed changes shall be clearly defined. A technical and cost justification shall be provided. The anticipated impact on existing facility systems and equipment shall be accessed, including constructability, startup and maintenance considerations and “What if” risk assessment on equipment, systems and human failures that could result in utility outages. (See 48 09 10.9 for additional information) Compliance with OSU BDS and its appendices shall be established. Personnel training and familiarization needs as well as maintenance needs shall be outlined. The impact on drawings, procedures and practices shall be described. A Failure Modes and Effects Assessment shall be provided for use in determining the potential impact on the design of facilities, structures, support systems and utilities as well as the acceptability of the consequences of a failure.

48 02 04. Work control

.1 DEVICE AND CABLE NUMBER ASSIGNMENT: Unique device and cable numbers shall be assigned according to Utilities naming and numbering conventions.

.2 DRAWINGS: All work shall be installed to original issued signed and stamped drawings, approved marked-up drawings or detailed sketches. New drawings and sketches shall conform to Utility practices for content and information organization. Installation using pre-approved marked-up University drawings is acceptable if the mark-ups show adequate detail to be used to control the installers' materials and practices and present a usable and complete record of the final installation.

.3 QC CHECK POINTS: The installation shall proceed with preplanned hold points to allow for work inspection by the Utility or an independent third party inspection and test agency. All critical tasks shall be done by qualified trained personnel.

.4 ELECTRICAL INSPECTION: Electrical inspection for completeness and compliance to the BDS, Code, Good Practices and the Design shall be performed on a regular basis for the various portions of the installation as the project progresses. This may be performed by the prime contractor, Utility personnel, or an independent agency. However the responsibility for seeing that this function is performed to the satisfaction of UTHVS rests with the prime contractor. Discrepancies and omissions shall be followed up and corrected in a thorough and timely fashion. Reference construction inspection checklists for primary electric service, when applicable.

.5 CHECKOUT AND COMMISSSIONG: There shall be a formal independent check-out and commissioning process. This activity shall be pre-planned and thoroughly documented. All test and calibration equipment shall be National Institute of Standards and Technology (NIST) (or Utility approved and appropriate agency) traceable.

Checkout shall verify all protection, interlocking, control functions, and alarming are operational and to spec.

Commissioning shall demonstrate that all systems are operational (meet fitness for use requirements); personnel are trained in operation and maintenance.

Third party involvement for the checkout and commissioning of Medium voltage equipment and systems shall be by a qualified Relay Checkout Organization (RCO) with a documented history of successfully conducting such work and staffed at a technical level adequate to perform an engineering review of the design as or if required.

Third party involvement for the checkout and commissioning of Low voltage equipment and systems shall be by a qualified Independent testing service (ITS) with a documented history of successfully conducting such work.

.6 JOB STATUS TRACKING: Status and tracking shall be appropriate to the size and complexity of the project. At a minimum all changes shall have their approval, implementation and documentation status recorded and tracked; open items and follow up activities noted.

.7 DOCUMENT UPDATES, RECORD DRAWING RELEASE AND AS-BUILTS: All University documents impacted by the change shall be updated. Project drawings shall be updated and kept current with as installed conditions and at completion of project, incorporated into the appropriate University drawing system. Vendor supplied documents with maintenance, trouble shooting and operation of equipment information shall be assembled and included in the Project O&M Manuals and retained in the University Vendor Document Control System.

.8 PROJECT CLOSE-OUT PACKAGE: Each change shall have a close-out package on file that contains the scoping and authorization documents, as-built record drawings, supporting vendor and technical correspondence, catalog information and, Project O&Ms. The package shall also contain a record of the change being functionally tested and released for operation.

A record of training along with training materials shall be included. Reference Project Closeout:

http://www.fod.ohio-state.edu/proj_del/index.htm

48 03 00 DESIGN REQUIREMENTS

Requirements of this Standard are based on good engineering practice and provide a uniform and consistent basis for the design, construction, maintenance and operation of electrical infrastructure and the electrical portions of Utility facilities on the OSU Main campus. Utilities UTHVS maintains a Planning and Design Guide that provides the technical basis for many of these requirements and should be consulted before recommending alternatives or any nonconformance.

48 03 01. Power Plant Busses

.1 INTRODUCTION: The primary objective of dividing plant boiler and chiller loads between the two primary feeds is to achieve some level of tolerance in the power plant to electrical system upsets. Major upsets originating with the external utility, AEP, will impact all boilers and chillers. The electrical system is equipped with emergency generation capacity to restart power plant boilers individually and re-establish critical steam loads, with the further objective of re-starting internal steam powered generation and re-establishing some critical electrical distribution circuits. For internal upsets, we seek to limit the potential impact to no more than half our steaming or cooling capacity. Grouping auxiliaries for each boiler or chiller facilitates switching during a power outage and limits the impact that an internal power outage will have on boiler and chiller operation.

.2 GENERAL CONSIDERATIONS**:** McCracken Power Plant electrical supplies are organized to limit the number of boilers and chillers impacted by the loss of any one bus or feeder. McCracken Power Plant receives power from three incoming feeds at 13.2 KV. These feeds are powered from OSU Sub and enter Smith Sub where they power Forced Draft (FD) fan Variable Frequency Drive's (VFD) for Boilers 1, 3, 5, 6 and 7. Two feeders, 412 and 612, fed from Smith Sub, power the power plant 480 VAC system. Plant chiller loads are powered at 4160 VAC from Smith Sub 4160 V systems and from the plant 480 V systems. The bus arrangements at Smith Sub support two independent feeds to the plant; one orientated to bus 400, one to bus 600. These busses are in turn fed from bus 100 and bus 300 respectively at OSU Sub. Each of these two busses can be alternatively fed from bus 200 at OSU Sub through bus 500 at Smith Sub.

Bus 400 orientated busses and feeders are: 13.2 KV Bus 401, 13.2 KV Feeder 412, 13.2 / 4 KV Transformer T1400 (North), 4160 V Bus 1400, Chiller Bus 89, FD Fan bus 1401, Transformers T2 and T3, 480 V Sub 2 and 3, T5, 480 Sub 5, Smith Sub 480 V MCC 2.

Bus 600 orientated busses and feeders are: 13.2 KV Bus 601, 13.2 KV Feeder 612, 13.2 / 4 KV Transformer T1600 (North), 4160 V Bus 1600, Chiller Bus 67, FD Fan bus 1601, Transformers T1 and T4, 480 V Sub 1 and 4, Smith Sub 480 V MCC 4.

All boilers and chiller groups have an orientation to either Bus 400 or Bus 600. This orientation governs the choice of chiller power as well as the choice of power sources to their respective auxiliary equipment (fuel oil pumps, ID fans, boiler feed pumps, chilled and condenser water and associated control power). Where redundant auxiliaries have been provided, the power orientation of all redundant auxiliaries shall be the same.

.3 MEDIUM VOLTAGE DISTRIBUTION SYSTEM: The McCracken Power Plant 5 KV power distribution system is supplied from two 10 MVA 13.2 KV to 4160 Volt power transformers located at the McCracken Substation. Each of these transformers powers a 4160 V bus that in turn powers miscellaneous plant boiler fans and large pumps as well as the larger chiller package compressors. Both of these busses are equipped with 2300 KVA emergency diesel generators capable of supplying critical plant electrical loads.

.4 LOW VOLTAGE DISTRIBUTION SYSTEM: The McCracken Power Plant 480 V power distribution system is supplied from one single ended and two double-ended unit substations located within the power plant. One double-ended substation (unit subs 1 and 2) is located in the MCC room. The other double-ended substation (unit subs 3 and 4) is located on the mezzanine on the east wall of the power plant. The single ended substation (unit sub 5) is located in north eastern end of the basement. The McCracken LV distribution is a mix of solidly grounded and resistance grounded distributions. Sub 1, 2 and 5 are operated high resistance grounded with ground location. Sub 3 and 4 are solidly grounded 3 wire systems. There are plans to convert these to resistance grounding. Plant loads are 3 phase or connected phase to phase. Single phase to ground loads are not permitted. Running a loadable neutral wire along with phase leads is not a requirement of the distribution system design.

.5 NEW CENTRALIZED FACILITIES: New facilities and major additions to facilities that have built-in redundancies of equipment or functionality shall be designed with electrical distribution systems that support and mirror those redundancies. The most common power system redundancies are designed around two or three bus schemes and reflect how the energy supply to the facility is provided. Facilities fed directly from the main OSU or West Campus Substation buses can be designed around a maximum of three buses as is the case with the South Regional Chiller Water Plant. Facilities fed off the MV distribution system sharing primary distribution system circuits with other buildings and facilities will generally be designed around a two bus scheme to keep feeder loadings within system design criteria contingency loading limits as is the case with the East Regional Chilled Water Plant. Both the South central Chilled Water and East Regional Chilled Water facilities have their Low Voltage distributions rated 575 V resistance grounded. Both also have their chillers powered off 5 kV busses. The 5 kV systems at both locations are low resistance grounded as well to reduce fault induced equipment damage and Arc flash levels.

.6 STANDBY POWER GENERATION: Standby power sources provided for, or as an adjunct to OSU Utility Facilities, designed with the capability to be operated in parallel with the MV distribution system shall be provided with a means to automatically isolate from the system upon loss of external utility connection.

Normally a standby power system will be automatically started on loss of external utility power and support a limited portion of the MV distribution, typically MV distribution within a facility such as a central chiller plant or the McCracken power plant. In this mode, they are not operated in parallel to the outside utility except to transfer load back to the external utility once the normal source of external power is restored. It is quite common however to run periodic load tests with the standby power system connected to the external utility. This is done to avoid the cost of a load bank installation and to conserve energy. It is under such conditions that this requirement applies.

Separation may be accomplished by direct interlocking or it may be accomplished through a reliance on protectives applied to the standby generators. OSU Utilities has a standing commitment with the external utility (American Electric Power) to advise them of the presence of standby generation on the OSU MV distribution system and keep them appraised of any changes in capacity, interlocking or protection provided. Principal among concerns for what is generically termed “Distributed Generation” is the potential for it to back feed into the external utility grid and cause a concern for personnel safety and equipment damage.

There are two MV Standby Power systems allied to Utilities facilities on the Main Campus; one at Smith Substation for McCracken Plant and one situated northwest of McCracken that supports the South Regional Chilled Water Plant. As part of the McCracken power plant LV system there is a single independent DG set aligned to Sub 2 480 V distribution. Standby Power System loading at Smith and the Chiller support facility involves load shedding and manual load restoration.

48 03 02. Electrical Component Shielding

Solid state and microprocessor based components applied in mission critical functions in the Bulk Power System shall comply with accepted industry standards for emission and susceptibility to Radio Frequency Interference (RFI), magnetic fields, Electro-static Discharge (ESD), ultra violet radiation, temperature, humidity, chemical attack and vibration. Careful attention shall be paid to these aspects of the application of this class of equipment because this relatively sensitive equipment will be placed in service in or in close proximity to sources of adverse environments and high-energy fields. Proof of equipment compatibility and documentation of its compliance to industry standards will be required before final acceptance.

48 01 03. Wire and Cable

.1 COPPER CONDUCTORS: Copper conductors of 98 percent conductivity shall be used unless use is restricted by Government Agencies.

.2 COLOR CODING

Color coding for power wiring in McCracken Power Plant and allied facilities shall be as follows:

Phase	**Voltage**		
	4.16KV	575, 480Y/277	240/208/120
Neutral	White or Grey	White or Gray	White
	(Each with identifiable colored stripe)		
A	Brown	Brown	Black
B	Orange	Orange	Red
C	Yellow	Yellow	Blue
Equipment Ground	Green, Black or Bare	Green w/ Yellow stripe	Green

Control wiring at 125 DC, 120 AC are not generally color-coded in panels, nor is there a prescribed conductor color associated with the voltage or polarity when run in jacketed multi conductor color coded cable.

.3 MEDIUM VOLTAGE CABLE (5 KV)

5,000-volt service cables shall be UL Listed, 1/c, copper, 115 mil Ethylene propylene rubber insulated, 5 kV, 133% rated, shielded, MV 105° cables with low smoke (critical Temperature Index > 260°C) zero Halogen*. Tape Shield Cables shall have a 5 mil bare copper tape applied helically over the extruded insulation shield with an average minimum overlap of 25 percent of the tape width. The overall jacket shall be a continuous extruded, 80 mil polyolefin jacket which meets or exceeds the requirements of ICEA S-93-639 WC 74.

*Note: The zero-Halogen requirement may be waived by UTHVS for applications where halogen bearing cable jacket material poses little or no risk to personnel or equipment. OSU Utilities maintains a listing of approved cable suppliers and approved cable jacket constructions.

.4 GENERAL REQUIREMENTS FOR MEDIUM VOLTAGE CIRCUITS

.4.1 Circuits shall be rated to carry a minimum of 120% rated continuous load at a 60°C ambient. If an emergency rating is involved, the installation shall be designed to 120% of the emergency duty rating. The minimum size cable allowed for medium voltage feeder circuits is 4/0. Individual motor and load circuits can have reduced wire sized commensurate with the requirement of the NEC. All medium voltage circuits shall be shielded cable unless otherwise authorized in the design drawings and approved by UTHVS.

.4.2 Circuits shall be routed in bonded steel conduit with a diameter of 4 inches or greater as required by the choice of cable conductor and configuration. Use of aluminum conduit is not permitted. Tray installation of MV power cable is restricted to areas of the power plant substation where environmental effects are controlled and physical protection can be assured. Power cable runs in tray shall conform to the NEC requirements for multiple conductor transposition, cooling, and shall have a 4/0 600 volt insulated ground conductor run for each set of three phase conductors in the circuit.

.4.3 Minimum bend radius considerations for the cable shall be observed at all times during installation and in the final installation and terminations.

.4.4 Oversized motor terminal boxes shall be specified to allow adequate termination space for motor leads to shielded cables

.4.5 Use of unshielded cable is restricted to locations where termination of shielded cable is not practical such as undersized motor terminal boxes. Use of unshielded cable must be approved in writing by UTHVS prior to installation. Such approval may be granted on a case by case basis for instances where the entire cable route is in rigid or flexible metallic conduit.

.4.6 Cable medium voltage terminations and splices shall be done with UTHVS approved Raychem Heat Shrink termination and splicing kits. All exposed energized surfaces on terminations shall be taped with UTHVS approved taping systems. Motor and equipment terminations to unshielded MV cable shall be taped or insulated with OSU Utility UTHVS approved taping systems or termination kits. All terminations shall be via bolted. Split bolts and pressure type fittings are not permitted. Cold shrink terminations are not approved. Certifications of the proposed installers shall be submitted to the University for review by the UTHVS personnel. All work performed on non-lead, medium voltage (1 kV to 35 kV) cables shall be performed by personnel with adequate training and experience, and certified as qualified by the UTHVS. To be considered qualified for cable splicing, the individual’s employer must submit a resume with past training and experience supported by documentation of their having had the appropriate formal training in the preparation of relevant medium voltage splices and terminations, prior to the individual performing any work. Splicing and termination experience shall be recent (one to five years depending on extent of prior experience) and relevant to the type of splice and cables being spliced.

.4.7 Fire tape is applied to exposed cable for the purpose of protecting that cable from the failure of adjacent cables. For the purposes of this discussion, “exposed cable” refers to cable hung in air or run in ventilated tray. Cable in conduit requires taping only to the point where the cable enters and exits the conduit. Cable vaults and Manholes are areas commonly associated with the need to fire tape however the criteria governing taping is broader and may require taping in other areas of an industrial facility such as a power plant or central chiller facility. The application of fire tape serves two purposes. It limits the proximal damage caused by a cable failure and it reduces the probability that a cable failure will result in the loss of redundant circuits. This is true for instances where there is little risk of a general area fire caused by a large combustible inventory. Where an area fire is a serious concern, the recommended solution is to reroute critical cables and/or their redundant cables. The application of fire tape to cables in or out of trays offers some protection from an area fire of limited duration and intensity. Where there is little or no risk of an area or tray fire, adding barriers to trays containing redundant cables or placing redundant cables in separate trays is an acceptable design approach.

.5 LOW VOLTAGE CABLE (600 volt class): For Power, Control and Protection

NOTE: Some Utilities central facilities 480 VAC and 575 VAC sources are solidly grounded but most are operated ungrounded. The choice of power source will materially affect the circuit protection design and may also effect the application of solid-state power switching equipment such as variable frequency drives. All protection and equipment designs shall accommodate the grounding condition for the power supply provided.

.5.1 Solid and stranded insulated conductor Wire: No.12 AWG and smaller may be solid. No. 10 and larger shall be stranded.

.5.2 Minimum size for all 125 VDC and 124/240 VAC branch circuits is No. 12 AWG.

.5.3 Minimum No. 14 AWG stranded for AC control wiring and auxiliary system circuits is permitted.

.5.4 Use of No. 12 AWG or greater for 125 VDC control wiring is required.

.5.5 Use of No 10 AWG for all current transformer circuit wiring is required.

.5.6 General Use insulation for 600 volt rated wire and cable shall be NEC, 600 volt class type XHHW2 with SIS allowed for power component internal control wiring. Jacketing shall be Low Smoke Zero Halogen. Nylon conductor jackets and the use of PVC for conductor insulation or jacketing are not acceptable for power plant, substations and associated facilities applications. All wiring between equipment, cabinets or control panels for low voltage power equipment power and control circuits shall be in conduit or tray. All control wiring between power components, cabinets and control panels shall be in jacketed color coded tray cables bearing suitable durable cable identifiers. Panel and component wiring shall have individual wire labels. Acceptable labeling conventions include: destination labeling, unique wire numbering. Distribution panel branch circuits at 120 Vac and 125 Vdc, powering controls for electrical and I&C equipment are classified as control cable and run in color coded jacked multi conductor cable. Wire sizes AWG 8 and larger are exempted from this rule.

.5.7 ICEA Method 1 Table E2 convention shall be used to color code individual conductors of all jacketed multi-conductor cable. Equipment manufacturer supplied “special cables” are exempted from this requirement.

.5.8 All power cables are to be terminated in UTHVS approved solid, long barrel, plated lugs. Power cables carrying high current (greater than 50 Amps) are to have two or more bolts. Crimps are to be made by a crimp tool approved by the lug manufacturer following their approved procedures. All crimps shall be six point or more. A 360 deg crimp is preferred. In instances where the equipment taking the termination does not support two or more bolts, UTHVS shall be consulted and will determine the acceptability of the single bolt termination. Mechanical type connectors are not generally considered acceptable for power applications. Bolted connections shall be torque to appropriate levels.

48 03 04. Conduit and Fittings

.1 Conduit shall be rigid steel except as noted in section 48 03 05 below. EMT and Aluminum conduit are not permitted for control or power circuits except as noted in section 48 03 05 below. Galvanizing or corrosion protection is required when conduit will be placed in a known corrosive environment or where it will be exposed to moisture or the elements. Fiberglass conduit is permitted only in tunnels areas where wet conditions persist. It is not permitted for general use or in explosion hazard areas (Class I Div. II or more stringent).

.2 Conduit shall be sized for the number and gauge of the wire contained. The minimum conduit size allowed is 1 inch conduit. NEC requirements for conductor count and fill shall be followed for power cable except where specifically waived by UTHVS.

.3 Pull boxes shall be spaced at appropriate intervals to allow for pulling cable and not exceeding the manufacturers maximum pulling tension or side wall pressures.

.4 Cable minimum bend radius limits shall be observed for all cables during installation and in the final installed condition. “L” boxes shall not be used for shielded power cables, multi-conductor control or instrument cables with more than four conductors of AWG #14 wire or greater.

.5 Conduits and boxes shall be routed and installed clear of traffic areas, equipment access lay-down or removal areas, mechanical equipment subject to high temperatures, movement, or thermal displacement.

.6 Conduit shall be supported at regular intervals in both the vertical and horizontal directions.

.7 Multiple circuit power cables shall have all three phases and ground present in each conduit.

.8 All rigid steel conduit shall be provided with grounding bushings.

.9 Fittings shall be threaded, 2”diameter and below with insulated throats, 2.5” and above with grounding bushings. Compression connectors are permitted where use of threaded fittings are not practical subject to prior written approval by UTHVS. Set screw and die cast type couplings and connectors are not allowed.

48 03 05. Trays

.1 Trays may be used for power, control or instrument cable in areas known to be free from injurious chemical environments significant dirt or debris accumulation, physical, and explosion hazards. Construction of all trays shall be galvanized steel with limited exceptions for MV power cable trays

.2 Power trays shall be ventilated, expanded metal construction or ladder style. Multi-circuit power cables shall have their phase circuits transposed to avoid heating from circulating currents in the tray. In corrosive or damp environments or where dirt accumulation will be heavy, galvanized steel conduit shall be used. Aluminum ladder tray may be used to support MV cable.

.3 Control and Instrument trays may be ventilated or enclosed construction, solid metal construction is preferred. The tray shall be enclosed and covered in areas where dirt accumulation is anticipated. In corrosive, dirty or damp environments galvanized steel conduit should be used. Control and Instrument trays shall not contain AC power cables. Power cables are defined as cables supplying power to motor driven equipment, heaters, transformers etc. or power distribution panels where the loading of the cable may be substantial. Branch circuits serving only control loads with low to negligible circuit loading may exempted from this requirement.

125 VDC and 120/240 VAC control cables should not be placed in with instrument (analog or digital) signal cables if possible. If they do share tray they should be separated by a physical metallic barrier. Control and instrument cable may share tray or conduit for short runs (10 ft or less) when entering equipment or where cable access is limited.

.4 All trays shall be grounded. A continuous 4/0 stranded bare copper conductor shall be run the length of the tray, clamped or bonded to each tray section, and run to building ground directly or through building steel at intervals along the tray run not to exceed 100 lineal feet of tray. This ground cable shall be run external to the tray and not placed in the tray with the electrical cables.

.5 All trays shall be sized for the intended tray loading and supported at regular intervals to building structural elements. Supporting tray from equipment, ductwork, pipes or pipe hangers is not permitted.

48 03 06. Grounding

.1 GENERAL: Station grounding is provided for personnel protection, reduce equipment over-voltage exposure due to lightning, and to control stray voltage caused by static charges and electrical faults. Equipment case or enclosure grounding serves the same purpose. Grounding of major power components serves the purpose of conducting equipment fault currents safely away with very little increase in local contact potential.

McCracken Power Plant has been provided with a continuous ground bus that runs the perimeter of the basement elevation. This ground bus is tied to the Smith Sub grounding system at multiple points. As a preferred practice, all grounds should be run to this bus. An acceptable alternative, equipment and enclosure grounds can be run and bonded to adequately grounded, pre-existing equipment skids, or building steel so long as the maximum ground resistance limitation is observed (see section 1.02.03).

New Facilities shall be provided with a continuous ground bus that runs the perimeter of the basement elevation in the areas where power cable or equipment is located. This ground bus is tied to the building grounding system at multiple points. As a preferred practice, all grounds should be run to this bus. An acceptable alternative, equipment and enclosure grounds can be run and bonded to adequately grounded, pre-existing equipment skids or building steel so long as the maximum ground resistance limitation is observed (see section .2.2.3 below).

McCracken Power plant has been provided with an isolated instrument system ground bus distributed throughout the basement elevation that serves as a high quality ground bus for control cabinet instrumentation system ground. This distributed ground bus is made up of 4/0 600 volt class insulated cable and is brought to ground at one point on the plant continuous perimeter ground bus. This is an instrument ground system and not intended for use to ground enclosures for safety purposes. Safety grounds and instrument grounds are to be kept isolated except where the two systems are joined at the perimeter ground connection.

New Facilities shall be provided with an isolated instrument system ground bus distributed throughout the building elevations that serves as a high quality ground bus for control cabinet instrumentation system ground. This distributed ground bus should be made up of 4/0 600 volt class insulated cable and brought to ground at one point on the plant continuous perimeter ground bus. This is an instrument ground system and not intended for use to ground enclosures for safety purposes. Safety grounds and instrument grounds are to be kept isolated except where the two systems are joined at the perimeter ground connection.

.2 PRACTICES

.2.1 Grounding practices shall reflect IEEE Std. 142 Recommended Practices, and IEEE Std. 665 Guide for Generating Station Grounding.

.2.2 Grounding systems applied shall conform to applicable requirements of the National Electric Safety Code for medium voltage installations (15 and 5 KV) and the NEC for low voltage installations. Where NEC requirements conflict with this specification, this specification shall govern.

.2.3 All connections in the grounding system shall be clamped, exothermic welded, Cad Weld or equivalent. Individual grounding rods connected to the grounding system shall have a measured ground resistance of ten ohms (10 Ω) or less. This measurement may be made by any of the commonly accepted methods for measuring ground rod resistance to earth. Grounding for power equipment power circuit neutral grounding shall be no greater than one tenth ohm (0.1 Ω) measured from the neutral bus to the local ground bus or grounded building structural steel. Primary circuit (13.2 kV system) grounding shall conform to the NESC for potential rise during ground fault. Ground resistance shall be no greater than three ohms (3 Ω) for cabinet and control circuit grounds. Only copper to copper ground connections may be clamped or bolted. All other terminations shall be exothermally welded (Cadweld®ed).

.2.4 All medium voltage and low voltage power apparatus enclosures shall be grounded by two independent paths separately attached to a common ground bus or ground reference. Equipment skids and multiple equipment enclosure line-up shall have two independent 4/0 grounding points. For one of these ground points, individual cabinets and small enclosures (e.g. lighting transformers) can utilize the ground carried back to the supply panel with the power cable as long as this conductor carries no load current and is properly identified as a grounding conductor. Multiple groupings of enclosures can have their equipment grounds daisy chained and do not require that both ground paths be direct to building or station ground so long as the maximum ground resistance limitation is observed. Portions of equipment skid may require separate grounding accommodations where vibration eliminators, nonconductive expansion joints or galvanic protection (isolation points) have been installed. These applications must be referred to the Design authority, UTHVS or the equipment manufacturer to establish the proper grounding design.

.2.5 Design Drawings shall show ground systems, protective conduit sizes, and relative locations. Specifications and drawings shall include detailed requirements of the grounding system. Each design should have a detailed grounding plan that adequately describes the grounding requirements for the enclosure/skid and also the grounding requirements for major powered electrical components contained therein.

.2.6 Grounding systems shall at a minimum conform to applicable requirements of the National Electric Safety Code (NESC) for medium voltage installations (13.2 and 5 kV) and the NEC for low voltage installations. Where NEC requirements conflict with this Standard, this Standard shall govern.

.2.7 Where an existing ground bus system is provided, equipment grounds shall be brought to this system at the nearest point and attached via bolted connection or bonding (McCracken Power Plant basement elevation). Where a ground bus has not been installed, equipment grounds shall be brought to the nearest ground point which may be a ground cable, ground node or grounded building steel.

.2.8 A ground bus shall be provided in any room or area where electrical power equipment (switchgear, motors, transformers etc.) are congregated. The grounding bus shall be continuous and traverse the perimeter of the room or area. It shall be bonded to structural steel and any existing ground busses or grounding systems in the vicinity. The bus shall be fabricated out of minimum 4 X ¼ inch electrical grade copper bar stock. Ground bus joints shall be bolted in a 4 bolt pattern or brazed. If the area extends beyond the foundation line of the plant, ground rods shall be driven at 20 foot intervals (or at alternate grid intersection points along the perimeter and bonded to the ground bus using bare 4/0 solid or 4/0 7 stranded copper cable. Self-standing structures with a 10,000 square foot footprint or greater containing electrical power equipment shall be provided with a ground mat made up of bare 4/0 solid copper cable maximum10 foot spaced in a grid pattern with all joints bonded together and with 4/0 bare copper risers bonded to structure steel and brought above grade to the building ground bus at two or more independent locations, preferably at extreme opposite ends of the ground mat. Smaller structures and all structures with conductive walls or architectural features shall be provided with perimeter grounds bonded to the building ground system and attached via bare 4/0 copper ground cables to ground rods spaced a maximum of 20 foot apart along the perimeter.

.2.9 Grounding cable shall be bare 4/0 copper. Solid conductor 4/0 cable shall be used for buried installations, in locations subject to chemical attack or persistently damp conditions, and to ground permanent structures. Stranded 4/0 7 conductor) may be used with the written approval of UTHVS as an alternative. 4/0 19 strand cable is acceptable above grade for supported ground cable runs in or on trays or structures and where the ground cable is likely to need to be removed for equipment maintenance or replacement and corrosion is not expected to be a concern.

.2.10 Conductor and insulation when specified shall conform to the following requirements:

.10.1 4/0 bare solid conductor shall be used in applications where the conductor is placed below grade or in a corrosive environment.

.10.2 4/0 bare medium stranded (7 conductor) may be used in lieu of solid conductor in below grade applications and in mildly corrosive environments, and where conductor flexibility is a consideration.

.10.3 4/0 bare high stranding (up to 19 strands) is permitted in all above grade applications where exposure to corrosives is not a concern.

.10.4 All 4/0 bare copper ground cables shall be properly supported:

Solid:	supported at 4 foot maximum spacing
Medium stranding:	supported at 3 foot maximum spacing
High stranding:	supported at 2 foot maximum spacing

.10.5 Ground cables may be required to be insulated based on their use.

Transformer and generator neutrals connected to neutral resistors or reactors to limit ground fault currents must be insulated. Cable insulation shall be line-to-line voltage rated. Ground cables running from the Grounding resistor/reactor and station ground shall be bare 4/0 copper unless specified differently in the design.

.10.6 4/0 ground cables run in conduit or tray with feeder cables shall be insulated to avoid the possibility of arcing from stray ground currents during a power system ground fault. The insulation system required in this application is 600 volt class.

.10.7 All control panel and instrument cabinet instrument signal grounds (high quality grounding requirements) will be grounded to the nearest instrument grounding bus. In remote areas where instrument grounds do not exist, they must be installed by the contractor under the guidance of the Utilities High Voltage Shop.

.10.8 All remote electrical equipment, temporary service switches and outlets are to be grounded. Power panel branch circuits powering duplex outlets shall not be supplied through GFI or ACFI at the source but, if a GFI outlet is required, have the GFI local to or integral with the local service connection or outlet.

48 04 00 MISCELLANEOUS SYSTEMS

48 04 01. DC System

.1 The Plant DC system is rated 125 VDC and is operated ungrounded.

.2 The DC system must be supplied with ground detection and equipped to alarm off nominal voltage, ground, charger failure and loss of AC power to the charger.

.3 DC system protection shall be provided either by selectively applied Fuses or Circuit breakers. Protection is designed to isolate and eliminate faults. Battery and main distribution circuit fuses and breakers shall be sized to accommodate the short circuit duty of the system. The Battery shall power the DC system through a circuit breaker or fuse rated to ride through all DC system load faults, distribution system cabinet faults, and charger faults, and open only for a sustained fault condition on the battery leads and their connection to the distribution panels and chargers.

.4 DC system loads shall be restricted to loads required for the safe and reliable operation of the power system. This includes any circuits, loads or devices requiring uninterrupted power availability during facility AC transients or loss. Examples include switchgear control, some motor operated valves, critical instrument and control inverters and emergency lubricating oil systems.

.5 The normal source of power to DC loads shall be the battery charger, with the battery receiving a float charge. In critical applications the University may require redundant battery chargers aligned in a primary and backup configuration. Switching may be accomplished with a transfer switch (not preferred) or through the use of output isolation devices in each charger. An acceptable alternative to two permanently installed chargers is a crosstie to another battery system or a provision to attach a temporary charger.

.6 The battery is the principal source of DC power to the DC system. The system control, monitoring, and provisions for maintenance and protection shall reflect this.

.7 DC System loads shall not require a battery tap, but shall be designed to operate at full battery voltage under normal and equalize voltage conditions. The use of low voltage control devices with series resistors is discouraged with the exception of indicating lamps that require series resistors for circuit reliability reasons.

.8 Surge or transient suppression schemes that can provide a short circuit path between battery positive and negative or from battery positive and negative to ground shall be fused.

.9 All circuit alarming and monitoring devices connected to the DC system shall be fused.

.10 Central DC system batteries shall be of the Substation type rechargeable wet cell design. They shall have a 20 year service life or better and be contained in transparent jars designed to facilitate the inspection of the battery internals. The Jar size (number of individual cells contained) shall be limited to what can be managed for replacement by two persons. The battery cells shall be housed in a suitably ventilated, lockable enclosure. The selection of battery technology shall appropriately reflect the service requirements and the ratings and limitations of the powered equipment.

48 04 02. Annunciators

.1 Local annunciators and remote annunciators shall be equipped with identical displays. All annunciators and remote annunciators shall be fully supervised, and annunciator systems shall be self-monitoring. The exact annunciator sequence for acknowledgement, test and reset will be determined by Utilities UTHVS for the specific design application.

.2 Annunciator power shall be supplied from the facility 125 VDC system. The annunciator system shall be designed to operate on a 125 VDC ungrounded system and be able to handle the transients common to such a system caused by the operation of electromechanical devices on that system and ambient radiated and conducted EMI emissions. Contact whetting may be off the 125 VDC system or an annunciator system generated source of voltage; 100 VDC or higher. The system shall be designed to recognize a contact closure or opening as the alarm condition.

Annunciation may signal critical system abnormal conditions such as failures and trips, conditions requiring prompt maintenance and conditions requiring routine maintenance follow-up or no immediate action (system status). The Annunciator system shall be designed to provide remote access to system and alarm point status as well as marshal alarm points into at least three categories of alarm for Utilities’ use in dispatching personnel for follow-up.

Audible alarms shall be provided only if expressly required by UTHVS. Generally, audible alarming for facilities having a central or remote control station location is not desired because of the nuisance. The same is true for visual indication (strobe lights).

48 04 03. Lighting

.1 The lighting design shall provide for both task and access/egress lighting.

.2 Task lighting shall be at illumination levels appropriate for reading labels, metering, test instruments, and written instructions.

.3 Access/Egress lighting levels shall be adequate to insure that personnel gaining access to and traversing or leaving plant areas can move safely and efficiently without concern for obstacles, tripping and bumping hazards.

48 05 00 WORK PRACTICES

All work performed in and for the McCracken Power Plant, central chiller and central steam generation facilities, and Allied Facilities shall be strictly controlled. These are operating facilities. As such, removal of equipment from service, starting, and operating equipment, connecting temporary loads, selection and assignment of power feeds, storage of construction materials, supplies, chemicals, and tools are under the control and at the discretion of Utility Management, Plant Operations, and Plant Maintenance staff.

All work shall be performed in accordance with approved drawings.

All work shall conform to the plant safety rules, processes and procedures. No work shall be commenced without the approval of the Power Plant management. Pre-job briefing of work crews is mandatory at the beginning of every shift. It is required that the contractor remains informed of the operating condition of the facility and provide continuous supervision of construction workers. Work space cleanliness shall be observed at all times. Leaks and spills shall be contained and cleaned up promptly. Waste materials shall be placed in suitable containers and removed at the end of every shift or work period.

All work space shall be returned to a clean and safe configuration at the end of the work shift or work period

48 05 01. Drawing System, Software and Firmware Control, Change Control, Labeling

.1 An engineered schematic design and vendor shop drawings must be submitted and approved by UTHVS before manufacturing and shipment is authorized. In addition, the University may also elect approval by inspection at manufacturer's plant before manufacturing and before shipment are authorized.

.2 Drawings submitted as “Construction” drawings shall be provided in reproducible but not alterable form for “record” as well as in native revisable format. The revisable format required for compatibility with the University CAD system is the current revision of AUTOCAD.

.3 Component and system software, firmware and configuration files shall also be provided in hard copy and or electronic media form as part of the “construction” package.

.4 Facilities Operations and Development and UTHVS require that complete and up to date schematic and point-to-point wiring diagrams and service manuals be furnished by the contractor as a part of his final submittal of Service and Instruction Manuals for the project. This information shall be prepared specifically for each component and system prior to construction and included in the project construction documentation (hardcopy and electronic).

.5 As the project progresses through the construction and commissioning process, an up to date marked up set of drawings shall be kept at site in a secure location under the control of the electrical contractor, prime contractor, or commissioning authority to serve as the Record Drawing Set for the project. Mark-ups to these drawings shall include all changes to the original design as well as a record of all changes and additions made to the design by construction contractor to accommodate interferences and as found conditions. These mark-ups shall be performed by qualified personnel, be complete and reflect good drafting practice. At the completion of the project, these marked up drawings shall be submitted to the original design entity for review and permanent incorporation onto project record drawings. These record drawings shall be provided within <u>60 days after (Temporary or Permanent/final) Certificate of Occupancy</u>. At no time shall the university be without up to date marked-up drawings for the project. Usable and complete copies of project as-built’s shall be made prior to removing the original marked-up drawings from site, and retained at site for use by the University engineering and maintenance personnel until the final record drawings can be issued and distributed for use.

.6 Facilities Operations and Development and UTHVS require that complete and up to date software and firmware, component configuration files, and source code where applicable be furnished by the contractor as a part of his final submittal for the project within 30 days of project completion. This information shall be prepared specifically for each programmable or configurable component and system included in the project.

.7 Labeling

.7.1 The Contractor, at the time of installation, shall label all major power components using terminology acceptable to UTHVS. Equipment labels shall provide the Name and function of the equipment as well as its power source. When the equipment is made up of two or more separately identifiable devices, sections, or compartments, these too shall be individually labeled. Nomenclature used on the labels shall be consistent with that used on the associated drawings, O&M documents and training materials. All labels identifying major equipment shall be readable from a distance of six feet. All labels providing instruction or used for the safe operation of major equipment shall be readable from a distance of three feet.

.7.2 Control devices such as control switches, relays, displays and instruments shown on One Lines, schematics, interconnection wiring diagrams etc. shall be labeled in nomenclature consistent with that used on the drawings.

.7.3 Labeling applied for the purposes of Operator safety, equipment protection and system operation considerations is Owner specified and may be applied by the Contractor based on contract documents (drawings or specifications) or may be applied upon construction completion by the Owner or the owner's representative. Regardless, labeling shall be completed prior to release of equipment and systems to Utilities for operation. Refer to Utilities internal procedures for Arc Flash Hazard labeling standards.

48 05 02. General Material and Contractor Requirements

.1 The Contractor shall specify only Underwriter's Laboratories listed equipment, assemblies, and materials when such items are available and technically acceptable to the design. The equipment and materials shall be installed in accordance with its listing. Equipment and materials shall be selected from a pre-approved Vendor list when available, and subject to UTHVS approval.

.2 Contractors submitting proposals to provide electrical design or construction services shall be required to demonstrate adequate competency, and recent relevant work history. This requirement applies to the contractor's supervision and work force as well as to subcontractors, their supervision and work force. Work experience, personnel credentials and work references shall be submitted in writing at the request of UTHVS for their review and approval. This requirement applies to all subcontractors as well. No electrical contractors shall be permitted to work on power plant or related facilities that have not established a verifiable record of quality of workmanship, safety and reliability.

48 06 00 SCHEDULES

48 06 01. Schedules (McCracken PP and Smith Sub)

The following orientations between power supply bus and electrically powered equipment shall be observed without exception. Control power and communication based control system power orientation shall reflect this orientation or be supplied from the Plant UPS.

.1 400 BUS ORIENTATION:

.1.1 Bus 400 orientated busses and feeders are:

- 13.2 KV Bus 401
- 13.2 KV Feeder to 480 Volt Unit Sub 2 and unit Sub 3 [T2, T3]
- 13.2 KV Feeder to 480 Volt Unit Sub 5 [T 5]
- 13.2 / 4 KV Transformer T1400 (North)
- 4160 V Bus 1400, Chiller Bus 89
- FD Fan bus 1401
- Smith Sub 480 V MCC. 2

.1.2 Bus 400 Associated Loads are:

- Boiler # 1
- Boiler # 3
- Boiler # 8 Future
- Chiller # 1
- Chiller # 2
- Chiller # 3
- Chiller # 5 Future
- Chiller # 8
- Chiller # 9
- Chiller # 10)

.2 600 BUS ORIENTATION:

.2.1 Bus 600 orientated busses and feeders are:

- 13.2 KV Bus 601
- 13.2 KV Feeder to 480 Volt Unit Sub 1 and unit Sub 4 [T1, T4]
- 13.2 / 4 KV Transformer T1600 (South)
- 4160 V Bus 1600, Chiller Bus 67
- FD Fan bus 1601
- Smith Sub 480 V MCC. 4

.2.2 Bus 600 Associated Loads are:

- Boiler # 5
- Boiler # 6
- Boiler # 7
- Chiller # 4
- Chiller # 6
- Chiller # 7

Bus and equipment power dependency schedules for Allied facilities and central Chiller Plants are unique to those facilities.

48 06 02. Schedules (South Campus Central Chiller Plant)

.1 BUS 100 C

5 kV Transformer 1100C
575 V Unit Sub 1A

575 V Unit Sub 3A (future)
Chiller # 1
Chiller # 2
Chiller # 3
Chiller # 4
Chiller # 7
Chiller # 8
Chiller # 9 (future)
Chiller # 10 (future)

.2 BUS 200 C

5 kV Transformer 1200C
575 V Unit Sub 1B
575 V Unit Sub 2A
Chiller # 1
Chiller # 2
Chiller # 5
Chiller # 6
Chiller # 7
Chiller # 8
Chiller # 11 (future)
Chiller # 12 (future)

.3 BUS 300 C

5 kV Transformer 1300C
575 V Unit Sub 2B
575 V Unit Sub 3B (future)
Chiller # 3
Chiller # 4
Chiller # 5
Chiller # 6
Chiller # 9 (future)
Chiller # 10 (future)
Chiller # 11 (future)
Chiller # 12 (future)

.4 Bus orientations for auxiliary components have their power orientation options aligned with the orientation options of the Chiller drives.

.5 Standby Power System alignment is to Bus 200C as is the Standby feed from West Campus Substation.

48 06 03. Schedules (East Regional Chilled Water Plant)

.1 PRIMARY SWITCH A (CKT 405)

5 kV Transformer TA powering Bus A
575 V Unit Sub Transformer T1A powering Bus 1A
Chiller # 1A
Chiller # 1B
Chiller # 2A
Chiller # 2B
Chiller # 3A
Chiller # 3B

Via 5 kV Tie

Chiller # 4A
Chiller # 4B
Chiller # 5A
Chiller # 5B
Chiller # 6A (Future)
Chiller # 6B (Future)

.2 PRIMARY SWITCH B (CKT 605)

5 kV Transformer TB powering Bus B
575 V Unit Sub Transformer T1B powering Bus 1B
Chiller # 4A
Chiller # 4B
Chiller # 5A
Chiller # 5B
Chiller # 6A (Future)
Chiller # 6B (Future)

Via 5 kV Tie

Chiller # 1A
Chiller # 1B
Chiller # 2A
Chiller # 2B
Chiller # 3A
Chiller # 3B

.3 Bus orientations for auxiliary components have their power orientation options aligned with the orientation options of the Chiller drives.

.4 A third feeder, CKT 505 is aligned to serve as back-up to Primary Switches A and B.

The assignment of motive power, control and instrumentation shall conform to the above described approach for all upgrades, expansions and modifications. Where facilities have UPS supplied busses for low voltage critical controls, critical feeds shall reflect the basic design approach given above for a division of power dependencies so as to avoid losing more than a portion of the powered equipment from a single power source failure. UPS Standby AC sources should be chosen to appropriately address the sustained loss of the UPS normal power, usually a battery/battery charger.

New construction designed to meet redundancy requirements shall have its major equipment motive power and control power dependencies defined and arranged at the Schematic Design stage to support those redundancy requirements.

48 08 00 TRAINING/TESTING AND COMMISSIONING

48 08 01. Training

.1 Operator training for routine operation of electrical systems or equipment shall be provided. Training requirements shall be set by the University on a case by case basis. Such training shall establish minimum training hours per shift, of on-site instruction for the daily operation of the system, to be attended by University's designated Operations personnel. All training shall be scheduled by the contractor in coordination with the University's Facilities Operations and

Development, Training Officer, and his designated representatives. Training sessions may be taped for future reference and training by the University.

.2 In addition to the warranty for labor and materials as specified in General Terms and Conditions: The vendor shall at the request of the University, provide additional technical on-site support for the system during warranty. All support shall be at the request of the University's Director of Utilities or designated representatives.

.3 The University desires to become self-sufficient and skilled to the point of being able to perform regular preventive maintenance, annual system inspections, remedial maintenance, and small renovations. In addition to the above Training for Operation, and Additional Support During Warranty, the design authority shall evaluate the following Training for System Maintenance categories and OEM manufacturer's standards and establish training expectations in the contract documents for:

.3.1 OEM hardware tools and documentation

.3.2 OEM software tools and documentation

.3.3 OEM training, at the University's FOD Training Center, on the use of the above hardware and software tools, and OEM certificate of "Authorized Warranty Service Technician" or equivalent. All training and diagnostics shall be identical to that as provided and available to the factory authorized service representatives. The training shall allow the University to perform all maintenance and inspection functions. The hardware tools shall include EEPROM programmers using industry standard IBM-compatible desktop PC's. The software tools shall perform on industry standard IBM-compatible desktop PC's, using industry standard MS-DOS or MS-Windows operating systems. The training shall be conducted by the manufacturer's trainers, and shall include classroom hands-on training with instructor and travel. All Training for System Maintenance shall be coordinated with the University's FOD Training Officer and shall accommodate multiple shifts of maintenance personnel.

.3.4 The system, devices, and applications, along with OEM training of the University's Operations personnel, shall allow the University to perform the periodic inspection of the systems and equipment provided.

.3.5 UTHVS personnel may be assigned to commissioning, check-out and startup support roles for the express purpose of training and familiarization on systems and equipment.

48 08 02. Testing

.1 FACTORY TESTING: Factory testing for major equipment and integrated systems shall demonstrate design compliance to procurement and functional specifications. It shall be conducted to appropriate industry standards and include third party testing and verification. The option for Owner acceptance by participation in the testing or through a review of the testing results shall be made available with a minimum of two weeks written notice prior to planned commencement of testing.

.2 INSTALLATION QC TESTING: The contractor shall supply appropriate technically competent support personnel to monitor workmanship and completeness. This shall involve in-line work inspection or audit inspection with rigorous corrective action, follow up and closure on non-conforming work products and methods. Tests and inspections shall include OSU Standards compliance and compliance to good industry practices. Instrument calibration and set-point verification shall be included in the contractors test and inspection planning and execution.

The contractor shall supply appropriate technically competent support personnel to test and inspect installations for fitness for service in accordance with Building Design Standards and NETA guidelines.

Testing shall be performed to demonstrate fitness for service of all components. A representative from the FOD Utilities High Voltage Shop (UTHVS)[HA1] shall witness the testing. Copies of test results shall be provided to FOD through Project Captain.

.3 POST INSTALLATION TESTING: The contractor shall supply appropriate technically competent support personnel to conduct and support a thorough pre-operational testing of all installed systems and components for all modes of operation in accordance with Building Design Standards and NETA guidelines. Testing shall include equipment controls, protective relays and safety interlocks.

.4 SYSTEM FUNCTIONAL TESTING: All systems shall be tested to demonstrate their ability to function as required over the full limits of their normal operational range and for any emergency range as called for in the system design. This testing shall be conducted with the systems and associated equipment installed and operating in their normal mounted orientation, settings and conditions of power supply and environment. This testing may be conducted in an integrated fashion with all system interfaced as designed or may be done piecemeal (overlapping) in a manner that demonstrates acceptable functionality of all interfaces, shared functions and dependencies.

.5 INTERLOCK VERIFICATION TESTING: Once all construction has been completed and all system installation and construction testing completed, the FOD or their appointed agent shall conduct testing designed to validate the proper operation of all system permissives, trips, critical sequences, operator HMI functions and annunciations. An independent testing Service (ITS) may be contracted to work in conjunction with the equipment suppliers' representatives to check out and startup LV switchgear, systems and equipment. A Relay Check-out Organization (RCO), working under direct engineering level supervision is generally required to perform checkout and startup of MV switchgear, systems and equipment.

.6 CERTIFICATION PROCESS: The Owner requires all test reports and records as well as individual certifications of any and all test authorities, the manufacturer or independent testing agencies be provided for review and acceptance. These records along with supporting documents showing acceptable resolution of open items, test discrepancies, failures and repair, retesting etc. will serve as the basis for certifying equipment for service by the Owner.

.7 ACCEPTANCE PROCESS: OSU Utilities, as the recognized authority having jurisdiction (AHJ) for Utility Plant equipment and distribution systems and facilities shall inspect for safe and conformant operation. The inspection shall follow due process and demonstrate due diligence in the review and acceptance of all installations and processes relating to quality, completeness and conformance to applicable Codes and Standards. Acceptance will be granted only after the inspection process has been completed to the AHJ's satisfaction and all documentation has been received, reviewed and accepted.

In the case of nonutility facilities, it is the standing protocol for OSU Utilities to defer to the ODIC for all low voltage inspections. The placement of the ODIC inspection sticker on low voltage switchgear is a requirement for primary service energization and Utilities relies on a successful completion of this inspection as Utilities performs only a cursory "housekeeping" inspection of the low voltage gear and verifies conformance to the BDS DIV 33 requirements that pertain to that main switchgear.

In the case of all Utility Facilities where Utilities is the AHJ, all inspections for both medium and low voltage systems are the responsibility of Utilities. On large projects, this inspection may be conducted for Utilities by an Independent Testing Agent. As noted above, these low voltage designs are not required to conform to the NEC. Hence the placement of an ODIC inspection sticker is not prerequisite to switchgear energization. However, UTHVS will in most cases require the ODIC inspection be present before the equipment is energized. This is to avoid contractor confusion and recognize the participation of ODIC.

Portions of the low voltage installation do however generally conform to the NEC. These portions are typically installations such as 120/208 systems for lighting and the like which are installed to the design documents but use industry installation practices administered by the electrical contractor and QC'd by that organization. From time to time, as a courtesy to OSU, the ODIC inspectors will perform an inspection of these installations and provide an inspection sticker to document that inspection. This sticker is not considered by Utilities to be an inspection based on the University BDS. OSU Utilities relies on the successful completion of the appropriate portions of the electrical checkout out and testing program conducted by Utilities staff and/or the Independent Testing Agent for their release to energize electrical distribution systems and equipment.

.7.1 Tests must be conducted in accordance with University requirements and shall be witnessed by representative(s) of UTHVS

.7.2 Medium and low voltage cable testing shall comply with NETA and AEIC guidelines with the following exceptions:

Hi-pot testing on 133% EPR insulated 13,200 volt system cable shall be a 42,000 volt DC High Pot performed by an approved test instrument witnessed by the UTHVS. The 42,000 volt High Pot test is applied in 7,000 volt intervals of one Min. duration with a 5 minute sustained interval at 42,000 volts. High Pot testing of existing installed primary cables is limited under normal conditions to 10,000 volts This 10,000 volt DC High Pot is applied gradually with a sustained duration at 10,000 volts for five minutes. The 42,000 test shall only be done after pulling, termination and splicing of new cables, but before splicing to the existing cables. A maximum of 10,000 volts dc high pot test shall be applied for all installations after splicing to existing cable.

Hi-pot testing on shielded 133% EPR insulated 4160 volt system cable shall be a 28,000 volt DC High Pot performed by an approved test instrument witnessed by the UTHVS Utility High Voltage Shop. The 28,000 volt High Pot test is applied in 7,000 volt intervals of one Min. duration with a 5 minute sustained interval at 28,000 volts. High Pot testing of existing installed primary cables is limited under normal conditions to 19,000 volts This 19,000 volt DC High Pot is applied gradually with a sustained duration at 19,000 volts for five minutes. The above limits apply to cables without the presence of a surge suppressor.

Hi-pot testing for 600 volt circuits may be elevated to a maximum 2500 VDC 1 minute duration for certain critical control components as identified by Utility High Voltage Services on a case by case basis.

.7.3 Commissioning Plan: The engineer, or commissioning agent, will provide a commissioning plan for all systems and associated devices. The Commissioning plan will include a detailed checklist to commission each item installed by the project. Each item will be commissioned by qualified professionals and factory trained personnel. Each device along with its electrical and process field connections will be field verified end to end. Each item shall be functionally tested to demonstrate the installation meets the design's technical and operational requirements to the satisfaction of The University, Utilities Department.

.7.4 Field calibration records: All transmitters and positioners will be field calibrated by personnel trained in field calibrations. Each calibration will be documented on a calibration sheet. Calibration sheets will have as a minimum: Tag Name, Description, Location, Process variable, Range, Calibrator type and model with last date of certified calibration, and calibration data showing As-Found and As-Left checks. Instrument calibration checks will be 0-25-50-75-100 percent of range recorded on the calibration sheet.

All Protective relays will be field calibrated by personnel trained in field calibrations. Each calibration will be documented on a calibration sheet. Calibration sheets will have as a minimum: Tag Name, Description, Location, and recorded on the calibration sheet.

48 09 00 INSTRUMENTATION & CONTROL FOR MAJOR ELECTRICAL PLANT EQUIPMENT

Note: Refer to 40 90 00 for requirements relating specifically to Process Control and monitoring for fluid systems and components.

48 09 10. Design Requirements for Instrumentation and Control for Power Plant and Auxiliary Equipment

.1 GENERAL: This section addresses the control of major substation and distribution system electrical equipment such as switchgear, large power transformers and auxiliary support systems and equipment such as station battery systems, automatic transfer controls medium and low voltage motor control centers and transfer switches. The requirements contained in this section are to be used in conjunction with the requirements of other BDS DIV 40 and 48 sections giving detail requirements relating to specific equipment and systems and their wiring and physical installation. Included in this section are requirements for controls using solid state and electromechanical relays, programmable logic controllers, motor starters, transfer switches, medium and low voltage switchgear, custom manufactured package systems, 125 v DC systems, power transformers of all sizes.

This section addresses the principal design criteria for the control of this equipment. The instrumentation referred to in this section is the power instrumentation required for the operation , testing and maintenance of this equipment such as ammeters, voltmeters, indicator lights, current transformers, potential transformers, shunts, meters, data acquisition systems etc.

.2 OPERABILITY: Controls shall be designed to address the range of normal and emergency service requirements relating to the equipment and systems being controlled. If controls are limited to manually initiated control functions, they should conform closely to conventions and practices widely used elsewhere for similar systems and equipment. Instrumentation needs to be present (at or near the control station location) to assist the operator in determining the effectiveness of the control actions taken. If the controls are automatic, they should contain features that provide status on the controls, the process and or parameters being controlled. These features should not depend on the same instruments providing the control variable inputs to the automation. Where automation has been applied to supplant manual control, the capability of some basic level of manual override should be provided along with the means for the operator to assess the situation and receive feedback on any manual operations undertaken (example: an E stop with indication, a speed control pot with speed indication).

.3 MAINTAINABILITY: Controls should be designed to facilitate planned maintenance for the systems and equipment being controlled. An example of this would be the inclusion of a manual control station to facilitate draining or filling operations or system post maintenance startup. Automatic controls should be provided with information relating to the availability of system equipment when it has been removed from service for maintenance. LOTO considerations relating to local power disconnects, power source lock-out, etc. must be accommodated.

.4 CONSTRUCTABILITY: Controls must be designed in conformance with the physical constraints of the facility. Control stations, cabinets, panels and compartments must be designed to facilitate cable access and provide adequate areas for orderly field cable marshaling and termination. Since the standards require the use of multi-conductor color coded jacketed and labeled cables with wire sizes in the AWG 10 to 14 for control conductors and AWG 16 for some instrumentation cables, cable management requires careful planning and design.

.5 TESTABILITY: Controls need to be designed to facilitate planned preoperational and post maintenance testing for the systems and equipment being controlled. This may mean designing the controls with built in test modes of operation, or it may simply involve designing the controls to facilitate LOTO depending on system complexity and the various types of testing to be accommodated.

Automatic controls should be provided with information relating to the availability of system equipment when it has been removed from service for maintenance and testing.

.6 HUMAN FACTORS

.6.1 Accessibility: Control stations need to be located where they can be conveniently reached and where they will not be in the way of routine or planned maintenance. Mounting control stations on equipment or in areas where access cold be restricted because of ambient noise, high temperature or a higher than normal risk of steam or water leaks should be avoided.

.6.2 Lighting: Control stations need to have lighting adequate to support the operator actions planned as well as sufficient access and egress lighting. Where task lighting cannot be supplied at high enough levels to accommodate operator needs, displays should be designed with back lighting or the control station should have its own source of task illumination.

.7 HUMAN MACHINE INTERFACE (HMI)

.7.1 Type: The HMI selected should be appropriate to the task being performed. Hard wired controls for simple control actions, touch screens for more complex tasks, and where a visuals or process displays would be helpful, analog displays for displaying rapidly changing parameters, digital where slow moving parameters are involved, where there is a wide range in the variable, or where precision is needed.

.7.2 Information displayed: The information displayed at a control station should be compatible with and adequate for the control actions planned for the station. Information displayed should be organized in a logical manner in relation to the control devices. Clutter should be avoided.

.7.3 Controls available: Control devices available at a control station should be limited to what is required for the intended operations. Main or frequently used controls should be located centrally within the easiest reach of the operator. Less frequently used control should be positioned in their own functional grouping, out of the central control area. Some controls that are not intended for normal control operations such as E-stops, or devices that would cause serious disruption if inadvertently operated should be placed in an accessible location but away from the more frequented areas of the control station. Functional grouping of controls is preferred. Clutter should be avoided. Guards should be provided or the “two independent action” rule should be employed where inadvertent operation could have grave repercussions.

.8 ENVIRONMENT

.8.1 Temperature, Humidity: Apply control components and locate control stations where they will not be exposed to adverse ambient temperatures, humidity and dew point cycling if at all possible. Enclosures should be designed with cabinet heaters for high humidity environments and should have a NEMA enclosure design consistent with the environment.

.8.2 Water hazards: Where water hazards could exist, control station equipment should be water tight or resistant. Care must be taken to insure that cable access is from below or low to the side. Where moisture intrusion is considered a risk, the control cabinet should be equipped with a bottom drain point that is screened to exclude insects and rodents.

.8.3 Proximate hazards: Locate control stations only where there is minimal risk of exposure to proximal hazards such as steam leaks, rupture diaphragms, safety valves, electrical Arc Flash, falling or tripping. Access to control stations should not involve climbing or the use of any temporary structures, ladders or scaffolding.

.9 FAILURE MODES AND EFFECTS ANALYSIS

.9.1 Design practices: The Design shall include a formal control plan that identifies and addresses all the key design features that define or impact on the design of the control system.

Discussion of intended operation:

- Automatic features
- Manual features
- HMI types and locations
- Design features
- Power Dependency
- Failure modes
- Tripping
- Interlocking
- Alarming

The design of the controls should observe to the extent practicable established and standardized control practices so as to benefit from past experience and lessons learned. The application of control components should be standardized around a limited set of approved components and manufacturer product lines to simplify spare parts stocking and training. Control circuit designs should be replicate between similar pieces of electrical power equipment and between similar systems.

.9.2 Failure modes

Control circuit failure modes should be identified and evaluated. Predominant failure modes should be accommodated by designing adequate annunciation and or indication to assure that the operator is aware of the failure and can take appropriate operator action. The impact of individual component failures should be minimized by applying the component in a manner so that the dominant failure mechanism would have the least significant impact on the system operation or potential for equipment damage.

Power dependencies should be identified and evaluated. Power sources should be selected to conform to the overall power dependencies of the prime movers in the system. The choice of control voltage should be based on the characteristics of the control power sources available.

Battery backed 125 vdc is the most reliable source but designs powered from battery backed 125 vdc should be energize to actuate, normally de-energized and be capable of being de-energized with critical systems in operation without the controlled system tripping. 125 vdc is the preferred source for electromechanical controls that must operate under blackout conditions and when system ac power is lost.

120 vac inverter backed control is the preferred power for ac powered electronic controls and instrumentation that must remain in service independent of the availability of system ac power. Inverter use should be restricted to this type of load and under no condition should an inverted backed ac source power motors or load with significant startup transients with the possible exception of switching type power supplies. Inverter sources are inherently current limiting, so the exposure of these circuits to shorts or grounds is a concern. This concern can be mitigated somewhat by providing a solid state transfer switch to an alternate source of ac with greater fault support capacity, and the appropriate selection of inverter output distribution panel circuit breakers. If electromechanical control devices such as relays and solenoids are powered off an inverter backed source, coil suppression is recommended.

Diesel backed ac is the preferred source for controls that can sustain a momentary or short term loss of ac power and still function acceptably once power is restored. In the case of Emergency Diesel Generator power, restoration usually occurs in around ten (10) seconds. In the case of Standby generators, restoration may take as long as a minute or more.

.9.3 System effects

The system effects of a control system or component failure need to be assessed and addressed in the control design. Control failure modes must be compatible with system and component preferred failure states. A fail closed air operated valve will generally require a solenoid and control circuit design where a solenoid coil or control power failure will result in the valve closure as well. A circuit breaker control which is designed to open and close the breaker is generally designed to fail as is. Safety considerations are another factor to be considered in control design. A failure in the trip circuit of a circuit breaker should remove power to both the close and trip portions of the breaker control circuits. This is a useful safety feature to avoid the possibility of closing a breaker whose trip circuit has already failed. Likewise, powering the closed indication of a circuit breaker by having the closed indicator light powered from the trip circuit through the trip coil of the breaker insures that the loss of closed indication on breaker closing will alert the operator to a possible abnormal situation with the breaker.

Note:
Charging power for an electrically charged circuit breaker should never be drawn from the trip circuit of the breaker if the charging motor is designed to go through its charging cycle after the breaker closes. This introduces a failure mode that would in effect be the equivalent of closing a CB with a failed trip circuit.

.9.4 Situational awareness

Particular care must be taken to insure that the instrumentation provided with controls provides adequate situational awareness for the operator to assess the effectiveness of automatic controls and to monitor manual control actions. Instruments and displays provided for monitoring the condition of the controlled system generally should not share signals with the instruments controlling the system. As a general rule instrumentation that the automatic control function relies upon for its control action should be independent of the instrumentation relied upon to determine effectiveness of the automatic controls or depended upon to take manual control action.

.9.5 Recovery and use of lower tier controls

It is customary to provide echelon control to complex systems. Echelon control involves applying controls in layers. A system may have a master control that provides system level commands from a system operator or automatic dispatch control. This Master control may control only that one system or a variety of systems to coordinate their individual automatic operations. A system then may have subsystems that have their own automation and so on. Each of these layers may have both automatic and manual control modes.

As a general rule, a system or group of systems that share an echelon control architecture should have their controls designed to allow higher echelon automation to automatically detect the loss of lower echelon automation and take appropriate compensatory action to address system control needs including operator situational awareness and appropriate adjustment of lower tier operating modes, set points and limits.

Echelon controls should not be applied where loss of a subsystem’s automation will result in a wholesale loss of system automation and wholesale reversion to manual control. Loss of automatic control at any level should always be readily recoverable by skilled operator action or result in placing the subsystem in a safe condition or operational mode with minimum disruption to the remainder of the control system.

48 09 20. General Requirements for Control and Instrumentation Circuits and Enclosures

Note: Refer to 40 90 00 for requirements relating specifically to Process Control and monitoring for fluid systems and components.

.1 AC and DC control circuits shall not be run in the same control cable. Low level instrument cables shall not be run in conduit or in tray shared by power, or 110 vac, 125 vdc control cables.

.2 All control panel, control cabinet and switchgear wiring No. 10 AWG and smaller shall be landed on OSU Utility approved terminal blocks. Stranded wire termination shall be with approved ring type solid un-insulated barrel design. No more than two wires shall be terminated on any screw type terminal point. Thread on wire nuts or split bolt connectors are not permitted. In-line control wire splices are not acceptable for new installations.

.3 Control cable butt splicing for modifications or upgrades is permitted with prior approval of UTHVS. Butt splices in control and instrument cable conductors shall be made with the appropriate sized butt connectors and insulated with electrical tape or approved heat shrink tubing with appropriate shimming.

.4 All control components are to be secured firmly to their supporting structures. Self-adhesive fasteners and thermo plastic fasteners are not acceptable.

.5 All cables and wiring that is field run to control panels or equipment enclosures shall be terminated on UTHVS approved terminal blocks. In general, termination of jacketed multi-conductor color coded cables #14 AWG and larger directly onto high density terminal blocks or termination modules is not acceptable.

Landing field wires directly on serviceable components is not permitted. Small local control stations may be excluded from this requirement. Termination of stranded wire to high density terminal blocks or terminal blocks that employ pressure type terminal clamping shall be via ferule. In instances where the use of ferrules is not practical, the wires are to be stripped to allow enough exposed conductor to permit full penetration into the terminal and tinned to form a solid conductor. Terminations made to terminal blocks that employ a pressure type terminal shall have conductor insulation extend up to the block and not show exposed conductor. High density screw type terminations, where permitted, shall employ insulated lugs where necessary to maintain adequate electrical clearance between adjacent terminations

.6 All current transformer secondary circuits shall be wired through shorting type terminal blocks.

.7 All control cabinet and enclosure control wiring shall be dressed neatly, bundled and laced. Heavy duty UV resistant tie-wraps are an acceptable method of lacing. Panduit may be used to organize and support control wiring in high density applications where expressly approved by UTHVS. No field cables shall be run along with cabinet wiring in Panduit and field cable jackets shall not be stripped back and the conductors run with cabinet wiring in Panduit. Cable and wire bundles shall be supported at regular intervals. Generally lacing to cabinet mounted tie points is an acceptable approach. Self-adhesive tie-downs are not acceptable. All control cable bundles shall be routed away from power circuits, crossing only at right angles.

.8 Every reasonable effort shall be made to separate 480 and 575 V equipment and circuits from control wiring. 480 V components and wiring shall be mounted separate from control components and provided separate access. Control components accessed for operations or maintenance shall not share the same enclosure with the power switching components or exposed power wiring without adequate protection from accidental contact by personnel or tools.

.9 In instances where low voltage (125 volts or less) control components and wiring must be housed in a common enclosure with power circuits (220 volts or above), exposed power circuit conductor surfaces shall be provided with a barrier to reduce the likelihood of accidental shock or burn.

.10 The preferred configuration for the separation of power and control is to have the power cabinet separate and to the side of the control cabinet. If this is not possible, the power cabinet and components should be mounted above rather than below the control cabinet or panel. Points of interface between control and power circuits such as control transformers shall be located with the power equipment. Secondary (control) fuses shall be located in the control area, not on the control transformer or in the power area.

.11 Adequate consideration shall be given to the operating temperature environment for temperature sensitive components. Electronics shall be mounted below the mid-plane of their housing enclosure. Sources of heat generation such as transformers and power supplies shall be mounted above, not under temperature sensitive equipment and enclosures shall be sized to operate closed without forced ventilation or the need for fans or filters. A maximum of 10° C temperature rise is allowed on enclosures for equipment rated 60° C or less. This shall be verified by heat run test or analysis and the rise shall be measured at the top of the enclosure.

.12 All control cables entering control cabinets and enclosures shall be secured by their jackets to a cabinet or enclosure support to provide a strain relief for the cable wire terminations. Field cables entering a cabinet shall not be bundled so as to obscure cable identifying labels. Cable identification labels shall be visible without removing equipment or disturbing the cable.

.13 Control wiring traversing hinges or other forms of flexible constructions shall be high-stranded and shall traverse the area of bending normal to the plane of rotation so as to impart a twisting rather than a bending motion to the cable or wire bundle.

.14 GENERAL WIRING REQUIREMENTS for Control Circuits
(See section 48 03 03)

.15 INSTRUMENTATION WIRING (300 volt class and below)

.15.1 Use of No. 16 AWG XHHW2 for all analog instrument circuit wiring (<50 V) is required.

.15.2 Use of manufacturers approved plenum rated cable for all communications and digitally based signal cables is required.

48 11 00 GENERATION (BULK, PEAKING, AND STANDBY)

(Reserved for future generating capacity additions)

48 19 00 POWER PLANT ELECTRICAL EQUIPMENT

(Reserved for Equipment Application Specifications)

48 19 01. Fusing and protective Devices (future)

48 19 02. Generic Specifications (future)

.1 MOTORS

.2 TRANSFORMERS

.3 SWITCHGEAR

.4 DISTRIBUTION PANELS

.5 VFDs

.6 SOFT STARTERS

.7 MV MCCs

.8 IINVERTERS

.9 CONTROL PANELS

.10 MOTOR CONTROL CENTERS AND LV STARTERS

Note: While this section of DIV 48 remains a work in progress, UTHVS maintains a supplemental Planning and Design Guide. This guide contains engineering guidance relevant to the above equipment design and application.

48 19 03. Models and Studies

The University (UTHVS) maintains current fault, coordination and Arc Fault studies for Main substations, the MV distribution System and all central facilities. These models and studies are available to Engineers performing work on the MV system and any of the Utility operated and maintained facilities. Any Engineered changes to these facilities or the MV system of sufficient scope to impact any of these models or studies will require the studies or models be updated by the Engineer. Models are kept current on a periodic basis by UTHVS and are updated as needed for small changes by UTHVS.

BUILDING AUTOMATION SYSTEM
PART 1 GENERAL

***Commentary:** Division 23 lists existing University Control Centers. This Appendix applies to the Columbus Campus – Academics and Research -- FOD Control Center. This Appendix also applies to all other Control Centers [to all building automation systems in all University buildings on all University campuses and locations], except where noted otherwise in the BDS or hereinafter. For OSUMC systems, see the separate OSUMC Appendix A - WMC. For Student Life, see the separate Student Life Appendix A - SL. The individual Control Centers have the authority to amend the requirements of this Appendix with the approval of the University Engineer. References to the FOD Control Center, or to the FOD Building Automation Department, or to FOD should be interpreted as meaning the appropriate Control Center for the given project. Review with the OSU Project Manager.*

1.01 SCOPE

A. The intent of this Appendix is to give guidance to the A/E for specifying a Building Automation System for new and renovated buildings. This Appendix may not be applicable to all renovation projects; however, the design approach should be confirmed with the OSU Project Manager and the FOD Building Automation Department. The long term goal is to provide the building with a complete Direct Digital Control (DDC) Temperature Control System to automatically control the operation of the entire Heating, Ventilating and Air Conditioning System and monitor and/or control auxiliary systems as applicable to the project scope of work. The new Building Automation System shall fully integrate into the existing district wide Building Automation BACnet network. The required integration shall include the creation of custom graphics and the compilation and display of all devices and objects on the existing Delta enteliWEB Frontend. All graphic displays will reside on the existing Delta Controls enteliWEB server ~~OWS~~ and be modified accordingly. In addition, the system shall perform the said integration through the use of BACnet over Ethernet or communications (Annex J only). Failure to mention any specific item or device does not relieve the Contractor of the responsibility for installing or integrating such device/peripheral in order to comply with the intent of the Drawings or this Specification.

B. Building Automation System (BAS) Contractor shall provide:

1. A fully integrated and fully programmable BACnet building automation system (BAS), UL listed (UL916 and UL864 If applicable), incorporating direct digital control (DDC) for energy management, equipment monitoring and control, as manufactured by Delta Controls by BCI, Siemens or Automated Logic by Pittsburgh Corporate Branch or an approved equivalent manufacturer. The A/E must submit the proposed "equivalent manufacturer" during the Schematic Design Phase to the OSU Project Manager for approval by the FOD Building Automation Department.

2. A UL864 listing shall be required for all controllers that are utilized in a smoke control sequence and as necessary to meet or exceed all national and local codes. In addition, UL864 devices and non UL864 shall not be permitted on the same network segment unless the devices are separated with a UL864 Ethernet switch. All MS/TP network segments shall be consistent with its UL864 or non UL864 implementation. In other words, there shall not be UL864 product and non UL864 product on the same MS/TP network segment.

2. Necessary conduit, wiring, enclosures, and panels, for all DDC temperature control equipment and devices. Installation shall comply with applicable local and national codes. <u>Top control panel conduit penetrations shall use a gasketed Meyers hub to prevent water infiltration. Old control panels shall be demolished with the old controller turned over to FOD-BAS.</u>

3. All components and control devices necessary to provide a complete and operable DDC system.

4. All final electrical connections to each stand-alone DDC Controller. Connect to 120VAC power as provided by the Division 26 contractor, to be terminated within 5 feet of the DDC Controller. [Note: A/E clearly defines the scope of work for each Prime Contractor in the Contract Documents.]

5. BAS Contractor shall be responsible for all electrical work associated with the BAS control system and as defined In the Contract Documents. This BAS control wiring shall be furnished and installed in accordance with the Electrical requirements as specified in Division 26, the National Electric Code, and all applicable local codes.

6. All Ethernet level devices require surge transient protection and shall be incorporated in design of system to protect electrical components. This includes but is not limited to, Building Controllers, Advanced Application Controllers and operator's workstations. Provide an external protection device listed under UL 1449 with minimum clamping voltage of 130 VRMS and surge current capability of 22,500Amps for all custom fabricated control panels (all main system components (i.e., AHUs, Chillers, Boilers, etc.).

7. All 120V and low voltage electrical control wiring exposed throughout the building shall be run in conduit in accordance with the Electrical requirements as specified in Division 26, the National Electric Code, and all applicable local codes. All low voltage wiring that is concealed in accessible ceilings may be run in plenum rated cable per the National and Local Electrical codes.

8. All 24VAC power required for operation of the BAS shall be by the BAS Contractor and shall be limited to 100 VA per the aforementioned codes. Any 24VAC power link that exceeds the 100 VA rating must be installed in conduit per Division 26 and all applicable codes, regardless of the nature of the installation.

9. BAS Contractor shall provide programming modifications necessary to fine tune sequences during commissioning, through the warranty period of system and for an additional 12 months at no extra cost to The Ohio State University.

C. HVAC Contractor provides:

1. All wells and openings for water and air monitoring devices, temperature sensors, flow switches and alarms furnished by BAS Contractor.

2. Installation of all control valves as per the contract drawings. The HVAC contractor is responsible for the correct installation of any domestic, hot or chilled water control valves and shall seek guidance from the temperature control contractor, as needed.

3. Installation of all dampers and adjacent access doors for smoke; outdoor air, return air, exhaust air, and ventilation dampers.

4. All package unit control panels including but not limited to, factory boiler panels, factory chiller panels, refrigerant monitors and specialty interface modules required for BACnet compliance.

D. Electrical Contractor provides:

1. Electrical Contractor shall provide dedicated 120 volt, 20 amp circuits and circuit breakers from normal and/or emergency power panel for each DDC Controller. Run power circuit within 5 feet of equipment installed and connected by BAS Contractor.

2. Electrical contractor will also provide smoke detector and smoke damper interlock and power wiring for all life safety applications.

E. General Product Description:

1. The building automation system (BAS) shall integrate multiple building functions including equipment supervision and control, alarm management, energy management and historical data collection utilizing the BACnet protocol.

2. The building automation system shall consist of the following:

   a. Stand-alone peer-to-peer Building Controllers with 32 bit processors, a minimum of 2 MB of flash memory and 10 bit A/D converters. BACnet over Ethernet or BACnet over IP connectivity is required for all Building Level and Advanced Application Controllers.

   b. Stand-alone peer-to-peer Advanced Application Controllers with 32 bit processors, a minimum of 1 MB flash memory and 10-bit A/D converters, and must communicate via BACnet MS/TP with a minimum baud rate of 76.8 kbps. The use of ARCNET, LON, proprietary, or any other protocol other than BACnet is strictly prohibited.

      Application Specific Controllers are not permitted at any level within the BAS system. All controllers must be Advanced Application Controllers and BTL listed.

   c. Portable operator's terminal(s) when requested.

   d. Provide seamless interconnection to the existing Delta Controls ~~central graphic workstation~~ enteliWEB server, and build Delta Controls standard and customized graphics displays in accordance with the existing formats utilizing Delta enteliVIZ HTML5 Designer. If the BAS controls contractor is unable to build the graphics displays (FOD Building Automation Department has final say whether or not the displays meet the University Standards) then the BAS controls contractor must sub-contract the displays with Delta Controls BCI at their own expense.

   e. All BACnet intrinsic alarming shall be disabled. All alarms shall reside in the local controller that is physically controlling the mechanical equipment. All alarms shall be setup as individual BACnet event objects, ~~and~~ Support BACnet Event Enrollment, and support Delta Controls Auto Generated Messaging for alarms. Non-Delta controllers must also set up their alarms and auto generated alarm messages at the BBMD level for the local subnet. If the BAS controls contractor is unable to set up the alarms (FOD Building Automation Department has final say whether or not the alarms meet the University Standards) then the BAS controls contractor must sub-contract the setup of the alarms with Delta Controls BCI at the expense of the BAS controls contractor.

3. The system shall be modular in nature and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, Building Controllers, Advanced Application Controllers, expansion modules and operator devices.

4. System architectural design shall eliminate dependence upon any single device for alarm reporting and control execution. Each DDC Controller shall operate independently by performing its own specified control, alarm management, operator I/O and data collection. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices. Alarm management and data collection that requires a single mechanism for user notification or viewing is strictly prohibited. A local outside air temperature reference is required for each facility. If applicable, the sensor must be hardwired to the hot water control panel. The local temperature reference may be shared with other controllers within the local facility. Sharing the outside temperature values between facilities is strictly prohibited unless fail over logic is in place. If the network share fails then the panels have to refer to the local temperature reference for control.

5. All Controllers shall be able to access any data from, or send control commands and alarm reports directly to, any other DDC Controller or combination of controllers on the network without dependence upon a central processing device (peer-to-peer). All Controllers shall also be able to send BACnet events to multiple operator workstations without dependence upon a central processing device.

F. System Lifecycle Support

1. BACnet Field Devices: Manufacturer shall provide product updates for the lifecycle of the installed DDC hardware at no additional cost to the University. Manufacturers shall provide software tools, licensing, and training necessary for the University's field technicians to deploy and install updates. Updates shall include all patches, firmware, and software revisions for the lifecycle of the hardware or until the manufacturer no longer provides support for the product. Updates shall be available to all devices on the existing district wide Building Automation BACnet network so that all facilities with like hardware are running on the same firmware and software revisions. The requirement for these updates includes, but is not limited to, products with embedded OS, PLC's, building level controllers, advanced application controllers, ~~application specific controllers~~,unitary controllers, and component interfaces.

2. Server Frontend Applications, Data Historians, and BACnet Advanced Operator Workstations: Manufacturers shall provide product updates and licensing for the life of the application at no additional cost to the University. Manufacturers shall provide software tools, licensing, and training necessary for the University's field technicians to deploy and install updates. Updates shall include all patches, service packs, security updates, and software revisions. If newly installed hardware is no longer supported by the application, the manufacturer shall upgrade the application to the most current version. If the operating system on the machine running the application has reached the end of its lifecycle (e.g., Windows Server 08R2 or Windows 7), then the manufacturer shall provide software and licensing for the application to run on a modern operating system.

1.02 RELATED WORK

A. Specified elsewhere:

1. _____ - Sequence of Operation
2. _____ - Variable Speed Control
3. _____ - Basic Mechanical Requirements
4. _____ - Motors

5. _____ - HVAC Pumps
6. _____ - Boilers
7. _____ - Chillers
8. _____ - Cooling Tower
9. _____ - Terminal Heat Transfer Units
10. _____ - Air Handling Units
11. _____ - Testing, Adjusting and Balancing
12. _____ - Basic Electrical Materials and Methods
13. _____ - Equipment Wiring

B. Materials furnished by the BAS contractor, but installed by others:

1. BAS Contractor to furnish the following to the Heating, Ventilation and Air Conditioning Contractor for installation by the HVAC contractor:
    a. Control valves and temperature sensor wells for wet systems
    b. Location of all wells and openings for temperature, pressure, and flow sensors for pipe systems
    c. Control dampers for air systems
    d. Variable Frequency Drives
    e. Location of all ducts and openings for temperature, pressure, flow, and humidity sensors for air systems.
2. BAS Contractor to furnish the following network communications to the Building Automation System Manager for installation:
    a. Juniper firewalls and managed Juniper switches
    b. Delta eBMGR-2 (BBMD)

1.03 QUALITY ASSURANCE

A. Materials and equipment shall be the catalogued products of manufacturers regularly engaged in production and installation of automatic temperature control systems and shall be manufacturer's latest standard design that complies with the specification requirements.

B. Install system using competent workers who are fully trained and factory certified in the installation of temperature control equipment. The factory certified diplomas shall be readily available at the request of the owner or A/E engineer.

C. The complete installation and proper operation of the Building Automation Controls System shall include debugging and calibration of each component in the entire system and shall be the single source responsibility of supplier. The BAS must be supplied and installed by the same controls contractor. Only Factory Authorized Distributors will be considered for installation. The letting of separate contracts by the prime HVAC Contractor for the Control System and a separate contract for its installation by a third party installer is strictly prohibited.

D. Supplier shall have an in-place support facility within 50 miles of the site with technical staff, spare parts inventory and all necessary test and diagnostic equipment.

E. All electronic equipment shall conform to the requirements of FCC Regulations, Part 15, Subpart B, Class A, governing radio frequency electromagnetic interference, and be so labeled.

F. BAS shall comply with, and be listed at time of bid for the following Underwriters Laboratories Standards:

1. UL 916 for Energy Management Equipment, per category PAZX for Energy Management Equipment.

2. UL 864 for Control Units for Fire-Protective Signaling Systems, per category UUKL for Smoke Control System Equipment.

G. Design and build all system components to be fault-tolerant.

1. Satisfactory operation without damage at 110% and 85% of rated voltage and at plus 3-Hertz variation in line frequency.

2. Static, transient and short-circuit protection on all inputs and outputs.

3. Protect communication lines against incorrect wiring, static transients and induced magnetic interference.

4. Network-connected devices to be AC-coupled or equivalent so that any single device failure will not disrupt or halt network communication.

5. All Building / System Controllers shall have real time clocks and data file RAM with battery and SRAM backup.

6. All controllers shall be EEPROM, flash driven.

7. The BAS Installer shall have a competent and factory certified Project Manager who is able to answer field questions, is aware of all schedules and schedule changes, and is responsible for the BAS Installer's work and the coordination of their work with all other trades. This Project Manager shall be available for onsite and shall respond to design, programming, and equipment related questions. Failure to provide the above services shall be considered a substantial breach of Contract Documents.

1.04 SUBMITTALS

A. ~~Submit 10 complete sets~~ Electronically submit a complete set of drawings showing the kind of control equipment for each of the various systems and their functions, along with indications on the drawing of all original setpoints and calibration values, and setup parameters, and sequence of operation of the automation system. **These drawings shall be submitted for approval to the A/E and FOD Building Automation Department**, together with a complete brochure describing the equipment and their functions and operation. Include all application software documentation (actual programs or their job-specific flow charts) with DDC system and schedule a review meeting with OSU and the A/E prior to the BAS contractor ordering material.~~at least two weeks before installation and start up.~~

1. Manufacturer's Product Data:

a. All equipment components

2. Shop Drawings:

a. System wiring diagrams with sequence of operation for each system as specified.

b. Submit manufacturer's product information on all hardware items along with descriptive literature for all software programs to show compliance with specifications.

c. System configuration diagram showing all panel types and locations as well as communications network layout and workstations.

B. Where installation procedures, or any part thereof, are required to be in accord with the recommendations of the manufacturer of the material being installed, printed copies of these recommendations shall be furnished to the A/E prior to installation. Installation of the item will not be allowed to proceed until the recommendations are received.

PART 2 PRODUCTS

2.00 BACnet CONFORMANCE

A. The Building Automation System (BAS) contractor shall supply a BACnet (ANSI/ASHRAE 135-2016) compliant system. Each device category and its required compliance are listed below under sections F-H. BACnet compatible systems that employ the use of proprietary 'gateways' (i.e. protocol router/converter) will not be accepted unless otherwise noted.

B. The BACnet system shall be capable of BACnet over Internet Protocol (IP) or BACnet over Ethernet communications. Annex J will be the basis of design for all BACnet/IP devices. All other configurations must be submitted prior to bid, in writing, for final approval by FOD Building Automation Department.

C. The primary Local Area Network (LAN) on the building's subnet shall be based upon the ISO 8802-3 Ethernet standard or BACnet/IP Annex J and will be required for all Building Controllers, System Controllers and Operator Work Stations. The use of MS/TP communications for interconnecting the said devices is strictly prohibited. The installation of all Ethernet wiring, accessories, and connectors shall conform to the ISO standard and/or guidelines identified herein. The connection media shall be Category 6, Unshielded Twisted Pair (UTP) wire. The maximum single network run shall not exceed more than 100 meters. ~~All panels must be home run to the BAS managed building switch.~~ All panels must be home run to either the building's BAS managed Juniper SRX Series firewall (340) or a BAS managed Juniper EX series (2300-C or 3400) building switch that is in turn home run to the before mentioned firewall. (See fig.1 in SEC 2.01 A 2) BAS managed Juniper building switches must be secured in a key-accessed enclosure with an appropriate receptacle to power the equipment located within the enclosure or be placed in a secured MDF/IDF closet. The use of unmanaged switches, hubs, or daisy chaining Ethernet between controllers is prohibited. If a run exceeds 100m, fiber must be used with department approved media converters. All exceptions must be approved by FOD Building Automation Department management.

The BAS system may utilize the customer's Local Area Network (LAN) provided the bandwidth consumption is less than 10% of the total network bandwidth. Under no circumstances, shall the customer's LAN be subject to failure and/or abuse. In efforts to decrease liability, all BACnet devices that reside on the LAN must support the BACnet Broadcast Management Device (BBMD) scheme. Multi-casting or Global broadcasting will not be permitted without the use of a BBMD.

D. The secondary or sub-network shall utilize the Master-Slave/Token-Passing protocol, as acknowledged by the ANSI/ASHRAE 135 standard. Proprietary RS-485 or equivalent links will not be considered unless otherwise noted. The MS/TP link shall operate at a 76.8 Kbps minimum. If a 3rd party device is unable to communicate at 76.8 Kbps it must be isolated to its own individual bus. Each subnet bus shall consist of no more than 50 devices. All exceptions will have to be approved in writing by the FOD Building Automation Department. All devices on a bus shall be subordinates of a single mechanical system. For example, putting VAV's that are served from two different AHU's on the same physical bus is strictly prohibited. The use of MS/TP repeaters have to be approved in writing by the FOD Building Automation Department. If repeaters are permitted the location of the repeaters has to be labeled and identified in the enclosure of the Ethernet connected level device along with drawing schematics.

E. The use of proprietary gateways to transmit input/output data, and/or related information, must reside on the Ethernet LAN and be approved by FOD Building Automation Department, in writing, prior to the bid.

F. **Building Controller Conformance (BC)**: The building controller must be certified and listed by BTL (BACnet Testing Laboratory) under Device Profile B-BC (Annex L of the BACnet standard) with support of the following BIBBs:

Alarm and Event Management BIBBs

AE-ACK-B, AE-ASUM-B, AE-ESUM-B, AE-INFO-B, AE-N-A, AE-N-E-B, AE-N-I-B

Device Management BIBBs

DM-BR-B, DM-DCC-B, DM-DDB-A, DM-DDB-B, DM-DOB-A, DM-DOB-B, DM-OCD-B, DM-RD-B, DM-TM-A, DM-TS-A, DM-TS-B, DM-UTC-A, DM-UTC-B

Data Sharing BIBBS

DS-COV-A, DS-COV-B, DS-COVU-A, DS-COVU-B, DS-RP-A, DS-RP-B, DS-RPM-A, DS-RPM-B, DS-WP-A, DS-WP-B, DS-WPM-B

Network Management BIBBS

NM-CE-A, NM-CE-B

Scheduling BIBBs

SCHED-A, SCHED-E-B, SCHED-I-B

Trending

T-ATR-B, T-VMT-E-B, T-VMT-I-B

G. **Advanced Application Controller Conformance (AAC)**: The AAC must be certified and listed by BTL (BACnet Testing Laboratory) under Device Profile B-AAC (Annex L of the BACnet standard) with support of the following BIBBs:

Alarm and Event Management BIBBs

AE-ACK-B, AE-ASUM-B, AE-ESUM-B, AE-INFO-B, AE-N-E-B, AE-N-I-B

Device Management BIBBs

DM-BR-B, DM-DCC-B, DM-DDB-A, DM-DDB-B, DM-DOB-A, DM-DOB-B, DM-LM-B, DM-OCD-B, DM-RD-B, DM-TM-A, DM-TS-B, DM-UTC-B

Data Sharing BIBBS

DS-COV-A, DS-COV-B, DS-COVU-A, DS-RP-A, DS-RP-B, DS-RPM-A, DS-RPM-B, DS-WP-A, DS-WP-B, DS-WPM-B

Network Management BIBBS

NM-CE-A

Scheduling BIBBs

SCHED-E-B, SCHED-I-B

Trending

T-ATR-B, T-VMT-E-B, T-VMT-I-B

H. **Read / Write Properties:** The entire BACnet BAS system (all BC, and AAC devices) shall support the following Read/Write properties within the given BACnet objects and shall permit dynamic creation and deletion thereof.

Analog Input Object

Read and Write Properties: Description, Name, Value, COV Increment, Out of Service, Reliability

Read Only Properties: Type, Units, Status Flags, Event State

Analog Output Object

Read and Write Properties: Description, Name, Value, Out of Service, Reliability

Read Only Properties: Type, Units, COV Increment, Status Flags, Event State, Priority Array

Analog Variable Object

Read and Write Properties: Description, Name, Value, Units, COV Increment, Out of Service, Reliability

Read Only Properties: Type, Status Flags, Event State`

Binary Input Object

Read and Write Properties: Description, Name, Value, Out of Service, Reliability

Read Only Properties: Type, Status Flags, Event State

Binary Output Object

Read and Write Properties: Description, Name, Value, Out of Service, Reliability, Minimum On/Off time

Read Only Properties: Type, Status Flags, Event State, Priority Array

Binary Variable Object

Read and Write Properties: Description, Name, Value, Out of Service, Reliability

Read Only Properties: Type, Status Flags, Event State

Event Enrollment Object

Read and Write Properties: Description, Name, Notification Class, Event Enable, Event Parameter, Event Type, Object Reference

Read Only Properties: Type, Event State, Event Time Stamps, Notification Type, Acknowledged Transactions

Notification Class Object

Read and Write Properties: Description, Name, Priority, Recipient List

Read Only Properties: Type, Notification Class

Calendar Object

Read and Write Properties: Description, Name

Read Only Properties: Type, Value

Schedule Object

Read and Write Properties: Description, Name, Object Reference, Weekly Schedule, Effective Period, Schedule Exceptions

Read Only Properties: Type, Value

Trendlog Object

Read and Write Properties: None

Read Only Properties: Description, Name, Type, Notification Class, Event Enable, Event State, Event Time Stamps, Notification Type, Acknowledge Transactions, Log Enabled, Start/Stop Time, Log Interval

Program Object

Read and Write Properties: Description, Name, Out of Service, Reliability, Program Change

Read Only Properties: Type, Status Flags

Loop Object

Read and Write Properties: Description, Name, Value, COV Increment, Out of Service, Reliability, Tuning Parameters, Action, Controlled Variable

Read Only Properties: Event State, Status Flag, Type

File Object

Read and Write Properties: Description, Name

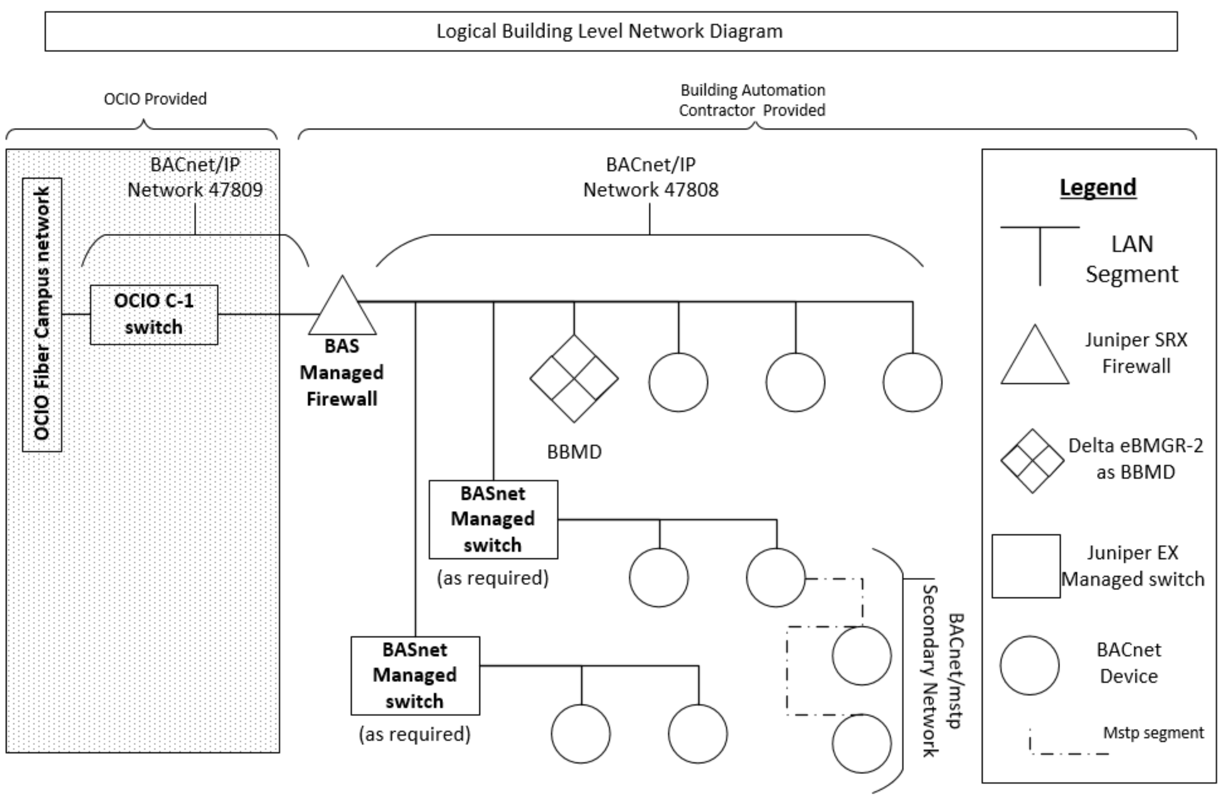
Read Only Properties: Type

2.01 NETWORKING COMMUNICATIONS

A. The design of the BAS network shall integrate operator workstations and stand-alone DDC Controllers on a peer-to-peer communications network, and other devices on other networks. The network architecture shall consist of the following four levels:

1. A district-wide Ethernet communications network based on the BACnet/IP protocol (Annex J.)

2. A building-wide peer-to-peer communications network between Building Controllers utilizing BACnet over Ethernet media or BACnet/IP Annex J supported by a local Delta eBMGR-2 acting as a BBMD and segmented from other building networks by a Juniper SRX series Firewall using Network Address Translation (NAT).



Note: The physical network layout for Ethernet devices is a star topology with the managed firewall being the central connection point for either BACnet devices or any managed switches. Daisy chaining of Ethernet devices or switches is strictly prohibited.

Fig. 1

3. BACnet MS/TP secondary networks extended from appropriate Building Controllers to associated Advanced Application Controllers.

4. Wireless communication between controllers or field devices is NOT permitted unless it has been submitted in writing for pre-approval from the FOD Building Automation Department.

B. Access to system data shall not be restricted by the hardware configuration of the building automation system. The hardware configuration of the BAS network shall be totally transparent to the user when accessing data or developing control programs.

C. Network design shall include the following provisions:

1. Provide high-speed data transfer rates for alarm reporting, quick report generation from multiple controllers and upload/download efficiency between network devices. System performance shall ensure that an alarm occurring at any DDC Controller is displayed at workstations and/or alarm printers within 5 seconds.

2. Support of any combination of DDC Controllers and operator workstations directly connected to the peer-to-peer network. A minimum of 50 devices shall be supported on a single network (including MS/TP).

3. Message and alarm buffering to prevent information from being lost.

4. Error detection, correction and retransmission shall be included to guarantee data integrity.

5. Synchronization of real-time clocks, to include automatic daylight savings time updating between all controllers shall be provided. Universal Time Coordinate based upon Greenwich Mean Time must be supported. (All BC devices must have Real Time Clocks with battery and SRAM backup, see section 1.03 H)

D. Acceptable protocols for intercommunications between building-wide peer-to-peer Building Controllers:

1. BACnet over Ethernet and BACnet/IP

2. BACnet/IP between subnets only

E. Secondary Local Area (communications) Network (LAN):

1. This communications network shall be limited to Building Controllers and Advanced Application Controllers and shall communicate bi-directionally with the BACnet peer-to-peer network.

2. Advanced Application Controllers shall be arranged on the LAN's in a functional relationship to the corresponding Building Controllers. For example, a VAV Advanced Application Controller serving a VAV terminal box shall be connected on a MS/TP network from the Building Controller that is controlling the corresponding air handling unit.

3. A maximum of 50 Advanced Application Controllers may be configured on any individual LAN from any Building Controller to insure adequate global data and alarm response times.

4. Acceptable protocols for intercommunications between Advanced Application Controllers and Building Controllers on a secondary network (with the exception of lab controllers, see SEC 2.01 J 11) are as follows:

   a. BACnet (MS/TP)~~BACnet over Ethernet, BACnet/IP~~

F. Network cabling should be in accordance with appropriate sections (i.e Sections VI, VII, and IX) from APPENDIX M - Communications Wiring Standard. For all Building Automation Projects, follow standards that apply to the Office of the Chief Information Officer (OCIO) and replace OCIO with FOD Building Automation Department.

2.02 BUILDING CONTROLLER

A. DDC (stand-alone) Controllers shall have a 32 bit processor with EEPROM, flash driven operating system (OS). They shall also be multi-tasking, multi-user, real-time digital control processors and permit I/O expansion for control / monitoring of up to 48 I/O. Controller size shall be sufficient to fully meet the requirements of this specification and provide a minimum scan rate of 3 scans per second.

B. Each Building Controller shall have sufficient flash memory (EEPROM), a minimum of 2 megabytes, to support its own operating system. In addition, there shall be additional SRAM memory for database handling, a minimum of 5 megabytes: Both the EEPROM and SRAM shall permit full implementation and support of all B-BC requirements of this specification, including:

1. Control processes
2. Energy management applications
3. Alarm management applications including custom alarm messages for each level alarm for each point in the system.
4. Historical/trend data for points specified
5. Maintenance support applications
6. Custom processes
7. Operator I/O
8. Dial-up communications
9. Manual override monitoring

C. Each Building Controller shall support:

1. Monitoring of the following types of inputs, without the addition of equipment outside of the Building Controller cabinet:
    a. Analog inputs
        1) 4-20 mA
        2) 0-10 Vdc
        3) Thermistors
    b. Digital inputs
        1) Dry contact closure
        2) Pulse Accumulator
        3) Voltage Sensing
2. Each Building Controller shall be capable of providing the following control outputs without the addition of equipment outside the Building Controller cabinet:
    a. Digital outputs (contact closure)
        1) Contact closure (motor starters, up to size 4)
    b. Analog outputs
        1) 4-20 mA
        2) 0-10 Vdc
        3) 0-135 Ohm (with external Transducer)

D. Each Building Controller shall have a minimum of 10 percent spare (panel real estate) capacity for future point connection and shall support up to 48 I/O with modular expansion modules. All expansion modules shall be located in the building controller enclosure or an attached enclosure within line of sight of the controlled equipment. The type of spares shall be in the same proportion as the implemented I/O functions of the panel, but in no case shall there be less than two spares of each implemented I/O type. Provide all processors, power supplies, database memory, program sequence memory, and communication controllers complete so that the implementation of any added point (within the above 10% spare) only requires the addition of the appropriate point input/output termination module, point sensor, and wiring.

1. Provide sufficient internal memory for the specified control sequences and have at least 25% of the memory available for future use.

2. Building Controllers shall provide at least one RS-232C serial data communication ports (BACnet PTP compatible) for operation of operator I/O devices such as industry standard printers, operator terminals, modems and laptop portable operator's terminals. Building Controllers shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers or terminals. System-wide access must be provided at each mechanical equipment room through the local Building Controller. Panel mounted terminals are not required. Furthermore, all Building Controllers shall include a hardwired, concealed and secured, RJ-11 or RJ-45 jack for use by the Portable Operators Workstation. The local operator, using the Portable Operators Workstation, shall plug into this jack, and shall perform all monitoring, control, and programming of sequences for any and all building-wide points and sequences while standing at any Advanced Application Controller.

E. As indicated in the point I/O schedule, the operator shall have the ability to manually override automatic or centrally executed commands at the Building Controller via local, point discrete, hand/off/auto operator override switches for digital control type points and gradual switches for analog control type points. These override switches shall be operable whether the panel processor is operational or not.

1. Switches shall be mounted either within the Building Controllers key-accessed enclosure, or externally mounted with each switch keyed to prevent unauthorized overrides.

2. Building Controllers shall monitor the status of all overrides and inform the operator that automatic control has been inhibited. Building Controllers shall also collect override activity information for reports.

G. Building Controllers shall provide local LED status indication for each digital input and output for constant, up-to-date verification of all point conditions without the need for an operator I/O device. Graduated intensity LED’s or analog indication of value shall also be provided for each analog output.

H. Each Building Controller shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all panel components. The Building Controller shall provide both local and remote annunciation of any detected component failures and for repeated failure to establish network communications.

I. Isolation shall be provided at all peer-to-peer network terminations, as well as all field point termination’s to suppress induced voltage transients consistent with current IEEE Standard C62.41.

J. In the event of the loss of normal power, there shall be an orderly shutdown of all Building Controllers to prevent the loss of database or operating system software. Programs residing in memory shall be protected either by using EEPROM under capacitor backup or by an uninterruptible power source (battery backup). The backup power source shall have sufficient capacity to maintain volatile memory in event of an AC power failure. Where interruptible power source is rechargeable (a rechargeable battery), provide sufficient capacity for a minimum of seventy-two hours backup. Charging circuitry, while the controller is operating under normal line power, shall constantly charge the rechargeable power source. A non-rechargeable power source shall not be permitted. Batteries shall be implemented to allow replacement without soldering.

1. Upon restoration of normal power, the Building Controller shall automatically resume full operation without manual intervention.

2. Should Building Controller memory be lost for any reason, the user shall have the capability of reloading the Building Controller via the local RS-232C port or from a network workstation PC.

K. Building Controllers must comply with Section 2.02, A-J and 2.03. Panels that lose communication or control due to a single sensor failure are not permitted.

L. Building Controllers will be used in each equipment room where major or more than two pieces of equipment are being controlled. The use of AAC devices for critical or main system equipment will not be permitted.

M. All points associated with a given mechanical system (i.e., an air handling unit) will be controlled from a single Building Controller or point expansion panels from the respective master. (i.e., remote motor control centers). All expansion modules shall be located in the building controller enclosure or an attached enclosure within line of sight of the controlled equipment. No points from a given mechanical system may be distributed among multiple panels - points must be run back to a single Building Controller dedicated to that mechanical system. Closed-loop control must never depend upon network communications. All inputs, program sequences, and outputs for any single DDC control loop shall reside in the same Building Controller. Loops shall be programmed to prevent wind up of the loop output when the loop is not in use.

2.03 BUILDING CONTROLLER RESIDENT SOFTWARE FEATURES

A. General:

1. All necessary software to form a complete operating system as described in this specification shall be provided.

2. The software programs specified in this Section shall be provided as an integral part of Building Controllers and shall not be dependent upon any higher level computer for execution.

3. Point naming convention shall be as referenced in Appendix A (see end of section). If the Appendix A does not cover the name required please submit name for approval by OSU Project Manager.

B. Control Software Description:

1. The Building Controllers shall have the ability to perform any or all of the following pre-tested control algorithms:

   a. Two-position control

   b. Proportional control

   c. Proportional plus integral control

d. Proportional, integral, plus derivative control

2. Control software shall include a provision for limiting the number of times that each piece of equipment may be cycled within any one-hour period.

3. The system shall provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads. This feature shall be resident in all Binary Output objects. The use of custom programming to prevent an excessive demand on start-up shall not be required.

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

C. All programs shall be executed automatically without the need for operator intervention and shall be flexible enough to allow user customization. Programs shall be applied to building equipment as described in the Sequence of Operations. Building Controllers shall have the ability to perform any or all of the following energy management routines:

1. Time-of-day scheduling
2. 365 day Calendar-based scheduling
3. Holiday scheduling
4. Temporary schedule overrides
5. Start-Stop Time Optimization
6. Automatic Daylight Savings Time Switch over
7. Night setback control
8. Enthalpy switch over (economizer)
9. Peak demand limiting
10. Temperature-compensated duty cycling
11. Fan speed/ control
12. Heating/cooling interlock
13. Cold deck reset
14. Hot deck reset
15. Hot water reset
16. Chilled water reset
17. Condenser water reset
18. Chiller sequencing
19. Chiller load monitoring

D. Building Controllers shall be able to execute custom, job-specific processes defined by the user, to automatically perform calculations and special control routines.

1. It shall be possible to use any of the following in a custom process:

    a. Any system measured point data or status

    b. Any calculated data

    c. Any results from other processes

    d. User-defined constants

    e. Arithmetic functions (+, -, *, /, square root, exponential, etc.)

    f. Boolean logic operators (and/or, exclusive or, etc.)

    g. On-delay/off-delay/one-shot timers

2. Custom processes may be triggered based on any combination of the following:

    h. Time interval

    i. Time-of-day

    j. Date

    k. Other processes

    l. Time programming

    m. Events (e.g., point alarms)

3. A single process shall be able to incorporate measured or calculated data from any and all other controllers on the network. In addition, a single process shall be able to issue commands to points in any and all other controllers on the network.

4. Processes shall be able to generate operator messages and advisories to operator I/O devices. A process shall be able to directly send a message to a specified device or cause the execution of a dial-up connection to a remote device such as a printer or pager.

5. The custom control programming feature shall be compiled and documented via English language descriptors. These descriptors (comment lines) shall be viewable from local operator I/O devices to facilitate troubleshooting.

E. Alarm management shall be provided to monitor and direct alarm information to operator devices. Each Building Controller shall perform distributed, independent alarm analysis and filtering to minimize operator interruptions due to non-critical alarms, minimize network traffic and prevent alarms from being lost. At no time shall the Building Controllers ability to report alarms be affected by either operator activity at a PC workstation, local I/O device or communications with other panels on the network.

1. All alarm or point change reports shall include the point's English language description and the time and date of occurrence.

2. The user shall be able to define the specific system reaction for each point. Alarms shall be prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of six priority levels shall be provided for each point. Point priority

levels shall be combined with user definable destination categories (PC, printer, DDC Controller, etc.) to provide full flexibility in defining the handling of system alarms. Each Building Controller shall automatically inhibit the reporting of selected alarms during system shutdown and start-up. Users shall have the ability to manually inhibit alarm reporting for each point.

3. Alarm reports and messages will be directed to a user-defined list of operator devices or PCs.

4. In addition to the point's descriptor and the time and date, the user shall be able to print, display or store a 200 character alarm message to more fully describe the alarm condition or direct operator response.

    a. Each Building Controller shall be capable of storing ~~all~~ custom alarm messaging text for each alarm. The alarm text shall be unique and user defined; custom text shall be available for all BACnet alarms and shall reside in the BC, not in an OWS or PC. Non-Delta controllers shall use the local subnet BBMD for custom alarm messaging. Alarm messages shall be in this format: Building Name-Equipment Name-Issue-University entity to notify of the issue.

    b. Alarms shall have ability to be acknowledged from the local operator I/O device, (once the problem is resolved).

5. Alarms shall be created only if they require an operator to take an action. The BAS contractor shall submit a complete alarm list with the controls submittal package. BAS contractor will submit a finalized alarm list in as-built documentation. The list will show the alarm Event Enrollment number, description, cause of the alarm and diagnostic steps to resolve the alarm.

6. All Air Handling Unit controllers shall minimally have the following alarms:

EV	Description
900	**Low Limit Thermostat Alarm**
901	**Supply Fan Status Critical**

F. A variety of historical data collection utilities shall be provided for manual or automatic sampling, storing and displaying system data for points as specified in the I/O summary.

1. Building Controllers shall store point history data for selected analog and digital inputs and outputs:

    a. Any point, physical or calculated may be designated for trending. Any point, regardless of physical location in the network, may be collected and stored in each Building Controller. Two methods of collection shall be allowed; either by a pre-defined time interval, or upon a pre-defined change of value. Sample intervals of 1 second to 7 days shall be provided. Each Building Controller shall have a dedicated RAM-based buffer for trend data and shall be capable of storing a minimum of 50,000 data samples + 1500 samples per connected Advanced Application Controller (i.e. VAV) if it cannot store trend logs.

2. Trend data shall be stored at the Building Controllers and uploaded to the workstation when retrieval is desired. Uploads shall occur based upon either; user-defined interval, manual command, or automatically when the trend buffers are full. Furthermore, the workstation shall notify the end-user if the hard drive capacity is low or if the database size is excessive. The OWS shall use a standard MSDE or SQL database handler for all

trend log management. All trend data shall be available to all BACnet OWSs and for use in 3rd party personal computer applications. File format type to be comma delineated.

3. Building Controllers shall also provide high resolution sampling capability for verification of control loop performance. Operator-initiated automatic and manual loop tuning algorithms shall be provided for operator-selected PID control loops as identified in the point I/O summary. Provide capability to view or print trend and tuning reports.

    a. The Loop object shall display the most recent historical data of its own performance. It shall illustrate the number of setpoint crossings and the maximum and average deviation from setpoint.

    b. Loop tuning shall be capable of being initiated either locally at the Building Controller, from a network workstation. For all loop tuning functions, access shall be limited to authorized personnel through password protection.

G. Building Controllers shall automatically accumulate and store run-time hours for digital input and output points as specified in the point I/O summary.

1. The totalization routine shall have a sampling resolution of one minute or less.

2. The user shall have the ability to define a warning limit for run-time totalization. Unique, user-specified messages shall be generated when the limit is reached.

H. Building Controllers shall automatically sample, calculate and store consumption totals on a daily, weekly or monthly basis for user-selected analog and digital pulse input type points as specified in the point I/O summary.

1. Totalization shall provide calculation and storage of accumulations of up to 99,999.9 units (e.g., kWh, gallons, BTU, tons, etc.).

2. The totalization routine shall have a sampling resolution of one minute or less.

3. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.

I. Building Controllers shall have the ability to count events such as the number of times a pump or fan system is cycled on and off. Event totalization shall be performed on a daily, weekly or monthly basis for points as specified in the point I/O summary.

1. The event totalization feature shall be able to store the records associated with a minimum of 9,999.9 events before reset.

2. The user shall have the ability to define a warning limit. Unique, user-specified messages, up to 200 characters, shall be generated when the limit is reached.

J. Advanced Application Controllers:

1. Each Building Controller shall be able to extend its performance and capacity through the use of remote Advanced Application Controllers. Each Advanced Application Controller shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each Advanced Application Controller shall be a microprocessor-based, 32 bit, multi-tasking, real-time digital control processor. Provide for control of terminal equipment including, but not limited to, the following:

    a. Rooftop units

b. VAV Boxes

c. Heatpumps

d. Fancoils, Univents

e. Laboratory Air Supply, Exhaust and Fume Hoods

f. Other terminal equipment or monitoring

2. Advanced Application Controllers must comply with Section 2.03, items A through I, and must be peer-to-peer devices. Advanced Application Controllers shall include all point inputs and outputs necessary to perform the specified control sequences. Provide a hand/off/automatic switch for each digital output for manual override capability. Switches shall be mounted either within the controller's key-accessed enclosure, or externally mounted with each switch keyed to prevent unauthorized overrides. In addition, each switch position shall be supervised in order to inform the system that automatic control has been overridden. Switches will only be required for non-terminal applications or where controllers are readily accessible (not required for VAVs, Heat pumps, etc. that are above ceilings or inaccessible). All inputs and outputs shall be of the Universal type, allowing for additional system flexibility. A minimum of 12 global points (i.e. chilled water temperature, hot water temperature, etc.) must be able to be accessed through the Advanced Application Controller. If global point access is unavailable with the Advanced Application then a Building Controller must be furnished.

3. Each Advanced Application Controller shall support its own real-time operating system. Provide a time clock with battery backup to allow for stand-alone operation in the event that communication with its Building Controller is lost and to insure protection during power outages. In the event that the AAC does not support a real time clock (RTC) function and it is being used on critical or system level equipment as mentioned in section 2.03 J.1 then a Building Controller supporting RTC functionality shall be used in its place. AAC devices without RTC functionality will be permitted for use on terminal or unitary equipment such as VAV boxes, fan coils, heat pumps, unit ventilators and auxiliary monitoring and control.

4. Provide each Advanced Application Controller with sufficient memory to accommodate point databases, operating programs, local alarming and local trending. All databases and programs shall be stored in non-volatile EEPROM under capacitor backup (lithium or rechargeable battery backup will not be permitted). Advanced Application Controllers must be fully programmable with a minimum of 200 lines of code available for custom programming. All programs shall be field-customized to meet the user's exact control strategy requirements. Advanced Application Controllers utilizing pre-packaged or canned programs shall not be acceptable. As an alternative, provide Building Controllers for all central equipment in order to meet custom control strategy requirements.

5. Programming of Advanced Application Controllers shall utilize the same language and code as used by Building Controllers to maximize system flexibility and ease of use. Should the system controller utilize a different control language, provide a Building Controller to meet the specified functionality.

6. Local alarming and trending capabilities shall be provided for convenient troubleshooting and system diagnostics. Alarm limits and trend data information shall be user-definable for any point.

7. Each controller shall have connection provisions for a portable operator's terminal. This tool shall allow the user to display, generate or modify all point databases and operating

programs. All new values and programs may then be restored to EEPROM via the programming tool.

8. Advanced Application Controllers that lose communication with master panels, and/or lose control due to a single sensor failure, are not acceptable.

9. At all Advanced Application Controllers include a hardwired, concealed and secured, RJ-11 or RJ-45 jack for use by the Portable Operators Workstation. The local operator, using the Portable Operators Workstation, shall plug into this jack, and shall perform all monitoring, control, and programming of sequences for any and all building-wide points and sequences while standing at any Advanced Application Controller.

10. At all Advanced Application Controllers, include the point database of the following minimum building-wide system data:

    i. Building Primary Hot Water Return and Supply Temperatures

    j. Building Primary Chilled Water Return and Supply Temperatures

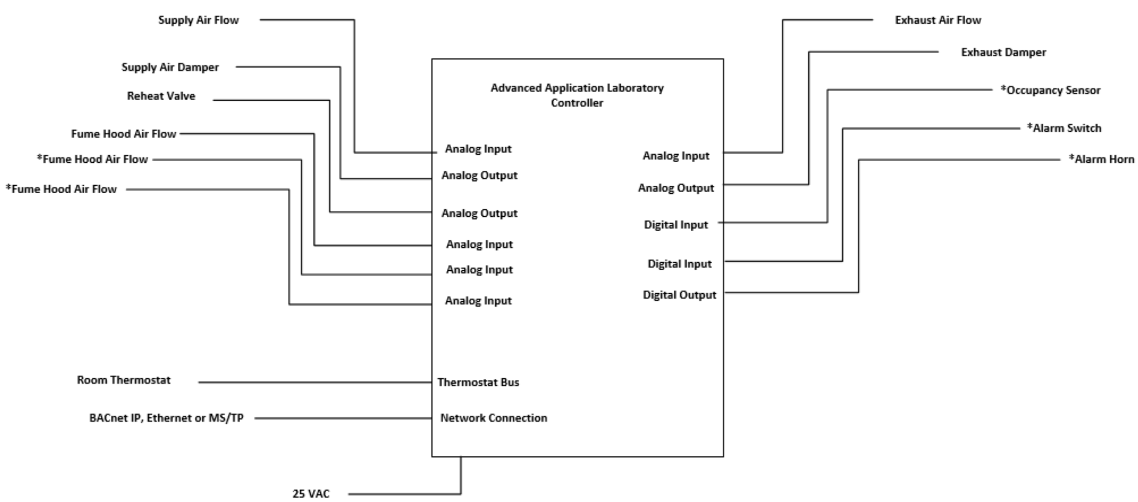
    k. Building Common Outside Air Temperature

    l. Database for 10 other building-wide points, as field selected by OSU.

    m. All VAV boxes including but not limited to dual duct boxes, mixing boxes, fan powered shall include a discharge air sensor.

11. <u>Advanced Application Controllers (AAC) shall be used to control laboratory HVAC processes. Each laboratory shall use a single AAC to control airflows, reheat valve(s) and monitor fume hood airflows. Airflow sensors, including the fume hood(s), shall be hard-wired analog inputs on the AAC. Supply and exhaust damper controls and reheat valves shall be hard-wired to analog outputs on the AAC. See Figure 2 below for an example. Laboratory AACs shall not be dependent in any way on a network connection (i.e. Ethernet, RS-485, proprietary, etc.) to function outside of the local thermostat.</u>

Laboratory Controller Example with 1 or more Fume Hoods
Figure 2



*Optional

~~2.04 APPLICATION SPECIFIC CONTROLLERS (ASC)~~

~~A. AAC devices shall be used for all intended ASC functionality. Use of Application Specific Controllers in lieu of Advanced Application Controllers requires prior approval by FOD Building Automation Department.~~

~~B. Each ASC shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each ASC shall be a microprocessor-based, 32-bit, multi-tasking, real-time digital control processor.~~

~~C. The use of these ASCs is limited to the monitor and control of building HVAC equipment that are outside of any mechanical equipment room, or outside of any electrical equipment room. All equipment located within, or controlled from within, any mechanical equipment room or electrical equipment room shall use the peer-to-peer Building Controller.~~

~~D. The electrical power source for these Application Specific Controllers shall be from local circuit breaker with appropriate fused, class 2, 100VA power-limited output. The breaker shall be dedicated to the Advanced Application Controllers, labeled accordingly, and locked-out from inadvertent casual shutoff.~~

~~E. Application Specific Controllers:~~

~~1. Provide for control of each piece of building HVAC equipment, including, but not limited to, the following:~~

~~a. Variable Air Volume (VAV) terminal boxes~~

~~b. Constant Air Volume (CAV) terminal boxes~~

~~c. Dual Duct (DD) terminal boxes~~

~~d. Unit Conditioners~~

~~e. Heat Pumps~~

~~f. Unit Ventilators~~

~~g. Fan Coil Units~~

~~2. Controllers shall include all point inputs and outputs necessary to perform the specified control sequences. All inputs and outputs shall be of the universal type; that is, the outputs may be utilized either as modulating or two-state, allowing for additional system flexibility. Analog outputs shall be industry standard signals such as 24V floating control and 0-10 VDC allowing for interface to a variety of modulating actuators. Terminal equipment controllers or AACs utilizing proprietary control signals and actuators shall not be acceptable. As an alternative, provide Building Controllers or other AACs with industry standard outputs for control of all terminal equipment.~~

~~3. Each controller performing space temperature control shall be provided with a matching room temperature sensor. The sensor shall be 10K Type-3 thermistor based providing the following minimum performance requirements are met:~~

~~a. Accuracy: ± 0.36°F~~

~~b. Operating Range: 32° to 158°F~~

~~c. Set Point Adjustment Range: 55° to 85°F (adjustable)~~

~~d. Set Point Modes:~~

~~1). Independent Heating~~
~~2). Independent Cooling~~
~~3). Night Setback Heating~~
~~4). Night Setback Cooling~~

~~e. Calibration Adjustments: None required~~

~~f. Installation: Up to 500 ft. from Controller~~

~~g. Each room sensor shall also include the following auxiliary devices or options:~~

~~1). Setpoint Adjustment Dial or equivalent buttons~~
~~2). Digital LED Temperature Indicator~~
~~3). Override Switch or button~~

~~4.). 2 % on board Humidity Sensor option~~

~~h. The setpoint adjustment shall allow for modification of the temperature in a minimum of .5º F increments by the occupant. Setpoint adjustment may be locked out, overridden or limited as to time or temperature through software by an authorized operator at the central workstation, Building Controller, or via the portable operator's terminal.~~

~~i. The temperature indication shall be a digital display visible without removing the sensor cover.~~

~~j. An override switch shall initiate override of the night setback mode to normal (day) operation when activated by the occupant. The override function may be locked out, overridden or limited as to the time through software by an authorized operator at the central workstation, Building Controller, or via the portable operator's terminal.~~

~~4. Each controller shall perform its primary control function independent of other DDC Controller LAN communications, or if LAN communication is interrupted. Reversion to a fail-safe mode of operation during LAN interruption is not acceptable. The controller shall receive its real-time data from the Building Controller time clock to insure LAN continuity. Each controller shall include algorithms incorporating proportional, integral and derivative (PID) values for all applications. All PID values and biases shall be field-adjustable by the user via terminals as specified herein. This functionality shall allow for tighter control of space conditions and shall facilitate optimal occupant comfort and energy savings. Controllers that incorporate proportional and integral (PI) control algorithms only, without derivative (D) control algorithms, shall not be acceptable.~~

~~5. Provide each terminal equipment controller with sufficient memory to accommodate point databases, operating programs, local alarming and local trending. All databases and programs shall be stored in non-volatile EEPROM, EPROM and PROM, or capacitor backup. The controllers shall be able to return to full normal operation without user intervention after a power failure of unlimited duration. Provide uninterruptible power supplies (UPS's) of sufficient capacities for all terminal controllers that do not meet this protection requirement. Operating programs shall be fully customizable for specific applications (programming language shall be identical to the Building Controllers). In addition, specific applications may be modified to meet the user's exact control strategy requirements, allowing for additional system flexibility. Controllers that require factory changes of any applications or that are algorithm based will not be acceptable.~~

~~6. Variable Air Volume (VAV) Box Controllers:~~

~~a. As a minimum, shall support the following types of applications for pressure independent terminal control:~~

~~1). VAV, cooling only~~
~~2). VAV, with hot water reheat~~
~~3). VAV, with electric reheat~~
~~4). VAV, fan-powered~~
~~5). VAV, fan-powered, with hot water reheat~~
~~6). VAV, fan-powered, with electric reheat~~

~~b. All VAV box control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory changes of any applications or that are algorithm based will not be acceptable~~

~~7. The VAV box controller shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F (0° to 50°C) and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).~~

~~a. The VAV controller shall include a differential pressure transducer that shall connect to the terminal unit manufacturer's standard averaging air velocity sensor to measure the velocity pressure in the duct. The controller shall convert this value to actual airflow in cfm. Single point air velocity sensing is not acceptable. The differential pressure transducer shall have a measurement range of 0 to 1 inch-WC and measurement accuracy of ±5% throughout its range, insuring primary air flow conditions shall be controlled and maintained to within ±5% of setpoint at the specified parameters. The BAS contractor shall provide the velocity sensor if required to meet the specified functionality.~~

~~b. The VAV box controller shall include provisions for manual and automatic reset of the differential pressure transducer in order to maintain stable control and insuring against drift over time. Reset shall be accomplished by stroking the terminal unit damper actuator to 0%, full closed, position so that a 0 cfm air volume reading is sensed. The controller shall automatically accomplish this whenever the end user desires. Manual reset may be accomplished by either commanding the actuator to 0% via the POT or by depressing the room sensor override switch. Reset of the transducer at the controller location shall not be necessary.~~

~~c. The VAV box controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.5°F (adj.) of setpoint at the room sensor location.~~

~~d. The VAV box controller performing space heating control shall incorporate a program allowing for modulation of a hot water reheat valve, or cycling up to three (3) stages of electric reheat, as required to satisfy space heating requirements. Each controller shall also incorporate a program that allows for~~

~~resetting of the associated air handling unit discharge temperature if required to satisfy space cooling requirements. This algorithm shall function to signal the respective DDC Controller to perform the required discharge temperature reset in order to maintain space temperature cooling setpoint.~~

~~e. All VAV boxes including but not limited to dual duct boxes, mixing boxes, fan powered shall include a discharge air sensor.~~

~~8. Constant Air Volume (CAV) Box Controllers:~~

~~a. As a minimum, shall support the following types of applications for pressure independent terminal control:~~

~~1). CAV, cooling only~~
~~2). CAV, with hot water reheat~~
~~3). CAV, with electric reheat~~

~~b. All CAV box control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes or those that are algorithm based will not be acceptable.~~

~~c. The CAV box controller shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC, allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).~~

~~d. The CAV controller shall include a differential pressure transducer that shall connect to the terminal unit manufacturer's standard averaging air velocity sensor to measure the velocity pressure in the duct. The controller shall convert this value to actual airflow in cfm. Single point air velocity sensing is not acceptable. The differential pressure transducer shall have a measurement range of 0 to 1 inch-WC and measurement accuracy of ±5% throughout its range, insuring primary air flow conditions shall be controlled and maintained to within ±5% of setpoint at the specified parameters. The BAS contractor shall provide the velocity sensor if required to meet the specified functionality.~~

~~e. The CAV box controller shall include provisions for manual and automatic reset of the differential pressure transducer in order to maintain stable control and insuring against drift over time. Reset shall be accomplished by stroking the terminal unit damper actuator to 0%, full closed, position so that a 0 cfm air volume reading is sensed. The controller shall automatically accomplish this whenever the end user desires. Manual reset may be accomplished by either commanding the actuator to 0% via the POT or by depressing the room sensor override switch. Reset of the transducer at the controller location shall not be necessary.~~

~~f. The CAV box controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.5°F (adjustable) of setpoint at the room sensor location.~~

~~g. Each controller performing space heating control shall incorporate an algorithm allowing for modulation of a hot water reheat valve or cycling up to three (3) stages of electric reheat as required to satisfy space heating requirements. Each controller shall also incorporate a program that allows for resetting of the associated air handling unit discharge temperature if required to satisfy space cooling requirements. This program shall function to signal the respective DDC Controller to perform the required discharge temperature reset in order to maintain space temperature cooling setpoint. Control of the terminal unit damper to maintain cooling setpoint shall not be permitted. As an alternative, Building Controllers or other Advanced Application Controller for the associated air handling equipment shall also directly control all CAV terminal units in order to provide the specified reset capability~~

~~h. Each controller performing space pressurization control shall incorporate programs allowing for pressurization via the following methods as a minimum:~~

~~1). Fixed air volume setpoints of supply and exhaust terminal units~~

~~2). Updating of air volume setpoints of supply and exhaust terminal units~~

~~i. Each supply and associated exhaust terminal controller may be set at a fixed air volume setpoint which is within a percentage of each other or an actual CFM differential to meet space pressurization requirements. The controllers shall incorporate provisions for independent occupied and unoccupied mode setpoints and differentials, allowing for additional flexibility. Applications requiring updating of air volume setpoints depending on a variable volume of air leaving the space either through the exhaust terminal(s) or other exhaust ducts shall utilize supply terminal unit controllers incorporating programs to allow for "tracking" of space exhaust(s) to maintain the required air volume differential.~~

~~j. Terminal unit tracking shall be accomplished via actual measurement of terminal unit air volumes as previously specified. Controllers which track within a range of CFM's versus actual CFM setpoints shall not be acceptable.~~

~~k. Zeroing of the differential pressure transducer shall be accomplished as previously specified for VAV box controllers. However, the method of stroking the terminal unit damper to a 0% position shall not be permitted should the controlled space(s) require constant pressurization or 24-hour per day operation. Controllers performing under 24-hour per day operation requirements shall incorporate an 'Auto-zero' auxiliary device(s) which functions to automatically zero the transducer without changing the damper position. This shall be accomplished by temporarily disengaging the transducer from the air velocity sensor so that a 0 cfm air volume reading is forced. The control damper position remains unchanged, as originally controlled before the start of the 'Auto-zero' recalibration. This shall automatically occur on a once per 24-hour basis, thus ensuring system accuracy as previously specified. Provide auxiliary devices and programming as required to perform this function.~~

~~l. Should a failure occur within the controller, the terminal unit damper shall automatically be positioned fully open or fully closed as previously defined by the operator. Controllers that revert to a pressure-dependent control mode during failure shall not be acceptable.~~

~~m. All VAV boxes including but not limited to dual duct boxes, mixing boxes, fan powered shall include a discharge air sensor.~~

~~9. Dual-Duct (DD) Box Controllers:~~

~~a. As a minimum, shall support the following types of applications for pressure independent terminal control:~~

~~1). DD - Constant Volume - Cold Duct & Hot Duct Air Velocity Sensors with optional auxiliary heat.~~
~~2). DD - Constant Volume - Cold Duct & Outlet Air Velocity Sensors with optional auxiliary heat.~~
~~3). DD - Variable Air Volume - Cold Duct & Hot Duct Air Velocity Sensors with optional auxiliary heat.~~
~~4). DD - Variable Air Volume - Cold Duct & Outlet Air Velocity Sensors with optional auxiliary heat.~~
~~5). DD -Variable Air Volume - Cold Duct & Hot Duct Air Velocity Sensors with changeover.~~

~~b. All DD box control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes or those that are algorithm based will not be acceptable.~~

~~c. The DD box controller shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).~~

~~d. The DD controller shall include a differential pressure transducer that shall connect to the terminal unit manufacturer's standard averaging air velocity sensor to measure the velocity pressure in the duct. The controller shall convert this value to actual airflow in cfm. Single point air velocity sensing is not acceptable. The differential pressure transducer shall have a measurement range of 0 to 1 inch-WC and measurement accuracy of ±5% throughout its range, insuring primary air flow conditions shall be controlled and maintained to within ±5% of setpoint at the specified parameters. The BAS contractor shall provide the velocity sensor if required to meet the specified functionality.~~

~~e. The DD box controller shall include provisions for manual and automatic reset of the differential pressure transducer in order to maintain stable control and insuring against drift over time. Reset shall be accomplished by stroking the terminal unit damper actuator to 0%, full closed, position so that a 0 cfm air volume reading is sensed. The controller shall automatically accomplish this whenever the end user desires. Manual reset may be accomplished by either commanding the actuator to 0% via the POT or by depressing the room sensor override switch. Reset of the transducer at the controller location shall not be necessary.~~

~~f. The DD box controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.5°F (adjustable) of setpoint at the room sensor location.~~

~~g. Each controller performing space heating control shall incorporate an program allowing for modulation of a hot water reheat valve or cycling up to two (2) stages of electric reheat as required to satisfy space heating requirements.~~

~~h. Provide two air velocity sensors and transducers to match the application. For VAV applications, provide separate minimum and maximum air volume setting for heating and cooling ducts. For CAV applications, provide separate air volume set points for occupied and unoccupied modes.~~

~~i. Zeroing of the differential pressure transducer shall be accomplished as previously specified for VAV box controllers. However, the method of stroking the terminal unit damper to a 0% position shall not be permitted should the controlled space(s) require constant pressurization or 24-hour per day operation. Controllers performing under 24-hour per day operation requirements shall incorporate an 'Auto-zero' auxiliary device(s) which function to automatically zero the transducer without changing the damper position. This shall be accomplished by temporarily disengaging the transducer from the air velocity sensor so that a 0 cfm air volume reading is forced. The control damper position remains unchanged, as originally controlled before the start of the 'Auto-zero' recalibration. This shall automatically occur on a once per 24-hour basis, thus ensuring system accuracy as previously specified. Provide auxiliary devices and programming as required to perform this function.~~

~~j. All VAV boxes including but not limited to dual duct boxes, mixing boxes, fan powered shall include a discharge air sensor.~~

~~10. Unit Conditioner Controllers:~~

~~a. As a minimum, shall support the following types of applications for terminal control:~~

~~1). Fan coil units~~
~~2). Induction units~~
~~3). Pressure dependent terminal boxes~~

~~b. As a minimum, shall support the following types of fan coil units:~~

~~1). Fan Coil, 2-pipe, heating or cooling~~
~~2). Fan Coil, 4-pipe, heating or cooling~~
~~3). Fan Coil, cooling, and electric heating~~
~~4). Fan Coil, 2-stage cooling, and electric heating~~
~~5). Fan Coil, 2-stage cooling, and hot water heating~~

~~c. As a minimum, shall support the following types of Induction units:~~

~~1). Induction Unit, 2-pipe~~
~~2). Induction Unit, 4-pipe~~

~~d. As a minimum, shall support the following types of pressure dependent terminal control:~~

~~1). Heating, or cooling~~
~~2). Hot water reheat~~

~~e. All Unit Conditioner control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to~~

~~facilitate system expansions. Controllers that require factory application changes or those that are algorithm based will not be acceptable.~~

~~f. The Unit Conditioner controllers shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC, allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F (0° to 50°C) and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).~~

~~g. The Unit Conditioner controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.5°F (adjustable) of setpoint at the room sensor location.~~

~~h. The Unit Conditioner controller performing space temperature control shall incorporate a program allowing for modulation of a hot water reheat and chilled water valve, or cycling up to three (3) stages of electric reheat and chilled water valve, as required to satisfy space heating requirements. Each controller shall also incorporate a program that allows for resetting of the associated air handling unit discharge temperature if required to satisfy space cooling requirements (if applicable). This program shall function to signal the respective DDC Controller to perform the required discharge temperature reset in order to maintain space temperature cooling setpoint.~~

~~i. All VAV boxes including but not limited to dual duct boxes, mixing boxes, fan powered shall include a discharge air sensor.~~

~~11. Heat Pump Controllers:~~

~~a. As a minimum, shall support the following types of applications for heat pump terminal control:~~

~~1). Heat Pump, water source~~
~~2). Heat Pump, air-to-air source~~
~~3). Heat Pumps, with ventilation air~~
~~4). Heat Pump, with auxiliary heat~~

~~b. All Heat Pump control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes or those that are algorithm based will not be acceptable.~~

~~c. The Heat Pump controllers shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC, allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F (0° to 50°C) and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).~~

~~d. The Heat Pump controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.5°F (adjustable) of setpoint at the room sensor location.~~

~~e. The Heat Pump controller performing space temperature control shall permit full control of the Heat pump regardless of its configuration.~~

~~f. All VAV boxes including but not limited to dual duct boxes, mixing boxes, fan powered shall include a discharge air sensor.~~

~~12. Unit Ventilator Controllers:~~

~~a. As a minimum, shall support the following types of applications for heating only unit ventilator applications:~~

~~1). Unit Ventilator, ASHRAE Cycle 1, 2 or 3~~
~~2). Unit Ventilator, ASHRAE Cycle 1, 2 or 3 with auxiliary reheat~~
~~3). Unit Ventilator, Nesbitt Cycle W~~
~~4). Unit Ventilator, Nesbitt Cycle W with auxiliary reheat~~

~~b. All Unit Ventilator controller applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes or those that are algorithm based will not be acceptable.~~

~~c. The Unit Ventilator controllers shall be powered from either a 115 or 230 VAC power source common to the unit ventilator. The controllers shall function normally under ambient conditions of 32° to 130°F and 10% to 95% (non-condensed). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).~~

~~d. The Unit Ventilator controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.5°F (adjustable) of setpoint at the room sensor location.~~

~~e. The Unit Ventilator controller shall also interface to averaging temperature sensor(s) located in the discharge or mixed air stream(s) as required by application. The sensor(s) must be 10-K type 3 thermistors, providing the following minimum performance requirements are met:~~

~~1). Probe: Averaging type~~
~~2). Accuracy: ± .50°F~~
~~3). Temperature Monitoring 0° to 180°F (-18° to 82°C)~~

2.04 PORTABLE OPERATOR'S TERMINAL (POT)

A. On request, provide One (1) portable operator terminal (POT). The POT shall be a laptop configuration and plug directly into any control panel. Provide the BACnet BAS software as required to provide complete functionality for viewing, modifying, restoring, and archiving of all data (including custom programs). The software used to setup and configure the BAS controls shall be the same software provided to the University at no additional expense.

B. Functionality of the portable operator's terminal connected at any controller:

1. Access all controllers on the network.

2. Backup and/or restore DDC Controller databases for all system panels, not just the DDC Controller connected thereto.

3. Display all point, selected point and alarm point summaries.

4. Display trending and totalization information.

5. Add, modify and/or delete any existing or new system point.

6. Command, change setpoint, enable/disable any system point.

7. Program and load custom control sequences as well as standard energy management programs.

C. Connection of a POT to a distributed control processor shall not interrupt nor interfere with normal network operation in any way, prevent alarms from being transmitted or preclude centrally-initiated commands and system modification.

D. Portable operator terminal access to controller shall be password-controlled.

E. Portable operator terminal minimum hardware and performance criteria shall be as referenced in Appendix A.1.

2.05 WORKSTATION OPERATOR INTERFACE SOFTWARE

A. Basic Interface Description

1. Operator workstation interface software shall minimize operator training through the use of English language prompting, English language point identification and industry standard PC application software. The software shall provide, as a minimum, the following functionality:

   a. Graphical viewing and control of environment

   b. Scheduling and override of building operations

   d. Definition and construction of dynamic and animated color graphic displays

   e. Editing, programming, storage and downloading of controller databases

2. Provide a graphical user interface, which shall minimize the use of a typewriter style keyboard through the use of a mouse or similar pointing device and "point and click" approach to menu selection. Users shall be able to start and stop equipment or change setpoints from graphical displays through the use of a mouse or similar pointing device. <u>All graphics shall be created in Delta enteliVIZ HTML 5 Designer</u>.

   a. Provide functionality such that all operations can also be performed using the keyboard as a backup interface device.

   b. Provide additional capability that allows at least 10 special function keys to perform often-used operations.

3. The software shall provide multi-tasking operating system such that alarm notification occurs while user is running other applications such as Word or Excel; trend data uploads occur in the background while other applications are running. The mouse shall be used to quickly select and switch between multiple applications. This shall be accomplished

through the use of Microsoft Windows[a] or similar industry standard software that supports concurrent viewing and controlling of systems operations.

a. Provide functionality such that any of the following may be performed simultaneously, and in any combination, via user-sized windows: (Vector based graphics)

1). Dynamic and animated color graphics and graphic control
2). Alarm management coordinated with section 2.04.E.
3). Time-of-day scheduling
4). Trend data definition and presentation
5). Graphic definition
6). Graphic construction

b. If the software is unable to display several different types of displays at the same time, the BAS contractor shall provide at least two operator workstations.

4. Multiple-level password access protection shall be provided to allow the user/manager to limit workstation control, display and data base manipulation capabilities. Privileges shall be customizable for each operator; the main menu shall reflect the privileges upon log on showing only the applications appropriate for the operator.

a. Customizable such that operators can monitor, command, or edit an application or group of points. An operator can be defined with privileges for access to a building, group or buildings, or areas (labs--point names with the designation "lab"), by application: the operator has monitor, command, and edit capability for time of day schedules and calendars (only) for the entire campus: or by function: the operator (i.e. security guard) has ability to view/monitor all areas of the campus and receive alarms, etc.

b. A minimum of 50 unique passwords, including user initials, shall be supported.

c. Operators will be able to perform only those commands available for their respective passwords. Menu selections displayed shall be limited to only those items defined for the access level of the password used to log-on.

d. The system shall automatically generate a report of log-on/log-off time and system activity for each user.

e. User-definable, automatic log-off timers of from 5 to 60 minutes shall be provided to prevent operators from inadvertently leaving devices on-line as well as have the capability to generate a report of log-on, log-off time, parameters modified, and system activity for each user.

5. Software shall allow the operator to perform commands including, but not limited to, the following:

a. Start-up or shutdown selected equipment

b. Adjust setpoints

c. Add/modify/delete time programming

d. Enable/disable process execution

e. Lock/unlock alarm reporting for points

f. Enable/disable totalization for points

g. Enable/disable trending for points

h. Override PID loop setpoints

i. Enter temporary override schedules

j. Define holiday schedules

k. Change time/date

l. Automatic daylight savings time adjustments

m. Enter/modify analog alarm limits

n. Enter/modify analog warning limits

o. View limits

p. Enable/disable demand limiting for each meter

q. Enable/disable duty cycle for each load

r. Operator shall have ability to schedule reports to print at a pre-specified time and frequency and directed to displays, printers, disk or emails. The reports shall be capable of querying all BACnet devices for all BACnet data and shall be available in industry standard formats such as Acrobat, Microsoft Word, Microsoft Excel and Crystal Reports.

1) Summaries shall be provided for specific points, for a logical point group, for a user-selected group or groups or for the entire BACnet network without restriction due to the hardware configuration of the building automation system. At a minimum, the report function shall provide all required BACnet data for the previously identified BACnet objects in section 2.00 J.

B. Scheduling

1. Provide a graphical spreadsheet-type format for simplification of time-of-day scheduling and overrides of building operations. Provide the following spreadsheet graphic types as a minimum:

   a. BACnet schedules

   b. BACnet calendars

2. Weekly schedules shall be provided for each building zone or piece of equipment with a specific occupancy schedule. Each schedule shall include columns for each day of the week as well as holiday and special day columns for alternate scheduling on user-defined days. Equipment scheduling shall be accomplished by simply inserting occupancy and vacancy times into appropriate information blocks on the graphic. In addition, temporary overrides and associated times may be inserted into blocks for modified operating schedules. After overrides have been executed, the original schedule will automatically be restored.

3. Zone schedules shall be provided for each building zone as previously described. Each schedule shall include all commandable points residing within the zone, unless custom programming is used to enable/disable the points. Each point may have a unique schedule of operation relative to the zone's occupancy schedule, allowing for sequential starting and control of equipment within the zone.

4. Monthly calendars, until the year 2090, shall be provided which allow for simplified scheduling of holidays and special days in advance. Holidays and special days shall be user-selected with the pointing device and shall automatically reschedule equipment operation as previously defined on the weekly schedules.

5. Occupancy schedules for Air Handling Units (AHU) should avoid starting and stopping the units. Lower static pressures and wider temperature set point dead bands should be utilized during unoccupied time periods to reduce energy consumption.

C. Collection and Analysis of Historical Data

1. Provide trending capabilities that allow the user to easily monitor and preserve records of system activity over an extended period of time. Any system point may be trended automatically at time-based intervals or changes of value, both of which shall be user-definable. Trend data may be stored on hard disk for future diagnostics and reporting. In addition, the BAS system shall automatically trend and archive all alarms and user activity (no exceptions).

2. Trend data report graphics shall be provided to allow the user to view all trended point data. The BAS system shall employ the use of Multiple Trend-Logs which may be customized to include up to 8 individual singe trends in one viewable and printable format. Provide additional functionality to allow any trended data to be transferred easily to Microsoft Office, Excel ®. This shall allow the user to perform custom calculations such as energy usage, equipment efficiency and energy costs and shall allow for generation of these reports on high-quality plots, graphs and charts.

3. Provide additional functionality that allows the user to view trended data on trend graph displays. Displays shall be actual plots of both static and/or real-time dynamic point data. A maximum of 8 points may be viewed simultaneously on a single graph, with color selection and line type for each point being user-definable. Displays shall include an 'X' axis indicating elapsed time and a 'Y' axis indicating a range scale in engineering units for each point. The 'Y' axis shall have the ability to be manually or automatically scaled at the user's option. Different ranges for each point may be used with minimum and maximum values listed at the bottom and top of the 'Y' axis. All 'Y' axis data shall be color-coded to match the line color for the corresponding point.

   a. Static graphs shall represent actual point data that has been trended and stored on disk. Exact point values may be viewed on a data window by pointing or scrolling to the place of interest along the graph. Provide capability to print any graph on the system printer for use as a building management and diagnostics tool.

   b. Dynamic graphs shall represent real-time point data. Any point or group of points may be graphed, regardless of whether they have been predefined for trending. The graphs shall continuously update point values. At any time the user may redefine sampling times or range scales for any point. In addition, the user may pause the graph and take "snapshots" of screens to be stored on the workstation disk for future recall and analysis. As with static graphs, exact point values may be viewed and the graphs may be printed.

4. New buildings or building renovation projects where the HVAC controls are upgraded must provide a Delta Coppercube and licensing for the University's Kaizen building analytics software. The Kaizen license period shall be for 5 years. The following formula shall be used to calculate the number of Kaizen trend logs to license:

   (Number of Building/System controllers X 50) + (number of AACs X 30) + (number of ASCs X 25) + (number of 3rd party BACNet interfaces X 25)

D. Dynamic Color Graphic Displays

1. Color graphic floor plan displays and system schematics for each piece of mechanical equipment, including air handling units, chilled water systems and hot water boiler systems, room level terminal unit equipment shall be provided by the BAS contractor as indicated in the point I/O summary of this specification to optimize system performance analysis and speed alarm recognition. The operator interface shall allow users to access the various system schematics and floor plans via a graphical penetration scheme, menu selection or text-based commands.

2. Dynamic temperature values, humidity values, flow values, percent load, and status indication shall be shown in their actual respective locations and shall automatically update to represent current conditions without operator intervention.

3. The windowing environment of the PC operator workstation shall allow the user to simultaneously view several graphics at a time to analyze total building operation or to allow the display of a graphic associated with an alarm to be viewed without interrupting work in progress.

4. Graphic generation software shall be provided to allow the user to add, modify or delete system graphic displays. <u>Delta enteliVIZ HTML 5 graphics shall be used</u>.

   a. The BAS contractor shall provide libraries of pre-engineered screens and symbols depicting standard air handling unit components (e.g., fans, cooling coils, filters, dampers, etc.), complete mechanical systems (e.g., constant volume-terminal reheat, VAV, etc.) and electrical symbols.

   b. The graphic package shall use a mouse or similar pointing device in conjunction with a drawing program to allow the user to perform the following:

      1) Define symbols
      2) Position and size symbols
      3) Define background screens
      4) Define connecting lines and curves
      5) Locate, orient and size descriptive text
      6) Define and display colors for all elements
      7) Establish correlation between symbols or text and associated system points or other displays
      8) Ability to import scanned images and CAD drawings in Autodesk ®, DWG format.

   c. Graphical displays can be created to represent any logical grouping of system points or calculated data based upon building function, mechanical system, building layout or any other logical grouping of points that aids the operator in the analysis of the facility.

      1) To accomplish this, the user shall be able to build graphic displays that include point data from multiple controllers.

   d. <u>The main graphic page for a building shall have an HTML hyperlink to a PDF file of the network riser diagram(s) for the building. Each system level graphic shall have an HTML hyperlink to a PDF file of the system Sequence of Operation and point to point wiring diagrams</u>.

5. Dynamic system status graphic of the site-specific architecture showing status of system hardware, including quantity and address of networks, field panels, terminal equipment controllers, and printers.

6. The BAS contractor shall employ the use of accurate floor plans as part of the overall graphics package. The floor plans shall illustrate the location of room sensors and equipment. In addition, the floor plans shall utilize a thermographic scheme to instantly alert the end user of hot and cold areas. The thermograph shall illustrate and automatically intensify the red and blue gradient fills for each area, as to indicate the severity of the overheating or overcooling problem.

7. Any graphical point that is "in hand" or overridden in the controller shall show up as the inverse of its normal color.

8. All graphics shall be loaded on the University's Delta enteliWEB server prior to start-up and commissioning of new DDC systems. Each point/dynamic object on all graphics shall be verified during point-to-point checkout of the DDC controller. Graphic verification shall be documented.

E. System Configuration and Definition:

1. All temperature and equipment control strategies and energy management routines shall be definable and fully programmable by the operator. System definition and modification procedures shall not interfere with normal system operation and control.

2. The system shall be provided complete with all equipment and documentation necessary to allow an operator to independently perform the following functions:

   a. Add/delete/modify stand-alone Building Controllers

   b. Add/delete/modify stand-alone Advanced Application Controllers

   c. Add/delete/modify operator workstations

   d. Add/delete/modify Application Specific Controllers, if used

   e. Add/delete/modify points of any type and all associated point parameters and tuning constants

   f. Add/delete/modify alarm reporting definition for points

   g. Add/delete/modify control loops

   h. Add/delete/modify energy management applications

   i. Add/delete/modify time and calendar-based programming

   j. Add/delete/modify totalization for points

   k. Add/delete/modify historical data trending for points

   l. Add/delete/modify custom control processes

   m. Add/delete/modify any and all graphic displays, symbols and cross-reference to point data

   n. Add/delete/modify dial-up telecommunication definition

   o. Add/delete/modify all operator passwords

   p. Add/delete/modify alarm messages

3. Definition of operator device characteristics, any controller's individual points, applications and control sequences shall be performed using instructive prompting software.

   a. All custom programming language must be line sequential, English text with a real time compiler. The operator shall be able to view all live data within the program with no exceptions. The use of secondary software or manual intervention shall not be required.

   b. If programming must be done with the PC workstation off-line, the BAS contractor shall provide at least 2 operator workstations.

   c. Inputs and outputs for any process shall not be restricted to a single DDC Controller, but shall be able to include data from any and all other network panels to allow the development of network-wide control strategies. Processes shall also allow the operator to use the results of one process as the input to any number of other processes (cascading).

   d. Provide the capability to backup and store all system databases on the workstation hard disk. In addition, all database changes shall be performed while the workstation is on-line without disrupting other system operations. Changes shall be automatically recorded and downloaded to the appropriate controller. Similarly, changes made at any Controllers shall be automatically uploaded to the workstation, ensuring system continuity. The user shall also have the option to selectively download changes as desired.

   e. Provide context-sensitive help menus to provide instructions appropriate with operations and applications currently being performed. The help menus shall be readily accessible by selecting an icon or by pressing a function button on the keyboard.

2.07 FIELD DEVICES

A. Temperature Sensors: Each temperature sensor shall match the requirements of the associated temperature controller and shall be based upon 10-K Type-3 thermistors. Each sensor shall be designed for the appropriate application (i.e., duct, immersion, etc.) and be provided with all necessary installation accessories. Ranges shall be selected to the middle of the control range. Temperature sensors must have a minimum accuracy of +/- 0.5 deg F or .5 % of scale; whichever will provide the least error in measurement.

   1. Electronic: A modulating solid state sensor with built-in detector, with continuous voltage or current output. Each sensor shall have individual setpoint adjustment. Input voltage shall be 24 VAC or less. Sensors shall be of matching type to the input detectors and output drives or sequencers.

   2. Thermostat guards shall be provided where specified, indicated on control diagrams, or indicated on floor plans. Guards shall be firmly attached to wall and thermostat cover shall be visible through the guard. All room sensors in public areas will have concealed setpoint adjustments.

   3. All room sensors in classroom, office, or common spaces will have exposed set point adjustments locked to provide adjustment between 68 degrees and 72 degrees only.

   4. Install thermostats and sensors at 4'-6" AFF to bottom unless otherwise noted on Architectural Drawings. Coordinate installation with the work of other trades before any rough-ins are made.

5. Duct Sensors: DDC duct sensors shall match the requirements of the associated controller incorporating an electrical signal to insure exact and proportional relationship between the measured variable and the transmitted signal. Static pressure sensors shall be mounted in temperature control panels with connecting sensor lines in hard copper. Where a device is used for sensing of Mixed Air Temperature or Preheat applications and the duct area is in excess of 24 square feet the instrument shall incorporate a capillary averaging element with a minimum length of 96 inches or a suitable array of duct sensors wired as a single input. Averaging sensors shall be used on any duct application where duct area exceeds 24 square feet.

6. Provide temperature sensors as required to meet the sequence of operation; in addition, provide temperature sensors in the following locations: return air, mixed air, coil ~~and~~ discharge air sections, and supply air temperature if not required by the sequence of operation.

7. Wireless sensors are NOT permitted unless it has been submitted in writing for pre-approval to the OSU Project Manager.

B. Humidity Sensors: The relative humidity transmitter monitors and transmits changes in humidity, accurate to +/- 2 % RH. Operating range shall be 0 to 99% RH.

C. Pressure Sensors: Duct static pressure analog sensors shall be high accuracy +/-1% of range suitable for the low pressures and selected for at least 50% over range Sensors shall have industry standard 4-20 mA output and zero end span adjustments.

D. Control Dampers (Multiple Blade Dampers): Automatic dampers furnished by the BAS Contractor shall be single blade or multiple blades as applicable. All dampers are to be sized to the application by the manufacturer using methods similar to control valve sizing. Dampers are to be installed by the HVAC Contractor under the supervision of the Temperature Control Contractor. All dampers furnished by air handling unit manufacturers must meet the requirements listed in this section. All blank-off plates and conversions necessary to install smaller than duct size dampers are the responsibility of the HVAC Contractor. All damper frames are to be constructed of No. 13 gauge galvanized sheet metal and shall have flanges for duct mounting. Damper blades shall not exceed 6 inches width. All blades are to be airfoil type construction and will be equal to Ruskin RCD 50 control dampers with blade and jamb seals. Blades are to be suitable for high velocity performance. All damper bearings are to be made of nylon. Bushings that turn in the bearings are to be oil impregnated sintered metal. Dampers hung with blades mounted vertically shall be provided with thrust bearings. Butyl rubber seals are to be installed along the top and bottom of the frame and along each blade edge. Independent, self-compensating, stainless steel end seals shall be installed to insure minimum leakage between blade ends and damper frame. Seals shall provide a tight closing low leakage damper. Damper sections shall not exceed 48" in length or 16 sq. ft. and shall have minimum of one operator per damper section. All dampers in modulating applications shall have opposed blades. Dampers in two position services shall have parallel blades. Where sequence requires, submittals shall include damper sizes and leakage characteristics. Leakage shall not exceed 3 cfm/sq. ft. at 1” of static pressure and shall be AMCA licensed as a Class 1A damper.

1. Control dampers will be sized by the temperature control contractor to the inside of the duct or duct liner whichever is smaller. Sizing of dampers to duct size and the subsequent cutting back of insulation to make dampers fit is unacceptable.

2. Control dampers used for outside air or exhaust air applications will be installed a minimum of 6" away from wall penetrations to allow for external mounting of their respective damper motors. Jack shafting in these applications will only be allowed to prevent having to mount motors in the outside airstream. When internal damper motor mounting is required the sheet metal contractor shall provide access panels at each

motor location to allow for ease of service. Provide in-line coalescing filters for pneumatic lines exposed to freezing air.

E. Damper Operators: Operators shall be electronic, spring return, low voltage (24VAC), and shall be properly sized so as to stroke the damper smoothly and efficiently throughout its range. Actuator responses shall be linear in response to sensed load.

1. Electronic damper motors for terminal boxes will be provided by the temperature control contractor and shipped to the terminal box manufacturer for mounting. Mounting charges shall be the responsibility of the terminal box manufacturer.

2. Damper operators on outside air intake/exhaust shall be spring return closed.

3. VAV Terminal Boxes using internal or proprietary actuators are unacceptable.

F. Automatic Control Valves: All valves sized greater than 2 ½" or steam applications shall be pneumatic. All valves shall be equipped with throttling plugs and removable composition discs and shall be manufactured by Siemens, Belimo, or Johnson Controls. All valves are to be sized by the Control Contractor and shall submit pressure drop calculations and guarantee sufficient size to meet the requirements of the equipment being served. Valve operators shall be of such design so as to provide adequate operating power for valve positioning.

1. Reheat valves controlled by AACs in VAV terminal applications shall utilize electronic actuation and shall fail normally closed (capacitor or spring driven failsafe). All reheat valves serving Laboratories and/or Vivariums (animal) rooms shall be electronic actuation and include spring return, to fail normally closed.

2. Three-way Valves: Three-way valves are to be of the three port mixing arrangement, designed expressly for mixing of two inlets and providing a common outlet. The use of reverse piped diverting valves shall not be acceptable. The Temperature Control Contractor will assist the HVAC Contractor in providing guidance as to the correct method of piping of all three-way valves. It is the responsibility of the HVAC contactor to evaluate the contract drawings for proper verification.

3. Butterfly valves for air handling unit coil control are unacceptable. If high GPM requirements dictate the valve size to be greater than 6", then Temperature Control contractor shall provide two control valves for the application, and the HVAC Contractor shall install the two control valves, for parallel and/or sequenced operation.

4. For all fan systems with separate pre-heat and separate 2nd heating coil. The pre-heat coil shall fail normally open, shall include separate analog output AO point for control, and separate analog input AI point for low-limit pre-heat discharge control. The separate 2nd heating coil shall fail normally closed, shall include separate analog output AO point, and separate analog input AI point for low-limit heating control.

5. For all fan systems with a single hot water coil, the coil shall fail normally open (i.e. AHUs, Fan coils Unit ventilators, UHs, CUHs, etc.)

6. Pressure drop through modulating control valves shall not exceed 7 psi and should be matched to the coil pressure drop whenever possible. Control valves for 2-position applications shall be line sized.

G Air Volume Measurement: Provide Tek-Air or Ebtron air flow measuring system including microprocessor panel and air flow measuring sensor struts as required to measure outside air intake flow as denoted on the Drawings.

1. DDC air flow measuring system shall have a velocity range from 350 to 6000 ft./min. with duct measurement accuracy (including repeatability, zero offset, and temperature compensation) of plus or minus 0.5 percent.

2. Pilot tube arrays and differential pressure arrays are not acceptable.

3. The air flow measurement stations shall include a digital LCD display that illustrates the actual CFM, not FPM or other variables.

H Smoke Detectors shall be furnished by the electrical contractor and installed by the HVAC contractor. The electrical contractor will provide the necessary interlock wiring for life safety functions.

I Air Static and Velocity Pressure Transmitter: The pressure transmitter shall be used for measuring duct static or velocity pressure in variable air volume fan systems. <u>Location of down duct static sensors shall be provided in the as-built drawings</u>.

J Low Limit Detection Thermostat: Low limit detection thermostats equal to Siemens 134-1511 shall be of the vapor tension capillary type having a sensing element a minimum of 20 feet in length. These thermostats shall be of the manual reset type. The elements shall be complete with necessary fittings to permit installation in the duct so as to sense the correct discharge temperatures. One low limit detection thermostat will be installed for every 24 square feet of protected area and arranged so as to stop their respective units and close the outside air dampers in the event discharge temperatures fall below 38 degrees F. The normally closed contact shall be wired to the fan circuit and the normally open contact (close on alarm) shall be wired to a DDC input. One common circuit is suitable for multiple thermostats on a single AHU coil area.

K Electric Thermostats: Heavy-duty snap action type with key operators rated at 10 FLA at 120 RIAC contacts suitable for the intended service. Provide manual selector switches as required in the sequence of operation.

L Fan and Pump Proof: Proof points for air handling unit fans, exhaust fans and pumps will be accomplished through the use of current sensing relays at the motor control center or motor starters. Current sensing relays shall be split-core design, for installation over any single power lead. Current sensing relays shall include field adjustable set screw for amperage setpoint adjustment, and shall include integral LED status light to locally indicate the ‘on’ and ‘off’ condition.

M Variable Frequency Drives: The Variable Frequency Drives (VFDs) shall be BACnet compatible. It is the responsibility of the BAS contractor to coordinate with the HVAC contractor to ensure that the proper drive is ordered with the appropriate native BACnet communications card (no gateways i.e. protocol router/converter are allowed). Additionally, the BAS contractor will ensure that VFDs are not directly connected to a major mechanical system controller (i.e. AHU, MAU). <u>The use of combination relay/current transformer is prohibited. Relays shall be mounted exterior of the VFD so LED indicators can be seen without opening the VFD.</u>

N. Electro-pneumatic (EP) transducers: “Poppet” valve style EP transducers are prohibited in occupied spaces, above the ceilings of occupied spaces, and wherever noise could be an issue. They are acceptable for mechanical room applications.

O. Non Delta, Siemens, or ALC controllers (i.e., those used on packaged Chillers, Boilers, and etc.) shall not be directly connected to a major mechanical system controller. A BACnet router (i.e. Delta DSM-RTR or approved equal) should be used to connect them to the Building Automation network.

2.08 LABELING

A. Provide labels for all field devices including sensors, transducers, thermostats, and relays. Exception: Room temperature and/or humidity sensors shall not be labeled.

B. Labels shall be black laminated plastic with white letters and adhesive backing or screw fasteners. Labels shall be located adjacent to device and permanently affixed to device mounting surface. Labels for sensors in pipes may be secured using chain around the sensor well.

C. Labels shall include system virtual/pseudo point name as well as English language name of device being controlled or specific condition being sensed.

D. Identify all control wiring at each end with a wire tags or labels machine print (no hand written).

E. Identify and label all control transformers by indicating all devices they power.

F. All 120 VAC panel power sources shall have labels in panels for electrical panel and breaker number.

PART 3 EXECUTION

3.01 SEQUENCE OF OPERATION

3.02 ON-SITE TESTING

A. Field Test: When installation of the system is complete, calibrate equipment and verify transmission media operation before the system is placed on-line. The installer shall complete all testing, calibrating, adjusting and final field tests. Verify that all systems are operable from local controls in the specified failure mode upon panel failure or loss of power. Upon completion of the work, contact the third party commissioning agent that the system is ready for final tests and commissioning. If there is no commissioning agent, contact the OSU Project Manager, and Architect/Engineer to inform them that the system is ready for final tests and commissioning. Commissioning shall be performed on all systems in BOTH heating and cooling seasons.

B. At the time of final inspection, this Contractor shall be represented by a person with the proper authority, who shall demonstrate, as directed by the commissioning agent or the A/E, that his work fully complies with the purpose and intent of the Specifications and Drawings. Labor, services, instruments, and tools necessary for demonstrations and tests shall be provided by the Contractor.

C. The Contractor shall test and adjust each instrument specialty and equipment furnished by him, prior to final acceptance. The Contractor shall demonstrate, for approval by the A/E, subsystems operate as coordinated and properly functioning, integrated system including the graphics, alarms and trending.

D. The Contractor shall furnish labor to provide adjustments and incidentals necessary to obtain the desired and intended results.

E. The Contractor shall turn over a printed copy and electronic copy of the completed and debugged operating software to OSU Construction Manager at the conclusion of the two year warranty.

3.03 SERVICE AND GUARANTEE

A. General Requirements: Provide all services, materials and equipment necessary for the successful operation of the entire BAS system for a period of ~~one~~ two years after completion of successful commissioning. Provide necessary material required for the work. Minimize impacts on facility operations when performing scheduled adjustments and non-scheduled work.

B. Description of Work: The adjustment and repair of the system includes all computer equipment, software updates (including all firmware updates), transmission equipment and all sensors and control devices. Provide the manufacturer's required adjustments and all other work necessary.

C. Personnel: Provide qualified personnel to accomplish all work promptly and satisfactorily. University shall be advised in writing of the name of the designated service representative, and of any changes in personnel.

D. Systems Modifications: Provide any recommendations for system modification in writing to University. Do not make any system modifications, including operating parameters and control settings, without prior approval of the OSU Project Manager. Any modifications made to the system shall be incorporated into the operations and maintenance manuals, and other documentation affected.

E. Software: Provide all software updates and verify operation in the system. These updates shall be accomplished in a timely manner, fully coordinated with the OSU Project Manager, and shall be incorporated into the operations and maintenance manuals, and software documentation.

F. As-Builds: Submit 1 complete sets of drawings to the OSU Project Manager electronically following OSU's Project Closeout Standards and showing the kind of control equipment for each of the various systems and their functions, along with indications on the drawing of all original setpoints and calibration values, and setup parameters, and sequence of operation of the automation system together with a complete brochure describing the equipment and their functions and operation. Include all application software documentation (actual programs or their job-specific flow charts) with DDC system.

1. Manufacturer's Product Data:

   a. All equipment components

1. Shop Drawings:

   a. System wiring diagrams with sequence of operation for each system as specified.

   b. Submit manufacturer's product information on all hardware items along with descriptive literature for all software programs to show compliance with specifications.

   c. System configuration diagram showing all panel types and locations as well as communications network layout and workstations.

   d. <u>Floor plan diagram showing VAV/CAV/Lab controller locations, network connection routing and location of power supply for the VAV/CAV/Lab controllers</u>.

Where installation procedures, or any part thereof, are required to be in accord with the recommendations of the manufacturer of the material being installed, printed copies of these recommendations shall be furnished to the Associate prior to installation. Installation of the item will not be allowed to proceed until the recommendations are received.

3.04 TRAINING

A. The Contractor shall provide competent instructors to give full instruction to designated personnel in the adjustment, operation and maintenance of the system installed rather than a general training course. Instructors shall be thoroughly familiar with all aspects of the subject matter they are to teach. All training shall be held during normal work hours of 7:00 a.m. to 3:30 p.m. weekdays as follows:

B. Provide 8 hours of training for FOD Building Automation Department personnel. Training shall include:

1. Explanation of drawings, operations and maintenance manuals
2. Walk-thru of the job to locate control components
3. Software, peripherals and panel communication procedures.
4. DDC Controller and ASC operation/function
5. Operator control functions including graphic generation and field panel programming
6. Operation of portable operator's terminal
7. Explanation of adjustment, calibration and replacement procedures

C. Provide up to 32 hours of additional training at the request of the OSU Project Manager for a period of one year from final completion of the project.

D. Since the University may require personnel to have more comprehensive understanding of the hardware and software, additional training must be available from the Contractor. If the University requires such training, it will be contracted at a later date. Provide description of available local and factory customer training.

PART 4 APPENDICES

Appendix A.1:

The minimum hardware requirements for the Portable Operator Terminal (POT) are as follows:

Intel i5-8265U or better processor 8 GB RAM

1 serial port (if available)

500.0 GB Hard Drive or larger

15.4” display

2X USB 3.0 Ports

DVD/CD-RW ROM Drive

Windows 7 Professional or later operating system (A/E verify these requirements with OSU Project Manager)

Integrated keyboard and pointing device

2 battery packs, 110 VAC adapter/charger

Carrying Case

Three-year limited warranty

Proprietary Software Key(s)

Operating System restore software including any Proprietary Software

Appendix A.2

Steam Desuperheater Control:

Provide a modular controller with associated input/output modules and touch-screen display mounted in a panel located in an area not subjected to high temperature or relative humidity. (Modular controller shall be Delta EnteliBUS eBMGR-TCH, or equivalent by an approved equivalent manufacturer.) Desuperheater control valve shall be as described in Division 23 for medium pressure steam service and shall have electro-pneumatic positioner and Class V shutoff. Provide high temperature sensor and transmitter.

Sensor:

Sensor Type	1000 Ohm +/- 0.1% @ 32 F
Temperature Coefficient	0.00375 Ohm/Ohm/Degree C
Sensitivity	2.1 Ohm/F @ 32 F
Measurement Range	-58 F to 932 F
Probe Material	304 Stainless Steel
Wiring Terminations	Two-wire nickel coated stranded copper, 24 inch long 22 AWG fiberglass insulated
Warranty	3 years
Model Number	S241HC (Minco, or equivalent)

Transmitter:

Supply Voltage	8.5 – 35 VDC unregulated
Sensor Input	1000 Ohm platinum 0.00375 Ohm/Ohm/Degree C
Measurement Range	0 F to 800 F
Signal Output	4 – 20 mA
Maximum Output Impedance	775 Ohm +/- 0.1% @ 24 VDC min
Accuracy	Calibration accuracy +/- 0.05% of span
Operating Temperature	-58 F to 160 F
Well Operating Pressure	3000 PSIG max
Well Material	304 Stainless Steel
Warranty	3 years
Model Number	TT111H-0800 (Minco, or equivalent)

Provide the following inputs and outputs:

Desuperheater Control Valve	Analog Output
Desuperheater Pump 1 Status	Binary Input
Desuperheater Pump 2 Status	Binary Input
Desuperheated Steam Temperature	Analog Input

Desuperheater control valve shall modulate to maintain steam temperature at 15 F above saturation temperature. Provide alarm for high temperature and pump failure.

Desuperheater pump package will be controlled by its own microprocessor controller.

END OF FOD APPENDIX A-FOD

BUILDING AUTOMATION SYSTEM
PART 1 GENERAL

Commentary: *Division 23 lists existing University Control Centers. This Appendix applies to **Student Life buildings** [to all building automation systems in all Student Life buildings on all University campuses and locations], except where noted otherwise in the BDS or hereinafter. For OSUWMC systems, see the separate OSUMC Appendix A - WMC. For FOD buildings see the separate FOD Appendix A - FOD. The individual Control Centers have the authority to amend the requirements of this Appendix with the approval of the University Engineer and the Student Life Building Automation Department. References to the FOD Control Center, or to the FOD Building Automation Department, or to FOD should be interpreted as meaning the appropriate Control Center for the given project. Review with the OSU Project Manager.*

DIRECT DIGITAL CONTROL SYSTEMS FOR STUDENT LIFE

PART 1 – GENERAL

1.1 Provide a complete system of automatic temperature controls (ATC) for this project, as required to accomplish the sequence of control for the various items of equipment and systems.

1.2 Related Documents

A. Drawings and general provisions of the contract, including general and supplementary conditions and Division 01 specification sections, apply to this section.

1) ASHRAE Standard 90.1
2) NFPA 70
3) National Electric Code

1.3 Summary

A. This section includes the following:

The ATC system shall be a stand-alone direct digital control (DDC) system utilizing electric actuation. The installed system shall be fully integrated into the existing Student Life Building Automation System’s web client application server via BACnet over IP protocol – using typical University Internet/Intranet data connections. ~~An installation specific connection shall be available in the HHph2 facility maintenance office.~~ Testing of the new control system will be done “end to end” through the JCI ADX system. A workstation at each building is not required unless it is required to accomplish the ATC’s building control architecture since all monitoring and control will be done through the JCI ADX system. System control graphics only need to reside on the JCI ADX system and do not need to be duplicated at the building level controllers. Within the scope of the project, Student Life will provide NAEs for system integration into Student Life ADX by ATC.

1) System operator application software shall be provided (two (2) copies). One (1) portable operator workstations shall be provided (refer to Part 2), fully functional for operation, maintenance, and engineering of installed systems – including all project specific software, tools, programs, tag/name files, and created graphics (and 2 soft backup copies of the “as built” same).

2) The control design allows the use of network controllers or building controllers architecture.

A. Option 1: The control system shall consist of a high-speed, peer to peer network of DDC controllers and a web based operator interface. A web server with a network interface card shall gather data from this system and generate web pages accessible through a conventional web browser.

Option 2: The BAS shall consist of central Servers and Routers, an Operator Workstation to provide access to the graphical operator interface software, stand-alone Building Controllers (BC), Custom Programmable Controllers (CPC) and Application Specific Controllers (ASC). The system shall be modular in nature and shall permit expansion of both capacity and functionality through the addition of workstations, DDC panels, sensors, actuators, etc.

1) The system shall directly control HVAC equipment as specified in Section 23 09 93 - Sequence of Operations for HVAC Controls. Each zone controller shall provide occupied and unoccupied modes of operation by individual zone. Furnish energy conservation features such as optimal start and stop, night setback, request based logic, and demand level adjustment of setpoints as specified in the sequence.
2) Provide for future system expansion to include monitoring of occupant card access, fire alarm, and lighting control systems.

3) System shall use the BACnet protocol for communication to the operator workstation or web server and for communication between control modules. I/O points, schedules, setpoints, trends, and alarms specified in Section 23 09 93 - Sequence of Operations for HVAC Controls shall be BACnet objects.

1.4 Scope

A. Furnish and install a complete Native BACnet Direct Digital Control (DDC) Temperature Control System to automatically control the operation of the entire Heating, Ventilating and Air Conditioning System. The DDC system shall fully integrate into the existing Student Life native BACnet Johnson ADX system. The system shall perform the said integration through the use of BACnet/IP communications (Annex J only). BACnet over Ethernet will not be supported for campus wide communications. Failure to mention any specific item or device does not relieve the Contractor of the responsibility for furnishing and installing such items or devices in order to comply with the intent of the Drawings and/or this Specification. The University reserves the right to self-perform this work.

B. Direct Digital Control System (DDC) Contractor shall provide:

1) A fully integrated building automation system (BAS), UL listed, incorporating direct digital control (DDC) for energy management, equipment monitoring and control. At the Contractor's option, a DDC system as manufactured by the following, meeting all requirements of this specification may be furnished:

a) Automated Logic by EMCOR

b) Delta Controls Inc. by BCI

c) Johnson Controls (JCI)

d) Trane

2) Necessary conduit, wiring, enclosures, and panels, for all DDC temperature control equipment and devices. Installation shall comply with applicable local and national codes.

3) All components and control devices necessary to provide a complete and operable DDC system as specified herein.

4) All final electrical connections to each DDC panel. Connect to 120VAC power to the nearest emergency panel provided by the Division 26 contractor. ATC shall provide all 120VAC wiring, conduit and breakers that are not included under the base electrical contract drawings.

5) DDC Contractor shall be responsible for all electrical work associated with the DDC control system and as called for on the Drawings. This DDC control wiring shall be furnished and installed in

accordance with the Electrical requirements as specified in Division 26, the National Electric Code, and all applicable local codes.

6) Surge transient protection shall be incorporated in design of system to protect electrical components in all Network and Main building DDC Controllers. Application Specific Controllers and Field Controllers do not require surge suppressors. Provide an external protection device listed under UL 1449 with minimum clamping voltage of 400 Volts and surge current capability of 26,000 Amps.
7) All 120V and low voltage electrical control wiring throughout the building shall be run in conduit in accordance with the Electrical requirements as specified in Division 26, the National Electric Code, and all applicable local codes.

8) All 24V power required for operation of the DDC system shall be by the DDC Contractor.

9) DDC Contractor shall provide programming modifications necessary to fine tune sequences during commissioning and through warranty period of systems at no additional cost to the University.

10) The new controls shall include graphic screens on the OSU SL JCI ADX system.
Testing of control system will be “end to end” through the JCI ADX system.

11) All energy meter wiring to OSU INSTEP. See drawings.

C. HVAC Contractor provides:

1) Installation of all wells and openings for water and air monitoring devices, temperature sensors, flow switches and alarms furnished by DDC Contractor.

2) ~~Installation of~~ Furnish and install all control valves and actuators.

3) ~~Installation of~~ Furnish and install all dampers and actuators, and adjacent access doors for smoke; outdoor air, return air, exhaust air, ~~and~~ ventilation dampers and flow sensors.

5) For all projects where the Student Life BAS Shop serves as the DDC/Temperature Control Contractor, the HVAC Contractor shall furnish and install all control valves, dampers, actuators, and flow sensors. Sizing and selection of control valves, dampers, actuators, and flow sensors shall be subject to Student Life BAS Shop review and approval. HVAC shall furnish and install access doors as needed.

5) All package unit control panels, including applicable gateway for BACnet interfacing.

D. General Product Description:

1) The DDC Contractor shall supply a BACnet (ANSI/ASHRAE 135-2004 Minimum) compliant system. BACnet compatible systems that employ the use of proprietary ‘gateways’ will not be accepted unless otherwise noted. In addition, all devices shall incorporate peer to peer communications. All DDC Contractors shall supply, prior to bid, Protocol Implementation Conformance Statements (PICS) and BACnet Interoperability Building Block (BIBB) summaries to the A/E for final approval.

2) The primary Local Area Network (LAN) shall be based upon the ISO 8802-3 Ethernet standard. The installation of all Ethernet wiring, accessories, and connectors shall conform to the ISO standard and/or guidelines identified herein. The preferred connection media shall be Category 6, shielded Twisted Pair wire. The maximum single network run shall not exceed more than 300 feet. ~~If additional distance is needed, the use of hubs or other Ethernet medias will be acceptable. However, the ‘cascading’ of more than 3 hubs on a single segment will not be accepted.~~ The DDC system may utilize the customer’s Local Area Network (LAN) provided the bandwidth consumption is less than 10% of the total network bandwidth. All Ethernet network devices shall be home run to Student Life

managed Ethernet switch. Under no circumstances, shall the customer's LAN be subject to failure and/or abuse. In efforts to decrease liability, all BACnet devices that reside on the LAN must support the BACnet Broadcast Management Device (BBMD) scheme. Global broadcasting will not be permitted without the use of a BBMD.

3) The BACnet system shall be capable of Internet Protocol (IP) communications.
BACnet/IP or Annex J will be considered the basis of design. All other configurations must be submitted prior to bid, in writing, for final approval. These configurations shall include but not be limited to, Annex H or third party BACnet tunneling routers.

4) The secondary or sub-network shall utilize the Master-Slave/Token-Passing protocol, as acknowledged by the ANSI/ASHRAE 135 standard. Proprietary RS-485 or equivalent links will not be considered unless otherwise noted. The MS/TP link shall operate at a 76.8 Kbps minimum, and utilize no more than 2 repeaters in any instance.

5) The use of proprietary gateways to transmit input/output data, and/or related information, must reside on the Ethernet LAN and be approved, in writing, prior to the bid.

6) The DDC Contractor or manufacturer representative shall support the installed system for a minimum of 2 years. The support shall include all software/firmware updates, full material warranty of actual controllers, and on- site training and support per 23 05 01.

7) The DDC system shall consist of the following:

a) Stand-alone DDC Controllers

b) Central Servers and Routers

c) Building Controllers (BC)

d) Custom Programmable Controllers (CPC)

e) Application Specific Controllers (ASC).

f) Operator Workstation

g) Stand-alone Direct Digital Control (DDC) panels

h) Associated sensors and controlled devices

8) The system shall be modular in nature and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, DDC Controllers, Application Specific Controllers and operator devices.

9) The system architectural design shall utilize a multi-tier communications network as specified.

10) The system architectural design shall require alarming to be built at the building controller level.

11) The BAS specified herein shall be capable of integrating multiple building functions including equipment supervision and control of all field I/O points and software points, alarm management, energy management, historical data collection and archiving, data storage, report generation and graphics interaction.

12) DDC Controllers shall be able to access any data from, or send control commands and alarm reports directly to, any other DDC Controller or combination of controllers on the network without dependence upon a central processing device.

13) Each controlled system shall have its own stand-alone DDC panel. Controllers shall not be shared across multiple controlled systems, nor shall controlled

systems be split across multiple controllers. Where point counts exceed the limits of a controller, provide auxiliary input/output expansion hardware such that there is a single processor for each equipment item.

a) For large systems, the active control points and control programming shall reside in one controller, while “monitor-only” points may reside in another separate single controller.

b) If there are still too many active control points for the I/O capacity of a single controller, then all programming shall reside in a single controller and a second controller shall be utilized as a remote I/O board. In this scenario, sanity checking shall be required for the remote points, and the system shall shut down and alarm upon loss of communications or other invalid data from the remote controller.

1.5 Submittals

A. Submit 10 complete sets of drawings (and one soft copy in PDF format) showing the kind of control equipment for each of the various systems and their functions, along with indications on the drawing of all original setpoints and calibration values, and setup parameters, and sequence of operation of the automation system. These drawings shall be submitted for approval to the A/E, and to The Ohio State University Student Affairs Building Automation, and to The Ohio State University Engineer’s Office, together with a complete brochure describing the equipment and their functions and operation. Include all application software documentation (actual programs or their job-specific flow charts) with DDC system and schedule a review meeting with the University’s Representative and the A/E at least two weeks before installation and start up.

1) Manufacturer's Product Data:

a) All equipment components

b) Shop Drawings:

(1) System wiring diagrams with sequence of operation for each system as specified.

(2) Submit manufacturer's product information on all hardware items along with descriptive literature for all software programs to show compliance with specifications.

(3) System configuration diagram showing all panel types and locations as well as communications network and workstations.

(4) System architecture diagram and descriptions.

(5) Approved room numbers are required to be included on all temperature control submittals, and all control as-built drawings.

(6) Submit all control drawings in Visio electronic format.

B. Where installation procedures, or any part thereof, are required to be in accord with the recommendations of the manufacturer of the material being installed, printed copies of these recommendations shall be furnished to the A/E prior to installation. Installation of the item will not be allowed to proceed until the recommendations are received.

1.6 Quality Assurance

A. Installer Qualifications: An experienced installer who is a certified installer of the DDC control system manufacturer for both installation and maintenance of BACnet based systems. The qualifications shall include all necessary debugging and calibration of each component of the system. Installers shall have minimum 10 years experience.

B. Manufacturer Qualifications: A firm experienced in manufacturing automatic temperature-control systems similar to those indicated for this project and with a record of successful in-service performance. Equipment and Installer shall have a support facility within 150 miles of the site with technical support staff.

C. Materials and equipment shall be the catalogued products of manufacturers regularly engaged in production and installation of automatic temperature control systems and shall be manufacturer's latest standard design that complies with the specification requirements.

D. Single source responsibility of supplier shall be the complete installation and proper operation of the DDC and control system and shall include debugging and proper calibration of each component in the entire system. The DDC must be supplied and installed by the same control contractor. Only Factory Authorized Distributors will be considered for installation. The letting of separate contracts by the prime HVAC Contractor for the Control System and a separate contract for its installation by a third party installer is strictly prohibited.

E. DDC shall comply with, and be listed at time of bid for the following Underwriters Laboratories Standards:

1) FCC Regulation, Part 15, Section 156.

2) National Electric Manufacturers Associations (NEMA).

3) Comply with ASHRAE 135-2004 (at a minimum) for DDC system control components.

4) DDC Product manufacturer shall be ISO 9001 Registered at the time of bid.

F. Design and build all system components to be fault-tolerant.

1) Satisfactory operation without damage at 110% and 85% of rated voltage and at plus 3 Hertz variation in line frequency.

2) Static, transient and short-circuit protection on all inputs and outputs.

3) Protect communication lines against incorrect wiring, static transients and induced magnetic interference.

4) Network-connected devices to be AC-coupled or equivalent so that any single device failure will not disrupt or halt network communication.

5) All real time clocks and data file RAM to be battery-backed for a minimum 72 hours and include local and system low battery indication.

6) All programs shall retain their memory for a minimum of 7 days upon loss of power.

G. The DDC Installer shall have a competent Project Manager who is able to answer field questions, is aware of all schedules and schedule changes, and is responsible for the DDC Installer's work and the coordination of their work with all other trades. This Project Manager shall be available for on site and shall respond to design, programming, and equipment related questions. Failure to provide the above services shall be considered a substantial breach of Contract Documents.

1.7 System Checkout

A. Provide necessary personnel as required to assist the Associate and Commissioning Agent in providing complete system operational testing. Refer to Section 01 91 13 - Commissioning.

1.8 An interconnecting wiring conduit system shall be installed between all DDC panels within the Building. The interconnecting conduit system shall be extended to the appropriate point to provide the link to the remote communications network. All communications cables required to provide the communications link between the DDC controllers and the external communications network shall be installed as a part of the project.

1.9 The basic control system shall include all sensors, controllers, instruments, valves, actuators, devices, installation and service for a complete and functional control system. All control devices (valves, dampers, actuators, etc.) shall be included under the ATC Sub-Contract unless specifically specified elsewhere in the HVAC Specification. Where Student Life BAS shop self-performs the control project, the HVAC Contractor shall be responsible for correctly sizing control valves and dampers.

1.10 All wiring shall be in compliance with Division 26 Electrical. All wiring shall be run in conduit.

1.11 Surge transient protection shall be incorporated in design of system to protect electrical components in all DDC Network Controllers, Building Controllers and Advanced Application Controllers. Application Specific Controllers outside the mini plant do not require surge protection. Provide an external protection device listed under UL 1449 with minimum clamping voltage of 400 Volts and surge current capability of 26,000 Amps.

1.12 In addition to Division 01 Allowances, the contractor shall include in his bid price the following for EACH building of the bid package: 4 additional digital points and 4 additional analog points with 100 ft of conduit and wire per point per building. Bid price shall include material and labor to install.

PART 2 - PRODUCTS

2.1 Networking Communications

A. Option #1: The design of the DDC network shall integrate web-based operator interface and stand-alone DDC Controllers on a peer to peer communications network, and other devices on other networks. The network architecture shall consist of the following levels:

1. A campus-wide Ethernet communications network based on TCP/IP protocol. Building to campus network shall be BACNET IP compatible.

2. A building-wide peer to peer communications network between DDC Controllers. Building network shall be BACNET IP compatible.

3. Many local area networks extended from appropriate DDC Controllers to associated Supplementary Controllers and associated Application Specific Controllers.

B. Option #2: The design of the DDC network is to provide a peer-to-peer networked, stand-alone, distributed control system with the capability to integrate the ANSI/ASHRAE Standard 135-2001 (BACnet) interoperable system. The network architecture shall consist of the following levels:

1. A campus-wide Ethernet communications network based on TCP/IP protocol. Building to campus network shall be BACNET IP compatible.

2. A building-wide peer-to-peer communications network between servers, routers, operator workstations and building controllers. Building network shall be BACNET IP compatible.

3. Many local area networks extended from appropriate Building Controllers to Routers, Custom Programmable Controllers and Application Specific Controllers, and shall communicate bi- directionally with the building-wide control network.

4. This communications network shall be limited to Building Controllers/Routers, Custom Programmable Controllers and Application Specific Controllers, and shall communicate bi- directionally with the building-wide communications network.

5. Acceptable protocols for this communications network are as follows a. BACnet via Master-Slave/Token-Passing protocol (MS/TP), as acknowledged by the ANSI/ASHRAE 135 standard.

C. Access to system data shall not be restricted by the hardware configuration of the DDC system. The hardware configuration of the DDC network shall be totally transparent to the user when accessing data or developing control programs.

D. Campus-wide Ethernet Communications Network:

1. Local within this building, provide one Ethernet link between the campus-wide Ethernet and the building-wide peer to peer network (Building Controller or DDC Controller network). At least one of the peer to peer network devices (e.g., Building Controller or DDC Controller) shall provide the interface to the Ethernet for remote monitor, remote manual control, remote alarm, and remote programming of sequences of any and all building-wide points and sequences over the Ethernet.

2. Remote at the Student Life (SL) office (Kinnear), provide one Ethernet link for monitor, control, alarm, displaying graphics, and simultaneous programming of sequences. If programming of sequences cannot be accomplished simultaneously while performing monitor, control, alarm, and displaying graphics, then provide a second Ethernet link to allow for simultaneous programming.

3. All Ethernet communications shall include software management and control for both access and privilege. The remote SA office shall manage all rights for access and privilege per each remote location, for remote monitor, remote manual control, remote alarm, and remote programming of sequences of any and all building-wide points.

E. Option#1: Building-wide peer to peer Communications Network:

1. Web-based Operator interface and DDC Controllers shall directly reside on a network such that communications may be executed directly between DDC Controllers and workstations on a peer-to-peer basis, without requirement for any device to operate or manage the network. A portion of the network management is built into each of the 'peer-to-peer members. 'Peer-to-peer' refers to controllers that (when interconnected) will act independently as equals, without a network manager, and will communicate in a token passing protocol with each other to pass data packet information for the purpose of building-wide monitoring and control. A special data packet called the 'token' is constantly and continually 'passed' to every member of the peer-to-peer communications network. Any peer-to-peer

device on the network can send a packet of data only when it has the ‘token’. Any peer-to-peer device on this network can request data from, or send data to, any other device on the network. With this procedure, token ensures that data collisions do not occur, and assures that all members of the network get equal opportunity for all data on the network.

2. Systems that operate via polled response or other types of protocols that rely on a network manager, file server, or similar device to manage panel-to-panel communications may be considered only if a similar device is provided as a standby. Upon a failure or malfunction of the primary network manager, the standby network manager shall automatically, without any operator intervention, assume all DDC network management activities.

3. All operator devices shall have the ability to access all point status and application report data or execute control functions for any and all other devices via the peer-to-peer network. Access to data shall be based upon logical identification of building equipment. No hardware or software limits shall be imposed on the number of devices with global access to the peer-to-peer network data.

4. Network design shall include the following provisions:

a) Provide high-speed data transfer rates for alarm reporting, quick report generation from multiple controllers and upload/download efficiency between network devices. System performance shall insure that an alarm occurring at any DDC Controller is displayed at workstations and/or alarm printers within 5 seconds.

b) Support of any combination of DDC Controllers and operator workstations directly connected to the peer-to-peer network. A minimum of 32 devices shall be supported on a single network.

c) Message and alarm buffering to prevent information from being lost.

d) Error detection, correction and retransmission shall be included to guarantee data integrity.

e) Synchronization of real-time clocks, to include automatic daylight savings time updating between all DDC Controllers shall be provided.

F. Option #2: Building-wide peer to peer Communications Network:

1. The building-wide control netwok shall be based upon the ISO 8802-3 Ethernet standard (IEEE 802.3), utilizing Internet Protocol (IP) communications and operate at a minimum of 10/100 Mb/sec. The installation of all Ethernet wiring, accessories, and connectors shall conform to the ISO standard

2. The preferred connection media shall be 10 Base-T, Category 6, shielded Twisted Pair wire. The maximum single network run shall not exceed more than
250 feet. If additional distance is needed, the use of hubs or other Ethernet media will be acceptable. However, the ‘cascading’ of more than 3 hubs on a single segment will not be accepted.

3. The BAS shall utilize the building-wide control network for communications between the servers, routers, operator workstations and building controllers.

4. The BAS shall not utilize the building-wide control network for Direct Digital Control (DDC) panels, Custom Programmable Controllers (CPC) and Application Specific Controllers (ASC) without written permission from the owner. These controllers shall be located on the local area networks unless approved by the owner.

5. ~~The BAS Contractor shall provide their own Ethernet communications network including all necessary Ethernet hubs, switches, routers, wiring/cabling etc. required to enable ELCN communications between the BAS equipment within the building. Provide an Ethernet switch as the point of connection to the Owner’s IT network to allow for BAS web access from the Owners network.~~The BAS

contractor shall provide their own Ethernet wiring/cabling to allow BAS web access from the owner's network.

6. With written permission from the Owner and the Owner's IT staff, the BAS system may utilize the Owner's IT infrastructure within the facility for the building- wide control network provided the bandwidth consumption is less than 5% of the total network bandwidth. Under no circumstances, shall the Owner's network be subject to failure and/or abuse.

a) The BAS Contractor shall be responsible for coordination with the Owner's IT staff to ensure that the BAS will perform in the Owner's environment without disruption to any other activities taking place on the infrastructure.

b) If permission is granted to use the Owner's IT network:

(1) The Owner shall provide the IP address(es) for the control system to utilize the Owners IT infrastructure.

(2) The BAS contractor is still responsible for the communications wiring between the BAS equipment and the Owner designated connection locations. Final connections shall be coordinated with the Owner's IT staff.

(3) The BAS Contractor shall conform to the Owner's IT standards for all wiring/cabling and connection details.

7. Acceptable protocols for this communications network are as follows a. BACnet/IP protocol (Annex J) as defined by ANSI/ASHRAE Standard 135-2001.

a) The system shall be a minimum conformance class 3, as identified by the standard. BACnet compatible systems that employ the use of proprietary 'gateways' will not be accepted unless otherwise noted.

8. All tools required to manage the ELCN shall be provided with the system

G. Local Area (Communications) Network (LAN):

1. This communications network shall be limited to Building Controllers/Routers, Custom Programmable Controllers, Supplementary Controllers and Application Specific Controllers, and shall communicate bi-directionally.

2. Building Controllers/Routers, Custom Programmable Controllers, Supplementary Controllers and Application Specific Controllers shall be arranged on the LAN's in a functional relationship to the corresponding DDC Controllers. For example, a VAV Application Specific Controller serving a VAV terminal box, shall be connected on a LAN from the DDC Controller that is controlling the corresponding air handling unit.

3. The BAS shall utilize the BLCN for communications between the BCs and the CPCs/ASCs and communications between CPCs and ASCs. All tools required to manage the BLCN shall be provided with the system.

4. Acceptable protocols for this communications network are as follows a. BACnet via Master-Slave/Token-Passing protocol (MS/TP), as acknowledged by the ANSI/ASHRAE 135 standard. The MS/TP link shall operate at a 76.8 Kbps minimum, and utilize no more than 2 repeaters in any instance.

5. Unless otherwise approved by Student Life, a maximum of 32 Supplementary Controllers and Application Specific Controllers may be configured on any individual LAN trunk from any DDC Controller to insure adequate global data and alarm response times. Each supplemental controller is limited by 64 to

each BACnet MSTP trunk of a network controller, each network controller is limited by its own BACnet MSTP trunk count.

2.2 DDC Network Controller

A. DDC (stand-alone) Controllers shall be microprocessor-based with a minimum word size of 16 bits. They shall also be multi-tasking, multi-user, real-time digital control processors consisting of modular hardware with plug-in enclosed processors, communication controllers, power supplies and input/output point modules. Controller size shall be sufficient to fully meet the requirements of this specification.

B. Each DDC Controller shall have sufficient memory, a minimum of 3 megabyte, to support its own operating system and databases, including:

1. Control processes

2. Energy management applications

3. Alarm management applications including custom alarm messages for each level alarm for each point in the system.

4. Historical/trend data for points specified

5. Maintenance support applications

6. Custom processes

7. Operator I/O

8. Dial-up communications

9. Manual override monitoring

C. Each DDC Controller shall support:

1. Monitoring of the following types of inputs, without the addition of equipment outside of the DDC Controller cabinet:

a) Analog inputs

(1) 4-20 mA

(2) 0-10 Vdc

(3) Thermistors

(4) 1000 ohm RTD's

b) Digital inputs

(1) Dry contact closure

(2) Pulse Accumulator

(3) Voltage Sensing

2. Each DDC Controller shall be capable of providing the following control outputs without the addition of equipment outside the DDC Controller cabinet:

a) Digital outputs (contact closure)

(1) Contact closure (motor starters, up to size 4)

b) Analog outputs (1) 4-20 mA
(2) 0-10 Vdc

D. Each DDC Controller shall have a minimum of 10 percent spare (panel real estate) capacity for future point connection in mechanical rooms, commercial kitchens and for air handling units (spare points are not required on field controllers for fan coils, valances and unitary equipment). The type of spares shall be in the same proportion as the implemented I/O functions of the panel, but in no case shall there be less than two spares of each implemented I/O type. Provide all processors, power supplies, database memory, program sequence memory, and communication controllers complete so that the implementation of any added point (within the above 10% spare) only requires the addition of the appropriate point input/output termination module, point sensor, and wiring.

1. Provide sufficient internal memory for the specified control sequences and have at least 40% of the memory available for future use.

E. [Deleted.]

F. The operator shall provide means or the ability to manually override automatic or centrally executed commands at the DDC Controller. These override switches shall be operable whether the panel processor is operational or not.

1. Switches shall be mounted either within the DDC Controllers key-accessed enclosure, or externally mounted with each switch keyed to prevent unauthorized overrides or be located within the DDC system software to electronically override locally on controller panel display using password protected keypad.

2. DDC Controllers shall monitor the status of all overrides and inform the operator that automatic control has been inhibited. DDC Controllers shall also collect override activity information for reports.

G. DDC Controllers shall provide local visual status indication for each digital and analog input and output for constant, up-to-date verification of all point conditions without the need for an operator I/O device. Status indication shall be visible at the local panel.

H. Each DDC Controller shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all panel components. The DDC Controller shall provide both local and remote annunciation of any detected component failures, low battery conditions or repeated failure to establish communication.

I. Isolation shall be provided at all peer-to-peer network terminations, as well as all field point termination's to suppress induced voltage transients consistent with current IEEE Standard C62.41.

J. In the event of the loss of normal power, there shall be an orderly shutdown of all DDC Controllers to prevent the loss of database or operating system software. Programs residing in memory shall be protected either by using EEPROM or by an uninterruptible power source (battery backup). The backup power source shall have sufficient capacity to maintain volatile memory in event of an AC power failure. Where un-interruptible power source is rechargeable (a rechargeable battery), provide sufficient capacity for a minimum of seventy-two hours backup. Charging circuitry, while the controller is operating under normal line power, shall constantly charge the rechargeable power source. A non-rechargeable power source shall not be permitted. Batteries shall be implemented to allow replacement without soldering.

1. Upon restoration of normal power, the DDC Controller shall automatically resume full operation without manual intervention.

K. Application Specific Controllers are not acceptable for Air Handlers or chiller plants.

L. DDC Controllers must comply with Section 2.02.A and 2.03. Panels that lose communication or control due to a single sensor failure are not permitted.

M. DDC Controllers or a Custom Programmable Controller (CPC) will be used in each equipment room where major or more than two pieces of equipment are being controlled.

N. All points associated with a given mechanical system (i.e., an air handling unit) will be controlled from a single DDC Controller or point expansion panels from the respective master. (i.e., remote motor control centers). No points from a given mechanical system may be distributed among multiple panels - points must be run back to a single DDC Controller dedicated to that mechanical system. Closed-loop control must never depend upon network communications. All inputs, program sequences, and outputs for any single DDC control loop shall reside in the same DDC Controller.

2.3 Stand Alone Building Controllers (BC)

A. Stand-alone BC panels shall be microprocessor based, multi-tasking, multi-user, real- time digital control processors. The BC shall provide an interface between the enterprise level operator interfaces and databases, and the building level controllers.

B. Each panel shall have sufficient memory to support its own operating system and database. Non-volatile memory shall be incorporated for all critical controller configuration data and 72-hour battery back-up shall be provided for all volatile memory.

C. All BCs shall communicate on the ELCN as well as the BLCN.

D. Each BC shall be able to extend its performance and capacity through the use of remote Application Specific Controllers (ASC) and Custom Programmable Controllers (CPC).

E. The BC shall have the following minimum capabilities:

1. Global control processes
2. Energy Management Applications
3. Scheduling
4. Alarm Management
5. Historical/Trend Data for all points
6. Time and Calendar synchronization
7. Maintenance Support Applications
8. Operator I/O
9. Dial-Up Communication
10. Manual Override Monitoring
11. Integration of BACnet controller data

F. (not used)~~The BC shall provide at least one RS-232C serial data communications ports for simultaneous operations of multiple operator I/O devices such as industry standard printers, laptop workstations, PC workstations and panel mounted or portable Operator Terminals. The BC shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers or network terminals~~

G. The BC shall monitor the status or position of all hardware overrides and include this information in logs and summaries to inform the operator that automatic control has been inhibited. BCs shall also collect override activity information for daily and monthly reports.

H. (not used)~~The BC shall provide local status indication for each binary input and output for constant, up-to-date verification of all point conditions without the need for an operator I/ O device.~~

I. Each BC shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all subsidiary equipment. The BC shall provide both local and remote annunciation of any detected component failures or repeated failure to establish communication. Indication of the diagnostic results shall be provided at each BC and shall not require the connection of an operator I/O device.

J. Isolation shall be provided at all network terminations, as well as all field point terminations to suppress induced voltage transients consistent with IEEE Standard 587- 1980. Isolation levels shall be sufficiently high as to allow all signal wiring to run in the same conduit as high voltage wiring where acceptable by electrical code.

K. In the event of the loss of normal power, there shall be an orderly shutdown of all BCs to prevent the loss of database or operating systems software. Upon restoration of normal power, the BC shall automatically resume full operation without manual intervention. Should BC memory be lost for any reason, the user shall have the capability of reloading the BC via the ELCN or via the local RS-232C port.

L. Each BC shall automatically and continuously maintain a history of all associated temperatures to allow users to quickly analyze comfort and equipment performance over the past 24 hours. A minimum of two samples per hour shall be stored.

M. Each BC shall have the ability to collect data for any property of any point connected on its BLCN.

N. The BC shall have the ability to back-up its database of points, control processes, logs, trends, histories etc. to the central server.

O. BCs used in conditioned ambient space shall be rated for operation at 32°F to 122°F and 5 to 95% RH, non-condensing. BCs used outdoors shall be rated for operation at -40°F to 140°F and 5 to 95% RH, non-condensing.

P. Each Building Controller shall have a minimum of 10 percent spare (panel real estate) capacity for future point connection in mechanical rooms, commercial kitchens and for air handling units (spare points are not required on field controllers for fan coils, valances and unitary equipment). The type of spares shall be in the same proportion as the implemented I/O functions of the panel, but in no case shall there be less than two spares of each implemented I/O type. Provide all processors, power supplies, database memory, program sequence memory, and communication controllers complete so that the implementation of any added point (within the above 10% spare) only requires the addition of the appropriate point input/output termination module, point sensor, and wiring.

1. Provide sufficient internal memory for the specified control sequences and have at least 25% of the memory available for future use.

2.4 DDC and Building Controller Resident Software Features

A. General:

1. All necessary software to form a complete operating system as described in this specification shall be provided.

2. The software programs specified in this Section shall be provided as an integral part of DDC Controllers and shall not be dependent upon any higher level computer for execution.

3. Point naming convention shall be as referenced in Appendix A.

B. Control Software Description:

1. The DDC Controllers shall have the ability to perform any or all of the following pre-tested control algorithms:

a) Two-position control

b) Proportional control

c) Proportional plus integral control

d) Proportional, integral, plus derivative control

e) Automatic control loop tuning

2. Control software shall include a provision for limiting the number of times that each piece of equipment may be cycled within any one-hour period.

3. The system shall provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads.

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

C. All programs shall be executed automatically without the need for operator intervention and shall be flexible enough to allow user customization. Programs shall be applied to building equipment as described in the Sequence of Operations. DDC Controllers shall have the ability to perform any or all of the following energy management routines:

1. Time-of-day scheduling

2. 365 day Calendar-based scheduling

3. Holiday scheduling

4. Temporary schedule overrides

5. Start-Stop Time Optimization

6. Automatic Daylight Savings Time Switch over

7. Night setback control

8. Enthalpy switch over (economizer)

9. Peak demand limiting

10. Temperature-compensated duty cycling

11. Fan speed/ control

12. Heating/cooling interlock

13. Hot water reset

14. Chilled water reset

15. Condenser water reset

16. Chiller sequencing

17. Chiller load monitoring

D. DDC Controllers shall be able to execute custom, job-specific processes defined by the user, to automatically perform calculations and special control routines.

1. It shall be possible to use any of the following in a custom process:

    a) Any system measured point data or status

    b) Any calculated data

    c) Any results from other processes

    d) User-defined constants

    e) Arithmetic functions (+, -, *, /, square root, exponential, etc.)

    f) Boolean logic operators (and/or, exclusive or, etc.)

    g) On-delay/off-delay/one-shot timers

2. Custom processes may be triggered based on any combination of the following:

    a) Time interval

    b) Time-of-day

    c) Date

    d) Other processes
    e) Time programming

    f) Events (e.g., point alarms)

3. A single process shall be able to incorporate measured or calculated data from any and all other DDC Controllers on the network. In addition, a single process shall be able to issue commands to points in any and all other DDC Controllers on the network.

4. Processes shall be able to generate operator messages and advisories to operator I/O devices. A process shall be able to directly send a message to a specified device.

5. The custom control programming feature shall be documented via English language descriptors. These descriptors (comment lines) shall be viewable from local operator I/O devices to facilitate troubleshooting.

E. Alarm management shall be provided to monitor and direct alarm information to operator devices. Alarm reporting and storage shall be done on the NAE(s) controllers, through the existing SL BAS Metasys server. Independent storage of alarms by the local controllers is not permitted
.

At no time shall the DDC Controllers ability to report alarms be affected by either operator activity at a PC workstation, local I/O device or communications with other panels on the network.

1. All alarm or point change reports shall include the point's English language description and the time and date of occurrence.

2. The user shall be able to define the specific system reaction for each point.
Alarms shall be prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of six priority levels shall be provided for each point. Point priority levels shall be combined with user definable destination categories (PC, printer, DDC Controller, etc.) to provide full flexibility in defining the handling of system alarms. Each DDC Controller shall automatically inhibit the reporting of selected alarms during system shutdown and start-up. Users shall have the ability to manually inhibit alarm reporting for each point.

3. Alarm reports and messages will be directed to a user-defined list of operator devices or PCs.

4. In addition to the point's descriptor and the time and date, the user shall be able to print, display or store a 200 character alarm message to more fully describe the alarm condition or direct operator response.

F. A variety of historical data collection utilities shall be provided to manually or automatically sample, store and display system data for points as specified in the I/O summary.

1. DDC Controllers shall store point history data for selected analog and digital inputs and outputs:

a) Any point, physical or calculated may be designated for trending. Any point, regardless of physical location in the network, may be collected and stored in each ~~DDC Controllers point group~~ Building Controller. Two methods of collection shall be allowed; either by a pre-defined time interval, or upon a pre-defined change of value. Sample intervals of l minute to 7 days shall be provided. Each DDC Controller shall have a dedicated RAM- based buffer for trend data and shall be capable of storing a minimum of 10,000 data samples.

2. Trend data shall be stored at the ~~DDC Controllers and uploaded to the workstation when retrieval is desired. Uploads shall occur based upon either; user-defined interval, manual command, or when the trend buffers are full.~~ Building Controller. All trend data shall be available for use in 3rd party personal computer applications. File format type to be comma delineated.

3. DDC Controllers shall also provide high resolution sampling capability for verification of control loop performance. Operator-initiated automatic and manual loop tuning algorithms shall be provided for operator-selected PID control loops as identified in the point I/O summary. Provide capability to view or print trend and tuning reports.

a) In automatic mode, the controller shall perform a step response test with a minimum one-second resolution, evaluate the trend data, calculate the new PID values and input these values into the selected LOOP statement.

b) For troubleshooting in manual mode, the operator shall be able to select variables to override default values. Calculated PID value shall then be reviewed before they are inserted into the selected LOOP statement.

c) Loop tuning shall be capable of being initiated either locally at the DDC Controller, from a network workstation or remotely using dial-in modems. For all loop tuning functions, access shall be limited to authorized personnel through password protection.

G. DDC Controllers shall automatically accumulate and store run-time hours for digital input and output points as specified in the point I/O summary.

1. The totalization routine shall have a sampling resolution of one minute or less.

2. The user shall have the ability to define a warning limit for run-time totalization. Unique, user-specified messages shall be generated when the limit is reached.

H. DDC Controllers shall automatically sample, calculate and store consumption totals on a daily, weekly or monthly basis for user-selected analog and digital pulse input type points as specified in the point I/O summary.

1. Totalization shall provide calculation and storage of accumulations of up to 99,999.9 units (e.g., kWh, gallons, BTU, tons, etc.).

2. The totalization routine shall have a sampling resolution of one minute or less.

3. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.

I. DDC Controllers shall have the ability to count events such as the number of times a pump or fan system is cycled on and off. Event totalization shall be performed on a daily, weekly or monthly basis for points as specified in the point I/O summary.

1. The event totalization feature shall be able to store the records associated with a minimum of 9,999.9 events before reset.

2. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.

J. Supplementary Controllers:

1. Each DDC Controller shall be able to extend its performance and capacity through the use of remote Supplementary Controllers. Each Supplementary Controller shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each Supplementary Controller shall be a microprocessor-based, multi-tasking, real-time digital control processor. Provide for control of central HVAC systems and equipment including, but not limited to, the following:

a) Heating and ventilating unit

b) Built-up air handling systems

c) Chilled and condenser water systems

d) Hot water systems

2. Supplementary Controllers must comply with Section 2.03, items A, B, C, D, G, H and I with the exception of global type programs and on line programming. Supplementary Controllers shall include all point inputs and outputs necessary to perform the specified control sequences. Provide a hand/off/automatic switch for each digital output for manual override capability. Switches shall be mounted either within the controller's key-accessed enclosure, or externally mounted with each switch keyed to prevent unauthorized overrides or be located within the DDC system software to electronically override locally on controller display with password.

3. In addition, each switch position shall be supervised in order to inform the system that automatic control has been overridden. As a minimum, 50% of the point inputs and outputs shall be of the Universal type, allowing for additional system flexibility. In lieu of Universal inputs and outputs, provide a minimum of 50% spare points of each type via additional point termination boards or controllers. A minimum of 12

global points (i.e. chilled water temperature, hot water temperature, etc.) must be able to be accessed through the Supplementary Controller. If global point access is unavailable with the Supplementary then a Master DDC Controller must be furnished.

4. Each Supplementary Controller shall support its own real-time operating system. Provide a time clock with battery backup to allow for stand-alone operation in the event that communication with its DDC Controller is lost and to insure protection during power outages.

5. Provide each Supplementary Controller with sufficient memory to accommodate point databases, operating programs. All databases and programs shall be stored in non-volatile EEPROM or a minimum of 72-hour battery backup shall be provided. Supplementary Controllers must be fully programmable. All programs shall be field-customized to meet the user's exact control strategy requirements. Supplementary Controllers utilizing pre-packaged or canned programs shall not be acceptable. As an alternative, provide Master DDC Controllers for all central equipment in order to meet custom control strategy requirements.

6. Programming of Supplementary Controllers shall utilize the same language and code as used by DDC Controllers to maximize system flexibility and ease of use. Should the system controller utilize a different control language, provide a DDC Controller to meet the specified functionality.

7. Local alarming ~~and trending~~ capabilities shall be provided for convenient troubleshooting and system diagnostics. Alarm limits ~~and trend data~~ information shall be user-definable for any point.

8. Each controller shall have connection provisions for a portable operator's terminal. This tool shall allow the user to display, generate or modify all point databases and operating programs. All new values and programs may then be restored to EEPROM via the programming tool.

9. Supplementary Controllers that lose communication with master panels, and/or lose control due to a single sensor failure, are not acceptable.

10. At all Supplementary Controllers include a hardwired, concealed and secured, RJ-11 or similar jack for use by the Portable Operators Workstation. The local operator, using the Portable Operators Workstation, shall plug into this jack, and shall perform all monitoring, control, and programming of sequences for any and all building-wide points and sequences while standing at any Supplementary Controller.

11. At all Supplementary Controllers, include the point database of the following minimum building-wide system data:

a) Building Primary Hot Water Supply Temperature

b) Building Primary Chilled Water Supply Temperature

c) Building Common Outside Air Temperature

d) Database for 10 other building-wide points, as field selected by the University.

2.5 Custom Programmable Controllers (CPC) and Application Specific Controllers (ASC’s)

A. Each Building or DDC Controller shall be able to extend its performance and capacity through the use of remote Custom Programmable Controllers (CPC) and Application Specific Controllers (ASC’s).

B. Each Custom Programmable Controllers and Application Specific Controller shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network.

C. Each controller shall retain its program, control algorithms, and setpoint information in non-volatile memory such that a power failure of any duration does not necessitate reprogramming of the controller, and it shall return to normal operation upon restoration of power.

D. The controller's setpoints and input/output point data shall be accessible through any operator, portable operator's terminal, or any BC connected to the BAS system.

E. (not used)

F. The controller shall provide the ability to download and upload configuration data, both locally at the controller and via the BAS communications networks.

G. Provide HOA switches for each digital output and label accordingly.

H. Two copies of any programming tool required to configure or program the controllers shall be provided to the Owner along with all appropriate documentation.

I. Controllers used in conditioned ambient space shall be rated for operation at 32°F to 122°F and 5 to 95% RH, non-condensing. Controllers used outdoors shall be rated for operation at -40°F to 140°F and 5 to 95% RH, non-condensing B.

J. The electrical power source for these Custom Programmable Controllers (CPC) and Application Specific Controllers shall be from local circuit breaker with appropriate fused, class 2, 100VA power-limited output. The breaker shall be dedicated to the Controllers, labeled accordingly, and locked-out from inadvertent casual shutoff.

K. Unitary Thermostat Controllers (UTC) are NOT permitted due to replacement cost.

L. Custom Programmable Controllers (CPC)

1. Controllers shall as a minimum support MS/TP BACnet LAN types. They shall communicate directly via this BACnet LAN at 9.6, 19.2, 38.4 and 76.8 Kbps, as a native BACnet device. Controllers shall be minimum BACnet conformance class 3.

2. Standard BACnet object types supported shall include as a minimum–Analog Input, Analog Output, Analog Value, Binary Input, Binary Output, Binary Value, Device, File and Program Object Types. All proprietary object types, if used in the system, shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information

3. All controllers shall have BACnet Protocol Implementation Conformance Statements (PICS) as per ANSI/ASHRAE Standard 135-2001.

4. Stand-alone CPCs shall be provided for, but not limited to, the following types of applications as shown on the drawings: Custom Air Handling Units, Boiler Plant and Chiller Plant.

5. The Custom Programmable Controller (CPC) shall be a fully user-programmable, digital controller that communicates via BACnet MS/TP protocol.

6. The CPC shall include troubleshooting LED indicators <u>or local display</u>.

7. The CPC shall have the capability to execute complex control sequences involving direct wired I/O points as well as input and output devices communicating over the Field LAN or the SA Bus.

8. Each stand-alone controller for major central station systems, i.e., air handling units, heat exchangers, pumping systems, etc., shall have a local display with operator keypad to view/adjust setpoints and start/stop equipment. Provide a means to prevent unauthorized personnel from accessing setpoint adjustments and equipment control functions.

9. Controllers shall include all point inputs and outputs necessary to perform the specified control sequences. Provide a minimum of one (1) spare outputs of each type. Analog outputs shall be industry standard signals such as 24V floating control, allowing for interface to a variety of modulating actuators.

M. Application Specific - Terminal Equipment Controllers:

1. Provide for control of each piece of building HVAC equipment, including, but not limited to, the following:

a) Variable Air Volume (VAV) terminal boxes

b) Constant Air Volume (CAV) terminal boxes

c) Fan Coil Units (FCU)

2. Controllers shall include all point inputs and outputs necessary to perform the specified control sequences. As a minimum, 50% of the point outputs shall be of the universal type; that is, the outputs may be utilized either as modulating or two-state, allowing for additional system flexibility. In lieu of universal outputs, provide a minimum of one (1) spare outputs of each type via additional point termination boards or controllers. Analog outputs shall be industry standard signals such as 24V floating control, allowing for interface to a variety of modulating actuators. As an alternative, provide DDC Controllers or other ASC's with industry standard outputs for control of all terminal equipment.

3. Each controller performing space temperature control shall be provided with a matching room temperature sensor. The sensor may be either RTD or thermistor type providing the following minimum performance requirements are met:

a) Accuracy: ± 1°F (± 0.6°C)

b) Operating Range: 35° to 115°F (2° to 46°)

c) Set Point Adjustment Range: 55° to 95°F (2° to 30°C)

d) Set Point Modes:

(1) Independent Heating

(2) Independent Cooling

(3) Night Setback Heating

(4) Night Setback Cooling

e) Calibration Adjustments: None required

f) Installation: Up to 100 ft. from Controller

g) Each room zone sensor thermostat shall include a terminal jack integral to the sensor assembly. The terminal jack shall be used to connect a portable operator's terminal to control and monitor all hardware and software points associated with the controller.

h) Refer to "Field Devices" section for sensor requirements.

4. Each controller shall perform its primary control function independent of other DDC Controller LAN communication, or if LAN communication is interrupted. Reversion to a fail-safe mode of operation during LAN interruption is not acceptable. The controller shall receive its real-time data from the DDC Controller time clock to insure LAN continuity. Each controller shall include algorithms incorporating proportional, integral and derivative (PID) values for all applications. All PID values and biases shall be field-adjustable by the user via terminals as specified herein. This functionality shall allow for tighter control of space conditions and shall facilitate optimal occupant comfort and energy savings. Controllers that incorporate proportional and integral (PI) control algorithms only, without derivative (D) control algorithms, shall not be acceptable.

5. Provide each terminal equipment controller with sufficient memory to accommodate point databases, operating programs, local alarming and local trending. All databases and programs shall be stored in non-volatile EEPROM, EPROM and PROM, or minimum of 72-hour battery backup shall be provided. The controllers shall be able to return to full normal operation without user intervention after a power failure of unlimited duration. Provide un-interruptible power supplies (UPS's) of sufficient capacities for all terminal controllers that do not meet this protection requirement. Operating programs shall be field-selectable for specific applications. In addition, specific applications may be modified to meet the user's exact control strategy requirements, allowing for additional system flexibility. Controllers that require factory changes of any applications are not acceptable.

6. Fan Coil (FCU) Controllers:

a) As a minimum, shall support the following types of applications for pressure independent terminal control:
(1) Two and four pipe Fan Coil Units

b) Fan Coil Unit Controllers shall support, but not be limited to, the operational sequences as described in the 230993 "Sequence of Operations for HVAC Controls" section of this spec.

c) The modes of operation supported by the Fan Coil Unit Controllers shall minimally include, but not be limited to, the following:

(1) Daily / weekly schedules
(2) Occupancy mode
(3) Unoccupied mode
(4) Temporary override mode

~~Daily / weekly schedules Occupancy mode Unoccupied mode Temporary override mode~~

d) At a minimum, Fan Coil Unit Controllers shall support the following types of point inputs and outputs:

(1) Modulated heating and cooling control outputs
(2) Space temperature inputs
(3) Analog space temperature setpoint adjustment inputs

~~Modulated heating and cooling control outputs Space temperature inputs~~
~~Analog space temperature setpoint adjustment inputs~~

7. Variable Air Volume (VAV) Box Controllers:

a) As a minimum, shall support the following types of applications for pressure independent terminal control:

(1) VAV, with hot water reheat

(2) VAV Zone Damper, with hot water reheat

b) All VAV box control applications shall be field-selectable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes are not acceptable.

c) The VAV box controller shall be powered from a 24 VAC source and shall function normally under an operating range of 18 to 28 VAC (-25% to +17%), allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 122°F (0° to 50°C) and 10% to 95%RH (non-condensing).

Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly.

d) The VAV controller shall include a differential pressure transducer that shall connect to the terminal unit manufacturer's standard averaging air velocity sensor to measure the velocity pressure in the duct. The controller shall convert this value to actual airflow in cfm. The differential pressure transducer shall have a measurement range of 0 to 4000 fpm (0 to 20.4 m/s) and measurement accuracy of ±5% at 400 to 4000 fpm (2 to 20 m/s), insuring primary air flow conditions shall be controlled and maintained to within ±5% of setpoint at the specified parameters. The BAS contractor shall provide the velocity sensor if required to meet the specified functionality.

e) The VAV box controller shall include provisions for manual and automatic reset of the differential pressure transducer in order to maintain stable control and insuring against drift over time. Reset shall be accomplished by stroking the terminal unit damper actuator to 0%, full closed, position so that a 0 cfm air volume reading is sensed. The controller shall automatically accomplish this whenever the system mode switches from occupied to unoccupied or vice versa. Manual reset may be accomplished by either commanding the actuator to 0% via the POT or by depressing the room sensor override switch. Reset of the transducer at the controller location shall not be necessary.

f) The VAV box controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.5°F (.9°C) of setpoint at the room sensor location.

g) The VAV box controller performing space heating control shall incorporate an algorithm allowing for modulation of a hot water reheat valve, as required to satisfy space heating requirements. Each controller shall also incorporate an algorithm that allows for resetting of the associated air handling unit discharge temperature if required to satisfy space cooling requirements. This algorithm shall function to signal the respective DDC Controller to perform the required discharge temperature reset in order to maintain space temperature cooling setpoint.

2.6 Portable Operator's Terminal (POT)

A. Provide one (1) portable operator terminal (POT) with a minimum LCD display of 80 characters by 25 lines and a full-featured keyboard and two (2) copies of system software tool. The POT shall be hand-held and plug directly into individual distributed control panels as described below. Provide a user-friendly, English language-prompted interface for quick access to system information, not codes requiring look-up charts.

B. Functionality of the portable operator's terminal connected at any controller:

1. Access all controllers on the network.

2. Backup and/or restore DDC Controller databases for all system panels, not just the DDC Controller connected thereto.

3. Display all point, selected point and alarm point summaries.

4. Display trending and totalization information.

5. Add, modify and/or delete any existing or new system point.

6. Command, change setpoint, enable/disable any system point.

7. Program and load custom control sequences as well as standard energy management programs.

C. Functionality of the portable operator's terminal connected to any application specific controller:

1. Provide connection capability at either the ASC or a related room sensor to access controller information.

2. Provide status, setup and control reports.

3. Modify, select and store controller database.

4. Command, change setpoint, enable/disable any controller point.

D. If the same portable operator's terminal cannot be used for both Building Controllers, Advanced Application Controllers and Application Specific Controllers provide separate POT's to accomplish the above functional requirements.

1. Provide 1 of each type portable operator's terminals as specified in A. above.

2. Provide as a minimum, a POT connection in each mechanical room capable of accessing entire system information.

E. Connection of a POT to a distributed control processor shall not interrupt nor interfere with normal network operation in any way, prevent alarms from being transmitted or preclude centrally-initiated commands and system modification.

F. Every workstation or portable operator terminal shall have the required "software keys" for operation.

G. Portable operator terminal access to controller shall be password-controlled.

H. The minimum hardware requirements for the Portable Operator Terminal (Laptop) are as follows:

3.0 GHz Intel Centrino Processor
2.0 GB RAM
1 serial and 1 parallel port
4 USB ports
120 GB IDE Hard Drive

15.4" Widescreen SVGA display Internal 10/100 Ethernet N.I.C. port DVD Read/Write Drive
Built-in wireless card, 802.11g compliant
Operating system compatible with current version of Workstation Interface Software (Windows 7)
Integrated keyboard and touchpad
2 Lithium battery packs, 110 VAC adapter/charger 2 type II (or 1 Type III) PCMCIA slots
56 K internal Modem Carrying Case
Three-year limited warranty All Software updates (good through one year after final building acceptance)

2.7 Web-Based Operator Interface

A. Basic Interface Description

1. Graphic user interface shall be provided at the building controller and at the remote JCI ADX monitoring station.

2. Operator interface software shall minimize operator training through the use of English language prompting, English language point identification and industry standard PC application software. The software shall provide, as a minimum, the following functionality:

a) Graphical viewing and control of environment

b) Scheduling and override of building operations

c) Collection and analysis of historical data

d) Definition and construction of dynamic color graphic displays

e) Editing, programming, storage and downloading of controller databases

3. Provide a graphical user interface, which shall minimize the use of a typewriter style keyboard through the use of a mouse or similar pointing device and "point and click" approach to menu selection. Users shall be able to start and stop equipment or change setpoints from graphical displays through the use of a mouse or similar pointing device.

a) Provide functionality such that all operations can also be performed using the keyboard as a backup interface device.

b) Provide additional capability that allows at least 10 special function keys to perform often-used operations.

4. The software shall provide multi-tasking operating system such that alarm notification occurs while user is running other applications such as Word or Excel; trend data uploads occur in the background while other applications are running. The mouse shall be used to quickly select and switch between multiple applications. This shall be accomplished through the use of Microsoft Windows[a] or similar industry standard software that supports concurrent viewing and controlling of systems operations.

a) Provide functionality such that any of the following may be performed simultaneously, and in any combination, via user-sized windows:

(1) Dynamic color graphics and graphic control

(2) Alarm management coordinated with section 2.04.E.

(3) Time-of-day scheduling

(4) Trend data definition and presentation

(5) Graphic definition

(6) Graphic construction

b) If the software is unable to display several different types of displays at the same time, the BAS contractor shall provide at least two operator workstations.

5. Multiple-level password access protection shall be provided to allow the user/manager to limit workstation control, display and data base manipulation capabilities. Privileges shall be customizable for each operator, the main menu shall reflect the privileges upon log on showing only the applications appropriate for the operator.

a) Customizable such that operators can monitor, command, or edit an application or group of points. An operator can be defined with privileges for access to a building, group or buildings, or areas (labs-- point names with the designation “lab”), by application: the operator has monitor, command, and edit capability for time of day schedules and calendars (only) for the entire campus: or by function: the operator (i.e. security guard) has ability to view/monitor all areas of the campus and receive alarms, etc.

b) A minimum of 50 unique passwords, including user initials, shall be supported.

c) Operators will be able to perform only those commands available for their respective passwords. Menu selections displayed shall be limited to only those items defined for the access level of the password used to log-on.

d) The system shall automatically generate a report of log-on/log-off time and system activity for each user.

e) User-definable, automatic log-off timers of from 5 to 60 minutes shall be provided to prevent operators from inadvertently leaving devices on-line as well as have the capability to generate a report of log-on, log-off time, parameters modified, and system activity for each user.

6. Software shall allow the operator to perform commands including, but not limited to, the following:

a) Start-up or shutdown selected equipment

b) Adjust setpoints

c) Add/modify/delete time programming

d) Enable/disable process execution

e) Lock/unlock alarm reporting for points

f) Enable/disable totalization for points

g) Enable/disable trending for points

h) Override PID loop setpoints

i) Enter temporary override schedules

j) Define holiday schedules

k) Change time/date

l) Automatic daylight savings time adjustments

m) Enter/modify analog alarm limits

n) Enter/modify analog warning limits

o) View limits

p) Enable/disable demand limiting for each meter

q) Enable/disable duty cycle for each load

r) Modify states text

7. Operator shall have ability to schedule reports to print at a pre-specified time and frequency and directed to either CRT displays, printers or disk. As a minimum, the system shall allow the user to easily obtain the following types of reports:

a) A general listing of all points in the network

b) List of all points currently in alarm

c) List of all points currently in override status

d) List of all disabled points

e) List of all points currently locked out

f) DDC Controller trend overflow warning

g) List all weekly schedules

h) List of holiday programming

i) List of limits and dead bands

(1) Summaries shall be provided for specific points, for a logical point group, for a user-selected group or groups or for the entire facility without restriction due to the hardware configuration of the building automation system. Under no conditions shall the operator need to specify the address of the hardware controller to obtain system information.

B. Scheduling

1. Provide a graphical spreadsheet-type format for simplification of time-of-day scheduling and overrides of building operations. Provide the following spreadsheet graphic types as a minimum:

a) Weekly schedules

b) Zone schedules

c) Monthly calendars

2. Weekly schedules shall be provided for each building zone or piece of equipment with a specific occupancy schedule. Each schedule shall include columns for each day of the week as well as holiday and special day columns for alternate scheduling on user-defined days. Equipment scheduling shall be accomplished by simply inserting occupancy and vacancy times into appropriate information blocks on the graphic. In addition, temporary overrides and associated times may be inserted into blocks for modified operating schedules. After overrides have been executed, the original schedule will automatically be restored.

3. Zone schedules shall be provided for each building zone as previously described. Each schedule shall include all commandable points residing within the zone. Each point may have a unique schedule of operation relative to the zone's occupancy schedule, allowing for sequential starting and control of equipment within the zone. Scheduling and rescheduling of points shall be accomplished easily via the zone schedule graphic.

4. Monthly calendars for a 24-month period shall be provided which allow for simplified scheduling of holidays and special days in advance. Holidays and special days shall be user-selected with the pointing device and shall automatically reschedule equipment operation as previously defined on the weekly schedules.

C. Collection and Analysis of Historical Data

NOTE: Graphics Trending described are intended to describe intent.Exact configuration shall be as allowed within the capabilities of the existing front end software.

1. Provide trending capabilities that allow the user to easily monitor and preserve records of system activity over an extended period of time. Any system point may be trended automatically at time-based intervals or changes of value, both of which shall be user-definable. Trend data may be stored on hard disk for future diagnostics and reporting.

2. Trend data report graphics shall be provided to allow the user to view all trended point data. Reports shall be customizable to include individual points or pre- defined groups of at least 6 points. Provide additional functionality to allow any trended data to be transferred easily to Microsoft Office, Excel ®. This shall allow the user to perform custom calculations such as energy usage, equipment efficiency and energy costs and shall allow for generation of these reports on high-quality plots, graphs and charts.

3. Provide additional functionality that allows the user to view trended data on trend graph displays. Displays shall be actual plots of both static and/or real-time dynamic point data. A minimum of 4 points shall be able to be viewed simultaneously on a single graph, with color selection and line type for each point being user-definable. Displays shall include an 'X' axis indicating elapsed time and a 'Y' axis indicating a range scale in engineering units for each point. The 'Y' axis shall have the ability to be manually or automatically scaled at the user's option. Different ranges for each point may be used with minimum and maximum values listed at the bottom and top of the 'Y' axis. All 'Y' axis data shall be color-coded to match the line color for the corresponding point.

a) Static graphs shall represent actual point data that has been trended and stored on disk. Exact point values may be viewed on a data window by pointing or scrolling to the place of interest along the graph. Provide capability to print any graph on the system printer for use as a building management and diagnostics tool.

b) Dynamic graphs shall represent real-time point data. Any point or group of points may be graphed, regardless of whether they have been predefined for trending. The graphs shall continuously update point values. At any time the user may redefine sampling times or range scales for any point. In addition, the user may pause the graph and take "snapshots" of screens to be stored on the workstation disk for future recall and analysis. As with static graphs, exact point values may be viewed and the graphs may be printed.

D. Dynamic Color Graphic Displays

NOTE: Graphics described are intended to describe intent. Exact configuration shall be as allowed within the capabilities of the existing front end software. Graphics shall only be created in the SLBAS Johnson Controls server.

1. Color graphic floor plan displays and system schematics for each piece of mechanical equipment, including air handling units, chilled water systems and hot water systems, room level terminal unit equipment shall be provided by the DDC contractor to optimize system performance analysis and speed alarm recognition.

2. The operator interface shall allow users to access the various system schematics and floor plans via a graphical penetration scheme, menu selection or text- based commands.

3. Dynamic temperature values, humidity values, flow values, percent load, and status indication shall be shown in their actual respective locations and shall automatically update to represent current conditions without operator intervention.

4. The windowing environment of the operator workstation shall allow the user to simultaneously view several graphics at a time to analyze total building operation or to allow the display of a graphic associated with an alarm to be viewed without interrupting work in progress.

5. Graphic generation software shall be provided to allow the user to add, modify or delete system graphic displays.

a) The DDC contractor shall provide libraries of pre-engineered screens and symbols depicting standard air handling unit components (e.g., fans, cooling coils, filters, dampers, etc.), complete mechanical systems (e.g., constant volume-terminal reheat, VAV, etc.) and electrical symbols.

b) The graphic package shall use a mouse or similar pointing device in conjunction with a drawing program to allow the user to perform the following:

(1) Define symbols

(2) Position and size symbols

(3) Define background screens

(4) Define connecting lines and curves

(5) Locate, orient and size descriptive text

(6) Define and display colors for all elements

(7) Establish correlation between symbols or text and associated system points or other displays

(8) Ability to import scanned images and CAD drawings in Autodesk ®, DWG format.

c) Graphical displays can be created to represent any logical grouping of system points or calculated data based upon building function, mechanical system, building layout or any other logical grouping of points which aids the operator in the analysis of the facility.

(1) To accomplish this, the user shall be able to build graphic displays that include point data from multiple DDC Controllers including Application Specific Controllers used for DDC equipment or VAV terminal unit control.

6. Dynamic system status graphic of the site-specific architecture showing status of system hardware, including quantity and address of networks, field panels, terminal equipment controllers, and printers.

E. System Configuration and Definition

1. All temperature and equipment control strategies and energy management routines shall be definable by the operator. System definition and modification procedures shall not interfere with normal system operation and control.

2. The system shall be provided complete with all equipment and documentation necessary to allow an operator to independently perform the following functions:

a) Add/delete/modify stand-alone DDC Controller panels

b) Add/delete/modify operator workstations

c) Add/delete/modify application specific controllers

d) Add/delete/modify points of any type and all associated point parameters and tuning constants

e) Add/delete/modify alarm reporting definition for points

f) Add/delete/modify control loops

g) Add/delete/modify energy management applications

h) Add/delete/modify time and calendar-based programming

i) Add/delete/modify totalization for points

j) Add/delete/modify historical data trending for points

k) Add/delete/modify custom control processes

l) Add/delete/modify any and all graphic displays, symbols and cross- reference to point data

m) Add/delete/modify dial-up telecommunication definition

n) Add/delete/modify all operator passwords

o) Add/delete/modify alarm messages

3. Definition of operator device characteristics, DDC Controllers individual points, applications and control sequences shall be performed using instructive prompting software.

a) Libraries of standard application modules such as temperature, humidity and static pressure control may be used as "building blocks" in defining or creating new control sequences. In addition, the user shall have the capability to easily create and archive new modules and control sequences as desired via a word processing type format.

b) Provide a library of standard forms to facilitate definition of point characteristics. Forms shall be self-prompting and incorporate a fill-in- the-blank approach for definition of all parameters. The system shall immediately detect an improper entry and automatically display an error message explaining the nature of the mistake.

c) Inputs and outputs for any process shall not be restricted to a single DDC Controller, but shall be able to include data from any and all other network panels to allow the development of network-wide control strategies. Processes shall also allow the operator to use the results of one process as the input to any number of other processes (cascading).

d) Provide the capability to backup and store all system databases on the workstation hard disk. In addition, all database changes shall be performed while the workstation is on-line without disrupting other system operations. Changes shall be automatically recorded and downloaded to the appropriate DDC Controller. Similarly, changes made at the DDC Controllers shall be automatically uploaded to the workstation, ensuring system continuity. The user shall also have the option to selectively download changes as desired.

e) Provide context-sensitive help menus to provide instructions appropriate with operations and applications currently being performed.

2.8 Portable Operator Software, Programming And Commissioning

A. Provide hard copies of all programs when University Representative has signed off as complete.

2.9 Field Devices

A. All devices and equipment shall be approved for installation. All devices shall be manufactured by Delta, Automated Logic, Trane, or Johnson Controls.

B. All analog inputs and outputs to/from all items, relating to the monitoring and control of variable speed drives for chilled water, shall be 4-20 MA DC or 0-10 VDC devices, loop- powered, isolated, allowing any single sensor to report identically to multiple systems.

C. Temperature Sensors: Each temperature sensor shall match the requirements of the associated temperature controller. Each sensor shall be designed for the appropriate application (i.e., duct, immersion, etc.) and be provided with all necessary installation accessories. Ranges shall be selected to the middle of the control range. Temperature sensors must have a minimum accuracy of +/- 2 deg F or .5 % of scale, whichever will provide the least error in measurement.

1. Electronic: A modulating solid state controller with built-in detector, P, PI, or PID controller, as required, with continuous voltage or current output. Each controller shall have individual setpoint, proportional band, start point, and span adjustments. Input voltage shall be 24 VAC or less. Each controller to be provided with night setback, summer/winter switchover or remote reset capabilities as required. Controllers shall be of matching type to the input detectors and output drives or sequencers.

2. Thermostat guards shall be provided where specified, indicated on control diagrams / floor plans and in open dining seating and recreational fitness areas. Guards shall be firmly attached to wall and thermostat cover shall be visible through the guard. All room sensors in open public areas shall have concealed setpoint adjustment.

3. All temperature sensors that serve corridors, dining (seating areas), fitness areas and lobbies shall have temperature sensor that is located behind a flush stainless steel cover. There will be no display, local adjustment or override on these sensors. These sensors will have setpoint adjustment through the BAS only.

4. All room sensors in student rooms, apartments, offices, conference rooms, workshops, upper floor lounges, classrooms, large assembly rooms, floor lounges, kitchen cooking, storage spaces shall have exposed set point adjustments to provide adjustment plus or minus 3 degrees from room setpoint. Setpoint shall be set from the operator's workstation. These sensors shall have override pushbuttons if they are associated with a fan coil or air handling unit system. Remote adjustment shall be able to be locked out at the operator's workstation. Due to the cost of replacement, thermostats and space temperature sensors that contain I/O controllers are not permitted.

5. Temperature sensors mounted on exterior walls shall be installed on an insulated base to prevent false reading of the exterior wall temperature.

6. Install thermostats and sensors at 4'-6" AFF to bottom unless otherwise noted on Architectural Drawings. Coordinate installation with the work of other trades before any rough-ins are made.

7. Duct Sensors: DDC duct sensors shall match the requirements of the associated controller incorporating an electrical signal to insure exact and proportional relationship between the measured variable and the transmitted signal. Static pressure sensors shall be mounted in temperature control panels with connecting sensor lines in hard copper. Where a device is used for sensing of Mixed Air Temperature or Preheat applications and the duct area is in excess of 24 square feet the instrument shall incorporate a capillary averaging element with a minimum length of 96 inches or a suitable array of duct sensors wired as a single input. Averaging sensors shall be used on any duct application where duct area exceeds 24 square feet.

8. Provide temperature sensors as required to meet the sequence of operation; in addition, provide temperature sensors in the following locations: return air, mixed air and discharge air sections if not required by the sequence of operation.

D. Humidity Sensors: The relative humidity transmitter monitors and transmits changes in humidity, accurate to +/- 2 % RH. Operating range shall be 0 to 99% RH.

E. Pressure Sensors: Duct static pressure analog sensors shall be high accuracy +/-1% of range suitable for the low pressures and selected for at least 50% over range Sensors shall have industry standard 4-20 mA output and zero end span adjustments.

F. Control Dampers (Multiple Blade Dampers): Automatic dampers ~~furnished by the DDC Contractor~~ shall be single blade or multiple blades as applicable. All dampers are to be sized to the application by the manufacturer using methods similar to control valve sizing. Dampers other than those within air handling units are to be installed by the HVAC Contractor under the supervision of the Temperature Control Contractor. All dampers furnished by air handling unit manufacturers must meet the requirements listed in this section. All blank-off plates and conversions necessary to install smaller than duct size dampers are the responsibility of the HVAC Contractor. All damper frames are to be constructed of No. 13 gauge galvanized sheet metal and shall have flanges for duct mounting. Damper blades shall not exceed 6 inches width. All blades are to be airfoil type construction in ducts with air velocities above 1500 FPM and will be equal to Ruskin CD 50 control dampers with blade and jamb seals. Blades are to be suitable for high velocity performance. All damper bearings are to be made of nylon. Bushings that turn in the bearings are to be oil impregnated sintered metal. Dampers hung with blades mounted vertically shall be provided with thrust bearings. Butyl rubber seals are to be installed along the top and bottom of the frame and along each blade edge. Independent, self-compensating, stainless steel end seals shall be installed to insure minimum leakage between blade ends and damper frame. Seals shall provide a tight closing low leakage damper. Damper sections shall not exceed 48" in length or 12 sq. ft. and shall have minimum of one operator per damper section. All dampers in modulating applications shall have opposed blades. Where sequence requires, submittals shall include damper sizes and leakage characteristics. Leakage shall not exceed 3 cfm/sq. ft. at 1" of static pressure and shall be AMCA licensed as a Class 1A damper. Outboard shaft supports with nylon bearings shall be provided at all damper operator connection points to prevent shaft deflection.

1. Control dampers used for outside air, relief air, or exhaust air applications shall be thermally insulated type, equal to TAMCO 9000 series, and shall be installed a minimum of 6" away from wall penetrations to allow for external mounting of their respective damper motors. Jack-shafting in these applications will only be allowed to prevent having to mount motors in the outside airstream. When internal damper motor mounting is required the sheetmetal contractor shall provide access panels at each motor location to allow for ease of service. Provide in-line coalescing filters for pneumatic lines exposed to freezing air.

G. Automatic Control Valves: General Design – Hydronic control valves shall be either equal percentage plug type or characterized ball type (note: plate and frame auto control valves may be butterfly type, as noted on the drawings). Unless noted otherwise, automatic control valves shall be constructed for 125 lb. wsp, with stainless steel stem, brass trim, Teflon or other suitable packing and replaceable or renewable seats. Valve bodies 2" and smaller shall be all bronze with screwed, sweat or flared ends, and larger valves cast iron body with flanged ends. The characterized ball type shall be specifically designed for modulating hydronic service, ANSI Class 125 working pressure, 0°F - 250°F operating range, stainless steel ball and stem, tested per MSS SP-72 and rated for 200,000 cycles, ISO 9001 compliant. Electric actuation on hydronic valves. All valves are to be sized by the Control Contractor and shall submit pressure drop calculations and guarantee sufficient size to meet the requirements of the equipment being served. Actuators shall be selected and furnished to be of sufficient size to position the valve stem at all positions under all static and dynamic forces within the piping system, e.g., must fully close plus fully open upon any and all system conditions. Select the largest available actuator optionally available for that valve and valve size. Positioning relays shall be furnished for all normally closed valve applications.

1. Hot water control valves shall close off against a pressure of 75 psid. Chilled water control valves shall close off against a pressure of 75 psid.

Air handling hot water coils shall fail open to coil. Air handling chilled water coils shall fail closed to coil.

2. Reheat valves controlled by Application Specific Controllers shall utilize floating point electronic actuation. Controllers shall have declutching mechanism to allow manual positioning of valve.

3. Three-way Valves: Three-way valves are to be of the three port mixing arrangement, designed expressly for mixing of two inlets and providing a common outlet. The use of reverse piped diverting valves shall not be acceptable. The ATC Contractor shall provide guidance to the HVAC Contractor as to the correct method of piping of all three-way valves.

4. Butterfly valves for air handling unit coil control are unacceptable. If high GPM requirements dictate the valve size to be greater than 6", then Temperature Control contractor shall provide two control valves for the application, and the HVAC Contractor shall install the two control valves, for parallel and/or sequenced operation. Two position "isolation" valves shall be bubble tight butterfly valves rated for dead end service.

5. The actuator on these valves shall have position indicator and manual override with a hand wheel operator. These are used on the district chilled water piping, boilers and heat exchangers as indicated on the drawings.

District chiller water valves shall close off against a pressure of 125 psid. The other isolation valves shall close off against a pressure of 75 psid.

H. Air Volume Measurement: Air flow measuring stations will be provided on supply air, return air and outside air of air handling units, utilizing electronic air flow traverse probes and transmitters designed to continuously monitor duct airflow volume or fan inlet volume. Each outside air airflow station shall have an auto-zeroing function, temperature compensation, and a digital cfm readout on the face. Each airflow measurement system will consist of single or multiple probes with velocity measuring sensors. Minimum accuracy for outside air airflow stations shall be 2% of reading with a field installed system accuracy of 5% or better, through a velocity range of 150 to 2500 fpm. Minimum accuracy for fan inlet airflow stations shall be 2% of reading or better, through a velocity range of 1000 to 8000 fpm. Each sensor will utilize the principle of vortex shedding or precision thermistor technology with temperature compensation. Signal amplifying sensors requiring flow corrections for field calibration are not acceptable. Airflow measuring stations shall be Ebtron Gold Series or Paragon Controls. Warranty of equipment including parts and labor will be for a period of two years. Provide access doors to allow visual inspection of airflow monitor if not accessible through the air handling unit or plenum.

Piezo airflow measuring tube will be furnished on the AHU and MUA supply and exhaust fans. Provide a DP sensor to monitor flow on each fan.

I. Smoke detectors are installed by the HVAC Contractor and furnished and wired by the Electrical Contractor.

J. Air static and velocity pressure transmitter: The pressure transmitter shall be used for measuring duct static or velocity pressure in variable air volume fan systems. Duct static pressure sensor shall be pitot-tube type with stainless steel pressure tip. Transmitter shall be equal to Dwyer Series 676.

K. Low Limit Detection Thermostat: Low limit detection thermostats equal to Landis & Staefa ET 134-1504 shall be of the vapor tension capillary type having a sensing element a minimum of 20 feet in length. These thermostats shall be of the manual reset type. The elements shall be complete with necessary fittings to permit installation in the duct so as to sense the correct discharge temperatures. One low limit detection thermostat will be installed for every 24 square feet of protected area and arranged so as to stop their respective units and close the outside air dampers in the event discharge temperatures fall below 38 degrees F. The normally closed contact shall be wired to the fan circuit and the normally open contact (close on alarm) shall be wired to a DDC input. One common circuit is suitable for multiple thermostats on a single AHU coil area.

L. Electric Thermostat: Heavy duty snap action type with key operators rated at 10 FLA at 120 RIAC contacts suitable for the intended services. Provide manual selector switch as required in the sequence of operation.

M. Fan and Pump Proof: Proof points for air handling unit fans, exhausts fans and pumps will be accomplished through the use of current sensing relays at the motor control center or VFD’s / motor starters. Current sensing relays shall be split-core design, for installation over any single power lead. Current sensing relays shall include field adjustable set screw for amperage setpoint adjustment, and shall include integral LED status light to locally indicate the "on" and "off" condition. Current sensing relays for motors on VFD's shall be designed for VFD applications, and shall be installed to read regardless of the position of the VFD H-O-A switch.

N. Carbon Dioxide Sensors

1. Carbon dioxide sensors shall be duct mounted non-dispersive infrared transmitters. Sensors shall include a relay with N.O. and N.C. output contacts, either a 4-20 MA or 0-10 VDC analog output, and angled display to indicate concentrations at the sensor.

Sensors shall be capable of measuring levels from 0-2000 PPM with an accuracy of 75 PPM in an operating temperature range of 32°F to 122°F and a relative humidity of 0 to 99% non-condensing. Sensors shall operate on 24 volt AC 2.5 watt single phase power.

2. Main sampling sensor shall be mounted in PCT enclosure with pump. Extend sampling tubes to exterior.

3. Typical Sensors:

a. Manufacturer and Model No. - Vulcain 90DM3ADT

b. Main Sampling Station: Manufacturer and Model No. - Vulcain 90DM4 with PCT enclosure.

O. Carbon Monoxide Sensors

1. CO sensors shall be surface mounted in loading dock according to manufacturer's recommendations. The sensor shall have a 4-20 MA or 0-10 VDC output. Sensors shall be capable of operation in an ambient of 0°F to 100°F. Minimum accuracy of 3% across range of 0 to 500 PPM.

2. Manufacturer and Model No. - Vulcain VA20IT Q1CO

P. Point Water Detector

1. Point water detectors shall be BAPI BA/LDT1-PS-BB for mechanical rooms and Windland WB-200 for elevator pits. ~~Liebert Liqui-tect 410, adjustable height with gold- plated probes and hermetically sealed electronics.~~ Unit shall have supervised operation and be suitable for floor mounting.

Q. Heat Tracing System

1. The following systems shall be heat traced for freeze protection:

a) Commercial Kitchen - condensate piping in Walk in Freezers.

b) Commercial Kitchen - Exterior fryer oil piping (supply and return) at loading dock.

c) Make up air units – chilled water piping above the roof that is not in a heated enclosure.

2. The system shall be engineered by Raychem and shall include, but not limited to, Raychem XL-TRACE self-regulating plastic insulated resistance cables having heating density as recommended by the manufacturer for the application, power distribution panel containing ground fault circuit breakers, one or more electronic monitoring panels that monitors each heat trace circuit's the ground fault status and the integrity of the heat trace circuit (high and low current) and shall include contacts for remote monitoring thru the B.A.S.

The Power Distribution Panel shall be equal to Tyco Thermal Controls DigiTrace HTPG with 40 amp 208-volt 3-phase main breaker. Individual heat tracing circuits shall be 120-1 phase. Locate the Panel inside the building and in a location that is serviceable.

3. Installation shall be in strict accordance with the manufacturer's recommendations, including wrapping with insulating tape. The ATC shall extend power from the emergency power panel. All control, wiring, transformers, etc…shall be included in the ATC contract.

2.10 Differential Pressure Transmitters

A. Differential pressure transmitters shall be diaphragm operated. Veris or Setra

B. Wiring terminals and electronics shall be in separate compartments, so the electronics remain sealed during installation. Reverse polarity protection shall be included to keep wiring mishaps from damaging the transmitter.

C. Transmitter output shall be a 4-20 mA or DC voltage signal, linear over the transmitter span, and the transmitter range shall be selected for the application and shall not exceed the nominal system working pressure of 50% minimum.

D. Differential pressure transmitters shall meet or exceed the following specifications:
1. Minimum accuracy shall be +/- 1% of calibrated span.

2. Damping: Adjustable time constant.
3. Calibration: Zero point and span adjustable to within 0.5% of full span.
4. Housing: Carbon steel or aluminum, NEMA 4 f. Over-range Limit: 200% of transmitter range 4.
5. Includes combined effects of linearity, hysteresis and repeatability. Stability shall be +/- .25% of upper range limit for six months. No internal mechanical linkages shall be used in the transmitter(s).

E. Transmitters shall be furnished with a 3-valve balancing manifold, as a complete assembly.

F. The DP transmitter shall be hard-wired to the system controller directly, and shall control the pumps. These analog values shall not be passed across the B.A.S. Network, and the closed-loop control of pump speed shall not occur over the B.A.S. Network.

PART 3 - EXECUTION

3.1 On-Site Testing

A. Provide the University's Representative and the Associate with approved operation and acceptance testing of the complete system. The University's Representative and the Associate will witness all tests.

B. Field Test: When installation of the system is complete, calibrate equipment and verify transmission media operation before the system is placed on-line. The installer shall complete all testing, calibrating, adjusting and final field tests. Provide a detailed cross- check of each sensor within the system by making a comparison between the reading at the sensor and a standard traceable to the National Bureau of Standards. Provide a cross-check of each control point within the system by making a comparison between the control command and the field-controlled device. Verify that all systems are operable from local controls in the specified failure mode upon panel failure or loss of power. Submit the results of functional and diagnostic tests and calibrations to the University's Representative and the Associate for final system acceptance.

C. Compliance Inspection Checklist: Submit in the form requested, the following items of information to the University's Representative and the Associate for verification of compliance to the project specifications. Failure to comply with the specified information shall constitute non-performance of the contract. The contractor shall submit written justification for each item in the checklist that he is unable to comply with. The University's Representative and the Associate will initial and date the checklist to signify contractor's compliance before acceptance of system.

1. Verify to the University's Representative and the Associate in letter form that supplier has in-place support facility. Letter shall show location of support facility, name and titles of technical staff, engineers, supervisors, fitters, electricians, managers and all other personnel responsible for the completion of the work on this project.

User_ Date A/E_ Date

2. Submit in data sheet form or official government approval form compliance to F.C.C. Regulation, Part 15, Section 15.

User_ Date A/E_ Date

3. Manually generate an alarm at a remote DDC Controller as selected by the University's Representative and the Associate to demonstrate the capability of the workstation and alarm printer to receive alarms within 5 seconds.

User_ Date A/E_ Date

4. Disconnect an operator workstation in the central control room and manually generate an alarm at a remote DDC Controller to demonstrate the capability of the system printer to receive alarms when the workstation is disconnected from the system.

User_ Date A/E_ Date

5. Disconnect one DDC Controller from the network to demonstrate that a single device failure shall not disrupt or halt peer-to-peer communication. Panel to be disconnected shall be selected by the University's Representative and the Associate.

User_ Date A/E_ Date

6. At a DDC Controller of the University's Representative and the Associate's choice, display on the portable operator's terminal:

a. At least one temperature setpoint and at least one status condition, i.e., on or off for a system or piece of equipment attached to that panel as well as for points at another DDC Controller on the network.

b. The diagnostic results as specified for a system or piece of equipment attached to that panel as well as for a system or piece of equipment attached to another DDC Controller.

c. The ability to add a new point to the DDC Controller with the POT and have it automatically uploaded to the workstation to modify that panel's stored database without having to power down or take the DDC panel off-line.

User_ Date A/E_ Date

7. At an ASC of the University's Representative and the Associate's choice, disconnect the LAN connection to demonstrate its lack of reliance on a DDC Controller to maintain full control functionality.

User_ Date A/E_ Date

3.2 Service And Guarantee

A. General Requirements: Provide all services, materials and equipment necessary for the successful operation of the entire BAS system for a period of one year after completion of successful performance test. Provide necessary material required for the work. Minimize impacts on facility operations when performing scheduled adjustments and non-scheduled work.

B. Description of Work: The adjustment and repair of the system includes all computer equipment, software updates, transmission equipment and all sensors and control devices. Provide the manufacturer's required adjustments and all other work necessary.

C. Personnel: Provide qualified personnel to accomplish all work promptly and satisfactorily. University shall be advised in writing of the name of the designated service representative, and of any changes in personnel.

D. Systems Modifications: Provide any recommendations for system modification in writing to University. Do not make any system modifications, including operating parameters and control settings, without prior approval of University. Any modifications made to the system shall be incorporated into the operations and maintenance manuals, and other documentation affected.

E. Software: Provide all software updates and verify operation in the system. These updates shall be accomplished in a timely manner, fully coordinated with the system operators, and shall be incorporated into the operations and maintenance manuals, and software documentation.

3.3 Training

A. The Contractor shall provide competent instructors to give full instruction to designated personnel in the adjustment, operation and maintenance of the system installed rather than a general training course. Instructors shall be thoroughly familiar with all aspects of the subject matter they are to teach. All training shall be held during normal work hours of 7:00 a.m. to 3:30 p.m. weekdays as follows:

B. Provide 8 hours of training for University's operating personnel. Training shall include:

1. Explanation of drawings, operations and maintenance manuals

2. Walk-thru of the job to locate control components

3. Operator workstation and peripherals

4. Building Controller, Advanced Application Controller and ASC operation/function

5. Operator control functions including graphic generation and field panel programming

6. Operation of portable operator's terminal

7. Explanation of adjustment, calibration and replacement procedures

C. Provide 24 hours of additional training for a period of one year from final completion of the project.

D. Provide 8 hours of A/E-directed engineering labor per each building.

E. Since the University may require personnel to have more comprehensive understanding of the hardware and software, additional training must be available from the Contractor. If the University requires such training, it will be contracted at a later date. Provide description of available local and factory customer training.

F. The DDC contractor shall work with the commissioning team to identify and complete the graphics programming (input and output) that will be required for the DDC system. The DDC system shall have the ability to link into the video and audio equipment for use with the DDC system. Training videos are intended to be part of the overall system.

G. The DDC contractor shall work with the commissioning team to provide the materials in a format that will become part of the training for OSU personnel.

3.4 Controller and Point Naming

Controllers shall be named using the building name, followed by equipment type, followed by the location (e.g.-Scott Hall, FCU, Rm 289)

The physical and virtual (pseudo) point naming convention has been standardized and in most cases will follow the pattern of designators as listed below.
A meeting between OSU SL BAS and the control contractor shall be scheduled to confirm point naming.

The first character is the type of mechanical system

Ahu = Air (Handler)
C = (Main) Cooling (Chiller System) Z = Zone
H = (Main) Heating (System) Rh = Reheat
RH = Relative Humidity D = Domestic
Rad = Fin Tube (Radiation) Ph = Preheat
Ch = Chilled
Con = Condenser P = Primary
S = Secondary E = Exhaust
The second character is the system or equipment number (used even if only one in group). Numbers only (no letters)

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- 99

The third through sixth characters are standardized University abbreviations, which describe the specific controlled process and/or condition being sensed.

SW-T = Supply Water Temp RW-T = Return Water Temp. P1-C = Pump #01 Start/Stop
P1-S = Pump #01 Status or Proof CD-SP = Cold Deck Setpoint
HD-O = Hot Deck Output
SF1-C = First or only Supply Fan Start/Stop RF2-S = Second Return Fan Status
SF1-V = First or only Supply Fan Velocity
3.5 Commissioning

The ATC Contractor shall take special care in reviewing and studying the Commissioning Specification 01 91 13 with regard to additional responsibilities and duties.

3.6 Testing And Acceptance

A. The DDC system shall be tested for acceptance by the commissioning team by providing operation of the DDC system for 120 continuous hours during which there shall be no major malfunction of the DDC system (major system failure requires a retest). Any other failures during the test shall be identified and an action plan developed to fix and retest that part (this does not require a full retest). This test shall begin upon the completion of the commissioning functional testing and the resolution of identified issues. The entire commissioning team shall approve commencement of the 120 hour tests. Upon completion and acceptance of this test, the DDC system warranty period can begin.

3.7 Record Program CD copy

A. After commissioning, testing and acceptance and final adjustments the ATC shall burn a CD and a USB flash drive of the DDC building programs and turn this over to OSU SL BAS. Disk shall identify the building Name and date of backup.

2.5 N, Steam Desuperheater Control:

Provide a modular controller with associated input/output modules and touch-screen display mounted in a panel located in
an area not subjected to high temperature or relative humidity. ~~(Modular controller shall be Delta EnteliBUS eBMGR-TCH, or equivalent by an approved equivalent manufacturer.)~~ Desuperheater control valve shall be as described in Division 23 for medium pressure steam service and shall have electro-pneumatic positioner and Class V shutoff. Provide high temperature sensor and transmitter.

Sensor:
Sensor Type 1000 Ohm +/- 0.1% @ 32 F Temperature Coefficient 0.00375 Ohm/Ohm/Degree C
Sensitivity 2.1 Ohm/F @ 32 F
Measurement Range -58 F to 932 F
Probe Material 304 Stainless Steel
Wiring Terminations Two-wire nickel coated stranded copper, 24 inch long 22 AWG fiberglass insulated Warranty 3 years
Model Number S241HC (Minco, or equivalent)

Transmitter:
Supply Voltage 8.5 – 35 VDC unregulated
Sensor Input 1000 Ohm platinum 0.00375 Ohm/Ohm/Degree C
Measurement Range 0 F to 800 F
Signal Output 4 – 20 mA
Maximum Output Impedance 775 Ohm +/- 0.1% @ 24 VDC min Accuracy Calibration accuracy +/- 0.05% of span
Operating Temperature -58 F to 160 F Well Operating Pressure 3000 PSIG max
Well Material 304 Stainless Steel
Warranty 3 years
Model Number TT111H-0800 (Minco, or equivalent) Provide the following inputs and outputs:
Desuperheater Control Valve Analog Output
Desuperheater Pump 1 Status Binary Input
Desuperheater Pump 2 Status Binary Input Desuperheated Steam Temperature Analog Input

Desuperheater control valve shall modulate to maintain steam temperature at 15 F above saturation temperature. Provide alarm for high temperature and pump failure.

Desuperheater pump package will be controlled by its own microprocessor controller.

END OF STUDENT LIFE APPENDIX A-SL

BUILDING AUTOMATION SYSTEM

PART 1 GENERAL

Commentary: *Division 23 lists existing University Control Centers. This Appendix applies to the OSU* ***Wexner Medical Center*** *(OSUWMC) Control Center. This Appendix applies to all building automation systems in all OSUWMC buildings on all University campuses and locations, except where noted otherwise in the BDS or hereinafter. For FOD systems, see the separate FOD Appendix A - FOD. For Student Life, see the separate Student Life Appendix A - SL. The individual Control Centers have the authority to amend the requirements of this Appendix with the approval of the University Engineer and OSUWMC Facilities Engineering. References to the FOD Control Center, or to the FOD Building Automation Department, or to FOD should be interpreted as meaning the appropriate Control Center for the given project. Review with the OSU Project Manager.*

1.01 SCOPE

A. Furnish and install a complete native BACnet DDC Building Automation System (BAS) as manufactured by Delta Controls, Inc, or Siemens. to automatically control the operation of the new HVAC system. The new Building Automation System shall fully integrate into the existing ~~district wide~~ approved vendor native BACnet ~~Delta Controls virtual private network (VPN)~~. The required integration shall include the creation of custom graphics and the compilation and display of all devices and objects on the existing Delta Controls Operator Workstation (OWS) and Webserver. All graphic displays will reside on the existing Delta Controls OWS and be modified accordingly. In addition, the system shall perform the said integration through the use of BACnet/IP communications (Annex J only). BACnet over Ethernet will not be supported for district wide communications. All integration work shall be performed in cooperation with Delta Controls, Inc. or its local representative. Failure to mention any specific item or device does not relieve the Contractor of the responsibility for installing or integrating such device/peripheral in order to comply with the intent of the Drawings or this Specification.

B. Proposed Equals shall be proposed as outlined in the Instructions to Bidders, Article 2.5, and as detailed below and must submit product for testing purposes prior to bid. To obtain approval to use unspecified products as ‘approved equals’, Bidders shall submit written requests to the Architect/Engineer at least ten (10) working days before the bid date. Requests received after this time will not be considered. Requests shall clearly describe the system for which approval is asked, including all data necessary to demonstrate that it meets all performance requirements of the specifications. This data shall include but is not limited to, Protocol Implementation Conformance Statements, Device Profile listings, BIBB Summaries and Read/Write documentation (all similar to what is listed under this specification). If the proposed equal is found to be acceptable, an addendum will be issued, as outlined in the Instructions to Bidders, Article 2.5, to all contractors on record. Submitted data shall be organized, tabulated, and annotated as follows:

1. Overall table of contents
2. Individual table of contents for each section

3. Tabulated list of included hardware and software (differentiated from available-but-not-included hardware and software)
4. Tabulated list of conformance to each paragraph of this specification, listing any exceptions thereto
5. Specific description of hardware, firmware, and software as proposed
6. Campus-wide Ethernet network diagram applicable to this project
7. Auto-dial/auto-answer communications network
8. Building-wide peer-to-peer Building Controller network diagram
9. Advanced Application Controller local area network diagram
10. Detailed description of graphic and display software characteristics
11. Detailed description of DDC control software characteristics
12. BACnet Compliance Documentation

C. Building Automation System (BAS) Contractor shall provide:

1. A fully integrated and fully programmable BACnet building automation system (BAS), UL listed (UL916 and UL864 If applicable), incorporating direct digital control (DDC) for energy management, equipment monitoring and control, as manufactured by Delta Controls or Siemens. The use of algorithmic or canned programming controllers will not be permitted. A UL864 listing shall be required for all controllers that are utilized in a smoke control sequence and as necessary to meet or exceed all national and local codes. In addition, UL864 devices and non UL864 shall not be permitted on the same network segment unless the devices are separated with a UL864 Ethernet switch. All MS/TP network segments shall be consistent with its UL864 or non UL864 implementation. In other words, there shall not be UL864 product and non UL864 product on the same MS/TP network segment.
2. Necessary conduit, wiring, enclosures, and panels, for all DDC temperature control equipment and devices. Installation shall comply with applicable local and national codes.
3. All components and control devices necessary to provide a complete and operable DDC system as specified herein.
4. All final electrical connections to each stand-alone DDC Controller. Connect to 120VAC power as provided by the Division 26 contractor, to be terminated within 5 feet of the DDC Controller.
5. BAS Contractor shall be responsible for all electrical work associated with the BAS control system and as called for on the Drawings. This BAS control wiring shall be furnished and installed in accordance with the Electrical requirements as specified in

Division 26, the National Electric Code, and all applicable local codes.

6. Surge transient protection shall be incorporated in design of system to protect electrical components in all Building Controllers, Advanced Application Controllers and operator's workstations. Provide an external protection device listed under UL 1449 with minimum clamping voltage of 130 VRMS and surge current capability of 22,500Amps for all custom fabricated control panels (all main system components (i.e., AHUs, Chillers, Boilers, etc.).

7. All 120V and low voltage electrical control wiring exposed throughout the building shall be run in conduit in accordance with the Electrical requirements as specified in Division 26, the National Electric Code, and all applicable local codes. All low voltage wiring that is concealed in accessible ceilings may be run in plenum rated cable per the National and Local Electrical codes.

8. All 24VAC power required for operation of the BAS shall be by the BAS Contractor and shall be limited to 100 VA per the aforementioned codes. Any 24VAC power link that exceeds the 100 VA rating must be installed in conduit per Division 26 and all applicable codes, regardless of the nature of the installation.

9. BAS Contractor shall provide programming modifications necessary to fine tune sequences during commissioning and through the warranty period of system and for an additional 12 months, at no extra cost to The Ohio State Medical Center.

10. New installation shall require data analytics and continuous commissioning implementation.

D. HVAC Contractor provides:

1. All wells and openings for water and air monitoring devices, temperature sensors, flow switches and alarms furnished by BAS Contractor.

2. Installation of all control valves as per the contract drawings. The temperature control contractor is not responsible for the incorrect installation of any domestic, hot or chilled water control valves.

3. Installation of all dampers and adjacent access doors for smoke; outdoor air, return air, exhaust air, and ventilation dampers.

4. ~~All package unit control panels including but not limited to, factory boiler panels, factory chiller panels, refrigerant monitors and specialty interface modules required for BACnet compliance~~ Package unit control panels, including but not limited to, factory boiler panels, factory chiller panels, and refrigerant monitors, shall communicate with building automation system to allow for centralized monitoring and access to available BACnet objects. Software tools and training for controllers shall be provide to the owner.

E. Electrical Contractor provides:

1. Electrical Contractor shall provide dedicated 120 volt, 20 amp circuits and circuit breakers

from normal and/or emergency power panel for each DDC Controller. Run power circuit within 5 feet of equipment installed and connected by BAS Contractor.

2. Electrical contractor will also provide smoke detector and smoke damper interlock and power wiring for all life safety applications.

F. General Product Description:

1. The building automation system (BAS) shall integrate multiple building functions including equipment supervision and control, alarm management, energy management and historical data collection utilizing the BACnet protocol.

2. The building automation system shall consist of the following:

   a. Stand-alone peer-to-peer Building Controllers with 32 bit processors, a minimum of 2 MB of flash memory and 10 bit A/D converters. Ethernet connectivity is required for all Building Controllers.

   ~~b.~~ Stand-alone peer-to-peer Advanced Application Controllers with 32 bit processors, a minimum of 1 MB flash memory and 10-bit A/D converters. Ethernet or MS/TP connectivity will be permitted for all AACs.~~Portable operator's terminal(s)~~

   c. Provide seamless interconnection to the existing ~~Delta Controls~~ central graphic workstation, and build ~~Delta Controls~~ standard and HTML / ASP customized graphics displays in accordance with the existing formats.

   d. <u>All BACnet intrinsic alarming shall be disabled. All alarming shall be setup in the existing vendor's central graphic workstation.</u>

3. The system shall be modular in nature and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, Building Controllers, Advanced Application Controllers, expansion modules and operator devices.

4. System architectural design shall eliminate dependence upon any single device for alarm reporting and control execution. Each DDC Controller shall operate independently by performing its own specified control, alarm management, operator I/O and data collection. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices. Alarm management and data collection that requires a single mechanism for user notification or viewing is strictly prohibited.

5. All Controllers shall be able to access any data from, or send control commands and alarm reports directly to, any other DDC Controller or combination of controllers on the network without dependence upon a central processing device (peer-to-peer). All Controllers shall also be able to send alarm reports to multiple operator workstations without dependence upon a central processing device.

6. BACnet Field Devices: Manufacturer shall provide product updates for the lifecycle of the installed DDC hardware at no additional cost to the University. Manufacturers shall provide software tools, licensing, and training necessary for the University's field technicians to deploy and install updates. Updates shall include all patches, firmware, and software revisions for the lifecycle of the hardware or until the manufacturer no longer provides support for the product. Updates shall be available to all devices on the existing district wide Building Automation BACnet network so that all facilities with like hardware are running on the same firmware and software revisions. The requirement for these updates includes, but is not limited to, products with embedded OS, PLC's, building level controllers, advanced application controllers, application specific controllers, unitary controllers, and component interfaces.

7. Server Frontend Applications, Data Historians, and BACnet Advanced Operator Workstations: Manufacturers shall provide product updates and licensing for the life of the application at no additional cost to the University. Manufacturers shall provide software tools, licensing, and training necessary for the University's field technicians to deploy and install updates. Updates shall include all patches, service packs, security updates, and software revisions. If newly installed hardware is no longer supported by the application, the manufacturer shall upgrade the application to the most current version. If the operating system on the machine running the application has reached the end of its lifecycle (e.g., Windows Server 08R2 or Windows 7), then the manufacturer shall provide software and licensing for the application to run on a modern operating system. If newer server product, software or operating system is available, it shall be installed with the project. Server front end applications shall reside on virtual servers located in the Medical Center Server Operations Center. Any server modifications or additions shall be at the cost of the BAS contractor.

1.02 RELATED WORK

A. Specified elsewhere:

1. _____ - Sequence of Operation
2. _____ - Variable Speed Control
3. _____ - Basic Mechanical Requirements
4. _____ - Motors
5. _____ - HVAC Pumps
6. _____ - Boilers
7. _____ - Chillers
8. _____ - Cooling Tower

9. _____ - Terminal Heat Transfer Units
10. _____ - Air Handling Units
11. _____ - Testing, Adjusting and Balancing
12. _____ - Basic Electrical Materials and Methods
13. _____ - Equipment Wiring

B. Materials furnished by the BAS contractor, but installed by others:

1. BAS Contractor to furnish the following to the Heating, Ventilation and Air Conditioning Contractor for installation by the HVAC contractor:
    a. Control valves and temperature sensor wells for wet systems
    b. Location of all wells and openings for temperature, pressure, and flow sensors for pipe systems
    c. Control dampers for air systems
    d. Variable Frequency Drives
    e. Location of all ducts and openings for temperature, pressure, flow, and humidity sensors for air systems.

1.03 QUALITY ASSURANCE

A. Materials and equipment shall be the catalogued products of manufacturers regularly engaged in production and installation of automatic temperature control systems and shall be manufacturer's latest standard design that complies with the specification requirements.

B. Install system using competent workmen who are fully trained and factory certified in the installation of temperature control equipment. The factory certified diplomas shall be readily available at the request of the owner or Architect/Engineer.

C. Single source responsibility of supplier shall be the complete installation and proper operation of the BAS and control system and shall include debugging and proper calibration of each component in the entire system. The BAS must be supplied and installed by the same control contractor. Only Factory Authorized Distributors will be considered for installation. The letting of separate contracts by the prime HVAC Contractor for the Control System and a separate contract for its installation by a third party installer is strictly prohibited.

D. Supplier shall have an in-place support facility within 50 miles of the site with technical staff, spare parts inventory and all necessary test and diagnostic equipment.

E. All electronic equipment shall conform to the requirements of FCC Regulations, Part 15, Subpart B, Class A, governing radio frequency electromagnetic interference, and be so labeled.

F. BAS shall comply with, and be listed at time of bid for the following Underwriters Laboratories Standards:

   1. UL 916 for Energy Management Equipment, per category PAZX for Energy Management Equipment.

   2. UL 864 for Control Units for Fire-Protective Signaling Systems, per category UUKL for Smoke Control System Equipment.

G. Product shall be ISO 9001 Registered at the time of bid.

H. Design and build all system components to be fault-tolerant.

   1. Satisfactory operation without damage at 110% and 85% of rated voltage and at plus 3-Hertz variation in line frequency.

   2. Static, transient and short-circuit protection on all inputs and outputs.

   3. Protect communication lines against incorrect wiring, static transients and induced magnetic interference.

   4. Network-connected devices to be AC-coupled or equivalent so that any single device failure will not disrupt or halt network communication.

   5. All Building / System Controllers shall have real time clocks and data file RAM with battery and SRAM backup.

   6. All controllers shall be EEPROM, flash driven.

   7. The BAS Installer shall have a competent and factory certified Project Manager who is able to answer field questions, is aware of all schedules and schedule changes, and is responsible for the BAS Installer's work and the coordination of their work with all other trades. This Project Manager shall be available for on site and shall respond to design, programming, and equipment related questions. Failure to provide the above services shall be considered a substantial breech of Contract Documents.

1.04 SUBMITTALS

A. Submit 10 complete sets of drawings showing the kind of control equipment for each of the various systems and their functions, along with indications on the drawing of all original setpoints and calibration values, and setup parameters, and sequence of operation of the automation system. These drawings shall be submitted for approval to the A/E and for review by OSUWMC HVAC Analyst Team, ~~These drawings shall be submitted for approval to the Associate,~~ together with a complete brochure describing the equipment and their functions and operation. Include all application software documentation (actual programs or their job-specific flow charts) with DDC system and schedule a review meeting with OSUWMC and the ~~Associate~~ HVAC Analyst Team at least two weeks before installation and start up.

1. Manufacturer's Product Data:
    a. All equipment components
2. Shop Drawings:
    a. System wiring diagrams with sequence of operation for each system as specified.
    b. Submit manufacturer's product information on all hardware items along with descriptive literature for all software programs to show compliance with specifications.
    c. System configuration diagram showing all panel types and locations as well as communications network and workstations.

B. Where installation procedures, or any part thereof, are required to be in accord with the recommendations of the manufacturer of the material being installed, printed copies of these recommendations shall be furnished to the Architect/Engineer prior to installation. Installation of the item will not be allowed to proceed until the recommendations are received.

PART 2- PRODUCTS

2.00 BACnet CONFORMANCE

A. The Building Automation System (BAS) contractor shall supply a BACnet (ANSI/ASHRAE 135-2004) compliant system. Each device category and its required compliance are listed below under sections F-H. BACnet compatible systems that employ the use of proprietary 'gateways' will not be accepted unless otherwise noted. All non-approved BAS Contractors shall supply, prior to bid, Protocol Implementation Conformance Statements (PICS), BACnet Interoperability Building Block (BIBB) summaries or Device Profile listings and a detailed listing of Read/Write capabilities to the Architect/Engineer for final approval (see proposed equals).

B. The BACnet system shall be capable of Internet Protocol (IP) communications. BACnet/IP or Annex J will be considered the basis of design. All other configurations must be submitted prior to bid, in writing, for final approval. These configurations shall include but not limited to, Annex H or third party BACnet tunneling routers.

C. The primary Local Area Network (LAN) shall be based upon the ISO 8802-3 Ethernet standard and will be required for all Building Controllers, System Controllers and Operator Work Stations. The use of MS/TP communications for interconnecting the said devices is strictly prohibited. The installation of all Ethernet wiring, accessories, and connectors shall conform to the ISO standard and/or guidelines identified herein. The preferred connection media shall be Category 6, Unshielded Twisted Pair (UTP) wire. The maximum single network run shall not exceed more than 300 feet. If additional distance is needed, the use of switches (not hubs) or other Ethernet medias will be acceptable. However, the 'cascading' of more than 3 switches on a single segment will not be accepted. The BAS system may utilize the customer's Local Area Network (LAN) provided the bandwidth consumption is less than 10% of the total network bandwidth.

Under no circumstances, shall the customer's LAN be subject to failure and/or abuse. In efforts to decrease liability, all BACnet devices that reside on the LAN must support the BACnet Broadcast Management Device (BBMD) scheme. Multi-casting or Global broadcasting will not be permitted without the use of a BBMD. The Ohio State Medical Center will require one BBMD device for every floor of every building. The Medical Center network will be segmented so that each floor will be a separate subnet from all others.

D. The secondary or sub-network shall utilize the Master-Slave/Token-Passing protocol, as acknowledged by the ANSI/ASHRAE 135 standard. Proprietary RS-485 or equivalent links will not be considered unless otherwise noted. The MS/TP link shall operate at a 76.8 Kbps minimum, and utilize no more than 2 repeaters in any instance. Multi channel repeaters will not be permitted.

E. The use of proprietary gateways to transmit input/output data, and/or related information, must reside on the Ethernet LAN and be approved, in writing, prior to the bid.

F. **Workstation conformance (OWS)**: The workstation must be scheduled or submitted to the BTL for future testing, under Device Profile B-OWS (Annex L of the BACnet standard) with support of the following BIBBs:

Alarm and Event Management BIBBs

AE-ACK-A, AE-ACK-B, AE-ASUM-A, AE-ASUM-B, AE-ESUB-A, AE-ESUM-B, AE-INFO-A, AE-INFO-B, AE-N-A, AE-N-E-B, AE-N-I-B

Device Management BIBBs

DM-BR-A, DN-DCC-A, DM-DCC-B, DM-DDB-A, DM-DDB-B, DM-DOB-A, DM-DOB-B, DM-LM-A, DM-LM-B, DM-OCD-A, DM-OCD-B, DM-RD-A, DM-RD-B,DM-TM-B, DM-TS-A, DM-UTC-A

Data Sharing BIBBS

DS-COV-A, DS-COV-B, DS-COVU-A, DS-COVU-B, DS-RP-A, DS-RP-B, DS-RPM-A, DS-RPM-B, DS-WP-A, DS-WP-B, DS-WPM-A, DS-WPM-B

Network Management BIBBS

NM-CE-A, NM-CE-B

Scheduling BIBBs

SCHED-A, SCHED-E-B, SCHED-I-B

Trending

T-ATR-A, T-ATR-B, T-VMT-A, T-VMT-E-B, T-VMT-I-B

G. **Building Controller Conformance (BC)**: The building controller must be certified and listed by BTL (BACnet Testing Laboratory) under Device Profile B-BC (Annex L of the BACnet standard) with support of the following BIBBs:

Alarm and Event Management BIBBs

AE-ACK-B, AE-ASUM-B, AE-ESUM-B, AE-INFO-B, AE-N-A, AE-N-E-B, AE-N-I-B

Device Management BIBBs

DM-BR-B, DM-DCC-B, DM-DDB-A, DM-DDB-B, DM-DOB-A, DM-DOB-B, DM-OCD-B, DM-RD-B, DM-TM-A, DM-TS-A, DM-TS-B, DM-UTC-A, DM-UTC-B

Data Sharing BIBBS

DS-COV-A, DS-COV-B, DS-COVU-A, DS-COVU-B, DS-RP-A, DS-RP-B, DS-RPM-A, DS-RPM-B, DS-WP-A, DS-WP-B, DS-WPM-B

Network Management BIBBS

NM-CE-A, NM-CE-B

Scheduling BIBBs

SCHED-A, SCHED-E-B, SCHED-I-B

Trending

T-ATR-B, T-VMT-E-B, T-VMT-I-B

H. **Advanced Application Controller Conformance (AAC)**: The AAC must be certified and listed by BTL (BACnet Testing Laboratory) under Device Profile B-AAC (Annex L of the BACnet standard) with support of the following BIBBs:

Alarm and Event Management BIBBs

AE-ACK-B, AE-ASUM-B, AE-ESUM-B, AE-INFO-B, AE-N-E-B, AE-N-I-B

Device Management BIBBs

DM-BR-B, DM-DCC-B, DM-DDB-A, DM-DDB-B, DM-DOB-A, DM-DOB-B, DM-LM-B, DM-OCD-B, DM-RD-B, DM-TM-A, DM-TS-B, DM-UTC-B

Data Sharing BIBBS

DS-COV-A, DS-COV-B, DS-COVU-A, DS-RP-A, DS-RP-B, DS-RPM-A, DS-RPM-B, DS-WP-A, DS-WP-B, DS-WPM-B

Network Management BIBBS

NM-CE-A

Scheduling BIBBs

SCHED-E-B, SCHED-I-B

Trending

T-ATR-B, T-VMT-E-B, T-VMT-I-B

I. **Application Specific Controllers (ASC):** ASCs will not be permitted on this project. The minimum level BACnet Controller that will be accepted by The Ohio State University Medical Center shall be listed as a B-AAC device under the BTL certification process.

J. **Read / Write Properties:** The entire BACnet BAS system (all OWS, BC, AAC and ASC devices) shall support the following Read/Write properties within the given BACnet objects and shall permit dynamic creation and deletion thereof.

Analog Input Object

Read and Write Properties: Description, Name, Value, COV Increment, Out of Service, Reliability

Read Only Properties: Type, Units, Status Flags, Event State

Analog Output Object

Read and Write Properties: Description, Name, Value, Out of Service, Reliability

Read Only Properties: Type, Units, COV Increment, Status Flags, Event State, Priority Array

Analog Variable Object

Read and Write Properties: Description, Name, Value, Units, COV Increment, Out of Service, Reliability

Read Only Properties: Type, Status Flags, Event State

Binary Input Object

Read and Write Properties: Description, Name, Value, Out of Service, Reliability

Read Only Properties: Type, Status Flags, Event State

Binary Output Object

Read and Write Properties: Description, Name, Value, Out of Service, Reliability, Minimum On/Off time

Read Only Properties: Type, Status Flags, Event State, Priority Array

Binary Variable Object

Read and Write Properties: Description, Name, Value, Out of Service, Reliability

Read Only Properties: Type, Status Flags, Event State

Event Enrollment Object

Read and Write Properties: Description, Name, Notification Class, Event Enable, Event Parameter, Event Type, Object Reference

Read Only Properties: Type, Event State, Event Time Stamps, Notification Type, Acknowledged Transactions

Notification Class Object

Read and Write Properties: Description, Name, Priority, Recipient List

Read Only Properties: Type, Notification Class

Calendar Object

Read and Write Properties: Description, Name

Read Only Properties: Type, Value

Schedule Object

Read and Write Properties: Description, Name, Object Reference, Weekly Schedule, Effective Period, Schedule Exceptions

Read Only Properties: Type, Value

Trendlog Object

Read and Write Properties: None

Read Only Properties: Description, Name, Type, Notification Class, Event Enable, Event State, Event Time Stamps, Notification Type, Acknowledge Transactions, Log Enabled, Start/Stop Time, Log Interval

Program Object

Read and Write Properties: Description, Name, Out of Service, Reliability, Program Change

Read Only Properties: Type, Status Flags

Loop Object

Read and Write Properties:	Description, Name, Value, COV Increment, Out of Service, Reliability, Tuning Parameters, Action, Controlled Variable
Read Only Properties:	Event State, Status Flag, Type

File Object

Read and Write Properties:	Description, Name
Read Only Properties:	Type

2.01 NETWORKING COMMUNICATIONS

A. The design of the BAS network shall integrate operator workstations and stand-alone DDC Controllers on a peer-to-peer communications network, and other devices on other networks. The network architecture shall consist of the following four levels:

1. A district-wide Ethernet communications network based on the BACnet/IP protocol (Annex J.)
2. An auto-dial/auto-answer BACnet PTP telecommunications network.
3. A building-wide peer-to-peer communications network between Building Controllers utilizing the BACnet protocol over Ethernet media.
4. BACnet MS/TP secondary networks extended from appropriate Building Controllers to associated Advanced Application Controllers.

B. Access to system data shall not be restricted by the hardware configuration of the building automation system. The hardware configuration of the BAS network shall be totally transparent to the user when accessing data or developing control programs.

C. District-wide Ethernet Communications Network (Primary Connection)

1. Local within this building, provide one Ethernet link between the campus-wide BACnet/IP virtual network and the building-wide peer-to-peer network (Building Controller network). Only one peer-to-peer Building Controller per floor shall provide the interface to the BACnet/IP virtual network for remote monitor, remote manual control, remote alarm, and remote programming of sequences of any and all building-wide points (BBMD device). Building automation systems shall utilize existing IT network for integration. A separate IP network is not permitted
2. Remote at the Central Utilities office (Room 009), provide one Ethernet link for monitor, control, alarm, displaying graphics, and simultaneous programming of sequences. If programming of sequences cannot be accomplished simultaneously while performing monitor, control, alarm, and displaying graphics, then provide a second Ethernet link to allow for simultaneous programming.

3. All Ethernet communications shall include software management and control for both access and privilege. The remote ~~Central Utilities~~ HVAC Analyst Team office shall manage all rights for access and privilege per each remote location, for remote monitor, remote manual control, remote alarm, and remote programming of sequences of any and all building-wide points.

~~D. Auto-dial/Auto-answer Telecommunication Network (Secondary connection):~~

~~E. BACnet PTP communications shall be provided to allow Building Controllers to communicate with remote operator stations and/or remote terminals on an intermittent basis via telephone lines, as indicated in the sequence of operations.~~

~~F. Auto-dial Building Controllers shall automatically place calls to workstations to report alarms or other significant events.~~

~~G. Building Controllers shall be able to store a minimum of 20 phone numbers of at least 20 digits. Retry a single primary number at a fixed interval until successful.~~

~~H. The auto-dial program shall include provisions for handling busy signals, "no answers" and incomplete data transfers. Provide as a minimum 3 secondary numbers when communications cannot be established with the primary device.~~

~~I. Operators at dial-up workstations shall be able to perform all control functions; all report functions and all database generation and modification functions as described for workstations connected via the network. Routines shall be provided to automatically answer calls from remote Building Controllers. The fact that communications are taking place with remote Building Controllers over telephone lines shall be completely transparent to an operator.~~

~~J. An operator shall be able to access remote buildings by selection of any facility by its logical name. The workstation dial-up program shall store the phone numbers of each remote site, so the user shall not be required to remember or manually dial telephone numbers.~~

~~K. A PC workstation may serve as an operator device on a network, as well as a dial-up workstation for multiple auto-dial DDC Controllers or networks. Alarm and data file transfers handled via dial-up transactions shall not interfere with network activity, nor shall network activity keep the workstation from handling incoming calls.~~

~~L. Dial-up communications shall make use of Hayes compatible modems and voice-grade telephone lines. Provide modems rated at 56K baud with auto ranging. System access to be provided through phone lines to the existing campus Front End Computer. If applicable, the cost of the phone line installation is the responsibility of this contractor and should be included in this contract.~~

D. Building-wide Peer-to-Peer Communications Network:

1. Operator workstations and Building Controllers shall directly reside on an Ethernet network such that communications may be executed directly between Building Controllers and workstations on a peer-to-peer basis, without requirement for any device

to operate or manage the network. A portion of the network management is built into each of the 'peer-to-peer members. 'Peer-to-peer' refers to controllers that (when interconnected) will act independently as equals, without a network manager, and will communicate in a token passing protocol with each other to pass data packet information for the purpose of building-wide monitoring and control. A special data packet called the 'token' is constantly and continually 'passed' to every member of the peer-to-peer communications network. Any peer-to-peer device on the network can send a packet of data only when it has the 'token'. Any peer-to-peer device on this network can request data from, or send data to, any other device on the network. With this procedure, token ensures that data collisions do not occur, and assures that all members of the network get equal opportunity for all data on the network.

2. Systems that operate via polled response or other types of protocols that rely on a network manager, file server, or similar device to manage panel-to-panel communications will not be considered.

3. All operator devices ~~either~~ resident on the peer-to-peer network~~, or connected via dial-up modems~~ shall have the ability to access all point status and application report data or execute control functions for any and all other devices via the peer-to-peer network. Access to data shall be based upon logical identification of building equipment. No hardware or software limits shall be imposed on the number of devices with global access to the peer-to-peer network data.

4. Network design shall include the following provisions:

    a. Provide high-speed data transfer rates for alarm reporting, quick report generation from multiple controllers and upload/download efficiency between network devices. System performance shall ensure that an alarm occurring at any DDC Controller is displayed at workstations and/or alarm printers within 5 seconds.

    b. Support of any combination of DDC Controllers and operator workstations directly connected to the peer-to-peer network. A minimum of 50 devices shall be supported on a single network (including MS/TP).

    c. Message and alarm buffering to prevent information from being lost.

    d. Error detection, correction and retransmission shall be included to guarantee data integrity.

    e. Synchronization of real-time clocks, to include automatic daylight savings time updating between all controllers shall be provided. Universal Time Coordinate based upon Greenwich Mean Time must be supported. (All BC devices must have Real Time Clocks with battery and SRAM backup, see section 1.03 H)

5. Acceptable protocols for intercommunications between building-wide peer-to-peer Building Controllers:

a. BACnet over Ethernet (BACnet/IP between subnets only)

E. Local Area (communications) Network (LAN):

1. This communications network shall be limited to Building Controllers and Advanced Application Controllers and shall communicate bi-directionally with the BACnet peer-to-peer network.

2. Advanced Application Controllers shall be arranged on the LAN's in a functional relationship to the corresponding Building Controllers. For example, a VAV Advanced Application Controller serving a VAV terminal box shall be connected on a MS/TP network from the Building Controller that is controlling the corresponding air handling unit.

3. A maximum of 64 Advanced Application Controllers may be configured on any individual LAN from any Building Controller to insure adequate global data and alarm response times.

4. Acceptable protocols for intercommunications between Advanced Application Controllers and Building Controllers, are as follows:

    a. BACnet (MS/TP), BACnet over Ethernet

2.02 BUILDING CONTROLLER

A. DDC (stand-alone) Controllers shall have a 32 bit processor with EEPROM, flash driven operating system (OS). They shall also be multi-tasking, multi-user, real-time digital control processors and permit I/O expansion for control / monitoring of up to 48 I/O. Controller size shall be sufficient to fully meet the requirements of this specification.

B. Each Building Controller shall have sufficient flash memory (EEPROM), a minimum of 2 megabyte, to support its own operating system. In addition, there shall be additional SRAM memory for database handling: Both the EEPROM and SRAM shall permit full implementation and support of all B-BC requirements of this specification, including:

1. Control processes

2. Energy management applications

3. Alarm management applications including custom alarm messages for each level alarm for each point in the system.

4. Historical/trend data for points specified

5. Maintenance support applications

6. Custom processes

7. Operator I/O

8. Dial-up communications

9. Manual override monitoring

C. Each Building Controller shall support:

1. Monitoring of the following types of inputs, without the addition of equipment outside of the Building Controller cabinet:

    a. Analog inputs

    1) 4-20 mA
    2) 0-10 Vdc
    3) Thermistors

    b. Digital inputs

    1) Dry contact closure
    2) Pulse Accumulator
    3) Voltage Sensing

2. Each Building Controller shall be capable of providing the following control outputs without the addition of equipment outside the Building Controller cabinet:

    a. Digital outputs (contact closure)

    1) Contact closure (motor starters, up to size 4)

    b. Analog outputs

    1) 4-20 mA

    2) 0-10 Vdc

    3) 0-135 Ohm (with external Transducer)

D. Each Building Controller shall have a minimum of 10 percent spare (panel real estate) capacity for future point connection and shall support up to 48 I/O with modular expansion modules. The type of spares shall be in the same proportion as the implemented I/O functions of the panel, but in no case shall there be less than two spares of each implemented I/O type. Provide all processors, power supplies, database memory, program sequence memory, and communication controllers complete so that the implementation of any added point (within the above 10% spare) only requires the addition of the appropriate point input/output termination module, point sensor, and wiring.

1. Provide sufficient internal memory for the specified control sequences and have at least 25% of the memory available for future use.

2. Building Controllers shall provide at least one RS-232C serial data communication ports

(BACnet PTP compatible) for operation of operator I/O devices such as industry standard printers, operator terminals, modems and laptop portable operator's terminals. Building Controllers shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers or terminals. System-wide access must be provided at each mechanical equipment room through the local Building Controller. Panel mounted terminals are not required. Furthermore, all Building Controllers shall include a hardwired, concealed and secured, RJ-11 or RJ-45 jack for use by the Portable Operators Workstation. The local operator, using the Portable Operators Workstation, shall plug into this jack, and shall perform all monitoring, control, and programming of sequences for any and all building-wide points and sequences while standing at any Advanced Application Controller.

E. As indicated in the point I/O schedule, the operator shall have the ability to manually override automatic or centrally executed commands at the Building Controller via local, point discrete, on-board supervised hand/off/auto operator override switches for digital control type points and gradual switches for analog control type points. These override switches shall be operable whether the panel processor is operational or not.

1. Switches shall be supervised and mounted either within the Building Controllers key-accessed enclosure, or externally mounted with each switch keyed to prevent unauthorized overrides.

2. Building Controllers shall monitor the status of all overrides and inform the operator that automatic control has been inhibited. Building Controllers shall also collect override activity information for reports.

G. Building Controllers shall provide local LED status indication for each digital input and output for constant, up-to-date verification of all point conditions without the need for an operator I/O device. Graduated intensity LED’s or analog indication of value shall also be provided for each analog output.

H. Each Building Controller shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all panel components. The Building Controller shall provide both local and remote annunciation of any detected component failures and for repeated failure to establish network communications.

I. Isolation shall be provided at all peer-to-peer network terminations, as well as all field point termination’s to suppress induced voltage transients consistent with current IEEE Standard C62.41.

J. In the event of the loss of normal power, there shall be an orderly shutdown of all Building Controllers to prevent the loss of database or operating system software. Programs residing in memory shall be protected either by using EEPROM under capacitor backup or by an uninterruptible power source (battery backup). The backup power source shall have sufficient capacity to maintain volatile memory in event of an AC power failure. Where interruptible power source is rechargeable (a rechargeable battery), provide sufficient capacity for a minimum of seventy-two hours backup. Charging circuitry, while the controller is operating under normal line power, shall constantly charge the rechargeable power source. A non-rechargeable power source shall not be permitted. Batteries shall be implemented to allow replacement without soldering.

1. Upon restoration of normal power, the Building Controller shall automatically resume full operation without manual intervention.

2. Should Building Controller memory be lost for any reason, the user shall have the capability of reloading the Building Controller via the local RS-232C port, via telephone line dial-in or from a network workstation PC.

K. Building Controllers must comply with Section 2.02, A-J and 2.03. Panels that lose communication or control due to a single sensor failure are not permitted.

L. Building Controllers will be used in each equipment room where major or more than two pieces of equipment are being controlled. The use of AAC or ASC devices for critical or main system equipment will not be permitted.

M. All points associated with a given mechanical system (i.e., an air handling unit) will be controlled from a single Building Controller or point expansion panels from the respective master. (i.e., remote motor control centers). No points from a given mechanical system may be distributed among multiple panels - points must be run back to a single Building Controller dedicated to that mechanical system. Closed-loop control must never depend upon network communications. All inputs, program sequences, and outputs for any single DDC control loop shall reside in the same Building Controller.

2.03 BUILDING CONTROLLER RESIDENT SOFTWARE FEATURES

A. General:

1. All necessary software to form a complete operating system as described in this specification shall be provided.

2. The software programs specified in this Section shall be provided as an integral part of Building Controllers and shall not be dependent upon any higher level computer for execution.

3. Point naming convention shall be as referenced in Appendix A (see end of section). The BC shall support a 128 character object name length. BCs that only permit a 32 character length will not be permitted.

B. Control Software Description:

1. The Building Controllers shall have the ability to perform any or all of the following pre-tested control algorithms:

   a. Two-position control

   b. Proportional control

c. Proportional plus integral control

d. Proportional, integral, plus derivative control

2. Control software shall include a provision for limiting the number of times that each piece of equipment may be cycled within any one-hour period.

3. The system shall provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads. This feature shall be resident in all Binary Output objects. The use of custom programming to prevent an excessive demand on start-up shall not be required.

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

C. All programs shall be executed automatically without the need for operator intervention and shall be flexible enough to allow user customization. Programs shall be applied to building equipment as described in the Sequence of Operations. Building Controllers shall have the ability to perform any or all of the following energy management routines:

1. Time-of-day scheduling
2. 365 day Calendar-based scheduling
3. Holiday scheduling
4. Temporary schedule overrides
5. Start-Stop Time Optimization
6. Automatic Daylight Savings Time Switch over
7. Night setback control
8. Enthalpy switch over (economizer)
9. Peak demand limiting
10. Temperature-compensated duty cycling
11. Fan speed/ control
12. Heating/cooling interlock
13. Cold deck reset
14. Hot deck reset

15. Hot water reset
16. Chilled water reset
17. Condenser water reset
18. Chiller sequencing
19. Chiller load monitoring

D. Building Controllers shall be able to execute custom, job-specific processes defined by the user, to automatically perform calculations and special control routines.

1. It shall be possible to use any of the following in a custom process:
    a. Any system measured point data or status
    b. Any calculated data
    c. Any results from other processes
    d. User-defined constants
    e. Arithmetic functions (+, -, *, /, square root, exponential, etc.)
    f. Boolean logic operators (and/or, exclusive or, etc.)
    g. On-delay/off-delay/one-shot timers
2. Custom processes may be triggered based on any combination of the following:
    a. Time interval
    b. Time-of-day
    c. Date
    d. Other processes
    e. Time programming
    f. Events (e.g., point alarms)
3. A single process shall be able to incorporate measured or calculated data from any and all other controllers on the network. In addition, a single process shall be able to issue commands to points in any and all other controllers on the network.
4. Processes shall be able to generate operator messages and advisories to operator I/O

devices. A process shall be able to directly send a message to a specified device or cause the execution of a dial-up connection to a remote device such as a printer or pager.

5. The custom control programming feature shall be compiled and documented via English language descriptors. These descriptors (comment lines) shall be viewable from local operator I/O devices to facilitate troubleshooting.

E. Alarm management shall be provided to monitor and direct alarm information to operator devices. Each Building Controller shall perform distributed, independent alarm analysis and filtering to minimize operator interruptions due to non-critical alarms, minimize network traffic and prevent alarms from being lost. At no time shall the Building Controllers ability to report alarms be affected by either operator activity at a PC workstation, local I/O device or communications with other panels on the network.

1. All alarm or point change reports shall include the point's English language description and the time and date of occurrence.

2. The user shall be able to define the specific system reaction for each point. Alarms shall be prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of six priority levels shall be provided for each point. Point priority levels shall be combined with user definable destination categories (PC, printer, DDC Controller, etc.) to provide full flexibility in defining the handling of system alarms. Each Building Controller shall automatically inhibit the reporting of selected alarms during system shutdown and start-up. Users shall have the ability to manually inhibit alarm reporting for each point.

3. Alarm reports and messages will be directed to a user-defined list of operator devices or PCs.

4. In addition to the point's descriptor and the time and date, the user shall be able to print, display or store a 200 character alarm message to more fully describe the alarm condition or direct operator response.

   a. Each Building Controller shall be capable of storing all custom alarm text for each alarm. The alarm text shall be unique and user defined; custom text shall be available for all BACnet alarms and shall reside in the BC, not in an OWS or PC.

   b. Alarms shall have ability to be acknowledged from the local operator I/O device, (once the problem is resolved).

5. In dial-up applications, operator-selected alarms shall initiate a call to a remote operator device.

F. A variety of historical data collection utilities shall be provided for manual or automatic sampling, storing and displaying system data for points as specified in the I/O summary.

1. Building Controllers shall store point history data for selected analog and digital inputs

and outputs:

a. Any point, physical or calculated may be designated for trending. Any point, regardless of physical location in the network, may be collected and stored in each Building Controller. Two methods of collection shall be allowed; either by a pre-defined time interval, or upon a pre-defined change of value. Sample intervals of 1 second to 7 days shall be provided. Each Building Controller shall have a dedicated RAM-based buffer for trend data and shall be capable of storing a minimum of 10,000 data samples.

2. Trend data shall be stored at the Building Controllers and uploaded to the workstation when retrieval is desired. Uploads shall occur based upon either; user-defined interval, manual command, or automatically when the trend buffers are full. Furthermore, the workstation shall notify the end-user if the hard drive capacity is low or if the database size is excessive. The OWS shall use a standard MSDE or SQL database handler for all trend log management. All trend data shall be available to all BACnet OWSs and for use in 3rd party personal computer applications. File format type to be comma delineated.

3. Building Controllers shall also provide high resolution sampling capability for verification of control loop performance. Operator-initiated automatic and manual loop tuning algorithms shall be provided for operator-selected PID control loops as identified in the point I/O summary. Provide capability to view or print trend and tuning reports.

   a. The Loop object shall display the most recent historical data of its own performance. It shall illustrate the number of setpoint crossings and the maximum and average deviation from setpoint.

   b. Loop tuning shall be capable of being initiated either locally at the Building Controller, from a network workstation or remotely using dial-in modems. For all loop tuning functions, access shall be limited to authorized personnel through password protection.

G. Building Controllers shall automatically accumulate and store run-time hours for digital input and output points as specified in the point I/O summary.

1. The totalization routine shall have a sampling resolution of one minute or less.

2. The user shall have the ability to define a warning limit for run-time totalization. Unique, user-specified messages shall be generated when the limit is reached.

H. Building Controllers shall automatically sample, calculate and store consumption totals on a daily, weekly or monthly basis for user-selected analog and digital pulse input type points as specified in the point I/O summary.

1. Totalization shall provide calculation and storage of accumulations of up to 99,999.9 units (e.g., kWh, gallons, BTU, tons, etc.).

2. The totalization routine shall have a sampling resolution of one minute or less.

3. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.

I. Building Controllers shall have the ability to count events such as the number of times a pump or fan system is cycled on and off. Event totalization shall be performed on a daily, weekly or monthly basis for points as specified in the point I/O summary.

1. The event totalization feature shall be able to store the records associated with a minimum of 9,999.9 events before reset.

2. The user shall have the ability to define a warning limit. Unique, user-specified messages, up to 200 characters, shall be generated when the limit is reached.

J. Advanced Application Controllers:

1. Each Building Controller shall be able to extend its performance and capacity through the use of remote Advanced Application Controllers. Each Advanced Application Controller shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each Advanced Application Controller shall be a microprocessor-based, 32 bit, multi-tasking, real-time digital control processor. Provide for control of terminal equipment including, but not limited to, the following:

   a. Rooftop units

   b. VAV Boxes

   c. Heat pumps

   d. Fan coils, Unit ventilators

   e. Other terminal equipment or monitoring

2. Advanced Application Controllers must comply with Section 2.03, items A through I, and must be peer-to-peer devices. Advanced Application Controllers shall include all point inputs and outputs necessary to perform the specified control sequences. Provide a hand/off/automatic switch for each digital output for manual override capability. Switches shall be mounted either within the controller's key-accessed enclosure, or externally mounted with each switch keyed to prevent unauthorized overrides. In addition, each switch position shall be supervised in order to inform the system that automatic control has been overridden. Switches will only be required for non-terminal applications or where controllers are readily accessible (not required for VAVs, Heat pumps, etc. that are above ceilings or inaccessible). All inputs and outputs shall be of the Universal type, allowing for additional system flexibility. A minimum of 12 global points (i.e. chilled water temperature, hot water temperature, etc.) must be able to be accessed through the Advanced Application Controller. If global point access is unavailable with the Advanced Application then a Building Controller must be furnished.

3. Each Advanced Application Controller shall support its own real-time operating system. Provide a time clock with battery backup to allow for stand-alone operation in the event that communication with its Building Controller is lost and to insure protection during power outages. In the event that the AAC does not support a real time clock (RTC) function and it is being used on critical or system level equipment as mentioned in section 2.03 J.1 then a Building Controller supporting RTC functionality shall be used in its place. AAC devices without RTC functionality will be permitted for use on terminal or unitary equipment such as VAV boxes, fan coils, heat pumps, unit ventilators and auxiliary monitoring and control.

4. Provide each Advanced Application Controller with sufficient memory to accommodate point databases, operating programs, local alarming and local trending. All databases and programs shall be stored in non-volatile EEPROM under capacitor backup (lithium or rechargeable battery backup will not be permitted). Advanced Application Controllers must be fully programmable with a minimum of 200 lines of code available for custom programming. All programs shall be field-customized to meet the user's exact control strategy requirements. Advanced Application Controllers utilizing pre-packaged or canned programs shall not be acceptable. As an alternative, provide Building Controllers for all central equipment in order to meet custom control strategy requirements.

5. Programming of Advanced Application Controllers shall utilize the same language and code as used by Building Controllers to maximize system flexibility and ease of use. Should the system controller utilize a different control language, provide a Building Controller to meet the specified functionality.

6. Local alarming and trending capabilities shall be provided for convenient troubleshooting and system diagnostics. Alarm limits and trend data information shall be user-definable for any point.

7. Each controller shall have connection provisions for a portable operator's terminal. This tool shall allow the user to display, generate or modify all point databases and operating programs. All new values and programs may then be restored to EEPROM via the programming tool.

8. Advanced Application Controllers that lose communication with master panels, and/or lose control due to a single sensor failure, are not acceptable.

9. At all Advanced Application Controllers include a hardwired, concealed and secured, RJ-11 or RJ-45 jack for use by the Portable Operators Workstation. The local operator, using the Portable Operators Workstation, shall plug into this jack, and shall perform all monitoring, control, and programming of sequences for any and all building-wide points and sequences while standing at any Advanced Application Controller.

10. At all Advanced Application Controllers, include the point database of the following minimum building-wide system data:

    a. Building Primary Hot Water Return and Supply Temperatures

b. Building Primary Chilled Water Return and Supply Temperatures

c. Building Common Outside Air Temperature

d. Database for 10 other building-wide points, as field selected by OSU.

2.04 ADVANCED APPLICATION CONTROLLERS (AAC) FOR "ASC" USE

A. Application Specific Controllers are not permitted for use unless otherwise approved by The Ohio State University Medical Center. AAC devices shall be used for all intended ASC functionality. ASCs, by default, do not support the required BIBBs, or Read/Write capabilities as desired by The Ohio State University Medical Center.

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, 32-bit, multi-tasking, real-time digital control processor.

C. The use of these AACs is limited to the monitor and control of building HVAC equipment that are outside of any mechanical equipment room, or outside of any electrical equipment room. All equipment located within, or controlled from within, any mechanical equipment room or electrical equipment room shall use the peer-to-peer Building Controller.

D. The electrical power source for these Advanced Application Controllers shall be from local circuit breaker with appropriate fused, class 2, 100VA power-limited output. The breaker shall be dedicated to the Advanced Application Controllers, labeled accordingly, and locked-out from inadvertent casual shutoff.

E. Advanced Application Controllers:

Provide for control of each piece of building HVAC equipment, including, but not limited to, the following:

a. Variable Air Volume (VAV) terminal boxes

b. Constant Air Volume (CAV) terminal boxes

c. Dual Duct (DD) terminal boxes

d. Unit Conditioners

e. Heat Pumps

f. Unit Ventilators

g. Fan Coil Units

Controllers shall include all point inputs and outputs necessary to perform the specified control sequences. All inputs and outputs shall be of the universal type; that is, the outputs may be utilized either as modulating or two-state, allowing for additional system flexibility. Analog outputs shall be industry standard signals such as 24V floating control and 0-10 VDC allowing for interface to a variety of modulating actuators. Terminal equipment controllers or AACs utilizing proprietary control signals and actuators shall not be acceptable. As an alternative, provide Building Controllers or other AACs with industry standard outputs for control of all terminal equipment.

Each controller performing space temperature control shall be provided with a matching room temperature sensor. The sensor shall be 10K Type-3 thermistor based providing the following minimum performance requirements are met:

a. Accuracy: ± 0.36°F

b. Operating Range: 32° to 158°F

c. Set Point Adjustment Range: 55° to 85°F (adjustable)

d. Set Point Modes:

   1). Independent Heating
   2). Independent Cooling
   3). Night Setback Heating
   4). Night Setback Cooling

e. Calibration Adjustments: None required

f. Installation: Up to 500 ft. from Controller

g. Each room sensor shall also include the following auxiliary devices or options:

   1). Setpoint Adjustment Dial or equivalent buttons
   2). Digital LED Temperature Indicator
   3). Override Switch or button

   4.). 2 % on board Humidity Sensor option

h. The setpoint adjustment shall allow for modification of the temperature in a minimum of .5º F increments by the occupant. Setpoint adjustment may be locked out, overridden or limited as to time or temperature through software by an authorized operator at the central workstation, Building Controller, or via the portable operator's terminal.

i. The temperature indication shall be a digital display visible without removing the sensor cover.

j. An override switch shall initiate override of the night setback mode to normal (day) operation when activated by the occupant. The override function may be locked out, overridden or limited as to the time through software by an authorized operator at the central workstation, Building Controller, or via the portable operator's terminal.

Each controller shall perform its primary control function independent of other DDC Controller LAN communications, or if LAN communication is interrupted. Reversion to a fail-safe mode of operation during LAN interruption is not acceptable. The controller shall receive its real-time data from the Building Controller time clock to insure LAN continuity. Each controller shall include algorithms incorporating proportional, integral and derivative (PID) values for all applications. All PID values and biases shall be field-adjustable by the user via terminals as specified herein. This functionality shall allow for tighter control of space conditions and shall facilitate optimal occupant comfort and energy savings. Controllers that incorporate proportional and integral (PI) control algorithms only, without derivative (D) control algorithms, shall not be acceptable.

Provide each terminal equipment controller with sufficient memory to accommodate point databases, operating programs, local alarming and local trending. All databases and programs shall be stored in non-volatile EEPROM, EPROM and PROM, or capacitor backup. The controllers shall be able to return to full normal operation without user intervention after a power failure of unlimited duration. Provide uninterruptible power supplies (UPS's) of sufficient capacities for all terminal controllers that do not meet this protection requirement. Operating programs shall be fully customizable for specific applications (programming language shall be identical to the Building Controllers). In addition, specific applications may be modified to meet the user's exact control strategy requirements, allowing for additional system flexibility. Controllers that require factory changes of any applications or that are algorithm based will not be acceptable.

Variable Air Volume (VAV) Box Controllers:

a. As a minimum, shall support the following types of applications for pressure independent terminal control:

   1). VAV, cooling only
   2). VAV, with hot water reheat
   3). VAV, with electric reheat
   4). VAV, fan-powered
   5). VAV, fan-powered, with hot water reheat
   6). VAV, fan-powered, with electric reheat

b. All VAV box control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory changes of any applications or that are algorithm based will not be acceptable

The VAV box controller shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F (0° to 50°C) and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).

a. The VAV controller shall include a differential pressure transducer that shall connect to the terminal unit manufacturer's standard averaging air velocity sensor to measure the velocity pressure in the duct. The controller shall convert this value to actual airflow in cfm. Single point air velocity sensing is not acceptable. The differential pressure transducer shall have a measurement range of 0 to 1 inWC and measurement accuracy of ±5% throughout its range, insuring primary air flow conditions shall be controlled and maintained to within ±5% of setpoint at the specified parameters. The BAS contractor shall provide the velocity sensor if required to meet the specified functionality.

b. The VAV box controller shall include provisions for manual and automatic reset of the differential pressure transducer in order to maintain stable control and insuring against drift over time. Reset shall be accomplished by stroking the terminal unit damper actuator to 0%, full closed, position so that a 0 cfm air volume reading is sensed. The controller shall automatically accomplish this whenever the end user desires. Manual reset may be accomplished by either commanding the actuator to 0% via the POT or by depressing the room sensor override switch. Reset of the transducer at the controller location shall not be necessary.

c. The VAV box controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.5°F (adj.) of setpoint at the room sensor location.

d. The VAV box controller performing space heating control shall incorporate a program allowing for modulation of a hot water reheat valve, or cycling up to three (3) stages of electric reheat, as required to satisfy space heating requirements. Each controller shall also incorporate a program that allows for resetting of the associated air handling unit discharge temperature if required to satisfy space cooling requirements. This algorithm shall function to signal the respective DDC Controller to perform the required discharge temperature reset in order to maintain space temperature cooling setpoint.

Constant Air Volume (CAV) Box Controllers:

a. As a minimum, shall support the following types of applications for pressure independent terminal control:

1). CAV, cooling only
2). CAV, with hot water reheat
3). CAV, with electric reheat

b. All CAV box control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes or those that are algorithm based will not be acceptable.

c. The CAV box controller shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC, allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).

d. The CAV controller shall include a differential pressure transducer that shall connect to the terminal unit manufacturer's standard averaging air velocity sensor to measure the velocity pressure in the duct. The controller shall convert this value to actual airflow in cfm. Single point air velocity sensing is not acceptable. The differential pressure transducer shall have a measurement range of 0 to 1 in WC and measurement accuracy of ±5% throughout its range, insuring primary air flow conditions shall be controlled and maintained to within ±5% of setpoint at the specified parameters. The BAS contractor shall provide the velocity sensor if required to meet the specified functionality.

e. The CAV box controller shall include provisions for manual and automatic reset of the differential pressure transducer in order to maintain stable control and insuring against drift over time. Reset shall be accomplished by stroking the terminal unit damper actuator to 0%, full closed, position so that a 0 cfm air volume reading is sensed. The controller shall automatically accomplish this whenever the end user desires. Manual reset may be accomplished by either commanding the actuator to 0% via the POT or by depressing the room sensor override switch. Reset of the transducer at the controller location shall not be necessary.

f. The CAV box controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.5°F (adj) of setpoint at the room sensor location.

g. Each controller performing space heating control shall incorporate an algorithm allowing for modulation of a hot water reheat valve or cycling up to three (3) stages of electric reheat as required to satisfy space heating requirements. Each controller shall also incorporate a program that allows for resetting of the associated air handling unit discharge temperature if required to satisfy space cooling requirements. This program shall function to signal the respective DDC Controller to perform the required discharge temperature reset in order to maintain space temperature cooling setpoint. Control of the terminal unit damper to maintain cooling setpoint shall not be permitted. As an alternative, Building Controllers or other Advanced Application Controller for the associated air handling equipment shall also directly control all CAV terminal units in order to provide the specified reset capability

h. Each controller performing space pressurization control shall incorporate programs allowing for pressurization via the following methods as a minimum:

    1). Fixed air volume setpoints of supply and exhaust terminal units

    2). Updating of air volume setpoints of supply and exhaust terminal units

i. Each supply and associated exhaust terminal controller may be set at a fixed air volume setpoint which is within a percentage of each other or an actual CFM differential to meet space pressurization requirements. The controllers shall incorporate provisions for independent occupied and unoccupied mode setpoints and differentials, allowing for additional flexibility. Applications requiring updating of air volume setpoints depending on a variable volume of air leaving the space either through the exhaust terminal(s) or other exhaust ducts shall utilize supply terminal unit controllers incorporating programs to allow for "tracking" of space exhaust(s) to maintain the required air volume differential.

j. Terminal unit tracking shall be accomplished via actual measurement of terminal unit air volumes as previously specified. Controllers which track within a range of CFM's versus actual CFM setpoints shall not be acceptable.

k. Zeroing of the differential pressure transducer shall be accomplished as previously specified for VAV box controllers. However, the method of stroking the terminal unit damper to a 0% position shall not be permitted should the controlled space(s) require constant pressurization or 24-hour per day operation. Controllers performing under 24-hour per day operation requirements shall incorporate an 'Auto-zero' auxiliary device(s) which functions to automatically zero the transducer without changing the damper position. This shall be accomplished by temporarily disengaging the transducer from the air velocity sensor so that a 0 cfm air volume reading is forced. The control damper position remains unchanged, as originally controlled before the start of the 'Auto-zero' recalibration. This shall automatically occur on a once per 24-hour basis, thus ensuring system accuracy as previously specified. Provide auxiliary devices and programming as required to perform this function.

l. Should a failure occur within the controller, the terminal unit damper shall automatically be positioned fully open or fully closed as previously defined by the operator. Controllers that revert to a pressure-dependent control mode during failure shall not be acceptable.

Dual-Duct (DD) Box Controllers:

a. As a minimum, shall support the following types of applications for pressure independent terminal control:

    1). DD - Constant Volume - Cold Duct & Hot Duct Air Velocity Sensors with optional auxiliary heat.
    2). DD - Constant Volume - Cold Duct & Outlet Air Velocity Sensors with

optional auxiliary heat.
3). DD - Variable Air Volume - Cold Duct & Hot Duct Air Velocity Sensors with optional auxiliary heat.
4). DD - Variable Air Volume - Cold Duct & Outlet Air Velocity Sensors with optional auxiliary heat.
5). DD -Variable Air Volume - Cold Duct & Hot Duct Air Velocity Sensors with changeover.

b. All DD box control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes or those that are algorithm based will not be acceptable.

c. The DD box controller shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).

d. The DD controller shall include a differential pressure transducer that shall connect to the terminal unit manufacturer's standard averaging air velocity sensor to measure the velocity pressure in the duct. The controller shall convert this value to actual airflow in cfm. Single point air velocity sensing is not acceptable. The differential pressure transducer shall have a measurement range of 0 to 1 inWC and measurement accuracy of ±5% throughout its range, insuring primary air flow conditions shall be controlled and maintained to within ±5% of setpoint at the specified parameters. The BAS contractor shall provide the velocity sensor if required to meet the specified functionality.

e. The DD box controller shall include provisions for manual and automatic reset of the differential pressure transducer in order to maintain stable control and insuring against drift over time. Reset shall be accomplished by stroking the terminal unit damper actuator to 0%, full closed, position so that a 0 cfm air volume reading is sensed. The controller shall automatically accomplish this whenever the end user desires. Manual reset may be accomplished by either commanding the actuator to 0% via the POT or by depressing the room sensor override switch. Reset of the transducer at the controller location shall not be necessary.

f. The DD box controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.5°F (adj) of setpoint at the room sensor location.

g. Each controller performing space heating control shall incorporate an program allowing for modulation of a hot water reheat valve or cycling up to two (2) stages of electric reheat as required to satisfy space heating requirements.

h. Provide two air velocity sensors and transducers to match the application. For VAV applications, provide separate minimum and maximum air volume setting for heating and cooling ducts. For CAV applications, provide separate air volume set points for occupied and unoccupied modes.

i. Zeroing of the differential pressure transducer shall be accomplished as previously specified for VAV box controllers. However, the method of stroking the terminal unit damper to a 0% position shall not be permitted should the controlled space(s) require constant pressurization or 24-hour per day operation. Controllers performing under 24-hour per day operation requirements shall incorporate an ‘Auto-zero’ auxiliary device(s) which function to automatically zero the transducer without changing the damper position. This shall be accomplished by temporarily disengaging the transducer from the air velocity sensor so that a 0 cfm air volume reading is forced. The control damper position remains unchanged, as originally controlled before the start of the ‘Auto-zero’ recalibration. This shall automatically occur on a once per 24-hour basis, thus ensuring system accuracy as previously specified. Provide auxiliary devices and programming as required to perform this function.

Unit Conditioner Controllers:

a. As a minimum, shall support the following types of applications for terminal control:

1). Fan coil units
2). Induction units
3). Pressure dependent terminal boxes

b. As a minimum, shall support the following types of fan coil units:

1). Fan Coil, 2-pipe, heating or cooling
2). Fan Coil, 4-pipe, heating or cooling
3). Fan Coil, cooling, and electric heating
4). Fan Coil, 2-stage cooling, and electric heating
5). Fan Coil, 2-stage cooling, and hot water heating

c. As a minimum, shall support the following types of Induction units:

1). Induction Unit, 2-pipe
2). Induction Unit, 4-pipe

d. As a minimum, shall support the following types of pressure dependent terminal control:

1). Heating, or cooling
2). Hot water reheat

e. All Unit Conditioner control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes or those that are algorithm based will not be acceptable.

f. The Unit Conditioner controllers shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC, allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F (0° to 50°C) and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).

g. The Unit Conditioner controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.5°F (adj) of setpoint at the room sensor location.

h. The Unit Conditioner controller performing space temperature control shall incorporate a program allowing for modulation of a hot water reheat and chilled water valve, or cycling up to three (3) stages of electric reheat and chilled water valve, as required to satisfy space heating requirements. Each controller shall also incorporate a program that allows for resetting of the associated air handling unit discharge temperature if required to satisfy space cooling requirements (if applicable). This program shall function to signal the respective DDC Controller to perform the required discharge temperature reset in order to maintain space temperature cooling setpoint.

Heat Pump Controllers:

a. As a minimum, shall support the following types of applications for heat pump terminal control:

1). Heat Pump, water source
2). Heat Pump, air-to-air source
3). Heat Pumps, with ventilation air
4). Heat Pump, with auxiliary heat

b. All Heat Pump control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes or those that are algorithm based will not be acceptable.

c. The Heat Pump controllers shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC, allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F (0° to 50°C) and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).

d. The Heat Pump controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.5°F (adj) of setpoint at the room sensor location.

e. The Heat Pump controller performing space temperature control shall permit full control of the Heat pump regardless of its configuration.

Unit Ventilator Controllers:

a. As a minimum, shall support the following types of applications for heating only unit ventilator applications:

   1). Unit Ventilator, ASHRAE Cycle 1, 2 or 3
   2). Unit Ventilator, ASHRAE Cycle 1, 2 or 3 with auxiliary reheat
   3). Unit Ventilator, Nesbitt Cycle W
   4). Unit Ventilator, Nesbitt Cycle W with auxiliary reheat

b. All Unit Ventilator controller applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes or those that are algorithm based will not be acceptable.

c. The Unit Ventilator controllers shall be powered from either a 115 or 230 VAC power source common to the unit ventilator. The controllers shall function normally under ambient conditions of 32° to 130°F and 10% to 95% (non-condensed). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).

d. The Unit Ventilator controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.5°F (adj) of setpoint at the room sensor location.

e. The Unit Ventilator controller shall also interface to averaging temperature sensor(s) located in the discharge or mixed air stream(s) as required by application. The sensor(s) must be 10-K type 3 thermistors, providing the following minimum performance requirements are met:

1). Probe: Averaging type
2). Accuracy: ± .50°F
3). Temperature Monitoring 0° to 180°F (-18° to 82°C)

2.05 PORTABLE OPERATOR'S TERMINAL (POT) ~~–~~Section 2.05 not applicable for OSUWMC

~~A. Provide One (1) portable operator terminal (POT). The POT shall be a laptop configuration and plug directly into any control panel. Provide the BACnet BAS software as required to provide complete functionality for viewing and modifying of all data (including custom programs).~~

~~B. Functionality of the portable operator's terminal connected at any controller:~~

~~Access all controllers on the network.~~

~~Backup and/or restore DDC Controller databases for all system panels, not just the DDC Controller connected thereto.~~

~~Display all point, selected point and alarm point summaries.~~

~~Display trending and totalization information.~~

~~Add, modify and/or delete any existing or new system point.~~

~~Command, change setpoint, enable/disable any system point.~~

~~Program and load custom control sequences as well as standard energy management programs.~~

~~C. Connection of a POT to a distributed control processor shall not interrupt nor interfere with normal network operation in any way, prevent alarms from being transmitted or preclude centrally-initiated commands and system modification.~~

~~D. Portable operator terminal access to controller shall be password-controlled.~~

~~E. Portable operator terminal minimum hardware and performance criteria shall be as referenced in Appendix A.2.~~

2.06 PERSONAL COMPUTER OPERATOR WORKSTATION

A. Personal computer operator workstations shall be provided for command entry, information management, network alarm management and database management functions. All real-time control functions shall be resident in the controllers to facilitate greater fault tolerance and reliability. Personal computer operator workstation minimum hardware and performance criteria shall be as referenced in Appendix A.2.

2.07 WORKSTATION OPERATOR INTERFACE SOFTWARE

A. Basic Interface Description

Operator workstation interface software shall minimize operator training through the use of English language prompting, English language point identification and industry standard PC application software. The software shall provide, as a minimum, the following functionality:

a. Graphical viewing and control of environment

b. Scheduling and override of building operations

c. Collection and analysis of historical data

d. Definition and construction of dynamic and animated color graphic displays

e. Editing, programming, storage and downloading of controller databases

Provide a graphical user interface, which shall minimize the use of a typewriter style keyboard through the use of a mouse or similar pointing device and "point and click" approach to menu selection. Users shall be able to start and stop equipment or change setpoints from graphical displays through the use of a mouse or similar pointing device.

a. Provide functionality such that all operations can also be performed using the keyboard as a backup interface device.

b. Provide additional capability that allows at least 10 special function keys to perform often-used operations.

The software shall provide multi-tasking operating system such that alarm notification occurs while user is running other applications such as Word or Excel; trend data uploads occur in the background while other applications are running. The mouse shall be used to quickly select and switch between multiple applications. This shall be accomplished through the use of Microsoft Windows[a] or similar industry standard software that supports concurrent viewing and controlling of systems operations.

a. Provide functionality such that any of the following may be performed simultaneously, and in any combination, via user-sized windows: (Vector based graphics)

1). Dynamic and animated color graphics and graphic control
2). Alarm management coordinated with section 2.04.E.
3). Time-of-day scheduling
4). Trend data definition and presentation

5). Graphic definition
6). Graphic construction

b. If the software is unable to display several different types of displays at the same time, the BAS contractor shall provide at least two operator workstations.

Multiple-level password access protection shall be provided to allow the user/manager to limit workstation control, display and data base manipulation capabilities. Privileges shall be customizable for each operator; the main menu shall reflect the privileges upon log on showing only the applications appropriate for the operator.

a. Customizable such that operators can monitor, command, or edit an application or group of points. An operator can be defined with privileges for access to a building, group or buildings, or areas (labs--point names with the designation "lab"), by application: the operator has monitor, command, and edit capability for time of day schedules and calendars (only) for the entire campus: or by function: the operator (i.e. security guard) has ability to view/monitor all areas of the campus and receive alarms, etc.

b. A minimum of 50 unique passwords, including user initials, shall be supported.

c. Operators will be able to perform only those commands available for their respective passwords. Menu selections displayed shall be limited to only those items defined for the access level of the password used to log-on.

d. The system shall automatically generate a report of log-on/log-off time and system activity for each user.

e. User-definable, automatic log-off timers of from 5 to 60 minutes shall be provided to prevent operators from inadvertently leaving devices on-line as well as have the capability to generate a report of log-on, log-off time, parameters modified, and system activity for each user.

Software shall allow the operator to perform commands including, but not limited to, the following:

a. Start-up or shutdown selected equipment

b. Adjust setpoints

c. Add/modify/delete time programming

d. Enable/disable process execution

e. Lock/unlock alarm reporting for points

f. Enable/disable totalization for points

g. Enable/disable trending for points

h. Override PID loop setpoints

i. Enter temporary override schedules

j. Define holiday schedules

k. Change time/date

l. Automatic daylight savings time adjustments

m. Enter/modify analog alarm limits

n. Enter/modify analog warning limits

o. View limits

p. Enable/disable demand limiting for each meter

q. Enable/disable duty cycle for each load

r. Operator shall have ability to schedule reports to print at a pre-specified time and frequency and directed to displays, printers, disk or emails. The reports shall be capable of querying all BACnet devices for all BACnet data and shall be available in industry standard formats such as Acrobat, Microsoft Word, Microsoft Excel and Crystal Reports.

    1) Summaries shall be provided for specific points, for a logical point group, for a user-selected group or groups or for the entire BACnet network without restriction due to the hardware configuration of the building automation system. At a minimum, the report function shall provide all required BACnet data for the previously identified BACnet objects in section 2.00 J.

B. Scheduling

Provide a graphical spreadsheet-type format for simplification of time-of-day scheduling and overrides of building operations. Provide the following spreadsheet graphic types as a minimum:

a. BACnet schedules

b. BACnet calendars

Weekly schedules shall be provided for each building zone or piece of equipment with a specific occupancy schedule. Each schedule shall include columns for each day of the week as well as holiday and special day columns for alternate scheduling on user-defined days. Equipment scheduling shall be accomplished by simply inserting occupancy and vacancy times into appropriate information blocks on the graphic. In addition, temporary overrides and associated times may be inserted into blocks for modified operating schedules. After overrides have been executed, the original schedule will automatically be restored.

Zone schedules shall be provided for each building zone as previously described. Each schedule shall include all commandable points residing within the zone, unless custom programming is used to enable/disable the points. Each point may have a unique schedule of operation relative to the zone's occupancy schedule, allowing for sequential starting and control of equipment within the zone.

Monthly calendars, until the year 2020, shall be provided which allow for simplified scheduling of holidays and special days in advance. Holidays and special days shall be user-selected with the pointing device and shall automatically reschedule equipment operation as previously defined on the weekly schedules.

C. Collection and Analysis of Historical Data

Provide trending capabilities that allow the user to easily monitor and preserve records of system activity over an extended period of time. Any system point may be trended automatically at time-based intervals or changes of value, both of which shall be user-definable. Trend data may be stored on hard disk for future diagnostics and reporting. In addition, the BAS system shall automatically trend and archive all alarms and user activity (no exceptions).

Trend data report graphics shall be provided to allow the user to view all trended point data. The BAS system shall employ the use of Multiple Trend-Logs which may be customized to include up to 8 individual singe trends in one viewable and printable format. Provide additional functionality to allow any trended data to be transferred easily to Microsoft Office, Excel ®. This shall allow the user to perform custom calculations such as energy usage, equipment efficiency and energy costs and shall allow for generation of these reports on high-quality plots, graphs and charts.

Provide additional functionality that allows the user to view trended data on trend graph displays. Displays shall be actual plots of both static and/or real-time dynamic point data. A maximum of 8 points may be viewed simultaneously on a single graph, with color selection and line type for each point being user-definable. Displays shall include an 'X' axis indicating elapsed time and a 'Y' axis indicating a range scale in engineering units for each point. The 'Y' axis shall have the ability to be manually or automatically scaled at the user's option. Different ranges for each point may be used with minimum and maximum values listed at the bottom and top of the 'Y' axis. All 'Y' axis data shall be color-coded to match the line color for the corresponding point.

a. Static graphs shall represent actual point data that has been trended and stored on disk. Exact point values may be viewed on a data window by pointing or scrolling to the place of interest along the graph. Provide capability to print any graph on the system printer for use as a building management and diagnostics tool.

b. Dynamic graphs shall represent real-time point data. Any point or group of points may be graphed, regardless of whether they have been predefined for trending. The graphs shall continuously update point values. At any time the user may redefine sampling times or range scales for any point. In addition, the user may pause the graph and take "snapshots" of screens to be stored on the workstation disk for future recall and analysis. As with static graphs, exact point values may be viewed and the graphs may be printed.

D. Dynamic Color Graphic Displays

Color graphic floor plan displays and system schematics for each piece of mechanical equipment, including air handling units, chilled water systems and hot water boiler systems, room level terminal unit equipment shall be provided by the BAS contractor as indicated in the point I/O summary of this specification to optimize system performance analysis and speed alarm recognition. The operator interface shall allow users to access the various system schematics and floor plans via a graphical penetration scheme, menu selection or text-based commands.

Dynamic temperature values, humidity values, flow values, percent load, and status indication shall be shown in their actual respective locations and shall automatically update to represent current conditions without operator intervention.

The windowing environment of the PC operator workstation shall allow the user to simultaneously view several graphics at a time to analyze total building operation or to allow the display of a graphic associated with an alarm to be viewed without interrupting work in progress.

Graphic generation software shall be provided to allow the user to add, modify or delete system graphic displays.

a. The BAS contractor shall provide libraries of pre-engineered screens and symbols depicting standard air handling unit components (e.g., fans, cooling coils, filters, dampers, etc.), complete mechanical systems (e.g., constant volume-terminal reheat, VAV, etc.) and electrical symbols.

b. The graphic package shall use a mouse or similar pointing device in conjunction with a drawing program to allow the user to perform the following:

   1) Define symbols
   2) Position and size symbols
   3) Define background screens
   4) Define connecting lines and curves
   5) Locate, orient and size descriptive text
   6) Define and display colors for all elements
   7) Establish correlation between symbols or text and associated system points or other displays
   8) Ability to import scanned images and CAD drawings in Autodesk ®, DWG format.

c. Graphical displays can be created to represent any logical grouping of system points or calculated data based upon building function, mechanical system, building layout or any other logical grouping of points that aids the operator in the analysis of the facility.

   1) To accomplish this, the user shall be able to build graphic displays that include point data from multiple controllers.

Dynamic system status graphic of the site-specific architecture showing status of system hardware, including quantity and address of networks, field panels, terminal equipment controllers, and printers.

The BAS contractor shall employ the use of accurate floor plans as part of the overall graphics package. The floor plans shall illustrate the location of room sensors and equipment. In addition, the floor plans shall utilize a thermographic scheme to instantly alert the end user of hot and cold areas. The thermograph shall illustrate and automatically intensify the red and blue gradient fills for each area, as to indicate the severity of the overheating or overcooling problem. Include location of down duct static sensors and monitored/controlled smoke/fire damper locations and open/close indication on floor plan graphics.

The BAS contractor shall provide simple, one-click access to sequence of operation, as-builts of MSTP wire routing, and other O&M deliverables

E. System Configuration and Definition:

All temperature and equipment control strategies and energy management routines shall be definable and fully programmable by the operator. System definition and modification procedures shall not interfere with normal system operation and control.

The system shall be provided complete with all equipment and documentation necessary to allow an operator to independently perform the following functions:

a. Add/delete/modify stand-alone Building Controllers

b. Add/delete/modify stand-alone Advanced Application Controllers

c. Add/delete/modify operator workstations

d. Add/delete/modify Application Specific Controllers, if used

e. Add/delete/modify points of any type and all associated point parameters and tuning constants

f. Add/delete/modify alarm reporting definition for points

g. Add/delete/modify control loops

h. Add/delete/modify energy management applications

i. Add/delete/modify time and calendar-based programming

j. Add/delete/modify totalization for points

k. Add/delete/modify historical data trending for points

l. Add/delete/modify custom control processes

m. Add/delete/modify any and all graphic displays, symbols and cross-reference to point data

n. Add/delete/modify dial-up telecommunication definition

o. Add/delete/modify all operator passwords

p. Add/delete/modify alarm messages

Definition of operator device characteristics, any controller's individual points, applications and control sequences shall be performed using instructive prompting software.

a. All custom programming language must be line sequential, English text with a real time compiler. The operator shall be able to view all live data within the program with no exceptions. The use of secondary software or manual intervention shall not be required.

b. If programming must be done with the PC workstation off-line, the BAS contractor shall provide at least 2 operator workstations.

c. Inputs and outputs for any process shall not be restricted to a single DDC Controller, but shall be able to include data from any and all other network panels to allow the development of network-wide control strategies. Processes shall also allow the operator to use the results of one process as the input to any number of other processes (cascading).

d. Provide the capability to backup and store all system databases on the workstation hard disk. In addition, all database changes shall be performed while the workstation is on-line without disrupting other system operations. Changes shall be automatically recorded and downloaded to the appropriate controller. Similarly, changes made at any Controllers shall be automatically uploaded to the workstation, ensuring system continuity. The user shall also have the option to selectively download changes as desired.

e. Provide context-sensitive help menus to provide instructions appropriate with operations and applications currently being performed. The help menus shall be readily accessible by selecting an icon or by pressing a function button on the keyboard.

2.08 WEB INTERFACE

A. General

1. Furnish a Web-based access interface to the EMS system based on a client-server architecture, and allow for an unlimited number of simultaneous users (with Windows 2003 Professional server). An operator shall be able to access all the information in the system via a standard Web browser. The Web-page software shall not require a per user licensing fee or annual fees.

2. The Web interface shall be a separate software package and be installed as an "overlay"

of the standard EMS software. The use of an embedded Web interface with a standard EMS software package will be prohibited (software packages must be separate).

B. Browser Technology

1. Browser shall be a standard version of Internet Explorer 5 (or higher) or Netscape 6 (or higher). No special vendor-supplied software shall be needed on the thin-client computers running the above browsers. All information shall be viewable, real-time and updated automatically without user interaction.

C. Web Display

1. Web page graphics shown on the browser shall be replicas of the EMS displays. Operators shall need no additional training to understand the information presented on the Web pages when compared to what is shown on the EMS displays.

2. The Web interface shall automatically discover and display new devices that are connected to the BACnet network. In addition, all objects and associated properties will be automatically displayed without "mapping" or user intervention.

3. An operator, via the Web, shall have the ability to:

   a. Navigate real-time through the system

   b. Change <u>all</u> setpoints

   c. View and acknowledge active alarms

   d. Configure the system to email alarms to any other computer on the wide-area network (WAN).

   e. Create and edit building schedules

   f. Trend any point or value and display graphically or in table format

   g. Manually override any input, output or value.

   h. Display a summary of overridden points

   i. Create new users or user groups, assign access privaleges and edit existing user access privaleges

   j. Link graphics to .PDF files, AutoCAD files and Visio files to display sequence of operations and as-built documentation.

   k. View and edit programs, and all input and output points

D. Web Page Generation

1. All “EMS” displays shall be converted to HTML files automatically. The operator shall not be required to program in HTML.
2. All Web page graphics shall have dynamic graphic links with full animation of system components.
3. The Web site shall automatically generate a “network” tree, indicating all devices connected to the network.

E. Password Security and Activity Log

1. Access via the Web browser shall utilize the same hierarchal security scheme as the EMS system. User shall be asked to log in once the browser makes connection to the Web-page. Once the user logs in, any and all changes that are made shall be tracked by the EMS system. The user shall be able to change only those items that the user has authority to change.

F. Hardware

1. The PC requirements for the Web interface shall be industry standard “off the shelf” technology. Furthermore, the Web interface software and standard EMS software shall be installed on the same PC.

2.08 FIELD DEVICES

A. Temperature Sensors: Each temperature sensor shall match the requirements of the associated temperature controller and shall be based upon 10-K Type-3 thermistors. Each sensor shall be designed for the appropriate application (i.e., duct, immersion, etc.) and be provided with all necessary installation accessories. Ranges shall be selected to the middle of the control range. Temperature sensors must have a minimum accuracy of +/- 0.5 deg F or .5 % of scale; whichever will provide the least error in measurement.

Electronic: A modulating solid state controller with built-in detector, P, PI, or PID controller, as required, with continuous voltage or current output. Each controller shall have individual setpoint, proportional band, start point, and span adjustments. Input voltage shall be 24 VAC or less. Each controller to be provided with night setback, summer/winter switchover or remote reset capabilities as required. Controllers shall be of matching type to the input detectors and output drives or sequencers.

Thermostat guards shall be provided where specified, indicated on control diagrams, or indicated on floor plans. Guards shall be firmly attached to wall and thermostat cover shall be visible through the guard. All room sensors in public areas will have concealed setpoint adjustments.

All room sensors in classroom, office, or common spaces will have exposed set point adjustments locked to provide adjustment between 68 degrees and 72 degrees only.

Install thermostats and sensors at 4’-6" AFF to bottom unless otherwise noted on Architectural Drawings. Coordinate installation with the work of other trades before any rough-ins are made.

Duct Sensors: DDC duct sensors shall match the requirements of the associated controller incorporating an electrical signal to insure exact and proportional relationship between the measured variable and the transmitted signal. Static pressure sensors shall be mounted in temperature control panels with connecting sensor lines in hard copper. Where a device is used for sensing of Mixed Air Temperature or Preheat applications and the duct area is in excess of 24 square feet the instrument shall incorporate a capillary averaging element with a minimum length of 96 inches or a suitable array of duct sensors wired as a single input. Averaging sensors shall be used on any duct application where duct area exceeds 24 square feet.

Provide temperature sensors as required to meet the sequence of operation; in addition, provide temperature sensors in the following locations: return air, mixed air and discharge air sections if not required by the sequence of operation.

B. Humidity Sensors: The relative humidity transmitter monitors and transmits changes in humidity, accurate to +/- 2 % RH. Operating range shall be 0 to 99% RH.

C. Pressure Sensors: Duct static pressure analog sensors shall be high accuracy +/-1% of range suitable for the low pressures and selected for at least 50% over range Sensors shall have industry standard 4-20 mA output and zero end span adjustments.

D. Control Dampers (Multiple Blade Dampers): Automatic dampers furnished by the BAS Contractor shall be single blade or multiple blades as applicable. All dampers are to be sized to the application by the manufacturer using methods similar to control valve sizing. Dampers are to be installed by the HVAC Contractor under the supervision of the Temperature Control Contractor. All dampers furnished by air handling unit manufacturers must meet the requirements listed in this section. All blank-off plates and conversions necessary to install smaller than duct size dampers are the responsibility of the HVAC Contractor. All damper frames are to be constructed of No. 13 gauge galvanized sheet metal and shall have flanges for duct mounting. Damper blades shall not exceed 6 inches width. All blades are to be airfoil type construction in ducts with air velocities above 1500 FPM and will be equal to Ruskin RCD 50 control dampers with blade and jamb seals. In applications with velocities less than 1500 FPM control dampers will be equal to Ruskin RCD46 control dampers. Blades are to be suitable for high velocity performance. All damper bearings are to be made of nylon. Bushings that turn in the bearings are to be oil impregnated sintered metal. Dampers hung with blades mounted vertically shall be provided with thrust bearings. Butyl rubber seals are to be installed along the top and bottom of the frame and along each blade edge. Independent, self-compensating, stainless steel end seals shall be installed to insure minimum leakage between blade ends and damper frame. Seals shall provide a tight closing low leakage damper. Damper sections shall not exceed 48" in length or 16 sq. ft. and shall have minimum of one operator per damper section. All dampers in modulating applications shall have opposed blades. Dampers in two position services shall have parallel blades. Where sequence requires, submittals shall include damper sizes and leakage characteristics. Leakage shall not exceed 1 % at 4" W.C. when tested per AMCA Standard 500.

Control dampers will be sized by the temperature control contractor to the inside of the duct or duct liner whichever is smaller. Sizing of dampers to duct size and the subsequent cutting back of insulation to make dampers fit is unacceptable.

Control dampers used for outside air or exhaust air applications will be installed a minimum of 6" away from wall penetrations to allow for external mounting of their respective damper motors. Jack shafting in these applications will only be allowed to prevent having to mount motors in the outside airstream. When internal damper motor mounting is required the sheet metal contractor shall provide access panels at each motor location to allow for ease of service.

E. Damper Operators: Operators shall be electronic, spring return, low voltage (24VAC), and shall be properly sized so as to stroke the damper smoothly and efficiently throughout its range. Actuator responses shall be linear in response to sensed load.

Electronic damper motors for terminal boxes will be provided by the temperature control contractor and shipped to the terminal box manufacturer for mounting. Mounting charges shall be the responsibility of the terminal box manufacturer.

Damper operators on outside air intake/exhaust shall be spring return closed.

VAV Terminal Boxes using internal or proprietary actuators are unacceptable.

F. Automatic Control Valves: All valves shall be equipped with throttling plugs and removable composition discs and shall be manufactured by Siemens or Belimo. All valves are to be sized by the Control Contractor and shall submit pressure drop calculations and guarantee sufficient size to meet the requirements of the equipment being served. All valve operators shall be electronically actuated, and of such design so as to provide adequate operating power for valve positioning.

Reheat valves controlled by AACs in VAV terminal applications shall utilize electronic actuation and shall fail normally closed (capacitor or spring driven failsafe). All reheat valves serving Laboratories and/or Vivariums (animal) rooms shall be electronic actuation and include spring return, to fail normally closed.

Three-way Valves: Three-way valves are to be of the three port mixing arrangement, designed expressly for mixing of two inlets and providing a common outlet. The use of reverse piped diverting valves shall not be acceptable. The Temperature Control Contractor will assist the HVAC Contractor in providing guidance as to the correct method of piping of all three-way valves. It is the responsibility of the HVAC contactor to evaluate the contract drawings for proper verification.

Butterfly valves for air handling unit coil control are unacceptable. If high GPM requirements dictate the valve size to be greater than 6", then Temperature Control contractor shall provide two control valves for the application, and the HVAC Contractor shall install the two control valves, for parallel and/or sequenced operation.

For all fan systems with separate pre-heat and separate 2nd heating coil. The pre-heat coil shall fail normally open, shall include separate analog output AO point for control, and separate analog input AI point for low-limit pre-heat discharge control. The separate 2nd heating coil shall fail normally closed, shall include separate analog output AO point, and separate analog input AI point for low-limit heating control.

For all fan systems with a single hot water coil, the coil shall fail normally open (i.e. AHUs, Fan coils Unit ventilators, UHs, CUHs, etc.)

Pressure drop through modulating control valves shall not exceed 7 feet. Control valves for 2-position applications shall be line sized.

G Air Volume Measurement: Provide Tek-Air or Ebtron air flow measuring system including microprocessor panel and air flow measuring sensor struts as required to measure outside air intake flow as denoted on the Drawings.

1. DDC air flow measuring system shall have a velocity range from 350 to 6000 ft./min. with duct measurement accuracy (including repeatability, zero offset, and temperature compensation) of plus or minus 0.5 percent.
2. Pilot tube arrays and differential pressure arrays are not acceptable.
3. The air flow measurement stations shall include a digital LCD display that illustrates the actual CFM, not FPM or other variables.

H Smoke Detectors shall be provided and installed by the HVAC contractor. The electrical contractor will provide the necessary interlock wiring for life safety functions.

I Air Static and Velocity Pressure Transmitter: The pressure transmitter shall be used for measuring duct static or velocity pressure in variable air volume fan systems.

J Low Limit Detection Thermostat: Low limit detection thermostats equal to Siemens 134-1511 shall be of the vapor tension capillary type having a sensing element a minimum of 20 feet in length. These thermostats shall be of the manual reset type. The elements shall be complete with necessary fittings to permit installation in the duct so as to sense the correct discharge temperatures. One low limit detection thermostat will be installed for every 24 square feet of protected area and arranged so as to stop their respective units and close the outside air dampers in the event discharge temperatures fall below 38 degrees F. The normally closed contact shall be wired to the fan circuit and the normally open contact (close on alarm) shall be wired to a DDC input. One common circuit is suitable for multiple thermostats on a single AHU coil area.

K Electric Thermostats: Heavy-duty snap action type with key operators rated at 10 FLA at 120 RIAC contacts suitable for the intended service. Provide manual selector switches as required in the sequence of operation.

L Fan and Pump Proof: Proof points for air handling unit fans, exhaust fans and pumps will be accomplished through the use of current sensing relays at the motor control center or motor starters. Current sensing relays shall be split-core design, for installation over any single power lead. Current sensing relays shall include field adjustable set screw for amperage setpoint adjustment, and shall include integral LED status light to locally indicate the ‘on’ and ‘off’ condition.

M Variable Frequency Drives: The Variable Frequency Drives (VFDs) shall be supplied under this contract. The VFD shall be manufactured by Siemens or ABB and shall be sized and designed to appropriately control the motor loads. All VFDs shall incorporate a user friendly LCD display that clearly illustrates the drives parameters and current status (sometimes called advanced display). The BAS contractor shall coordinate with the electrical and HVAC contractor to ensure the proper implementation, location and wiring of all VFDs. The BAS contractor will be responsible for all low voltage wiring, while the electrical contractor will be responsible for all high voltage or line / load side wiring.

2.09 LABELING

A. Provide labels for all field devices including sensors, transducers, thermostats, and relays. Exception: Room temperature and/or humidity sensors shall not be labeled.

B. Labels shall be black laminated plastic with white letters and adhesive backing or screw fasteners. Labels shall be located adjacent to device and permanently affixed to device mounting surface. Labels for sensors in pipes may be secured using chain around the sensor well.

C. Labels shall include system virtual/pseudo point name as well as English language name of device being controlled or specific condition being sensed.

D. Identify all control wiring at each end with a wire tags or labels.

PART 3- EXECUTION

3.01 SEQUENCE OF OPERATION

3.02 ON-SITE TESTING

A. Field Test: When installation of the system is complete, calibrate equipment and verify transmission media operation before the system is placed on-line. The installer shall complete all testing, calibrating, adjusting and final field tests. Verify that all systems are operable from local controls in the specified failure mode upon panel failure or loss of power. Upon completion of the work, notify the Owner, and/or Architect/Engineer that the system is ready for final tests and inspection.

B. At the time of final inspection, this Contractor shall be represented by a person with the proper authority, who shall demonstrate, as directed by the Architect/Engineer, that his work fully complies with the purpose and intent of the Specifications and Drawings. Labor, services, instruments, and tools necessary for demonstrations and tests shall be provided by the Contractor.

C. The Contractor shall test and adjust each instrument specialty and equipment furnished by him, prior to final acceptance. The Contractor shall demonstrate, for approval by the Architect/Engineer, subsystems operate as coordinated and properly functioning, integrated system.

D. The Contractor shall furnish labor to provide adjustments and incidentals necessary to obtain the desired and intended results.

E. The Contractor shall turn over a printed copy and electronic copy of the completed and debugged operating software to OSU at the conclusion of the two year warranty.

F. The contractor shall contact the owner prior to connection of new equipment to any existing building automation system network or device.

G. Final acceptance is required by owner BAS representative.

3.03 SERVICE AND GUARANTEE

A. General Requirements: Provide all services, materials and equipment necessary for the successful operation of the entire BAS system for a period of two years after completion of successful performance test. Provide necessary material required for the work. Minimize impacts on facility operations when performing scheduled adjustments and non-scheduled work.

B. Description of Work: The adjustment and repair of the system includes all computer equipment, software updates, transmission equipment and all sensors and control devices. Provide the manufacturer's required adjustments and all other work necessary.

C. Personnel: Provide qualified personnel to accomplish all work promptly and satisfactorily. The OSU Medical Center shall be advised in writing of the name of the designated service representative, and of any changes in personnel.

D. Systems Modifications: Provide any recommendations for system modification in writing to OSU. Do not make any system modifications, including operating parameters and control settings, without prior approval from OSU. Any modifications made to the system shall be incorporated into the operations and maintenance manuals, and other documentation affected.

E. Software: Provide all software updates and verify operation in the system. These updates shall be accomplished in a timely manner, fully coordinated with the system operators, and shall be incorporated into the operations and maintenance manuals, and software documentation.

F. As-Builds: Submit 1 complete sets of drawings to the OSU Project Manager electronically following OSU's Project Closeout Standards and showing the kind of control equipment for each of the various systems and their functions, along with indications on the drawing of all original setpoints and calibration values, and setup parameters, and sequence of operation of the automation system together with a complete brochure describing the equipment and their functions and operation. Include all application software documentation (actual programs or their job-specific flow charts) with DDC system.

1. Manufacturer's Product Data:
    a. All equipment components
2. Shop Drawings:
    a. System wiring diagrams with sequence of operation for each system as specified.
    b. Submit manufacturer's product information on all hardware items along with descriptive literature for all software programs to show compliance with specifications.

c. System configuration diagram showing all panel types and locations as well as communications network layout and workstations.

Where installation procedures, or any part thereof, are required to be in accord with the recommendations of the manufacturer of the material being installed, printed copies of these recommendations shall be furnished to the Architect/Engineer prior to installation. Installation of the item will not be allowed to proceed until the recommendations are received.

Hardcopies of panel wiring diagrams shall be placed within the respective panel enclosure.

3.04 TRAINING

A. The Contractor shall provide competent and certified instructors to give full instruction to designated personnel in the adjustment, operation and maintenance of the system installed rather than a general training course. Instructors shall be thoroughly familiar with all aspects of the subject matter they are to teach. All training shall be held during normal work hours of 8:00 a.m. to 4:30 p.m. weekdays as follows:

B. Provide 40 hours of training for the OSU Medical Center operating personnel. Training shall include:

Explanation of drawings, operations and maintenance manuals

Walk-thru of the job to locate control components

Operator workstation and peripherals

Building Controller, Advanced Application Controller operation/function

Operator control functions including graphic generation and field panel programming

Operation of portable operator's terminal

Explanation of adjustment, calibration and replacement procedures

C. Provide 8 hours of additional training quarterly for a period of one year from final completion of the project.

D. Since OSU may require personnel to have more comprehensive understanding of the hardware and software, additional training must be available from the Contractor. If OSU requires such training, it will be contracted at a later date. Provide description of available local and factory customer training.

END OF APPENDIX A-WMC

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REQUIREMENTS TO ASSURE ACCESS FOR INDIVIDUALS WITH DISABILITIES

The University views each construction project as an opportunity to maximize the accessibility and usability of its built environment. Providing and improving access to the built environment should be an integral part of the design and development process. The following Access Requirements are based on the "2010 ADA Standards for Accessible Design" , developed by the U.S. Architectural & Transportation Barriers Compliance Board and the *Ohio Building Code 2011- Chapter 11 - ICC A117.1-2009:*

All numerical references below are to Article and Paragraph numbers in the 2010 ADA Standards as published in the Code of Federal Regulations (28 CFR Part 35.151 and the 2004 ADDAG at 36 CFR part 1191 appendices B and D) September 15, 2010. The 2010 ADA Standards shall be considered part of these standards as if reprinted in full herein. The following revisions and/or additions to ADAAG shall also be part of the University Standards:

101.1, 201.1, 202.1 & 202.5	Proposed departures from the ADA guidelines or University Standards addressing access for individuals with disabilities based on equivalent facilitation (alternative methods of providing equal or greater access), structural impracticability or technical infeasibility shall be submitted in writing and must receive approval of both the University Architect and the ADA Coordinator.
2.06.2.6	Performance Areas. This section should be read to include access to raised lecture podiums.
203.9, 206.2.8 & 215.3	Areas Used Only by Employees as Work Areas. A minimum of five percent (5%) of individual work areas (excluding Elevator pits, elevator penthouses, mechanical rooms, piping or equipment catwalks) should be designed to allow wheel chair maneuvering clearances and reach ranges when furnished and equipped)
215 & 702	Provision of both audible and visible alarms shall be required at all locations where either type is required. EXCEPTION: Fire alarm systems in medical care facilities shall be permitted to be provided in accordance with industry practice.
221	Provide accessible seating as required by the table at 221.2.1.1 Accessible seating shall be located at both the front and rear of the room in all new construction and wherever feasible in renovations.

403.4 & 404.2.4.4	At changes in floor elevation, especially subtle changes, provide a readily visible change in color and/or pattern to alert visually impaired (but not blind) individuals to the potential "tripper".
404.2.3	Note that nominal 32" doors do not comply. It is recommended that 36" doors be used.
404.2.7	Doorknobs shall not be used without prior approval of the University Architect. Provide lever handles. If an exception is provided the Project Manager shall notify the ADA Coordinator.
404.3	Add 404.3(1) to read as follows: "Provide power assisted door operators on all cross-corridor doors occurring in main corridors. If in compliance with applicable code, magnetic door "hold-opens" may be used in lieu of power assisted operators".
406.1	Provide ramps at all crosswalks leading to (or from) an accessible area or route. Locate said ramps so as to provide the most direct route possible.
406.3 & Figure 406.3	Straight-sided ramps are not permitted without prior approval of the University Architect.
406	Construction of ramp shall conform to construction requirements for sidewalks in regard to concrete thickness, base thickness, base compaction, etc.
407.2.1 & 309.4	Hall call buttons shall be centered at 36" above finish floor. Call buttons shall not be located on the elevator doorjamb and must be located for easy access by wheelchair-bound users.
410	Platform lifts are not permitted in new construction unless approval is granted by the University Architect and the ADA Coordinator. The basis for approval shall be extenuating circumstances, not including aesthetics.
602	Drinking fountains shall comply with 307 & 602..
604	Water closets & Stalls shall comply with 604.3.
604.8.1.1 & Figure 604.8.1.1	All wheelchair accessible toilet stalls shall be 60" x 60". Therefore void Figure 604.8.1.1(b) and amend the dimensions on Figure 604.8.1.1(a) to provide a 60" x 60" stall. Note that prior approval by the University Architect and the ADA Coordinator must be obtained to use other stall configurations [such as Figure 604.8.1.1(a)] on remodeling projects only and only where absolutely required by existing conditions.
604.8.1.2	Add the following note: All accessible stalls shall have slide latch door hardware.
607.6 & 608.6	Wheelchair accessible tubs and showers shall be equipped with a standard wall-mounted nozzle and a hand-held shower sprayer with a 59" hose minimum. Mount hand-held sprayer at 42" above the bottom of the tub or shower basin. Provide controls that will permit use of either the wall-mounted and hand-held shower sprayers individually or both sprayers at the same time.

603.2.3	Add the following: "All Toilet Rooms, except "private" rooms containing a single water closet, shall be equipped with Push-Pull door hardware. Latches are neither needed nor desired on the doors of multiple fixture Toilet Rooms".
603.2.3(1)	Add the following paragraph: "Avoid the use of vestibules with inner and outer doors as access to Toilet Rooms." -.
609.8	Add paragraph 609.9 as follows: "Grab bar fastening system shall be of a concealed type".
<u>ORC Sec. 9.57</u>	<u>Whoever erects or replaces a sign containing the international symbol of access shall use forms of the word “accessible” rather than forms of the word “handicapped” or the word “disabled” whenever words are included on the sign.</u>

END OF APPENDIX B

ENERGY AND SUSTAINABILITY

1. General

   a. All “Qualifying Building Construction Projects” shall be required to address the goals of the University’s Green Build and Energy Policy 3.10.

   b. “A Qualifying Building Construction Project” shall be understood to mean new construction, improvement, renovation, enlargement, or other alterations to a building or structure, or part of a building or structure, which building is intended for permanent occupancy, and which project includes a major energy consuming systems, components, or equipment.

   c. Qualifying Building Construction Projects with budgets at or above the Board of Trustees’ Authorization threshold shall comply with the LEED provisions outlined in appendix X.

   d. Qualifying Building Construction Projects above $200,000 and under the Board of Trustees’ Authorization threshold shall:

      i. Achieve an energy efficiency that is **5%** better than the then current Ohio Mechanical Code, ASHRAE standards.

         1. Should the cost differential between code compliant systems and the enhanced systems necessary to meet the energy efficiency provision herein exceed 15%, and a simple payback calculation illustrate that in excess of 10 years, the foregoing presents baseline grounds for exemption. An exemption or variance request related to this requirement shall be administered through the Building Design Standards Adjudication process.

      ii. Demonstrate Construction Material Recycling and Waste Management pursuant to section 01 40 00 of the BDS, Employ Enhanced Refrigerant Management and Utilize low-emitting materials per LEED defined requisites

2. Policy 3.10 Energy Compliance Documentation

   a. Policy 3.10 compliance submittals shall be as described in Division 00, Part 2.

   b. The energy costs used in energy and life cycle cost analyses shall be obtained from OSU Energy Services and Sustainability (ESS).

   c. The A/E design team’s choice of energy sources for heating decision related to the “point of use energy source” to produce heat or other energy consuming systems is subject to the approval of the University Engineer. The A/E design team should review this choice early in the design phase with the University’s Project Manager and obtain the University Engineer’s approval (email is sufficient).

END OF APPENDIX C

REQUIREMENTS FOR SURVEY INFORMATION

General Requirements

1. All survey work performed on or for The Ohio State University shall be in Ohio State Plane South, NAD83(86), NAVD88 Datum and submitted to the Facilities Operations and Development Survey Group (Campus Surveyor)
2. Cadastral (survey) entities.
    a. Property Lines: Locate and dimension all property lines and show bearings of same. Include parcel Id's and ownership of same.
    b. Easements: Clearly and fully describe and delineate all rights, restrictions, easement locations, etc. on or adjacent to the proposed site.
    c. Right-of-Ways: Clearly and fully describe and delineate all right-of-ways on or adjacent to the proposed site.
3. Utilities: Show and delineate all above and below ground utility routes, and note ownership of same when not owned and maintained by The Ohio State University. Show locations of all utility features such as: utility poles, hydrants, valves, sewer structures, manholes, junction/pull boxes, transformers, switch gear, control boxes, pedestals, meters, regulators, irrigation features, etc.
    Items with special requirements:
    a. Pipes: (i.e. water, chilled water, etc.) Indicate size and where applicable denote invert elevation, direction of flow and pressure, and top of pipe elevation (if accessible).
    b. Manholes: Provide the location and elevation of the center of the manhole lid, and elevation of the manhole rim. Provide an elevation at the bottom of the structure plus invert elevations and directions for all pipes entering/exiting the manhole. Provide the structures internal dimensions relative to the access hole, construction material and an estimate of the current condition.
    c. Electric and Data Communications: Show the size of the duct bank and the conduit configuration. Indicate by means of a section cut or detail which conduits are in use and which are spares, and provide duct bank/conduit elevation (if accessible).
    d. Tunnels: Indicate internal dimensions, construction material and type. Provide locations of all vents, pipe drops and access points.
4. Topography.
    a. Bench Marks: Permanent bench marks shall be provided on adjacent structures for future use.
    b. Spot Grades: Spots grades shall be furnished, as needed, to supplement elevations recorded on topographic features to provide a density of points that are no greater than twenty-five (25) feet apart.
    c. Contours: A contour map is to be provided at one (1) foot contour intervals with an index contour interval of five (5) feet, unless otherwise noted. All breaks and obstructions shall be provided and accounted for within the contour map.
    d. Digital Elevation Model: A DEM of points used to create the contour map shall be provided in AutoCAD format. Points shall be grouped onto individual layers according to type.

5. Topographic features: Show and delineate all natural and man-made features, on and adjacent to the proposed site, as to provide the most accurate depiction of the current site conditions.
   Items with special requirements:
   a. Buildings: Show all building corners and wall planes where they intersect the ground (foot print), and indicate all overhangs and cantilevers (roof print).
   b. Hardscapes: Show and indicate the extents and material types of all hard surfaces to include; roads, drives, curbs, walls, walks, etc.
   c. Signage: Indication location, type and verbiage of all signage on or adjacent to the proposed site.
   d. Paint Markings: show and indicate the location and extents of all paint markings on or adjacent to the proposed site to include; road striping, cross-walks, parking lot lines, etc.
   e. Vegetation: Show and depict through symbols all trees, shrubs, planting beds, mulch beds and lawn areas. Where trees or shrubs are planted in mass, delineate the extents of the vegetation and label the area as appropriate.
6. Drafting: Electronic drawings shall be prepared and provided at a scale of 1:1 and submitted in AutoCAD format, to include any and all xref's, plot styles and fonts. A hard copy print/plot shall accompany the electronic version and should be provided at a scale of 1" = 40'.
   a. Electronic and hardcopy drawings should include: a north arrow, title of drawing, symbol legend, name and address of Owner and Surveyor, date, revision designation, scale of drawing and legal title of property.
7. Seal: Affix seal of the Registered Professional Surveyor responsible, and provide signature on all hardcopy plots.

Coordination of Underground Utilities Recording during Construction:

1. Prior to the installation, uncovering or work to any utility (new or existing), the contractor/construction management liaison shall notify the Campus Surveyor of the proposed work, to include type of utility and scope. Provide notification within one (1) business day prior to excavation.
2. After notification, the contractor/construction management liaison shall provide the Campus Surveyor access to the utility, and ensure that the appropriate data collection (survey) has been completed prior to covering the utility. Failure to provide for the appropriate data collection (survey) the contractor may be responsible for the uncovering/excavation of the utility so that its proper location and attributes can be recorded by the Campus Surveyor or his/her representative. Documentation by the contractor/construction management liaison in-lieu of the Campus Surveyor will not be accepted, unless information is provided as indicated below.

Use of Consultants/Private Survey Companies to Perform Underground Utilities Recording

Other than contacting the Campus Surveyor to record the underground utilities installed or encountered during the construction as described as above, projects with significant impacts to university owned and operated utilities; shall include funding for Consultants/Private Survey Companies to perform construction survey work. The scope of the survey work shall be approved by the University Engineer prior to completion of schematic design. All work will be completed within the guidelines identified below.

1. All survey work (utility, topographic, etc.) performed by consultants shall meet all general requirements, listed above.
2. Completed surveys shall be submitted to the Facilities Operations and Development Survey group (Campus Surveyor) as-well-as the appropriate Project Manager or requesting Architect/Engineer (A/E) firm for review. Deliverables shall include an electronic drawing in AutoCAD format, including a layering standard approved by the Campus Surveyor, as well as a hardcopy plot/print. Survey deliverables shall indicate all control points and bench marks used with their corresponding N,E,Z coordinates. An ASCII text file of the collected points shall be provided, as-well-as any field notes (to include sketches and Station Recovery Notes), along with a copy/description of any surveying codes that have not been translated from their original raw data format.
3. Surveys performed by consultants/private survey companies will carry the same notification process as described under “Coordination of Underground Utilities Recording during Construction”, listed above. The Campus Surveyor shall be given the opportunity to inspect all new and existing facilities and perform additional data collection at his/her discretion.
4. S.U.E – Any buried utility/facility on the Ohio State Campus that is to be exposed through non-invasive (or any other means) will carry the same notification process as described under “Coordination of Underground Utilities Recording during Construction”, listed above.
5. Data collection performed by consultants/private survey companies, without properly notifying the Campus Surveyor, may not be accepted and may result in re-exposing the utility/facility.

END OF APPENDIX E

TITLE SHEET AND TITLE BLOCK STANDARD DRAWINGS

These Title Sheet and Title Block standard drawings are to be utilized on all projects for Facilities Operations and Development.

Signature blocks to be included should be verified with the Project Manager for the specific project.

Please follow the links below to download the files:

Title Sheet – Local Administration	.dwg .dxf
Title Block – Local Administration	.dwg .dxf

END OF APPENDIX F

CLEANING, FLUSHING, & WATER TREATMENT PROCEDURE
FOR BUILDING HYDRONIC SYSTEMS

1.01 GENERAL

A. The following Guideline assumes the chemicals for the CFW Procedure (Cleaning, Flushing, and Water Treatment) are provided by the Water Treatment Supplier (WTS) working directly for the University:

1. This Guideline is intended to provide the Project A/E (Architect/Engineer) with general procedural information that is intended to benefit the efficiency and longevity of the University's building closed loop hydronic systems (e.g. heating hot water; chilled water). It is the responsibility of the A/E to adjust the Guideline specifics to meet the needs of the particular Project system. A CFW Procedure should be developed by the A/E and included in the Project Manual for all projects that modify existing or install new Building Hydronic Systems.

2. The implementation of this CFW Procedure is the responsibility of the Prime Contractor defined by the A/E in the Project Manual.

3. For standalone building recirculating hydronic systems, recommend to OSU Project Manager whether CFW Procedure should be applied to both new and existing piping or to new piping only. Thoroughly clean and passivate hydronic systems prior to operation of the building systems. For chilled water systems that will be connected to a Campus Central Chiller Plant, all new and existing piping shall be thoroughly cleaned and passivated prior to operation of the building systems and/or circulation to any of the Campus Central Chilled Water Plants (McCracken, East Regional, and South Campus Chiller Plants).

4. The A/E shall provide the OSU WTS and the Contractor with a calculated water volume (gallons) of the hydronic system(s) for the CFW Procedure and the required flow rate (GPM) to remove debris, slag and/or surface corrosion byproducts.

5. The Water Treatment Supplier shall submit to the OSU Project Manager, the SDS (Safety Data Sheets) documentation for all chemicals used for the CFW process.

6. The A/E shall provide a piping system drawing or sketch to identify the hydronic piping system scope of work that will be flushed and cleaned, including bypass or isolation valves to protect equipment that may be damaged during the CWF process. The A/E's drawings shall identify the connections to feed the chemicals and the makeup water as well as the location of the sanitary floor drains to bleed and flush the wastewater used to clean and passivate the pipes. The makeup water source(s) and bleed locations selected shall provide adequate capacity to drain and flush the system within a 4-hour period (or as directed by the OSU Project Manager).

If the existing pipe and valve taps are inadequate, provide new valve connections.

7. The Contractor shall prepare a plan to implement the CFW Procedure and provide a detailed sketch based on the A/E's drawing, showing bypasses, valves, blank-offs, blind flanges, etc., as necessary to accomplish the work. The Contractor shall provide documentation and acceptance of the CFW procedure to the OSU Project Manager. See Exhibit C.

B. Prerequisites for the Process of Cleaning & Flushing:

1. The Contractor shall inform the OSU Office of Environment Health & Safety (EHS) prior to the planned cleaning and flushing process. EHS will serve as the initial and primary contact with the city of Columbus Division of Sewerage and Drainage (DOSD). The required Standard Operating Procedure (SOP) and Pre-Approval documents are attached to this Guideline as Exhibit A and Exhibit B.

2. The chemicals used by the Contractor needs to be in compliance with the City of Columbus; the WTS shall furnish this information to the Contractor and the OSU EHS for their use and disposition.

C. Preparation for Cleaning:

1. Contractor shall install a BYPASS pipe wherever needed between the hydronic return & supply lines to recirculate the entire system using the hydronic pumps installed. The diameter of this pipe shall be at least 1/3 of the diameter of the main hydronic lines. The contractor shall also remove or cap the temporary BYPAS to a permanent configuration (to allow future CFW) when flushing is complete and approved water chemistry is achieved.

2. Contractor shall remove all strainer screens prior to flushing all systems, including mud from the dirt legs. Contractor shall clean and replace/reinstall all strainer screens after the final cleaning and flushing procedure has passed the final test criteria noted herein.

3. Complete circulation must be achieved during the cleaning procedure. The A/E shall develop a CFW PLAN to achieve a minimum velocity of three feet per second (3 ft/s) in the pipes to ensure the cleaning chemicals will work properly. If necessary, isolate parts of the piping system to attain at least (3 ft/s) in piping being flushed. All electric, pneumatic, and thermostatic operated valves shall be full open. All dead end runs shall be looped together with piping not less than one-third the size of the run.

D. Cleaning Chemical (PreKleen-1301 or approved equivalent):

1. The cleaning solution shall be formulated to remove light grease, cutting oils, loose mill scale, organics, and extraneous construction debris. The cleaner shall contain a polyphosphate, an anionic polymer dispersant, and a low-foaming surfactant. Formulations shall not contain any ingredient that may be harmful to system materials of construction and shall be acceptable to the City of Columbus for discharge to the city sanitary sewer system. Sufficient cleaner shall be used to effectively clean and condition all piping so as to promote the formation of a uniform passivating film on all metal surfaces.

E. Pre-Operational Cleaning Procedure:

1. Prior to adding PreKleen-1301, the WTS shall run a conductivity test on a sample of system water. The WTS shall record this reading.

2. Add (PreKleen-1301) directly into the system via a bypass chemical feeder or chemical transfer pump at a dosage rate of 1-2 gallons per 1,000 gallons system volume.
3. After system water has been circulated, WTS shall run a conductivity test on a sample of system water to confirm sufficient cleaner has been added. The conductivity should be 500-1000 mmhos/cm greater than the conductivity reading obtained prior to adding PreKleen-1301. If cleaner concentration is insufficient, add more PreKleen-1301 until concentration is sufficient.

4. After Pre-Kleen 1301 concentration is sufficient, circulate the system water for 48 hours minimum [120 hours maximum].

5. After obtaining permission from OSU EHS, drain the system completely, paying particular attention to mud from drop legs and all low points. If draining quickly is not possible, slowly bleed the system to drain until all the cleaning solution has been removed.

6. Refill the system with clean potable water.

7. Recirculate for 8-12 hours and then completely drain the system again.

8. The WTS shall sample the water and run a conductivity test to determine if the cleaner has been flushed out of the system. The conductivity of the sample should be approximately the same as city water conductivity indicating the cleaner has been removed from the system. If necessary, bleed the system to drain until the conductivity approximates the city water conductivity.

9. Test Criteria Requirements - WTS shall sample the water to determine the following:
   a. TDS levels should be less than 3500

   b. pH level should be between 9 to 11
   c. ATP should be <75. Determine bacteria activity by running ATP tests. If ATP (Alive) value exceeds 75, biocide should be added to kill bacteria. Micro Control 15N, or approved equivalent, at a dosage of (1) pint per 1,000 gallons volume should be added and circulated for 24 hours. Resample and run ATP tests again to confirm bacteria kill.
   d. Iron levels should be <1.0 ppm, If the iron concentration is >1.0 ppm, Contractor shall continue flushing the system with clean potable water until it is <1.0 ppm.

10. After WTS confirms that the system meet the required test criteria, Contractor shall reinstall all strainers and add the corrosion inhibitor: (5) gallons of CorrPro-1380, or approved equivalent, per 1,000 gallons system volume to develop 500-1000 ppm nitrite as NO_2. The length of time between the completion of the cleaning procedure and the addition of the corrosion inhibitor shall not exceed (24) hours.

Exhibit A

The Ohio State University

Slug Discharges Standard Operating Procedure

Janice Fry
Date of Revision: 18 November 2014

The Ohio State University
Office of Environmental Health & Safety
1314 Kinnear Road
Columbus, OH 43212
Phone: (614) 292-1284
Fax: (614) 292-6404
www.ehs.osu.edu

1.02 DISCHARGES

A. Introduction:

This document outlines the steps to take for slug discharges to the sanitary sewer. A slug discharge is any non-routine discharge to the sanitary sewer, whether the discharge is planned or an accidental release, at a flow rate or concentration that could cause a violation of prohibited discharge standards. The most common types of planned slug discharges are from cleaning and flushing of water lines, tanks, or boilers.

B. Planned Discharges:

1. Planned slug discharges to the sanitary sewer require pre-approval from the City of Columbus Division of Sewerage and Drainage (DOSD) Pretreatment Office. EHS will serve as the primary contact with the DOSD.

C. The project manager or supervisor of any project that proposes discharging water to the sanitary sewer shall contact the Environmental Safety and Health (EHS) Environmental Affairs Office as soon as possible in advance of the planned discharge. The primary EHS contacts for discharges to the sanitary sewer are:

Janice Fry	(614) 292-3223
Kent Halloran	(614) 292-5529
Tom Novotny	(614) 688-1764

D. The following information is needed prior to notifying DOSD:

1. Proposed date(s) of discharge,

2. Proposed total volume and rate of discharge,

3. Material Safety Data Sheets (MSDS) or Safety Data Sheets (SDS) of all chemicals known to be in the discharge,

4. Estimated concentrations of the chemicals in the discharge, and

5. Any other available information regarding the expected nature of the discharge, such as pH, dissolved solids, metals, temperature, etc.

See Attachment 1 for a form to record all the necessary information needed for DOSD approval. The form should be completed and returned to EHS.

The DOSD may require that the discharge be analyzed for specific pollutants of concern prior to granting approval. These specific pollutants and concentrations limits not to be exceeded are listed in Table 1.

Table 1. City of Columbus Division of Sewerage and Drains Discharge Limits

Pollutant	Discharge Limit (ug/L)
Arsenic	1,000
Beryllium	Non detect
Cadmium	500
Chromium	20,000
Chromium, hexavalent	No limit
Copper	2,700
Cyanide	5,000
Hydrocarbon fats, oil, and grease (FOG)	200,000
Phenol	No limit
Bis(2ethylhexyl)Phthalate	No limit
Lead	4,000
Mercury	20
Molybdenum	No limit
Nickel	5,000
Selenium	10,000
Silver	3,000
Zinc	5,500

The DOSD will consider other known pollutants in the planned discharge on a case by case basis.

Once the DOSD has approved the discharge, the discharge must not occur before, during, or immediately after a significant rain or snow melt event. The DOSD should be consulted regarding the timing of the discharge if wet weather or snow melt is a factor.

E. Instructions for Obtaining DOSD Approval of Planned Discharges:

1. The primary DOSD contact for approval of planned discharges is Jim Carpenter at (614) 645-1942.

2. If no one is available at that number, the secondary contact number for DOSD is (614) 645-5876. If no one is available at either number, leave a brief message.

3. If an immediate response is required, contact the Jackson Pike Wastewater Treatment Plant Supervisor's office at (614) 645-3138 (extension-2) to obtain permission prior to discharge.

4. Record the name of the wastewater treatment plant supervisor that granted permission for the discharge.

5. Immediate email follow-up to joc@columbus.gov and pretreatment@columbus.gov is also required. Include information regarding the nature and volume of the discharge, the date and time of discharge, and the name of the wastewater treatment plant supervisor that granted permission to discharge.

6. Attach files of the applicable MSDSs or SDSs to the email.

7. A cc: of this email should be addressed to:

Janice Fry	fry.71@osu.edu
Kent Halloran	halloran.21@osu.edu
Tom Novotny	novotny.66@osu.edu

F. Pre-Approved Routine Discharges:

1. The McCracken Power Plant's routine discharges (boiler blowdown, spent brine from water polishers and softeners, etc.) are allowed under the McCracken Power Plant's Slug Control Plan as approved by the DOSD.

G. Prohibited Discharges:

1. Prohibited Sanitary Sewer Discharges:

Section 1145.20 of the City of Columbus municipal Code of Ordinances prohibits specific types of discharges to the sanitary sewer, including, but not limited to:

a. Solid or viscous substances, including oils of any kind
b. Flammable or explosive substances
c. Any discharge that will cause the sewage temperature in the public sewer to be above one hundred twenty (120) degrees Fahrenheit (forty-nine (49) degrees C) after mixing with other flow in the public sewer at the nearest accessible point downstream from the user, or above one hundred four (104) degrees Fahrenheit (forty (40) degrees C) at the influent to the POTW treatment facility, or above one hundred sixty (160) degrees Fahrenheit (seventy-one (71) degrees C) in the user's sewer at the nearest accessible point upstream from confluence with the public sewer system.
d. Corrosive substances
e. Any discharge with a pH below 5.0 S.U. or above 12.5 S.U.
f. Oxygen-demanding pollutants (biochemical oxygen demand (BOD), etc.)
g. Toxic or poisonous substances
h. Radioactive wastes
i. Wastes regulated under the Resource Conservation and Recovery Act (RCRA)

2. Prohibited Storm Sewer Discharges:

    a. Planned discharges to the storm sewer are not allowed under any circumstances.
    Contact EHS immediately if an accidental release to the storm sewer has occurred. The primary EHS contacts for accidental discharges to the storm sewer are:

Kent Halloran	(614) 292-5529
Tom Novotny	(614) 688-1764
EHS 24-hr Emergency Response	(614) 292-1284 (option#1, then select option#2)

3. Unplanned Discharges:
    a. Immediate notification to the DOSD is required if an unplanned slug discharge has occurred.
    b. An EHS representative will immediately notify the Pretreatment Section of the City of Columbus DOSD at 645-5876 of any unplanned non-routine discharge to the sanitary sewer system.
    c. This is required to enable the wastewater treatment plant to take appropriate countermeasures to minimize potential risk to the wastewater treatment workers, damage to the wastewater treatment system, and/or the receiving waters.
    d. In the event of an unplanned slug discharge, all appropriate MSDSs or SDSs will be consulted to provide the wastewater treatment plant with timely information.
    e. If no one is available at DOSD to accept the telephone notification, the EHS representative will call the DOSD Sewer Maintenance Section at (614) 645-7102, which is answered 24 hours / day.

4. A follow up report must be written and submitted to the Pretreatment Department by EHS within five (5) calendar days of the incident. The report shall contain the following:
    a. A description of the discharge
    b. The cause of the discharge
    c. The exact dates and times of the discharge, and if the discharge continues, the time by which the discharge is expected to be corrected.
    d. Any and all steps taken, or to be taken, to reduce, eliminate, and prevent recurrence.

5. See Attachment 2 for a template of a follow up notification letter to DOSD.
    The written report shall be sent to:

    City of Columbus
    Division of Sewerage and Drainage
    Pretreatment Section
    1250 Fairwood Avenue
    Columbus, Ohio 43206-3372

Pre-Approval Information for Slug Discharge to Sanitary Sewer

The City of Columbus Division of Sewerage and Drainage (DOSD) requires pre-approval of non-routine slug discharges to the sanitary sewer. To expedite the approval process, the project manager should complete this form with all the required information and return to EHS along with Material Safety Data Sheets (MSDS) or Safety Data Sheets (SDS) of any chemicals known to be in the discharge. EHS will notify the project manager when the DOSD approves the discharge. No discharges may occur prior to DOSD approval. Actual approved discharge may be subject to delay in the event of significant rain or snow melt events.

Description of process necessitating discharge to sanitary: ______________________

Project Manager name/contact information: ______________________

Location of proposed discharge: ______________________

Proposed date(s) and time of discharge: ______________________

Proposed total volume of discharge: ______________________

Anticipated rate of discharge: ______________________

Estimated concentrations of any chemicals in the discharge: ______________________

Any other available information regarding the expected nature of the discharge, such as pH, dissolved solids, metals, temperature, etc.

____

Return the completed form to either:

Janice Fry
fry.71@osu.edu
138 McCracken Power Plant
2003 Millikin Rd
Columbus, OH 43210
614-292-3223

Kent Halloran
halloran.21@osu.edu
1314 Kinnear Rd
Room 106
Columbus, OH 43212
614-292-5529

{Date}

Mr. Jeff Bertacchi
Pretreatment Program Manager
Division of Sewerage and Drainage
1250 Fairwood Avenue
Columbus, OH 43206-3372

Dear Mr. Bertacchi,

This letter serves as a written follow up to a telephone notification made to {insert name of DOSD employee who took the telephone report} of the Division of Sewerage and Drains on {insert date of telephone notification} regarding an unplanned slug discharge from The Ohio State University to the sanitary sewer.

The unplanned discharge occurred on {insert date}, at approximately {insert time} and consisted of approximately {insert volume} of wastewater from {insert description of process or source of wastewater discharged}, containing {insert any known constituents of concern}.

This discharge was caused by {insert description of cause}. The Ohio State University has implemented the following measures to prevent a recurrence of this discharge: {insert description of corrective action taken}. [Optional text, if applicable: {Attached are MSDSs of the known constituents in the discharge.}]

Please contact me at 614-{insert phone number} or {insert email address} if you require additional information.

Sincerely,
{insert signature}

{insert name}
{insert title}

cc: Tom Novotny
Mike St. Clair

Exhibit B

The Ohio State University

Pre-Approval Information for Slug Discharge to Sanitary Sewer

Janice Fry
Date of Revision: 18 November 2014

The Ohio State University
Office of Environmental Health & Safety
1314 Kinnear Road
Columbus, OH 43212
Phone: (614) 292-1284
Fax: (614) 292-6404
www.ehs.osu.edu

1.03 PRE-APPROVAL // SLUG DISCHARGE

The City of Columbus Division of Sewerage and Drainage (DOSD) requires pre-approval of non-routine slug discharges to the sanitary sewer. To expedite the approval process, complete this form with all the required information and return to EHS along with Material Safety Data Sheets (MSDS) or Safety Data Sheets (SDS) of any chemicals known to be in the discharge. EHS will notify the project manager when the DOSD approves the discharge. No discharges may occur prior to DOSD approval. Actual approved discharge may be subject to delay in the event of significant rain or snow melt events.

Description of process necessitating discharge to sanitary: ____________________

Project Manager name/contact information: ____________________

Location of proposed discharge: ____________________

Proposed date(s) and time of discharge: ____________________

Proposed total volume of discharge: ____________________

Anticipated rate of discharge: ____________________

Estimated concentrations of any chemicals in the discharge: ____________________

Any other available information regarding the expected nature of the discharge, such as pH, dissolved solids, metals, temperature, etc.

____

Return the completed form to either:

Janice Fry	Kent Halloran
fry.71@osu.edu	halloran.21@osu.edu
138 McCracken Power Plant	1314 Kinnear Rd
2003 Millikin Rd	Room 106
Columbus, OH 43210	Columbus, OH 43212
614-292-3223	614-292-5529