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SPECIFICATION DIVISION 23

NUMBER SECTION DESCRIPTION

END OF CONTENTS TABLE

DIVISION 23
SECTION 230900 - MECHANICAL SYSTEMS CONTROLS

REVISION NOTES:

MAY 2024: BALL STYLE CONTROL VALVES ARE NOW SPECIFIED TO BE NICKEL COATED BRASS OR STAINLESS STEEL CONSTRUCTION DUE TO WATER QUALITY ISSUES CASUING CORROSION AND FAILURE IN BALL VALVES WITH BRASS CONSTRUCTION. LTDE INSTALLATION REQUIREMENTS HAVE BEEN ADJUSTED TO MATCH MANUFACTURER RECOMMENDED INSTALLATION REQUIREMENTS.

APRIL 2023: MODIFIED AUTOMATIC CONTROL VALVE SECTION 2.17 AND DAMPER OPERATORS SECTION 2.19 TO INCLUDE ELECTRIC ACTUATION AS THE PREFERRED OPTION FOR NEW PROJECTS. REORGANIZED SECTION 2.17 TO SIMPLIFY VALVE REQUIREMENTS PER CONTROLS AD HOC SPECIFICATION SUBCOMMITTEE.

JUNE 2021: ADDED PRELIMINARY CHANGE OF VALUE INCREMENTS FOR DATA SHARING TO PART 3. D. KARLE, AS REQUESTED BY UM CONTROLS AD HOC TEAM.

SEPTEMBER 2020: EXTENSIVE REVISION BY AEC CONTROLS AD HOC SPEC TEAM.

MAY 2019: ADD COMBINATION ROOM TEMP AND HUMIDITY SENSOR. ADD ROOM TEMPERATURE CONTROLLER ("RTC"). REVISE ROOM TEMPERATURE CONTROLLER FOR FAN COILS ("RTC-F"). REVISE BALL VALVE ACTUATORS TO MODULATING TYPE. ADDED FLN AND BLN WIRE COLORS. AS APPROVED BY HVAC MTT. D. KARLE.

DECEMBER 2018: ADD CONDENSATION SENSOR, ALARM INDICATION STATION, OCCUPANCY COUNTER. IMPROVE TEC SPECIFICATION LANGUAGE (2.5). REVISE ROOM DIFFERENTIAL PRESSURE INDICATING GAUGE TO CENTER ZERO MODEL. PART 3: INDICATED THAT SETPOINTS ON DOCUMENTS ARE PRELIMINARY AND MUST BE FINALIZED WITH THE ENGINEER AND COMMISSIONING AUTHORITY PRIOR TO PROGRAMMING. ADDED SELF CALIBRATION DEVICE REQUIREMENTS. PER HVAC MTT. D. KARLE.

MAY 2018: ADDED ONICON AS APPORVED FOR EM FLOW METERS (WATER) PER HVAC MTT. D. KARLE.

JUNE 2016: REVISED SECTION TO ADD CONSTANT VOLUME VENTURI(CVV) FUME HOOD LAB AIRFLOW CONTROLS. VAV FUME HOOD LAB AIRFLOW CONTROLS, INCLUDING ALL OTHER MECHANICAL CONTROLS IN THE VAV FUME HOOD LAB, REMAINS IN MS230910. REFER TO DESIGN GUIDELINE 230030 FOR ADDITIONAL GUIDANCE. ALSO ADDED INFO ON UTILITY METERING ("DATA ACQUISITION PANELS"). D. APPEL.

EDITOR'S NOTE:

IF THE PROJECT WILL NOT SPLIT THE WORK BETWEEN THE MECHANICAL SYSTEMS CONTROLS CONTRACTOR AND THE UNIVERSITY OF MICHIGAN AS DESCRIBED IN 1.3, UTILIZE SPECIFICATION SECTION 230901.

THESE SPECIFICATIONS MUST BE CUSTOMIZED APPROPRIATELY FOR EACH PROJECT, E.G. ADDING SPECIFICATIONS FOR COMPONENTS NOT ALREADY

SPECIFIED IN PART 2. HOWEVER, DELETING COMPONENTS SPECIFIED IN PART 2 IS NOT TYPICALLY NECESSARY OR RECOMMENDED. IN ADDITION TO THESE SPECIFICATIONS, THE PLANS ARE TO INCLUDE THE FOLLOWING, AS A MINIMUM:

SCHEMATIC LAYOUT OF EACH SYSTEM SHOWING ALL DDC AND CONTROL COMPONENTS.

LOCATIONS OF ALL DDC PANEL ARRAYS.

PROVIDE TWO 20 AMP POWER CIRCUITS AT EACH DDC/AUXILIARY PANEL LOCATION. ONE CIRCUIT IS FOR THE DDC PANEL, THE OTHER IS FOR THE AUXILIARY PANEL. ELECTRICAL POWER REQUIREMENTS TO BE COORDINATED WITH ELECTRICAL DRAWINGS.

WIRING DIAGRAMS FOR EACH SYSTEM TO SHOW INTENT OF AUTOMATIC OR INTERLOCKED OPERATION.

SCHEDULES FOR DAMPERS, AIRFLOW MEASURING STATIONS, STATIC PRESSURE PROBE LOCATIONS, HUMIDITY RESET, TEMPERATURE RESET, DAY/NIGHT CONTROL ZONE, ETC.

THE SCOPE OF THIS SPECIFICATION INCLUDES CONTROLS FOR ANY LAB ROOM WITHOUT VAV FUME HOODS OR COMBINATION SASHES. IF A LAB ROOM INCLUDES THOSE HOOD TYPES, U-M MASTER SPEC 230910 MUST BE INCLUDED TO COVER ALL MECHANICAL CONTROLS IN THOSE ROOMS.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

ALWAYS INCLUDE PARAGRAPH 1.1.A AND B IN EVERY SPECIFICATION SECTION. EDIT RELATED SECTIONS 1.1.B TO MAKE IT PROJECT SPECIFIC.

A. Drawings and general provisions of the Contract, Standard General and Supplementary General Conditions, Division 1 Specification Sections, and other applicable Specification Sections including the Related Sections listed below, apply to this Section.

B. Related Sections

1. 019100 Project Commissioning
2. 220523 Valves
3. 233600 Air Terminal Units
4. 230910 VAV Fume Hood Laboratory Air Flow Controls
5. Division 26: Electrical

1.2 SUMMARY

A. This Section specifies mechanical systems controls applicable to all project controls except for labs with variable air volume (VAV) fume hoods, including combination (vertical/horizontal) sash fume hoods. Controls in rooms with VAV and combination sash hoods shall be in accordance with Section 230910.

1.3 REFERENCES

A. Definitions

1. Area Level Network: The network that allows communication between B-BC controllers, 3rd party controllers, and the owner's BAS server.
2. Field Level Network: The network that allows communication to/from B-AAC's, B-ASC's, and other field controllers to/from B-BC controllers.
3. Terminal equipment controller: A controller associated with a specific piece of equipment (e.g. VAV box, fan coil unit, cabinet unit, etc.)

B. Abbreviations and Acronyms

1. ALN: Area Level Network
2. BMS: Building Management System
3. BTL: BACnet Testing Labs http://www.bacnetinternational.net/btl/
4. B-AAC: BACnet Advanced Application Controller
5. B-ASC: BACnet Application Specific Controller
6. B-AWS: BACnet Advanced Workstation
7. B-OD: BACnet Operators Device
8. B-BC: BACnet Building Controller
9. B-SA: BACnet Smart Actuator
10. B-SS: BACnet Smart Sensor
11. BBMD: BACnet Broadcast Management Device
12. BDT: BACnet Distribution Table
13. CAV: Constant Air Volume
14. DDC: Direct Digital Control
15. FCU: Fan Coil Unit
16. FLN: Field Level Network
17. MSCC: Mechanical Systems Controls Contractor
18. VAV: Variable Air Volume

1.4 SUBMITTALS

A. Submittals shall, as a minimum, consist of the following:

1. Schematic diagrams of all systems being controlled and/or monitored indicating all DDC points, point numbers (using UM conventions), sensors, relays, controllers, valves, dampers, complete control wiring schematics (including starter, VSD, DX system, etc. wiring diagrams), pneumatic tubing, DDC panel maps, etc.
2. HMI display graphic pages including each analog and digital point that will be displayed.
3. Wiring of each point to the DDC panels, including terminal block numbers.
4. Layout of all auxiliary devices and panels, and wiring of relays, contacts, etc. Include terminal block numbers at all control panels, at all mechanical equipment, and at all control devices.
5. Complete Sequence of Operation for each system being controlled, including set points, alarms settings, etc. in narrative format.
6. Pneumatic compressed air supply equipment, risers, and major tubing runs.

7. Complete bill of materials to identify and quantify all devices.
8. Product data including a description and complete engineering data for each control system component.
9. Layout and nomenclature for all nameplates.
10. Point nomenclature and controller addressing: All point and object names shall be named utilizing the UM standard naming convention. Obtain the naming convention and controller addresses from UM prior to providing submittals. This shall include all BACnet devices.
11. Network diagrams indicating network switches, routers, servers, and peripheral devices, including location of each device (room number), device name, address, instance number, approximate cable lengths, and indicating network connection points to Owner's BAS and/or Utility Meter data acquisition system. Provide separate diagrams for the building network and terminal device network.
12. Wiring diagrams and locations of power supplies.
13. Additional submittal items required for any room designated as a lab:
    a. Equipment schedule for each room or zone, with the following information:
        1) Equipment tag, room served, occupied/unoccupied min., max., offset CFM, network address, and network and power trunk identifier.
        2) Model number of each control component.
        3) Function of each terminal device and control component.
14. Resume of any personnel proposed to work on University of Michigan’s building automation server.

B. Submit, as a minimum, the following design data schedules indicating:

1. Airflow Measuring Probes:
    a. Device tag.
    b. Equipment served/function.
    c. Model number.
    d. Size, type, and location.
    e. Station area in square feet.
    f. Max/Min Range.
    g. Magnehelic scale range.
    h. Velocity pressure range.
2. Air and water pressure sensors:
    a. Device tag.
    b. Equipment served/function.
    c. Model number.
    d. Size, type, and location.
    e. Max/Min Range.
3. Control Dampers:
    a. Damper tag.
    b. Equipment served/function.
    c. Model number.
    d. Blade configuration and orientation.
    e. Size in width, height, and blade width.
    f. Pressure drop.
    g. Type of seals (blade and edge).
    h. Normal position.
    i. Size, quantity, type, and model number of actuators.

Method of actuator mounting and actuation.

4. Control Valves:
   a. Valve tag.
   b. Equipment served/function.
   c. Valve flow rate (GPM).
   d. Line size.
   e. Specified valve pressure drop (ft. head).
   f. Valve size.
   g. Valve Cv.
   h. Actual valve pressure drop (ft. head).
   i. Valve normal position.
   j. Valve spring range.
   k. Valve shut-off rating (ft. head).
   l. Valve body pressure/temperature rating.
   m. Valve type/model number.
   n. Actuator type/model number.
5. Terminal Equipment Devices:
   a. Device tag.
   b. Equipment served/function.
   c. Model number and application code.
   d. Associated sensor location/tag.
   e. Size, control values, etc.

C. Submittal Submission Requirements

1. In compliance with the submittal distribution plan for the project, submit an additional copy of the submittals to the Operations & Maintenance Engineering department.
2. Submittals shall be provided in a searchable PDF (OCR) format.
3. Submittals shall include a complete table of contents indicating every piece of equipment included under each tab.
4. A paper and electronic copy shall be submitted to the UM DDC shop and Cx Agent after the submittal is approved.
   a. Provide updated sections or pages in paper and electronic format to reflect construction changes or field changes as they occur.
5. Control drawings shall be minimum 11" x 17" size.
6. The submittal shall be organized into bookmarked/tabbed sections consisting of (at minimum) the following categories:
   a. Control Drawing tabbed sections:
      1) Network Diagrams
      2) Schedules: Control Valves, Control Dampers/Actuators, Liquid Flow Meters, Air Flow Meters, Terminal Units, Lab Terminal Units
      3) A section shall be provided for each temperature control panel indicating all equipment associated with that panel. All of the following shall be included in this tab:
         a) Equipment control diagrams
         b) Project specific wiring diagrams of controlled or alarmed equipment
         c) Aux. & LPI panel layout and wiring diagrams
         d) DDC panel layout diagrams

      4) A separate section for terminal equipment controllers.

b. Product Data tabbed sections: Temperature Devices, Humidity Devices, Pressure Devices, Hydronic Flowmeters, Airflow Meters, Auxiliary Panel Devices, Pneumatic Components, Electric Components, Miscellaneous Components

7. For the paper version, each section shall consist of tabbed divider sheets indexed to a table of contents.
8. For the electronic version, each tabbed section shall be bookmarked.
9. Since many items are interrelated and should be checked concurrently, all of the MSCC's submittal drawings and product data sheets shall be submitted at one time. No consideration will be given to partial submittals, except valves, flowmeters and damper submittals on approval only. Any partial submittals must be included in the complete submittal package.

D. Project Record Documents and Operation and Maintenance Manuals

1. Provide the specified number of paper copies of complete operation and maintenance instructions for all system components furnished. Additionally provide a final electronic copy of the above in two formats: Microstation or AutoCAD compatible format and searchable PDF (OCR) format.
2. Include as-built system schematic drawings and wiring diagrams.
3. Include updated network diagram including final locations of power supplies and end of line resistors.
4. Include updated terminal device schedule indicating final device name, address and power trunk designation. Update terminal device schedule to indicate the order in which they are connected on the communication trunk.
5. Indicate final set points, settings, and adjustments of all components.
6. Provide factory calibration certificates for steam and water flowmeters, differential pressure hydronic sensors, differential pressure transmitters used for laboratory control, "matched" temperature transmitters, and any other factory calibrated device.
7. Include project specific catalog cuts and data sheets indicating installation, operation, maintenance, repair, wiring diagrams, calibration, calibration tolerances, inspection period, cleaning methods and cleaning materials for all components. The O&M manual shall be organized in a manner similar to the product submittal package.

REVISE ARTICLE 1.5 AS REQUIRED FOR THE SPECIFIC PROJECT

1.5 MAINTENANCE MATERIAL SUBMITTALS

A. Spare Parts/Extra Stock Materials

B. Tools

C. Software and Licensing

1.6 QUALITY ASSURANCE

A. Manufacturers and Products: The products and manufacturers specified in this Section establish the standard of quality for the Work. Subject to compliance with all requirements, provide specified products from the manufacturers named in Part 2.

1. Where not indicated in Part 2, all devices shall be as manufactured by Honeywell, Johnson Controls or Siemens.

B. Reference Standards: Products in this section shall be built, tested, and installed in compliance with the specified quality assurance standards; latest editions, unless noted otherwise.

1. Underwriters Laboratory or Intertek (ETL) (listed and labeled).
2. National Electric Manufacturer's Association (standards pertaining to components and devices for electrical control systems)
3. National Fire Protection Associate NFPA 90A "Standard for the Installation of Air Conditioning and Ventilating Systems"
4. National Electrical Code NFPA 70.
5. ASHRAE Standard 135 BACnet - A Data Communication Protocol for Building Automation and Control Networks
6. UL Compliance: DDC Controllers for this project shall comply with UL916 Standard for Energy Management Equipment. DDC Controllers associated with equipment utilized in a smoke control application shall also comply with UUKL-UL 864 "Standard for Control Units and Accessories for Fire Alarm Systems".
7. National Institute of Standards and Technology (NIST), NIST IR 6392 Annex B: Profiles of Standard BACnet Devices.
8. Electronics Industries Association (EIA)
   a. EIA-232: Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange
   b. EIA-485: Standard for Electrical Characteristics of Generator and Receivers for Use in Balanced Digital MultiPoint System

1.7 DELIVERY, STORAGE AND HANDLING

A. Store materials and equipment raised off the floor on pallets and protected with coverings to prevent damage due to weather and construction activities. Store in areas that prevent damage due to freezing and extreme temperatures or sunlight. Arrange coverings to provide air circulation to avoid damage from condensation or chemical build-up. Protect from damage, dirt and debris at all times.

B. Shipping and storage protection shall be provided by manufacturer to insure that the interior and exterior of components are completely protected from damage, dirt or weather. Components shall be continuously covered with plastic or other durable means, until just prior to installation. Maintain protection after installation to protect against ongoing construction activities.

1.8 SCOPE OF WORK

A. The complete control system work shall be split between the Mechanical Systems Controls Contractor and the University of Michigan as outlined below. As it relates to the extent of responsibility for work within this specification section, "provide" shall mean the identified party both furnishes and installs such item(s). "Furnish" shall mean the identified party furnishes the item for installation by others.

B. Summary of work by the Mechanical Systems Controls Contractor- shall include, but not be limited to:

1. Temperature control system consisting of all pneumatic and Direct Digital Controls (DDC) sensors, transducers, relays, switches, data communication network, etc. and all associated control wiring and conduit systems.
2. Laboratory control systems except in rooms with VAV hoods or combination sash fume hoods. (Programming and some components provided by UM. Refer to section "DDC related work by the University of Michigan").
3. Provide fume hood monitors except in rooms with VAV hoods or combination sash fume hoods.
4. Install UM furnished devices for terminal equipment.

EDITOR: DRAWINGS SHOULD INDICATE LOCATION AND TYPE OF COMMUNICATION CONNECTION SHOWING NECESSARY CONDUIT TO THAT LOCATION (NEAREST DDC PANEL FOR EXISTING BUILDINGS OR NEAREST DATA CLOSET FOR NEW BUILDINGS).

5. Connection of new DDC panels to permit communication to the owner's Building Automation System (BAS). Connection to host computer via trunk connection to an existing DDC panel, data closet, or local Ethernet data port as indicated on the drawings. Where not indicated on the drawings, provide a proposed network design for review and approval by the owner.
6. Engineering, submittals, as-built drawings, and operation and maintenance manuals.
7. Provide an auxiliary temperature control panel adjacent to each DDC panel. Provide additional auxiliary panels as required to house the required quantity of control components. Provide all wiring between the DDC panel and the auxiliary panel(s).
8. Provide a Loop-Powered Indicator (LPI) panel adjacent to the auxiliary panel. Provide additional LPI panels as required to house the required quantity of LPIs. Provide all wiring between the DDC panel and the LPI panel(s).
9. When loop powered indicators are not shown on control diagrams, provide a Human Machine Interface (HMI)at each DDC panel array. Provide all wiring and accessories required to enable the HMI to function as specified.
10. For existing panels, punch the LPI panel doors.
11. Provide free standing unistrut racks to support all DDC panels and equipment. Mount all panels.
12. Assembly of DDC panel circuit boards, associated I/O modules, and communication hardware into U-M furnished DDC and UPS panel enclosures. Provide all interconnecting power wiring between the DDC panel power supply and the UPS panel duplex receptacle.
13. Provide a minimum 8"x 8" wiring trough extending over and between each DDC, auxiliary temperature control, and LPI panel.
14. Provide thermostats, control valves, dampers, operators, meters, control air tubing, etc.

15. Provide gauges, indicating devices, electric and electronic control accessories, and other control system devices.
16. Except where indicated otherwise under "DDC related work by the University of Michigan", provide setup/programming, calibration and start-up services of control systems, e.g. electronic room temperature controllers. This shall include all programming required to network back to owner's BAS.
17. Termination of all wires and pneumatic lines within the DDC panel, auxiliary panel and LPI panel, including the power supply.
18. Termination of all field wiring including but not limited to: sensors, actuators, H/O/A switches, hard-wired safeties, relays, terminal equipment controllers, network wiring, etc.
19. For U-M Utility's energy metering, install U-M furnished data acquisition panel. Provide wiring from meters and transmitters to utility data acquisition panels. Provide dedicated Ethernet communication wiring to utility data acquisition panels from local data closet. Terminations inside panels by U-M.
20. Provide site supervision of mechanical control work and coordination with related electrical and fire alarm work and packaged controls.
21. Provide all control wiring and electrical components necessary for each system to permit automatic or interlocked operation, such as: air cooled condensing units, high level alarm circuits, damper end switches, fuel oil pumping/monitoring systems, chiller control/interface panels, boiler control/interface panels, early break contacts on disconnects to VSD's, cooling tower vibration switches, etc.
22. All other work and components required for complete and operational control systems, and that allows the sequence of operation indicated on the drawings or elsewhere to be achieved, except work specified as provided or furnished by the University of Michigan.
23. Start-up, calibration, and checkout of sensors, transducers, thermostats, control valves, dampers/damper operators, meters, and all other components provided. Verify correct functionality of DDC points and inputs/outputs associated with terminal equipment controllers and correct all deficiencies.
24. Commission all mechanical controls provided. Provide a detailed list of every control point installed to the project Commissioning Authority (CxA), and verify proper operation of each component prior to commissioning the controls with the CxA. Include, in checklist format, a detailed procedure to verify all aspects of the controls' Sequence of Operation.
25. Training of U-M personnel to familiarize operations staff with the configuration, operation, and maintenance of provided controls.

C. DDC related work by the University of Michigan:

1. Point database entry.
2. Provide programming for DDC panels and terminal equipment controllers, excluding rooms with VAV fume hoods and hoods with combination sashes.
   a. Provide programming required to achieve the sequence of operation and the control intent indicated on the documents.
   b. Tune control loops.

c. Program the following alarms, whether specifically indicated in the sequence of operation or not. Include appropriate deadbands and time delays:
    1) For every indicated setpoint, create a variation from setpoint alarm. Examples include air handler discharge temperature, chilled water temperature, end-of-line DP, etc.
    2) Status does not match command.
    3) Failed point.
    4) Exception: Unless specifically indicated, alarms are not required for terminal equipment controllers controlling space temperature.
d. Programming lines shall be grouped into subparts and explained with comment fields. The comment fields shall include the related part of the project sequence of operation that each program subpart is intended to accomplish. All unused program lines or sections shall be deleted from the final program.

3. Provide temporary programming to provide building heating or cooling during construction.
4. Furnish all DDC panel circuit boards, associated I/O modules, and communication hardware.
5. Furnish DDC panel UPS.
6. Furnish proprietary Siemens control components per detailed list on control drawings except labs with VAV fume hoods or combination sash fume hoods.
7. Furnish all DDC panel enclosures and UPS enclosures.
8. Start-up and checkout of DDC panels.
9. Verify correct functionality of every DDC point associated with every DDC panel, and for every input and output associated with every TEC.
10. Commission DDC controllers and verify each sequence of operation with the project CxA.
11. Training of UM personnel on the various Sequences of Operation, the DDC panel and its connections, the LPI panel, the UPS panel, and terminal equipment controllers and their related components.
12. Configure all controllers to serve BACnet data to BACnet Clients installed on the network. Each controller shall be configured and programmed to map all the BACnet objects associated with the controller, as selected by UM BAS. Provide a list of all objects to UM BAS at least 2 weeks in advance of this work. UM BAS will return the list indicating the specific objects to be mapped. Configure the controllers to utilize a change of value subscription with the clients that reside on the IT network. Change of value increments shall be as selected by the UM BAS department and tuned to minimize IT network traffic.
13. Provide and participate in all sustainable design requirements, including but not limited to providing temporary control and operation of air handlers to achieve LEED IEQ Credit 3.2 building flush-out. Refer to specification section 018113 Sustainable Design Requirements
14. Program HMI display with graphics and point information. Submit for review and approval by owner.

15. Furnish data acquisition panels for metering of all utilities, including steam, condensate and BTU metering. Provide internal panel components including din rail, fuse, power terminal block, power supply, 24V terminal block, communication module, and read out modules. Terminate all input/output wiring and data connections to the panel. Start-up, configure and commission the panel.
16. Equipment schedules.
17. System Profile integration.
18. Generation of system graphics.
19. Provide remote notification alarms via email, text messages, etc. to U-M personnel.
20. Work with U-M IT department to obtain the required IP addresses.
21. For new panels, punch the LPI panel doors. MSCC must drop off and pick up doors from U-M's shop.
22. Selection of the appropriate size, type, and quantity of DDC controllers to be used.
23. Configure trends for every analog (30 minute trend interval) and digital(change of value) input to DDC panels. Configure room temperature (or the controlled variable) trends for every terminal equipment controller, at a 30 minute interval.

1.9 ITEMIZED QUOTATION

A. When requested, immediately provide an itemized bid breakdown to the Owner post bid, for review and approval. Include itemized material costs for all major components (along with model numbers), installation labor costs, subcontractor labor and itemized material cost, and engineering costs, for base bid and for each alternate, for the entire work scope of the Mechanical Systems Controls.

EDITOR: CONTACT THE UM DESIGN MANAGER TO DETERMINE WHICH OF THE BELOW CONTROLS INSTALLATION CONTRACTORS ARE TO BE LISTED AS ACCEPTABLE FOR YOUR SPECIFIC PROJECT.

1.10 ACCEPTABLE MECHANICAL SYSTEMS CONTROLS CONTRACTORS

A. The following MSCCs are acceptable for the furnishing and installation of pneumatic, electric and DDC components as specified in this section:

1. Siemens Building Technologies
2. Johnson Controls, Inc.
3. Fontanesi & Kann Company

1.11 COORDINATION

A. Provide controls and control wiring compatible with equipment provided by others and with existing equipment and controls.

B. Coordinate the installation of controls with the installation of other project equipment.

C. Coordinate with laboratory equipment suppliers (constant flow fume hoods, etc.) regarding dimensions and mounting location for alarm monitors and assure proper accommodation is made for the installation of other devices related to laboratory airflow controls.

D. Coordinate panel locations, space requirements, and other control device locations during the development of the Project Coordination Drawings.

1.12 WARRANTY

A. Provide a complete warranty for parts and labor for a minimum of one year from the date of Substantial Completion.

PART 2 - PRODUCTS

2.1 GENERAL

A. DDC panels, including field and zone controllers/panels and all related software shall be the Siemens Apogee Building Automation System.

B. Provide components compatible with new and existing DDC controller I/O modules, and with equipment provided by others. The MSCC shall become familiar with the DDC system's requirements, limitations, and characteristics.

C. Any parts not described within this specification shall be submitted as an "Owner's Options/Voluntary Alternates" on the bid form, in accordance with the alternate product requirements contained in the Instructions to Bidders. UM reserves the right to reject any part not pre-approved which could result in bid disqualification.

2.2 GENERAL DDC CONTROL ARCHITECTURE

A. All control points indicated on the documents shall be directly connected to primary DDC panels as current or voltage signals, not via the communication network, unless specifically shown otherwise.

B. The Area Level Network shall be a BACnet/IP Ethernet network and the Field Level Network shall be a BACnet MS/TP unless shown otherwise on the documents. The FLN shall utilize the Master-Slave/Token-Passing (MS/TP) protocol, as acknowledged by the ANSI/ASHRAE 135 standard. This secondary network shall be provided and installed by the MSCC. Proprietary RS-485 or equivalent links will not be considered unless otherwise noted. The MS/TP link shall operate at a 38.4 Kbps minimum. Repeaters shall not be used in any instance.

C. BACnet Broadcast Management shall be facilitated by one B-BC per IP Subnet and incorporate a BACnet Distribution Table, provided by U-M BAS dept. B-BC's that handle BBMD's and I/O functionality shall be properly sized to handle memory & processing requirements.

D. Terminal units (VAV, FCU, etc) shall be connected directly to primary field panels. Use of a BacNet MS/TP to IP router is not acceptable.

E. System architectural design shall eliminate dependence upon any single device for control execution. Each DDC controller shall operate independently by performing its own specified control, 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. Data collection that requires a single mechanism for user notification or viewing is strictly prohibited.

F. All controllers within a building shall be able to access any data from, or send control commands directly to, any other DDC controller or combination of controllers in the same building without dependence upon a central processing device (peer-to-peer).

SPEC EDITOR'S NOTE: THE TYPE OF DDC CONTROLLER REQUIRED FOR EACH APPLICATION MUST BE IDENTIFIED ON THE PROJECT DOCUMENTS. CONSULT UM O&M ENGINEERING FOR MODEL NUMBERS.

2.3 GENERAL DDC CONTROLLER REQUIREMENTS

A. Stand-alone microprocessor board with ROM and fully custom programmable RAM, EPROM, and/or EEPROM memory, integral interface equipment and power surge protection. DDC controllers shall be connected directly to sensors, controlled devices and the communication network.

B. All DDC controllers shall use the latest version of ANSI/ASHRAE Standard 135 BACnet standard for communications, have passed BTL certification as available and be listed as compliant with UL916 Standard for Energy Management Equipment. DDC controllers used in smoke control applications must also be listed as compliant with UL864 Standard for Control Units and Accessories for Fire Alarm Systems.

C. Controllers shall be listed by BACnet Testing Laboratories (BTL) as conforming to the required standard device profile and support all of the minimum required BACnet Interoperability Building Blocks (BIBBs) associated with this device profile.

D. The "Present_Value" property of all analog output and binary output objects shall be writable so that Systems Monitoring personnel have the capability to override all system outputs from the central BMS server(s).

E. Each DDC controller shall support firmware upgrades without the need to change hardware.

F. 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 for any system.

G. DDC controller types shall be one of three types, a BACnet Building Controller (B-BC), a BACnet Advanced Application Specific Controller (B-AAC) or a BACnet Application Specific Controllers (B-ASC).

1. Building Controllers (B-BC) shall be used for all major mechanical equipment and/or systems (i.e. chilled water, heating hot water, large AHU's, etc.).
2. Advanced Application Specific Controllers (B-AAC) shall be used, as an extension of a B-BC's performance & capacity, for control of all medium and small mechanical systems and/or terminal equipment.
3. Application Specific Controllers (B-ASC) shall only be used for the terminal equipment indicated under the B-ASC section of this specification.

H. Any controller supplied under this specification must provide all integration functionality required to meet the sequence of operation and to communicate with the owner's building automation system.

I. BACnet Building Controller (B-BC):

1. Provide controllers conforming to the latest version of ANSI/ ASHRAE 135 BACnet Building Controller (B-BC) standard device profile and support all of the minimum required BACnet Interoperability Building Blocks (BIBBs) associated with this device profile.
2. Controllers shall support Internet Protocol (IP) for communications to other BC's and the BMS front-end and MS/TP communication to B-AAC's and B-ASC's.
3. Controllers shall have a minimum 64 bit processor with an EEPROM, flash driven operating system. They shall be multitasking, multi-user, real-time digital control processors and permit I/O expansion for control / monitoring. Controller size shall be sufficient to fully meet the requirements of the project documents. Controllers shall be fully programmable while supporting standard energy management functions, including but not limited to:
   a. Alarm detection and reporting
   b. Automatic Daylight Saving Time switchover
   c. Calendar-based scheduling
   d. Closed loop PID control
   e. Duty cycling
   f. Economizer control
   g. Equipment scheduling, optimization and sequencing
   h. Event scheduling
   i. Historical trend collection
   j. Holiday scheduling
   k. Logical programming
   l. Reset schedules
   m. Night setback control
   n. Peak Demand Limiting (PDL)
   o. Start-Stop Time Optimization (SSTO)
   p. Temperature-compensated duty cycling
   q. Temporary schedule override
4. Provide controller with integral power switch. If an integral switch is not provided by the manufacturer, the MSCC shall provide a separate dedicated transformer and switch within each enclosure for each controller present.
5. 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.
6. Controllers shall provide local LED status indication for power, communications, status and each digital output for constant, up-to-date verification of all point conditions without the need for an operator I/O device.
7. Controller shall utilize optically isolated digital outputs.

8. All points associated with a given mechanical system (e.g., an air handling unit) will be controlled from a single Building Controller or point expansion panel(s) from the respective master. All expansion modules shall be located in the building controller enclosure or an attached enclosure. 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. Multiple mechanical systems shall be allowed on a single controller. 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.
9. A variety of historical data collection utilities shall be provided for manual or automatic sampling, storing and displaying system point data.
    a. Building Controllers shall store point history data for selected analog and digital inputs and outputs.
10. 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. Provide capability to view or print trend and tuning reports.
    1) Loop tuning shall be capable of being initiated either locally at the Building Controller or from a network workstation. For all loop tuning functions, access shall be limited to authorized personnel through password protection.
11. Provide controller with battery backup capable of maintaining SDRAM memory for a minimum of 30 days.
12. Provide controllers that, upon full system power recovery, all clocks shall be automatically synchronized, and all controlled equipment shall be automatically re-started based on correct clock time and sequence of operation.
13. For expansion purposes, provide enough space and extend rail(s) within each control panel to allow the addition of (1) future I/O module per DIN rail.
14. Controllers shall provide at least one data communication port for operation of operator I/O devices such as portable laptop operator's terminals. Controllers shall allow temporary use of portable devices without interrupting the normal operation of permanently connected printers or terminals. A USB port shall alternatively be available to support local HMI tools connection.

J. BACnet Advanced Application Specific Controller (B-AAC):

1. Provide where indicated on project documents, or when required by application when approved by owner.
2. Provide controllers conforming to the latest version of ANSI/ASHRAE 135 BACnet Advanced Application Specific Controller (B-AAC) standard device profile and support all of the minimum required BACnet Interoperability Building Blocks (BIBBs) associated with this device profile.
3. Controllers shall support MS/TP communication to B-BC’s and other B-AAC’s and B-ASC’s.
4. Controller shall be a microprocessor-based, 32 bit, multi-tasking, real-time digital control processor capable of stand-alone operation.

a. If the hardware point requirements of any system should exceed the I/O configuration of available B-AAC offerings then a B-BC must be used. Control of one piece of mechanical equipment may not be performed by more than one controller.

5. Provide each controller with sufficient memory to accommodate point databases and operating programs. All databases and programs shall be stored in non-volatile EEPROM. The controllers shall be able to return to full normal operation without user intervention after a power failure of unlimited duration.
6. Controllers must be fully programmable. All programs shall be field-customized to meet the user's exact control strategy requirements.
7. All points used for a single mechanical system shall be connected to the same B-AAC.
8. Controller shall utilize optically isolated digital outputs.
9. Analog outputs shall be 24V floating control, 0-10VDC, or 4-20mA as required by the device being modulated.
10. Each controller shall perform its primary control function independent of other DDC controller communications, or if communication is interrupted. Reversion to a fail-safe mode of operation during network interruption is not acceptable. Controller shall receive its real-time data from the Building Controller time clock to insure network continuity.
11. 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 operator terminals.
12. Controllers shall provide diagnostic LEDs for power, communications and processor status. The controller shall continually check the status of its processor and memory circuits.
13. The B-AAC providing control of a system shall have all associated points connected directly to it unless approved otherwise.

K. BACnet Application Specific Controller B-ASC (Also referred to as Terminal Equipment Controller-"TEC") and related room temperature sensor (RTS)

1. Only for use with air terminal units (VAV boxes, CAV boxes, dual-duct mixing boxes), or where indicated. Provide B-AAC controllers when required by application.
2. Controllers:
   a. Provide electronic damper operators compatible with the controller and the air terminal units provided. Actuator shall utilize a brushless DC operator, min 35 in-lbs of torque, floating control (unless noted otherwise).
   b. Controllers shall have an internal differential pressure transducer(s) capable of utilizing the total and static pressure signals from the air terminal unit's velocity sensor. The differential pressure transmitter maximum error shall be 5% of reading, not to exceed a velocity pressure error of 0.023" w.c., for the flow range 0-5600 fpm. Associated velocity sensor shall be furnished by air terminal unit manufacturer.
   c. Each controller shall have electronic outputs compatible with the electronically operated air terminal unit tempering coil control valve and perimeter radiation control valve where applicable.

d. Provide a discharge air sensor, mounted on the discharge of the terminal box reheat coil and/ or the outlet of dual duct mixing boxes, interfaced with the controller.
e. Where a pressure offset is described on the drawings, or when a damper based auto-calibration routine adversely affects control, utilize an auto-zero auxiliary device to temporarily disengage the differential pressure sensor from the air velocity sensor. This shall function so that a 0 cfm air volume reading is forced without changing the damper position to prevent negatively affecting room pressurization.

3. RTS shall have a digital temperature display, set point button, and override button. Sensor shall be thermistor type, 55°F-95°F range, +/-0.18°F resolution and capable of being field calibrated. Provide sensor with auxiliary communications port to allow remote connection to VAV controller(s) with a laptop computer, to facilitate configuration and commissioning of controllers.
   a. Zone Sensors shall not be located on perimeter walls. Where explicitly indicated on drawings to do so and/or in locations near exterior walls and/or subject to drafts, sensors shall have insulated mounting bases to prevent false room temperature readings.

4. Provide all other devices except those indicated as furnished by the equipment manufacturer. Install equipment manufacturer provided devices when not pre-installed. The MSCC shall coordinate devices furnished by others and provide all devices not furnished by them to provide a complete operating system that achieves the sequence of operation requirements.
5. The MSCC may send TECs to the equipment manufacturer for factory mounting, or may field mount TECs. All mounting costs are the responsibility of the MSCC.
6. TECs shall be provided with metal enclosure, complete with conduit knockouts (enclosure provided by MSCC).
7. Connect TECs to the Siemens DDC control panel controller FLN of the AHU or system being served.
8. Power to TECs and associated controlled devices shall be 24 VAC, provided by the MSCC.
9. Approved Manufacturers:
   a. Siemens

L. HUMAN MACHINE INTERFACE panel(HMI)- (color touchscreen panel)

1. 15” LCD, glass front, industrial color touchscreen. Custom configured to provide a graphic matching the control diagram in the construction drawings for each piece of equipment or system controlled by a building controller (B-BC). HMI shall display all analog and digital points. Standard default view shall be a read only display.
2. HMI shall connect to the BACnet MS/TP network at the DDC controller as well as to the campus ethernet for management and configuration of the device. Route ethernet cable to data closet if local switch is unavailable.
3. HMI shall at a minimum satisfy BACnet Operator Device (OD) functionality as a local MS/TP device.
4. HMI shall be suitable for operation in un-conditioned equipment room (32°F-122°F, 30%-90%RH).

5. Mount the HMI through the Auxiliary (Aux.) temperature control panel face, utilizing mounting bolts, with its center-line a nominal 60" A.F.F. Provide an additional Aux. panel for the HMI when insufficient room exists in the main Aux. panel.
6. Approved Manufacturers:
   a. Loytec LVIS-3ME15-G2 with mounting frame

SPECIFICATION EDITOR: SYSTEMS (AHU'S CHILLER, ETC) THAT ARE FED FROM EMERGENCY POWER SOURCES SHALL HAVE THEIR ASSOCIATED DDC CONTROLLERS AND DDC DEVICES FED FROM THE SAME EMERGENCY POWER SOURCE. A/E TO INDICATE PROPER CIRCUITS ON DOCUMENTS.

M. Controller Power Supplies:

SPECIFICATION EDITOR: THE AE SHALL CLEARLY INDICATE SOURCE OF POWER FOR ALL DDC CONTROLS. POWER SOURCE (NORMAL VS EMERGENCY) & PRIORITY SHALL MEET OR EXCEED THAT OF THE EQUIPMENT BEING CONTROLLED.

1. Power supplies shall be provided by the MSCC. Power source (i.e. normal vs. emergency power & emergency power priority) shall match that of the equipment and/ or system being controlled.
2. Provide each DDC panel with a line filter, surge suppressor, electrical disconnect, control fuse or circuit breaker, and control transformer. All sized and provided by the MSCC.
3. Within control enclosures provide insulated, modular, feed-through, clamp-style terminal blocks suitable for rail-mounting with end plates and partitions for the termination of all field wiring in control enclosures. Wire nut connectors or similar devices shall not be used.

2.4 NETWORK SWITCHES

A. Provide network switches with 120V plug-in power supply. Switches shall be sized for the number of connected devices + 1 extra port for service access.

1. 5 port switch – NETGEAR model FS105
2. 8 port switch – NETGEAR model GS108E
3. 16 port switch – NETGEAR model GS116E

B. Network switches shall not be powered from the 24VAC terminal unit power supplies unless approved by Owner.

IMPORTANT: DESIGNER SHALL CLEARLY DELINEATE ON THE PROJECT DRAWINGS WHICH SPACES ARE LABORATORIES.

2.5 LABORATORY CONTROLS

A. Provide laboratory controls for any space designated as a laboratory and where indicated, except for rooms with VAV fume hoods and hoods with combination sashes. System shall include: temperature, pressure, and other sensors/transmitters; control valves; control, network, and power wiring; power supplies; routers, servers, and all other devices required for a complete system.

1. The system shall utilize conventional terminal air flow units for supply and general room exhaust and venturi style terminal air flow units for constant volume fume hoods and any other constant volume exhaust point. Refer to related section 233600.
2. Provide programming of all laboratory controls.
3. The system shall function to achieve the sequences of operation detailed on the drawings.
4. Each room or zone shall have a dedicated control system. Systems shall be independent and stand-alone from the Owner's BAS. Failures of the BAS system or network communications between the BAS and the system (cut communication cables, router or server failures, etc.) shall have no impact on individual laboratory control.
5. The system shall perform the following control functions:
    a. Pressurization Control: Control supply and auxiliary/general exhaust at a volumetric offset to maintain lab pressurization (positive, negative, or neutral). Controller shall maintain a constant offset (adjustable) between the sum of the room's total exhaust and the make-up/supply air volumes. This offset shall represent the volume of air that will transfer to or from the corridor or other adjacent rooms. Pressurization control shall consider networked devices, non-networked devices, and any number of constant volume devices.
    b. Lab Temperature Control: Regulate lab space temperature through a combination of supply air volumetric control and control of reheat coils and other auxiliary temperature control devices, in response to temperature sensor(s).
    c. Occupancy Control: Reset minimum volume settings and/or temperature control set points, based upon external signals from occupancy detectors, local over-ride buttons, and similar devices.
    d. Constant volume fume hoods and other constant volume exhaust points (excluding general room exhaust): The self-actuated Constant Volume Venturi (CVV) Terminal Airflow Unit shall maintain a constant airflow set point.
    e. Fume Hood Monitoring: Alarm unsafe condition at each fume hood.
    f. Each lab room shall include a labeled Room Differential Pressure Indicating Gauge to indicate room pressurization relative to the adjacent room or corridor. Provide an engraved POS/NEG label (with 3/8” high lettering) adjacent to the gauge labeled “Correct Room Pressure Offset: X, where X = “POS” (positive) or “NEG” (negative) as indicated by the room volumetric offset indicated on the design documents.
    g. Other control functions as indicated on the drawings.
    h. Interface with the Owner’s Siemens Apogee Building Automation System.

CONSIDER IF OTHER LABORATORY EQUIPMENT WOULD BENEFIT FROM BEING EQUIPPED WITH A FUME HOOD MONITOR AND INDICATE THAT EQUIPMENT ACCORDINGLY. EXAMPLES: EXISTING FUME HOODS, BIO-SAFETY CABINETS.

B. All conventional terminal units used for laboratory controls shall utilize the following. Provide B-BC or B-AAC type controllers, as required for the application.

1. For laboratories utilizing B-BC type controllers, provide the following:
    a. Controller (in addition to the B-BC requirements elsewhere in this specification):
        1) Supports wall switch or contact closure to change between occupied and unoccupied mode.
        2) Input and output types and quantities suitable for the application.
    b. Differential Pressure Transmitter:
        1) +/- 0.25% of full scale reading, drift not to exceed 0.1% of full scale per year, range not to exceed 1.5 times the velocity pressure at the terminal unit's maximum cataloged flow rate. 4-20mA output.
        2) Factory calibrated. Provide factory calibration certificate.
        3) Mounting on terminal unit to match factory calibration mounting orientation.
        4) Approved Mfr./Model: Setra C267
2. For laboratories utilizing B-AAC type controllers:
    a. Controller (in addition to the B-AAC requirements elsewhere in this specification):
        1) Controller specifically designed for high accuracy lab pressure control.
        2) Air flow sensor read 5 times per second.
        3) Supports wall switch or contact closure to change between occupied and unoccupied mode.
        4) Input and output types and quantities suitable for the application. Minimum two air velocity sensor inputs.
    b. Differential Pressure Transmitter:
        1) "Off Board" style differential pressure transmitter, maximum error 3.5% of reading not to exceed a velocity pressure error of 0.023" w.c., for the flow range 0-5600 fpm.
        2) With automatic calibration feature allowing periodic recalibration of airflow measurement without impacting room pressurization during the calibration routine. Auto-calibration shall occur on start-up and at an adjustable frequency selectable for 1 to 6 times per day.
        3) Approved mfr.: Siemens

C. Provide fume hood monitors for constant volume fume hoods and for other laboratory equipment where indicated.

1. Monitor shall include audible alarm, visual LED alarm, and a common (single) alarm silence button.
2. The fume hood monitor shall provide an alarm indication for the following conditions:
    a. Low fume hood face velocity as detected by:
        1) Insufficient differential static pressure as detected by the TAU- CVV pressure switch (Phoenix CVV Terminal Air Flow Units).
        2) Insufficient air volume, as detected by the air flow station (Siemens CVV Terminal Air Flow Units).
        3) Sash raised above sash stop position.

b. When an alarm condition is detected, audible and visual alarm indicators shall activate. Pushing the alarm silence button shall mute the alarm for an adjustable time delay, initially set at 10 minutes. Alarm shall re-sound after the time delay, until alarm condition clears. Visual alarm shall remain lit until alarm conditions clears.

3. Sash position shall be sensed by using a vertical sash position sensor. The vertical sash sensor shall consist of a precision 10-turn potentiometer mechanically coupled to a constant tension spring reel. Resolution shall be +/- 1/2 inch or better. A stainless steel, burr and snag-free cable shall be attached to the spring reel. Expected lifetime based on manufacturer's tests shall be over 200,000 full height sash movements. Sash sensor shall be installed in a location on the fume hood easily accessible for service.
4. Fume hood monitor shall be suitable for surface mounting on the front of the fume hood.
5. Approved fume hood monitors:
   a. Phoenix FHM530 Controller (Provide for Phoenix CVV Terminal Air Flow Units)
   b. Siemens (Provide for Siemens CVV Terminal Air Flow Units)

BELOW PARAGRAPH INDICATES THAT POWER SUPPLIES SHOULD BE INSTALLED ABOVE DOORS TO LABS. DESIGNATE THE LOCATION OF THIS EQUIPMENT ON THE DRAWINGS. WORK WITH ELECTRICAL ENGINEER TO DESIGNATE THE RECEPTACLE PANEL CIRCUITS TO FEED LAB CONTROL POWER SUPPLIES. DEPENDING ON LOAD, MULTIPLE POWER SUPPLIES MAY BE FED FROM A SINGLE 120 VAC CIRCUIT.

D. Install power supplies secured to a wall and mounted above the doors to labs, unless indicated otherwise. Utilize receptacle panel circuits designated for powering lab control power supplies.

E. Provide power supplies for lab airflow controls in NEMA 1 metal enclosures, adequately ventilated to prevent overheating of the equipment, with exterior labeled "Laboratory Airflow Controls Power Supply", and listing the room numbers served. If power supply is located above the ceiling or otherwise concealed, also provide an engraved label in an approved location visible without removing any building component. Maximum cabinet projection from wall shall be 8 inches. Label each secondary circuit inside the cabinet with the room number(s) served.

1. Control transformers shall be rated NEC Class 2 and shall meet all the requirements and recommendations of the laboratory airflow controls manufacturer.
2. No more than five pressurization zones shall be served from a single control transformer. No control transformer shall exceed 500 VA.
3. Each pressurization zone shall be powered by a dedicated (isolated) secondary circuit. Each secondary circuit shall include a disconnect switch, "power on" indicator, and be current limited with a slow blow fuse or circuit breaker.

F. Provide a disconnect switch, with shielded terminations, for line side power (one per control transformer). Locate inside the power supply enclosure.

2.6 TEMPERATURE TRANSMITTERS AND ACCESSORIES

A. Duct, Outside Air, Liquid Immersion:

1. Temperature sensor assemblies shall consist of a Resistive Temperature Device (RTD's) with a 4-20 mA 2-wire transmitter and gasketed utility box enclosure. Sensing element shall be platinum with 100 ohms resistance at 32 deg. F. Accuracy shall be +/- 1/2 deg. F over the entire range.
   a. Single point duct temperature sensor shall be rigid bulb type with stainless steel (SS) sheath, aluminum tip, and have a calibrated span of 20-120 deg. F or 30-250 deg. F for heating applications.
   b. Averaging element duct mounted temperature sensor shall have a SS minimum 25 ft. long continuous element sensor along the entire length, and have a calibrated span of 20-120 deg. F or 30-250 deg. F for heating applications. Provide sufficient sensor(s)/sensor lengths so that the elements are strung at 2 foot increments horizontally across the entire face of the coil. Provide additional sensors and wiring back to the DDC panel as needed to meet this requirement.
   c. Rigid averaging element duct mounted temperature sensor shall have a brass case, bendable sheath, continuous element sensor along the entire length, and have a calibrated span of 20-120 deg.
   d. Liquid immersion temperature sensors shall have a probe with SS well, and weather tight enclosure. Sensor well length shall be 1/3 of the pipe diameter, minimum 2.5 inches. Transmitters for chilled water shall have a calibrated span of 20-120 deg. F or 30-250 deg. F for heating applications.
   e. Only when specifically indicated, surface mount thermal-ribbon flexible sensor for pipe mounting shall have SS braid over lead wires, use pressure sensitive adhesive, must be properly insulated, and have a calibrated span of 30-250 deg. F.
   f. Room temperature sensors (non-TEC) shall have a span of 20-120 deg. F, locking covers, and when pneumatic, match the pneumatic thermostats used.
   g. Adjustable room temperature sensors (non-TEC) shall have a digital temperature display, high accuracy set point slide, flush mounted override button, and a temperature range of 55-95 deg. F.
   h. Approved Manufacturers:
      1) TCS
      2) Siemens
      3) Minco

B. High Precision Liquid Immersion: (for temperature inputs used for BTU calculations and where noted)

1. Temperature transmitter with 100 ohm platinum RTD sensor and 4-20 mA 2-wire DC output. Zero and span shall be continuously adjustable. Sensor and transmitter shall be a matched assembly. Accuracy shall be +/- 0.1% of calibrated transmitter span, including combined effects of repeatability, hysteresis and linearity. Calibrated range shall be 20 to 120 deg. F. Both CHWS and CHWR sensor/transmitter assemblies shall have the same span and shall be factory calibrated as a matched pair.
2. Liquid immersion sensors shall have welded stainless steel thermowell. Transmitters shall be of the potted type or shall have a thermally isolated watertight enclosure. Sensor well length shall be 1/3 of the pipe diameter, minimum 2.5 inches.
3. Approved Manufacturers:
   a. TCS
   b. Minco

2.7 HUMIDITY TRANSMITTERS AND ACCESSORIES

A. Room and Duct Type:

1. Sensor element shall be thin film capacitive type or bulk polymer resistance type, accuracy of +/- 2% RH, range of 0-100% RH with 4-20 mA 2-wire linear output. Factory calibrate for maximum accuracy at mid-range of normal operating humidity. All humidity sensors shall be resistant to chlorine and other cleaning agents.
2. Room Sensors shall have locking cover.
3. Duct Sensors shall have duct probe and mounting plate.
4. Approved Manufacturers:
   a. Siemens
   b. TCS
   c. General Eastern
   d. Vaisala

2.8 COMBINATION T & H TRANSMITTERS AND ACCESSORIES

A. Combination Room Temperature and Humidity Transmitter:

1. Single enclosure wall mounted room temperature and humidity sensor. Without display unless indicated otherwise on the contract documents. White casing/cover/fascia color. With service port to enable two-point calibration using either a PC or Vaisala HUMICAP Handheld Humidity and Temperature Meter HM70. Unit supply voltage 20-28 VDC.
2. Room temperature RTD shall be 100 ohm platinum sensor with 4-20 mA loop powered 2-wire output transmitter, 23-131°F temperature range, accuracy of +/- .54°F between 86-104°F.
3. Room humidity sensor shall have a 4-20 mA loop powered 2-wire output transmitter, humidity range of 0-90 percent RH, accuracy of +/- 1.7 percent RH at temperature range of 50-104°F, stability in typical HVAC applications of +/- 0.5 percent RH/year.
4. Provide with certificate of calibration.
5. Approved Manufacturers:
   a. Vaisala HMW92 Series

B. Outside Air Temperature and Humidity Transmitter:

1. Single point outside air temperature RTD shall be 1000-ohm thin film platinum resistor sensor with 4-20 mA 2-wire output transmitter with solar shield.
2. Outside air humidity sensor shall be thin film alumina substrate capacitance signal generating sensor with 4-20 mA 2-wire output transmitter with 0-100% relative humidity range within +/- 1% RH.
3. Approved Manufacturers:
   a. Vaisala

2.9 VIVARIUM TEMPERATURE AND HUMIDITY TRANSMITTERS AND ACCESSORIES

A. Vivarium Temperature and Humidity Transmitters for Wet Service:

1. Room temperature RTD shall be 100 ohm platinum sensor with 4-20 mA 2-wire output transmitter. Transmitter shall be waterproof or shall be remote mounted.
2. Room humidity sensor shall have a 4-20 mA 2-wire output transmitter, 0-100% relative humidity range, accuracy of +/- 2% RH, shall be waterproof, and shall be resistant to chlorine and other cleaning agents.
3. Combination T & H units shall comply with the above, but shall be mounted in a single enclosure.
4. All vivarium sensors shall have rust proof and waterproof covers and be protected by a stainless steel "U"-shaped guard firmly attached to the wall.
5. Approved Manufacturers:
   a. Vaisala (combination temp. and humidity)
   b. TCS (temp. only)
   c. Siemens(temp. only)

2.10 PRESSURE TRANSMITTERS AND ACCESSORIES

A. Air Differential Pressure Transmitter:

1. Variable capacitance type with ranges not exceeding 150% of maximum expected input. Transducer shall have zero and span adjustment. Output shall be 2-wire 4-20 mA with 24 VDC input.
2. Safe over pressure rating shall be minimum 5 times the range.
3. Temperature compensated with thermal error of not greater than 0.04% of full scale in temperature range of 40 to 100 deg. F.
4. Accuracy shall be 1% of full scale.
5. Approved Manufacturers:
   a. Air Monitor
   b. Setra
   c. Modus

B. Air Static Pressure Sensors- Duct, Area, Outside Air:

1. For use with Air Differential Pressure Transmitter
2. Duct mounted sensors shall be easily removable for cleaning, have multiple sensing ports, and fabricated of aluminum, copper, or SS. Sensors used in outdoor or condensing environments shall not be copper.
3. Wall or ceiling (area) mounted sensors shall be shielded, suitable for surface or flush mounting, complete with multiple sensing ports, contain a pressure impulse suppression chamber, and fabricated of aluminum, paintable steel, or SS as required.

4. Outside air mounted sensors shall be shielded, complete with multiple sensing ports, maintain sensing accuracy regardless of wind flow direction or pattern, and fabricated of aluminum or SS.
5. Accuracy shall be 1% of actual pressure value.
6. Provide a companion 4" Magnehelic gauge, mounted at auxiliary panel, of appropriate span for each sensor. Gauges shall be graduated in inches W.C. Provide a phenolic identification tag for each gauge.
7. Approved Manufacturers:
   a. Air Monitor
   b. Siemens
   c. Dwyer
   d. Honeywell

C. Airflow Sensors:

1. For use with Air Differential Pressure Transmitter
2. Provide where indicated amplified signal airflow traverse probe(s) or airflow stations, complete with straighteners when required, capable of continuously monitoring the fan or duct capacities (air volumes) it serves.
3. Each airflow array shall contain multiple total and static pressure sensors positioned at the center of equal and symmetrical cross-sectional areas, and interconnected by their respective averaging manifolds.
4. Sensors shall not protrude beyond the surface of the array, nor shall be adversely affected by particle contamination normally present in building airflow systems.
5. The airflow array shall be fabricated of galvanized steel or aluminum of adequate gauge to withstand the velocities to be encountered and with all required mounting brackets, plates, gaskets, and flanges.
6. Accuracy shall be a minimum of 3 percent of actual airflow over the designed range of flow.
7. Provide a companion 4" Magnehelic gauge, mounted at auxiliary panel, of appropriate span for each sensor array. Gauges shall be graduated in CFM for airflow measurement. Provide a phenolic identification tag for each gauge.
8. Approved Manufacturers:
   a. Air Monitor
   b. Tek-Aire
   c. Dietrich-Standard
   d. Ramsey Air

D. Steam/Liquid Differential Pressure Transmitters: (flow only)

1. Each differential pressure transmitter shall be selected and calibrated for operations between 0 and 125% of the normal differential pressure and up to 150-psig line pressure. The calibration point shall be rounded upward to the nearest 10 inches WC (for spans less than 200" WC) or to the nearest 5 psi for larger spans. Calibration date shall be included on an embossed tag attached to each transmitter.
2. The accuracy, including linearity, hysteresis and repeatability, of the transducer for measuring differential pressure shall be better than 0.25% of the span stated above throughout a minimum of a 6:1 turndown. Turndown ratio shall be based on the actual flow span.

3. The transmitter shall not be damaged by pressures of up to 500 psig on either side of the transducer and all wetted parts shall be inert in the presence of up to a 40% concentration of ethylene or polypropylene glycol in water.
4. Provide a drain valve for each side of the pressure chamber. Furnish and install mounting brackets appropriate for the installation location.
5. Span and zero shall be individually adjustable.
6. Shall be 2-wire and 4-20mA output.
7. Approved manufacturers:
    a. Tobar
    b. ITT Barton
    c. Dietrich - Standard
    d. ABB
    e. Siemens
    f. Rosemont/Fischer
    g. Honeywell

E. Steam/Liquid Differential Pressure Transmitters: (pressure only)

1. Each differential pressure transmitter shall be selected and calibrated for operations between 0 and 200% of the normal differential pressure. The calibration point shall be rounded upward to the nearest 10 inches WC (for spans less than 200" WC) or to the nearest 5 psi for larger spans. Calibration date shall be included on an embossed tag attached to each transducer. Adjust output signal span to 150% of the differential pressure setpoint determined by the water balancer or the maximum differential pressure expected at the point of measurement.
2. The accuracy, including linearity, hysteresis and repeatability, of the transmitter for measuring differential pressure shall be better than 2% of the span stated above throughout a minimum of a 4:1 turndown. Turndown ratio shall be based on the actual differential span.
3. The transmitter shall not be damaged by pressures of up to 500 psig on either side of the transducer and all wetted parts shall be inert in the presence of up to a 40% concentration of ethylene or polypropylene glycol in water.
4. Provide a drain valve for each side of the pressure chamber. Furnish and install mounting brackets appropriate for the installation location.
5. Span and zero shall be individually adjustable.
6. Shall be 2-wire and 4-20 mA output.
7. Approved manufacturers:
    a. Tobar
    b. ITT Barton
    c. Dietrich - Standard
    d. ABB
    e. Siemens

F. Steam/Liquid Pressure Transmitters: (pressure only)

1. The pressure transmitter shall be selected and calibrated for 150% of the normal operating pressure at the location of installation.

2. The accuracy, including linearity, hysteresis and repeatability, of the transmitter for measuring differential pressure shall be better than 2% of the span stated above throughout a minimum of a 10:1 turndown.
3. The transmitter shall not be damaged by pressures of up to twice its range. All wetted parts shall be inert in the presence of up to a 40% concentration of ethylene or polypropylene glycol in water.
4. Provide an isolation valve and pressure gauge on the inlet of each pressure transmitter.
5. Shall be 2-wire and 4-20 mA output.
6. Approved manufacturers:
   a. ABB
   b. Siemens
   c. Kele
   d. Setra
   e. Dwyer

G. Steam/Liquid Flow Sensors: (differential pressure type)

1. Uni-directional sensors shall be of the venturi type or velocity pressure type. They shall be constructed of stainless steel, sized to the system's range of flow, and have an accuracy of 0.5%.
2. Bi-directional sensors shall be of the velocity pressure type. They shall be constructed of stainless steel, sized to the system's range of flow, and have an accuracy of 0.5%.
3. Approved Manufacturers
   a. Preso
   b. Gerand
   c. Dietrich-Standard (Annubar Diamond II)

H. Three Valve Manifolds for Steam/Liquid Pressure Transmitter:

1. Provide a three-valve manifold for each transducer. Pressures of up to 500 psig shall not damage the manifold. All wetted parts shall be inert in the presence of up to a 40% concentration of ethylene or polypropylene glycol in water.
2. The manifold shall be designed for direct mounting on the transducer it serves and utilizes two quarter turn valves to provide zeroing, blocking and normal service modes.
3. Approved Manufacturers:
   a. D/A Manufacturing

EDITOR: CONTACT THE UTILITIES AND PLANT ENGINEERING DEPARTMENT VIA THE U-M DESIGN MANAGER FOR INSTRUCTIONS ON TYPE OF FLOW METER TO USE FOR STEAM, CONDENSATE, CHILLED WATER, AND HEATING HOT WATER.

2.11 METERS AND ACCESSORIES

A. Liquid Electro-Magnetic Flowmeters:

1. The meter system shall consist of a primary flow sensor and transmitter. The flow sensor shall be equipped with 150-lb. flanges. The meter system shall be installed with all necessary grounding components and gaskets per manufacturer's instructions. The meter shall be capable of bi-directional operation. The meter shall be sized appropriately for the range of flow for the system. The electrodes shall be SS or Hasteloy C. The transmitter shall be provided with a remote mounting bracket, cable, integral LCD display, NEMA 4X housing, shall indicate flow rate and totalized flow, shall have an isolated 2-wire 4-20 mA linear output flow rate signal, and shall have a pulsed output signal for totalization. The transmitter shall be capable of being field calibrated and reprogrammed from the outside housing via magnetic probe or security protected integral keypad menu switching. Unit electronics shall have noise immunity. The primary flow sensor and transmitter shall be mounted in accessible locations. Unit shall have the capability to maintain flow total in non-volatile memory. The flowmeter and transmitter as a unit shall have the following minimum characteristics:
    a. Flowmeter Liner:
        1) Heating hot water, domestic hot water, and other water systems operating at or above 110°F: Teflon
        2) Chilled water, domestic cold water, and other water systems operating below 110°F: Polyurethane
        3) Steam condensate: Teflon to 300°F, Ceramic over 300°F, and as suitable for the expected fluid conditions.
    b. Accuracy:
        1) At 1 to 33 feet per second velocity: ±0.5% of rate.
        2) At 0.3 feet per second velocity: ±2% of rate.
    c. Each unit shall be factory calibrated for the specified flow and shall be calibrated in both directions if the application is bi-directional. Calibration shall be a minimum of three point. Specific performance test data shall be furnished with the meter.
    d. Each meter shall provide two analog 4-20 mA signals or a single 4-20 mA signal and a digital contact closure on reverse flow.
    e. Meters for steam condensate shall be capable of sensing with condensate conductivity down to 6 µS/cm.
2. Provide a phenolic tag for each transmitter to identify service and meter ID number (i.e. SECONDARY CHILLED WATER FLOW, FM-1, etc.).
3. Approved Manufacturers (Water)
    a. ABB
    b. Siemens
    c. EMCO
    d. Rosemount
    e. Krohne
    f. Onicon
4. Approved Manufacturers (Steam Condensate)
    a. Rosemount
    b. Krohne
    c. ABB

B. Steam (Vapor) Flowmeters (Vortex-Shedding Type):

1. The meter system shall consist of a primary flow sensor and transmitter. The flow sensor body and wetted parts shall be SS, and shall be flanged and suitable for the service rating. The meter shall be installed with all necessary grounding components and gaskets per manufacturer's instructions. The transmitter shall be provided with a remote mounting bracket and cable, integral LCD display, NEMA 4X housing, shall indicate flow rate and totalized flow, shall have an isolated 2-wire 4-20 mA linear output flow signal and a pulsed output signal for totalization. The transmitter shall be capable of being field calibrated and reprogrammed from the outside housing via magnetic probe or security protected integral keypad menu switching. Unit electronics shall have noise immunity. Unit shall have the capability to maintain flow total in non-volatile memory. The primary flow sensor and transmitter shall be mounted in accessible locations. The flowmeter shall be provided with a 1-year warranty and application non-degradation performance guarantee. The flowmeter and transmitter as a unit shall have the following minimum characteristics:
    a. Temperature range shall be –40 to +750°F.
    b. Accuracy shall be 1.0% of rate and 0.1% of full scale.
    c. Repeatability shall be 0.15% of flow rate.
    d. Each meter shall be factory calibrated for the specified flow range prior to shipment and specific performance test data shall be furnished with the meter.
    e. Meter range shall accommodate the minimum and maximum expected flow for the steam pressure at the installed location.
    f. Meter shall be equipped with a temperature and pressure compensation feature.
2. Provide a phenolic tag for each transmitter to identify service and Meter ID number (i.e. MEDIUM PRESSURE STEAM FLOW – LSI BUILDING, etc.).
3. Approved Manufacturers
    a. Rosemount
    b. Krohne
    c. ABB

C. Steam (Vapor) Flow Meters (Differential-Pressure Type)

1. The meter system shall consist of a differential pressure primary flow element, a differential pressure transmitter (or transmitters), and a flow monitor/computer. The flow sensor body and wetted parts shall be SS, and shall be equipped with 150-lb. flanges. The transmitter(s) and flow computer shall be provided with a remote mounting bracket and cable, integral LCD display, and NEMA 4X housing. Flow computer shall indicate flow rate and totalized flow, shall have an isolated 2-wire 4-20 mA linear output flow signal and a pulsed output signal for totalization. Unit electronics shall have noise immunity. The transmitter shall be capable of being field calibrated and reprogrammed from the outside housing via magnetic probe or security protected integral keypad menu switching. Unit shall have the capability to maintain flow total in non-volatile memory. The flowmeter and transmitter as a unit shall have the following minimum characteristics:
    a. Temperature range shall be –40 to +750°F.

b. Accuracy shall be 1.0% of rate or better and 0.1% of full scale.
c. Repeatability shall be 0.15% of flow rate.
d. Each meter shall be factory calibrated for the specified flow range prior to shipment and specific performance test data shall be furnished with the meter.
e. Meter range shall accommodate the minimum and maximum expected flow for the steam pressure at the installed location.
f. Meter shall be equipped with a temperature and pressure compensation feature.
g. V-cone horizontal pilot lines shall be pitched back to steam lines and shall not trap condensate.

2. Provide a phenolic tag for each meter to identify service and Meter ID number (i.e. MEDIUM PRESSURE STEAM FLOW – LSI BUILDING, FM-1 etc.).
3. Approved Manufacturers
   a. McCrometer (V-cone-style meter)
   b. Preso (Venturi-style meter)
   c. Gerand Engineering (Venturi-style meter)

TWO METHODS OF CALCULATING ENERGY CONSUMPTION (BTUS), WITH THE RESPECTIVE EQUIPMENT REQUIRED, ARE SPECIFIED BELOW: (1) BY THE DDC SYSTEM OR (2) BY A "BTU METER". D.2 IS USED WHEN UTILITY (REVENUE) BILLING OF A SYSTEM IS PLANNED. D.1 IS USED WHEN ENERGY CONSUMPTION IS COLLECTED FOR INFORMATIONAL PURPOSES ONLY. ASSURE THE CONTROL DRAWINGS INDICATE WHICH METHOD, IF ANY, IS TO BE USED FOR EACH SYSTEM.

D. BTU Metering

1. (BTU determination via virtual point) When the control drawings describe BTU or BTU/hr trending, provide the following for each point described:
   a. One (1) liquid flowmeter unit with transmitter as specified elsewhere in this section.
   b. Two (2) high-precision matched temperature sensor assemblies with transmitters as specified elsewhere in this section. Sensor with SS well shall be installed in each respective supply and return pipe as shown on project drawings.
   c. These devices shall be wired to a local DDC panel. Calculations for instantaneous and totalized load shall be incorporated into the panel control code, and the necessary virtual points shall be created to allow remote monitoring and trending via the DDC system.
2. When a BTU meter is indicated on the control drawings, provide all the requirements described above for BTU virtual points, and additionally provide a Flow/BTU computer. Flow/BTU computer shall be programmable for various flow meter types including linear, square law, or multi-point linearization data interpretation:
   a. Inputs shall include 4-20ma flow from flow meter, and 4-20ma from two temperature sensors.
   b. Flow and temperature inputs shall be simultaneously connected to this computer and looped to the local DDC panel.

c. Flow/BTU computer shall operate in an environment of 0 to 50 C, shall include a keypad for data input and retrieval, and an EEPROM/nonvolatile RAM. Unit shall calculate and provide:
   1) Two 4-20ma analog outputs indicating btu, mass or volume flow rate, temperature 1, temperature 2, delta temperature, pressure, density, and peak demand.
   2) One isolated pulse output indicating btu, mass or volume total
   3) Two NC/NO relay outputs assignable to trip according to various rate, total, temperature or pressure readings Programmable as latching or non-latching, or as pulsed output of a total.

d. Outputs shall be stored in a battery backed data logger, selectable for continuous or periodic log modes.

e. Unit shall have a real time clock and shall date stamp logged data. Unit shall have an RS-232 port and shall be capable of setup from a laptop computer. The supplier shall set up and verify BTU measurement and shall train U of M personnel in all aspects of BTU computer setup and operation.

f. Computer shall calculate and display heat, mass or Volume flow rate, resettable total, non-resettable total, temperature input 1, temperature input 2, delta temperature, density, pressure, peak demand, and time/date stamp.

g. Provide a phenolic tag for each transmitter and flow computer (as applicable) to identify service and ID number (e.g. CHILLED WATER BTU METER – LSI BUILDING, etc.).

h. Mount Flow/BTU computer in a NEMA 4 enclosure: Minimum size 16” (H) x 14” (W) x 8” (D), hinged cover, pad-lockable latch, and stainless steel hinge. Provide cutout in enclosure face and mount computer in face. Where multiple computers are supplied, they may be mounted in a common enclosure.

i. Approved Manufacturers and Models for Flow/BTU Computer:
   1) Kessler-Ellis Supertrol II with MS816 enclosure.

2.12 MISCELLANEOUS DEVICES

A. Alarm Indication Station

1. Alarm indicating station with red alarm LED, alarm horn, horn momentary silence switch, adjustable alarm delay and alarm repeat time, and alarm status relay.
   a. Supply Voltage: 24 VAC @ 100 mA or 24 VDC @ 34 mA.
   b. Alarm Time Delay: None, or 1 to 31 seconds in one-second increments, or 10 to 310 seconds in 10-second increments.
   c. Alarm Horn: Continuous or pulsed tone, 70 db minimum.
   d. Alarm Repeat Time: None, or 1 to 7 minutes in one-minute increments, or 10 to 70 minutes in 10-minute increments.
   e. Alarm Relay: SPDT, 0.5A @ 24 VAC, 1.0A @ 30 VDC, follows horn or lamp action, selectable.
   f. Connections: Screw terminals, 22 – 14 AWG wires.
   g. Mounting: Brushed stainless steel plate mountable to standard single junction box, with two screws provided.
2. Accepted Manufacturer:
   a. Kele Model RAD-1.

B. Carbon Dioxide Sensors:

1. Carbon dioxide sensing cell shall consist of a non-dispersive infrared carbon dioxide gas cell that uses a pulsed source and has no free air optical path. Output shall be linearized 4-20 mA for use with 24 VDC input. The unit shall be specifically designed for the wall or duct application specified. Duct aspiration boxes shall be by the manufacturer. Unit shall have span adjustment. The unit shall have no moving parts.
2. Minimum requirements:
   a. Range: 0-2,000 ppm
   b. Accuracy: 3 % of full scale
   c. Repeatability: 1% of full scale
   d. Power Consumption: less than 3 watts
   e. Zero Drift at Constant Temp.: 100 ppm per 24 hrs(random not cumulative)
   f. Max. allowable Drift in 1 year: 20 ppm
3. Unit shall not require calibration for a period of 1 year or more.
4. Approved Manufacturers:
   a. Valtronics
   b. Telaire

C. Carbon Monoxide and Combustible Gas Sensors:

1. Sensors shall be a micro-processor-based system for continuous monitoring and use catalytic, electro-chemical, diffusion cell, or solid-state type sensing. Output shall be linearized 4-20 mA for use with 24 VDC input with green LED normal operation indicator. Unit shall provide a SPDT pilot duty low voltage alarm contact with an adjustable set point. The unit mounting shall be wall, duct aspiration, or ceiling to suit application. The unit shall specifically designed for the application and shall be explosion proof, as required. Unit shall have single point set point and span adjustment. The unit shall have no moving parts. Units mounted outdoors shall be waterproof and rustproof.
2. Minimum requirements:
   a. Range: as required for application; ppm, %, % L.E.L.
   b. Accuracy: 3-5% of full scale
   c. Repeatability: 1% of full scale
   d. Power Consumption: 5 watts or less
   e. Relay contact rating: 5 amp at 24 VDC, 150 VA max. inductive
   f. Zero Drift at Constant Temp.: 0 per 24 hrs (random not cumulative)
   g. Max. allowable Drift in 1 year: 1% of full scale.
3. Approved Manufacturers:
   a. Draegar
   b. Vulcain

D. Condensation Sensor - Pipe Mounting Type

1. Sensor with built-in relay contact that opens upon detection of condensation, for sensing condensation when mounted on bare pipe.
   a. Supply voltage: 24 VAC/VDC ±10%
   b. Power consumption: Maximum 1.6 VA
   c. Relays contacts: rated 1 amp @ 24 VAC/VDC

d. Operating temperature: -20… +50°C
e. Display: LED (visible without removing cover), green – power supply ok, red – condensation sensed, contact open.
f. With pipe mounting bracket.

E. Current Sensing Relays

1. Provide current sensors with donut transformers capable of monitoring AC current, maximum input current ranges from 20 to 300 amp, peak, with digital output signals having adjustable high and low current trips. An LED shall provide visual indication and shall not bleed through.
   a. Provide special current sensing relays designed to monitor belt breakage, when indicated or described in the Sequence of Operation.
2. Approved Manufacturer:
   a. Neilsen Kuljian
   b. Veris Industries

F. Electronic to Pneumatic Transducers

1. Provide transducers to convert electronic signals from the Siemens analog output modules to linear proportional pneumatic signals for all DDC controlled modulating pneumatic devices. The transducer shall be a panel-mounted device, with hand/auto switch, override dial for manual override control, and a 0-30 psig output gauge. Supply voltage shall be 19-26 VAC. Control signal shall be 0-10 VDC or 4-20 mA. Output accuracy shall be 1/4 psig at 75 Deg. F, producing a 0-15 psig pneumatic signal. Output repeatability shall be .05 psig maximum. Transducers shall be high capacity non-bleed devices with a minimum output capacity of 500 SCIM, except special circumstances that require a constant bleed controller with branch exhaust on signal loss.
2. Approved Manufacturers:
   a. Non-bleed Type:
      1) Siemens
      2) ACI - PXP
   b. Bleed Type:
      1) ACI – PXP

G. Liquid Detectors

1. Liquid detectors shall utilize microchip technology for detection of conductive liquids through one of the following types of sensors: gold-plated probes, self-adhesive sensor tape with copper electrodes and durable cotton cover, or rope type sensor. Detectors shall be selected based on the best use for the application. Power requirement shall be 11-27 VAC or VDC and have a green LED normal operation indicator. Unit shall have a SPDT pilot duty low voltage alarm contact. Unit shall be waterproof and rustproof. A red LED shall indicate the presence of liquid. Unit shall have an adjustable set point.
2. Approved Manufacturers:
   a. R. E. Technologies, Inc
   b. Water Alert

H. Loop-Powered Indicators:

1. Where indicated, analog sensors (i.e., temperature, humidity, CO2, CO, etc.) shall be provided with a Loop-Powered Indicator (LPI) mounted on a separate dedicated LPI panel, except those sensors that are provided with a local display. Local displays shall be mounted at the DDC panel array.
2. Indicator shall be designed to display any 4-20 mA transmitter signal directly in the engineering unit of the measured media. The display shall be powered directly by the measured 4-20 mA signal without requiring an additional power supply. Indicator shall not impose impedance on the current loop beyond the capability of the transmitter.
3. Display shall have minimum 5/16" LCD digits, with 3-1/2 digit capability selectable decimal point and selectable scale. Accuracy of indication shall be 0.1% of scale.
4. Indicator shall be provided with a lettered plate indicating appropriate engineering units.
5. Approved Manufacturer:
   a. R. E. Technologies, Inc. (Kele Assoc.)

I. Occupancy Counters (People Counters)

1. Dual Sensor - Differential Thermal Imaging Counter
   a. General
      1) Provide combination BACnet-MS/TP and Analog Output counting devices for Dynamic Ventilation Reset Controls to be mounting where indicated on the plans and controlling ventilation to occupied zones as populations vary, in compliance with the Ventilation Rate Procedure in ASHRAE 62.1-2013 and 2016.

   b. Counters shall provide data on net zone populations to dynamically calculate the ASHRAE Standard 62.1 Ventilation Rate.
      1) Each counter shall consist of a center-top door frame mounted counter, using a dual thermopile differential thermal imaging counters, an integral microprocessor-based design capable of providing net population data to the controls network for use in ventilation reset based on accurately measured real- time zone populations.
      2) Counter with steel enclosure shall have an overall size of: 6.12L x 2.94W x 1.36H inches and weigh approx. 0.25 lbs.
      3) Counters shall have an environmental operating range of no less than 65° F to 85° F and 5% – 95% RH, non-condensing.
   c. Population Counter Design and Counting Performance
      1) Counter shall be mounted to provide zone entry and exit data to the network for maintenance of a net zone population value to less than ±5% of actual or ±3 people, whichever is larger.
      2) Counter design shall be optimized for single entry/exit interior doors, ≤ 42 x ≤ 96 in.

3) Small deviations or accumulation in counts shall be adjusted when "population reset interval" is selected during configuration and set up. Upon activation, the total net population in memory shall be 'zeroed' based on the user-determined reset period selected or every 24 hours during a predetermined non-occupied period.
4) Power, Connectivity and Communications
   a) The BACnet / analog combination counters shall be capable of communicating with other devices using an RS-485 standard interface and BACnet-MS/TP protocol, implemented as a Master node.
   b) Communication speed shall be field-selectable by dip switch between 9.6, 19.2, 38.4 and 76.9 kBaud.
   c) The counter-network communications shall be capable of field configuration and setup using a simple dip- switch interface.
   d) A simultaneous 0-10 VDC scalable and protected analog output shall also be available to provide net counts.
   e) All counters shall be powered with individual 24 VAC transformers (22.8V to 26.4V under load) @1.2 V-A nominal.

2. The manufacturer's authorized representative shall review and approve counter position placement for each location indicated on the plans.
3. Accepted Manufacturer:
   a. EBTRON, Inc. Model CENSUS - C100, Single-entry interior door occupancy counter.

J. Pressure to Electronic Transducers

1. Provide transducers to convert linear proportional pressure signals to interface with the Siemens analog input modules. The transducer shall be a panel-mounted device, with input pressure snubber, as required, and gauge. Supply voltage shall be 19-26 VAC. Control signal shall be 4-20 mA. Accuracy shall be 1 percent full scale. Thermal effect shall be less than 1 percent full scale on zero and less than 1 percent of reading on span. Transducer shall have elastomer seals and SS wetted parts.
2. Approved Manufacturers:
   a. Siemens
   b. Setra
   c. Modus
   d. ACI
   e. Dwyer

K. Room Differential Pressure Indicating Gauges

1. Dial (4" dia.) in metal case, diaphragm actuated, black figures on white background, front recalibration adjustment, center zero scale with scale range of 0.05-0-0.2" WC with 0.005 minor divisions, suitable for surface or flush mounting. Accuracy +/- 2% of full scale. With plastic gauge mounting plate for flush mounting and space pressure sensor consisting of pressure port, barbed tubing connection, and sensor plastic mounting plate suitable for mounting on a standard electrical junction box.
2. Approved Manufacturers:

a. Dwyer "Magnehelic" 2000-00N with A-465 pressure sensor and A-464 flush mounting plate (provide A-368 mounting bracket for surface mount applications)

THE DESIGNATION "RTC" SHOULD BE USED ON THE CONTROL DRAWINGS WHEN THE BELOW TYPE OF CONTROLLER IS INTENDED.

2.13 ELECTRONIC ROOM TEMPERATURE CONTROLLER (RTC)- CHILLED BEAMS, FIN TUBE, AND SIMILAR TERMINAL DEVICES WITHOUT A FAN

A. Room Temperature Controller:

1. UL listed configurable electronic room temperature controller with LCD display. Use only where specifically called for on control drawings. With the following features:
   a. Two part controller consisting of plastic base plate and detachable plastic controller housing, white casing/cover/fascia color. The base shall include screw terminals to allow all wiring to be terminated on the base, as opposed to directly on the controller. The controller housing shall mechanically and electrically engage the base and shall include all electronics and a built-in room temperature sensor.
   b. LCD display shall display the measured room temperature in °F.
   c. Control shall be by room temperature sensing.

REVISE OUTPUT REQUIREMENT TO FLOATING CONTROL WHEN FLOATING TYPE CONTROL VALVES ARE USED. FLOATING CONTROL IS NOT APPROPRIATE FOR APPLICATIONS THAT MAY DESIRE FAIL OPEN OR FAIL CLOSED CONTROL VALVES SUCH AS CHILLED BEAMS.

   d. Shall provide the number and type of inputs and outputs required to meet the sequence of operation.
      1) Provide a minimum of two analog outputs for 0-10VDC modulating valve actuators.
      2) Output Action (analog): Selectable normally open or normally closed.
      3) Inputs: Provide a minimum of two binary inputs and one universal input.
      4) Input and Output Ratings: As required for controlled devices.
   e. Setpoint Adjustment Buttons: The controller face shall provide an "up" setpoint adjustment button and a "down" setpoint adjustment button, or touch display, to allow occupant adjustment of setpoint.

NOTE THE AUTOMATIC CHANGEOVER MODE DESCRIBED BELOW. IF A MFR. DOES NOT OFFER THIS FUNCTION FOR 2-PIPE HEATING/COOLING APPLICATIONS, PIPING AT THE FAN COIL WILL NEED TO BE CONFIGURED WITH A SMALL BYPASS TO ASSURE THE CONTROLLER SENSES THE CURRENT 2-PIPE SYSTEM WATER TEMP.

f. Automatic Changeover Mode (provide for two pipe applications): the controller shall detect if the system is in heating or cooling mode by measuring the system water temperature at the fan coil and automatically switching the controller to heating or cooling control mode. An icon on the controller LCD shall indicate which mode the system is in, heating or cooling. Provide a strap-on-pipe temperature sensor device wired to the controller, for measuring system water temperature. The controller shall also include a purge mode function to assure proper acquisition of system water temperature by the strap-on sensor. Purge mode function shall open the fan coil 2-way control valve (for an adjustable time period) at two hour intervals if the control valve has remained closed during that interval.

g. The controller shall provide the following setpoint modes:
   1) Normal (Occupied) Mode: Controller maintains the heating and cooling occupant adjustable setpoint.
   2) Un-Occupied Mode: Controller maintains set-back/set-up heating and cooling setpoint; activated by a remote contact closure wired to a status input on the controller. Not occupant adjustable.

h. Override Button or Touch Display: The controller face shall include a button or touch display that allows the occupant to temporarily switch to Normal (occupied) mode. The duration of the temporary occupied mode shall be adjustable from 0 to 24 hours. When override is activated, Normal Mode setpoint operation shall be invoked and the controller shall provide a network point to signal the Owner's DDC system via BACnet MS/TP that occupied mode has been requested.

i. Operating Voltage: 24 VAC.

j. Power Consumption: 12 VA maximum.

k. Control Transformer: Provide control transformer when required.

l. Control Deviation Including Sensor Inaccuracy at 77 °F: ± 1 °F maximum.

m. Programmable Features: It shall be possible to program (configure) the following controller functions without special software. These features shall be provided directly by the controller. Programming/configuration mode shall be accessible via either a password or by non-intuitive button activation sequences.
   1) Cooling setpoint range, all Modes: Adjustable 54 °F to 100 °F.
   2) Heating setpoint range, all Modes: Adjustable 40 °F to 90 °F.
   3) Heating maximum setpoint (adjustable 40 °F to 90 °F) and cooling minimum setpoint (adjustable 54 °F to 100 °F).
   4) Proportional band adjustable from 3°F to 10°F.
   5) Dead-band between heating and cooling adjustable in 1°F increments, over a range 2°F to 5°F.
   6) Other parameters as required to meet the requirements of this specification and the control sequence of operation.

n. Serial Communications: Provide Controller with BACnet Testing Laboratories certified BACnet MS/TP Communications compatible with Siemens controls.
o. BAS Connections: Connect to the Siemens DDC control panel controller FLN or BACnet MS/TP network.

2. Warranty: 18 month unconditional parts and labor warranty and 5 year unconditional warranty for all parts including sensors.
3. Approved Manufacturers, subject to compliance with all the above requirements:
a. Schneider Electric SE7200 Series or Schneider Electric SE8300 Series
b. Viconics VT7200 Series or Viconics VT8300 Series

THE DESIGNATION "RTC-F" SHOULD BE USED ON THE CONTROL DRAWINGS WHEN THE BELOW TYPE OF CONTROLLER IS INTENDED.

2.14 ELECTRONIC ROOM TEMPERATURE CONTROLLER (RTC-F)- FAN COILS (FCU), UNIT HEATERS (UH), AND CABINET UNIT HEATERS (CUH)

A. Room Temperature Controller:

1. UL listed configurable electronic room temperature controller with LCD display, for modulating control of 2 or 4 pipe FCUs/UHs/CUHs. Use only where specifically called for on control drawings. With the following features (Fan speed relay board provided with the controlled equipment. Coordinate with equipment manufacturer and assure controller is compatible with relay board. Provide additional components to make compatible if required.):
a. Two part controller consisting of plastic base plate and detachable plastic controller housing, white casing/cover/fascia color. The base shall include screw terminals to allow all wiring to be terminated on the base, as opposed to directly on the controller. The controller housing shall mechanically and electrically engage the base and shall include all electronics and a built-in room temperature sensor.
b. LCD display shall display the measured room temperature in °F.
c. Control shall be by room temperature sensing. Provide return air sensor where indicated as required.
d. Outputs for modulating valve actuator and three-speed fan control or ECM fan control.

REVISE OUTPUT REQUIREMENT TO FLOATING CONTROL WHEN FLOATING TYPE CONTROL VALVES ARE USED. FLOATING CONTROL IS NOT APPROPRIATE FOR APPLICATIONS THAT MAY DESIRE FAIL OPEN OR FAIL CLOSED CONTROL VALVES SUCH AS CHILLED BEAMS.

NOTE THAT AS OF MAY 2019 VICONICS AND SCHNEIDER ELECTRIC CONTROLLERS FOR ECM FANS HAVE AVAILABLE ONLY ONE OUTPUT FOR CONTROL VALVES(2-PIPE OPERATION).

e. Provide the number and type of inputs and outputs required to meet the sequence of operation.
1) Provide a minimum of two analog outputs for 0-10VDC modulating valve actuators or 2-10VDC ECM fan control.

2) Output Action (analog): Selectable normally open or normally closed.
3) Inputs: Provide a minimum of two binary inputs and one universal input.
4) Input and Output Ratings: As required for controlled devices.

f. Fan Speed Selector Switch, Button, or Touch Display: that allows occupant to select high, medium, low or automatic fan speed. When setpoint dead-band is exceeded, the controller shall turn on the fan at the speed selected and modulate the control valve. In automatic mode, once the control valve opens to maximum position, the fan shall modulate from minimum speed/2VDC to maximum speed/10VDC.
1) If controlling single speed equipment, provide ability to jumper or program the controller so that regardless of fan "switch position", controller turns on fan to fixed speed when setpoint dead-band is exceeded.

g. Setpoint Adjustment Buttons: The controller face shall provide an "up" setpoint adjustment button and a "down" setpoint adjustment button, or touch display, to allow occupant adjustment of setpoint.

h. It shall be possible to set the fan control for either continuous fan operation independent of room temperature, or for the fan to turn on and off dependent on room temperature.

NOTE THE AUTOMATIC CHANGEOVER MODE DESCRIBED BELOW. IF A MFR. DOES NOT OFFER THIS FUNCTION FOR 2-PIPE HEATING/COOLING APPLICATIONS, PIPING AT THE FAN COIL WILL NEED TO BE CONFIGURED WITH A SMALL BYPASS TO ASSURE THE CONTROLLER SENSES THE CURRENT 2-PIPE SYSTEM WATER TEMP.

i. Automatic Changeover Mode (provide for two-pipe applications): the controller shall detect if the system is in heating or cooling mode by measuring the system water temperature at the fan coil and automatically switching the controller to heating or cooling control mode. An icon on the controller LCD shall indicate which mode the system is in, heating or cooling. Provide a strap-on-pipe temperature sensor device wired to the controller, for measuring system water temperature. The controller shall also include a purge mode function to assure proper acquisition of system water temperature by the strap-on sensor. Purge mode function shall open the fan coil 2-way control valve (for an adjustable time period) at two hour intervals if the control valve has remained closed during that interval.

j. The controller shall provide the following setpoint modes:
1) Normal Mode: Controller maintains the heating and cooling occupant adjustable setpoint.
2) Standby Mode: Controller maintains standby heating and cooling setpoints. Not occupant adjustable.
3) Economy Mode: Controller maintains set-back/set-up heating and cooling setpoint; activated by a remote contact closure wired to a status input on the controller. Not occupant adjustable.

k. Standby Switch or Button: the controller face shall include a standby switch/button/touch screen that allows the occupant to activate stand-by mode by a single key stroke.

l. Operating Voltage: 24 VAC.
m. Power Consumption: 12 VA maximum.
n. Control Transformer: Provide control transformer when required.
o. Control Deviation Including Sensor Inaccuracy at 77 °F: ± 1 °F maximum.
p. Programmable Features: It shall be possible to program (configure) the following controller functions without special software. These features shall be provided directly by the controller. Programming/configuration mode shall be accessible via either a password or by non-intuitive button activation sequences.
1) Cooling setpoint range, all Modes: Adjustable 54 °F to 100 °F.
2) Heating setpoint range, all Modes: Adjustable 40 °F to 90 °F .
3) Heating maximum setpoint (adjustable 40 °F to 90 °F) and cooling minimum setpoint (adjustable 54 °F to 100 °F).
4) Proportional band adjustable from 3°F to 10°F.
5) Dead-band between heating and cooling adjustable in 1°F increments, over a range 2°F to 5°F.
6) Two Pipe Applications:
a) Heating/Cooling Changeover Cooling Switch Point: <75 °F.
b) Heating/Cooling Changeover Heating Switch Point: >77 °F.
c) Purge function active or inactive.
d) Purge function time duration.
7) Fan Control in the Economy Mode: On or off.
8) Other parameters as required to meet the requirements of this specification and the control sequence of operation.

2. Serial Communications: Provide Controller with BACnet Testing Laboratories certified BACnet MS/TP Communications compatible with Siemens controls.
3. BAS Connections: Connect to the Siemens DDC control panel controller FLN or BACnet MS/TP network.
4. Warranty: 18 month unconditional parts and labor warranty and 5 year unconditional warranty for all parts including sensors.
5. Approved Manufacturers subject to compliance with all the above requirements:
a. Schneider Electric SE7300 Series or Schneider Electric SE8300 Series
b. Viconics VT7300 Series or Viconics VT8300 Series

2.15 ELECTRIC COMPONENTS

A. Components shall be Honeywell, Johnson, or Siemens, unless listed otherwise.

B. Low temperature detection thermostats shall be duct type, fixed 5 deg. F differential, range 30 to 60 deg. F. Sensing element shall have a 20-foot long capillary tube responding to the lowest temperature sensed along any 12 inches of bulb length. Switch shall be SPDT 120 VAC, UL listed, rated for 10 amps at 120 VAC full load. Unit shall be manually reset. Provide one thermostat for every 20 square feet of coil surface.

C. High temperature detection thermostats shall be two-position type, range and element shall be suitable for the service, single or double pole, normally open or normally closed as required. Set point shall be adjustable over the full range. Switch shall be UL listed, rated for 10 amps at 120 VAC full load. Unit shall be manually reset.

D. Immersion electric thermostats shall be two-position type, range and element shall be suitable for the service, single or double pole, normally open or normally closed as required, with stainless steel separable well. Set point shall be adjustable over the full range. Switch shall be UL listed, rated for 10 amps at 120 VAC full load.

E. Remote-bulb electric thermostats shall be two-position type, range and element shall be suitable for the service, single or double pole, normally open or normally closed as required, with stainless steel separable well as required. Set point shall be adjustable over the full range. Switch shall be UL listed, rated for 10 amps at 120 VAC full load.

F. Wall-mounted electric thermostats shall be two-position type, range and element shall be suitable for the service, single or double pole, normally open or normally closed as required. Set point shall be adjustable over the full range. Switch shall be UL listed, rated for 10 amps at 120 VAC full load.

G. Strap-on electric thermostats shall be two-position type, range and element shall be suitable for the service, single or double pole, normally open or normally closed as required. Set point shall be adjustable over the full range. Switch shall be UL listed, rated for 10 amps at 120 VAC full load.

H. Differential Pressure Switches:

1. Shall provide electrical switching action upon a sensed pressure differential increase between two points. Sensitivity shall be suitable for the application. Set point shall be adjustable over the full range of the device. Switching action shall SPDT. Electrical switch rating shall be 10 amps at 120 VAC, minimum.
2. Pressure rating of switch and connecting tubing:
   a. Fan - Rated for 12 inches WC.
   b. Pump – Maximum deadhead system pressure.
3. Switches used for safety shutdown applications shall be of the manual reset type.
4. Approved Manufacturers:
   a. Honeywell
   b. Siemens
   c. Dwyer
   d. Cleveland Airflow

I. Limit Switches:

1. Limit switches shall be oil tight type with appropriate operator to provide required function.
2. Approved Manufacturers:

a. Honeywell
b. Siemens
c. Allen-Bradley
d. GE
e. Square D

J. Control Relays and Contactors:

1. Relays shall be a minimum DPDT, of proper coil voltage, with neon indicator light, and of sufficient rating for specified purpose. Relay base shall be of the screwed terminal type.
2. Contactors shall be definite purpose type, have adequate number of poles, of proper coil voltage, and of sufficient rating for specified purpose. Contactors used for DDC interface control shall contain a Hand-Off-Auto switch.
3. Approved Manufacturers:
   a. Dayton
   b. Siemens
   c. Allen-Bradley
   d. GE
   e. Square D

K. Selector Switches:

1. Switches shall be multiple position type, oil-tight, watertight, dust-tight, have the adequate number of contact blocks, capable of additional contact blocks, and of sufficient rating for specified purpose. Nomenclature plate shall be provided with appropriate wording, units, etc.
2. Approved Manufacturers:
   a. Dayton
   b. Siemens
   c. Allen-Bradley
   d. GE
   e. Square D

L. Push Buttons and Pilot Lights:

1. Push button switches and pilot lights shall be, oil-tight, watertight, dust-tight, have the adequate number of contact blocks, capable of additional contact blocks, and of sufficient rating for specified purpose. Nomenclature plate shall be provided with appropriate wording, units, etc.
2. Pilot lights shall be neon or LED, push-to-test type with replaceable lens. Lens shall be of the appropriate color for application served.
3. Approved Manufacturers:
   a. Dayton
   b. Siemens
   c. Allen-Bradley
   d. GE
   e. Square D

M. Fuse Holder/Disconnects:

1. Fuse holder/disconnects shall be provided for all control circuits inside auxiliary control panels, and shall be of appropriate size/type for service.
2. Approved Manufacturers:
   a. Little Fuse

b. Dayton
c. Buss
d. GE

N. Terminal Blocks:

1. Terminal blocks shall be modular, barrier type, direct mount, single pole, and snap together to any required number of poles. Units shall be rated for 300 volts, 20 amp., handle wire sizes from 22-12 AWG, and have a marking strip for identification.
2. Approved Manufacturers:
   a. Little Fuse
   b. Dayton
   c. Buss
   d. GE

O. Toggle Switches:

1. A toggle switch shall be provided for every auxiliary and local control panel that utilizes a 120 VAC power source as a means to turn off the power to that panel and shall be of appropriate size/type for service. Toggle switches shall be rated 120/277 volts, 20 amps, SPDT, specification grade, extra-heavy duty, back and side wired, with brown handles.
2. Approved Manufacturers:
   a. Leviton
   b. Pass & Seymor
   c. Hubbell
   d. Arrow Hart
   e. Bryant

2.16 ELECTRICAL ACCESSORIES

A. Wiring and Conduit

1. The MSCC shall provide all DDC and related control wiring, conduit, and J-hook cable hanging system. Wire and cable shall be pulled from device or control point to the DDC, Auxiliary, UPS, or LPI panels and run between DDC, Auxiliary, UPS, or LPI panels. MSCC shall be responsible for sizing all wiring to allow for proper function.
2. The MSCC shall develop a logical and systematic wire numbering scheme for each panel assembly. All wire and cable shall be labeled and tagged on both ends. Within a panel assembly, wiring shall be tagged 4 inches down from the point at which the wire enters the cabinet with the corresponding point number or wire number. All other wiring shall be tagged within 4 inches of the termination point.
   a. Labels shall be thermal printed type designed specifically for wiring identification.
3. All wiring carrying voltages greater than 24 volts or rated as Class 1 circuits shall be run in conduit.
4. All wiring carrying voltages 24 volts nominal or less shall be run as follows:
   a. Wiring routed in shafts, walls, below grade, and in any concealed or inaccessible space, or above ceilings requiring the use of a tool to access or held in place by clips or similar devices: run wiring in conduit.

b. Wiring routed in exposed locations such as mechanical and electrical rooms or in rooms without ceilings (i.e. exposed to deck above): run in conduit.
c. ALN wiring: run in conduit.
d. Wiring above accessible lay-in ceiling areas: Utilize J-hook hangers.
    1) Provide UL Listed zinc electro-plated steel or plastic J-hooks, sky blue color, plenum use approved, with minimum 1-inch wide cable support area, rated for the cable type being supported. Provide with integral cable retainer strap to provide containment of cables within the hanger.
    2) Install J-hooks with J-hook bottoms a minimum of 10 feet A.F.F. and no less than 2 feet above the ceiling.
    3) Space hangers at maximum 5 foot intervals, with additional hangers located a maximum of 3 feet from both sides of any change in direction. Wiring shall not sag more than 12 inches between J-hooks. Install wiring and J-hooks in a neat and workman-like manner, routed parallel or perpendicular to the building column lines.
    4) Install to protect wire from damage and to allow for wire replacement. Do not exceed 50 % of the wire capacity specified by the J-hook manufacturer (first installation), or route control wiring in non-control-wiring J-hooks.
e. Wiring to wall mounted devices such as room sensors, switches, and similar devices: New walls--Route wiring in wall in minimum 1/2 inch conduit. Stub conduit up/down into accessible ceiling space, terminating conduit with a 90 degree bend and a strain relief to prevent wire damage. Install wall box for device mounting. Existing Walls--Route wiring in wall in minimum 1/2 inch flexible conduit. Stub flex up/down into accessible ceiling space, terminating flex with a bushing to prevent wire damage. Install wall box for device mounting.
f. Wiring to perimeter radiation valves and similar control devices requiring wiring to be routed in walls: Route wiring in wall in minimum 1/2 inch conduit. Stub conduit up/down into accessible ceiling space, terminating conduit with a 90 degree bend and a strain relief to prevent wire damage. Provide maximum 12 inch long flexible metal conduit for the final connection to the device.

5. Conduits shall be sized on a maximum fill of 40% capacity.
6. Five separate conduit systems shall be provided:
    a. DO/DI and 120 VAC control wiring.
    b. AO/AI wiring (may also contain DI wiring if rated as Class II teflon jacketed twisted pair)
    c. Pneumatic tubing.
    d. ALN/FLN cables.
    e. 24VAC (note exception under TEC Wiring Requirements)

    Exception: DO’s, DI’s, AI’s, and AO’s between VSD’s and DDC panels may share the same conduit if all wiring meets Class I wiring standards and provided all analog signals use a 4-20mA signal.

7. All junction boxes and couplings on conduit containing DDC related wiring or pneumatic tubing shall be painted sky blue color. Alternative: Allied Tube True Color® EMT, color blue, may be used in lieu of painted fittings and junction boxes.
8. Data transmission cabling and equipment grounding procedures shall meet the latest FCC guidelines for electromagnetic field generation.
9. All control wiring sizes and types shall meet the equipment manufacturer's recommendations.
10. Minimum DDC Wiring and Cable Requirements:
    a. Digital Output: Minimum #14 AWG THHN
    b. Digital Input: Teflon jacketed twisted pair #20 -or- #16 AWG THHN minimum.
    c. Analog Output: Twisted pair NEC-rated CMP #20 AWG
    d. Analog Input: Twisted pair NEC-rated CMP #20 AWG
    e. Data Transmission (Non-BACnet): Teflon jacketed twisted shielded pair #22 AWG 12-1/2 pico-ferrad, 6 twists/foot, with 22 AWG ground wire.
    f. Data Transmission (BACnet MS/TP): BACnet Testing Laboratories compliant communication cable utilizing a twisted pair cable to include an additional conductor to be used for common or signal reference when required.
    g. Data Transmission (BACnet IP): BACnet Testing Laboratories compliant Ethernet communication cable.

    All wire sizes listed are for lengths up to 750'.
11. All control wiring shall have insulation rated for 300 volts minimum, and be installed per NEC requirements. Exposed wiring running in return plenums, air handling devices, and where required by code shall be plenum rated.
12. DDC panel to DDC panel (ALN) wiring insulation outer jacket color shall be orange.
13. Terminal unit (FLN) wiring insulation outer jacket color shall be orange with blue stripe.
14. TEC Wiring Requirements:
    a. FLN & 24VAC Class II power wiring may be routed in the same conduit.
    b. Provide all necessary 24 VAC transformers, 24 VAC power distribution wiring, etc. to TECs for a complete operating system. Transformers shall have primary and secondary fuse protection and shall be mounted in an electrical closet, auxiliary panel or other suitable accessible location with disconnecting means. Provide a pilot light for each transformer, to indicate the presence of load power.
    c. Terminal fittings or insulating bushings shall be used to protect wiring associated with TECs at enclosures, junction boxes, etc.

B. Provide all necessary 24 VAC transformers, 24 VAC power distribution wiring, etc. for a complete operating system. Transformers shall have primary and secondary fuse protection and shall be mounted in an electrical closet, auxiliary panel or other suitable accessible location with disconnecting means. Provide a pilot light for each transformer, to indicate the presence of load power.

C. Provide conduit and wiring to power all 120 VAC control accessories such as flow meters, BTU meters, data acquisition panels, and actuators. Feed this power from an auxiliary control panel, with a separate disconnect and fuse for each device, located in the auxiliary panel.

D. For TEC's, provide 120 VAC conduit and wiring between electrical panels and TEC power supply transformers.

2.17 AUTOMATIC CONTROL VALVES AND ACTUATORS

A. General:

1. Unless indicated otherwise on the control drawings, provide the control valve body style (globe, ball, butterfly, etc.) indicated for each application (hydronic, steam, etc.) noted below.
2. Except where otherwise noted, valve bodies 2 inches IPS and smaller shall be single seated bronze, and shall have screwed end connections. Valve bodies 2-1/2 inches IPS and larger shall be cast iron, and shall have flanged end connections. Valve stem packing shall be PTFE or EPDM. Packless construction is acceptable. Valve linkage shall have an adjustment for valve lift.
3. Valve rangeability shall be no less than 50:1 for valve $C_v \leq 1$, no less than 100:1 for valve $C_v > 1$.
4. When indicated, provide separate SPDT limit switches which actuate at the full open and full closed valve position.
5. All electrically actuated control valves installed in locations exposed to outdoor conditions shall be provided with NEMA 4/4X weather resistant housings and thermostatically controlled heaters for climates that reach below freezing.

B. High Performance Butterfly Valves

1. May be used for hydronic applications, when approved, for valves 5" and larger.
2. High performance butterfly valves shall comply with Related Section 220523 Valves.
3. Approved Manufacturers
   a. Per Related Section 220523 Valves

STEAM CONTROL VALVES: REVISE THE VALVE PRESSURE DROP SPECIFIED BELOW TO THAT APPROPRIATE FOR YOUR PROJECT. FOR EXAMPLE, FOR LOCATIONS CLOSE TO THE CENTRAL POWER PLANT, A PRESSURE DROP HIGHER THAN THE INDICATED 4 PSIG WOULD BE APPROPRIATE. ALSO NOTE THAT THE BELOW VALVE SIZING CRITERIA ASSUMES THAT THE STEAM PRESSURE REQUIREMENT FOR THE EQUIPMENT SERVED BY THE CONTROL VALVE IS 1 PSI OR LESS. ALWAYS VERIFY THE EQUIPMENT PRESSURE REQUIREMENT AND MODIFY THE BELOW ACCORDINGLY.

C. Hydronic Control Valves

1. General Valve Requirements
   a. Maximum pressure drop across any hydronic system valve at maximum flow and valve size shall be as indicated.
   b. When not indicated, valves shall be sized for a pressure drop of 3 psig for chilled water and 4 psig for hot water based on the maximum flow rate scheduled for the device controlled.

c. Two-way valves shall have equal percentage characteristics for heating and cooling applications, either linear or equal percentage for other applications as appropriate, linear for three-way valves.
d. 2 year unconditional warranty, parts and labor. 5 year unconditional parts warranty.

2. Globe Style Valves (May be used for sizes 1" and larger).
   a. Bodies and trim shall be rated for service pressures through 125 psig at 250 deg. F, globe style.
   b. Hydronic system valves shall have replaceable plugs and seats of SAE 72 brass or AISI 300 series stainless steel, selected for maximum lift under application conditions.
   c. Shall provide safe and reliable operation in water or in up to 50% glycol/water solutions, at fluid temperatures between 35°F and 212°F and static pressures up to 300 psi.
   d. Bronze body with female NPT end connections.
   e. Differential pressure rating (valve operating): 30 PSID maximum.
   f. Provide valves with the flow coefficient indicated, or if not indicated, subject to engineer's approval, with a Cv appropriate for good control and considering the system differential pressure available.
   g. Approved Manufacturers
      1) Siemens
      2) Honeywell
      3) Johnson

ALTHOUGH AVAILABLE UP TO 4", BALL VALVES SHOULD TYPICALLY ONLY BE USED FOR SMALL CONTROL VALVE APPLICATIONS, E.G. VAV BOXES, FAN COILS. THIS SPECIFICATION IS ONLY FOR BALL VALVES UP TO 3/4" DIAMETER.

3. Ball Style Control Valves
   a. Control Valve Body: Quarter turn ball valves, 2-way and 3-way configuration as indicated, for 2 position or modulating service, with the following features:
      1) 1/2" or 3/4" valve size.
      2) Nickel coated brass or stainless steel body with female NPT end connections.
      3) Stainless steel or chrome plated brass ball, with reinforced EPDM or PTFE O-ring seals.
      4) Blow-out proof stainless steel or chrome plated brass stem with double O-ring EPDM or PTFE seals.
      5) Shall provide safe and reliable operation in water or in up to 50% glycol/water solutions, at fluid temperatures between 35°F and 212°F and static pressures up to 300 psi.
      6) Ball and stem seals shall be formulated to prevent degradation by typical water treatment chemicals and Chloramines.
      7) Minimum close-off rating: 200 PSI.
      8) Differential pressure rating (valve operating): 30 PSID maximum.
      9) Downstream leakage: maximum of 0.01% of design flow at rated close-off differential pressure.

10) 0 - 90 degree angle of rotation.
11) Valves for modulating service shall be equipped with a characterized ball (glass filled polymer flow insert) that provides an equal percentage flow characteristic.
12) Valves for two position control shall be reduced port type as required for the appropriate valve Cv.
13) Provide valves with the flow coefficient indicated, or if not indicated, subject to engineer's approval, with a Cv appropriate for good control and considering the system differential pressure available.

b. Approved Manufacturers:
1) Johnson Controls
2) Belimo

D. Steam Control Valves

1. Globe Style.
a. Bodies and trim shall be rated for scheduled saturated steam service pressures. Steam valve replaceable plugs and seats shall be stainless steel, hardened to not less than 500 Brinnel.
b. Valves shall have modified linear characteristics and shall be sized based on a 5 psig inlet pressure and a maximum drop of 4 psig.
c. 2 year unconditional warranty, parts and labor. 5 year unconditional parts warranty.
d. Approved Manufacturers
1) Siemens
2) Honeywell
3) Johnson

E. Control Valve Actuators

EDITOR: WHENEVER POSSIBLE, THE USE OF ELECTRIC ACTUATION FOR CONTROL VALVES IS PERFERRED. PNEUMATIC ACTUATION MAY ONLY BE CONSIDERED FOR PARTIAL RETROFITS OF EXISTING SYSTEMS WITH PNEUMATIC CONTROLS. CONSULT WITH THE UM DESIGN TEAM IF PNEUMATIC CONTROLS ARE REQUIRED. CONTROL VALVES LOCATED IN AN UNCONDITIONED ENVIRONMENT SHOULD BE ELECTRIC.

NOTE THAT MOST ELECTRIC BUTTERFLY VALVE ACTUATORS ARE NOT AVAILABLE WITH A SPRING RETURN OPTION WITHOUT THE ADDITION OF A BATTERY OR CAPACITOR TO DRIVE THE ACTUATOR TO ITS FAILSAFE POSITION. CAREFUL CONSIDERATION SHOULD BE GIVEN TO THE APPLICATION OF THIS TYPE OF CONTROL VALVE BEFORE USE.

WHEN THE USE OF ELECTRIC ACTUATORS IS PLANNED, THE METHOD OF GETTING POWER TO THOSE ACTUATORS MUST BE CONSIDERED. READ THE BELOW SPEC SECTION CAREFULLY AND NOTE THE SIZE RANGE FOR VARIOUS ACTUATOR VOLTAGES. THE CONTROLS CONTRACTOR SHALL NOT RUN POWER WIRING ABOVE 120V. THEREFORE:

FOR 120V ACTUATORS, POWER TO SUCH ACTUATORS IS THE RESPONSIBILITY OF THE CONTROLS CONTRACTOR AND IS TO BE ROUTED FROM THE DDC AUXILARY PANEL (SEE SECTION 2.5). IF YOUR PROJECT HAS A LARGE NUMBER OF 120V ACTUATORS, THE STANDARD (2) 20 AMP CURCUITS RUN TO THE DDC AUX PANEL MAY NOT BE ENOUGH. DETERMINE THE TOTAL AMPERAGE OF SUCH ACTUATORS AND DIRECT THE ELECTRICAL DESIGNER TO DESIGNATE ADDITIONAL 120V CIRCUITS TO THE DDC AUX PANEL, IF REQUIRED.

1. Except as noted otherwise, actuators shall be electric.

2. Provide actuator manufactured by the respective control valve manufacturer and factory assembled with the valve body.
3. Ball Style Control Valve Actuators
    a. Actuator shall include a manually operated hand wheel/ lever for manual override of the valve position.
    b. Modulating Actuators (0-10V or 4-20mA)
        1) UL listed electronic rotary actuator designed for operation with the ball type control valve, with the following features:
        2) The actuator shall be of the same manufacturer as the valve body and shall be integrally mounted to the valve at the factory.
        3) For direct coupling to the valve shaft without the use of linkages, use an ISO-style mounting pad.
        4) Minimum cycle life: 60,000 full strokes at maximum rated torque.
        5) Torque: as required for smooth positioning and closure of the valve against a maximum differential pressure of 30 PSI and to provide close-off up to 200 PSI.
        6) Motor runtime to rotate the valve ball 90°: 90 seconds maximum, 20 seconds minimum.
        7) Spring return runtime to rotate the valve ball 90°: 90 seconds maximum, 20 seconds minimum.
        8) For use with a 24VAC power supply with the ability to operate off the same power supply required for the temperature controller.
        9) For use with 0-10Vdc output proportional plus integral room controllers, fully compatible with the specified temperature controller. Unless indicated otherwise on the control drawings:
            a) Heating coil (non-vivarium applications): Normally open spring return actuation.
            b) Heating Coil(vivarium applications): Normally closed spring return actuation.
            c) Cooling coil: Normally closed spring return actuation.
        10) Electronic stall detection/overload protection. Actuator shall sense that maximum rotational position has been reached even when control signal is still applied and stop rotating prior to actuator damage.
        11) Rotation mechanically limited by adjustable integral limit stops.
        12) Mechanical range adjustment.
        13) Valve position indicator.
        14) Actuator/actuator housing: Brushless DC motor design, NEMA type 1 or 2 enclosure, die-cast aluminum alloy or UL 94 listed plastic housing, lubricated gears, with a thermal barrier to prevent condensation on the actuator parts when used for chilled water applications. It shall be possible to rotate the actuator to any of four rotational angles in 90° increments, relative to the valve body.
        15) Ambient temperature operating range: -20°F and 120°F.
        16) Maximum actuator noise level, running or spring return: 40 dBA.
    c. Floating Point Actuators
        1) Shall only be used for VAV box applications

2) 24 VAC 3-position floating control, 7/32” (5.5 mm) stroke minimum, direct-coupled to valve bodies without the use of tools, with sufficient power to prevent valves from lifting off their seats. With visual position indication, manual override knob, UL-listed for plenum installations.
3) The actuators shall be fail-safe open for perimeter heating applications.
4) The actuators shall be fail-in-place for reheat control valves.

4. Butterfly Valve Actuators
   a. Electric Actuators
      1) Actuators shall utilize split capacitor, reversible electric motor driving a compound epicyclic gear, thermal overload protected, factory tested, factory lubricated, localized mechanical position indicator readable at 25 feet, 0-90 degree reversible operation, bolt directly to valve top plate.
      2) Housing shall be weatherproof and suitable for outdoor location (NEMA 4X or IP66 rated).
      3) Provide thermostatically controlled heater for prevention of condensation at low temperatures.
      4) Provide auxiliary limit switches to confirm open/closed valve position.
      5) For modulating valves, provide 0-10 VDC or 4-20 mA feedback signal for valve position.
      6) Actuator voltage shall be 120 VAC. 120V actuators shall be fed out of the DDC auxiliary panel with a separate disconnect and fuse. Disconnect and fuse to be located in the DDC auxiliary panel.
      7) In all cases the MSCC shall provide the required control wiring to the actuators.
      8) Actuator ambient temperature range shall be -20 deg. F to +140 deg. F.
      9) Actuator shall include a manually operated hand wheel for manual override of the valve position.

   b. Pneumatic Actuators
      1) Pneumatic actuators shall be pneumatic rotary type with rack and pinion to provide constant output torque rated for at least 125 percent, pilot positioner with gauges, spring return, adjustable travel stops, factory tested, factory lubricated, self-draining body, integral pneumatic parting,
      2) Actuators shall have localized mechanical position indicator readable at 25 feet, 0-90 deg. reversible operation, capable of operating in any valve mounting position.
      3) Actuators shall be capable of being mounted in line or transverse to pipeline, and bolt directly to valve top plate.
      4) Valves shall be actuated with 60-psig air and 3-15 psig pilot service. Valves used for isolation do not require pilot positioners. Actuator shall include a manually operated hand wheel for manual override.

5) Provide speed control valves for On/Off (2-position) actuators for adjustment of actuator speed

5. Globe Valve Actuators
   a. Valves shall spring return to normal position as indicated.
   b. Select with sufficient close-off power for system pressure, pump shut off head, highest operating torque, and torque requirements of valves that may stick because of infrequent use.
   c. Select to provide smooth proportioning control under operating conditions normal to the system.
   d. Electric Actuators
      1) All actuators shall have visual position indication.
      2) Actuator shall be electric motor driving, microprocessor signal controlled.
      3) Modulating valves shall be positive positioning, responding to a 0-10VDC, 2-10VDC or 4-20mA signal.
      4) Power: All actuators shall be 24VAC power and less than 100VA draw. Power shall be via Class 2 wiring.
      5) Fail Safe: Valves actuators shall position the valve in a fail-safe position when the power supply is disrupted or the signal goes to 0.
      6) Valves shall have a means to manually open the valve when power is not available, such as a hand wheel or a geared crank with a clutch. A release button (clutch) or handle on the actuator shall be provided to allow for manual override.
      7) The actuator shall be designed with a current limiting motor protection.
      8) Actuator shall provide minimum torque required for proper valve close-off. The close-off differential pressure rating of the valve shall exceed the highest possible head pressure available at the pump plus 10%, and still be rated for a Class IV leakage.
      9) The actuator shall have the capability of adding auxiliary switches or feedback potentiometer if specified.
      10) Actuators shall be UL and CSA listed.
   e. Pneumatic Actuators
      1) Pneumatic, rolling diaphragm, spring loaded, piston type.
      2) Spring range shall be as required for non-overlapping sequencing or as indicated on drawings.
      3) Ratio relays or accumulators used for sequencing valves are not acceptable unless specifically indicated on the drawings.
6. Valve body/actuator control action shall be as follows unless noted otherwise:
   a. Heating coil valves (non-vivarium) shall be normally open to flow through the coil.
   b. Heating coil valves (vivarium) shall be normally closed to flow through the coil.
   c. Heat exchanger valves (steam or water) shall be normally open to flow through the heat exchanger.
   d. Cooling coil valves shall be normally closed to flow through the coil.

e. Humidifier valves shall be normally closed to flow through the humidifier.
f. Condenser water valves shall be normally open to flow through the cooling tower.
g. Isolation valves shall be normally open.
h. Drain valves shall be normally closed.

2.18 AUTOMATIC CONTROL DAMPERS

EDITOR'S NOTE: CONTROL DAMPERS SHALL BE SCHEDULED ON THE DRAWINGS. INDICATE THE DAMPER STATIC PRESSURE AND VELOCITY RATING IN THE SCHEDULE. FOR DAMPERS USED IN ANY APPLICATIONS REQUIRING SPECIALTY MATERIALS OF CONSTRUCTION, REFER TO SECTION 2.18.E (CONSULT WITH UM DESIGN MANAGER).

A. Multi-blade type. Provide with parallel blades for two-position, throttling, and modulating service unless noted otherwise. Provide required drive axles, linkage, jackshafts, and accessories for proper damper operation. Damper blades, frames, linkages, jackshafts and other parts of the damper actuation system shall not distort or rack during operation. Dampers shall close tightly, and operate in a smooth, hesitation and slack-free manner over the entire range of travel, at the maximum air pressure and velocity at the mounting location. Additionally, multiple section dampers shall operate in unison section-to-section.

B. Face and bypass dampers shall each be capable of passing 100% of unit rated CFM. Pressure drops shall be approximately the same in either extreme position, including the pressure drops of coils and bypass components.

C. All automatic control dampers shall conform to these specifications, including those provided by equipment manufacturers.

D. All control dampers shall be low leakage type and shall meet the following minimum requirements:

1. Leakage: 6.0 CFM/sq. ft. max. at 3" WC.
2. Frames: 13 gauge (minimum) galvanized steel, minimum 2 inch in frame depth, welded or riveted with corner reinforcement.
3. Blades: 16 gauge (minimum) stamped galvanized steel or aluminum airfoil type, maximum blade size 8 inches wide, 48 inches long. Axles and axle extensions shall be minimum 1/2 inch solid galvanized steel. Dampers which are required to have a static pressure rating over 4" WC shall have minimum 3/4 inch solid galvanized steel axles/axle extensions.
4. Blade Seals: Synthetic elastomeric or neoprene, inflatable type, mechanically attached, field replaceable.
5. Jackshafts: Provide to drive adjacent vertical sections of multiple damper assemblies to ensure uniform operation. Minimum 3/4 inch solid or 1" hollow (minimum 1/8 inch wall thickness) galvanized steel. Where jackshafts penetrate air handling casing walls, provide greasable ball bearing supports sleeved and sealed to prevent casing leakage. Provide intermediate greasable ball bearing supports bolted to damper frames for jack shafts extending across multiple damper sections.
6. Jamb Seals: Stainless steel.

7. Bearings: Oil impregnated sintered bronze or lubricant free, solid stainless steel. Provide thrust washers at bearings for all dampers that are to be mounted with blades in the vertical position.
8. Linkages: Deflection and slack-free. Zinc plated, fully exposed, connected to blade faces (located in the air stream). Linkages may be located in-jamb for single damper flange mounting arrangements, provided linkage is external to the duct and easily accessible for maintenance.
9. Static pressure Rating: As scheduled on the drawings, or provide dampers rated for the maximum pressure to be encountered at the mounting location but not less than 4" WC.
10. Velocity Rating: As scheduled on drawings, or provide dampers rated for the maximum velocity to be encountered at the mounting location.
11. Temperature Limits: -40 to 200 deg. F.
12. Provide through-bolted connections for connecting axle or jackshaft extensions. Set screw arrangements are not allowed.
13. Selection and sizing criteria: Damper selection and sizing shall be based on damper schedule shown on the drawings. For dampers that are not scheduled on the drawings, selection and sizing shall be based on the procedure contained in Engineering Manual of Automatic Control, Honeywell, Inc., 1997.

E. For dampers located in stainless steel ductwork, PVC coated ductwork, fume hood exhaust ductwork, and exhaust fan outside air bleed-in ductwork, fabricate and size as indicated above, with the following additional requirements:

1. Frames, blades, blade axles and extensions, blade seals, jackshafts, linkages, and all other components exposed to the airstream: Type 316 stainless steel.
2. Bearings: Solid stainless steel.
3. Damper operators shall be mounted outside of air stream. Extend damper axles and jackshafts to permit mounting outside of air stream.

F. Approved Manufacturers:

1. Honeywell
2. Ruskin
3. Vent Products
4. American Warming & Ventilating
5. Arrow United Industries
6. White Environmental
7. Johnson Controls

2.19 DAMPER OPERATORS

EDITOR: WHENEVER POSSIBLE, THE USE OF ELECTRIC ACTUATION FOR DAMPER ACTUATORS IS PREFERRED. PNEUMATIC ACTUATION MAY ONLY BE CONSIDERED FOR PARTIAL RETROFITS OF EXISTING SYSTEMS WITH PNEUMATIC CONTROLS. CONSULT WITH THE UM DESIGN MANAGER IF PNEUMATIC CONTROLS ARE REQUIRED.

A. General:

1. Damper operators shall be electric unless specifically noted otherwise on the drawings.

2. Damper operators shall be installed in accessible locations. Damper operators shall not be installed inside ducts or air units that convey hazardous exhaust.
   a. Single section dampers should be configured with an extended shaft actuator mounting arrangement with the actuator mounted in an accessible location outside the ductwork.
   b. Multiple section dampers should be connected with a jackshaft arrangement which is extended to an accessible location outside the duct. Where possible tandem mounted actuation should be provided on one side of the damper assembly.
   c. Damper actuators mounted onto the same jackshaft should be controlled using a leader/follower wiring design with the DDC panel signal being wired to the master actuator and the remaining slave actuators being controlled through the master feedback signal.
3. Electric Operators:
   a. Maintenance free electric actuator, reversible, with push rod and bracket for swivel mounting and for the transmission of power.
   b. Synchronous motor with load independent running time providing parallel operation of several operators. Gear train with low noise level.
   c. Magnetic hysteresis coupling with magnetic transmission of torque, with no mechanical contact between the coupling members.
   d. The actuator shall be safe against blocking and overload proof even when operated continuously.
   e. 24 or 120 VAC, 4-20 mA or 0-10 VDC input, reversible, direct-drive, metal or aluminum housing, brushless DC motor with stall protection, quiet, low-power operation, have visual position indicator, manual override, and a 0-10VDC feedback signal output.
   f. Actuators located outdoors shall be provided with internal heaters and should operate in the ambient temperature range of -20°F to 140°F.
   g. Actuators located outdoors shall be NEMA4x or IP66 rated or shall be provided with weatherproof NEMA 4X stainless steel enclosures that have removable covers with clasps or machine screws (no sheet metal screws) and that do not require removing fasteners.

4. Electronic damper operators used with TECs
   a. Operators shall be 24 VAC 3-position floating control type and utilize a 90-degree rotation.
   b. Operators shall be direct-drive, have sufficient power to operate the damper against system pressures, provide visual position indication, have manual override, and shall be UL-listed for plenum installations. Operators shall be of the fail-in-place type.

5. Pneumatic Operators: Rolling diaphragm piston type with 8-13# spring range, as indicated on drawings, or as required to achieve specified performance.

B. Provide operator mounting brackets. Provide devices to connect operator drive shafts to dampers, damper linkages, and jackshafts.

C. Quantity of operators: Provide a sufficient number to achieve unrestricted movement throughout damper range, such that one operator does not operate more than the maximum square footage of damper area as recommended in standard catalog of manufacturer. Minimum torque rating for sizing electric actuators on duct systems that operate above 1" of static pressure is 14 in-lbs/ft^2. Provide sufficient number so dampers close tightly, operate in a smooth, hesitation and slack-free manner over the entire range of travel at the maximum air pressure and velocity at the mounting location, and so that multiple section dampers operate in unison section-to-section. Provide spring return to normal position.

D. Where end switches are shown on control diagrams, it is not acceptable to utilize the internal damper operator end switches. Where shown, external end switches should be provided that are secured to the damper blades, linkages, or jackshaft independently of the damper operator(s).

E. Approved Manufacturers:

1. Honeywell
2. Johnson
3. Siemens
4. Belimo

2.20 PNEUMATIC CONTROL COMPONENTS

A. Components shall be Honeywell, Johnson, or Siemens, unless listed otherwise.

B. Electric-pneumatic relays shall be two-position, have a metallic body, can be field or panel mounted, have a 120 VAC coil, and 3 or 4 ports. Only Johnson E.P. relays are acceptable.

C. Pressure-electric switches shall be two-position, appropriate range and element, suitable for the service, single or double pole, normally open or normally closed as required. Set point shall adjustable over the full range. Switch rating shall be 8.0 amps at 120 VAC, minimum.

D. Differential pressure transmitter shall be one-pipe, 3-15 psig output, capable of measuring pressure differentials of positive or negative type, operate on the force-balance principal, have an overpressure rating of 30" WC, accuracy of 5 percent full scale, and of the range suitable for the service.

E. Pneumatic room thermostats shall be direct acting, dual (minimum 5°F dead band – 2 output branch lines) or single setpoint, 2-pipe, large capacity, adjustable proportioning type, containing dual or single bi-metallic elements, adjustable differential, minimum setting no greater than 1-1/2 deg. F over a range of 55 to 85 deg. F. Provide tamperproof covers with exposed setpoint indicator in black lettering, exposed thermometer, exposed setpoint adjustment in non-public areas and key operated setpoint adjustment in public areas.

F. Pneumatic humidistats shall be of the adjustable proportioning, 2-pipe type, duct or wall mounted, reverse acting, adjustable sensitivity, sensitive hydroscopic membrane, temperature compensated, 20-90% RH range room, 25-65% RH range for duct, and 55-95% RH range for high-limit applications. Room type shall have tamperproof cover. Duct type shall come mounted inside a galvanized duct mounting box.

G. Temperature transmitters shall be one pipe, directly proportional output signal to measured variable, linearity within plus or minus 1/2% of range for 200 deg. F span and plus or minus 1% for 50 deg. F span, with appropriate 50, 100, 200 deg. F temperature range, compensated bulb, averaging capillary, rod and tube or room transmitter operating on 20 psig input pressure and 3 to 15 psig output. Room transmitter shall be provided with cover and wall plate.

H. Humidity transmitters shall be one pipe, directly proportional output signal to measured variable, linearity within plus or minus 1% of range, temperature compensated, sensitive hydroscopic membrane, room or duct mounted, operating on 20 psig input pressure and 3 to 15 psig output. Room transmitter shall be provided with cover and wall plate.

I. Receiver-controllers shall be single or dual input models direct or reverse acting with mechanical set point adjustment, calibrated proportional band adjustment, and calibrated authority adjustment. Provide proportional control mode for temperature control applications, and proportional plus integral control mode for differential pressure control applications. Proportional band shall extend from 2 to 40% of primary sensor span, authority from 0 to 200% of primary sensor span and integral time from 1/2 to 20 minutes. Suitable for input signal of associated transmitter and output signal required by controlled device.

J. Signal selector relays shall be capable of receiving two or more input signals and transmitting the highest or lowest pressure, with 1:1 input/output ratio.

K. Booster relays shall be proportional type for increasing the volume capacity of an input signal to a directly proportional output signal.

L. Pneumatic switching relays shall be snap acting, switching type with adjustable switching setpoint and fixed differential, single or double pole, and metallic body, for connecting a common port to either of two other ports based on the switching signal.

M. Pneumatic multi-purpose relays shall be two-valve design, high accuracy, high repeatability, metallic body, internal relief, high capacity, proportional, with adjustable set point, capable of being used as direct or reverse acting, amplifying, signal advancing, minimum pressure output, or lower pressure transfer. Removal of main air to the relay causes the branch line output to go to zero.

N. Pneumatic gradual position switches shall provide regulated pressure to a controlled device, with knob and pointer for manual adjustment, graduated scale plate with appropriate markings, suitable for surface or flush mounting on wall or panel as indicated.

O. Pneumatic selector switches shall be two or three position with metallic bodies, have indicating plates with appropriate markings, and suitable for panel or wall mounting. Switches installed in finished rooms shall be recessed in wall and provided with faceplate.

P. Field Mounted Gauges:

1. Provide 1-1/2” air pressure gauges on branch lines of pneumatic systems at controllers, transmitters, valve and damper operators, relays, switches, regulators; and DDC output points. Accuracy shall be 2.5 percent of full scale for the middle half of scale and 3.5 percent elsewhere. At dampers or devices that utilize multiple actuators, a single gauge in a readily visible location is acceptable.

Q. Panel Mounted Pneumatic Gauges:

1. All transmitters shall be provided with receiver gauges.
2. Door mounted analog indicator gauges shall be 3-1/2” diameter with a 1% accuracy.
3. Sub-panel mounted analog indicator gauges shall be 2-1/2” diameter with a 1% accuracy.
4. A 1-1/2” gauge shall be provided on the main air supply inside each control panel.

2.21 LOCAL, AUXILIARY, UPS, LPI AND SIMILAR PANELS

A. Unitized cabinet type for each system under automatic control with relays and controls mounted in cabinet and temperature indicators, pressure gauges, pilot lights, push buttons and switches flush on cabinet panel face, or as detailed on drawings.

B. Doors shall be removable, right or left hand hinged, locking, keyed alike and to other U-M control panels.

C. Removable perforated subpanel to permit mounting of controls without drilling holes.

D. Wall mounted or support kit or unistrut type frame for floor mounting.

E. Unit shall have knockouts, NEMA Type 1, and listed under UL508 Industrial Control Panel Enclosures.

F. UPS panel shall be mounted directly below the primary DDC control panel.

G. Auxiliary panels shall not be smaller than 24"x24".

2.22 UNINTERRUPTABLE POWER SUPPLY (UPS)

A. UPS shall be sized for continuous full load use of primary DDC controller panel plus an additional 25% for a period of at least 5 minutes. Minimum size shall be 700 VA.

B. Provide a UPS with the following features:

1. Audible alarm when main power is not available
2. Automatic internal bypass
3. Provide with a network communication card for remote monitoring by Web/SNMP thru layer network.
4. RF noise filtering.
5. Over-voltage protection.
6. Three outlet receptacles minimum.
7. Visual status alert light.
8. Sealed maintenance-free hot-swappable batteries.

C. Provide a fan ventilated panel enclosure of adequate size to house the UPS.

D. Approved Manufacturers:

1. Schneider Electric – APC, model BR700G, BR1000G, BR1300G, BR1500G as required.

2.23 AHU SAFETIES ENCLOSURES (FIRE ALARM TO TEMPERATURE CONTROL INTERFACE BOX)

A. Enclosures shall utilize a standard 4-11/16" x 4-11/16" square electrical box and blank clover. One half of the blank cover shall be painted red and the other blue. A red neon indicator light shall be installed in the red half of the cover and a blue neon indicator light shall be installed in the blue half of the cover. A terminal strip shall be installed inside the electrical box with two terminals in one half, labeled "H1" and "H2" (for HVAC use), and two additional terminals in the other half, labeled "F1" and "F2" (for fire alarm use). The red neon indicator shall be wired to the F terminals and the blue neon indicator to the H terminals.

THE UNIVERSITY'S HIGH PRESSURE AIR SUPPLY IS AVAILABLE ON CENTRAL CAMPUS VIA THE STEAM TUNNEL SYSTEM. AS OF SEPTEMBER 2020 THE DEWPOINT IS NOT GUARANTEED. NEW PROJECTS CONNECTING TO THE TUNNEL SHOULD VERIFY THE DEWPOINT WITH UM CENTRAL UTILITY PLANT TO DETERMINE IF DESICCANT DRYERS ARE REQUIRED FOR THE CONTROL AIR.

2.24 PNEUMATIC ACCESSORIES

A. Control Air Supply

1. Control air supply shall be from the University's high-pressure (steam tunnel) air supply or from a temperature control compressed air station as indicated on the project documents. System shall be sized for expected use, including air usage of laboratory airflow units or process control actuators (whether this equipment is provided by the MSCC or not), plus 10 percent extra capacity. When providing a control Compressed Air Station, provide a Refrigerated Air Dryer if none of the pneumatic tubing or pneumatic components are exposed to outside air conditions. Provide a Regenerative Desiccant Air Dryer when pneumatic tubing or pneumatic components are exposed to outside air conditions.

B. Compressed Air Station

1. Temperature control air compressors shall be reciprocating oil type through 25 HP, rotary screw over 25 HP, specifically designed for pneumatic controls, shall be of the simplex or duplex type, tank or base mounted unit assemblies, have combination intake filter/silencer, and totally enclosed belt guards. Compressors shall be sized based on no more than 1/3 run time with an appropriately sized tank and an average tank pressure of 70 psig for optimum performance. Simplex units shall only be used when backing up another control air supply.
2. Tank shall be of adequate size and contain a shut-off ball valve, ASME safety relief valve, pressure switch operated start/stop control, 120 VAC electronic automatic drain with manual bypass and air pressure gauge.

3. Duplex models shall be complete with NEMA 1 enclosure, starters, disconnects, automatic alternator, H-O-A switches (left H position spring return for test only), low oil shutdown switch, push-to-test pilot lights, and 3-position switch for selection of: compressor 1 only/automatic alternate/compressor 2 only operation. PRV/filter/dryer assemblies may be mounted to the compressor/tank assembly.
4. Approved Manufacturers:
   a. Quincy
   b. ACP
   c. Divilbis
   d. Ingersol-Rand

C. Tubing

1. Copper tubing shall be new hard drawn, air grade, ASTM B75 for 3/8 inch and smaller or type L, ASTM B68 for 1/2 inch and larger, with solder joint or compression type fittings, at the option of the MSCC.
2. Plastic tubing (all sizes) shall be black virgin, polyethylene, ASTM D1248, Type 1, Class C, Grade 5, meeting crack test performance required by ASTM D1693 and be fire retardant (FR) rated. Multi-tube harness material shall be as specified above with a polyester film barrier and vinyl jacket not less than 0.062 inches thick. All non-metallic tubing shall be 1/4" O.D. minimum; micro-sleeve is not acceptable.

D. Pressure Reducing Valves:

1. Pressure reducing valves (PRV) shall be diaphragm operated, self-relieving, designed to provide precision control of air supply pressures, and shall be located after any filters or dryers.
2. PRV shall be capable of being mounted in any position, shall have locking set point handle, and SS inlet strainer.
3. PRV shall have metal or plastic body and shall be provided with 2-1/2” gauge of appropriate units.
4. PRV’s that are not self-relieving shall be provided with a separate relief valve of appropriate range.
5. Approved Manufacturers:
   a. Wilkerson
   b. Hankison
   c. Parker
   d. Van-Air
   e. Johnson
   f. Honeywell
   g. Siemens

E. DDC/Auxiliary/Local Control Panel Air Filters:

1. Provide an in-line air filter for main air supply to each DDC, auxiliary and local control panels capable of removing solids and petroleum-based oils.
2. Filter efficiency shall be 99.9% of 0.5 micron particles.
3. Filter element shall be visible and shall change color to indicate when to be replaced.
4. Minimum capacity shall be 500 SCIM and 30 psig.
5. Approved Manufacturers:
   a. Wilkerson
   b. Hankison

c. Parker
d. Van-Air

F. Coalescing Air Filters:

1. Provide a duplex set of coalescing air filters for the main air supply to all building temperature controls.
2. Duplex assembly shall include upstream and downstream pressure gauges and isolation ball valves for each filter.
3. Filter shall have a replaceable cartridge and drain port.
4. Filter shall be designed to remove oil and water droplets down to 0.01 microns and particulates down to 0.08 microns. Minimum capacity shall be 10 SCFM and 150 psig.
5. Coalescing filters shall be located downstream of refrigerated air dryers and upstream of chemical or desiccant dryers.
6. Approved Manufacturers:
   a. Wilkerson
   b. Hankison
   c. Parker
   d. Van-Air

G. Particulate Air Filters:

1. Whenever chemical or desiccant dryers are used, provide a duplex set of particulate air filters for the main air supply to all building temperature controls located downstream of chemical or desiccant dryers.
2. Duplex assembly shall include upstream and downstream pressure gauges and isolation ball valves for each filter.
3. Filter shall have a replaceable cartridge and drain port.
4. Filter shall be designed to remove particulates down to 0.1 microns. Minimum capacity shall be 10 SCFM and 150 psig.
5. Approved Manufacturers:
   a. Wilkerson
   b. Hankison
   c. Parker
   d. Van-Air

H. Refrigerated Air Dryers:

1. Provide a 120 VAC air-cooled refrigerated dryer capable of providing 35 deg. F dew point air.
2. Unit shall have power on light, high temperature light, valved air bypass piping, and air-to-air precooler/reheater.
3. Heat exchanger to be non-fouling, tube-in-tube, self-cleaning with smooth surfaces.
4. Compressor shall have hot gas bypass, as required, and shall be protected by thermal and current overloads.
5. Condenser fan shall have thermal overload protection.
6. Approved Manufacturers:
   a. Wilkerson
   b. Hankison
   c. Parker
   d. Van-Air

I. Regenerative Desiccant Air Dryers:

1. Provide a 120 VAC regenerative type desiccant dryer of the optimal size to ensure sufficient contact time and capable of providing -40 deg. F dew point air at 150 psig.

2. Units shall have an adjustable solid-state timer and purge flow economizer valve, on/off switch, power on light, separate fill and drain ports for ease of desiccant replacement without piping removal, heavy duty purge exhaust mufflers for quiet operation, non-lubricated air control valves, Teflon seated check valves, visible moisture indicator, visible purge flow indicator, pressure relief valve, ASME code constructed/stamped pressure vessels, SS support screens and air diffusers, tower pressure gauges, structural floor frame and stand for large sizes, wall mounting brackets and supports for small sizes, pre-piped and wired, and complete with air bypass piping.
3. Approved Manufacturers:
   a. Wilkerson
   b. Hankison
   c. Parker
   d. Van-Air

J. In-line Desiccant Air Dryers:

1. Provide an in-line desiccant dryer of the optimal size to ensure sufficient contact time and capable of providing 4,000 cubic feet of –40 deg. F dew point air at 150 psig with a dryer inlet temperature of 68 deg. F.
2. Units shall have a removable bowl or fill port for ease of desiccant replacement without piping removal, visible moisture indicator, and air bypass piping.
3. Not to be used as a substitute for Regenerative Desiccant Air Dryers when providing a control compressed air station.
4. Approved Manufacturers:
   a. Wilkerson
   b. Hankison
   c. Parker
   d. Van-Air

2.25 IDENTIFICATION AND LABELS

A. The MSCC shall provide black phenolic nameplates with engraved white minimum 1/4” high lettering (3/8” high at room differential pressure indicators), for each DDC or auxiliary panel, panel door mounted devices, and all LPI’s, permanently attached, to identify field panel number, building, area, service, etc.

B. All control devices located within auxiliary panels shall be labeled with legible identification that corresponds with the as-built drawings via black permanent marker. Use plastic or metal tags when it is not possible to mark directly on the device.

PART 3 - EXECUTION

3.1 INSTALLATION - GENERAL

A. All system components shall be installed per manufacturer’s installation recommendations.

B. Coordinate with 3rd party equipment supplier BACnet object lists and integrate into Owner's BAS system, including assigning Instance numbers based on Owner's convention. Submit a list of available BACnet objects and proposed naming convention for owner approval. Map all BACnet objects selected by owner (using owner designated naming convention) to be viewable at the field panel and BAS server.

C. Configure all controllers to serve BACnet data to BACnet Clients installed on the network. Each controller shall be configured and programmed to map all the BACnet objects associated with the controller, as selected by UM BAS. Provide a list of all objects to UM BAS at least 2 weeks in advance of this work. UM BAS will return the list indicating the specific objects to be mapped. Configure the controllers to utilize a change of value subscription with the clients that reside on the IT network. Change of value increments shall be as selected by the UM BAS department and tuned to minimize IT network traffic.

1. Data Sharing:
   a. Data communication from Building Controllers to Engineering Workstation and BAS web server shall be programmed to use Change of Value (COV) data sending and not continuous data polling to limit network traffic.
   b. Data communication parameters for analog inputs and analog values shall be operator configurable. Preliminary values are provided below, obtain approval from UM BAS of specific values for the project:
      1) Minimum Send Time (where property is available): 1 minute
      2) Maximum Send Time (where property is available): 15 minutes
      3) Send on Delta (COV):
         a) Space Temperature: ±1.0°F
         b) Process Temperature: ±1.0°F
         c) Duct Static Pressure: ±0.1" WC
         d) Relative Humidity: ±1.0%
         e) Air Flow: ±5% of calibrated span
         f) Water Flow: ±2% of calibrated span
         g) Water Pressure: ±0.5 psi
         h) Space Pressure (Pharmacy & ORs): ±0.005" WC
         i) Space/ Building Pressure (General): ±0.01" WC
         j) Space CO2 sensors: ±100 ppm
         k) Gas Monitoring (O2 Depletion): ±0.1% O2
         l) Not Mentioned Above: ±5% of range of sensor
         m) Analog Values (calculated values): Same as COV for calculation input values (e.g. calculated space air flow offset would have a COV of ±5% of the value range, same as individual air terminal air flows)
         n) Digital data points shall be sent whenever a state change occurs.

D. Ensure all control components are located and installed correctly so that the specified and intended performance and the sequence of operation is achieved, including components supplied and installed by others.

E. Wall mounted devices shall be mounted on an electrical box. Thermostats, room temperature sensors, push-buttons, and other adjustable devices meant for room occupant operation shall be mounted 44 inches to center above the finished floor (or as permitted by ADA requirements referenced in UM Design Guideline 1.0 Codes and Regulatory Agencies). This requirement does not apply to control panels and devices mounted in penthouses, mechanical rooms, and other spaces normally inaccessible to room occupants.

F. Zone thermostatic controls used to control both heating and cooling, e.g. a variable volume terminal unit also controlling a reheat coil and/or fin tube radiation, shall be programmed (DDC systems) or set up (non-DDC systems) with a heating setpoint of 71 deg. F and cooling setpoint of 76 deg. F, and a dead-band of 5 deg. F, unless indicated otherwise on the Drawings.

G. All set points and alarm points shown on the documents are preliminary. Finalize with the Engineer and Commissioning Authority prior to programming. Revise settings as required during commissioning.

H. For fan coil/terminal unit controllers and similar programmable electronic controllers, obtain approval of programmable settings from the Engineer and Commissioning Authority prior to programming. Revise settings as required during commissioning.

I. System I/O's shall not be split between different DDC panels.

J. Fire Alarm to Temperature Control Interface Box shall be mounted at the DDC panel array.

K. Install all conduit, wiring, cable, tubing and equipment in a first-class manner, using proper tools, equipment, hangers, and supports, and in locations as required for a neat, attractive installation. No material shall be exposed if it is possible to conceal it. Exposed materials shall be installed only with consent of the Owner. Conduit shall not be supported from work of other trades.

L. For all rooms with a pressure or CFM offset, seal the inside of conduits routed to room mounted devices at the point where the device is mounted. Utilize material specifically made for this purpose.

M. Support all sensors as recommended by the manufacturer. Averaging element temperature sensors shall be mounted securely from coil frames in a horizontal serpentine manner at intervals not to exceed 4 feet; provide rigid supplemental metallic support structure when required. For element directional changes, minimum bend radius shall be no less than 2". Use mounting clips which prevent element wear due to vibration.

N. Install low temperature detectors as recommended by the manufacturer: devices shall be mounted securely from coil frames horizontally with no upward pitch at intervals not to exceed 1 foot. Provide rigid supplemental metallic support structure when required. For element directional changes, minimum bend radius shall be no less than 2". Use mounting clips which prevent element wear due to vibration.

O. Panels and meter enclosures shall be rigidly mounted. Panels shall be wall mounted or provide free-standing Unistrut type frames for floor mounting.

P. Provide a pouch or other containing method inside each control panel and insert a copy of the corresponding system control drawings.

Q. Provide supplemental Hand-Off-Auto switches and contactors to permit automatic or manual operation of equipment from the DDC system (e.g. single phase equipment which uses fractional motor starters, etc.).

R. Extreme care shall be used in making connections to other equipment to ensure that the safeties on this equipment are not inadvertently bypassed or overridden by the DDC.

S. Ensure all dampers, valves, thermowells, flowmeters, and other miscellaneous control components are located and installed correctly so that the specified and intended performance and the sequence of operation is achieved, including components supplied and installed by others.

T. Limit switches used on dampers shall be set at approximately 95% of full stroke (opened and closed).

U. Flow meters shall be installed with at least 10 diameter of straight pipe length upstream and five diameter of straight pipe length downstream or per manufacturer's recommendations.

V. Power supply to flow meters and BTU meters shall be 115 VAC from the auxiliary DDC panel, and power connection for each device shall be installed with a lockable local service disconnect. Flow meter transmitters/displays and BTU meters shall be mounted 4 feet above finished floor. They shall be located at the DDC panel array unless the maximum available cable length is exceeded. All meter components, including sensors, shall be mounted in accessible locations.

W. Airflow sensors shall be installed so that the manufacturer's recommended upstream and downstream conditions are achieved to produce maximum accuracy.

X. Remove any unused items that are part of renovations or demolition, including, but not limited to: conduit, wire, tubing, controllers, controlled devices, relays, enclosures, etc. Do not abandon in place.

Y. Locate all control components and accessories such that they are easily accessible for adjustment, service and replacement.

Z. Install constant flow fume hood monitors surface mounted on the front of the fume hood. Furnish exact dimensions and location to the fume hood factory to allow for concealed wiring to the monitor.

AA. Install constant flow fume hood sash position sensors and sash travel limit brackets in a neat and workmanlike manner. Install cables and wires in a manner which avoids contact by the user during normal use, and allows vertical sashes to be positioned without binding, twisting or tangling.

BB. Flush mount room differential pressure indicating gauges above one door outside of each lab, animal room, and where indicated, in the corridor wall at the entrance expected to be most frequently used, or as otherwise shown. Surface mounting is permitted on non-drywall walls. Mount related pressure sensor in ceiling or wall of lab. Attach tubing to gauge so that the intended room offset is displayed on the largest scale range of the gauge. Mount POS/NEG label adjacent to gauge and visible from floor.

3.2 CONTROL PANELS

A. Arrange control panel I/O modules and points as follows:

1. Processor, power & communication modules – top right

2. DI points – center right
3. DO points – bottom right
4. AI points – top left
5. AO points – bottom left

B. Control module address layout shall be as follows:

1. Right column – Address keys 1-6
2. Left column – Address keys 7 and above.

C. Control panels shall be assembled in a neat and workmanlike manner:

1. Maintain separation of class 1 and class 2 wiring. Use separate conduit connections to control panel for each wire type. I/O wiring shall enter control panel through a conduit directly above the module that it will connect to.
2. Wiring shall be bundled neatly together at 4-inch intervals using nylon tie straps. Wire bundle straps shall be secured to panel backplane using screws or mounting rails. Wiring troughs shall not be used.
3. Any extra wiring shall be coiled up in the wiring trough, strapped, and tagged as spare.
4. For door mounted devices, the installing contractor shall properly dress and bundle the wiring or tubing in a way that does not interfere with fully opening and closing the door.
5. Wiring shall be tagged with point address or wire number 4 inches down from the point at which the wire enters the cabinet.
6. Route wiring into panel for each termination leaving enough excess wire to reach the bottom of the enclosure. Wire shielding and jacketing for all signal wiring shall be left intact to within 4 inches of final termination.
7. The 24VAC power supply in the DDC panel shall only be used to power the controller and shall be fed by a dedicated 120V circuit. Provide separate control transformers as required to power other devices.
8. Network switches shall be installed on the floor of the cabinet or lower right corner of the backplane.
   a. Network jacks and cabling shall be installed neatly and strapped securely to the panel or backplane.
   b. Plug in power supply for network switch shall be plugged into the 120V service outlet with extra cord coiled neatly.
9. Controller module labels shall be installed into each module with final point names and addresses listed. Where not possible, include a printout of panel point addresses with the as-built drawing set left in panel.
10. Auxiliary panels shall be powered with a dedicated 120VAC circuit and contain a service disconnect in the upper right corner. Final circuit number shall be tagged on switch cover.
11. Auxiliary panel components shall be laid out in an organized manner and positioned to conserve available space for future use. All devices shall be mounted on panel backplanes. Auxiliary panels shall not be loaded beyond 90% of the backplane capacity.
12. Motor load wiring shall not be routed into or through control panels.
13. No voltage higher than 120 VAC shall be routed into or through control panels.

3.3 INSTALLATION – POWER, CONTROL, AND NETWORK WIRING

A. All wiring to devices installed inside auxiliary/local panels shall enter/exist via terminal strips, except twisted/shielded sensor wiring.

B. DDC sensor cabling shall not be spliced.

C. Refer to Part 2 for additional installation requirements.

3.4 INSTALLATION – PNEUMATIC AIR

A. Provide a control air shut-off valve for each panel. Downstream, install an in-line air filter for main air supply to each DDC, auxiliary and local control panel.

B. Plastic tubing may be used in all locations, except in mechanical rooms, shafts, or exposed locations, unless run in conduit.

C. Tubing shall not be attached to conduits with current carrying conductors or fire protection piping. It shall be adequately supported with no noticeable sagging between supports, and protected from abrasion and galvanic corrosion. All pneumatic tubing shall be concealed in finished areas.

D. A PRV shall be installed on each floor to provide control air supply, when control air is required on the floor.

E. Provide all required control air and associated tubing.

3.5 LABELLING

A. Labelling methods and color scheme shall be reviewed and approved by UM before proceeding.

B. Labels for devices in offices, public, and similar spaces shall be thermal printed on clear adhesive tape.

1. Label terminal unit controllers with address (non-BACnet) or Instance number (BACnet), affixing label to ceiling grid or access panel at unit location. Use nominal 3/16” high black block-style font.
2. Label exterior of room mounted control devices with address (non-BACnet) or Instance number (BACnet). Use nominal 12 point block-style black font.

C. Label the field end of every DO/DI/AO/AI connected to a B-BC controller. Labels shall be thermal printed on white adhesive tape.

1. Nomenclature shall include point name and address (non-BACnet) or Instance number (BACnet). Use nominal 12 point block-style black font attached to exterior of device.

D. Refer to Part 2 for additional labelling requirements.

3.6 CALIBRATION, START-UP, AND COMMISSIONING

A. Perform commissioning activities as described here-in and in accordance with Related Sections Participate in the commissioning process in accordance with the project commissioning documents. This applies to all controls including those provided as part of 3rd party equipment.

B. All work performed at the Building Automation Server shall be by personnel approved by the University of Michigan.

C. Except where specifically indicated elsewhere in this specification, the MSCC shall calibrate and start-up control devices and systems, including compressors, dryers, etc.

D. Program all auto calibration routines to self-calibrate outside the hours of normal space occupancy. When this is not possible, program the self calibration to occur during hours of lowest occupancy. Establish with the Owner, working with the Commissioning Authority, a self calibration schedule that will be the least intrusive to building occupants. Phase self-calibration routines (as opposed to all devices simultaneously calibrating) to avoid negatively impacting air handler operation.

E. Provide all necessary equipment, test gases, etc. for calibration, and calibrate all sensors (i.e. CO2, CO, combustible gas, etc.) in accordance with the manufacturer's recommendations. Specialized equipment, test gases, etc. shall be turned over to owner upon completion and acceptance.

F. After control components have been installed and connected, test, adjust and re-adjust as required all control components in terms of function, design, systems balance and performance. Control devices, linkages and other control components shall be calibrated and adjusted for stable and accurate operation in accordance with the design intent and to obtain optimum performance from the equipment controlled. All control valves shall be stroked and spring ranges verified and set. All dampers shall be stroked to verify proper and smooth operation. Cause every device to automatically operate as intended to ensure its proper functionality. Make systems ready for acceptance tests.

G. Provide tuning of all control loops:

    1. Adjust PID control loop parameters to optimize system performance and response time.
    2. Loops shall be tuned to provide the accuracy indicated on the contract documents. Where not indicated, provide the following:
        a. Temperature +/- 1 deg F
        b. Duct static Pressure +/- 0.1 in WC
        c. Hydronic pressure +/- 0.5 PSIG.
        d. Other setpoints: As required for the application and directed by the Engineer.
    3. For system setpoints that are impacted by seasonal variations, return to verify and optimize control loop tuning.
    4. Response time to achieve setpoint shall be as typically achievable for such control loops or as indicated on the contract documents. Interpretation of typically achievable response times shall be as determined by the Engineer.

H. Provide support to UM BAS for connecting and backing up all field controllers to the server. At least one week prior to connecting any field panel to the BAS server, provide the following for UM BAS approval:

    1. Field panel backup file (.P2 extension)
    2. Field panel backup log file (.log extension)
    3. Electronic copy of current field annotated (red-lined) control diagrams for systems or panel being connected.
    4. Any special alarm or alarm handling requirements

I. Provide any trend setup, reporting and trend graphs in advance of functional testing and by dates specified by the Commissioning Authority to verify proper operation of controls and systems. Trend intervals and storage duration shall be as designated by the commissioner. All such trends shall be deleted before each panel is connected to the BAS server.

J. Set constant flow fume hood monitor alarms as follows:

1. Insufficient differential static pressure/air volume:
   a. Face velocity 80 FPM (standard hoods) or 60 FPM (Reduced Face Velocity Hoods.
2. Sash above the sash stop position.
   a. Time delay to re-alarm after silence button pushed: 10 minutes.
   b. Alarm shall clear when sash returned to sash stop position or lower.
   c. Floor mounted hoods: Alarm shall activate when any sash is above its sash stop position; time delay and alarm clear shall be same as above.

ARTICLE 3.7 IS WRITTEN ASSUMING A LARGE PROJECT. EDIT AS APPROPRIATE, IN PARTICULAR FOR SMALLER PROJECTS.

3.7 TRAINING

A. Provide comprehensive training for the entire mechanical controls system.

B. The party that performed the portion of the control work as outlined in Section 1 shall provide the training related to that work.

C. Provide an agenda of the proposed training for approval by the Commissioning Authority.

D. Training shall include a combination of site walkthrough and classroom training as required to review the complete control system. At minimum provide the following:

1. One half hour minimum of classroom training per each construction drawing sheet included for the mechanical controls. Provide a complete explanation of the following for the controls on each sheet:
   a. The Sequence of Operation, alarms, and trend logs
   b. Schedule and grouping for each piece of equipment
   c. Overview of program layout and modules including explanation of each section of code and variables used.
   d. Identify which sensors are critical for the proper function of the controls.
   e. Location of critical sensors and manual reset devices
   f. The calibration, setup, and maintenance of all control devices
   g. Review the contents of the O&M relative to the controls on each sheet.
   h. Graphical user interface training. Review each system and floor plan graphic and explain the meaning of each point type.
   i. Review of terminal equipment controller applications used for the project including all subpoints and custom applications.

j. Interfaces to other systems (e.g. fire alarm system, packaged controllers, etc.)

2. Also to be provided as part of classroom training:
   a. A review of the network diagram and the type, location, and function of each network device
   b. Demonstrate bench calibration of critical or unique sensors. The Owner and Commissioner shall have exclusive rights to identify which sensors require this training. Maximum 8 hours training.
   c. Programming of non-DDC controllers including passwords, alarms and setting tuning parameters and set point limits.
3. One half hour minimum of field training per each construction drawing sheet included for the mechanical controls. At minimum provide the following:
   a. Walk down each piece of equipment controlled, generally reviewing the Sequence of Operation.
   b. Identify the location of:
      1) Controllers and DDC panels
      2) Critical sensors and manual reset devices. Demonstrate the reset of devices.
      3) Damper operators and control valves
      4) Meters, including any UM data acquisition panels
      5) Pneumatic system components
      6) UPS
      7) Network devices
   c. Review the information presented and operation of touchscreen displays and other indicating devices.
   d. Interfaces to other systems (e.g. fire alarm system, packaged controllers, etc.)

END OF SECTION 230900