

**BuildingName**  
**The Description of the Project**  
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**SPECIFICATION DIVISION 23**

NUMBER            SECTION DESCRIPTION

**DIVISION 23**

SECTION 230900 - MECHANICAL SYSTEMS CONTROLS

**END OF CONTENTS TABLE**



DIVISION 23  
SECTION 230900 - MECHANICAL SYSTEMS CONTROLS

REVISION NOTES:

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 APPROVED 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.

SEPTEMBER 2014: GENERAL REVISION INCLUDING: U-M TO PROVIDE UPS ENCLOSURE, REQUIRE THAT ALL COMPONENTS TO ACHIEVE THE SEQUENCE OF OPERATION BE PROVIDED, REQUIRE ALARMS BE PROGRAMMED, "ITEMIZE QUOTATION" REVISED TO "WHEN REQUESTED", "SUBMITTALS" REVISED TO REQUIRE DATA SHEETS BE ORGANIZED BEHIND TABS, VARIOUS TECHNICAL UPDATES INCLUDING: RELOCATED CONTROL VALVE RANGEABILITY REQUIREMENTS TO APPLY TO CONTROL VALVES, TEC ELECTRONIC ACTUATORS REVISED TO SPECIFY A MINIMUM STROKE LENGTH, "PNEUMATIC ACCESSORIES" REVISED TO ELIMINATE DRYERS WHEN USING TUNNEL AIR. REVISED STAT HEIGHT TO 44" A.F.F. TO MATCH ELECTRICAL SPEC.S AND ADA. D. KARLE FOR HVAC MTT.

DEC. 2013: REVISED BTU METER DESCRIPTION TO DELETE SPARLING (BTU COMPUTER NO LONGER AVAILABLE FROM SPARLING), IMPROVE DESCRIPTION, ADD BTU METER ENCLOSURE INFO. DELETED SOME MFR.S AS APPROVED FROM STM AND STM CONDENSATE LIST BASED ON FEEDBACK FROM U-M PLANT ON QUALITY PROBLEMS. D. KARLE FOR HVAC MTT.

OCT. 2011: ADDED REQUIREMENT TO PROVIDE UPS PANEL (ARTICLES 1.1 AND 2.11) OPEN WIRE (ARTICLE 2.6) AND IMPROVED THE DAMPER SPECIFICATION (ARTICLE 2.8) (DK, PER HVAC MECH TECH TEAM)

LATEST REVISION DATE: 1/4/11 - BY S. WOLDT FOR THE HVAC MECH/TECH TEAM

DEC. 2010: REVISED FOR COMPLIANCE WITH ASHRAE 90.1 2007 (DK, PER MECH TECH TEAM)

DEC. 2010: ADDED PART 2.3, SPEC. FOR FAN COIL CONTROLLER. ADDED SPEC FOR ELECTRICALLY ACTUATED BALL STYLE CONTROL VALVES (2.7) (DK, PER MECH TECH TEAM).

6/26/06: ADDED ADA REQUIREMENTS FOR DEVICE MOUNTING HEIGHTS, SECTION 3.1.B. (DK)

5/31/06: ADDED PARAGRAPHS C AND D TO ARTICLE 2.5, REQUIRING CONTROLS CONTRACTOR TO RUN 120 VAC POWER TO ALL CONTROL ACCESSORIES. THIS REQUIREMENT WAS ONLY PARTIALLY COVERED IN SOME SECTIONS. CLARIFIED IN 1.1.C.10 THAT CONTRACTOR DELIVERS AND PICKS UP LPI DOORS FROM U-M'S SHOP. (DK)

EDITOR'S NOTE:

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. COMPONENTS TO BE INSTALLED IN AUXILIARY CONTROL PANELS (LOOP POWERED INDICATORS, E.P. RELAYS, P.E. SWITCHES, DIFFERENTIAL PRESSURE TRANSDUCERS, ETC.) SHALL BE SO INDICATED BY SOME METHOD. (I.E. ASTERISK)

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 WHICH INCLUDES HOODS WITH 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. Division 26: Electrical
  - 2. 220523 Valves
  - 3. 233600 Air Terminal Units
  - 4. 230910 VAV Fume Hood Laboratory Air Flow Controls

**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.

*IF THE PROJECT WILL NOT SPLIT THE WORK BETWEEN THE MECHANICAL SYSTEMS CONTROLS CONTRACTOR AND THE UNIVERSITY OF MICHIGAN AS DESCRIBED IN 1.3, REVISE 1.3 AND THE BALANCE OF THE SPECIFICATION ACCORDINGLY.*

**1.3 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. The Mechanical Systems Controls Contractor shall be a direct Sub-contractor to the Contractor.
- C. 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. Provide control work and programming of all TECs in all labs except in rooms with VAV hoods, including combination sash fume hoods.
  - 3. Provide fume hood monitors except in rooms with VAV hoods, including combination sash fume hoods.
  - 4. Install Terminal Equipment Controllers (TECs) on terminal equipment. Install Room Temperature Sensors (RTS's).

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

5. Connection of new DDC panels to the Automation Level Network (ALN) to permit communication to the Building Automation System (BAS). Ethernet connection of Utility Meters to host computer. Connection to host computer via trunk connection to an existing DDC panel, communications closet, or local Ethernet data port, and as indicated on the drawings.
6. Engineering, submittals, as-built drawings, and operation and maintenance manuals. Configure modular DDC panel terminations such that analog inputs and analog outputs terminate on separate modules, do not intermix analog outputs and inputs on the same module.
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. Auxiliary panels shall not be smaller than 24"x24", and shall have a 1' high by minimum 2' wide (but not less than panel width) contiguous clear area which can be used for future expansion. 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. Install a UPS panel directly under the DDC enclosure. Provide all interconnecting power wiring between the DDC panel power supply and the UPS panel duplex receptacle.
10. Provide a 6"x 6" wiring trough extending over and between each DDC, auxiliary temperature control, and LPI panel.
11. Installation of U-M furnished DDC and UPS panel enclosures.
12. Provide thermostats, control valves, dampers, operators, meters, control air tubing, etc.
13. Provide gauges, indicating devices, electric and electronic control accessories, and other control system devices.
14. Provide setup/programming, calibration and start-up services of non-DDC control systems, e.g. electronic room temperature controllers.
15. Termination of all wires for input/output (I/O) devices external to the DDC panel, including, but not limited to: sensors, H/O/A switches, hard-wired safeties, relays, etc., TECs, RTS's, Field Level Network (FLN), and any other field devices.
16. Termination of all wires inside auxiliary panels.
17. 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 communication wiring to utility data acquisition panels. Terminations inside panels by U-M.
18. Provide site supervision of mechanical control work and coordination with related electrical and fire alarm work and packaged controls.

19. 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.
20. 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.
21. Start-up, calibration, and checkout of sensors, transducers, thermostats, control valves, dampers/damper operators, meters, and all other components provided.
22. 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.
23. Training of U-M personnel to familiarize operations staff with the configuration, operation, and maintenance of provided controls.

D. DDC related work by the University of Michigan:

1. Termination of all wires and pneumatic lines within the DDC panel, excluding the power supply.
2. Termination of the I/O wires that run between the DDC panel and the auxiliary panel(s) (DDC panel end only).
3. Termination of the LPI wires within the LPI panel(s).
4. Point database entry.
5. Create, enter and checkout all "Powers Process Control Language" (PPCL) programming, excluding rooms designated as laboratories. To include all DDC panels and DDC Terminal Equipment Controllers.
  - a. Provide all programming required to achieve the sequence of operation and the control intent indicated on the documents.
  - b. Program the following alarms, whether specifically indicated in the sequence of operation or not. Include appropriate deadbands and time delays:
    - 1) For every indicated or implied 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.
  - c. 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.
6. Provide temporary programming to provide building heating or cooling during construction.

7. Selection of the appropriate size, type, and quantity of DDC panels to be used.
8. Provide all DDC panel circuit boards, associated I/O modules, and communication hardware.
9. Furnish DDC panel UPS.
10. Furnish TECs and RTS's for all rooms types except labs with VAV fume hoods.
11. Furnish all DDC panel enclosures and UPS enclosures.
12. Provide 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.
13. Punch the LPI panel doors provided by MSCC. MSCC must drop off and pick up doors from U-M's shop.
14. Start-up and checkout of DDC panels and termination of associated sensors, transducers, and other components at the DDC panel.
15. Verify correct functionality of every DDC point associated with every DDC panel, and for every input and output associated with every TEC.
16. 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.
17. Commission DDC panels and verify each sequence of operation including at TECs and similar DDC controllers, with the project CxA.
18. Training of U-M personnel on the various Sequences of Operation, the DDC panel and its connections, the LPI panel, the UPS panel, and the TECs or similar controllers and their related components that were provided by the University of Michigan.

#### **1.4 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, 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.

#### **1.5 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. Honeywell, Inc.
  3. Johnson Controls, Inc.

**EDITOR: CONTACT THE UM DESIGN MANAGER TO DETERMINE WHICH OF THE ABOVE CONTROLS INSTALLATION CONTRACTORS ARE TO BE LISTED AS ACCEPTABLE FOR YOUR SPECIFIC PROJECT. DO NOT LIST CONTRACTORS**



**IN HIDDEN TEXT WITHOUT SPECIFIC PERMISSION FROM U-M DESIGN  
MANAGER OR PLANT ENGINEER.**

**1.6 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. 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.
- D. 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.

**1.7 SUBMITTALS**

- A. The Mechanical Systems Controls Contractor (MSCC), prior to submitting the specified number of submittal drawings through the General Contractor (GC) or Construction Manager (CM) shall:
  - 1. Pre-submit two copies of preliminary shop drawing submittals directly to the designated Plant Operations Engineer and. Submit copies of the transmittal only to the GC or CM.
  - 2. The Plant Engineer will meet with the MSCC to discuss his review comments.
  - 3. The MSCC shall incorporate the review comments, as required, into the final shop drawing submittals. No work shall be done until the final submittals are approved.
- B. Shop drawings shall contain, as a minimum, 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. Wiring of each point to the DDC panels, including terminal block numbers.
  - 3. 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.
  - 4. Complete Sequence of Operation for each system being controlled, including set points, alarms settings, etc. in narrative format.
  - 5. Schematic diagram of the total DDC system layout, including all panels, trunk cables, peripheral devices, locations, etc.
  - 6. Pneumatic compressed air supply equipment, risers, and major tubing runs.
  - 7. Complete bill of materials to identify and quantify all devices.
  - 8. A schedule of all nameplates and associated wording.

9. An index of sheets for ease of access.
  10. Network diagram indicating routers, servers, and peripheral devices, including location of each device (room number) and indicating network connection points to Owner's BAS and/or Utility Meter data acquisition system.
  11. Wiring diagrams and locations of power supplies.
  12. 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., and offset CFM; lab subnet description, name, and network address; network and power trunk identifier.
      - 2) Model number of each control component.
      - 3) Function of each TAU and control component
- C. 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.
    - j. Method of actuator mounting and actuation.
    - k. .
  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. TECs:
- a. Device tag.
  - b. Equipment served/function.
  - c. Model number and application code.
  - d. Associated sensor location/tag.
  - e. Size, control values, etc.

D. Submittal Requirements

- 1. Shop drawings shall be 11" x 17" size (minimum).
- 2. All schematics and drawings shall be done on CAD. The electronic files shall be in IBM compatible Autocad version 2004 (or above) format.
- 3. Product data shall include description and complete engineering data for each control system component.
- 4. Data sheets shall be organized behind sheet tabs. Each sheet tab shall indicate the category or component name (i.e. valves, dampers, relay & switches, thermostats, temperature transmitters, pressure transmitters, air flow stations, TECs, etc.).
- 5. Since many items are interrelated and should be checked concurrently, all of the MSCC's DDC related shop drawings shall be submitted at one time. No consideration will be given to partial submittals, except valve and damper submittals on approval only. Any partial submittals must be included in the complete submittal package.

E. Project Record Documents

- 1. Revise shop drawings to reflect actual installation and operating sequences and provide a final electronic file on CD.

F. Operation and Maintenance Manuals

- 1. The MSCC shall provide the specified number of copies of complete operation and maintenance instructions for all system components furnished.
- 2. Include as-built system schematic drawings and wiring diagrams.
- 3. Indicate final set points, settings, and adjustments of all components.
- 4. 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.

**1.8 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.

**1.9 DELIVERY, STORAGE AND HANDLING**

- A. 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 on-going construction activities.

**1.10 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.

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

**2.2 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 PPCL 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. 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.**

- C. 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.
- D. 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. 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.

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

**2.3 ELECTRONIC SENSORS, INDICATORS, TRANSDUCERS AND COMPONENTS**

A. Temperature and Humidity Sensors:

- 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.
  - 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. Outside air sensor shall be designed to mount on a conduit, include an elbow type enclosure, sun shield, and have a calibrated span of -58-122 deg.
  - e. Liquid immersion temperature sensors shall have 5 1/2" long probe with SS well, and weather tight enclosure. Transmitters for chilled water shall have a calibrated span of 20-120 deg. F or 30-250 deg. F for heating applications.
  - f. 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.
  - g. Room temperature sensors (non-TEC) shall have a span of 20-120 deg. F, locking covers, and when pneumatic, match the pneumatic thermostats used.
  - h. 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.
  - i. Approved Manufacturers:
    - 1) TCS
    - 2) Siemens
    - 3) Minco
- 2. Outside Air Master Temperature and Humidity Sensors - Dual System:
  - a. 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.
  - b. 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.

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- c. Approved Manufacturers:
  - 1) Vaisala
- 3. High Precision Temperature Sensors: (for temperature inputs used for BTU calculations)
  - a. 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.
  - b. Liquid immersion sensors shall have welded stainless steel thermowell. Transmitters shall be of the potted type or shall have a thermally isolated watertight enclosure. Length of sensor and thermowell shall be selected based on the diameter of the pipe to provide accurate, reliable and homogeneous sensing of the liquid temperature.
  - c. Approved Manufacturers:
    - 1) TCS
    - 2) Minco
- 4. Humidity Sensors:
  - a. 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.
  - b. Room Sensors shall have locking cover.
  - c. Duct Sensors shall have duct probe and mounting plate.
  - d. Approved Manufacturers:
    - 1) Siemens
    - 2) TCS
    - 3) General Eastern
    - 4) Vaisala
- 5. Combination Room Temperature and Humidity Sensor:
  - a. 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.
  - b. 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.
  - c. 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.
  - d. Provide with certificate of calibration.
  - e. Approved Manufacturers:
    - 1) Vaisala HMW92 Series
- 6. Vivarium Temperature and Humidity Sensors: (for wet service)



- a. 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.
- b. 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.
- c. Combination T & H units shall comply with the above, but shall be mounted in a single enclosure.
- d. 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.
- e. Approved Manufacturers:
  - 1) Vaisala (combination temp. and humidity)
  - 2) TCS (temp. only)
  - 3) Siemens(temp. only)

B. Loop-Powered Indicators

- 1. All 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.)

C. Pressure and Flow Sensors

- 1. Air Differential Pressure Transducer:
  - a. 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.
  - b. Safe over pressure rating shall be minimum 5 times the range.
  - c. Temperature compensated with thermal error of not greater than 0.04% of full scale in temperature range of 40 to 100 deg. F.
  - d. Accuracy shall be 1% of full scale.
  - e. Approved Manufacturers:
    - 1) Air Monitor
    - 2) Setra
    - 3) Modus
- 2. Air Static Pressure Sensors:

- a. 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.
  - b. Wall or ceiling 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.
  - c. 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.
  - d. Accuracy shall be 1% of actual pressure value.
  - e. 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.
  - f. Approved Manufacturers:
    - 1) Air Monitor
    - 2) Siemens
    - 3) Dwyer
    - 4) Honeywell
3. Airflow Sensors:
- a. 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.
  - b. 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.
  - c. Sensors shall not protrude beyond the surface of the array, nor shall be adversely affected by particle contamination normally present in building airflow systems.
  - d. 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.
  - e. Accuracy shall be a minimum of 3 percent of actual airflow over the designed range of flow.
  - f. 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.
  - g. Approved Manufacturers:
    - 1) Air Monitor
    - 2) Tek-Aire
    - 3) Dietrich-Standard
    - 4) Ramsey Air
4. Steam/Liquid Differential Pressure Transducers: (flow only)

- a. Each differential pressure transducer 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.
  - b. 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.
  - c. The transducer 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.
  - d. Provide a drain valve for each side of the pressure chamber. Furnish and install mounting brackets appropriate for the installation location.
  - e. Span and zero shall be individually adjustable.
  - f. Shall be 2-wire and 4-20mA output.
  - g. Approved manufacturers:
    - 1) Tobar
    - 2) ITT Barton
    - 3) Dietrich - Standard
    - 4) ABB
    - 5) Siemens
    - 6) Rosemont/Fischer
    - 7) Honeywell
5. Steam/Liquid Differential Pressure Transducers: (pressure only)
- a. Each differential pressure transducer 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.
  - b. The accuracy, including linearity, hysteresis and repeatability, of the transducer 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.
  - c. The transducer 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.
  - d. Provide a drain valve for each side of the pressure chamber. Furnish and install mounting brackets appropriate for the installation location.
  - e. Span and zero shall be individually adjustable.
  - f. Shall be 2-wire and 4-20 mA output.
  - g. Approved manufacturers:
    - 1) Tobar
    - 2) ITT Barton
    - 3) Dietrich - Standard
    - 4) ABB

- 5) Siemens
6. Indication Gauges for Steam/Liquid Pressure Transducers:
  - a. Each transducer shall come with an indicating gauge that reads in GPM for flow measurement or inches WC for pressure sensing. The gauge shall be analog differential pressure type piped in parallel to the transducer.
  - b. The analog pressure gauge shall be selected and calibrated for the same span as the transducer it serves.
  - c. The accuracy, including linearity, hysteresis and repeatability, of the gauge for measuring differential pressure shall be better than 3% of the span stated above throughout its span. Calibration data shall be included on an embossed tag attached to each gauge.
  - d. The gauge shall not be damaged by pressures of up to 500 psig on either side of the gauge and all wetted parts shall be inert in the presence of up to 40% concentration of ethylene or polypropylene glycol in water.
  - e. Scale shall be a minimum of 4.5" diameter. Furnish and install two bleed fittings for each gauge and mounting brackets appropriate for the installation location.
  - f. Gauges shall be field mounted. Provide a LPI for readout at the DDC panel array. Provide a phenolic identification tag for each gauge and indicator.
  - g. Approved manufacturers:
    - 1) Beckman
    - 2) Moore
    - 3) Testoterm
    - 4) Dwyer
    - 5) Transducer manufacturer's gauge
7. Steam/Liquid Flow Sensors: (differential pressure type)
  - a. 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%.
  - b. 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%.
  - c. Approved Manufacturers
    - 1) Preso
    - 2) Gerand
    - 3) Dietrich-Standard (Annubar Diamond II)
8. Three Valve Manifolds for Steam/Liquid Pressure Transducers:
  - a. 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.
  - b. 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.
  - c. Approved Manufacturers:
    - 1) 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.**

9. Liquid Flowmeters: (Electro-Magnetic Type)
  - a. 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:
    - 1) Flowmeter Liner:
      - a) Heating hot water, domestic hot water, and other water systems operating at or above 110°F: Teflon
      - b) Chilled water, domestic cold water, and other water systems operating below 110°F: Polyurethane
      - c) Steam condensate: Teflon to 300°F, Ceramic over 300°F, and as suitable for the expected fluid conditions.
    - 2) Accuracy:
      - a) At 1 to 33 feet per second velocity: ±0.5% of rate.
      - b) At 0.3 feet per second velocity: ±2% of rate.
    - 3) 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.
    - 4) 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.
    - 5) Meters for steam condensate shall be capable of sensing with condensate conductivity down to 6 µS/cm.
  - b. Provide a phenolic tag for each transmitter to identify service and meter ID number (i.e. SECONDARY CHILLED WATER FLOW, FM-1, etc.).
  - c. Approved Manufacturers (Water)
    - 1) ABB
    - 2) Siemens
    - 3) EMCO
    - 4) Rosemount
    - 5) Krohne

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- 6) Onicon
- d. Approved Manufacturers ( Steam Condensate)
  - 1) Rosemount
  - 2) Krohne
  - 3) ABB
- 10. Steam (Vapor) Flowmeters (Vortex-shedding type):
  - a. 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:
    - 1) Temperature range shall be -40 to +750°F.
    - 2) Accuracy shall be 1.0% of rate and 0.1% of full scale.
    - 3) Repeatability shall be 0.15% of flow rate.
    - 4) 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.
    - 5) Meter range shall accommodate the minimum and maximum expected flow for the steam pressure at the installed location.
    - 6) Meter shall be equipped with a temperature and pressure compensation feature.
  - b. Provide a phenolic tag for each transmitter to identify service and Meter ID number (i.e. MEDIUM PRESSURE STEAM FLOW - LSI BUILDING, etc.).
  - c. Approved Manufacturers
    - 1) Rosemount
    - 2) Krohne
    - 3) ABB
- 11. Steam (Vapor) Flow Meters (Differential-pressure type)

- a. 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 re-programmed 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:
  - 1) Temperature range shall be -40 to +750°F.
  - 2) Accuracy shall be 1.0% of rate or better and 0.1% of full scale.
  - 3) Repeatability shall be 0.15% of flow rate.
  - 4) 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.
  - 5) Meter range shall accommodate the minimum and maximum expected flow for the steam pressure at the installed location.
  - 6) Meter shall be equipped with a temperature and pressure compensation feature.
  - 7) V-cone horizontal pilot lines shall be pitched back to steam lines and shall not trap condensate.
- b. 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.).
- c. Approved Manufacturers
  - 1) McCrometer (V-cone-style meter)
  - 2) Preso (Venturi-style meter)
  - 3) 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". 12.b IS USED WHEN UTILITY (REVENUE) BILLING OF A SYSTEM IS PLANNED. 12.a 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.*

- 12. BTU Metering
  - a. DDC BTU metering shall be accomplished using the following equipment at each metering point:
    - 1) One (1) liquid flowmeter unit with transmitter as specified elsewhere in this section.
    - 2) 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.

- 3) 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.
- b. When a BTU meter is indicated on the control drawings, provide a Flow/BTU computer which is programmable for various flow meter types including linear, square law, or multi-point linearization data interpretation.
- 1) Inputs shall include 4-20ma flow from flow meter, and 4-20ma from two temperature sensors.
  - 2) Flow and temperature inputs shall be simultaneously connected to this computer and looped to the local DDC panel.
  - 3) 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:
    - a) Two 4-20ma analog outputs indicating btu, mass or volume flow rate, temperature 1, temperature 2, delta temperature, pressure, density, and peak demand.
    - b) One isolated pulse output indicating btu, mass or volume total
    - c) 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.
  - 4) Outputs shall be stored in a battery backed data logger, selectable for continuous or periodic log modes.
  - 5) 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.
  - 6) 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.
  - 7) Provide a phenolic tag for each transmitter and flow computer (as applicable) to identify service and ID number (i.e. CHILLED WATER BTU METER - LSI BUILDING, etc.).
  - 8) Mount Flow/BTU computer in a NEMA 4 enclosure: Minimum size 16" (H) x 14" (W) x 8" (D), hinged cover, padlockable 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.
  - 9) Approved Manufacturers and Models for Flow/BTU Computer:
    - a) Kessler-Ellis Supertrol II with MS816 enclosure.

D. 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

E. 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

F. 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

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G. 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

H. 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

I. 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

J. 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, green - power supply ok, red - condensation sensed, contact open.
  - f. With pipe mounting bracket.

K. 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.

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- 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: EBTRON, Inc. Model CENSUS - C100, Single-entry interior door occupancy counter.

L. 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: Kele Model RAD-1.

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

**2.4 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 of the corresponding AHU serving the space (by MSCC).
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.**

**2.5 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 of the corresponding AHU serving the space (by MSCC).
  - 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

**2.6 DDC TERMINAL EQUIPMENT CONTROLLERS (TEC) AND RELATED ROOM TEMPERATURE SENSOR (RTS)**

- A. Provide application specific DDC Terminal Equipment Controllers and related Room Temperature Sensors. TECs shall be provided with auto-zero modules and any required output modules. Auto-zero modules shall provide periodic recalibration of the air velocity transducer without changing the air volume delivered to the room. RTS shall have a digital temperature display, set point button, override button, and temperature range of 55-95 deg. F.
- B. When indicated, U-M will furnish DDC TECs and RTSS. U-M will also provide any required TEC output modules, including auto-zero modules.
- C. 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. Connect all TECs to the Siemens DDC control panel controller FLN of the AHU or system being served. 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.
  - 1. TECs shall be provided with metal enclosure, complete with conduit knockouts (enclosure provided by MSCC).
- D. Power to TECs and associated controlled devices shall be 24 VAC, provided by the MSCC.
- E. Approved Manufacturers:

1. Siemens

**2.7 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, water-tight, 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, wa-tertight, 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 & Seymour
    - c. Hubbell
    - d. Arrow Hart
    - e. Bryant

**2.8 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, with 6'-0" spare coiled at the panel. All wire and cable shall be labeled and tagged 4 inches down from the point at which the wire enters the cabinet with the corresponding point number.
  - 2. All wiring carrying voltages greater than 24 volts shall be run in conduit.
  - 3. 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: 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.
  - 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.
- 4. Conduits shall be sized on a maximum fill of 40% capacity.
  - 5. Four separate conduit systems shall be provided:
    - a. DO/DI and 120 VAC control wiring.
    - b. AO/AI wiring.
    - c. Pneumatic tubing.
    - d. ALN/FLN cables.
 Exception: DO's, DI's, AI's, and AO's (including pneumatic tubing) installed between VSD's and DDC panels may share the same conduit.
  - 6. 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.

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7. Data transmission cabling and equipment grounding procedures shall meet the latest FCC guidelines for electromagnetic field generation.
  8. All control wiring sizes and types shall meet the equipment manufacturer's recommendations.
  9. DDC Wiring and Cable Requirements:
    - a. Digital Output: Minimum #14 AWG THHN
    - b. Digital Input: Teflon jacketed twisted pair #16 -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: 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 certified communication cable.
    - g. Data Transmission (BACnet IP): BACnet Testing Laboratories certified Ethernet communication cable.
    - h. All wire sizes listed are for lengths up to 750'.
  10. 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.
  11. DDC panel to DDC panel (BLN) wiring insulation outer jacket color shall be orange.
  12. Terminal unit (FLN) wiring insulation outer jacket color shall be orange with blue stripe.
  13. TEC Wiring Requirements:
    - a. 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.
    - b. 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.

## 2.9 AUTOMATIC CONTROL VALVES AND ACTUATORS

### A. General:

1. With the exception of TECs, actuators shall be pneumatic unless specifically noted otherwise on the drawings.
2. 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 tetrafluorethylene, spring-loaded, self-adjusting. Packless construction is acceptable. Valve linkage shall have an adjustment for valve lift. Valve to have rising stem, renewable seat and disc, repackable under pressure.
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.

- B. High performance butterfly valves may be used when approved for valves 2-1/2" and larger and shall be full lug, have carbon steel body, 316 stainless steel offset disc, one-piece stainless steel shaft and bearings with thrust surfaces, PTFE seat, Teflon stem packing and rated for 150 psi and 450 degrees F, and in compliance with Related Section "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. Steam valve 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 Brinell. Valves shall have modified linear characteristics and shall be sized based on a 5 psig inlet pressure and a maximum drop of 4 psig.

*ALTHOUGH AVAILABLE UP TO 4", BALL VALVES SHOULD TYPICALLY ONLY BE USED FOR SMALL CONTROL VALVE APPLICATIONS, E.G. FAN COILS. THIS SPECIFICATION IS ONLY FOR BALL VALVES UP TO 3/4" DIAMETER. DESIGNER SHALL SPECIFICALLY NOTE ON THE DESIGN DRAWINGS WHERE BALL STYLE CONTROL VALVES WITH ELECTRIC ACTUATORS ARE TO BE USED. BE AWARE OF THE MAXIMUM DIFFERENTIAL PRESSURE RATING (D.1.H) FOR THESE TYPE VALVES. NOTE THAT THE MINIMUM FLUID TEMP. RATING IS 35°F; THIS BALL VALVE SPEC IS NOT SUITABLE FOR LOW TEMP SERVICE, HOWEVER LOW TEMP TRIM IS AVAILABLE, CONSULT MFR.S.*

- D. Ball Style Control Valve and Actuator Assembly (provide where specifically noted on the design drawings):

1. 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:
  - a. 1/2" or 3/4" valve size.
  - b. Forged brass body with female NPT end connections.

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- c. Nickel or chrome plated brass ball, with Teflon reinforced EPDM O-ring seals.
  - d. Blow-out proof brass stem with double O-ring EPDM seals.
  - e. 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.
  - f. Ball and stem seals shall be formulated to prevent degradation by typical water treatment chemicals and Chloramines.
  - g. Minimum close-off rating: 200 PSI.
  - h. Differential pressure rating (valve operating): 30 PSID maximum.
  - i. Downstream leakage: maximum of 0.01% of design flow at rated close-off differential pressure.
  - j. 0 - 90 degree angle of rotation.
  - k. Valves for modulating service shall be equipped with a characterized ball (glass filled polymer flow insert) that provides an equal percentage flow characteristic.
  - l. Valves for two position control shall be reduced port type as required for the appropriate valve Cv.
  - m. 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.
2. Actuators: UL listed electronic rotary actuator designed for operation with the ball type control valve, with the following features:
- a. The actuator shall be of the same manufacturer as the valve body and shall be integrally mounted to the valve at the factory.
  - b. For direct coupling to the valve shaft without the use of linkages, to an ISO-style mounting pad.
  - c. Minimum cycle life: 60,000 full strokes at maximum rated torque.
  - d. 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.
  - e. Motor runtime to rotate the valve ball 90°: 90 seconds maximum, 20 seconds minimum.
  - f. Spring return runtime to rotate the valve ball 90°: 90 seconds maximum, 20 seconds minimum.
  - g. For use with a 24VAC power supply with the ability to operate off the same power supply required for the temperature controller.

**BELOW PARAGRAPH ASSUMES MODULATING CONTROL. IF FLOATING POINT VALVE ACTUATION IS DESIRED, MODIFY THE BELOW ACCORDINGLY.**

- h. 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:
  - 1) Heating coil (non-vivarium applications): Normally open spring return actuation.
  - 2) Heating Coil(vivarium applications): Normally closed spring return actuation.
  - 3) Cooling coil: Normally closed spring return actuation.



- i. 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.
  - j. Rotation mechanically limited by adjustable integral limit stops.
  - k. Mechanical range adjustment.
  - l. Valve position indicator.
  - m. 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.
  - n. Ambient temperature operating range: -20°F and 120°F.
  - o. Maximum actuator noise level, running or spring return: 40 dBA.
- 3. 2 year unconditional warranty, parts and labor. 5 year unconditional parts warranty.
- 4. Approved Manufacturers:
  - a. Siemens
  - b. Johnson Controls
  - c. Belimo
- E. Hydronic system valve bodies and trim shall be rated for service pressures through 125 psig at 250 deg. F, globe style. 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. Maximum pressure drop across any hydronic system valve at maximum flow and valve size shall be as indicated. 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. When not indicated, valves shall be sized for a pressure drop of 3 psig for chilled water and 4 psig for hot water.
- F. Standard Valve 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 cumulators used for sequencing valves are not acceptable unless specifically indicated on the drawings.
  - 4. Valves shall spring return to normal position as indicated.
  - 5. 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.
  - 6. Select to provide smooth proportioning control under operating conditions normal to the system.
- G. Butterfly Valve Actuators:

1. Pneumatic actuators shall be 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, localized mechanical position indicator readable at 25 feet, 0-90 deg. reversible operation, capable of operating in any valve mounting attitude, capable of being mounted in line or transverse to pipeline, and bolt directly to valve top plate. 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.

**EDITOR: 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 AUXILIARY PANEL (SEE SECTION 2.5). IF YOUR PROJECT HAS A LARGE NUMBER OF 120V ACTUATORS THE STANDARD (2) 20 AMP CIRCUITS 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.**

**FOR 208V OR 480V ACTUATORS, POWER TO THE ACTUATORS SHALL BE DESIGNATED AS THE RESPONSIBILITY OF THE ELECTRICAL CONTRACTOR. FOR THESE HIGH VOLTAGE ACTUATORS, DIRECT THE ELECTRICAL DESIGNER TO INDICATE POWER TO EACH ACTUATOR ON THE ELECTRICAL DRAWINGS. THIS POWER SHALL NOT BE RUN OUT OF OR THROUGH THE DDC AUXILIARY PANEL.**

2. Electric actuators shall have permanent split capacitor, reversible electric motor which drives a compound epicyclic gear, thermal overload protection, factory tested, factory lubricated, localized mechanical position indicator readable at 25 feet, 0-90 degree reversible operation, bolt directly to valve top plate. Housing shall be weatherproof and suitable for outdoor location. Provide thermostatically controlled heater for prevention of condensation at low temperatures. Actuator voltage shall be 120 VAC through 12" and 208 or 480 VAC above 12". 120V actuators shall be fed out of the auxiliary panel with a separate disconnect and fuse. Disconnect and fuse to be located in the auxiliary panel. 208V or 480V actuator power shall be provided to 208/480V actuators by others. In all cases the MSCC shall provide the required control wiring to the actuators. Actuator ambient temperature range shall be -20 deg. F to +140 deg. F. Actuator shall include a manually operated hand wheel for manual override of the valve position.

- H. Electronic valve actuators used with TECs shall be 24 VAC and use 3-position floating control, 7/32" (5.5 mm) stroke minimum, shall be direct-coupled to valve bodies without the use of tools, shall have sufficient power to prevent valves from lifting off their seats, shall provide visual position indication, shall include manual override knob, and shall be UL-listed for plenum installations. Actuators shall be fail-safe or fail-in place as follows:
  - 1. Actuators shall be fail-safe open for perimeter heating applications.
  - 2. Actuators shall be fail-in-place for reheat control valves and cooling coil valves.
- I. Typical valve body/actuator control actions shall be as follows:
  - 1. Heating coil valves (non-vivarium) shall be normally open to flow through the coil.
  - 2. Heating coil valves (vivarium) shall be normally closed to flow through the coil.
  - 3. Heat exchanger valves (steam or water) shall be normally open to flow through the heat exchanger.
  - 4. Cooling coil valves shall be normally closed to flow through the coil.
  - 5. Humidifier valves shall be normally closed to flow through the humidifier.
  - 6. Condenser water valves shall be normally open to flow through the cooling tower.
  - 7. Isolation valves shall be normally open.
  - 8. Drain valves shall be normally closed.
- J. Approved Manufacturers:
  - 1. All control valves except butterfly type:
    - a. Siemens
    - b. Honeywell
    - c. Johnson
  - 2. High performance butterfly valves:
    - a. Jamesbury - 815L
    - b. Watts - QF series X
    - c. Dezurik - BHP
    - d. Xomox Pliaseal
    - e. Bray - Braylok Series 41

**CONTROL DAMPERS SHALL BE SCHEDULED ON THE DRAWINGS. INDICATE THE DAMPER STATIC PRESSURE AND VELOCITY RATING IN THE SCHEDULE.**

**2.10 AUTOMATIC CONTROL DAMPERS**

- 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) 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 jack-shaft 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., 1988.
- 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 air-stream: 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

**2.11 DAMPER OPERATORS**

A. General:

1. With the exception of TECs, operators shall be pneumatic unless specifically noted otherwise on the drawings.
2. Provide smooth, proportional control with sufficient power for air velocities 20% greater than maximum design velocity and to provide tight seal against maximum system pressures. Provide spring return to normal position. Damper operators shall be installed in accessible locations. Damper operators shall not be installed inside ducts or air units that convey hazardous exhaust.

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

C. Electric Operators: Maintenance free electric actuator, reversible, with push rod and bracket for swivel mounting and for the transmission of power. Synchronous motor with load independent running time providing parallel operation of several operators. Gear train with low noise level. Magnetic hysteresis coupling with magnetic transmission of torque, with no mechanical contact between the coupling members. The actuator shall be safe against blocking and overload proof even when operated continuously.

D. Electronic Operators: Maintenance free, 24 or 120 VAC, 4-20 mA or 0-10 VDC input, reversible, direct-drive or push rod and bracket, metal or aluminum housing, brushless DC motor with stall protection, quiet, low-power operation, have visual position indicator, and manual override.

E. Electronic damper operators used with TECs shall be 24 VAC 3-position floating control type and utilize a 90-degree rotation. 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.

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

- G. 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. 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.
- H. Approved Manufacturers:
  - 1. Honeywell
  - 2. Johnson
  - 3. Siemens
  - 4. Belimo

**2.12 PNEUMATIC 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 over-pressure 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 hygroscopic 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 hygroscopic 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.

**2.13 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 and LPI panel minimum size shall be 19-1/2" high by 16-3/8" wide by 5-3/4" deep.

**2.14 AHU SAFETIES ENCLOSURES**

- A. Enclosures shall utilize a standard 4-11/16" x 4-11/16" square electrical box and blank cover. 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.



**2.15 ROOM DIFFERENTIAL PRESSURE INDICATING GAUGES**

- A. 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.
- B. Approved Manufacturers:
  - 1. 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 UNIVERSITY'S HIGH PRESSURE AIR SUPPLY IS AVAILABLE ON CENTRAL CAMPUS VIA THE STEAM TUNNEL SYSTEM AND IS DELIVERED AT -50 DEG. F DEW POINT. THEREFORE CONTROLS USING THIS AIR SUPPLY SHOULD NOT NORMALLY REQUIRE REFRIGERATED OR DESICCANT AIR DRYERS, EVEN WHEN EXPOSED TO OUTDOOR AIR CONDITIONS.**

**2.16 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. For projects utilizing the University's high pressure air supply, unless indicated otherwise on the drawings, no air dryers are required.
- 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

**2.17 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**

- A. Install all system components as recommended by the manufacturer, including air compressors, dryers, filters, etc.

- B. Thermostats, room temperature sensors, push-buttons, and other adjustable devices meant for room occupant operation shall be mounted 44" to center above the finished floor. This requirement does not apply to control panels and devices mounted in penthouses, mechanical rooms, and other spaces normally inaccessible to room occupants.
- C. 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.
- D. System I/O's shall not be split between different DDC panels.
- E. AHU safeties enclosure shall be mounted at the wiring/tubing DDC panel array interface trough.
- F. 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.
- G. Support all sensors and devices as recommended by the manufacturer. Space sensors shall be mounted on an electrical box.
- H. Provide a control air shut-off valve for each panel.
- I. Panels and meter enclosures shall be rigidly mounted.
- J. Plastic tubing may be used in all locations, except in mechanical rooms, shafts, or exposed locations, unless run in conduit.
- K. 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.
- L. A PRV shall be installed on each floor to provide control air supply.
- M. All wiring to devices installed inside auxiliary/local panels shall enter/exist via terminal strips, except twisted/shielded sensor wiring.
- N. Provide a pouch or other containing method inside each control panel and insert a copy of the corresponding system control drawings.
- O. Provide supplemental Hand-Off-Auto switches and contactors, as required, to permit automatic operation of equipment from the DDC system (i.e. single phase equipment which uses fractional motor starters, etc.).
- P. Extreme care shall be used in making connections to other equipment to see that the safeties on this equipment are not inadvertently bypassed or overridden by the DDC.

- Q. All equipment having moving parts and controlled by the DDC shall be provided with warning labels no less than 2 in. in height, and in bright warning color, stating that the equipment is remotely started by automatic controls. Such labels shall be posted clearly in the area of any moving parts, such as belts, fans, pumps, etc. The University of Michigan will furnish and install these warning labels.
- R. 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.
- S. Limit switches used on dampers shall be set at approximately 95% of full stroke (opened and closed). Where a single limit switch is indicated, set at approximately 75% of full stroke.
- T. MSCC shall provide all necessary equipment, test gases, etc. for calibration, and shall calibrate all sensors (i.e. CO<sub>2</sub>, 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.
- U. Flow meters shall be installed with at least 10 diameter of straight pipe length upstream and five diameter of straight pipe length downstream. 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.
- V. Airflow sensors shall be installed with the appropriate upstream and downstream clearances per manufacturer's instructions.
- W. 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.
- X. DDC sensor cabling shall not be spliced.
- Y. Locate all control components and accessories such that they are easily accessible for adjustment, service and replacement.
- Z. Participate in the commissioning process in accordance with the project commissioning documents.
- AA. 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.
- BB. 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.

- CC. 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.
- DD. 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.
- EE. Flush mount room differential pressure indicating gauges above one door outside of each lab, animal room, and where indicated, in the corridor wall at 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. For example, if the monitored room is to be negative to a corridor, connect the room tube to the 0 - 0.2" port. Mount POS/NEG label adjacent to gauge and visible from floor.

### **3.2 CALIBRATION AND START-UP**

- A. The MSCC shall provide calibration and start-up for temperature control devices and systems, including compressors, dryers, etc.
- B. 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.
- C. 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.
- D. 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.
- E. After equipment has been accepted and operated in normal service for two weeks, check the adjustment of control components and recalibrate/replace where required.

**END OF SECTION 230900**