SECTION 23 09 13 - INSTRUMENTATION AND CONTROL DEVICES

PART 1 - GENERAL

1.1 SUMMARY

A. The devices listed in this section are control system field devices generally connected to the Building Automation System. These devices have been placed in a separate section for clarity. See Section 23 09 00 for system standard and for items not clarified in this section.

B. Include all required factory and field calibration of each instrumentation device to accurately measure and control the desired variable.

C. Steam and chilled water connections and parameters from the Central Utilities Plant (CUP) to the individual buildings are further defined in Part 3 of the Manual of Guidelines and Standards for Design and Construction Projects and in the university Metering Standard.

D. All wiring requirements in this section shall be considered in addition to the requirements in Division 26 not in place of Division 26.

PART 2 - PRODUCTS

2.1 GENERAL

A. All input and output devices will be of the type which are universally accepted in the industry, can easily be second sourced and are fully compatible with the BAS.

B. Required components:
1. All components shall be included to meet the intent of sections 23 09 00 and 23 09 93
2. Pilot positioners shall be included where necessary to assure smooth operation of all analog pneumatic outputs.

2.2 SYSTEM INPUTS OR MEASUREMENT DEVICES

A. General
1. All sensor and signal conditioning equipment will be of the type which are universally accepted in the industry, can easily be second sourced and are compatible with all of the manufacturer's equipment.
2. See section 23 09 93 for required points.
3. Provide components that are fully compatible with the Building Automation System (BAS). Include all required factory and field calibration of each instrumentation device to accurately measure the desired variable.
4. All sensors to be installed in conditioned areas to prevent damage to the device. All devices to be installed in areas within the operating range of the device.

B. Temperature Transmitters:
1. General: Temperature sensor/transmitters shall have ranges appropriate for applications, input resolution of 0.2 Deg. F, accuracy of .4 degree F and stability of .3 degree F over the entire span. Pneumatic sensors are not allowed.
2. Space:
   a. Space sensors (non-flush mounted) shall be provided with a portable service tool jack. Set-point adjustment will only be required as needed by LEED or the specific sequence of operation.

b. Sensors (non-flush mounted) shall be capable of providing temporary zone or building controls override, as needed by LEED and the specific sequence of operation.
c. Occupancy adjustment will only be required as needed by LEED or the specific sequence of operation.

3. Duct Averaging:
   a. Duct mounted averaging sensors shall utilize a sensing element incorporated in a copper capillary.
   b. If the cross section of the duct where the sensor is located is larger that 24 inches long by 24 inches wide, averaging sensors of adequate length shall be specified to assure accurate temperature. Provide averaging sensors in all mixed air applications.
4. Outside Air: Sunshields shall be provided for outside air sensors.
5. Liquids
   a. Temperature sensors for liquids and steam shall have wells of appropriate type for the application and separable from the sensing element. Strap on sensors will not be accepted.

C. Differential Pressure Transmitters – Air and Water:
1. General: The differential pressure transmitters shall be temperature compensated.
2. Performance:
   a. Sensing range shall be suitable for the application with accuracy of +/- 1% including hysteresis and non-linearity of range and repeatability of +/- 0.2% of range.
   b. The sensor element shall be capable of withstanding up to 800% of rated pressure without damage.
   c. The sensor range shall be selected such that the anticipated set-point is approximately mid-range. Range may be larger if necessary to keep all anticipated measurements within the range.
3. Air Application:
   a. The sensor element shall be capable of withstanding at least 5 psi differential pressure.
   b. For applications referencing outdoor air, provide an outdoor static reference enclosure that eliminates wind effects.
   c. Provide a metal pitot tube for all duct static measurements.
   d. Provide a recessed housing with metal fittings designed for space static measurements.
   e. Provide bi-directional sensors for all air filter monitoring.
4. Water Application:
   a. For all water measurements, provide an isolation valve manifold and a permanently installed local visual gauge.
   b. The sensor element shall be capable of withstanding a pressure of twice the full scale pressure.
   c. Sensors shall have a minimum range of 0 - 50 PSI and a minimum of 100 PSI line pressure

D. Humidity Transmitters:
1. General:
   a. Humidity sensing elements shall be of the solid-state type.
2. Performance:
   a. The sensing element shall have a minimum range of 10% -99%, with an accuracy of +/_ 2% of range.
   b. Provide lockable metal guards for all sensors located in public areas.

E. Air Velocity Sensors For VAV Box Control:
1. General:
   a. The sensor shall sense a velocity range that is appropriate for each box.
   b. Repeatability including transmitter shall be +/- 5% of the CFM reading across the range of flow required by the application.
   c. The consultant shall determine if the airflow transmitter included in the controller will meet the above accuracy and specify an external transmitter where necessary.
2. Performance:

a. Thermal anemometer sensors shall use constant temperature differential technology and operate from 30F degree F to 120 F. degrees F
b. Differential pressure sensors shall provide periodic auto-calibrate to insure accurate velocity pressure measurement at low flows.

F. Refrigerant Gas Monitoring:
1. General:
a. Provide an alarm light, horn, local digital LED readout, and a 4-20mA analog output to the BAS.
2. Performance: Provide a halogen refrigerant gas monitoring system for the chiller room that shall specifically sense the type of refrigeration utilized in the chillers.
a. The sensing range shall be such that the alarm level is approximately mid range of the full sensing range, with accuracy of +/- 3% of full scale.
b. Sample each point a minimum of once every minute.
3. The alarm levels shall be as follows:
a. 10ppm for HCFC-123.
b. 100ppm for HFC-134A and R-22.

G. Flow Sensor – Air:
1. General:
a. The sensor shall utilize a multi-point airflow measuring array with a minimum of one sensing point for every two square feet of area (rounded down).
2. The accuracy of the flow measurement shall be +/- 3% of full scale.
3. Airflow measuring element accuracy shall be +/- 2% of the actual airflow span.
4. Differential Pressure Sensor/Transducer Performance: Refer to Differential Pressure Transmitter specification above.
5. Mount airflow probes on fan inlets with locknuts. When use of locknuts is not an option, the use of “lock-tight” is acceptable.
6. BAS air flow sensors shall be scaled to report in KCFM.

H. Flow Sensor – Steam / Energy Meter :
1. Vortex Type: Piping location for meter must meet the manufacturer’s recommendation for minimum specified length of straight pipe. Meter sizing must consider maximum peak steam load and minimum steam flow during low load conditions (125 psi saturated steam). Dual station metering arrangement may be required to capture both peak flows and low-load off-season flow. Meter data communication must be coordinated with Building Automation System (BAS) interface requirements provided by Siemens. Acceptable communication protocols are Modbus and BACnet.
2. Meter must be in place and demonstrated to be operational to campus energy engineer prior to utility start-up.
a. Temperature and pressure compensated vortex-shedding mass flow meter.
b. Flanged, in-line body, flow element with electronic transmitter producing a linear flow signal.
c. High precision (0.4% of full scale) pressure transducer.
d. 20:1 turndown ratio or better, accuracy better than 1% of span.
e. Integrate meter data registers via approved communication protocol into Siemens BAS panel. Steam flow, pressure, temperature, flow totalizer registers are to be integrated into BAS at a minimum. Coordinate meter minimum and maximum flow output values with campus energy engineer through the University Project Manager.
f. Mass flow will be totalized by meter and be integrated into BAS.
g. NEMA 4X enclosure.
h. Alphanumeric LCD display with user selectable display options.
i. Integral mass flow totalizer with reset possible only with security code or non-resettable.
j. Remote display is required if meter cannot be reached without ladder. Display shall be installed at eye level while standing on floor.
k. Mounting hardware.

l. Calibration certification.

3. Acceptable Manufacturers: Sierra Instruments 240S or 240i series, Spirex/Sarco VLM series
4. Alternate technology acceptable product is Micrometer V-Cone series with KEP-ES flow computer for more difficult locations to meet manufacturer's installation requirements. This product will need UCD engineering services approval prior to use.

I. Flow Sensor –Chilled Water Meter :

1. Ultrasonic Type: Piping location for meter must meet the manufacturer's recommendation for minimum specified length of straight pipe The metering of the cooling energy (chilled water) is based on the total BTU (British Thermal Units) of energy delivered to the building converted to cooling Ton-hours. Determination of Ton-hours of energy requires a minimum of two temperature sensors (one on the supply line, one on the return line) and a flow meter, preferably on the supply line (building chilled water design conditions are CHWS=41 degree F and CHWR=56 degree F). Meter data communication must be coordinated with Building Automation System (BAS) interface requirements provided by Siemens. Acceptable communication protocols are Modbus and BACnet.
2. Meter must be in place and demonstrated to be operational to campus energy engineer prior to utility start-up.
    a. Dual channel transit time flow and energy meter. Utilize 2 meters for single channel meters.
        1) Channel 1 for primary chilled water.
        2) Channel 2 for secondary chilled water.
    b. High precision clamp-on flow transducers.
    c. Insertion (wetted) type RTDs w/ 4 wire output (balanced) individually accurate to within 0.1 degree F and provided as a matched pair.
    d. NEMA 4X enclosure.
    e. Alphanumeric LCD display with user selectable display options.
    f. Integrated energy (Ton-hour) totalizer with reset possible only with security code or non-resettable.
    g. Integrate meter data registers via approved communication protocol into Siemens BAS panel. Minimum required registers shall be water flow rate, supply and return temperatures, cooling tons, totalized ton-hours.
    h. Display shall be installed at eye level while standing on floor.
    i. Mounting hardware.
    j. RTD and flow transducer cables.
    k. Calibration certification.
    l. Acceptable Manufacturers: Siemens SITRANS FUE1010 series, Spirex/Sarco UTM10-E series, Sierra Instruments InnovaSonic 205i series

J. Carbon Dioxide Sensor:

1. General: The CO2 sensor shall utilize a single-beam, non-dispersive infrared detecting element.
2. Performance:
    a. The sensor shall have a range of 0-2000 ppm
    b. Accuracy +/- 50 ppm
    c. Repeatability +/- 10 ppm.
    d. Drift less than 20 ppm/yr
    e. Sensors shall be field calibrated for altitude.

K. Current Transducer:

1. General:
    a. Rated for 120% of maximum amperage of monitored system with 4-20 mA output.
    b. Provide matched removable clamp-on type current transformer.
2. Performance:
    a. Accuracy: +/- 0.5% of full scale
    b. Repeatability/Linearity: +/- 0.1% of full scale.

L. Level Transmitter:
1. Capacitance Type: PTFE coated 316 SS probe with ¾ inch NPT or 150 LB connection, 4-20mA output.
2. Displacement Type: C-Iron or steel case with 316 SS displacer, specific gravity adjustment, 4-20mA output.
3. Ultrasonic Type:
   a. Two-inch NPT connection, CPVC material, auto temperature compensation, NEMA-4X housing, 120 VAC power mA isolated output.
   b. Provide two adjustable relay contacts which may be set to alarm at particular level values, an electronic transmitter corresponding to 0-100% of level span, self-testing and calibrating and adjustable noise/echo filters.

M. Water meters:
1. Application: Domestic water, irrigation, evaporative cooling
2. Meters shall meet or exceed AWWA C700 and C710 Standards, utilize magnetic drive register, have excellent low flow measurement.
3. Water meters shall have a pulse output to the BAS.
4. Acceptable Manufacturers: Badger, Neptune, Sensus
5. Badger (preferred):
   a. Up to 2” Recordall disc series, over 2” Turbo series, all Badger meters require RTR pulse transmitter
6. Neptune:
   a. Up to 2” T-10, over 2” HP Turbine, all Neptune meters require TRICON/E3 pulse transmitter
7. Sensus:
   a. Up to 2” SR II, over 2” Turbo, all Sensus meters require Sensus Pulse transmitter

N. Electric Energy/Power Meter:
1. Reference Division 26.

2.3 SYSTEM OUTPUTS OR CONTROL DEVICES

A. Electro-Pneumatic Transducers (I/P):
1. General: Shall accept industry standard electronic signals and provide standardized pneumatic outputs.
2. Performance:
   a. The accuracy of conversion shall be 4% of full scale, linearity +/- 1% of full range at ambient temperatures of 40 to 120F.

B. Control Relays:
1. Shall be UL listed plug-in type with dust cover and LED “energized” indicator or RIB with indicator.
2. Contact rating, configuration and coil voltage shall be suitable for the application.

C. Manual Control Switches:
1. Shall be UL listed for use in NEMA 1 enclosures with contact arrangement and rating suitable for the application.
2. Bat handle or knob actuator with nameplate clearly identifying function of each switch position.

D. Low Temperature Protection Thermostats:
1. General:
   a. Shall be the manual reset type.
   b. The element shall be properly supported to cover the entire downstream side of the heating coil with a minimum of three loops.
   c. Separate thermostats shall be provided for each 25 square feet of coil face area or fraction thereof.

d. Provide a single point for low temperature reset button when 8 or more low temperature detectors are installed.

2. Performance:
   a. The set point shall be adjustable with a minimum range of 34 F to 50 F.
   b. The thermostat shall operate in response to the coldest one foot length of the 20 sensing element regardless of the temperature at other parts of the element.

E. Differential Pressure Switches:
1. Pressure differential switches (air or water service) shall be UL listed, Snap-acting, pilot duty rated (125 VA minimum), NEMA enclosure appropriate for the application, with scale range such that an adjustable set point is approximately at the mid-point of the device span.
2. Provide metal pitot tubes for airside differential pressure switches measuring duct static.

F. High/Low Static Pressure Limit Switches:
1. Shall be UL listed line voltage snap-acting pilot duty rated (125 VA minimum), NEMA 1 enclosure.
2. Provide manual reset unless otherwise required by the application
3. Provide metal pitot tubes for airside differential pressure switches measuring duct static.

G. Current Sensing Switches:
1. Shall be UL listed for line voltage with SPDT snap-acting, pilot duty rated (125 VA minimum) with range such that the set-point is at approximately the mid-point of span of the device.
2. Provide a maximum switching differential of 0.5 amps.

H. Valve or Damper Limit (End) Switches:
1. Shall be UL listed line voltage SPDT snap-acting pilot duty rated (125 VA minimum) NEMA 1 enclosure, with roller type actuating arm suitable for damper position application.
2. Provide end open and closed status switches as a minimum on all motorized valves utilized for equipment isolation. Provide end switches on all isolation dampers.

I. Positive Positioners:
1. General: Shall be high capacity force balance relay type with suitable mounting provisions and position feedback linkage tailored for particular actuator.
2. Performance:
   a. The positioner shall reposition the actuator on an input (pilot) signal change or 1/8 PSI or less.
   b. The repeatability shall be +/- 2%.

J. Electro-Pneumatic (EP) Solenoid Air Valves:
1. Shall be UL listed, snap-acting, 3 way air valve with 3-port (common, N.O, & N.C.).
2. Provide bronze or plastic body with stainless steel trim. Minimum safe pressure shall be 30 PSIG at 130 F ambient and/or control air temperature.
3. Provide coil voltages as required up to 460 VAC. Provide an open type for panel mounting or enclosed type with a NEMA 1 housing for remote installation.

K. Control Valves – Globe:
1. General: All control valves, unless otherwise required by application, shall meet the following:
   a. All modulating valve/actuator combinations for water application shall have linear flow or equal percentage characteristics in relationship to valve actuator input.
   b. The minimum close-off rating of any-two valve/actuator combination shall be 110% of the total system (pump) head for water application or 50 psid, whichever is greater.
   c. Valves shall have valve position indication on the valve.
   d. Water valves utilized in modulating applications shall be sized for a 4 to 6 psi drop with a maximum of 7 psi and a minimum of 3 psi. Application with flows less than 2 gpm may utilize pressure drops less than 3 psi.
   e. The valves shall be rated to 240 deg. F and 125 psig, two-way or three-way as required.

2. Valves ½" to 1":
   a. The valve body shall be nickel plated brass or bronze and provided with sweat or screwed fittings as required.
   b. Provide a screwed type with NPT fittings. Provide valves with equal percentage or linear flow characteristics.
3. Valves 1" to 6":
   a. The valve body shall be cast iron with a chrome nickel steel or stainless steel seat and inner valve material.
   b. Valves 1" to 2" shall be screwed type with NPT fittings.
   c. Valves 2-1/2" and larger shall be flanged.
   d. Provide linear flow characteristics.
4. Valves 6" and Greater: Provide one of the following types:
   a. Rotary globe valves equal to Masonelian Camflex II. Provide equal percentage or linear flow characteristics.
   b. Linear globe valves equal to Fisher. Provide equal percentage or linear flow characteristics.
   c. High performance butterfly valves/actuator combination that shall provide equal percentage flow characteristics at low flow. Provide Keystone K-Loc.

L. Control Valves – Butterfly:
1. General:
   a. Butterfly valves shall not be utilized for any modulating applications with valve sizes of six inches and under.
   b. Butterfly valves utilized for two-position control shall be line-sized.
   c. The minimum close-off rating for any two-way valve/actuator combination shall be 110% of the total system (pump) head for water application or 50 psid, whichever is greater.
   d. All valves shall have valve position indication on the valve.
2. Construction:
   a. Two-way and three-way butterfly valves shall have:
      1) a cast iron valve body
      2) aluminized bronze disc
      3) stainless steel stem
      4) disc seal suitable for bubble-tight shut off

M. Control Valves – Ball:
1. General:
   a. Ball valves shall not be utilized for modulating control unless approved by the engineer prior to bid. Exception: Only characterized ball valves providing equal percentage flow characteristics will be considered for modulating control applications.
   b. The minimum close-off rating for any two-way valves/actuator combination shall be 110% of the total system (pump) head for water applications or 50 psid, whichever is greater.
   c. All valves shall have position indication on the valve.
   d. The pressure drop calculations shall include the pressure drops of the fittings required to install a valves several sizes smaller than the pipe it is being installed in.
2. Ball Valves (2" or less):
   a. Valves shall utilize bronze bodies with female NPT threads. Valve bodies may also be stainless steel, titanium or nickel with operating pressure up to 2000 psi.
   b. Provide a blowout proof stem design, glass-reinforced Teflon thrust seal washer and stuffing box ring with minimum 600 psi rating. Stem packing gland screw shall be adjustable for wear.
   c. Standard chromium plated bronze ball or where specified, stainless steel ball and stem, shall be rated at a minimum of 600 psi water, cold, non-shock service, and 150 psi for saturated steam service. All valves shall be provided with reinforced Teflon seats.
3. Ball Valves (2-1/2" to 6"):
   a. Valves shall have flanged carbon steel or stainless steel bodies rated at 150 psi working pressure.
   b. Provide a blowout stem design and reinforced PTFE thrust seal washer.

c. Provide a stainless steel ball and stem and reinforced PTFE seats, packing and o-ring.

N. Control Valves – Low Pressure Steam:
1. General:
a. Low pressure steam valves shall be sized for a maximum 42% pressure drop of inlet pressure.
b. The minimum close-off rating any two-way valve/actuator combination shall be inlet pressure for steam applications.
c. All valves shall have valve position indication on the valve.
d. All modulating valve/actuator combination for steam applications shall have equal percentage flow characteristic in relation to valve actuator signal input.
2. Construction:
a. The valves shall be two-way with a rating to 360 deg. F up to 230 psig.
b. The valve body shall be cast iron with a chrome nickel steel or stainless steel seat and inner valve material.

O. Control Valves – Chilled water Infrastructure Connection
1. General:
a. The control valve must be a two-way valve design.
b. The control valve must be of industrial quality.
c. When combined with actuator, the assembly must deliver a minimum 100:1 turn-down ratio.
d. The minimum close-off rating any two-way valve/actuator combination shall be inlet pressure of 100 psi (230’ W.C.) differential.
e. All valves shall be sized for 3-5 PSID pressure drop across the valve at full flow.
f. All valves shall have valve position indication on the valve.
g. All modulating valve/actuator combination for this application shall have equal percentage flow characteristic in relation to valve actuator signal input.
2. Construction:
a. The valves shall be two-way with a rating to 360 deg. F up to 230 psig.
b. The valve body shall be cast iron with a chrome nickel steel or stainless steel seat and inner valve material.
3. Acceptable Manufacturers: Keystone, Fisher, or approved equivalent.

P. Valve Actuators – Chilled water Infrastructure Connection
1. General:
a. Shall provide tight close-off at design system pressure and shall provide smooth modulation at design flow and pressure conditions.
b. The control valve actuator must be of industrial quality.
c. When combined with actuator, the assembly must deliver a minimum 100:1 turn-down ratio.
d. The minimum close-off rating any two-way valve/actuator combination shall be inlet pressure of 100 psi (230’ W.C.) differential.
e. The valve actuators shall be electrically actuated with proportional modulation and must fail in place.
f. All modulating valve/actuator combination shall have valve position indication on the actuator.
g. All modulating valve/actuator combination for this application shall have equal percentage flow characteristic in relation to valve actuator signal input.
h. Provide a hand wheel or manual position dial to allow manual positioning of valve.
i. Provide actuators with internal heaters if installed outdoors.
j. Provide end (limit) switches for open/closed position indication feedback.
k. Provide a position indicator feedback signal. Signal shall supply a mA or VDC analog feedback signal. It shall have infinite resolution with a linearity error of less than +/- 1% of full span.

l. Upon loss of analog control signal, the actuator shall have the ability of to stay in place, drive fully open, drive fully closed or drive to a pre-determined position.

2. Construction:
   a. The actuator shall function normally at temperatures of 40 to 185 degrees F, 0-99 % humidity, and withstand short temperature excursions 10% above the rated temperature with no permanent damage to the unit.
   b. The motor shall be a no burnout type, with no duty cycle limitations, capable of 60 starts and stops per minute for high-demand times such as start-up and process upsets.
   c. The actuator shall hold a minimum of 200% of the rated torque when the motor is de-energized
3. Acceptable Manufacturers: Beck, or approved equivalent.

Q. Control Dampers:
1. Motorized dampers, unless otherwise required by the application, shall meet the following:
   a. Damper frames shall use 12 or 13 gauge galvanized steel channel or 1/8" extruded aluminum with reinforced corner bracing.
   b. The damper blades shall not exceed eight (6) inches in width or 48" in length.
   c. Damper bearings shall be oil-impregnated sintered bronze or bearing grade nylon. Bushings that turn in the bearing are to be oil impregnated sintered metal.
   d. All blade edges and top and bottom of the frame shall be provided with replaceable, butyl rubber or neoprene seals. Side seals shall be spring-loaded stainless steel, synthetic elastomer, or combinations of both. The seals shall provide a maximum leakage rate of ½% of maximum flow or 10 CFM/SF leakage at 4" W.C. close-off pressure.
   e. The damper linkage shall be concealed and provide a linear flow or equal percentage characteristic as required.
   f. Airfoil type dampers shall be used for any modulating air volume applications, pressure control applications, or air velocities greater than 1500 FPM.
   g. Provide a minimum of one damper actuator per damper section.
2. Blade Arrangement:
   a. Unless parallel blade dampers are necessary for mixing outdoor/return air streams, dampers other than fire dampers shall be opposed blade type.

R. Electronic Actuators:
1. Value Actuators for Primary HVAC Equipment:
   a. Shall provide tight close-off at design system pressure and shall provide smooth modulation at design flow and pressure conditions.
   b. The valve actuators shall be electrically actuated with proportional modulation and spring return.
   c. Provide a hand wheel at the valve or manual position dial mounted in the BAS panel to allow manual positioning of valve.
2. Valve Actuators for Butterfly Valves:
   a. Shall provide tight close-off at design system pressure and shall provide smooth modulation over the full range of expected flow and pressure conditions.
   b. Provide actuators with internal heaters if installed outdoors.
   c. Provide 2 sets of end switches, one set for limiting of the stroke, the other set for open/closed position indication feedback.
   d. Provide a hand wheel at the valve or manual position dial mounted in the BAS panel to allow manual positioning of valve.
3. Valve Actuators for VAV Terminal Units:
   a. The valve actuator shall be electrically actuated with proportional or 3 point floating modulation.
   b. Thermally actuated valve actuators are not acceptable.
4. Damper Actuators for Primary Equipment:
   a. Shall be selected per manufacturer's recommendations to provide sufficient close-off force to effectively seal damper and to provide smooth modulating control over the full range of expected flow and pressure conditions.

b. Shall be proportional modulating or 2-position as required by the application and have a position indicator for external indication of damper position.
c. Provide modulating actuators with manual override release to manually position the actuator without disconnecting damper linkage.
d. Provide adjustable stops for both open and closed positions.
e. Provide spring return to the closed position on all dampers that open to the outdoors.

5. Damper Actuators for VAV Box Terminal Unit Control:
a. Provide a rotary type capable of permanent stall operation without damage.
b. Provide adjustable stop pins on the actuator for stroke limit.
c. The actuator shall fit directly over the damper shaft.
d. VAV terminals 3,000 CFM or greater must be provided with high torque actuator.

S. Pneumatic Actuators:
1. General:
a. Pneumatic actuators shall be piston-rolling diaphragm type with easily replaceable beaded, molded neoprene diaphragm.
b. Actuator size and spring ranges selected shall be suitable for intended application.
c. Provide a manual position dial mounted in the BAS panel to allow manual positioning of each actuator or group of actuators utilized for a modulating control application.
d. All modulating valve applications shall be provided with spring return to the normal position.
e. All damper applications with outdoor air openings shall be provided with spring return to the closed position.
f. All actuator torque rating shall be 150% of the requirements of the application.
2. Damper Actuators:
a. Shall be selected per manufacturer's recommendations to provide sufficient close-off force to effectively seal damper and to provide smooth modulating control under design flow and pressure conditions.
b. The actuator body shall be cast aluminum.
3. Valve Actuator:
a. Shall provide tight close-off at design system pressure and shall provide smooth modulation over the full range of expected flow and pressure conditions.
b. The actuator body shall be cast aluminum.
4. Positive Positioners: Shall be provided on actuators for inlet vane control, modulating dampers, and modulating valves to provide smooth modulation or proper sequencing.

2.4 AUXILIARY EQUIPMENT

A. Building Automation System (BAS) Controls Transformers:
1. Shall be UL listed Class 2 current limiting type, or shall be furnished with over-current protection in both primary and secondary circuits for Class 2 service.

B. Pneumatic Indicating Gauges and Test Ports:
1. Control signal indicating and test gauges shall be 1-1/2", back-connected, 0 to 30 PSIG.
2. Test ports shall be quick-disconnect type using needle probe or threaded pin valve type.
3. Permanent indicating gauges shall be furnished for all pneumatic transducer and relay outputs used to position actuators or PE switches.
4. Gauges shall be in local control panels when applicable.
5. Test ports shall be provided for all EP, relay and signal conditioning inputs which do not directly signal actuators.
6. One main (supply) air pressure gage shall be installed in each local control panel.

C. Enclosures:
1. General:
a. Mounting: All Controllers, Relays, Transducers, transmitters, relays, etc. shall be housed in a NEMA enclosure rated for the installed conditions.

b. Panels shall be NEMA type suitable for applications as required with hinged door and key-lock latch.

2. Terminations and Connections:
   a. Interconnections between internal and face-mounted devices pre-piped and wired with color-coded tubing/conductors shall be neatly installed in plastic tray and/or tie-wrapped.
   b. All wiring within the panel shall be shall be run in wiring tray in accordance with NEMA and UL standards, and shall meet all local codes.
   c. Terminals for field connections shall be UL listed for 600V service, individually identified per control shop drawings, with adequate clearance for field wiring.
   d. Control air terminations for field connection shall be individually identified as per control shop drawings.
3. General Application Controller Panel Enclosures
   a. Provide a 120 VAC receptacle in each panel, and a fused on /off power switch for the panel power supply. Where ganged together panels within 8 feet of each other may be served by the same convenience 120 VAC receptacles.
   b. Provide a main air gauge for control power sources to each local panel containing pneumatic controls. Provide air gages for each pneumatic output. Indicator lights on BAS outputs similar to Siemens module PTM6.1 do not meet this standard.
   c. Provide a final as-built control drawing of panel and related devices, reduced, laminated, and mounted inside of the panel door.
   d. Use of existing control panels to house new controllers is discouraged. Use of existing control panels for junction panels is acceptable under the following conditions.
      1) All excess devices, wiring and tubing shall be removed.
      2) All remaining devices, wiring and tubing shall be tagged and neatly revised.

D. Wiring and Conduit:
1. All wire will be copper and meet the minimum wire size for the application.
2. Input wiring shall not be in the same conduit as power wiring. Communication wiring shall not be in the same conduit as power or output wiring.
3. Where different wiring classes terminate within the same enclosure, maintain clearances and install barriers per the National Electric Code.
4. Where wiring is required to be installed in conduit, EMT shall be used. Conduit shall be minimum ½ inch galvanized EMT. Compression fittings shall be used for interior locations and watertight compression fittings for exterior locations. Provide conduit seal off fitting where exterior conduits enter the building or between areas of high temperature/moisture differential.
5. Flexible metallic conduit (max. 3 feet) shall be used for connections to motors, actuator controllers, and sensors mounted on vibration producing equipment. Liquid-tight flexible conduit shall be use in exterior locations and interior locations subject to moisture.
6. Junction boxes shall be provided at all cable splices, equipment terminations, and transitions from EMT to flexible conduit. Interior dry location J-boxes shall be galvanized pressed steel, nominal four-inch square with cover. Exterior and damp location J-boxes shall be cast alloy FS boxes with threaded hubs and gasket sealed covers.
7. Wire inside walls should be in conduit, low voltage wire in ceilings should be ran in the information system cable tray and should enter room along with other low voltage wiring through a 2” conduit from the cable tray to a point of penetration in the adjacent room and run on J Hooks or bridle rings in the ceiling space of a room.
8. Low Voltage/Wire and Cable: All LV/W&C shall be run in conduit in floors and walls spaces. In hallways LV/W&C shall be run in the common telecom and other low voltage system cable tray. LV/W&C must be run in a conduit sleeve, minimum 2” dia. with plastic bushings, from the point it leaves the cable tray to the interior side of a room. Once the LV/W&C enters the room it can be supported from bridle rings or j-hooks. Wiring shall comply with Section 28 31 00 and approved NEC.
9. Low Voltage/Wire and Cable and Hallway Devices: LV/W&C running from the cable tray to devices in the hallway shall be protected by plenum rated flexible sleeving or flexible metal conduit. LV/W&C in sleeving or flexible metal conduit shall be supported per NEC and installed with UL approved connectors and plastic bushings on both ends.

10. Low Voltage/Wire and Cable Insulation Sleeve Color: BAS conductor insulation colors allowed are:
    a. Points Blue Jacket
    b. BLN Orange Jacket
    c. FLN Orange with blue stripe jacket
    d. Power Dark blue or black jacket
11. Where the space above a suspended ceiling is a supply or return air plenum, any wiring not run in conduit shall be plenum rated. EXCEPTION: Any wire run in suspended ceiling that is used to control outside air dampers, provide smoke control functions or to connect the system to the fire management system shall be in conduit.

E. Pneumatic Tubing:
1. Provide a complete air piping system for pneumatic actuator controls.
2. Control air piping shall be hard drawn type “L” copper tubing with wrought copper fittings and lead free joints.
3. Polyethylene tubing “FR” (flame retardant and self-extinguishing) can only be for terminal connections to devices with a maximum length of 18 inches and within control cabinets, enclosed raceways or conduits.
4. All pneumatic tubing shall be copper tubing or routed within a metallic conduit system
5. Conceal piping except in:
    a. Mechanical rooms.
    b. Areas where other piping is exposed.
6. Secure exposed copper tubing at regular intervals and run parallel with the lines of the building.
7. Install only tool-made pipe bends.
8. Where exposed in mechanical rooms and occupied spaces, support non-metallic tubing in:
    a. Adequately-supported, rigid, metallic raceways (conduit).
    b. EMT pipe
    c. Install in a neat and workman-like manner.
9. Fasten flexible connections bridging cabinets and doors, neatly along hinge side. Protect against abrasion
10. All tubing penetrating a metal barrier (i.e. air handler casing or duct) shall be protected with bulkhead fittings
11. Tie and support the tubing neatly.
12. Number-code or color-code tubing, except local individual room control tubing for future identification and servicing of control system,
13. Do not install pneumatic devices or tubing where there is danger of freezing.
14. Provide gauges on all branch lines from transducers. Locate in cabinet.
15. Provide gauges on all output transducers.

PART 3 - .EXECUTION

3.1 INSTALLATION, GENERAL

A. Remote control devices not in local panels shall be accessible for adjustment and service-below 7’ above finished floor whenever possible.

B. All transducers, transmitters, relays, etc., shall be mounted in a panel with hinged doors in an orderly manner and shall be properly labeled with permanent labels to identify the parts of the system being served. All thermostats shall be labeled with device number and point address.

C. Component panels shall be mounted at eye level for accessibility and service, and located within 50 feet of the system served, unless otherwise shown on the plans.

3.2 SYSTEM INPUTS OR MEASUREMENT DEVICES

A. Temperature Sensors:
   1. Space: Mount room temperature sensors 60 inches above finished floor.
   2. Outside Air:
      a. The contractor is responsible for providing a sensor that accurately reflects outdoor air temperature throughout the year in any weather conditions.
      b. The outside air temperature sensor shall be located on a northern exposure away from any heat sinks or sources.
      c. Sunshields shall be provided such that the sensor is shaded for all possible solar angles.
   3. Duct Averaging
      a. The sensor shall be installed according to manufacturer's recommendation and looped and fastened at a minimum of every 36 inches. Firmly supported ½' EMT is acceptable.
      b. The sensor shall be thermally isolated from the unit.
   4. Water:
      a. Temperature sensors for liquids and steam shall be installed in wells of appropriate type for the application. Strap on sensors will not be accepted.
      b. Coordinate the locations of all thermo wells to provide for accurate and reliable temperature readings.
      c. Provide heat conductive compound between the well and sensor element.

B. Low Temperature Protection Thermostats:
      a. All low limit thermostats shall be firmly supported in the ductwork or air handling unit using ½" EMT or other auxiliary support.

C. Humidity Transmitters: Duct mounted sensors shall be mounted a minimum of 20 duct diameters downstream of any type of humidifiers or evaporative cooling equipment.

D. Differential Pressure Transmitters:
   1. Coordinate the locations of all water pressure differential transmitters such that the transmitter is located in the hydronically furthest lines. Confirm that there are no automatic modulating or two position valves between the transmitter taps and the pump.
   2. Locate the air pressure differential transmitter for VAV fan control approximately 2/3rd of the distance down the furthest duct. A location at or near the air handling system supply fan discharge is unacceptable.

E. Flow Meters
   1. All weld-o-lets for flow meters must be installed in a manner that no lip is in the pipe.

F. Airflow Stations
   1. The installation shall be a minimum of 10 duct diameters below and 5 duct diameters above any tees or elbows in the ductwork or in the inlet cone for each supply and return fan. If the fans are double wheel double inlet (DWDI) fans, provide a flow sensor at each fan inlet.

G. Air Velocity Sensors for Terminal Box Control
   1. The terminal box air flow measurement needs to be installed with the minimum duct diameters to assure accurate measurement of minimum ventilation air flow.

H. Differential pressure Switches
   1. All differential pressure switches shall be calibrated to specifications provided by the mechanical engineer.

3.3 AUXILIARY EQUIPMENT

A. Wiring Installation Methods:
   1. General:

a. At a minimum, install systems and materials in accordance with manufacturer's instructions, rough in drawings and equipment details.
b. Install electrical components in compliance with requirements of applicable Sections of Division 26.
c. Install all control wiring 50 volts and above in conduit.

2. Installation:
a. All control wiring shall be installed in a neat and workmanlike manner parallel to building lines, with adequate support and shall be supported from or anchored to structural members.
b. Conduit supported from or anchored to piping, duct supports, the ceiling suspension system, or other electrical conduits are not acceptable.
c. Wiring buried in slab on grade concrete or explosion proof areas shall be in rigid metal conduit.
d. Provide adequate strain relief for all field terminations.
e. Varistors shall be installed on the control side of all output relays and on both sides of the transformers.
f. All terminations shall be neat with no stray strands.
g. An additional number of spare wires shall be included in each run as determined by the university for future use.

B. Control Air Piping Installation Methods:
1. General:
a. All control air piping shall be installed in a neat and workmanlike manner parallel to building lines with adequate support.

2. Installation:
a. Piping above suspended ceilings shall be supported from or anchored to structural members.
b. Tubing shall not be supported by or anchored to electrical conduits or the ceiling suspension system.
c. Sleeve through concrete surfaces in minimum one inch (25 mm) sleeves, extended 6 inches (150 mm) above floors and one inch (25 mm) below bottom surface of slabs.
d. Isolate air supply with wire-braid reinforced rubber hose or polyethylene tubing.
e. Purge tubing with dry, oil-free compressed air before connecting control instruments.
f. Lines buried in slab on grade concrete shall be in rigid metal conduit. Lines in concrete or masonry walls shall be in EMT.
g. All pneumatic piping that penetrates metal shall be protected with grommets from wear from the metal.

C. Identification:
1. General
a. Verify label nomenclature with the university before engraving or printing.
b. All control equipment shall be individually and clearly identified by control shop drawing designation:
c. Paper labels are not acceptable.

2. Control Panels
a. Provide engraved Bakelite or lithographed metal nameplates with panel number and system served
b. Utilize white ½ inch high letters on a black background.
c. Embossed labels are not acceptable

3. Component sub-panels – metal tags or laser printed, adhesive backed, metallized polyester film labels.
4. Control valves and damper actuators – brass tags or engraved Bakelite tags.
5. Other remote control devices – metal tags or laser printed, adhesive backed, metallized polyester film labels.
6. Control Conduit Junction Boxes – Painted with a Blue/Green stripe.

7. Label room temperature sensors with point name and address of the terminal controller served by the sensor.
8. For all control devices located above the ceiling attach an additional label to the ceiling “T” frame with pop rivets. Use engraved nameplates, 3”x1”, black lettering on white background.
9. Number-code conductors and pneumatic tubing appropriately for future identification and servicing of control system. Reflect this tagging or color coding system on the Project Record Documents

D. VFD interface wiring.
1. All safety circuit and BAS control wiring to VFDs shall be connected to a terminal strip in a NEMA enclosure external to the drive before entering the drive. This is to allow servicing these circuits without opening the drive.

END OF SECTION 23 09 13