SECTION 23 09 14

**PNEUMATIC AND ELECTRIC INSTRUMENTATION AND CONTROL DEVICES FOR HVAC**

**BASED ON DFD MASTER SPECIFICATION DATED 5/6/2024**

***This section has been written to cover most (but not all) situations that you will encounter. Depending on the requirements of your specific project, you may have to add material, delete items, or modify what is currently written. The Division of Facilities Development (DFD) expects changes and comments from you.***

**P A R T 1 - G E N E R A L**

**SCOPE**

This section includes control system specifications for all HVAC work as well as related control for systems found in other specification sections. Included are the following topics:

PART 1 - GENERAL

[Scope](#OLE_LINK1)

[Point List](#OLE_LINK2)

[Related Work](#RELATED_WORK)

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[Thermostat Guards](#Thermostat_Guards)

[Electric/Electronic Thermostats](#ELECTRIC_THERMOSTATS)

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[Pneumatic System Accessories](#PNEUMATIC_SYSTEMS_ACCESSORIES)

[Duct Smoke Detector and Fire Alarm Interface Modules](#DUCT_SMOKE_DETECTOR)

[Air Flow Stations](#AIR_FLOW_STATIONS)

[Water Flow Measurement](#WATER_FLOW_MEASUREMENT)

[Steam Flow Measurement](#STEAM_FLOW_MEASUREMENT)

[Steam Condensate Ultrasonic Flow Meters](#STEAM_CONDENSATE_ULTRASONIC_FLOW_METERS)

[Time Clocks](#TIME_CLOCKS)

[Temperature Control Panels](#TEMPERATURE_CONTROL_PANELS)

[Temperature Sensors](#TEMPERATURE_SENSORS)

[Humidity Sensors](#HUMIDITY_SENSORS)

[Pressure Transducers (Air)](#PRESSURE_TRANSDUCERS_AIR)

[Pressure Transducers (Liquid/Steam)](#PRESSURE_TRANSDUCERS_LIQUID_STEAM)

[Differential Pressure Switches](#DIFFERENTIAL_PRESSURE_SWITCHES)

[Current Status Switches](#CURRENT_STATUS_SWITCHES)

[Electric to Pneumatic Transducers](#ELECTRIC_TO_PNEUMATIC_TRANSDUCER)

[Carbon Dioxide (CO2) Sensor](#CO2_Sensor)

[Condensation Monitors](#Condensation_Monitors)

[Fume Hood Presence Sensors](#Fume_Hood_Presence_Sensors)

[Emergency Shutdown Switches](#SHUTDOWN_SWITCHES)

[Power Supplies](#POWER_SUPPLIES)

[Communicating Thermostats](#Communicating_Thermostats)

PART 3 - EXECUTION

[Installation](#INSTALLATION)

[Air Piping](#AIR_PIPING)

[Wire and Air Piping Conduit and Tubing Installation Schedule](#INSTALLATION_SCHEDULE)

[Air Compressors](#AIR_COMPRESSORS_Installation)

[Refrigerated Air Dryers](#REFRIGERATED_AIR_DRYERS_Installation)

[Control Dampers](#CONTROL_AND_SMOKE_DAMPER)

[Control Valves](#CONTROL_VALVES_Installation)

[Control System Instrumentation](#CONTROL_SYSTEM_INSTRUMENTATION)

[Room Thermostats and Temperature Sensors](#ROOM_THERMOSTATS_AND_TEMPERATURE_SENSORS)

[Low Limit Thermostats (Freezestats)](#LOW_LIMIT_THERMOSTATS)

[Air Flow Stations](#AIR_FLOW_STATIONS_Installation)

[Liquid and Steam Flow Sensors](#LIQUID_AND_STEAM_FLOW_SENSORS)

[Steam Condensate Water Meters](#Steam_Condensate_Water_Meters)

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[Air Pressure Safety Switches](#Air_Pressure_Safety_Switches)

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[Preconstruction Review Meeting](#PRECONSTRUCTION_REVIEW_MEETING)

[Construction Verification](#Construction_Verification_Items)

[Functional Performance Testing](#Functional_Performance_Testing)

[Agency Training](#Agency_Training)

**POINT LIST** (Section 23 09 15)

This point list should detail every point wired to the DDC controllers provided under Section 23 09 23 or 23 09 24 and should be used to clarify the scope of work for the contractor providing work under this Section. Do not use one point chart for multiple systems unless the systems have completely identical points. Use point list templates provided by DFD.

**RELATED WORK**

Section 01 91 01 or 01 91 02 – Commissioning Process

Section 23 08 00 – Commissioning of HVAC

Section 23 05 93 - Testing, Adjusting, and Balancing for HVAC - Coordination

Section 23 09 15 - Direct Digital Control Input/Output Point Summary Tables

Delete 23 09 24 or 23 09 23 depending on whether the DDC controls are bid or negotiated.

Section 23 09 23 - Direct Digital Control System for HVAC

Section 23 09 24 - Direct Digital Control System for HVAC (Informational purposes only)

Section 23 09 93 - Sequence of Operation

Section 23 33 00 - Ductwork Accessories - for control damper installation

Division 23 - HVAC - Equipment provided to be controlled or monitored

Division 26 - Electrical - Installation requirements & Equipment provided to be controlled or monitored

Division 28 - Electronic Safety and Security

**REFERENCE**

Applicable provisions of Division 1 govern work under this section.

**WORK NOT INCLUDED**

***Include the following sentence only when working with a central campus automation system or an existing building undergoing remodeling or addition and the existing DDC system will be extended. Contact DFD engineering personnel if there are questions.***

Direct digital controls and energy management interface, as specified in Section 23 09 24.

**QUALITY ASSURANCE**

Installing contractor must be a manufacturer's branch office or an authorized representative of a Direct Digital Control (DDC) equipment manufacturer that provides engineering and commissioning of the DDC equipment. Submit written confirmation of such authorization from the manufacturer. Indicate in letter of authorization that installing contractor has successfully completed all necessary training required for engineering, installation, and commissioning of equipment and systems and that such authorization has been in effect for a period of not less than three years. DDC equipment may or may not be required to be installed by this contractor as part of the project, but the intent of this quality assurance specification is to ensure that the installing contractor has the capabilities to engineer, install, and commission the field devices supplied under this section for temperature control.

**REFERENCE STANDARDS**

ANSI B16.22 Wrought Copper and Wrought Copper Alloy Solder Joint Pressure Fittings

ANSI/ASTM B32 Specification for Solder Metal

ASTM B75 Seamless Copper Tube

ASTM D1693 Environmental Stress-Cracking of Ethylene Plastics

ASTM D 635 Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position

UL 94 Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

AMCA 500-D Laboratory Method of Testing Dampers for Rating

**SYSTEM DESCRIPTION**

***Select or modify one of the following descriptions after discussion with DFD.***

System is to be pneumatic.

System is to be electric/electronic.

System is to use direct digital control logic with pneumatic actuation.

System is to use direct digital control with electric actuation for air handling units; direct digital control with electric actuation for room temperature, room humidity, and terminal airflow control; and electric control for other terminal units.

System is to use direct digital control with pneumatic actuation for air handling units; direct digital control with electric actuation for room temperature, room humidity, and terminal airflow control; and electric or pneumatic control for other terminal units.

All pneumatic tubing and electrical wiring are to be permanently tagged or labeled (within one inch of terminal strip) with a numbering system to correspond with the "Record Drawings". Tags or labels shall be printed not hand written.

**SUBMITTALS**

Include the following information:

Manufacturer’s data sheets indicating model number, pressure/temperature ratings, capacity, methods and materials of construction, installation instructions, and recommended maintenance. General catalog sheets showing a series of the same device is not acceptable unless the specific model is clearly marked.

Schematic flow diagrams of systems showing fans, pumps, coils, dampers, valves, and other control devices. Each control device provided under this Section shall be uniquely labeled. Duplicate labeling may be used within similar mechanical systems. Label each device with setting or adjustable range of control. Indicate all wiring, clearly, differentiating between factory and field installed wiring. Wiring should be shown in schematics that detail contact states, relay references, etc. Diagrammatic representations of devices alone are not acceptable.

Details of construction, layout, and location of each temperature control panel within the building, including instruments location in panel and labeling. Also include on drawings location of mechanical equipment controlled (room number), horsepower and flow of motorized equipment (when this data is available on plans), locations of all remote sensors and control devices (either by room number or column lines).

Schedule of control dampers indicating size, leakage rating, arrangement, pressure drop at design airflow, and number and size of operators required.

Schedule of control valves indicating system in which the device is to be used, rated capacity, flow coefficient, flow required by device served, actual pressure drop at design flow, size of operator required, close-off pressure, and locations where valves are to be installed.

A complete description of each control sequence for equipment that is not controlled by direct digital controls. Direct digital controlled equipment control sequences will be provided by the DDC control contractor.

Calculations completed to determine size of control air compressor(s) and dryer (s).

Prior to request for final payment, submit record documents which accurately record actual location of control components including panels, thermostats, wiring, and sensors. Incorporate changes required during installation and start-up.

***Delete the following two paragraphs when the DDC Control System is part of the Division 23 bid and Section 23 09 23 is used. Contact DFD engineering personnel if there are questions.***

Provide a complete set of Submittal Drawings to the 23 09 24 DDC Contractor to enable them to coordinate the interfacing of the 23 09 14 controls with the 23 09 24 supplied controls. The 23 09 24 contractor is also required to provide any information regarding their supplied control equipment to the 23 09 14 contractor so that the 23 09 14 contractor can complete his engineered Submittal Drawings.

Provide a complete set of control Record Drawings to the 23 09 24 DDC Contractor to enable them to provide a complete composite set of drawings incorporating DDC and electric/pneumatic controls as specified. Where communication and/or power wiring is specified to be provided under this Section, ppoint to point routing of communication trunks and power wiring between DDC controllers, DDC communication devices, control panels, and Ethernet switches shall be documented in the control Record Drawings.

The user agency may choose to review the submittals and record control drawings to ensure they are in compliance with the contract documents.

All submittals are to comply with submission and content requirements specified in specification Section 01 91 01 or 01 91 02.

**DEMOLITION**

The consulting engineer should verify and specify in detail what is to be demolished. Special attention should be given to existing temperature control air systems as to whether it should be demolished or re-used.

Where existing control devices, piping, or wiring are discontinued from use, remove, and turn over to owner. If owner does not want them remove from premises. Remove any previously abandoned control devices in a similar manner.

**DESIGN CRITERIA**

Size all control apparatus to properly supply and/or operate and control the apparatus served.

Provide control devices subject to corrosive environments with corrosion protection or construct them so they are suitable for use in such an environment.

Provide devices exposed to outside ambient conditions with weather protection or construct them so they are suitable for outdoor installation.

Use only UL labeled products that comply with NEMA Standards. Electrical components and installation to meet all requirements of the electrical sections (Division 26) of project specifications.

# **OPERATION AND MAINTENANCE DATA**

All operations and maintenance data shall comply with the submission and content requirements specified under section GENERAL REQUIREMENTS.

***Delete the following if there are no additional requirements.***

In addition to the general content specified under GENERAL REQUIREMENTS supply the following additional documentation:

1. Lubrication instructions, including list/frequency of lubrication
2. List indicating types and grades of oil and/or grease, packing materials, normal and abnormal tolerances for devices, and method of equipment adjustment.
3. Table noting full load power factor, service factor, NEMA design designation, insulation class and frame type for each motor provided
4. A complete set of record control drawings.
5. ***[A/E and commissioning provider to define detailed operation and maintenance data requirements for equipment specifications added to this section.]***

**MATERIAL DELIVERY AND STORAGE**

Provide factory shipping cartons for each piece of equipment and control device. This contractor is responsible for storage of equipment and materials inside and protected from the weather.

**P A R T 2 - P R O D U C T S**

***If there are air handling units on the project, do not delete air piping specification as this is needed for static/differential pressure measurement.***

**AIR PIPING**

ASTM B75 seamless, hard drawn, or annealed copper tubing with ANSI B16.22 wrought copper fittings, except final connections to apparatus may be made with brass compression-type fittings. Use ANSI/ASTM B32, 95/5 tin antimony solder.

Virgin polyethylene plastic tubing classified as flame retardant under UL 94 and conforming to ASTM D1693 stress-crack test.

**CONTROL AIR SUPPLY**

***Use this only for remodeling projects, additions to existing buildings, or where compressed air is available from a central plant. Consultants should indicate the location of existing air mains and the adequacy of compressor capacity to handle remodeling or additions. User agency and DFD will assist in this determination.***

The need for surge tanks and additional air/oil filters and dryers serving instrument air service extension must also be verified with DFD and user agency.

Extend existing air supply for new work.

**AIR COMPRESSORS**

***Use only duplex air compressor assemblies.***

***For applications where more than 20 SCFM air usage is required rotary vane air compressors can be supplied as an alternative to reciprocating compressors. These compressors will have lower noise and generally less maintenance than large reciprocating units.***

# Reciprocating Air Compressors:

Compressors may be tank mounted or base mounted with an independent tank. Provide a duplex compressor assembly. Size each compressor to serve the entire control system when operating no more than 1/3 of the time with a maximum of six (6) starts per hour. Each compressor to be belt driven with an oil pressure switch on pressure lubricated compressors to automatically shut down the unit on loss of oil pressure. Compressors under 10HP may be splash lubricated, over 10 HP compressor will be pressure lubricated***.*** Include fusible disconnect switches, magnetic starters with three phase overload protection, and an alternator to switch the lead compressor after each run cycle or run both compressors if one cannot handle the load.

# Rotary Vane Air Compressors:

Manufacturer: compare Hydrovane, Mattei, Pneumofore, or approved equal.

Provide two compressors each capable of handling full load requirements. Compressors to be of oil injected rotary vane design with direct flexible coupled motor not exceeding 1750 RPM. Provide after cooler radiator, multi-stage oil separator, condensate separator, and automatic drain. Include fusible disconnect switches, magnetic starters with three phase overload protection, and an alternator to switch the lead compressor after each run cycle or run both compressors if one cannot handle the load. Control to be on-load/off load pressure activated inlet valve control with timed off load shutdown.

Steel air storage tanks to be ASME stamped for a pressure 50% higher than the operating pressure of the system or 150 psig, whichever is greater. Tanks to be provided with an automatic tank drain and furnished with a relief valve sized in accordance with ASME requirements. Where air storage tanks are installed independently from compressor assembly, provide interconnecting piping and wiring.

Accessory devices to include an intake air filter for **[indoor][outdoor]** installation, air intake silencer to provide attenuation of not less than 35 dB at 2000 Hz, belt guard on each compressor motor-drive assembly, relief valve, shutoff valves, air storage tank pressure gauge, operating pressure control.

**SURGE TANKS**

Surge tanks are required for buildings that are supplied by campus air systems that are known to have surging problems. Verify with user agency if surging is a problem. As a rule, they are not required.

Steel surge tanks to be ASME stamped for a pressure 50% higher than the operating pressure of the system or 150 psig, whichever is greater. Provide a minimum of a 60 gallon tank with an automatic tank drain.

Provide reducing valves where air pressure supplied to surge tank is above pressure required by control devices served. Furnish with an air pressure gauge and safety relief valve mounted on the tank.

**REFRIGERATED AIR DRYERS**

Do not specify refrigerated air dryers if desiccated lab air is available. Coordinate with plumbing designer to provide tap for control air after desiccant dryer and capacity increase for control air usage.

Provide a refrigerated air dryer with pressure regulator, filter, moisture separator, bypass valve, automatic drain, and pressure relief valve. Minimum capacity shall be equal to the calculated air quantity with a safety margin of 50%. Compressor shall be internally isolated from air dryer frame to prevent vibration transmission.

Instrumentation to include power on light, failure light, refrigerant suction pressure gauge, and air outlet pressure gauge.

For applications requiring airflow at or above 25 SCFM, equip dryer with hot gas bypass to maintain continuous operation and stable dew point of +13°F at 20 psig main pressure.

Equip with a coalescing filter with a replaceable element with an efficiency rating of 99.999+% for particles .025 microns or larger and a charcoal filter with an efficiency rating of 100% for particles .025 microns and larger.

**P****RESSURE REDUCING AIR VALVES**

Provide pressure reducing valves with integral relief and with enough flow capacity to reduce air pressure to that required for control devices.

**CONTROL DAMPERS**

***Dampers used for perchloric, or high chloride compound applications should be constructed of 316 stainless steel. For general fume hood exhaust 304 stainless steel construction is acceptable.***

***End switches should be specified for dampers when required to prove the damper open before the fan is allowed to run. These should only be used when fan static can damage ductwork. Where possible interlock directly to fan starter so Hand/Off/Auto switch will activate damper in Hand position****.*

Provide control dampers shown on the plans and as required to perform the specified functions. Dampers shall be rated for velocities that will be encountered at maximum system design and rated for pressure equal or greater than the ductwork pressure class as specified in Section 23 31 00 of the ductwork where the damper is installed.

Use only factory fabricated dampers with mechanically captured replaceable resilient blade seals, stainless steel jamb seals and with entire assembly suitable for the maximum temperature and air velocities encountered in the system.

All dampers in stainless steel, PCD coated steel, PVC, PTFE, or fiberglass ductwork shall be constructed of stainless steel.

All dampers in aluminum ductwork shall be constructed of stainless steel or aluminum.

Dampers in galvanized ductwork shall be constructed of galvanized steel and/or aluminum.

All dampers, unless otherwise specified, to be rated at a minimum of 180º F working temperature. Leakage testing shall be certified to be based on latest edition of AMCA Standard 500-D and all dampers, unless otherwise specified, shall have leakage ratings as follows:

Damper Class Differential Pressure Leakage

Class IA 1” w.g. ≤3 CFM/ft2

Class I 4” w.g. ≤8 CFM/ft2

Class I 8” w.g. ≤11 CFM/ft2

Class I 12” w.g. ≤14 CFM/ft2

Leakage rate dampers for differential pressures that they will encounter at maximum system design pressures.

Steel framed dampers: Nailor models 2010 & 2020; Greenheck models VCD-33 & VCD-42; Johnson Controls model VD-1630; Ruskin Models CD60 & CD40; other approved equal.

Aluminum frame and blade dampers: Nailor models 2010EAF & 202EAF; Greenheck model VCD-43; Ruskin model CD50; Arrow model AFD-20; other approved equal.

***Wherever possible locate outside air and return dampers directly adjacent to one other and as far upstream of the connection to the AHU as possible to facilitate mixing. Do not use packaged mixing sections on modular AHU’s unless absolutely necessary. Where mixing arrangements are used, show the direction of the damper blades directed at each other on the plans.***

Dampers used for directed mixing of airstreams, i.e., outside air and return air, to be parallel blade type and sized for an air velocity of 1800 to 2000 fpm with the damper blades shall be arranged so that the air streams are directed at one another to facilitate mixing. Dampers used for throttling or modulating applications other than air stream mixing to be opposed blade type. Two position dampers may be parallel or opposed blade type.

Dampers used for isolation on the discharge of centrifugal fans shall have damper blades perpendicular to the fan shaft to minimize system effect. Dampers mounted with blades vertically shall be designed for vertical blade orientation.

Dampers for applications other than fume exhaust to have frames of not less than 16 gauge galvanized steel or 12 gauge extruded aluminum. Blades to be two-ply steel airfoil of not less than 2 x 20 gauge galvanized steel (14 gauge equivalent) or extruded aluminum airfoil, with stainless steel, acetal, Celcon, bronze, or nylon bearings. Maximum allowable blade width is 8 inches. Use plated steel linkage hardware.

Dampers used for laboratory fume or general exhaust systems shall have not less than 8” wide x 14 gauge frames and not less than 16 gauge two-ply airfoil blades. Laboratory fume exhaust damper frames, blades, and axles to be constructed of 304 stainless steel. Laboratory general exhaust damper frames, blades, and axles to be constructed of galvanized steel. Dampers shall be selected for a minimum rating of 10” water gauge at a velocity of 4000 FPM and rated at a minimum of 250º F. Blade bearings to be constructed of stainless steel or Teflon. Blade seals to be silicone. Leakage testing shall be certified to be based on latest edition of AMCA Standard 500-D and laboratory fume exhaust dampers, shall have leakage ratings as follows:

Damper Class Differential Pressure Leakage

Class I 1” w.g. ≤4 CFM/ft2

Class I 4” w.g. ≤8 CFM/ft2

Class I 8” w.g. ≤11 CFM/ft2

Class I 12” w.g. ≤14 CFM/ft2

Laboratory fume and general exhaust dampers: Ruskin model CD80AF; Greenheck model HCD-230; or approved equal.

Maximum damper width is 48 inches; where required width exceeds 48 inches, use multiple damper sections. Inside frame free area shall be a minimum of 90% of total inside duct area.

Multiple width damper sections shall utilize jack shaft linkages unless noted below. Sections over 144 inches wide shall be actuated from two locations on the jack shaft. Double width damper sections for two-position operation may be actuated without jack shafts if each damper section is actuated separately. Dampers that have multiple width and multiple vertical sections shall have a jackshaft for each vertically stacked set of dampers and be provided with crossover linkages between jack shafts to transfer uneven loading.

Jack shafts shall be extended outside of the ductwork for external actuator mounting. Provide bearings on the point of exit for support of damper shafts to prevent wear on the shaft and the ductwork. If locating actuators out of the air stream is impossible, obtain mounting location approval from the designer unless the contract documents indicate in air stream mounting is acceptable. In no cases shall damper actuators for fume exhaust systems be located in the air stream or require entering the air stream to service an actuator.

Provide weatherproof NEMA 4 enclosures (Belimo N4 option or equal, Belimo ZS-100 or ZS-150 are not acceptable) that have removable covers that have clasps or machine screws (no sheet metal screws) and that do not require removing fasteners from the ductwork to prevent actuator failure or freeze-up when mounting in locations exposed to harsh environments or outdoor locations.

Size operators for smooth and positive operation of devices served, and with sufficient torque capacity to provide tight shutoff against system temperatures and pressure encountered. For electric modulating actuation, use fully proportional actuators with zero and span adjustments. For two-position electric actuation use 24 VAC for DDC controlled actuators, 120 VAC actuators may be used for hardwire interlocking. See 23 09 15 for specific type of input signal required. Actuator stroke times shall match the requirements of the DDC controllers provided under 23 09 23 or 23 09 24, and/or the specific system requirements for proper operation. All electric actuators will be provided with overload protection to prevent motor from damage when stall condition is encountered. Equip operators with spring return for applications involving fire, freeze protection, moisture protection or specified normally open/closed operation. If spring return actuators are not available for applications because of torque requirements or other application requirements, stored energy fail safe may be used if approved by the AE. Face and bypass dampers for heating applications shall fail to the face position. For all two position isolation dampers that are controlled by the DDC system, provide actuators that are powered open and closed and do not utilize the actuator fail position spring for DDC commanded operation unless specified. This is to prevent fast closure by the spring return. Dampers wired to fan power can utilize the actuator fail position spring to actuate the damper.

Where control sequences require damper position indication or interlock, provide damper end switches integral to the damper actuators with form “C” contacts. Damper end switches shall have adjustable positions that can be set for proving the damper open, closed, or both depending on the specified application. End switch contact ratings shall be suitable for application. Where multiple banks of dampers are provided and not physically interlocked, end switches shall be provided for each bank of dampers and wired together to prove all dampers are in the position to be indicated. End switches shall not contain mercury.

All power required for electric actuation shall be provided by this contractor if it is not able to be directly provided from the DDC controller.

Provide operators with linkages and brackets for mounting on device served.

***Delete the following paragraph if pneumatic actuation is not used on the project.***

For pneumatic actuation, use rolling diaphragm, piston type operators with adjustable stops.

Provide pilot positioners for pneumatic operators serving all modulating outside air, return air, relief air, and face and bypass dampers, where more than one operator is controlled in sequence, or where required to provide sufficient power to the operator.

**CONTROL VALVES**

Provide all control valves as shown on the plans/details and as required to perform functions specified. Spring ranges must be selected to prevent overlap of operation and simultaneous heating and cooling.

Size operators to allow smooth and positive operation of devices served and to provide sufficient torque capacity for tight shutoff against system temperatures and pressure encountered. For electric modulating actuation, use fully proportional actuators with 0-10VDC inputs and zero and span adjustments unless specified otherwise in the chart below. If TriState with feedback is specified, valve position shall be fed back to the controller and controller shall position valve based on this feedback. For two-position electric actuation use 24 VAC for DDC controlled actuators, 120 VAC actuators may be used for hardwire interlocking. Electric actuators, for applications other than terminal units, shall be provided with a manual override capability. All electric actuators shall be provided with a visible position indicator.

All power required for electric actuation shall be provided by this contractor if it is not able to be directly provided from the DDC controller.

Provide operators that are full proportioning or two-position, as required for specified sequence of operation. Provide spring-return for applications involving fire, freeze protection, moisture protection or specified normally open/closed operation. Valves shall move to their fail positions on loss of electrical power.

***Delete the following paragraph for projects that do not use pneumatic actuation.***

For pneumatic actuated systems, use rolling diaphragm, spring loaded, and piston type operators. Valves shall move to their fail positions on loss of air pressure to the actuator. For high pressure (> 20 PSI) full proportioning pneumatic actuators, provide with zero bleed pilot positioners that are integral with the actuator. For high pressure two-positioning actuators, provide with electro-pneumatic solenoid air valve and adjustable bleed orifice integral with the actuator.

Provide end switches integral to the valve actuator to prove the valve open, closed, or both to meet the application where specified in the plans or specifications. End switch contact ratings shall be suitable for application.

Two-position shut-off valves used for isolation of mechanical devices shall be sized for a maximum pressure drop of 2 PSI at design flow and shall be a minimum of line size.

Provide operators with linkages and brackets for mounting on device served.

All valves unless specifically noted on the plans or indicated below shall be globe style valves.

***Choose one of the following tables and modify accordingly. The first table is typical for a project with all pneumatic actuation. The second is typical for a project with all electric actuation.***

***For pneumatic actuated valves, consider specifying butterfly valves for modulating water system application where the Cv requirements exceed 160. When reviewing sizing of butterfly valves in these applications keep in mind entering and leaving pipe sizes effects on valve sizing.***

***For steam grid humidifiers with manifolds, specify line size steam valves in the steam supply to the humidifier. This should be a normally closed valve that is closed whenever the humidifier is locked out.***

***If using electric actuated terminal unit valves, do not require normally open or closed valve actions unless critically important. This would require the use of spring return actuators which are larger and more expensive.***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **VALVE SERVING** | **TYPE**  Globe  Butterfly (BF)  Ball  Press Independent Ball (PI Ball) | **SIGNAL**  2-Position (24VAC)  Pneumatic | **SPRING**  **RETURN**  REQUIRED  Yes / No | **FAIL**  **POSITION**  Open (thru Coil)  Closed (bypass Coil) |
| Reheat Coil | Globe | Pneumatic | Yes | Open |
| Radiation/Convector | Globe | Pneumatic | Yes | Open |
| CUH and UH | Globe | Pneumatic or 2-Pos Elect | Yes | Open |
| Fan Coil Heating | Globe | Pneumatic | Yes | Open |
| Fan Coil Cooling | Globe | Pneumatic | Yes | Closed |
| AHU Heating Coil | Globe | Pneumatic | Yes | Open |
| AHU Cooling Coil | Globe or BF1 | Pneumatic | Yes | Closed |
| Humidifier | Globe | Pneumatic | Yes | Closed |
| Humidifier Shutoff | Globe | Pneumatic | Yes | Closed |
| HW Heat Exchanger | Globe | Pneumatic | Yes | Open |
| Process CHW HX | Globe | Pneumatic | Yes | Open |
| Process CHW Isolation | BF | Hi Pressure Pneumatic | Yes | See Flow Diagram |

See plan details, notes, and schedules for where two-way and three-way valves should be used.

1. Equivalent Cv butterfly valves may be used where 3” and larger globe valves would be required.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **VALVE SERVING** | **TYPE**  Globe  Butterfly (BF)  Ball | **SIGNAL**  0-10 VDC  TriState (24VAC)  2-Position Elect  Pneumatic (Pneu) | **SPRING**  **RETURN**  REQUIRED  Yes  No | **FAIL**  **POSITION**  Open (thru Coil)  Closed (bypass Coil)  Last Position |
| Reheat Coil | Ball | 0-10 VDC | No | Last Position |
| Radiation w/Reheat | Ball | 0-10 VDC | No | Last Position |
| Standalone Radiation | Ball | 0-10 VDC | No | Last Position |
| CUH and UH | Ball | TriState or 2-Pos Elect | Yes | Open |
| Steam Terminal Units | Globe | 0-10 VDC | No | Last Position |
| Fan Coil Heating | Ball | 0-10 VDC | No | Last Position |
| Fan Coil Cooling | Ball | 0-10 VDC | No | Last Position |
| AHU Hot Water Coil | Ball | 0-10 VDC | Yes | Open |
| AHU Steam Coil | Globe | 0-10 VDC | Yes | Open |
| AHU Cooling Coil | Ball | 0-10 VDC | Yes | Closed |
| Humidifier | Globe | 0-10 VDC | Yes | Closed |
| Humidifier Shutoff | Globe | 2-Pos Elect | Yes | Closed |
| HW Heat Exchanger | Globe | 0-10 VDC | Yes | Open |
| Process CHW HX | Ball | 0-10 VDC | Yes | Open |
| Process CHW Isolation | Butterfly | 2-Pos Elect | Yes | See Flow Diagram |

See plan details, notes, and schedules for where two-way and three-way valves should be used.

WATER SYSTEMS:

Use equal percentage valves for two-way control valves; size for a pressure drop not less than 4 psi or more than 6 psi. Where valve sizes are less than line size, Corrected Cv should be used to correct for piping reducers/increasers. Modulating valve size should never be less than half of line size. Consult with AE for acceptable pressure drop if available valve selections do not fall within the desired pressure range. Note: For low flows, the required minimum Cv size will result in lower pressure drop than 4 psi.

Use three-way valves sized for a maximum pressure drop of 5 psi and that have linear characteristics so that the valve pressure drop remains constant regardless of the valve position.

***Delete the following two paragraphs for equipment controlled by electric thermostats and DDC systems. These systems should only use ball valves.***

Globe valves 2" and smaller: Cast bronze or forged brass body, brass plug and brass or stainless steel seat, stainless steel stem, screwed ends, suitable for use on water systems at 150 psig and 240° F. Seat leakage with actuator supplied will meet ANSI class IV leakage (0.01%). For globe valves that are specified to fail in place, valves shall be open when the stem is up. Only the following globe valve body styles will be acceptable for terminal unit control: Siemens Powermite 599 VF Series (599 VE Series Zone Valves are not acceptable), Invensys VB7200 Series, Johnson Controls VG7000 Series, Belimo G200 and G300 Series, and Honeywell V5011/V5013 Series. Minimum size for globe valves shall be 0.7 Cv.

Globe valves 2-1/2" and larger: Iron body, brass plug and seat, stainless steel stem, spring loaded Teflon, or EPDM (EPT) packing, flanged ends, suitable for use on water systems at 150 psig and 240° F.

Butterfly valves: Iron body, stainless steel shaft, bronze bearings, and resilient seat. Disc to be aluminum-bronze, nickel-plated ductile iron, cast iron with welded nickel edge, Nylon 11 coated, or stainless steel. Valve assembly to be bubble tight, suitable for use on water systems at 150 psig and 240° F. For pneumatically actuated valves, provide pilot positioners on all operators for butterfly valves used in modulating applications. When butterfly valves are used in modulating applications, entering, and leaving pipe sizes and required transition distances shall be detailed on the control valve submittals. The control contractor shall be responsible for coordinating the proper pipe sizes and transitions with the mechanical contractor to provide the correct Cv at 70° open position.

***Delete the following two paragraphs for systems that use pneumatic actuation.***

Characterized Ball Valves 2” and smaller: The following manufacturers are acceptable: Honeywell, Belimo, Johnson Controls, KMC Controls, Yamatake, Bray, Siemens, Siral. Forged brass or bronze body, stainless steel shaft and ball, reinforced Teflon or PTFE ball seals, double O-ring stem seals, characterized disk, maximum of ANSI Class IV (0.01%) leakage, suitable for use on water systems at 150 psig and 212° F. Minimum size for ball valves shall be 0.4 Cv.

Characterized Ball Valves 2-1/2” and larger: Brass or cast iron body, stainless steel shaft and ball, reinforced PTFE Ball seats, EPDM double O-ring stem seals or reinforced PTFE stem packing, characterized disk, iron flanged ends, maximum of ANSI Class IV (0.01%) leakage, suitable for use on water systems at 218 psig and 280° F.

***Do not use ball valves for steam applications as a rule. Use for zone steam applications where size may be an issue for fitting the valve under an enclosure may be acceptable. These valves have not been used for the length of time necessary to have proven performance or longevity.***

STEAM SYSTEMS (15 psig and less):

Use equal percentage or modified equal percentage valves that have a minimum rangeability of 30 to 1. Size for a pressure drop equal to 80% of the inlet steam gauge pressure. For integral face and bypass coils, size steam valves for a pressure drop that will provide an inlet pressure recommended by coil manufacturer for freeze protection. Typically, this is 5 PSI for single tube and 2 PSI for inner distributing tube types. Seat leakage with actuator supplied will meet ANSI class III leakage (0.1%) or better.

Globe valves 2" and smaller: Bronze body, cage trim, brass or stainless steel plug and seat, stainless steel stem, screwed ends, suitable for 35 psig saturated steam (281°F). Only the following globe valve body styles shall be acceptable for terminal unit control: Siemens Powermite 599 VF Series (599 VE Series Zone Valves are not acceptable), Invensys VB7200 Series, Johnson Controls VG7000 Series, Belimo G200 and G300 Series, Honeywell V5011/V5013 Series.

Characterized ball valves 2” and smaller: Forged brass or bronze body, stainless steel shaft and ball, Reinforced PTFE Ball seats, double O-ring stem seals, characterized disk, maximum of ANSI Class IV (0.01%) leakage, suitable for use on steam systems at 15 psig and 250° F. Minimum size for ball valves shall be 0.7 Cv.

Globe valves 2-1/2" and larger: Iron body, brass or stainless steel plug and seat, stainless steel stem, flanged ends, suitable for suitable for 35 psig saturated steam (281°F).

Characterized ball valves 2-1/2" and larger: Brass or cast iron body, stainless steel shaft and ball, reinforced PTFE Ball seats, EPDM double O-ring stem seals or reinforced PTFE stem packing, characterized disk, iron flanged ends, maximum of ANSI Class IV (0.01%) leakage, suitable for use on steam systems at 25 psig and 280° F.

***Design pressure and temperature ratings for steam valves will vary with the degree of superheat available in the system. For systems served from a central heating plant, verify specific requirements with DFD.***

***For applications for steam coils that will require higher degrees of turndown, consider specifying ball valves only due to higher rangeability. See section 23 05 23 for temperature and pressure requirements.***

STEAM SYSTEMS (over 15 psig to 100 psig saturated steam):

Use equal percentage globe valves. Size for a pressure drop equal to 45% of the absolute inlet pressure. Seat leakage with actuator supplied will meet ANSI class III leakage (0.1%) or better.

2" and smaller: Bronze body, cage trim, bronze plug and seat, stainless steel stem, screwed ends, suitable for 100 psig steam at 338°F.

2-1/2" and larger: Iron body, bronze plug, stainless steel stem and seat, flanged ends, suitable for 100 psig steam at 338°F.

STEAM SYSTEMS (over 100 psig and superheated)

Contact DFD to verify class and materials for valves on systems with steam pressures above 100 psig and for systems which may have superheated steam.

**CONTROL SYSTEM INSTRUMENTATION**

Manufacturers: Bulb Type - Johnson Controls, Ashcroft, Marshall, Weksler

Solar Digital Type – Trerice, Palmer, or equal.

SOLAR POWERED DIGITAL DUCT THERMOMETERS:

Solar powered thermometer that is self-powered with no batteries required. LCD display digits ½” minimum with adjustable swivel mount and minimum 6” probe that is vibration resistant.

PIPE THERMOMETERS:

9 inch stem type with an adjustable swivel mount. Scale graduations of 2°F and mid-range accuracy of ±1°F. Install thermometers in separable brass wells filled with conductive fluid. Thermometer temperature range shall not be more than twice the expected temperature range at installed location.

REMOTE BULB THERMOMETERS:

3 inch or larger dial type with recalibration screw on face. Accuracy within 1% of scale range. Thermometers with sensing elements in air ducts with an area of above 6 square feet to have averaging liquid or gas filled capillary sensing elements. Provide separable wells for all pipeline applications. Thermometer temperature range shall not be more than twice the expected temperature range at installed location.

**THERMOSTAT GUARDS**

***Show locations on the plans where thermostat guards are required and where heavy duty guards should be provided. For correctional institutions consult with the agency to the specific type of guard they may want.***

Provide clear plastic locking covers keyed the same. For locations that are subject to physical abuse, provide metal guard, Johnson Controls GRD10A-601, Shaw Perkins Series 16 or equal.

**ELECTRIC/ELECTRONIC THERMOSTATS**

ELECTRIC THERMOSTATS:

For single setpoint applications, provide line or low voltage electric type suitable for heating or heating and cooling as required. Provide the required number of heating and/or cooling stages required for the application. For line voltage ventilation applications utilizing fans and where specified in the sequence of operations, provide an integral manual On/Off/Auto selector switch. Minimum contact rating shall be equal or greater to electrical load of device being controlled. For all thermostats not located in mechanical rooms, provide concealed adjustment. For thermostats located in mechanical rooms, provide exposed adjustment.

LOW VOLTAGE ELECTRONIC THERMOSTATS:

Manufacturers: Honeywell, Johnson Controls, Viconics, or equal.

Where unoccupied setpoints are specified, provide electronic programmable type with seven day setup/setback scheduling with a minimum of two occupied and unoccupied schedules per day through keypad entry on front of unit. For heating and cooling applications, provide automatic heating/cooling switchover. For applications that control fans, provide fan override switch. For ventilation or packaged economizer applications provide a dry contact for ventilation damper or economizer initiation. For thermostat control of economizer, provide a 0-10VDC modulated output for economizer damper control.

For applications that require integration to the building automation system, provide a BACnet communication interface. If a communication interface is specified, occupancy scheduling in the thermostat is not required.

Only use pneumatic low limit thermostats for pneumatic only systems. For DDC control with pneumatic or electric actuation use electric low limit thermostats.

LOW LIMIT THERMOSTATS (freezestats):

Electric two-position type with temperature sensing element and manual reset for all applications except integral face and bypass steam heating coils which shall have auto-reset freezestats and latching relays (see execution section for details). Unit to be capable of opening control circuit if any one-foot length of sensing element is subject to a temperature below the setpoint. Length of sensing element to be not less than one lineal foot per square foot of coil surface areas. Unless otherwise indicated, set low limit controls at 36°F.

AQUASTATS:

Line voltage type with single pole, double throw switch of adequate rating for the applied load.

REMOTE BULB THERMOSTATS:

Line voltage type with single pole, double throw switch of adequate rating for the applied load. Thermostat to have adjustable setpoint suitable for controlled load.

IMMERSION TYPE THERMOSTAT SENSORS:

Rod and tube type with linear output. Provide separable wells with heat conductive fluid for installation in pipeline. Units shall be factory calibrated.

FIRESTATS:

UL labeled, manual reset, line voltage type with 135°F setpoint.

***Delete the following pneumatic specifications if there are no pneumatic controls provided on the project.***

**PNEUMATIC THERMOSTATS**

Provide insulated subbase for all thermostats installed on outside walls or walls exposed to outside air temperatures. Subbase to provide a minimum of one half inch of insulation.

PNEUMATIC SINGLE TEMPERATURE ROOM THERMOSTATS:

Two-pipe, non-bleed, proportioning relay type with adjustable throttling range, lockable but adjustable stops, and test plug for calibration. Furnish with concealed adjustment on a brushed aluminum or brushed nickel cover

Thermostats used for both heating and cooling control are to have separate sensing elements, an adjustable deadband of 2°F to 10°F, and minimum setpoint range of 60°F to 90°F.

Use direct or reverse acting thermostats to match device being controlled.

PNEUMATIC DUAL TEMPERATURE ROOM THERMOSTATS:

Use dual temperature type thermostats in spaces with an occupied/unoccupied cycle of operation. Dual temperature thermostats shall have two sets of temperature sensing elements; one for occupied operation and one for unoccupied operation. Initiate changeover centrally by a change in control air supply pressure. Provide manual reset to permit return to normal temperatures during unoccupied cycles. Units shall reset to normal during the next cycle of operation. Furnish with concealed adjustment on a brushed aluminum or brushed nickel cover

ASPIRATING THERMOSTATS:

Similar to pneumatic room thermostats except flush mounted in an insulated wall box with cover plate. Positively induce room air over the sensing elements by the same compressed air supply as used with the thermostat. Secure cover plate with vandal-proof screws. Furnish with concealed adjustment on a brushed aluminum or brushed nickel cover.

LOW LIMIT THERMOSTATS (freezestats):

Two-position pneumatic type with temperature sensing element and manual reset. Unit to be capable of opening control circuit if any one-foot length of sensing element is subject to a temperature below the setpoint. Length of sensing element to be not less than one lineal foot per square foot of coil surface areas. Unless otherwise indicated, set low limit controls at 36°F.

REMOTE BULB THERMOSTATS:

One or two-pipe, proportioning, direct or reverse acting to match device being controlled. Thermostat to have adjustable setpoint and throttling range. Capillary to remote bulb shall be armored.

DUCT THERMOSTATS:

Pneumatic, one or two-pipe proportioning type, with adjustable setpoint and throttling range. Units shall be direct or reverse acting to match device being controlled. Sensing element to be averaging type, temperature compensated, armored, with minimum length of 8 feet.

**PNEUMATIC HUMIDISTATS**

ROOM HUMIDISTATS:

Wall mounted, proportioning type, with adjustable 2% RH throttling range, 30% to 80% RH operating range at temperatures to 110°F, and cover with setpoint indication. Cover shall match room thermostat.

DUCT HUMIDISTATS:

Insertion type, fully proportioning, adjustable 2% RH throttling range, and operating range from 20% to 80% RH at temperatures to 150°F. Minimum length of sampling tube to be 12 inches.

Require pneumatic high limit humidistats for DDC systems with pneumatic actuation.

HIGH LIMIT HUMIDISTAT:

Two position, reverse acting, insertion type, with setpoint adjustable in 2% RH increments.

The following three specification articles are for pneumatic control systems only, remove if control system is DDC with electric or pneumatic actuation.

**RECEIVER CONTROLLERS**

Pneumatic controllers to be high capacity type, fully adjustable, direct, or reverse acting, 2-pipe non-bleed design, with adjustable proportional band. Capable of accepting 1 or 2 transmitter inputs with a separate third input port for local or remote control point adjustment. Provide direct reading scales to match range on input devices or separate adjustment switches with calibrated dials.

**PNEUMATIC TRANSMITTERS**

BUILDING STATIC PRESSURE TRANSMITTERS:

One pipe, direct acting, double bell, differential type with temperature compensation, scale range 0.01 to 1.0 inch w.g. positive or negative, and sensitivity of 0.0005 inch w.g. Transmit pneumatic signal to receiver with matched scale range.

PRESSURE TRANSMITTERS:

One pipe, direct acting, indicating type, with range suitable for system, and proportional pneumatic output as required.

TEMPERATURE TRANSMITTERS:

One pipe, with linearity within 1/2 percent of range for 200°F span and one percent of range for 50°F span and equipped with a compensated bulb, averaging capillary, or rod and tube sensing element. Range to be suitable for system. Pneumatic output signal to be directly proportional to measured variable.

HUMIDITY TRANSMITTERS:

One pipe, with linearity within ±1% for a 70 percent relative humidity span, capable of withstanding 95 percent relative humidity without loss of calibration. Pneumatic output signal directly proportional to measured variable.

**PNEUMATIC SYSTEMS ACCESSORIES**

PILOT POSITIONERS:

Adjustable start point (2-12 psig) and span (5-13 psig), equipped with brackets for mounting on operator.

PRESSURE GAUGES FOR PROCESS VARIABLE INDICATION:

Manufacturer's standard, black letters on white background, 2\_1/2 inch diameter, flush or surface mounted, with front calibration screw, suitable dial range calibrated to match sensor, in appropriate units.

INSTRUMENT PRESSURE GAUGES:

Manufacturer's standard, black letters on white background, 1\_1/2 inch diameter, and stem mounted with suitable dial range.

RELAYS:

For summing, reversing, amplifying, high or low-pressure selection, with fixed 1:1 [or adjustable] input/output ratio.

SWITCHES:

With indicating plates, accessible adjustment, calibrated, and marked.

**TIME CLOCKS**

***Time clocks should only be used where direct digital control or a central building automation system is not available for start/stop control, or where use a DDC systems cannot be economically justified. Consult with DFD prior to use of mechanical time clocks.***

UL listed, digital, 7-day, minimum of 10 on/off programs per day, holiday programming, automatic daylight savings switchover, and minimum of seven-day battery back-up.

**DUCT SMOKE DETECTOR AND FIRE ALARM INTERFACE MODULES**

***Coordinate with Division 28 to provide duct detectors or fire alarm control modules for air handling unit and exhaust system shutdown and smoke control inputs to the DDC system. In most cases fire alarm control modules will be the most effective and flexible way of achieving this interface. Ensure that the logic matrix for the fire alarm devices to trigger a HVAC response is clearly specified.***

Duct smoke detectors and fire alarm control modules shall be provided by others. Provide wiring, conduit, and necessary interface with fire alarm system to perform specified sequence of operation.

**AIR FLOW STATIONS**

For duct mounted airflow stations, design ductwork in such a way that there is adequate straight runs to provide for accurate air flow measurement (a minimum of 10 duct diameters upstream and 5 duct diameters downstream - more if possible) and with minimum velocities above 700 FPM for air stream other than outside air. Minimum outside air velocities should be above 100 FPM. If any of these criteria cannot be met, consult with DFD – the AE will be held responsible for designs that result in misapplication of air flow measurement. Velocities below this speed are very difficult to measure and will likely result in inaccurate readings.

Fan piezometers are preferred over fan inlet probes and should be specified to come with the fans where air flow measurement is required for control. Fan inlet probes are acceptable but should be avoided on small fans because of access for mounting and system effect on fan performance.

All dampers should be located downstream of the airflow station. Provide for access doors upstream or where required for all duct mounted air flow stations for maintenance purposes. Show all air flow stations on plans and indicate if they are duct, piezometer, or fan inlet type. Schedule maximum and minimum airflow on plans and specifications for all air systems that have airflow stations, so the contractor has the information to determine flow station type and pressure transducer allowed.

Provide duct mounted airflow station type based on the following minimum design velocities. Pitot or thermal dispersion flow stations can be used for fan inlet flow stations. Outside air flow stations shall be thermal dispersion type only. Turndown of variable volume fan systems must be considered. Provide an airflow station schedule detailing the airflow range to be measured, corresponding velocity pressure, differential pressure transducer range, and the airflow station size.

Air Velocity Duct Mounted Air Flow Station Type

0-700 FPM Thermal Dispersion

>700 FPM Thermal Dispersion or Multi-probe velocity pressure pitot style

Duct mounted Multi-probe velocity pressure pitot air flow stations:

Multi-probe duct velocity pressure sensing station constructed of minimum 16 gauge galvanized steel casing, and multiple metallic velocity pressure sensors with automatic averaging manifold. For duct installations, provide an aluminum honeycomb cell air straightener with maximum openings of ½” and minimum of 3” depth. Each airflow measuring element shall contain multiple Total and Static pressure sensors, placed at equal distances (for rectangular Ducts) and at concentric area centers (for circular ducts) along the element length. The number of sensors on each element and the quantity of elements utilized at each installation shall comply with the ASHRAE standards for duct traversing. The airflow measuring elements shall be capable of producing steady, non-pulsating Total and Static pressure signals, with accuracy within ±2% of actual flow. Airflow resistance to be less than or equal to 0.23 inches of water at 4000 feet per minute air velocity.

Fan inlet probe air flow stations:

For fan inlet probes provide two probes for each fan inlet (for DWDI fans provide four probes). Pressure drop caused by the airflow elements shall not exceed 0.03” w.c. at 2000 FPM. Airflow elements shall be provided with all necessary pivot mounting hardware and signal connection fittings for connection to tubing provided by the installing contractor. For pitot type air flow stations, the static and total pressure manifold piping by the installing contractor shall be piped symmetrically so take-off will be located where line lengths between all probes are equal in length. Thermal dispersion type shall not to be used for inlet probe air flow stations.

Fan inlet piezometers:

Where fan inlet piezometers are provided, these shall be used by the control contractor for air flow measurement. The air velocity transducers shall be provided under this Section and sized as described below.

For duct mounted and fan inlet pitot flow stations or factory mounted piezometers, air velocity transducers range shall be sized less than two times the design velocity pressure at maximum flow and will meet the requirements under the PRESSURE TRANSDUCERS (AIR)specification later in this specification section unless noted below. For air handling units with multiple fans where flow is measured at the fan, provide a pressure transducer for each fan. Manifolding of static and total pressure from multiple fans is prohibited.

Thermal dispersion air flow stations:

Manufacturers: Ebtron, Air Monitor, Kurz Instruments, or equal.

Probe Sensor Density:

Area (sq. ft.) Sensors

<= 1.5 2

>1.5 to <4 4

4 to <8 6

8 to <12 8

12 to <16 12

>=16 Minimum 4 sensors per 4 square feet of area where area is rounded up or down to the nearest 4 square foot area, i.e. ≤18 sq. ft. = 16 sensors, >18 sq. ft. = 20 sensors

Airflow Sensor Accuracy: ±2% of reading

Calibrated Range: 0-2500 FPM for duct applications and 5000 FPM for fan inlet applications

Temperature Sensor Accuracy: ±0.15°F

Temperature: -20°F to +140°F

Relative Humidity: 0 to 95% (non-condensing)

Provide transmitter that will average up to sixteen sensors and provide two field selectable linear analog output signals (4-20mA and 0-10 VDC) proportional to airflow and temperature. Sensor electronic circuitry other than the temperature sensors shall not be exposed to the air stream and shall be protected from moisture to prevent failure.

**WATER FLOW MEASUREMENT**

## **For use in campus and central plant chilled water and hot water flow measurement applications. Flow sensor provides analog outputs for flow rate for connection to the central control system. These would typically be used for total building flow measurement. Use one of the two specifications listed below for the flow meter and then choose the other options listed after the flow meter specifications as required for the application.**

***This specification is for electromagnetic flow measurement and allows both a “hot tap” style flow sensor or a flanged full bore flow sensor. Use electromagnetic flow measurement systems for all projects unless lower cost is desired. The insertion flow sensor can be installed and serviced without system shutdown. Electromagnetic insertion flow sensors cannot provide bi-directional flow readings. If bi-direction flow measurement is required, a full bore or insertion turbine flow sensor will be required. All accuracy statements must be complete including a percentage of reading accuracy over a stated velocity range. Provide schedule on drawings.***

Manufacturers: Onicon Inc., Emerson Rosemount, Yokogawa., or approved equal.

Provide an Electromagnetic Flow Meter complete with integral electronics module. The flow meter shall be either a full bore flanged meter or insertion style meter installed in either the supply or return pipe of the system to be measured following the manufacturer’s installation instructions. Full bore style flow meters shall be installed via flanges matching the ANSI class (150, 300) required for the application. The installing contractor is responsible for providing suitable mating flanges. For installations in non-metallic pipe, install grounding rings between flanges. Insertion style flow meters shall be installed through a 1” full port ball valve to enable insertion and removal of the meter without system shutdown. Insertion flow meters shall be hand-insertable up to 400 psi.

# **The manufacturer shall provide a certificate of NIST traceable wet-calibration for each flow meter. Accuracy shall be as follows:**

# **± 1% of reading over a 10:1 turndown (from 2 to 20 ft/s)**

Overall rangeability shall be from 0.25 ft/s to 20 ft/s (80:1 turndown ratio).

The flow meter shall have a maximum operating pressure of 400 PSI, maximum operating temperature of 2000 F (optional 3000 F peak) and a pressure drop of less than 1 PSI at 17 feet per second flow velocity.

The flow meter shall have a minimum of one analog output, 0-10 VDC or 4-20 mA for connection to the BAS for liquid flow rate and a scalable dry contact output for totalization unless the flow meter is connected to a BTU measurement system that will provide this output or be directly integrated to the BAS. The flow meter shall also include integral frequency output for diagnostic purposes and for connection to local display. All outputs shall be linear with flow rate.

Local display of flow rate to be provided in a steel NEMA 4 remote wall mounted enclosure with internal terminal strip connections and shall be powered by 24 VAC or VDC and provide necessary power to flow meter.

The following two paragraphs for BTU measurement is for use on buildings that will be required to pay for utility services or to monitor energy usage. If in question, contact DFD to see if this will be a requirement.

Provide a BTU Measurement System that shall consist of a flow sensor, two temperature sensors, a BTU meter, thermowells and all required mechanical installation hardware. The BTU meter shall include a front panel mounted display for BTU total, liquid flow rate, supply temperature and return temperature. The meter shall be supplied by 24VAC or 24VDC to provide power to the BTU meter electronics, flow meter, and temperature sensors.

The BTU measurement system shall provide a BACnet MSTP RS-485 communication interface that will provide information corresponding to total thermal energy transfer, supply temperature, return temperature, and liquid flow rate. For meters that do not have integral BACnet communications, provide a separate gateway device that will provide a BACnet MSTP communication interface. All programming of the gateway device shall be provided by this contractor. Temperature sensors shall be calibrated and matched for the specific temperature range for each application. The calculated differential temperature used in the energy calculation shall be accurate to within + 0.150F (including the error from individual temperature sensors, sensor matching, input offsets, signal conditioning, and calculations). When DDC PI control loops are specified in 23 09 93 that use flow or temperatures from the flow meter and BTU measurement system, provide a compatible discrete hardwired output to the DDC controller that is doing the control loop in addition to the information provide through the communication interface.

**STEAM FLOW MEASUREMENT**

The following flow measurement specification is for use in a campus or central plant steam measurement applications. It is the responsibility of the A/E to arrange sufficient space to install the flow sensing devices, so they are capable of performing their intended task in an accurate manner. Show the location of the steam meter on the plans. Provide schedule including measurement flow range on drawings. If a high pressure meter is used, take the meter pressure drop into account when sizing the steam PRV station.

The selection of the steam meter shall be based on the following parameters and recommendations to guarantee that the accuracy of the steam meter station reading stays within the ± 1% of the actual flow from 5% to 100% of the maximum rated flow, and ± 1% of FSD from 1% to 5% of the maximum rated flow and the repeatability within ± 0.5% over the entire specified turndown.

* The location of the steam meter shall comply with the straight-run pipe lengths upstream and downstream recommended by the manufacturer.
* For high pressure applications (> 15 PSI), the pressure drop through the primary element and sensor, shall not be greater than 400 inches w.c. / 14.4 PSI for the maximum mass flow rate.
* For low pressure applications (<15 PSI), the pressure drop through the primary element and sensor, shall not be greater than 50 inches w.c. / 1.8 PSI.
* The mass flow rate shall be computed in lbs./hour, temperature and pressure compensated. The steam meter turndown shall be no less than 30 to 1 for high pressure applications and 15 to 1 for low pressure applications based on actual flow conditions or the turndown required in the meter schedule, whichever is greater.

Primary Element, Flow Sensor:

Manufacturers: Spirax/Sarco ILVA, Veris Accelebar, V-Cone, or approved equal.

* A Variable Area, either non-spring loaded, or spring loaded, shall be used as the primary element of the steam meter. The material of the internal components of the flow sensor must be 316-stainless-steel. The body of the primary element may be steel. The primary element shall comply with standard codes, ISO, ASME.
* The flow sensor shall be installed between pipe flanges, with body constructed of 316 stainless steel, rated for 200 psig and 660°F for high pressure applications and rated for 150 psig and 370°F for low pressure applications. If the primary flow element is a wafer or lug type arrangement and is longer than its flange-to-flange dimension, then a spool piece shall be included of sufficient length to permit the removal of the primary flow element with spool piece and eliminate disassembly of any downstream or upstream piping when servicing the element. Provide a separate flanged spool piece (specified under Section 23 05 15) that can directly replace the meter assembly when it is removed. Coordinate with mechanical contractor for providing required spool pieces and proper installation of the meter.

Secondary Elements, Differential Pressure and Gauge Pressure Transmitter(s):

Manufacturers: Rosemount, Honeywell, ABB, Siemens, Foxboro, or approved equal.

* The output shall be 4-20mA with digital signal with HART protocol. The accuracy shall be at least ±0.1% of span, 4 to 20mA, and ±0.07% of span, digital. Drift less than ±0.1% of URL over at least 8,000 hours.
* Maximum range for the differential pressure measurement shall be 0 to 400 inches w.c. with a transmitter pressure rating of 300 psi. Range limits for absolute pressure shall be 0 to 300 psia. The transmitter shall be energized with a 24-VDC source. The Differential Pressure transmitter shall be mounted below the flow element using process tubing as specified below.
* Provide stacked (two) differential pressure transmitters for Veris Accelebar, V-Cone, or other fixed orifice primary element flow sensors. Size transmitters as required to meet or exceed accuracy and turndown requirements for the specified application.

RTD Temperature Sensor:

Manufacturers: Rosemount, Honeywell, ABB, Moore, JMS or approved equal.

* Furnish a spring loaded Dual Element RTD assembly.
* The temperature process input range shall be a minimum of 20 to 600°F.
* The hermos-well shall be 316-stainless steel, suitable for the size of the process pipe, and provided with a ¾-inch NPT process connection.

Flow Computer:

Manufacturers: Kessler-Ellis Products model 749, Spirax/Sarco FP93B, Foxboro, or equal.

* The flow computer shall provide loop powered, 4-20 mA inputs for the temperature and pressure compensated mass flow rate in lbs./hr. The flow computer shall totalize the mass flow rate and shall be equipped with BACnet MSTP or BACnet/IP communication. Provide a gateway (Real Time Automation or equivalent) to convert Modbus TCP/IP RTU communications port or Modbus RTU RS-485 to BACnet protocol, if necessary.
* Standard LCD indicator with backlight shall be included with the flow computer.
* The flow computer shall provide precise and reliable measurement of absolute/gauge and differential pressure, sensor and electronics temperatures, and process temperature from an external transmitter/RTD combination. It shall calculate densities, according to Steam Tables ASME 1997, and mass flow rates for the actual pressure and temperature in line for both saturated and superheated steam.
* Meter data in the form of total consumption, flow rate and a meter diagnostic must be communicated to the Building Automation System (BAS). Consumption shall be in billable units, klbs. Of steam. Flow rate will be in klbs. /hr of steam. Meter diagnostic will be in the form of Normal or Failure.
* Power for flow computer to be 24 VAC/VDC. Provide transformer or power supply externally mounted to flow computer.

The process connectors, normally NPT 3/8-inch, shall be 316 stainless steel. A 316 stainless steel 3-valve manifold to mount the pressure differential transmitter shall be supplied. Drain/vent material and isolation valves shall be also 316 stainless steel and furnished. A minimum of 18” horizontal piping off of primary device before vertical piping to secondary element shall be provided. Interconnections and drawings for installation of the primary, secondary, and tertiary elements of the corresponding devices shall be submitted prior to their installation for review by the project AE. Installation and piping to be provided by the Division 23 mechanical contractor in accordance with manufacturer supplied installation drawings.

***Include the following if you are metering the Steam distribution or total building condensate being sent back to the plant. Be sure to add a note on the E sheets to highlight the EC scope for these meters. Coordinate with Campus IT group for Ethernet or Intranet connectivity.***

**STEAM CONDENSATE ULTRASONIC FLOW METERS FOR UTILITY DISTRIBUTION**

PUMPED CONDENSATE RETURN:

Manufacturers: Flexim Ultrasonic (FLUXUS F/G721), Panametrics (DigitalFlow), or Siemens (SITRANS FS).

Ultrasonic Flow Meter:

Single-channel, ultra-sonic meter will measure and output both liquid flow rate and thermal energy use. Energy shall be measurable in BTU and PPH. Flow rates and units shall be displayed and adjustable using the remote mounted flow computer.

Also includes NIST traceable wet flow certificate of accuracy. Provide the following:

* Service: Thermal energy measurement for Pumped Condensate Return Line
* Communications: Include BACnet MSTP communications port – provide BACnet MSTP gateway device if required
* Analog outputs: Qty. ( 1 ) 4-20 mA output provided
* Binary outputs: Qty. ( 2 ) solid-state relay outputs provided
* Supply power: 120 volts AC
* Transducers: verify size of transducer with manufacturer based on pipe size, rated for liquid temperatures of -40F to 266F, provided with integral jacketed signal cable (32 feet long).
* RTD Temperature Sensors: RTD’s are strap-on, surface mounted design, rated for service temperatures from -58F to 482F, provided with integral jacketed signal cable (20 feet long).
* Stainless steel mounting hardware kit for transducers and temperatures sensors.
* Accuracy: +/- 1% of reading +/- 0.02 ft/s
* Turndown: 1000:1

**TEMPERATURE CONTROL PANELS**

Constructed of steel or extruded aluminum, with hinged door, keyed lock, and baked enamel finish. Install controls, relays, transducers, and automatic switches inside panels. Label devices with permanent printed labels and provide asbuilt wiring/piping diagram within enclosure. Provide raceways for wiring and poly within panel for neat appearance. Provide termination blocks for all wiring terminations. Label outside of panel with panel number corresponding to plan tags and asbuilt control drawings as well as building system(s) served.

Control panels that have devices or terminations that are fed or switch 50V or higher shall enclose the devices, terminations, and wiring so that Personal Protective Equipment (PPE) is not required to service the under 50V devices and terminations within the control panel. As an alternative, a separate panel for only the 50V and higher devices may be provided and mounted adjacent to the under 50V control panel.

For panels that have 120VAC power feeds provide a resettable circuit breaker. Provide label within the panel indicating circuit number of 120VAC serving panel

***Include the following paragraph for DDC controlled systems. Include a service shutdown binary input for all air handling unit systems in the DDC point chart.***

Provide a service shutdown toggle switch for each air handling unit system located inside the temperature control panel that will initiate a logical shutdown of the air handling unit system. Label the switch so it is clear which position is shut down and which is auto.

***Include the following paragraph for pneumatic control only.***

Manual switches including damper “minimum-off” positioning switches, “summer-winter switches”, “manual-automatic switches”, dial thermometers, pressure gauges, and receiver indicating gauges shall be flush mounted in front door of panel. Clearly identify each item with engraved nameplates.

**TEMPERATURE SENSORS**

***Consult with the agency as to the type of terminal unit sensors to be provided on the project including desired adjustments, overrides, and guards. Clearly specify where the different types of sensors and guards should be located on the plans or in the specifications. Show outside air temperature sensor locations on plans in location that will not be influenced by sun or exhaust/relief air.***

Thermistor temperature sensor manufacturers: PreCon, BAPI, and ACI

Use thermistor or RTD type temperature sensing elements constructed so accuracy and life expectancy is not affected by moisture, physical vibration, or other conditions that exist in each application.

RTD’s shall be of nickel or platinum construction and have a base resistance of 1000Ω at 70°F and 32°F respectively. 100Ω platinum RTD’s are acceptable if used with temperature transmitters.

The temperature sensing device used must be compatible with the DDC controllers used on the project.

RTD

Accuracy (Room Sensor Only) minimum + 1.0°F

Accuracy (Averaging) minimum + 1.2°F

Accuracy (Other than Room Sensor or Averaging) minimum + 0.65°F

Range (Bulb) minimum -40 – 220°F

Range (Averaging) minimum -40 – 200°F

Thermistor

Accuracy (All) minimum + 0.36°F

Range (Bulb) minimum -30 – 230°F

Range (Averaging) minimum -30 – 200°F

Heat Dissipation Constant minimum 2.7 mW/°C

Temperature Transmitter

Accuracy minimum + 0.1°F or +0.2% of span

Output 4-20 mA

Provide limited range or extended range sensors if required to sense the range expected for a respective point. Use RTD type sensors for extended ranges beyond -30 to 230°F. If RTD’s are incompatible with DDC controller direct temperature input, use temperature transmitters in conjunction with RTD’s.

Use wire size appropriate to limit temperature offset due to wire resistance to 1.0°F. If offset is greater than 1.0°F due to wire resistance, use temperature transmitter. If feature is available in DDC controller, compensate for wire resistance in software input definition.

***Select one of the two paragraphs below based on what the agency wants for terminal unit temperature sensors and edit as required. Multiple styles may be desired in which case both paragraphs should be used, and the where each type of sensor should be clearly specified on the plans with unique symbols.***

Terminal unit sensors shall be provided with blank covers and no adjustments and shall be provided under this Section.

Terminal unit sensors shall be provided with digital displays that indicate room temperature and setpoint and have a manual occupancy override and indication of occupancy status. Provide setpoint adjustment as specified in the DDC Input/Output Summary Table and sequence of operation. Terminal unit space sensors specified with overrides or adjustments shall be furnished under Section 23 09 23 or 23 09 24.

***Delete the following sentence if only one style of thermostat is used.***

If multiple styles of terminal unit sensors are specified, provide style of sensor as indicated on the plans. If terminal unit sensors are specified above to both have displays and have blank covers and the plans do not specify the type to use, sensors with displays shall be used and shall be provided under Section 23 09 23 or 23 09 24.

Use averaging elements on duct sensors when the ductwork is ten square feet or larger. All mixed air and heating coil discharge sensors shall have averaging elements regardless of duct size. For mixed air, heat wheel leaving outside air, and heating coil discharge sensors, provide multiple sensors for coverage of the coil to be one foot of coverage for 2 ft2 of air plenum or coil size with a +25% variance allowable for the coverage, i.e. a single 24’ averaging element shall cover an area of up to 60 ft2 and two 24’ sensors would cover areas of 60 ft2 to 120 ft2, three 24’ for 180 ft2 and larger. A maximum of three 24’ averaging sensors shall be used for any of the above applications regardless of plenum or coil size. Averaging temperature sensors with a maximum length of 24’ shall be used for large coil or plenum applications where more than one averaging temperature sensor is required unless a smaller element can provide the coverage as specified above. Each averaging temperature element shall be wired to a separate analog input on the DDC controller.

For all averaging temperature sensor applications other than the three specified above, provide a single averaging sensor of a length that will provide the coverage as specified above. For plenum or coils larger than 60 ft2, one averaging sensor with a minimum length of 24’ shall be provided.

In piping systems use temperature sensors with separable wells designed to be used with temperature element.

**HUMIDITY SENSORS**

For non-critical humidity applications, use the following specification.

Use capacitive thin-film polymer sensor types with a range of 0-100% RH. Accuracy to be no less than **[±2%]** in the range of 20% RH to 80% RH with a response time of 120 seconds or less. Provide covers for room humidity sensors as specified for temperature sensors.

For outside air applications, use sensor designed for outside air use along with weather enclosure. Provide sensor equal to Vaisala Model HMD60UO w/ DTR503B enclosure and weather resistant mounting hardware.

***For pool humidity applications, use the following specification.***

For humidity sensors in pool applications, provide a sensor that has both a humidity and temperature sensors without a display and an IP65 rated enclosure. Space humidity sensor accuracy to be a minimum of 2.0 %RH accuracy from 0-90 %RH and 3 %RH accuracy from 90 – 100 %RH humidity, with NIST traceable calibration certificate. Temperature sensor accuracy to be a minimum of + or - 0.36. For space humidity Vaisala model HMW112 or equal and for duct humidity Vaisala model HMW110 or equal.

***For critical humidity applications such as chilled beam applications where multiple sensors are needed and accuracy is critical, or any other application where high accuracy and low drift is needed, use the following specification. This will also provide accurate dewpoint measurement if required.***

For space humidity sensors, provide a humidity sensor that has both humidity and temperature sensors and display. Space humidity sensor accuracy to be a minimum of 1.7 %RH accuracy from 0-90 %RH and 2.5 %RH accuracy from 90 – 100 %RH humidity at temperatures from 50 to 104 DegF, with NIST traceable calibration certificate. Temperature sensor accuracy to be a minimum of + or - 0.54 DegF at temperatures from 50 to 86 DegF, Vaisala model HMW92D or equal. Duct humidity sensor accuracy to be a minimum of 1.5 %RH accuracy from 0-90 %RH and 2.5 %RH accuracy from 90 – 100 %RH at temperatures from 50 to 104 DegF, with NIST traceable calibration certificate. Vaisala model HMD65 or equal.

***Where the agency needs to maintain high accuracy humidity measurement, provide the following specification. Discuss with DFD if this is warranted.***

Provide a handheld humidity and temperature meter and all cables and accessories for connection to space and duct humidity sensors for calibration, a duct humidity probe, and carrying case for the indicator and probe. Handheld humidity sensor accuracy to be a minimum of 1 %RH accuracy from 0-90 %RH and 1.7 %RH accuracy from 90 – 100 %RH humidity with NIST traceable calibration certificate, Vaisala model HM70 or equal.

***Where outside air humidity is required for process calculations and high accuracy and durability is required, use the following specification.***

OUTDOOR AIR HUMIDITY AND TEMPERATURE MONITORING:

Provide an outdoor air humidity and temperature sensor with an integrated radiation shield. Humidity sensor accuracy to be a minimum of ±2 %RH accuracy from 0-90 %RH and ±3 %RH accuracy from 90 – 100 %RH at temperatures from 50 to 86 DegF. Temperature sensor accuracy ±0.36 ºF. Vaisala model HMS112 or approved equal.

**PRESSURE TRANSDUCERS (AIR)**

Provide pressure transducers specified below for the following applications:

* Duct static pressure applications where setpoints are specified to control at greater than 0.1” w.c.
* Pitot type fan inlet air flow stations.
* Air filtration in fan powered equipment.

Manufacturers: Mamac Systems, Setra, and Veris Industries.

Provide a transmitter that operates on the capacitance principle and is capable of sensing low positive, negative or differential pressures. Transmitter shall have a minimum of three pressure ranges adjustable by an onboard switch or jumper. Size the transmitter where the middle or high range is suitable for the application. Use a bi-directional transmitter for applications that may have both positive and negative pressure excursions. Transmitter shall be provided with an integral four-digit display of the pressure sensed.

Accuracy (including non-linearity and hysteresis) + 1% FS

Compensated Temperature Range 32°-140° F

Temperature Effect 0-1”wc Range .09% FS/°F

>1”wc Range .02% FS/°F

Output 4-20 MA

Load Impedance (smallest maximum acceptable) 800 Ω max.

Operating Temperature 32°-140° F

For air filtration monitoring, size differential pressure transducers to provide for the following ranges:

Filter Type Scale Range (inch W.G.)

Panel filters 0.0 to 0.5

MERV 7 0.0 to 1.0

MERV 11 0.0 to 2.0

MERV 14 0.0 to 2.0

HEPA filters 0.0 to 4.0

Roll filters 0.0 to 1.0

Activated carbon filters 0.0 to 2.0

Provide pressure transducers specified below for the following applications:

* Duct static pressure applications where setpoints are specified to control at 0.1” w.c. or lower.
* All duct mounted pitot type air flow stations.
* Space/building static control or monitoring.

Manufacturers: Paragon Controls MicroTrans, Air Monitor Veltron DPT2500 Plus, or approved equal.

The airflow transducer shall provide noise filtration and automatic auto-zeroing. The automatic zeroing circuit shall be capable of maintaining the transducer output to within ±0.25% of operating span. The transducer output shall be locked and maintained at the last given output value during the automatic zeroing period so as not to interrupt the automatic control process. Use a bi-directional transmitter for applications that may have both positive and negative pressure excursions. Transmitter shall be provided with an integral four-digit display of the pressure sensed.

Transducer Span: <2 times the design velocity pressure at maximum flow, single range

Accuracy: ±0.25% of full scale, including non-linearity, hysteresis, deadband, and non-repeatability

Temperature Effect: ±0.15% of full scale/°F

Response: 0.5 sec. for 98% of full span change

Overpressure: 5 PSIG Proof

Power: 24VAC/VDC

Analog Output: 0-5VDC, 0-10VDC, or 4-20mA field adjustable

Auto Zero Frequency: every 1 to 24 hours on 1 hour intervals

For space or building static pressure monitoring, use Vaisala model SPH10 Static Pressure Head, or approved equal for outside air reference and Mamac A-523 or equal for space reference. For fan housing or duct static or differential pressure sensing, use gasketed metal static pressure sensors. Mamac A-520 or equal. Mount in location shown on plans or approved by AE.

**PRESSURE TRANSDUCERS (LIQUID/STEAM)**

***Show locations of all pressure sensors and differential pressure sensors and gauges on the plans and show sensors along with gauges on details.***

Provide a transmitter that utilizes capacitive or thin film strain gauge sensing. Provide for an analog gauge piped in parallel with the transducer. Gauge shall meet specifications as specified in Section 23 05 15. Coordinate with mechanical contractor to provide and install this gauge. For differential pressure applications provide with bypass valve manifold assembly with valved venting capability.

Accuracy (including non-linearity and hysteresis) + 0.5% FS

Compensated Temperature Range 32°-150° F

Temperature Effect (over compensated range) 0.03%/°F

Output 4-20 MA

Load Impedance (smallest maximum acceptable) 600 Ω Minimum

Operating Temperature 0°-175° F

Hysteresis 0.75% of span

**DIFFERENTIAL PRESSURE SWITCHES**

***Specify current switches for most status point applications. Where direct measurement of the process medium is deemed critical to indicate system status, specify differential pressure switches. Where current switches only are used, delete this specification.***

Differential pressure switches shall sense both inlet and outlet of fans and pumps. Device shall be rated for 150% of maximum system pressures that may be encountered. Provide with pressure differential that will be required to meet specified operation and/or to prevent nuisance “toggling” of the device in the system served. For static pressure sensing, use gasketed metal static pressure sensors for insertion into fan housing and ductwork. Mamac A-520 or equal.

**AIR PRESSURE SAFETY SWITCHES**

Air pressure safety switches shall be a differential pressure switch that will sense differential, negative, or positive pressure as required by the sequence of operation specification. Device shall be rated for a minimum of 150% of maximum system pressures that may be encountered. Provide with pressure range that will be required to meet specified operation in the system served. Provide with a normally closed contact that will open above setpoint and will not close until the manual reset button is depressed. Setpoint shall be manually adjustable. For static pressure sensing, use gasketed metal static pressure sensors for insertion into fan housing and ductwork. Mamac A-520 or equal.

**CURRENT STATUS SWITCHES**

Provide a current sensor with adjustable threshold and digital output with LED display, equal to a Veris model H-708/H-904. Threshold adjustment must be by a multi-turn potentiometer or set by multiprocessor that will automatically compensate for frequency and amperage changes associated with variable frequency drives. When used on variable speed motor applications, use a current sensor that will not change state due to varying speeds. Current switches with integral relays shall not be used for start/stop and status motor applications.

**ELECTRIC TO PNEUMATIC TRANSDUCERS**

***Electric to pneumatic transducers should only be used where existing pneumatic actuation is being retained.***

Electric to pressure transducers shall have internal pressure feedback to compare actual commanded pressure value and will compensate for leakage or drift. Provide with manual override. Output of transducer shall bleed to zero PSI on power fail.

High air capacity 500 SCIM at 20 psig

Low air consumption 15 SCIM at 20 psig

Input 4-20 MA / 0-10VDC

Output 0-20 psig

Linearity 1% of span

Hysteresis 1% of span

This contractor shall be responsible for verifying that the input of electric to pneumatic transducers is compatible with the output of the DDC controller provided under 23 09 24 or 23 09 23.

**CARBON DIOXIDE (CO2) SENSOR**

Provide a Carbon Dioxide (CO2) sensor that shall utilize non-dispersive infrared (NDIR) technology. The sensor shall have a linear analog output over a range of 0-2000 ppm and have built in display of CO2 level. The sensor shall have an automatic calibration algorithm that will compensate for sensor drift over time due to sensor element degradation. Unit shall be provided with a 0-10VDC or 4-20mA analog output that is selectable and a field adjustable relay alarm output. Accuracy shall be better than ±5% of reading or ±50ppm whichever is higher. The sensor shall be user calibratable with a minimum calibration interval of five years.

**CONDENSATION MONITORS**

Provide condensation monitors to be strapped to CW piping that will have a contact switch in the event an

RH greater than 90% is sensed. Unit shall operate with a supply voltage of 24VAC and be coated to protect

against dust and contamination. Use capacitive thin-film polymer sensor types with a setpoint of 90% RH

+/- 3%. LED indication of relay status.

Provide sensor equal to Elektronik Model EE46 w/ mounting hardware.

**FUME HOOD PRESENCE SENSORS:**

Manufacturers: Pepperl & Fuchs Proscan/38a or approved alternate.

Infrared sensor shall be mounted to top/front of fume hood to indicate presence of individual in front of

fume hood. Provide swivel mounting bracket and all mounting hardware.

Minimum Detection Field: 72” x 3”

Switch Open Time: 3 min/10 s, programmable

Light type: Infrared, modulated light

Function display: LED red: on for object detection

Operating elements: Programmable switch for switching type, open time, detection field

Operating voltage: 12-38 V DC / 12-28 V AC

Signal output: Relay

**EMERGENCY SHUTDOWN SWITCHES**

***Include the switches specified below where required. See Section 23 52 00 for where boiler kill switches are required. Emergency HVAC shutdown switches are required at most entrances on Department of Military Affairs buildings.***

Boiler Kill Switch: Kele WPS-MP-BS-CLM with auxiliary contacts Kele PILNCCB or equal.  Switch shall be a push-pull maintained contact switch with clear hinged lockout lid and auxiliary contacts for DDC monitoring and each boiler.  Labeling shall be provided to indicate switch is for Emergency Boiler Shut-Down and action required to reset.

Emergency HVAC Shutdown Switch: Kele ST120SL-RP1-HS or WPS-RP2-HS or equal. Switch shall be a momentary contact switch with raised lid to access switch. Labeling shall be provided to indicate the switch is for Emergency HVAC Shut-Down.

**POWER SUPPLIES**

***All power supplies and transformers for temperature control equipment should be provided by this contractor. Do not specify power supplies or transformers for temperature control equipment under Division 26.***

Provide all required power supplies for transducers, sensors, transmitters, and relays. All low voltage transformers shall have a resettable secondary circuit breaker and be listed as class 2 power supplies. All transformer assemblies in enclosures shall have isolated high and low voltage compartments with separate removeable covers for connections.

**COMMUNICATING THERMOSTATS**

***THE FOLLOWING SPECIFICATIONS FOR COMMUNICATING THERMOSTATS SHOULD BE DELETED FOR DFD PROJECTS UNLESS THE CRITERA BELOW IS MET.***

***Only allow the use of communicating thermostats for applications where a fully programmable controller is not needed and where this type of controller will be cost effective, i.e. dormitory rooms, small building furnaces, etc, and integration to a BAS is desired. These controllers are also advantages when there is limited space for a separate DDC controller to be mounted, i.e. individual radiation terminal unit control. Specify that Communicating Thermostats may be used for a given terminal unit type in the 23 09 93 sequence of operation for that terminal unit type and ensure that it has the capabilities for the sequence that is specified - these are not all fully programmable and have limitations on their functionality. Delete the specifications below for projects where these devices are not desired. If communicating thermostats are used, edit the line at the top of 23 09 15 point chart to indicate they are provided under Section 23 09 14.***

The following thermostat(s) may be used only where specified to be allowed in the 23 09 93 specification sequence of operation for a given terminal unit type. Where not specified in the terminal unit sequence of operation and DDC control is required, an application specific controller shall be used.

Fan Coil Thermostat

Viconics model VT8300, Johnson Controls model TEC3000, Alerton VLD-362, or approved equal.

The fan coil unit DDC thermostat shall have a backlit touchscreen display that will display room temperature and provide for adjustable setpoints. The thermostat shall have the capability to be programmed locally with the setpoint parameters adjustable from the building automation system. The heating and cooling setpoint adjustments shall have the ability to be limited through the building automation system. The unit shall directly control the heating and cooling valves, and unit fan, and have two configurable binary inputs for functions such as remote night setback, service or filter alarms, motion detector and window status and have an analog input for monitoring discharge air temperature. For applications where a dehumidification sequence is specified or humidity monitoring is required, the thermostat shall have an integral humidity sensor. The thermostat shall use BACnet MSTP communication protocol and be integrated into the building DDC system. See DDC Input/Output Summary and sequence of operation for connected points and programming requirements.

Radiation Thermostat

Viconics model VT8300, Johnson Controls model TEC3000, Alerton VLD-362, or approved equal.

The radiation DDC thermostat shall have a backlit touchscreen display that will display room temperature and provide for adjustable setpoints. The thermostat shall have the capability to be programmed locally with the setpoint parameters adjustable from the building automation system. The heating setpoint adjustments shall have the ability to be limited through the building automation system. The unit shall directly control the heating valve, and have two configurable binary inputs for functions such as remote night setback, service or filter alarms, motion detector and window status and have an analog input for monitoring radiation temperature. The thermostat shall use BACnet MSTP communication protocol and be integrated into the building DDC system. See DDC Input/Output Summary and sequence of operation for connected points and programming requirements.

Staged Heating / Cooling Thermostat

Viconics model VT8600, Johnson Controls model TEC3000, Alerton VLD-362, or approved equal.

The radiation DDC thermostat shall have a backlit touchscreen display that will display room temperature and provide for adjustable setpoints. The thermostat shall have the capability to be programmed locally with the setpoint parameters adjustable from the building automation system. The heating and cooling setpoint adjustments shall have the ability to be limited through the building automation system. The unit shall directly control the heating and cooling staged outputs, and have two configurable binary inputs for functions such as remote night setback, service or filter alarms, motion detector and window status and have an analog input for monitoring discharge temperature. The unit shall be capable of modulated economizer damper control and shall have an auxiliary binary output that can be programmed for controlling a minimum outside air damper when indexed to occupied mode. The thermostat shall use BACnet MSTP communication protocol and be integrated into the building DDC system. See DDC Input/Output Summary and sequence of operation for connected points and programming requirements.

Heat Pump Thermostat

Viconics model VT8600, Johnson Controls model TEC3000, Alerton VLD-362, or approved equal.

The heat pump DDC thermostat shall have a backlit touchscreen display that will display room temperature and provide for adjustable setpoints. The thermostat shall have the capability to be programmed locally with the setpoint parameters adjustable from the building automation system. The heating and cooling setpoint adjustments shall have the ability to be limited through the building automation system. The unit shall directly control the heating and cooling stages, reversing valve, and unit fan, and have two configurable binary inputs for functions such as remote night setback, service or filter alarms, motion detector and window status and have an analog input for monitoring discharge air temperature. The thermostat shall use BACnet MSTP communication protocol and be integrated into the building DDC system. See DDC Input/Output Summary and sequence of operation for connected points and programming requirements.

Multiple Terminal Thermostat

Viconics model VT8000, Johnson Controls model TEC3000, Alerton VLD-362, or approved equal.

The DDC thermostat shall have a backlit touchscreen display that will display room temperature and provide for adjustable setpoints. The thermostat shall have the capability to be programmed locally with the setpoint parameters adjustable from the building automation system. The heating and cooling setpoint adjustments shall have the ability to be limited through the building automation system. The unit shall directly control the heating and cooling terminal units through the type of outputs as specified in 23 09 15. The unit shall have two configurable binary inputs for functions such as remote night setback, service or filter alarms, motion detector and window status and have an analog input for monitoring an additional temperature. If the application requires an analog output for heating or cooling and binary output(s) for heating or cooling and the thermostat does not support both analog and binary outputs, provide an analog to binary device capable of converting an analog output signal to binary outputs. This device shall have adjustable input thresholds for setting the trip level for each binary output and adjustable deadbands to prevent load over-cycling. The thermostat shall use BACnet MSTP communication protocol and be integrated into the building DDC system. See DDC Input/Output Summary and sequence of operation for connected points and programming requirements.

**P A R T 3 - E X E C U T I O N**

**INSTALLATION**

Install system with trained mechanics and electricians employed by the control equipment manufacturer or an authorized representative of the manufacturer. Where installing contractor is an authorized representative of the control manufacturer, such authorization shall have been in effect for a period of no less than three years.

Install all control equipment, accessories, wiring, and piping in a neat and workmanlike manner. All control devices must be installed in accessible locations. This contractor shall verify that all control devices furnished under this Section are functional and operating the mechanical equipment as specified in Section 23 09 93.

***Include the following paragraph only when working with DDC Control System that is not part of the bid and negotiated by the State utilizing section 23 09 24. Contact DFD engineering personnel if there are questions.***

All cables to the electronic input/output devices, sensors, relays, and interlocking wiring (all of which shall be supplied and installed under this section of specification) interfaced with the Direct Digital Control System shall be extended into the 23 09 24 DDC panel with a minimum of 5 ft. of cable to allow for termination by the 23 09 24 DDC Contractor. This contractor shall provide a technician to inspect and validate all tubing, wiring, and field devices associated with the DDC interface in coordination with and under direction of the 23 09 24 DDC Contractor to ensure that each device is operating per the control sequences as specified in Section 23 09 93.

Label all control devices except for terminal unit devices with permanent printed labels that correspond to control drawings. Labeling for each device shall be unique within each mechanical system. Temperature control junction and pull boxes shall be identified utilizing spray painted green covers. Other electrical system identification shall follow the 26 05 53 specification. For control devices mounted above accessible ceilings, label the ceiling tile grid at the ceiling tile that is to be removed for access to the control device. The label shall be pre-printed using clear polyester tape with black bold 28 size font for ceilings under 12 feet. For ceilings over 12 feet high, use bold 40 size font. For accessible ceilings, use an arrow to point at ceiling tile to be removed for access.

All control devices and electrical boxes mounted on insulated ductwork shall be mounted over the insulation. Provide mounting stand-offs where necessary for adequate support. Cutting and removal of insulation to mount devices directly on ductwork is not acceptable. This contractor shall coordinate with the insulation contractor to provide for continuous insulation of ductwork.

Mounting of electrical or electronic devices shall be protected from weather if the building is not completely enclosed. This Contractor shall be solely responsible for replacing any equipment that is damaged by water that infiltrates the building if equipment is installed prior to the building being enclosed.

Provide all electrical relays and wiring, line, and low voltage, for control systems, devices, and components. Install all high voltage and low voltage wiring (includes low voltage cable) in metal conduit, Electrical Non-metallic Tubing (ENT), or Electrical Metallic Tubing (EMT), as scheduled below and hereafter referred to generically as conduit except above accessible ceilings as noted below. See Wire and Air Piping Conduit Installation Schedule below for specific conduit or tubing to be used. All raceways, enclosures, fittings, and associated supports shall be provided and installed according to the requirements set forth in Division 26, NFPA 70 (NEC) and Chapter SPS 316 of the Wisconsin Administrative Code. All conduits shall be routed parallel and/or perpendicular to walls and adjacent piping. Raceways shall be located to maintain headroom and working clearance around equipment and devices that require inspection and service.

In general, support all raceways from the building structure. No component of a raceway system shall be secured to corrugated metal roof deck. Do not impose on the installations of other trades. Securing conduit, rods, straps, hangers, etc. to suspended ceiling components, electrical raceways, plumbing piping, fire protection sprinkler piping, HVAC piping or ductwork, or their associated support systems, will not be accepted.

Conduit shall be a minimum of 1/2 " for low voltage control provided the pipe fill does not exceed 40%.

Minimum low voltage wiring gauge to be 18 AWG for outputs and 20 AWG for inputs. All low voltage wiring to be stranded.

Low voltage wiring can be run without conduit above accessible lay-in tile ceilings. All wiring in mechanical rooms, above inaccessible hard ceilings, exterior locations, and in any exposed areas, and in all other locations shall be installed in conduit. Wire for wall sensors shall be installed in conduit concealed in the wall. Wiring for radiation valves shall be installed in conduit concealed in the wall. For retrofit installations, all wiring for sensors and valves shall be installed in conduit concealed in new walls. Sensor wiring for existing walls shall be installed without conduit and concealed in the wall (fished) where possible. If running wire concealed in the existing wall is not possible, install in surface raceway as specified or if not specified, consult with the AE for raceway type and color to be provided.

Where low voltage wiring is installed free-air, installation shall comply with the following:

* Wiring shall utilize the cable tray wherever possible.
* Wiring shall run at right angles and be kept clear of other trades work.
* Wiring shall be supported utilizing "J" or "Bridal-type" steel mounting rings anchored to ceiling concrete, piping supports, walls above ceiling or structural steel beams. Mounting rings shall be of open design (not a closed loop) to allow additional wire to be strung without being threaded through the ring. For mounting rings that do not completely surround the wire, attach the wire to the mounting ring with a strap.
* At HVAC terminal units only, where the wiring serves a specific device; e.g., controller, actuator, transmitter, etc. associated with the unit, the j-hooks or Bridal rings required to support the wiring, may be secured to the rods or straps that support the ductwork or piping that serves the unit. Wall penetrations shall be sleeved.
* Supports shall be spaced at a maximum 4-foot interval unless limited by building construction. If wiring "sag" at mid-span exceeds 6-inches; another support shall be used.
* Wall penetrations shall be sleeved, and fire stopped as specified.
* Wiring shall not be supported from existing cabling, existing tubing, plumbing or steam piping, ductwork, any component of a suspended ceiling, or electrical or communications conduit.

***The A/E must properly coordinate the necessary power wiring with Division 26. Ensure that emergency power is supplied to DDC panels that serve equipment that is fed by emergency power.***

Control panels serving equipment fed by emergency power shall also be served by emergency power. This contractor shall be responsible for all 120VAC power, not provided in the Division 26 specifications, required for equipment provided under this section. Power shown for temperature control panels on plans may be utilized by the 23 09 24 and/or 23 09 23, and 23 09 14 contractors.

Provide communication trunk wiring to integrated devices (i.e., VFD’s, Flow Meters, Chillers, Lighting Panels, Electrical Meters, etc.) and terminal unit controllers that are specified to be connected to the building automation system. Communication trunk wiring shall be as required by the equipment specified under the 23 09 23 or 23 09 24 Sections and shall be routed to the DDC panel designated for that equipment as shown on the plans or the closest DDC panel if not designated. If communication trunks require daisy chained style wiring, provide two communication cables to the DDC panel so that the communication trunk is not dead ended.

Install all terminal unit DDC controls and associated sensors furnished under Section 23 09 14, 23 09 23, or 23 09 24 that are field mounted at the terminals units (not terminal unit controls that are mounted in centralized temperature control panels). For terminal units, i.e., fin tube radiation, convectors, cabinet unit heaters, fan coils, where the DDC controller is to be installed in the terminal unit enclosure, the DDC controller shall be installed in a location within the terminal unit enclosure designed to house controls. In no cases shall DDC controllers be installed in the convective or forced air flow stream of the terminal unit.

***Delete the following paragraph if communicating thermostats are not used on the project.***

Install communicating thermostats and associated sensors furnished under this Section. All communication wiring, power supplies and wiring, programming, and commissioning of communicating thermostats shall be provided under this Section. Provide all labor and information necessary for integration of the communicating thermostats into the DDC system provided under Section 23 09 23 or 23 09 24.

Above accessible lay-in tile ceilings where VAV box DDC controllers are designed to be directly mounted on air terminals, the DDC controller shall be installed without an enclosure. Above accessible lay-in tile ceilings where additional controllers are required, they shall not be mounted directly to the ductwork but be mounted on din rail or back panel in an accessible location as close as possible to the terminal unit(s) being controlled. In exposed ceilings or in mechanical rooms, provide an equipment enclosure that completely encloses the DDC controller and allows for conduit terminations shall be provided as described below..

In mechanical rooms or other locations where the VAV terminal is not above an accessible lay-in ceiling, the enclosure will be provided under Section 23 36 00. If other terminals are associated and controlled from the same VAV terminal DDC controller and additional controllers are required for control, the Section 23 09 23 or 23 09 24 contractor shall provide the enclosure for mounting under this Section.

Any devices other than DDC controllers, i.e., relays, pressure switches or sensors, etc. associated with VAV terminal unit control shall be installed in an enclosure furnished under this Section.

Where occupancy sensors are to be interlocked with terminal units that serve more than one room, all occupancy sensors for the rooms served shall be wired in parallel and wired to the terminal unit DDC controller.

This contractor shall provide all 24VAC power transformers and wiring for DDC terminal unit controls. This contractor shall provide all communication wiring to the DDC supervisory controller for the terminal units provided under 23 09 23 or 23 09 24. Provide all power and communication wiring type and installation as required by the DDC controller manufacturer for the terminal units. Tag all terminal units with printed labels to match the terminal unit room schedules. This contractor shall terminate wiring for all terminal unit controllers and perform end to end point checkout of all inputs and outputs to the terminal unit controllers. This contractor shall verify the communication trunk and controller addressing.

Start/stop and safety relays for motor loads shall be mounted remotely at the VFD or starter being controlled. Label these relays per above tagging requirements and locate in position on the VFD or starter where the label and power indication light for the relay is visible.

***Delete the following paragraph if Section 23 09 24 is not used.***

If terminal unit controllers are furnished under Section 23 09 24, the 23 09 24 contractor shall provide a laptop or other tools and training to the 23 09 14 contractor on how to perform the communication trunk testing and end to end point checkout as described above. Terminal unit room schedules are to be provided under this Section and supplied to the 23 09 24 contractor. The 23 09 24 contractor shall provide engineered control drawings for installation of the terminal unit controllers and deliver these to the 23 09 14 contractor in time to meet the project schedule for the installation of these terminals. Communication trunk wiring for the DDC control panels provided under Section 23 09 24 shall be provided by the 23 09 24 contractor unless otherwise specified.

Install "hand/off/auto" selector switches on systems where automatic interlock controls are specified and "hand/off/auto" selector switches are not supplied with the equipment controlled. Control panel power will not be required for “hand” switch to operate. When switch is in "hand" position, allow manual operation of the selected device without operating the interlocked motors but allowing all unit safety devices to stay in the circuit.

Install all shutdown switches furnished under this Section where specified or shown on the plans. Boiler kill switches shall be wired to each boiler safety circuit and an auxiliary contact shall be wired to a DDC binary input. Emergency HVAC shutdown switches shall be wired to DDC binary inputs for shutdown of all HVAC equipment serving the building.

For service shutdown switches provided in temperature control panels for service shutdown of HVAC systems, label the associated VFD’s or motor starters that there is a service shutdown switch and the temperature control panel designation where the switch is located.

All wiring in control panels shall be terminated on a terminal strip. Wire nuts are not acceptable. A maximum of two wires shall be terminated under any one terminal.

Utilizing a control panel as a raceway for wiring to another control panel is prohibited.

All pneumatic tubing, cabling and electrical wiring terminated at controllers, devices and terminal strips are to be permanently tagged or labeled with permanent adhesive labels within one inch of terminal strip with a numbering system to correspond exactly with the "Record Drawings". Jumpers where both ends of the wire are visible and terminations are within 6” of each other do not need to be labeled. Spare wires are to be labeled as “Spare” with unique number designations.

After completion of installation, test and adjust control equipment. Submit data showing set points and final adjustments of controls.

**AIR PIPING**

Do not delete air piping specification for electrically actuated DDC systems if there is static or differential pressure measurement devices being used.

Conceal piping whenever possible. Exposed piping may be run only in mechanical rooms, storage rooms, or other areas where mechanical systems piping is exposed.

Mechanically attach tubing to supporting surfaces. Sleeve through concrete surfaces in minimum one-inch sleeves, extended 6 inches above floors and one inch below bottom surface of slabs. Fire stop any open space in the sleeve after the air piping is installed if the sleeve is in a fire rated surface.

Isolate air supply from compressor assembly with wire braid reinforced rubber hose or polyethylene tubing.

Take-offs shall enter top of main air piping wherever possible. Install a shut-off valve at each PRV connection to high-pressure air main.

Purge tubing with dry, oil free compressed air before connecting control instruments.

Install all polyethylene tubing in conduit as scheduled below unless specified otherwise hereafter. Exposed polyethylene tubing not exceeding 18 inches may be used for connection to an instrument or operator without being installed in conduit. All Conduit to be independently supported, all boxes must be supported, all conduit ends to have bushings for protection of tubing.

Conduit shall be a minimum of 1/2 " for poly tubing provided the pipe fill does not exceed 40%.

Minimum poly tubing size allowed is ¼” OD. If an instrument has a barbed fitting that will only accept 5/32” tubing, connection to the device can be made with 5/32” tubing that is as short as is practical. Couplings are acceptable in this instance.

Install all exposed piping and conduit parallel to or at right angles to the building structure and support adequately at uniform intervals. Use only tool made bends in copper air pipe.

Tubing must be installed and supported in a manner as specified for exposed locations and acceptable to DFD.

Where polyethylene tubing is installed free-air, installation shall consider the following:

* Tubing shall run at right angles and be kept clear of other trades work.
* Tubing shall be supported utilizing "J-" or "Bridal-type" mounting rings anchored to ceiling concrete, piping supports or structural steel beams. Rings shall be designed to maintain tubing bend to larger than the minimum bend radius (typically 4 x tubing diameter).
* Supports shall be spaced at a maximum 4-foot interval unless limited by building construction. If tubing "sag" at mid-span exceeds 6-inches, another support shall be used.
* Tubing shall never be laid directly on the ceiling grid or attached in any manner to the ceiling grid wires.
* Air piping may be routed with Class 2 control wiring in J-hooks.

Tubing shall not be attached to existing cabling, existing tubing, plumbing or steam piping, ductwork, ceiling supports or electrical or communications conduit.

Tubing connected to air terminal unit devices shall be attached to the terminal unit device to prevent tubing from becoming kinked or becoming disconnected. Tubing serving air terminals may be routed on top of ductwork serving that terminal unit for a maximum distance of eight feet.

Tubing directly connected to steam valve actuators shall be copper tubing for a minimum of six inches.

Where tubing is connected to ductwork at an exterior location for sensing purposes, the tubing shall be sloped to a heated interior location without sags or traps in the tubing to prevent condensation to be trapped in the tubing and prevent accurate sensing. Install drip leg at low point at interior location and note location on control record drawings.

Number code all polyethylene tubing and install neatly with no concealed splices.

Test entire piping system by pressurizing it to 20 psig for 24 hours. Pressure drop during this period shall not exceed 3 pounds.

Low-pressure air mains shall be designed so that the pressure at any point in the main shall not vary by more than 1 PSI from the pressure at the air pressure regulator.

Piping material used shall be as follows:

Use hard copper tubing for all main air lines, above 30 psi.

All exposed copper to be hard drawn.

Use only polyethylene tubing inside panels.

In concealed locations (other than noted below) hard copper, soft copper, or polyethylene tubing in conduit shall be used.

Polyethylene tubing in block, stud. or concrete walls must be in conduit and associated boxes to be of steel.

Where air piping is within concrete slab or under grade use only polyethylene tubing in conduit

For exposed outdoor locations, use hard copper or polyethylene tubing in conduit. Provide shielding for polyethylene tubing that is used for final device connection that will be exposed to direct sunlight.

For static sensing lines connected to ductwork located in exposed outdoor locations, slope piping from connection into building to a location that will be above freezing so any condensation will run into the building and not freeze in piping. Piping tap shall not be on the bottom of the ductwork. Provide a drip leg of 3/8” tubing a minimum of one foot in length in an accessible location inside the building that will collect condensation from the sensing line.

Polyethylene tubing may be used in exposed areas if run in a fully enclosed rigid metal raceway or metal conduit and ambient temperature is less than 150°F.

Use copper tubing, where subject to temperatures in excess of 150°F or where adjacent to heating pipes passing through a common sleeve.

When polyethylene tubing is used above accessible lay-in acoustical panel ceilings it must be fire resistance “FR” rated pass the UL 94 vertical flame test with a rating of V2, be rated as self-extinguishing under ASTM D 635, and may be run without conduit.

High pressure rated polyethylene tubing in conduit may be used for branch lines to high-pressure actuators. Compression fittings must be used for high-pressure (above 30 PSI) applications.

For pneumatic actuated dampers that are involved in a smoke control system, all air piping shall be hard copper, except within control panels and shall be isolated from the non-smoke control system controls by automatic isolation valves in the event of a smoke control event. Installation shall conform to applicable International Building Code Section 909 requirements.

**WIRE AND AIR PIPING CONDUIT AND TUBING** **INSTALLATION SCHEDULE**

The following conduit schedule shall apply to both polyethylene tubing and wire in conduit where conduit is specified for air tubing or wiring. Conduit and tubing referenced below shall meet specifications in Section 26 05 33 and as defined below.

Air piping shall be run in independent conduit without wiring. In no cases shall wiring and air piping share a conduit, raceway, or cable tray.

Where air piping and wiring share a trough or wire management system above a control panel, code required separation shall be provided.

Conduit other than that specified below for specific applications shall not be used.

Underground Installations within Five Feet (1.5 m) of Foundation Wall: Rigid steel conduit.

Underground Installations More than Five Feet (1.5 m) From Foundation Wall: Rigid steel conduit. Plastic-coated rigid steel conduit. Schedule 40 PVC conduit.

Under Slab on Grade Installations: Schedule 40 PVC conduit.

Exposed Outdoor Locations: Rigid steel conduit.

Concealed in Concrete and Block Walls: Rigid steel conduit. Schedule 40 PVC conduit. Electrical Nonmetallic Tubing (ENT).

***Check with structural engineer whether conduit within slab permitted.***

Within Concrete Slab: Rigid steel conduit. Schedule 40 PVC conduit. Electrical Nonmetallic Tubing (ENT).

***In the following paragraph, Schedule 40 PVC may only be used for special applications such as locations with corrosive atmospheres.***

Wet Interior Locations: Rigid steel conduit. [Schedule 40 PVC conduit][PVC coated rigid steel conduit].

Concealed Dry Interior Locations: Rigid steel conduit. Intermediate metal conduit. Electrical Metallic

Tubing (EMT).

Exposed Dry Interior Locations: Rigid steel conduit. Intermediate metal conduit. Electrical metallic tubing.

Exposed Dry Interior Locations for Control Devices with Conduit Connections: EMT or Flexible Metal Conduit (FMC). Minimum length shall be one foot (300 mm); maximum length shall be three feet (900 mm). Minimum size FMC of 3/8”.

Exposed Dry Interior Locations for Control Devices without Conduit Connections: Where HVAC equipment control panels or devices do not provide for the direct connection of conduits, exposed wiring may be extended to complete the final connections in dry locations, providing it does not exceed 18 inches in length.

**AIR COMPRESSORS**

Install air compressor assembly on concrete foundation with sole plates and vibration isolators where indicated on drawings. See section 23 05 48 for vibration isolation requirements. Level, grout, and bolt in place. Pipe automatic condensate drain from air storage tank to nearest floor drain; use copper drain line. Install replaceable cartridge type filter-silencer for each compressor; install upstream and downstream shutoff valves and bypass valve to facilitate cartridge change.

Install line size ball valve and check valve on compressor discharge when remote tanks are used.

Where water-cooled aftercoolers are used, install a shut-off valve in water supply piping to aftercooler. Pipe copper drain from aftercooler to nearest floor drain.

**REFRIGERATED AIR DRYERS**

Locate refrigerated air dryer in discharge air line from tank. Mount dryer where shown on plans. Install pressure regulator downstream of dryer. Pipe automatic drain to nearest floor drain; use copper drain line. Install valved bypass around air dryer and around filter assembly.

**CONTROL DAMPERS**

All control dampers furnished by the control manufacturer are to be installed by the Mechanical Contractor under the coordinating control and supervision of the Control Contractor in locations shown on plans or where required to provide specified sequence of control.

Damper end switches, where required, shall be integral to the actuator that is mounted to the damper drive shaft or auxiliary shaft attached to a damper drive blade. End switches shall be adjusted to prove the damper the position opposite the fail position of the damper actuator unless the control sequence requires a different position to be proven to accomplish the specified control sequence.

Coordinate installation with the sheetmetal installer to obtain smooth duct transitions where damper size is different than duct size. Blank off plates will not be accepted.

Each operator shall serve a maximum damper area of 36 square feet. Where larger dampers are used, provide multiple operators.

**CONTROL VALVES**

All temperature control valves furnished by the control manufacturer are to be installed by the Mechanical Contractor under the coordinating control and supervision of the Control Contractor in locations shown on plans or where required to provide specified sequence of control.

Steam valve actuators shall be mounted between 45 and 90 degrees from upright vertical to prevent over heating of the actuator unless this orientation is specifically prohibited by the manufacturer. All other valves shall be mounted in the upright vertical position. If upright vertical mounting is not possible due to lack of space, obtain approval from the mechanical engineer of record on the project for alternate mounting that meet the manufacturers recommended installation. Radiation control valves shall not be located in the convective air flow above the heating element.

Provide pilot positioners on all valves where more than one pneumatic operator is controlled in sequence, for all valves 3” and larger, or where required to provide sufficient power. Where two or more valves are operated in sequence, pilot positioners to have adjustable start point (2-12 psig) and span (5-13 psig).

**CONTROL SYSTEM INSTRUMENTATION**

***Delete the first paragraph for projects that do not have pneumatic controls.***

For pneumatically actuated systems install pressure gauges as follows: for indication of supply air pressure in each temperature control panel; at the output of pneumatic/electric transducers; the output of each pneumatic controller; the output of each solenoid air valve; the input of each PE switch; at each modulated damper and valve except terminal devices; other points where the visible indication of air pressure is required for operating and maintenance purposes. On dampers and valves with pilot positioners, locate gauge in the output of positioner to controlled device. Mount gauges so they are visible when looking at the monitored device. At each receiver controller input port, install a 1-1/2" diameter dial indicator with scale to match input range (in degrees F., % R.H., in. w.c., etc.). Equip control air output line with a 1-1/2" diameter air pressure gauge.

Install thermometer on the discharge of the AHU after the supply fan, all coils, and humidifiers but before any booster coils. Install thermometer to permit easy reading from the floor or operating platform. Adjust swiveled mounting for easy reading from floor.

**ROOM THERMOSTATS AND TEMPERATURE SENSORS**

***Consultant must list the locations where each type of thermostat should be used in the project. Overlay plans to check for conflicts with casework and other wall mounted devices before locating thermostat locations on plans. Mounting heights should be scheduled or noted on the plans if multiple heights are required. A height of 60 inches above the floor is standard for non-adjustable sensors, 70 inches for non-adjustable sensors in locations where systems furniture is located, and 48 inches or other ADA required height when adjustable thermostats or adjustable sensor devices are used. Any thermostat or sensor that has adjustment even if concealed or under a locked cover must be mounted at ADA required height.***

Check and verify location of thermostats, humidistats, and other exposed control sensors with plans and room details before installation. Locate room thermostats and sensors [\_\_\_\_] inches above floor. Align with light switches and humidistats. For drywall installations, thermostat mounting shall use a back-box attached to a wall stud, drywall anchors are not acceptable.

Any room thermostats or sensors mounted on an exterior wall shall be mounted on a thermally insulated sub-base. Subbase to provide a minimum of one half inch of insulation.

For thermostats or sensors seal the conduit and any other opening to prevent air movement that could affect the measurement.

Provide guards on thermostats and sensors in entrance hallways, other public areas, or in locations where thermostat is subject to physical damage.

For reheat coil discharge temperature sensors, mount in the duct a minimum of three feet downstream of the reheat coil.

For applications that require more than one averaging element for mixed air, heat wheel outside air leaving, and heating coil discharge temperatures, the elements shall be distributed horizontally across the coil in a serpentine fashion to sense the average temperature across the plenum or coil across the horizontal expanse of the coil, i.e. across the top, middle, and bottom the coil where three averaging sensors are required.

**LOW LIMIT THERMOSTATS (Freezestats)**

Install low limit controls where indicated on the drawings or as specified. Unless otherwise indicated, install sensing element on the downstream side of heating coils. When air handling units have chilled water coils downstream of the heating coil, the element shall be located at the entering side of the chilled water coil. For single row heating coils in air handling units without chilled water coils, the element shall be run in the shadow of the heating coil tubing as much as possible or be located a minimum of 2 feet downstream of the heating coil.

Distribute (serpentine) sensing element horizontally across the coil to cover every square foot of coil; on larger coils this may require more than one instrument.

Mount the unit head in an accessible location as to allow for resetting after low limit trips while still meeting manufacturer's installation requirements for proper function. Mount units using flanges and element holders. Provide duct collars or bushings where sensing capillary passes through sheetmetal housings or ductwork; seal this penetration to eliminate air leakage. Elements shall be supported across coils or openings adequately to prevent movement from air current. Support methods shall be those suitable for use in air plenums with temperatures of up to 180 deg F. Metal fastening clips are the preferred method. Securing elements by use of plastic or nylon cable ties will not be accepted. Special attention should be paid to ensure elements will not rub on fasteners or other edges that will eventually cause damage.

***Delete the following paragraph for projects that do not have integral face and bypass steam coils.***

Integral Face and Bypass Steam Heating Coil Freezestats:

For integral face and bypass coils the elements are to be run vertically on the downstream face of the heating coil inside the damper enclosure, this will require drilling the frame to run element around the by-pass. Provide an auto-reset freezestat for each coil vertical heating tube. The head of the freezestat shall be mounted outside the unit, if possible, above the coils and any excess capillary shall be mounted out of the air stream above the coil. If the head of the freezestat cannot be mounted outside of the unit, it should be mounted downstream of the coil. Provide latching relays with LED indicator of relay status for each freezestat so that the relay will remain latched after the freezestat resets. Label each freezestat and corresponding relay to provide an easy method to determine which freezestat(s) have tripped. Provide a momentary reset switch and connection for remote contact reset from the DDC system for resetting the freezestat alarm. The relays shall be unlatched after a power fail. Mount latching relays in a hinged cover panel mounted at a maximum of five feet above the floor in an accessible location adjacent to the AHU on a wall or freestanding Unitstrut stand. Reset switch shall be mounted on the cover and be labeled “Freezestat Reset”.

**AIR FLOW STATIONS**

Install airflow stations in accordance with manufacturer's recommendations. Install straightening vanes upstream of unit where required per manufacturers recommendations. Air flow stations shall be located upstream of any associated control dampers. If shown differently on plans, consult with AE on acceptable location. If air flow stations have associated displays, these should be mounted at 5’ AFF. If this is not possible, consult with AE on acceptable location. Provide all labor to set up flow sensors per manufacturer’s instructions in coordination with the test and balance contractor to meet the accuracy as specified.

**LIQUID AND STEAM FLOW SENSORS**

Install where indicated on the drawings and details for flow sensing in hydronic and/or steam piping systems. Do not install close to elbows, valves, or other piping specialties, which might affect the reading of the sensor; follow manufacturer's installation instructions. Where flow meters are located more than five feet above the floor or where they cannot be read due to equipment location, provide remote mounting of the flow meter display and programming controls. Location of remote mounted display shall be so that the flow measurement display shall be mounted four to five feet above finished floor. BTU Measurement System displays shall be located so that the display and programming controls are four to five feet above finished floor. All piping to and from sensors shall be by Section 23 21 13 and 23 22 13 contractor and shall comply with requirements of Sections 23 21 13 and 23 22 13. Provide all labor to set up flow sensors per manufacturer’s instructions in coordination with the test and balance contractor to meet the accuracy as specified.

**STEAM CONDENSATE WATER METERS**

Mechanical contractor shall install steam condensate meters and associated piping. Install so that they shall always stay flooded and provide a trap to provide for this, if necessary.

Basic parameters to be set on a Flow Meter:

**Parameters Measuring**

For channel A Channels A B Y Z

Pipe outer diameter = (pipe O.D. in inches ) Measure **x** (mark on channel A)

Pipe wall thickness = (wall thickness - inches ) A: Sound Path = 2 (two sound paths)

Pipe material = (PVC, C.S., SS, etc. ) Suggested trans. spacing = (read only)

Lining in pipe = [**No]** or yes Signal strength = 4 bars or more (read only)

Roughness = 0.000 (default value) Actual trans. spacing = (enter actual spacing )

Medium = Water

Temperature = 160 °F (average fluid temp)

Transducer type = standard

Units = PPH

Scale = 1,000

Provide all labor to set up flow sensors per manufacturer’s instructions in coordination with the test and balance contractor to meet the accuracy as specified.

**PRESSURE TRANSDUCERS AND HIGH LIMIT PRESSURE SWITCHES**

Install capped tees in air piping at air pressure transducers for connection of calibration equipment. Capped tee shall consist of two inch poly tubing capped with a brass plug. Rubber caps are not acceptable. Install Petes Plugs fittings at each take-off from main piping for liquid pressure transducers for connection of calibration equipment. Install differential pressure transducers for filter monitoring at the filter section of the air handling unless otherwise specified. All other differential or static pressure transducers and differential or static pressure high limit switches for air applications should be mounted in the temperature control panel serving the equipment being controlled or monitored. All devices mounted on equipment shall be mounted in a location that is at a maximum of five feet above the floor. For all air static and differential pressure applications, use metal static pressure tips for insertion into the fan housing or ductwork. For steam and liquid applications, provide shutoff valves at piping takeoff points.

High and low static safety switches shall be labeled with the static pressure trip setpoint and shall match the record control drawing sequence of operation.

**TEMPERATURE CONTROL PANELS**

Mount control panels adjacent to associated equipment on vibration-free walls or freestanding angle iron supports. All control panel openings shall be plugged. Conduits and other penetrations on the top of the cabinets shall be sealed on the exterior of the cabinet with silicone caulk to resist water penetration. Provide a separate control panel for each major mechanical system, i.e. AHU, hot water system, chilled water system, etc. as outlined in the point charts and shown on the plans. One control panel may accommodate more than one major mechanical system in same equipment room only where specifically stated in the contract documents. Provide permanent printed labeling for instruments and controls inside cabinet and engraved plastic nameplates on cabinet face.

Provide as-built control drawings of all systems served by each local panel in a location adjacent to or inside of panel cover. Provide a protective cover or envelope for drawings.

**DIFFERENTIAL PRESSURE SWITCHES**

Provide for each fan or pump specified or shown on point list. Provide shutoff valves at piping takeoff points. Readjust pressure and/or differential setpoints for proper operation after final balancing is completed.

**CURRENT STATUS SWITCHES**

Provide for each fan or pump specified or shown on point list. Set threshold adjustment to indicate belt or coupling loss. Readjust threshold for proper operation after final balancing is completed. Use the variable frequency drive (VFD) integrated relay output for motor status, if provided on the VFD, in lieu of a discrete current switch. A separate current switch provided under this Section shall be wired in parallel with the VFD motor status relay when a bypass starter is provided on the VFD to prove motor status in the bypass mode. When a VFD serves more than one fan, provide a separate current switch for each fan served.

**PRECONSTRUCTION REVIEW MEETING**

This contractor shall attend a meeting or meetings as required prior to construction to review the control system on the project. The meeting attendees shall consist of the AE of Record, DFD, CxP, User Agency, Section 23 09 14 Contractor, Section 23 09 23 or 23 09 24 Contractor, and the Division 23 Contractor. All sequences covered within specification section 23 09 93 and related system configurations and devices shall be reviewed in detail and any corrections to the sequences and mechanical systems shall be made through the DFD construction change process.

The GPC shall schedule the meeting after the final control submittals from all 23 09 xx specifications Sections have been completed and submitted to the AE.

# **CONSTRUCTION VERIFICATION**

Contractor is responsible for utilizing the construction verification checklists supplied under specification Section 23 08 00 in accordance with the procedures defined for construction verification in Section 01 91 01 or 01 91 02.

**FUNCTIONAL PERFORMANCE TESTING**

For commissioning of control systems, the following items shall be complete by the contractor prior to functional performance testing:

* Completed functional performance tests written by the commissioning agent shall have been reviewed at the controls Preconstruction Review Meeting.
* All point to point checkout for each input/output shall be complete and documented.
* All changes to the design need to be incorporated prior to testing.

# **AGENCY TRAINING**

All training provided for agency shall comply with the format, general content requirements and submission guidelines specified under Section 01 91 01 or 01 91 02.

***Delete the paragraph below and specify training hours under 23 09 23 section if the DDC controls are open bid (not negotiated by DFD). The required amount of training will vary with each facility. Videotaping of training must be reviewed for each project. This may not be required or could be reduced. Coordinate this with the owner agency and DFD during development of the project. If Section 23 09 24 is used, training under this Section should still be minimal and in some cases can be deleted since training under Section 23 09 24 will cover most items provided under this Section. Specialty items such as metering, will require some training under this Section.***

Contractor to provide factory authorized representative and/or field personnel knowledgeable with the operations, maintenance and troubleshooting of the system and/or components defined within this section for a minimum period of [XX] hours.

END OF SECTION