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USACE / NAVFAC / AFCEC **UFGS-23 09 13 (November 2015)**
Change 2 - 05/21

Preparing Activity: USACE **Superseding**
UFGS-23 09 23 (May 2011)
UFGS-23 09 23.13 20 (August 2009)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2025
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DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING (HVAC)

SECTION 23 09 13

INSTRUMENTATION AND CONTROL DEVICES FOR HVAC

11/15, CHG 2: 05/21

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SECTION 23 09 13

INSTRUMENTATION AND CONTROL DEVICES FOR HVAC
11/15, CHG 2: 05/21

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NOTE: This guide specification covers the requirements for instrumentation and control devices for HVAC when combined with a companion DDC Network. Please refer to the respective specification sections for Direct Digital Control Devices and Utility Monitoring and Control Systems.

Adhere to UFC 1-300-02 **Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.**

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR)**.**
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PART 1 GENERAL

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NOTE: This section is for use on all USACE and AFCEC projects and for additions or retrofits to existing NAVFAC systems.

This specification covers installation of local control devices and instrumentation. It is primarily intended for building level control systems which are to be integrated into a Utility Monitoring and Control System (UMCS) Front End as specified in Section 25 10 10 UTILITY MONITORING AND

CONTROL SYSTEM (UMCS) FRONT END AND INTEGRATION.

The HVAC Control System design must be in accordance with UFC 3-410-02 Direct Digital Control for HVAC and Other Building Control Systems.

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1.1 SUMMARY

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NOTE: Designer is to add location and site specific requirements.

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This section provides for the instrumentation control system components excluding direct digital controllers, network controllers, gateways etc. that are necessary for a completely functional automatic control system. When combined with a Direct Digital Control (DDC) system, the Instrumentation and Control Devices covered under this section must be a complete system suitable for the control of the heating, ventilating and air conditioning (HVAC) and other building-level systems as specified and indicated.

a. Install hardware to perform the control sequences as specified and indicated and to provide control of the equipment as specified and indicated.

b. Install hardware such that individual control equipment can be replaced by similar control equipment from other equipment manufacturers with no loss of system functionality.

c. Install and configure hardware such that the Government or their agents are able to perform repair, replacement, and upgrades of individual hardware without further interaction with the installing Contractor.

1.1.1 Verification of Dimensions

After becoming familiar with all details of the work, verify all dimensions in the field, and advise the Contracting Officer of any discrepancy before performing any work.

1.1.2 Drawings

The Government will not indicate all offsets, fittings, and accessories that may be required on the drawings. Carefully investigate the mechanical, electrical, and finish conditions that could affect the work to be performed, arrange such work accordingly, and provide all work necessary to meet such conditions.

1.2 RELATED SECTIONS

Related work specified elsewhere.

Section 01 30 00 ADMINISTRATIVE REQUIREMENTS

Section 23 30 00 HVAC AIR DISTRIBUTION

Section 23 05 15 COMMON PIPING FOR HVAC

Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC

Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM

1.3 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC. (AMCA)

AMCA 500-D	(2018) Laboratory Methods of Testing Dampers for Rating
AMCA 511	(2010; R 2016) Certified Ratings Program for Air Control Devices

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C12.1	(2014; Errata 2016) Electric Meters - Code for Electricity Metering

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B16.15	(2024) Cast Copper Alloy Threaded Fittings Classes 125 and 250
ASME B16.18	(2021) Cast Copper Alloy Solder Joint Pressure Fittings
ASME B16.22	(2021) Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
ASME B16.26	(2024) Cast Copper Alloy Fittings for Flared Copper Tubes

ASME B16.34	(2021) Valves - Flanged, Threaded and Welding End
ASME B40.100	(2022) Pressure Gauges and Gauge Attachments
ASME BPVC SEC VIII D1	(2023) BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1

ASTM INTERNATIONAL (ASTM)

ASTM A269/A269M	(2024) Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
ASTM A536	(2024) Standard Specification for Ductile Iron Castings
ASTM B32	(2020) Standard Specification for Solder Metal
ASTM B75/B75M	(2020) Standard Specification for Seamless Copper Tube
ASTM B88	(2022) Standard Specification for Seamless Copper Water Tube
ASTM D635	(2018) Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
ASTM D638	(2014) Standard Test Method for Tensile Properties of Plastics
ASTM D792	(2013) Density and Specific Gravity (Relative Density) of Plastics by Displacement
ASTM D1238	(2013) Melt Flow Rates of Thermoplastics by Extrusion Plastometer
ASTM D1693	(2015) Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics

FLUID CONTROLS INSTITUTE (FCI)

FCI 70-2	(2021) Control Valve Seat Leakage

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 142	(2007; Errata 2014) Recommended Practice for Grounding of Industrial and Commercial Power Systems - IEEE Green Book

INTERNATIONAL SOCIETY OF AUTOMATION (ISA)

ISA 7.0.01	(1996) Quality Standard for Instrument Air

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C12.20	(2015; E 2018) Electricity Meters - 0.1, 0.2, and 0.5 Accuracy Classes
NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA/ANSI C12.10	(2011; R 2021) Physical Aspects of Watthour Meters - Safety Standard

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2023; ERTA 1 2024; TIA 24-1; TIA 25-2) National Electrical Code
NFPA 90A	(2024) Standard for the Installation of Air Conditioning and Ventilating Systems

UL SOLUTIONS (UL)

UL 94	(2023; Reprint Jan 2024) UL Standard for Safety Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
UL 555	(2006; Reprint Aug 2016) UL Standard for Safety Fire Dampers
UL 555S	(2014; Reprint Oct 2020) UL Standard for Safety Smoke Dampers
UL 1820	(2004; Reprint May 2013) UL Standard for Safety Fire Test of Pneumatic Tubing for Flame and Smoke Characteristics
UL 5085-3	(2006; Reprint Jan 2022) UL Standard for Safety Low Voltage Transformers - Part 3: Class 2 and Class 3 Transformers

1.4 SUBMITTALS

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NOTE: Submittals related to this section are specified in UFGS 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.
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Submittal requirements are specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

1.5 DELIVERY AND STORAGE

Store and protect products from the weather, humidity, and temperature variations, dirt and dust, and other contaminants, within the storage condition limits published by the equipment manufacturer.

1.6 INPUT MEASUREMENT ACCURACY

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NOTE: This paragraph is referenced elsewhere in the specification. If this paragraph is edited, removed, renamed etc make sure to verify that all references to it are updated as needed.
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Select, install and configure sensors, transmitters and DDC Hardware such that the maximum error of the measured value at the input of the DDC hardware is less than the maximum allowable error specified for the sensor or instrumentation.

1.7 SUBCONTRACTOR SPECIAL REQUIREMENTS

Perform all work in this section in accordance with the paragraph entitled CONTRACTOR SPECIAL REQUIREMENTS in Section 01 30 00 ADMINISTRATIVE REQUIREMENTS.

PART 2 PRODUCTS

2.1 EQUIPMENT

2.1.1 General Requirements

All products used to meet this specification must meet the indicated requirements, but not all products specified here will be required by every project. All products must meet the requirements both Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC and this Section.

2.1.2 Operation Environment Requirements

Unless otherwise specified, provide products rated for continuous operation under the following conditions:

2.1.2.1 Pressure

Pressure conditions normally encountered in the installed location.

2.1.2.2 Vibration

Vibration conditions normally encountered in the installed location.

2.1.2.3 Temperature

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NOTE: Designer must decide if suggested outside air temperature range is sufficient, and provide a range if it's not.
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a. Products installed indoors: Ambient temperatures in the range of 0 to 50 degrees C 32 to 112 degrees F and temperature conditions outside this range normally encountered at the installed location.

b. Products installed outdoors or in unconditioned indoor spaces: Ambient temperatures in the range of [-37 to +66 degrees C-35 to +151 degrees F

] [_____] and temperature conditions outside this range normally encountered at the installed location.

2.1.2.4 Humidity

10 to 95 percent relative humidity, non-condensing and also humidity conditions outside this range normally encountered at the installed location.

2.2 WEATHERSHIELDS

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NOTE: Enclosures are specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC

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Provide weathershields constructed of galvanized steel painted white, unpainted aluminum, aluminum painted white, or white PVC.

[2.3 TUBING

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NOTE: Pneumatic sections included in the event pneumatic actuators are required for special circumstances (actuator response time or explosive environments). The Designer can include or delete as required by the project circumstances

Keep the bracketed text for pneumatic applications

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2.3.1 Copper

Provide ASTM B75/B75M or ASTM B88 rated tubing meeting the following requirements:

a. For tubing 9 mm 0.375 inch outside diameter and larger provide tubing with minimum wall thickness equal to ASTM B88, Type M

b. For tubing less than9 mm 0.375 inch outside diameter provide tubing with minimum wall thickness of 0.6 mm 0.025 inch

c. For exposed tubing and tubing for working pressures greater than 207 kPa 30 psig provide hard copper tubing.

d. Provide fittings which are ASME B16.18 or ASME B16.22 solder type using ASTM B32 95-5 tin-antimony solder, or which are ASME B16.26 compression type.

2.3.2 Stainless Steel

For stainless steel tubing provide tubing conforming to ASTM A269/A269M

2.3.3 Plastic

Provide plastic tubing with the burning characteristics of linear low-density polyethylene tubing which is self-extinguishing when tested in accordance with ASTM D635, has UL 94 V-2 flammability classification or better, and which withstands stress cracking when tested in accordance with ASTM D1693. Provide plastic-tubing bundles with Mylar barrier and flame-retardant polyethylene jacket.

2.3.4 Polyethylene Tubing

Provide flame-resistant, multiple polyethylene tubing in flame-resistant protective sheath with mylar barrier, or unsheathed polyethylene tubing in rigid metal, intermediate metal, or electrical metallic tubing conduit for areas where tubing is exposed. Single, unsheathed, flame-resistant polyethylene tubing may be used where concealed in walls or above ceilings and within control panels. Do not provide polyethylene tubing for [systems indicated as critical and] smoke removal systems, or for systems with working pressures over 206 kPa 30 psig. Provide compression or brass barbed push-on type fittings. Provide extruded seamless polyethylene tubing conforming to the following:

a. Minimum Burst Pressure Requirements: 690 kPa at 24 degrees C 100 psig at 75 degrees F to 172 kPa at 66 degrees C 25 psig at 150 degrees F.

b. Stress Crack Resistance: ASTM D1693, 200 hours minimum.

c. Tensile Strength (Minimum): ASTM D638, 7584 kPa 1100 psi.

d. Flow Rate (Average): ASTM D1238, 0.30 decigram per minute.

e. Density (Average): ASTM D792, 921 kg per cubic meter 57.5 pounds per cubic feet.

f. Burn rate: ASTM D635

g. Flame Propagation: UL 1820, less than 1.5 meters 5 feet ASTM D635

h. Average Optical Density: UL 1820, less than 0.15 ASTM D635

]2.4 WIRE AND CABLE

Provide wire and cable meeting the requirements of NFPA 70 and NFPA 90A in addition to the requirements of this specification and referenced specifications.

2.4.1 Terminal Blocks

For terminal blocks which are not integral to other equipment, provide terminal blocks which are insulated, modular, feed-through, clamp style with recessed captive screw-type clamping mechanism, suitable for DIN rail mounting, and which have enclosed sides or end plates and partition plates for separation.

2.4.2 Control Wiring for Binary Signals

For Control Wiring for Binary Signals, provide 18 AWG (1.02 mm diameter) 18 AWG copper or thicker wire rated for 300-volt service.

2.4.3 Control Wiring for Analog Signals

For Control Wiring for Analog Signals, provide 18 AWG (1.02 mm diameter) 18 AWG or thicker, copper, single- or multiple-twisted wire meeting the following requirements:

a. minimum 50 mm (2 inch) 2 inch lay of twist

b. 100 percent shielded pairs

c. at least 300-volt insulation

d. each pair has a 20 AWG tinned-copper drain wire and individual overall pair insulation

e. cables have an overall aluminum-polyester or tinned-copper cable-shield tape, overall 20 AWG tinned-copper cable drain wire, and overall cable insulation.

2.4.4 Power Wiring for Control Devices

For 24-volt circuits, provide insulated copper 18 AWG or thicker wire rated for 300 VAC service. For 120-volt circuits, provide 14 AWG or thicker stranded copper wire rated for 600-volt service.

2.4.5 Transformers

Provide UL 5085-3 approved transformers. Select transformers sized so that the connected load is no greater than 80 percent of the transformer rated capacity.

2.5 AUTOMATIC CONTROL VALVES

****

NOTE: Ball valves are generally less expensive than globe valves, but because of potential cavitation problems should only be used in 2-position and chilled water applications. It is recommended that you coordinate their use with the local maintenance staff because unlike globe valves, maintenance is more likely to require complete removal of the valve.

Show each valve's Kv (m^3/hr) and/or Cv (gal/min) on the Valve Schedule. Kv = 0.857 x Cv. Modulating control valves should be sized for maximum full flow pressure drop between 50 percent and 100 percent (typically between 21 - 34 kPa 3 - 5 psig of the branch circuit it is controlling. Two position valves must be the same size as the connected piping.

Valves having class IV leakage ratings are typically used in process applications rather than HVAC. Class III leakage ratings are typical for HVAC applications unless strict environmental control is required.

****

Provide valves with stainless-steel stems and stuffing boxes with extended necks to clear the piping insulation. Provide valves with bodies meeting ASME B16.34 or ASME B16.15 pressure and temperature class ratings based on the design operating temperature and 150 percent of the system design operating pressure. Unless otherwise specified or indicated, provide valves meeting FCI 70-2 [Class III leakage rating][Class IV leakage rating]. Provide valves rated for modulating or two-position service as indicated, which close against a differential pressure indicated as the

Close-Off pressure and which are Normally-Open, Normally-Closed, or Fail-In-Last-Position as indicated.

2.5.1 Valve Type

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NOTE: Special attention must be paid to system pressure for hot water applications. Ball valves are more susceptible to cavitation than globe valves having the same pressure drop due to higher internal velocities in the ball valve. To prevent cavitation within the valve, the designer may need to increase the hydronic system pressure. Cavitation can occur when using ball valves for hot water service due to the increased internal velocity through the ball valve. The designer should take in to consideration the drop in system pressure through the valve to prevent cavitation at the outlet of the valve.

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2.5.1.1 Liquid Service 150 Degrees F or Less

Use either globe valves or ball valves except that butterfly valves may be used for sizes 100 mm 4 inch and larger.

2.5.1.2 Liquid Service Above 150 Degrees F

a. Two-position valves: Use either globe valves or ball valves except that butterfly valves may be used for sizes 100 mm 4 inch and larger.

b. Modulating valves: Use globe valves except that butterfly valves may be used for sizes 100 mm 4 inch and larger.

2.5.1.3 Steam Service

Use globe valves except that butterfly valves may be used for sizes 100 mm 4 inch and larger.

2.5.2 Valve Flow Coefficient and Flow Characteristic

2.5.2.1 Two-Way Modulating Valves

Provide the valve coefficient (Kv) (Cv) indicated. Provide equal-percentage flow characteristic for liquid service except for butterfly valves. Provide linear flow characteristic for steam service except for butterfly valves.

2.5.2.2 Three-Way Modulating Valves

Provide the valve coefficient (Kv) (Cv) indicated. Provide linear flow characteristic with constant total flow throughout full plug travel.

2.5.3 Two-Position Valves

Use full line size full port valves with maximum available (Kv) (Cv).

2.5.4 Globe Valves

2.5.4.1 Liquid Service Not Exceeding 66 Degrees C 150 Degrees F

a. Valve body and body connections:

(1) valves 38 mm 1-1/2 inches and smaller: brass or bronze body, with threaded or union ends

(2) valves from 51 mm to 76 mm 2 inches to 3 inches inclusive: brass, bronze, or iron bodies. 51 millimeters2 inch valves with threaded connections; 63 to 76 mm 2-1/2 to 3 inches valves with flanged connections

b. Internal valve trim: Brass or bronze.

c. Stems: Stainless steel.

d. Provide valves compatible with a solution of 50 percent ethylene or propylene glycol.

2.5.4.2 Liquid Service Not Exceeding 121 Degrees C 250 Degrees F

a. Valve body and body connections:

(a) 1) valves 38 mm 1-1/2 inches and smaller: brass or bronze body, with threaded or union ends

(b) 2) valves from 51 mm to 76 mm 2 inches to 3 inches inclusive: brass, bronze, or iron bodies. 51 millimeters2 inch valves with threaded connections; 63 to 76 mm 2-1/2 to 3 inches valves with flanged connections

b. Internal trim: Type 316 stainless steel including seats, seat rings, modulation plugs, valve stems, and springs.

c. Provide valves with non-metallic parts suitable for a minimum continuous operating temperature of 121 degrees C 250 degrees F or 28 degrees C 50 degrees F above the system design temperature, whichever is higher.

d. Provide valves compatible with a solution of 50 percent ethylene or propylene glycol

2.5.4.3 Hot water service 121 Degrees C 250 Degrees F and above

a. Provide valve bodies conforming to ASME B16.34 Class 300. For valves 25 mm 1 inch and larger provide valves with bodies which are carbon steel, globe type with welded ends. For valves smaller than 25 mm 1 inch provide valves with socket-weld ends. Provide valves with virgin polytetrafluoroethylene (PTFE) packing. Provide valve and actuator combinations which are normally closed.

b. Internal trim: Type 316 stainless steel including seats, seat rings, modulation plugs, valve stems, and springs.

2.5.4.4 Steam Service

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NOTE: For modulating valves at 103 kPa 15 psig or less inlet steam pressure, the design pressure drop should be 80 percent of the inlet gauge pressure. Higher than 103 kPa 15 psig inlet steam pressure, the pressure drop must be 42 percent of the inlet absolute pressure.
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For steam service, provide valves meeting the following requirements:

a. Valve body and connections:

(a) 1) valves 38 mm 1-1/2 inches and smaller: complete body of brass or bronze, with threaded or union ends

(b) 2) valves from 51 mm to 76 mm 2 inches to 3 inches inclusive: body of brass, bronze, or carbon steel

(c) 3) valves 100 mm 4 inches and larger: body of carbon steel. 50 mm 2 inch valves with threaded connections; valves 63 mm 2-1/2 inches and larger with flanged connections.

b. Internal Trim: Type 316 stainless steel including seats, seat rings, modulation plugs, valve stems, and springs.

c. Valve sizing: sized for [103.4 kPa] [15 psig] [_____] inlet steam pressure with a maximum [83 kPa] [12 psi] [_____] differential through the valve at rated flow, except where indicated otherwise.

2.5.5 Ball Valves

2.5.5.1 Liquid Service Not Exceeding 66 Degrees C 150 Degrees F

a. Valve body and connections:

(a) 1) valves 38 mm 1-1/2 inches and smaller: bodies of brass or bronze, with threaded or union ends

(b) 2) valves from 51 mm to 76 mm 2 inches to 3 inches inclusive: bodies of brass, bronze, or iron. 50 mm 2 inch valves with threaded connections; valves from 63 to 76 mm 2-1/2 to 3 inches with flanged connections.

b. Ball: Stainless steel or nickel-plated brass or chrome-plated brass.

c. Seals: Reinforced Teflon seals and EPDM O-rings.

d. Stem: Stainless steel, blow-out proof.

e. Provide valves compatible with a solution of 50 percent ethylene or propylene glycol.

2.5.6 Butterfly Valves

Provide butterfly valves which are threaded lug type suitable for dead-end service and modulation to the fully-closed position, with carbon-steel bodies or with ductile iron bodies in accordance with ASTM A536. Provide butterfly valves with non-corrosive discs, stainless steel shafts supported by bearings, and EPDM seats suitable for temperatures from -28.9

to +121.1 degrees C -20 to +250 degrees F. Provide valves with rated Kv Cv of the Kv Cv at 70 percent (60 degrees) open position. Provide valves meeting FCI 70-2 Class VI leakage rating.

2.5.7 Pressure Independent Control Valves (PICV)

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NOTE: Pressure independent control valves minimize flow fluctuations due to changes in piping pressure. These valves are more expensive than other control valve options, but can provide more steady process control where fast changes in piping pressure are expected.

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Provide pressure independent control valves which include a regulator valve which maintains the differential pressure across a flow control valve. Pressure independent control valves must accurately control the flow from 0-100 percent full rated flow regardless of changes in the piping pressure and not vary the flow more than plus or minus 5 percent at any given flow control valve position when the PICV differential pressure lies between the manufacturer's stated minimum and maximum. The rated minimum differential pressure for steady flow must not exceed 34.5 kPa 5 psid across the PICV. Provide either globe or ball type valves meeting the indicated requirements for globe and ball valves. Provide valves with a flow tag listing full rated flow and minimum required pressure drop. Provide valves with factory installed Pressure/Temperature ports ("Pete's Plugs") to measure the pressure drop to determine the valve flow rate.

2.5.8 Duct-Coil and Terminal-Unit-Coil Valves

For duct or terminal-unit coils provide control valves with either [flare-type][screw type] or solder-type ends. Provide flare nuts for each flare-type end valve.

2.6 DAMPERS

2.6.1 Damper Assembly

Provide single damper sections with blades no longer than 1.2 m 48 inches and which are no higher than 1.8 m 72 inches and damper blade width of 203 mm 8 inches or less. When larger sizes are required, combine damper sections. Provide dampers made of steel, or other materials where indicated and with assembly frames constructed of 2.8 mm 0.07 inch minimum thickness [galvanized][stainless] steel channels with mitered and welded corners. Steel channel frames constructed of 1.5 mm 0.06 inch minimum thickness are acceptable provided the corners are reinforced.

a. Flat blades must be made rigid by folding the edges. Blade-operating linkages must be within the frame so that blade-connecting devices within the same damper section must not be located directly in the air stream.

b. Damper axles must be 13 mm 1/2 inch minimum, plated steel rods supported in the damper frame by stainless steel or bronze bearings. Blades mounted vertically must be supported by thrust bearings.

c. Provide dampers which do not exceed a pressure drop through the damper of 10 Pa 0.04 inches water gauge at 5 m/s 1000 ft/min in the wide-open position. Provide dampers with frames not less than 50 mm 2 inch in width. Provide dampers which have been tested in accordance with AMCA 500-D.

2.6.2 Operating Linkages

For operating links external to dampers, such as crank arms, connecting rods, and line shafting for transmitting motion from damper actuators to dampers, provide links able to withstand a load equal to at least 300 percent of the maximum required damper-operating force without deforming. Rod lengths must be adjustable. Links must be brass, bronze, zinc-coated steel, or stainless steel. Working parts of joints and clevises must be brass, bronze, or stainless steel. Adjustments of crank arms must control the open and closed positions of dampers.

2.6.3 Damper Types

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NOTE: As of July 2009, UFC 4-010-01 requires a maximum OA damper leakage of 15 L/s per square meter at 249 Pa 3 cfm per square foot at 1 iwc static, which is a Class 1A damper. If this UFC or a similar requirement for a low-leakage damper is applicable to the project select Class 1A.

Otherwise:
1) If the application is in a very cold climate or where the system runs continuously consider selecting Class 1.

2) In other flow control applications select Class 2

For reference only, AMCA 511 leakage classifications at 1017 Pa 4 iwc static are:
Class 1A: N/A.

Class 1: 41 L/s per square meter 8 cfm per square foot of damper area.

Class 2: 102 L/s per square meter 20 cfm per square foot of damper area.

Class 3: 406 L/s per square meter 80 cfm per square foot of damper area.

AMCA 511 leakage classifications at 256 Pa 1 iwc static are:
Class 1A: 15 L/s per square meter 3 cfm per square foot of damper area.

Class 1: 20 L/s per square meter 4 cfm per square foot of damper area.

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2.6.3.1 Flow Control Dampers

Provide parallel-blade or opposed blade type dampers for outside air, return air, relief air, exhaust, face and bypass dampers as indicated on the Damper Schedule. Blades must have interlocking edges. The channel frames of the dampers must be provided with jamb seals to minimize air leakage. Unless otherwise indicated, dampers must meet AMCA 511 [Class 1A][Class 1][Class 2] requirements. Outside air damper seals must be suitable for an operating temperature range of -40 to +75 degrees C -40 to +167 degrees F. Dampers must be rated at not less than 10 m/s 2000 ft/min air velocity.

2.6.3.2 Mechanical Rooms and Other Utility Space Ventilation Dampers

Provide utility space ventilation dampers as indicated. Unless otherwise indicated provide AMCA 511 class 3 dampers. Provide dampers rated at not less than 7.6 m/s 1500 ft/min air velocity.

2.6.3.3 Smoke Dampers

Provide smoke-damper and actuator assemblies which meet the current requirements of NFPA 90A, UL 555, and UL 555S. For combination fire and smoke dampers provide dampers rated for 121 degrees C 250 degrees F Class II leakage per UL 555S.

2.7 SENSORS AND INSTRUMENTATION

Unless otherwise specified, provide sensors and instrumentation which incorporate an integral transmitter. Sensors and instrumentation, including their transmitters, must meet the specified accuracy and drift requirements at the input of the connected DDC Hardware's analog-to-digital conversion.

2.7.1 Analog and Binary Transmitters

Provide transmitters which match the characteristics of the sensor. Transmitters providing analog values must produce a linear 4-20 mAdc, 0-10 Vdc signal corresponding to the required operating range and must have zero and span adjustment. Transmitters providing binary values must have dry contacts rated at 1A at 24 Volts AC.

2.7.2 Network Transmitters

Sensors and Instrumentation incorporating an integral network connection are considered DDC Hardware and must meet the DDC Hardware requirements of Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS when used in a BACnet network.

2.7.3 Temperature Sensors

Provide the same sensor type throughout the project. Temperature sensors may be provided without transmitters. Where transmitters are used, the range must be the smallest available from the manufacturer and suitable for the application such that the range encompasses the expected range of temperatures to be measured. The end to end accuracy includes the combined effect of sensitivity, hysteresis, linearity and repeatability between the measured variable and the end user interface (graphic presentation) including transmitters if used.

2.7.3.1 Sensor Accuracy and Stability of Control

2.7.3.1.1 Conditioned Space Temperature

Plus or minus 0.3 degrees C 0.5 degree F over the operating range.

2.7.3.1.2 Unconditioned Space Temperature

a. Plus or minus 0.6 degrees C 1 degree F over the range of -1 to +55 degrees C 30 to 131 degrees F AND

b. Plus or minus 2 degrees C 4 degrees F over the rest of the operating range.

2.7.3.1.3 Duct Temperature

Plus or minus 0.3 degrees C 0.5 degree F

2.7.3.1.4 Outside Air Temperature

a. Plus or minus 1 degree C 2 degrees F over the range of -35 to +55 degrees C -30 to +130 degrees F AND

b. Plus or minus 0.6 degrees C 1 degree F over the range of -1 to +40 degrees C 30 to 130 degrees F.

2.7.3.1.5 High Temperature Hot Water

Plus or minus 2 degrees C 3.6 degrees F.

2.7.3.1.6 Chilled Water

Plus or minus 0.4 degrees C 0.8 degrees F over the range of 2 to 18 degrees C 35 to 65 degrees F.

2.7.3.1.7 Dual Temperature Water

Plus or minus 1 degree C 2 degrees F.

2.7.3.1.8 Heating Hot Water

Plus or minus 1 degree C 2 degrees F.

2.7.3.1.9 Condenser Water

Plus or minus 1 degree C 2 degrees F.

2.7.3.2 Transmitter Drift

The maximum allowable transmitter drift: 0.1 degrees C 0.25 degrees F per year.

2.7.3.3 Point Temperature Sensors

Point Sensors must be encapsulated in epoxy, series 300 stainless steel, anodized aluminum, or copper.

2.7.3.4   Temperature Sensor Details

2.7.3.4.1   Room Type

Provide the sensing element components within a decorative protective cover suitable for surrounding decor.

2.7.3.4.2   Duct Probe Type

Ensure the probe is long enough to properly sense the air stream temperature.

2.7.3.4.3   Duct Averaging Type

Continuous averaging sensors must be one foot in length for each 0.1 square m 1 square foot of duct cross-sectional area, and a minimum length of 1.5 m 5 feet.

2.7.3.4.4   Pipe Immersion Type

For pipes with larger than 7.6 cm 3 inch diameter, provide minimum 7.6 cm 3 inch immersion. For pipes with less than 7.6 cm 3 inch diameter, provide immersion at least half the diameter of the pipe. Provide each sensor with a corresponding pipe-mounted sensor well, unless indicated otherwise. Sensor wells must be stainless steel when used in steel piping, and brass when used in copper piping.

2.7.3.4.5   Outside Air Type

Provide the sensing element rated for outdoor use

2.7.4   Relative Humidity Sensor

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NOTE: 3 percent RH Accuracy may be sufficient for typical comfort cooling applications. For applications with more stringent requirements, a 2 percent RH accuracy may be desired.

****

Relative humidity sensors must use bulk polymer resistive or thin film capacitive type non-saturating sensing elements capable of withstanding a saturated condition without permanently affecting calibration or sustaining damage. The sensors must include removable protective membrane filters. Where required for exterior installation, sensors must be capable of surviving below freezing temperatures and direct contact with moisture without affecting sensor calibration. When used indoors, the sensor must be capable of being exposed to a condensing air stream (100 percent relative humidity) with no adverse effect to the sensor's calibration or other harm to the instrument. The sensor must be of the wall-mounted or duct-mounted type, as required by the application, and must be provided with any required accessories. Sensors used in duct high-limit applications must have a bulk polymer resistive sensing element. Duct-mounted sensors must be provided with a duct probe designed to protect the sensing element from dust accumulation and mechanical damage. Relative humidity (RH) sensors must measure relative humidity over a range of 0 percent to 100 percent with an accuracy of plus or minus [2][3] percent. RH sensors must function over a temperature range of 4.4 to 57.2 degrees C 40 to 135 degrees F and must not drift more than 1 percent per year.

2.7.5 Carbon Dioxide (CO2) Sensors

****
NOTE: In applications where the expected outside air temperature range exceeds the listed values, the designer must make accommodations to place to OA CO Sensor in a conditioned 100 percent Outside Airstream.
****

Provide photometric type CO2 sensors with integral transducers and linear output. Carbon dioxide (CO2) sensors must measure CO2 concentrations between 0 to 2000 parts per million (ppm) using non-dispersible infrared (NDIR) technology with an accuracy of plus or minus 50 ppm and a maximum response time of 1 minute. The sensor must be rated for operation at ambient air temperatures within the range of 0 to 50 degrees C 32 to 122 degrees F and relative humidity within the range of 20 to 95 percent (non-condensing). The sensor must have a maximum drift of 2 percent per year. The sensor chamber must be manufactured with a non-corrosive material that does not affect carbon dioxide sample concentration. Duct mounted sensors must be provided with a duct probe designed to protect the sensing element from dust accumulation and mechanical damage. The sensor must have a calibration interval no less than 5 years.

2.7.6 Differential Pressure Instrumentation

2.7.6.1 Differential Pressure Sensors

Provide Differential Pressure Sensors with ranges as indicated or as required for the application. Pressure sensor ranges must not exceed the high end range indicated on the Points Schedule by more than 50 percent. The over pressure rating must be a minimum of 150 percent of the highest design pressure of either input to the sensor. The accuracy must be plus or minus 1 percent of full scale. The sensor must have a maximum drift of 2 percent per year

2.7.6.2 Differential Pressure Switch

Provide differential pressure switches with a user-adjustable setpoint which are sized for the application such that the setpoint is between 25 percent and 75 percent of the full range. The over pressure rating must be a minimum of 150 percent of the highest design pressure of either input to the sensor. The switch must have two sets of contacts and each contact must have a rating greater than it's connected load. Contacts must open or close upon rise of pressure above the setpoint or drop of pressure below the setpoint as indicated.

2.7.7 Flow Sensors

2.7.7.1 Airflow Measurement Array (AFMA)

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NOTE: Care should be utilized in determining which technology is best suited for the application. While differential pressure measurement is usually the least expensive, it has limitations on the minimum velocities it can measure on a repeated

basis. Due to the very small pressure differentials at velocities below 400 fpm, outside influences (building pressure, wind velocities, etc.) have a greater effect on the repeatability. When sizing AFMS for applications where the minimum OA and economizer functions are combined into one AFMS (and associated damper), a review of the conditions at the minimum OA flow is prudent to make sure the desired AFMS can accurately read at this design point.
****

2.7.7.1.1 Airflow Straightener

Provide AFMAs which contain an airflow straightener if required by the AFMA manufacturer's published installation instructions. The straightener must be contained inside a flanged sheet metal casing, with the AFMA located as specified according to the published recommendation of the AFMA manufacturer. In the absence of published documentation, provide airflow straighteners if there is any duct obstruction within 5 duct diameters upstream of the AFMA. Air-flow straighteners, where required, must be constructed of 3 mm 0.125 inch aluminum honeycomb and the depth of the straightener must not be less than 40 mm 1.5 inches.

2.7.7.1.2 Resistance to Airflow

The resistance to air flow through the AFMA, including the airflow straightener must not exceed 20 Pa 0.085 inch water gauge at an airflow velocity of 10 m/s 2,000 feet per minute (fpm). AFMA construction must be suitable for operation at airflow velocities of up to 25 m/s 5000 fpm over a temperature range of 4 to 49 degrees C 40 to 120 degrees F.

2.7.7.1.3 Outside Air Temperature

****
NOTE: Ensure that outside air temperature range is appropriate for the environment at the project site, and provide a range if it's not.
****

In outside air measurement or in low-temperature air delivery applications, provide an AFMA certified by the manufacturer to be accurate as specified over a temperature range of [-29 to +49 degrees C-20 to +120 degrees F] [_____].

2.7.7.1.4 Pitot Tube AFMA

Each Pitot Tube AFMA must contain an array of velocity sensing elements. The velocity sensing elements must be of the multiple pitot tube type with averaging manifolds. The sensing elements must be distributed across the duct cross section in the quantity and pattern specified or recommended by the published installation instructions of the AFMA manufacturer.

a. Pitot Tube AFMAs for use in airflow velocities over 3.0 m/s 600 fpm must have an accuracy of plus or minus 5 percent over a range of 2.5 to 12.5 m/s 500 to 2500 fpm.

b. Pitot Tube AFMAs for use in airflow velocities under 3.0 m/s 600 fpm must have an accuracy of plus or minus 5 percent over a range of 0.6

to 12.5 m/s 125 to 2500 fpm.

2.7.7.1.5 Electronic AFMA

Each electronic AFMA must consist of an array of velocity sensing elements of the resistance temperature detector (RTD) or thermistor type. The sensing elements must be distributed across the duct cross section in the quantity and pattern specified or recommended by the published application data of the AFMA manufacturer. Electronic AFMAs must have an accuracy of plus or minus 5 percent over a range of 0.6 to 12.5 m/s 125 to 5,000 fpm and the output must be temperature compensated over a range of 0 to 100 degrees C 32 to 212 degrees F.

2.7.7.1.6 Fan Inlet Measurement Devices

Fan inlet measurement devices cannot be used unless indicated on the drawings or schedules.

2.7.7.2 Orifice Plate

Orifice plate must be made of an austenitic stainless steel sheet of 3. mm 0.125 inch nominal thickness with an accuracy of plus or minus 1 percent of full flow. The orifice plate must be flat within 0.1 mm 0.002 inches. The orifice surface roughness must not exceed 0.5 µm 20 micro-inches. The thickness of the cylindrical face of the orifice must not exceed 2 percent of the pipe inside diameter or 12.5 percent of the orifice diameter, whichever is smaller. The upstream edge of the orifice must be square and sharp. Where orifice plates are used, concentric orifice plates must be used in all applications except steam flow measurement in horizontal pipelines.

2.7.7.3 Flow Nozzle

Flow nozzle must be made of austenitic stainless steel with an accuracy of plus or minus 1 percent of full flow. The inlet nozzle form must be elliptical and the nozzle throat must be the quadrant of an ellipse. The thickness of the nozzle wall and flange must be such that distortion of the nozzle throat from strains caused by the pipeline temperature and pressure, flange bolting, or other methods of installing the nozzle in the pipeline must not cause the accuracy to degrade beyond the specified limit. The outside diameter of the nozzle flange or the design of the flange facing must be such that the nozzle throat must be centered accurately in the pipe.

2.7.7.4 Venturi Tube

Venturi tube must be made of cast iron or cast steel and must have an accuracy of plus or minus 1 percent of full flow. The throat section must be lined with austenitic stainless steel. Thermal expansion characteristics of the lining must be the same as that of the throat casting material. The surface of the throat lining must be machined to a plus or minus 1.2 µm 50 micro inch finish, including the short curvature leading from the converging entrance section into the throat.

2.7.7.5 Annular Pitot Tube

Annular pitot tube must be made of austenitic stainless steel with an accuracy of plus or minus 2 percent of full flow and a repeatability of plus or minus 0.5 percent of measured value. The unit must have at least one static port and no less than four total head pressure ports with an averaging manifold.

2.7.7.6 Insertion Turbine Flowmeter

Provide dual axial turbine flowmeter with all installation hardware necessary to enable insertion and removal of the meter without system shutdown. All parts must meet or exceed the pressure classification of the pipe system it is installed in. Insertion Turbine Flowmeter accuracy must be plus or minus 0.5 percent of rate at calibrated velocity., within plus or minus of rate over a 10:1 turndown and within plus or minus 2 percent of rate over a 50:1 turndown. Repeatability must be plus or minus 0.25 percent of reading. The meter flow sensing element must operate over a range suitable for the installed location with a pressure loss limited to 1 percent of operating pressure at maximum flow rate. The flowmeter ,must include either dry contact pulse outputs, 4-20mA, 0-10Vdc or 0-5Vdc outputs. The turbine rotor assembly must be constructed of Series 300 stainless steel and use Teflon seals.

2.7.7.7 Vortex Shedding Flowmeter

Vortex Shedding Flowmeter accuracy must be within plus or minus 0.8 percent of the actual reading over the range of the meter. Steam meters must contain density compensation by direct measurement of temperature. Mass flow inferred from specified steam pressure are not acceptable. The flow meter body must be made of austenitic stainless steel and include a weather tight NEMA 4X electronics enclosure. The vortex shedding flowmeter body must not require removal from the piping in order to replace the shedding sensor.

2.7.7.8 Ultrasonic Flow Meter

Provide Ultrasonic Flow Meters complete with matched transducers, self aligning installation hardware and transducer cables. Ultrasonic transducers must be optimized for the specific pipe and process conditions for the application. The flow meter accuracy must plus or minus 1 percent of rate from 0.3 to 12 meters/sec 0 to 40 ft/sec. The flowmeter must include either dry contact pulse outputs, 4-20mA, 0-10Vdc or 0-5Vdc output.

2.7.7.9 Insertion Magnetic Flow Meter

Provide insertion type magnetic flowmeters with all installation hardware necessary to enable insertion and removal of the meter without system shutdown. All parts must meet or exceed the pressure classification of the pipe system it is installed in. Flowmeter accuracy must be no greater than plus or minus 1 percent of rate from 0.6 to 6 meters/sec 2 to 20 feet/sec. Wetted material parts must be 300 series stainless steel. The flowmeter must include either dry contact pulse outputs, 4-20mA, 0-10Vdc or 0-5Vdc outputs.

2.7.7.10 Positive Displacement Flow Meter

The flow meter must be a direct reading, gerotor, nutating disc or vane type displacement device rated for liquid service as indicated. A counter must be mounted on top of the meter, and must consist of a non-resettable mechanical totalizer for local reading, and a pulse transmitter for remote reading. The totalizer must have a six digit register to indicate the volume passed through the meter in [liters] [gallons], and a sweep-hand dial to indicate down to 1 L 0.25 gallons. The pulse transmitter must have a hermetically sealed reed switch which is activated by magnets fixed on gears of the counter. The meter must have a bronze body with threaded or flanged connections as required for the application. Output accuracy must be plus or minus 2 percent of the flow range. The maximum pressure drop at full flow must be 34 kPa 5 psig.

2.7.7.11 Flow Meters, Paddle Type

Sensor must be non-magnetic, with forward curved impeller blades designed for water containing debris. Sensor accuracy must be plus or minus 1 percent of rate of flow, minimum operating flow velocity must be 0.3 meters/second 1 foot per second. Sensor repeatability and linearity must be plus or minus 1 percent. Materials which will be wetted must be made from non-corrosive materials and must not contaminate water. The sensor must be rated for installation in pipes of 76 mm to 1 m 3 to 40 inch diameters. The transmitter housing must be a NEMA 250 Type 4 enclosure.

2.7.7.12 Flow Switch

Flow switch must have a repetitive accuracy of plus or minus 10 percent of actual flow setting. Switch actuation must be adjustable over the operating flow range, and must be sized for the application such that the setpoint is between 25 percent and 75 percent of the full range.. The switch must have Form C snap-action contacts, rated for the application. The flow switch must have non flexible paddle with magnetically actuated contacts and be rated for service at a pressure greater than the installed conditions. Flow switch for use in sewage system must be rated for use in corrosive environments encountered.

2.7.7.13 Gas Flow Meter

Gas flow meter must be diaphragm or bellows type (gas positive displacement meters) for flows up to 19.7 L/sec 2500 SCFH and axial flow turbine type for flows above 19.7 L/sec 2500 SCFH, designed specifically for natural gas supply metering, and rated for the pressure, temperature, and flow rates of the installation. Meter must have a minimum turndown ratio of 10 to 1 with an accuracy of plus or minus 1 percent of actual flow rate. The meter index must include a direct reading mechanical totalizing register and electrical impulse dry contact output for remote monitoring. The electrical impulse dry contact output must not require field adjustment or calibration. The electrical impulse dry contact output must have a minimum resolution of 3 cubic meters 100 cubic feet of gas per pulse and must not exceed 15 pulses per second at the design flow.

2.7.8 Electrical Instruments

Provide Electrical Instruments with an input range as indicated or sized for the application. Unless otherwise specified, AC instrumentation must be suitable for 60 Hz operation.

2.7.8.1 Current Transducers

****

NOTE: Select the required accuracy for current transducers. Note that higher accuracy transducers will be more expensive and will likely require a more expensive/better quality controller.

****

Current transducers must accept an AC current input and must have an accuracy of plus or minus [0.5] [2] percent of full scale. The device must have a means for calibration. Current transducers for variable frequency applications must be rated for variable frequency operation.

2.7.8.2 Current Sensing Relays (CSRs)

Current sensing relays (CSRs) must provide a normally-open contact with a voltage and amperage rating greater than its connected load. Current sensing relays must be of split-core design. The CSR must be rated for operation at 200 percent of the connected load. Voltage isolation must be a minimum of 600 volts. The CSR must auto-calibrate to the connected load or be adjustable and field calibrated. Current sensors for variable frequency applications must be rated for variable frequency operation.

2.7.8.3 Voltage Transducers

Voltage transducers must accept an AC voltage input and have an accuracy of plus or minus 0.25 percent of full scale. The device must have a means for calibration. Line side fuses for transducer protection must be provided.

2.7.8.4 Energy Metering

2.7.8.4.1 Watt or Watthour Transducers

Watt transducers must measure voltage and current and must output kW or kWh or both kW and kWh as indicated. kW outputs must have an accuracy of plus or minus 0.5 percent over a power factor range of 0.1 to 1. kWh outputs must have an accuracy of plus or minus 0.5 percent over a power factor range of 0.1 to 1.

2.7.8.4.2 Watthour Revenue Meter (with and without Demand Register)

****

NOTE: The intent of including meters in this Section is for energy monitoring as may be required for interface to a UMCS. Meters are typically only required by this Section for retrofit applications. Coordination of meter installation and meter requirements with other specifications may be required.

Select the revenue meter accuracy as required for the application. For most applications, the 0.5 accuracy class should be suitable/sufficient. (Note the 0.5 accuracy class allows a 0.5 percent error, while the 0.2 class allows 0.2 percent).

****

All Watthour revenue meters must measure voltage and current and must be in accordance with ANSI C12.1 with an ANSI C12.20 Accuracy class of [0.5] [0.2] and must have pulse initiators for remote monitoring of Watthour consumption. Pulse initiators must consist of form C contacts with a current rating not to exceed two amperes and voltage not to exceed 500 V, with combinations of VA not to exceed 100 VA, and a life rating of one billion operations. Meter sockets must be in accordance with NEMA/ANSI C12.10. Watthour revenue meters with demand registers must output instantaneous demand in addition to the pulse initiators.

2.7.8.4.3 Steam Meters

Steam meters must be the vortex type, with pressure compensation, a minimum turndown ratio of 10 to 1, and an output signal compatible with the DDC system.

2.7.8.4.4 Hydronic BTU Meters

The BTU meter is to be supplied with wall mount hardware and be capable of being installed remote from the flow meter. The BTU meter must include an LCD display for local indication of energy rate and for display of parameters and settings during configuration. Each BTU meter must be factory configured for its specific application and be completely field configurable by the user via a front panel keypad (no special interface device or computer required). The unit must output Energy Rate, Energy Total, Flow Rate, Supply Temperature, and Return Temperature. An integral transmitter is to provide a linear analog or configurable pulse output signal representing the energy rate; and the signal must be compatible with building automation system DDC Hardware to which the output is connected.

2.7.9 pH Sensor

The sensor must be suitable for applications and chemicals encountered in water treatment systems of boilers, chillers and condenser water systems. Construction, wiring, fittings and accessories must be corrosion and chemical resistant with fittings for tank or suspension installation. Housing must be polyvinylidene fluoride with O-rings made of chemical resistant materials which do not corrode or deteriorate with extended exposure to chemicals. The sensor must be encapsulated. Periodic replacement must not be required for continued sensor operation. Sensors must use a ceramic junction and pH sensitive glass membrane capable of withstanding a pressure of 689 kPa at 66 degrees C 100 psig at 150 degrees F. The reference cell must be double junction configuration. Sensor range must be 0 to 12 pH, stability 0.05, sensitivity 0.02, and repeatability of plus or minus 0.05 pH value, response of 90 percent of full scale in one second and a linearity of 99 percent of theoretical electrode output measured at 24 degrees C 76 degrees F.

2.7.10 Oxygen Analyzer

Oxygen analyzer must consist of a zirconium oxide sensor for continuous sampling and an air-powered aspirator to draw flue gas samples. The analyzer must be equipped with filters to remove flue air particles. Sensor probe temperature rating must be 435 degrees C 815 degrees F. The sensor assembly must be equipped for flue flange mounting.

2.7.11 Carbon Monoxide Analyzer

****
NOTE: Enter the range for the CO Analyzer
****

Carbon monoxide analyzer must consist of an infrared light source in a weather proof steel enclosure for duct or stack mounting. An optical detector/analyzer in a similar enclosure, suitable for duct or stack mounting must be provided. Both assemblies must include internal blower systems to keep optical windows free of dust and ash at all times. The third component of the analyzer must be the electronics cabinet. Automatic flue gas temperature compensation and manual/automatic zeroing devices must be provided. Unit must read parts per million (ppm) of carbon monoxide in the range of [_____] to [_____] ppm and the response time must be less than 3 seconds to 90 percent value. Unit measurement range must not exceed specified range by more that 50 percent. Repeatability must be plus or minus 1 percent of full scale with an accuracy of plus or minus 1 percent of full scale.

2.7.12 Occupancy Sensors

****

NOTE: Avoid using occupancy sensors with instant start fluorescent ballasts for instant start of lamps because they shorten the lamp life. Use only rapid start fluorescent ballasts.

Show which type of occupancy sensor to use drawings: Ultrasonic sensors are best suited for spaces with partitions or dividers; Infrared sensors are best suited in line-of-sight applications. Dual mode sensor are available for situations where only one mode will not adequately identify occupancy.

Show occupancy sensor mounting location on drawings. Office furniture is less likely to interfere with (block) ceiling mounted sensors. In retrofit applications, occupancy sensors can be installed in place of existing light switches.

Dual-technology sensors (one sensor incorporating both types) ordinarily turn lighting ON when both technologies sense occupancy. Then, detection by either technology will hold lighting ON.

****

Occupancy sensors must have occupancy-sensing sensitivity adjustment and an adjustable off-delay timer with a setpoint of 15 minutes. Adjustments accessible from the face of the unit are preferred. Occupancy sensors must be rated for operation in ambient air temperatures ranging from 5 to 35 degrees C 40 to 95 degrees F or temperatures normally encountered in the installed location. Sensors integral to wall mount on-off light switches must have an auto-off switch. Wall switch sensors must be decorator style and must fit behind a standard decorator type wall plate. All occupancy sensors, power packs, and slave packs must be UL listed. In addition to any outputs required for lighting control, the occupancy sensor must provide an output for the HVAC control system.

2.7.12.1 Passive Infrared (PIR) Occupancy Sensors

PIR occupancy sensors must have a multi-level, multi-segmented viewing lens and a conical field of view with a viewing angle of 180 degrees and a detection of at least 6 m 20 feet unless otherwise indicated or specified. PIR Sensors must provide field-adjustable background light-level adjustment with an adjustment range suitable to the light level in the sensed area, room or space. PIR sensors must be immune to false triggering from RFI and EMI.

2.7.12.2 Ultrasonic Occupancy Sensors

Ultrasonic sensors must operate at a minimum frequency 32 kHz and must be designed to not interfere with hearing aids.

2.7.12.3 Dual-Technology Occupancy Sensor (PIR and Ultrasonic)

Dual-Technology Occupancy Sensors must meet the requirements of both PIR and Ultrasonic Occupancy Sensors.

2.7.13 Vibration Switch

Vibration switch must be solid state, enclosed in a NEMA 250 Type 4 or Type 4X housing with sealed wire entry. Unit must have two independent sets of Form C switch contacts with one set to shutdown equipment upon excessive vibration and a second set for monitoring alarm level vibration. The vibration sensing range must be a true rms reading, suitable for the application. The unit must include either displacement response for low speed or velocity response for high speed application. The frequency range must be at least 3 Hz to 500 Hz. Contact time delay must be 3 seconds. The unit must have independent start-up and running delay on each switch contact. Alarm limits must be adjustable and setpoint accuracy must be plus or minus 10 percent of setting with repeatability of plus or minus 2 percent.

2.7.14 Conductivity Sensor

****

NOTE: Remove the bracketed text for new construction (Contractor cannot meet this requirement). For retrofit projects, coordinate with the project site to determine need for this analysis.

****

Sensor must include local indicating meter and must be suitable for measurement of conductivity of water in boilers, chilled water systems, condenser water systems, distillation systems, or potable water systems as indicated. Sensor must sense from 0 to 10 microSeimens per centimeter (μS/cm) for distillation systems, 0 to 100 μS/cm for boiler, chilled water, and potable water systems and 0 to 1000 μS/cm for condenser water systems. Contractor must field verify the ranges for particular applications and adjust the range as required. The output must be temperature compensated over a range of 0 to 100 degrees C 32 to 212 degrees F. The accuracy must be plus or minus 2 percent of the full scale reading. Sensor must have automatic zeroing and must require no periodic maintenance or recalibration.

2.7.15 Compressed Air Dew Point Sensor

Sensor must be suitable for measurement of dew point from -40 +27 degrees C -40 +80 degrees F over a pressure range of 0 to 1 MPa 0 to 150 psig. The transmitter must provide both dry bulb and dew point temperatures on separate outputs. The end to end accuracy of the dew point must be plus or minus 2.8 degrees C 5 degrees F and the dry bulb must be plus or minus 0.6 degrees C 1 degree F. Sensor must be automatic zeroing and must require no normal maintenance or periodic recalibration.

2.7.16   NOx Monitor

Monitor must continuously monitor and give local indication of boiler stack gas for NOx content. It must be a complete system designed to verify compliance with the Clean Air Act standards for NOx normalized to a 3 percent oxygen basis and must have a range of from 0 to 100 ppm. Sensor must be accurate to plus or minus 5 ppm. Sensor must output NOx and oxygen levels and binary output that changes state when the NOx level is above a locally adjustable NOx setpoint. Sensor must have normal, trouble and alarm lights. Sensor must have heat traced lines if the stack pickup is remote from the sensor. Sensor must be complete with automatic zero and span calibration using a timed calibration gas system, and must not require periodic maintenance or recalibration.

2.7.17   Turbidity Sensor

Sensor must include a local indicating meter and must be suitable for measurement of turbidity of water. Sensor must sense from 0 to 1000 Nephelometric Turbidity Units (NTU). Range must be field-verified for the particular application and adjusted as required. The output must be temperature compensated over a range of 0 to 100 degrees C 32 to 212 degrees F. The accuracy must be plus or minus 5 percent of full scale reading. Sensor must have automatic zeroing and must not require periodic maintenance or recalibration.

2.7.18   Chlorine Detector

The detector must measure concentrations of chlorine in water in the range 0 to 20 ppm with a repeatability of plus or minus 1 percent of full scale and an accuracy of plus or minus 2 percent of full scale. The Chlorine Detector transmitter must be housed in a non-corrosive NEMA 250 Type 4X enclosure. Detector must include a local panel with adjustable alarm trip level, local audio and visual alarm with silence function.

2.7.19   Floor Mounted Leak Detector

Leak detectors must use electrodes mounted at slab level with a minimum built-in-vertical adjustment of 3 mm 0.125 inches. Detector must have a binary output. The indicator must be manual reset type.

2.7.20   Temperature Switch

2.7.20.1   Duct Mount Temperature Low Limit Safety Switch (Freezestat)

Duct mount temperature low limit switches (Freezestats) must be manual reset, low temperature safety switches at least 3 meters 1 foot long per square meter square foot of coverage which must respond to the coldest 450 mm 18 inch segment with an accuracy of plus or minus 2 degrees C 3.6 degrees F. The switch must have a field-adjustable setpoint with a range of at least -1 +10 degrees C 30 to 50 degrees F. The switch must have two sets of contacts, and each contact must have a rating greater than its connected load. Contacts must open or close upon drop of temperature below setpoint as indicated and must remain in this state until reset.

2.7.20.2   Pipe Mount Temperature Limit Switch (Aquastat)

Pipe mount temperature limit switches (aquastats) must have a field adjustable setpoint between 15 and 32 degrees C 60 and 90 degrees F, an accuracy of plus or minus 2 degrees C 3.6 degrees F and a 5 degrees C 10 degrees F fixed deadband. The switch must have two sets of contacts, and each contact must have a rating greater than its connected load. Contacts must open or close upon change of temperature above or below setpoint as indicated.

2.7.21 Damper End Switches

****

NOTE: If the HVAC system design includes smoke dampers in the return air and fan discharge, or other dampers requiring end switches, show the end switches on drawings.

Dampers that have the potential to close off all airflow to/from a fan should have end switches providing an interlock with the fan control circuit. Interlock should be active in all modes (Hand, Automatic and Bypass).

****

Each end switch must be a hermetically sealed switch with a trip lever and over-travel mechanism. The switch enclosure must be suitable for mounting on the duct exterior and must permit setting the position of the trip lever that actuates the switch. The trip lever must be aligned with the damper blade.

End switches integral to an electric damper actuator are allowed as long as at least one is adjustable over the travel of the actuator.

2.7.22 Air Quality Sensors

Provide full spectrum air quality sensors using a hot wire element based on the Taguchi principle. The sensor must monitor a wide range of gaseous volatile organic components common in indoor air contaminants like paint fumes, solvents, cigarette smoke, and vehicle exhaust. The sensor must automatically compensate for temperature and humidity, have span and calibration potentiometers, operate on 24 VDC power with output of 0-10 VDC, and have a service rating of 0 to 60 degrees C 32 to 140 degrees F and 5 to 95 percent relative humidity.

[2.8 INDICATING DEVICES

****

NOTE: Indicating devices are typically provided by the Mechanical Contractor and the specifications of ancillary indicating devices is located in Sections 23 30 00 HVAC AIR DISTRIBUTION, 23 05 15 COMMON PIPING FOR HVAC. Both sections are listed in Subpart 1.2

With the re-organization of the indicating devices are specified in other sections are are included here to ensure they are included in the project specification. If the indicating devices are adequately listed on other sections, then remove all or part of the bracketed text.

****

All indicating devices must display readings in [metric (SI)][English (inch-pound)] units.

2.8.1 Thermometers

Provide bi-metal type thermometers at locations indicated. Thermometers must have either 230 mm 9 inch long scales or 90 mm 3.5 inch diameter dials, with insertion, immersion, or averaging elements. Provide matching thermowells for pipe-mounted installations. Select scale ranges suitable for the intended service, with the normal operating temperature near the scale's midpoint. The thermometer's accuracy must be plus or minus 2 percent of the scale range.

2.8.1.1 Piping System Thermometers

Piping system thermometers must have brass, malleable iron or aluminum alloy case and frame, clear protective face, permanently stabilized glass tube with indicating-fluid column, white face, black numbers, and a 230 mm 9 inch scale. Piping system thermometers must have an accuracy of plus or minus 1 percent of scale range. Thermometers for piping systems must have rigid stems with straight, angular, or inclined pattern. Thermometer stems must have expansion heads as required to prevent breakage at extreme temperatures. On rigid-stem thermometers, the space between bulb and stem must be filled with a heat-transfer medium.

2.8.1.2 Air-Duct Thermometers

Air-duct thermometers must have perforated stem guards and 45-degree adjustable duct flanges with locking mechanism.

2.8.2 Pressure Gauges

Provide pipe-mounted pressure gauges at the locations indicated. Gauges must conform to ASME B40.100 and have a 100 mm 4 inch diameter dial and shutoff cock. Select scale ranges suitable for the intended service, with the normal operating pressure near the scale's midpoint. The gauge's accuracy must be plus or minus 2 percent of the scale range.

Gauges must be suitable for field or panel mounting as required, must have black legend on white background, and must have a pointer traveling through a 270-degree arc. Gauge range must be suitable for the application with an upper end of the range not to exceed 150 percent of the design upper limit. Accuracy must be plus or minus 3 percent of scale range. Gauges must meet requirements of ASME B40.100.

2.8.3 Low Differential Pressure Gauges

Gauges for low differential pressure measurements must be a minimum of 90 mm 3.5 inch (nominal) size with two sets of pressure taps, and must have a diaphragm-actuated pointer, white dial with black figures, and pointer zero adjustment. Gauge range must be suitable for the application with an upper end of the range not to exceed 150 percent of the design upper limit. Accuracy must be plus or minus two percent of scale range.

[2.8.4 Pressure Gauges for Pneumatic Controls

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NOTE: Remove this paragraph if pneumatic devices are not required.

****

Gauges must [have a 0 to 207 kPa 0 to 30 psi scale][sufficient scale to display the full range of expected pressures] with 5 kPa 1 psi graduations.

]]2.9 OUTPUT DEVICES

2.9.1 Actuators

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NOTE: Include the appropriate bracketed text if pneumatic actuators are used.

Edit the control Schematic drawing to show electric and/or pneumatic actuators along with their failsafe positions (NO, NC, or fail-in-last-position (FILP)). See the UFC for design guidance on choosing actuator fail-to positions.

Include the bracketed text if using electric actuator position feedback. This should be limited to primary equipment, such as built-up air handlers. Show this feedback signal on the control schematic drawings or specifically state where this requirement applies. Add the actuator position to the Points Schedule as a network variable available to be monitored by the UMCS (present or future).

****

Actuators must be electric (electronic) [or pneumatic as indicated]. All actuators must be normally open (NO), normally closed (NC) or fail-in-last-position (FILP) as indicated. Normally open and normally closed actuators must be of mechanical spring return type. Electric actuators must have an electronic cut off or other means to provide burnout protection if stalled. Actuators must have a visible position indicator. [Electric actuators must provide position feedback to the controller as indicated.] Actuators must smoothly and fully open or close the devices to which they are applied. Electric actuators must have a full stroke response time in both directions of 90 seconds or less at rated load. Electric actuators must be of the foot-mounted type with an oil-immersed gear train or the direct-coupled type. Where multiple electric actuators operate from a common signal, the actuators must provide an output signal identical to its input signal to the additional devices. [Pneumatic actuators must be rated for 172 kPa 25 psi operating pressure except for high-pressure cylinder-type actuators.] All actuators must be rated for their operating environment. Actuators used outdoors must be designed and rated for outdoor use. Actuators under continuous exposure to water, such as those used in sumps, must be submersible.

Actuators incorporating an integral network connection are considered DDC Hardware and must meet the DDC Hardware requirements of Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

2.9.1.1 Valve Actuators

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NOTE: Indicate in the Valve Schedule a close-off pressure that is 150 percent of the pump dead head pressure for 2-way valves and 200 percent of the valve differential pressure for 3-way valves, or

equivalent torque values.
****

Valve actuators must provide shutoff pressures and torques as indicated on the Valve Schedule.

2.9.1.2 Damper Actuators

Damper actuators must provide the torque necessary per damper manufacturer's instructions to modulate the dampers smoothly over its full range of operation and torque must be at least 7.3 Nm/square m 6 inch-pounds/1 square foot of damper area for opposed blade dampers and 10.9 Nm/square m 9 inch-pounds/1 square foot of damper area for parallel blade dampers.

****
NOTE: Remove the bracketed text if pneumatic devices are not required.
****

[2.9.1.3 Positive Positioners

****
NOTE: Positive positioners may be required for larger valves and actuators or where high-speed actuation is needed. Edit the drawings to show positive positioners when they are required. The typical drawings do not show/require them due to maintenance requirements for these devices. See UFC 3-410-02 for more information.
****

Positive positioners must be a pneumatic relay with a mechanical position feedback mechanism and an adjustable operating range and starting point.

]2.9.1.4 Electric Actuators

Each actuator must have distinct markings indicating the full-open and full-closed position. Each actuator must deliver the torque required for continuous uniform motion and must have internal end switches to limit the travel, or be capable of withstanding continuous stalling without damage. Actuators must function properly within 85 to 110 percent of rated line voltage. Provide actuators with hardened steel running shafts and gears of steel or copper alloy. Fiber or reinforced nylon gears may be used for torques less than 16 inch-pounds.

a. Two-position actuators must be single direction, spring return, or reversing type. Two position actuator signals may either be the control power voltage or line voltage as needed for torque or appropriate interlock circuits.

b. Modulating actuators must be capable of stopping at any point in the cycle, and starting in either direction from any point. Actuators must be equipped with a switch for reversing direction, and a button to disengage the clutch to allow manual adjustments. Provide the actuator with a hand crank for manual adjustments, as applicable. Modulating actuator input signals can either be a 4 to 20 mAdc or a 0-10 VDC signal.

****

NOTE: Non spring return (NSR) or Fail in Last Position Actuators (FILP) are both acceptable alternatives for non safety or equipment protection applications. They are not recommended for applications such as AHU mixing boxes, preheat coils, steam-water heat exchanges, etc..

Provide in the design valve and damper schedule a designation on the need for spring return and desired fail position for each valve and damper.

****

c. Floating or pulse width modulation actuators are acceptable for non-fail safe applications unless indicated otherwise provided that the floating point control (timed actuation) must have a scheduled re-calibration of span and position no more than once a day and no less than once a week. The schedule for the re-calibration should not affect occupied conditions and be staggered between equipment to prevent falsely loading or unloading central plant equipment.

[2.9.1.5 Pneumatic Actuators

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NOTE: Remove this paragraph if pneumatic devices are not required.

****

Provide piston or diaphragm type actuators with replaceable diaphragm/piston.

]2.9.2 Solenoid-Operated Electric to Pneumatic Switch (EPS)

Solenoid-Operated Electric to Pneumatic Switches (EPS) must accept a voltage input to actuate its air valve. Each valve must have three-port operation: common, normally open, and normally closed. Each valve must have an outer cast aluminum body and internal parts of brass, bronze, or stainless steel. The air connection must be a 10 mm 0.38 inch NPT threaded connection. Valves must be rated for 345 kPa 50 psig.

2.9.3 Electric to Pneumatic Transducers (EP)

****

NOTE: Depending on the application, the designer may choose to select an EP and actuator combination to operate over the full range in less than 90 seconds.

****

Electric to Pneumatic Transducers (EPs) must convert either a 4-20 mAdc input signal, a 0-10 Vdc input signal to a proportional 0 to 140 kPa 0 to 20 psig pneumatic output. The EP must withstand pressures at least 150 percent of the system supply air pressure (main air). EPs must include independent offset and span adjustment. Steady state air consumption must not be greater than 0.23 L/s 0.05 scfm. EPs must have a manual adjustable override for the EP pneumatic output. EPs must have sufficient output capacity to provide full range stroke of the actuated device in both directions within [90][_____] seconds.

2.9.4 Relays

****

NOTE: Panel mounted relays have historically be specified as 'socket type' for UMCS. Recent popularity of encapsulated types of relays under brand names such as 'RIB.' has increased which provides flexibility in mounting relays at the controlled device (i.e. Motor Starters) that allows for low voltage wiring be run to/from the panel to the device rather than medium voltage.

****

Relays must have contacts rated for the intended application, indicator light, and dust proof enclosure. The indicator light must be lit when the coil is energized and off when coil is not energized.

Control relay contacts must have utilization category and ratings selected for the application. Each set of contacts must incorporate a normally open (NO), normally closed (NC) and common contact. Relays must be rated for a minimum life of one million operations.

2.10 USER INPUT DEVICES

User Input Devices, including potentiometers, switches and momentary contact push-buttons. Potentiometers must be of the thumb wheel or sliding bar type. Momentary Contact Push-Buttons may include an adjustable timer for their output. User input devices must be labeled for their function.

2.11 MULTIFUNCTION DEVICES

Multifunction devices are products which combine the functions of multiple sensor, user input or output devices into a single product. Unless otherwise specified, the multifunction device must meet all requirements of each component device. Where the requirements for the component devices conflict, the multifunction device must meet the most stringent of the requirements.

2.11.1 Current Sensing Relay Command Switch

The Current Sensing Relay portion must meet all requirements of the Current Sensing Relay input device. The Command Switch portion must meet all requirements of the Relay output device except that it must have at least one normally-open (NO) contact.

Current Sensing Relays used for Variable Frequency Drives must be rated for Variable Frequency applications unless installed on the source side of the drive. If used in this situation, the threshold for showing status must be set to allow for the VFD's control power when the drive is not enabled and provide indication of operation when the drive is enabled at minimum speed.

2.11.2 Space Sensor Module

****

NOTE: Indicate requirements for each space sensor module on the Space Sensor Module and Occupancy

Sensor drawing.

Space Sensor Modules may be commonly referred to as Thermostats but should not be confused with devices that have contact outputs for control of heating/cooling equipment (fans, compressors, etc.).

Note that any device which includes control functionality (including a thermostat) is a DDC Controller and is specified in Sections 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC and 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.
****

Space Sensor Modules must be multifunction devices incorporating a temperature sensor and one or more of the following as specified and indicated on the Space Sensor Module Schedule:

a. A temperature indicating device.

b. A User Input Device which must adjust a temperature setpoint output.

c. A User Input Momentary Contact Button and an output to the control system indicating zone occupancy.

d. A three position User Input Switch labeled to indicate heating, cooling and off positions ('HEAT-COOL-OFF' switch) and providing corresponding outputs to the control system.

e. A two position User Input Switch labeled with 'AUTO' and 'ON' positions and providing corresponding output to the control system.

f. A multi-position User Input Switch with 'OFF' and at least two fan speed positions and providing corresponding outputs to the control system.

Space Sensor Modules cannot contain mercury (Hg).

[2.12 COMPRESSED AIR STATIONS

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NOTE: Remove this bracketed paragraph if pneumatic devices are not required.
****

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NOTE: The designer will estimate the required control air consumption to calculate the required motor horsepower of the control air compressor and coordinate with the electrical designer.

For hospitals and critical installations, a standby compressor will be provided. For all other applications, the portion covering standby compressor will be deleted. For hospitals, delete the Contractor option permitting the use of polyethylene tubing in lieu of copper.

Indicate on the drawings the locations where metallic raceway or electric metallic tubing is not required for protection of nonmetallic tubing.
****

2.12.1   Air Compressor Assembly

Air compressors for pneumatic control systems must be the tank-mounted, electric motor driven, air cooled, reciprocating type with integral [duplex motors and compressors][single motor and compressor], tank, controller, [alternator switch,]pressure switch, belt guard[s], pressure relief valve, automatic moisture drain valve and must be supported by a steel base mounted on an air storage tank. Compressor piston speeds must not exceed 2.28 meter/second 450 fpm. Provide compressors with a dry-type combination intake air filter and silencer with baked enamel steel housing. The filter must be 99 percent efficient at 10 µm 10 microns. The pressure switch must start the compressor[s] at 482 kPa 70 psig and stop the compressor[s] at 620 kPa 90 psig. The relief valve must be set for 69 to 172 kPa 10 to 25 psig above the control switch cut-off pressure. Provide compressor capacity suitable for not more than a [33][50] percent run time, at full system control load. Compressors must have a combination type magnetic starter with undervoltage protection and thermal-overload protection for each phase and must automatically restart after a power outage. Motors 0.5 hp and larger must be three-phase.[

A second (duplex arrangement) compressor of capacity equal to the primary compressor must be provided, with interlocked control to provide automatic changeover upon malfunction or failure of either compressor. A manual selector switch must be provided to index the lead compressor including the automatic changeover.]

2.12.2   Compressed Air Station Specialties

2.12.2.1   Refrigerated Air Dryers

Provide each air compressor tank with a refrigerant air dryer sized for continuous operation at full delivery capacity of the compressor. The air must be dried at a pressure of not less than 483 kPa 70 psi to a temperature not greater than 2 degrees C 35 degrees F and an ambient air temperature between 13 and 35 degrees C 55 and 95 degrees F. The dryer must be provided with an automatic condensate drain trap with manual override feature with an adjustable cycle and drain time. Locate each dryer in the air piping between the tank and the pressure-reducing station. The refrigerant used in the dryer must be one of the fluorocarbon gases and have an Ozone Depletion Potential of not more than 0.05. A five micron pre-filter and coalescing-type 0.03 µm micron oil removal filter with shut-off valves must be provided in the dryer discharge.

2.12.2.2   Compressed Air Discharge Filters

Provide a disposable type in-line filter in the incoming pneumatic main at each pneumatic control panel. The filter must be capable of eliminating 99.99 percent of all liquid or solid contaminants 0.1 micron or larger. Provide the filter with fittings that allow easy removal/replacement. Each filter bowl must be rated for 1034 kPa 150 psi maximum working pressure. A pressure regulator, with high side and low side pressure gauges, and a safety valve must be provided downstream of the filter.

2.12.2.3 Air Pressure-Reducing Stations

Provide air compressors with a pressure-reducing valve (PRV) with a field adjustable range of 0 to 345 kPa 0 to 50 psig discharge pressure, at an inlet pressure of 482 to 620 kPa 70 to 90 psig. Provide a factory-set pressure relief valve downstream of the PRV to relieve over-pressure. Provide a pressure gage upstream of the PRV with range of 0 to 689 kPa 0 to 100 psig and downstream of the PRV with range of 0 to 207 kPa 0 to 30 psig. For two-pressure control systems, provide an additional PRV and downstream pressure gage. Pressure regulators of the relieving type must not be used.

2.12.2.4 Flexible Pipe Connections

The flexible pipe connections must be designed for 1034 kPa and 120 degrees C 150 psi and 250 degrees F service, and must be constructed of rubber or tetrafluoroethylene resin tubing with a reinforcing protective cover of braided corrosion-resistant steel, bronze, monel, or galvanized steel. The connectors must be suitable for the service intended and must have threaded or soldered ends. The length of the connectors must be as recommended by the manufacturer for the service intended.

2.12.2.5 Vibration Isolation Units

The vibration isolation units must be standard products with published loading ratings, and must be single rubber-in-shear, double rubber-in-shear, or spring type.

2.12.3 Compressed Air Tanks

The air storage tank must be fabricated for a working pressure of not less than 1380 kPa 200 psi and constructed and certified in accordance with ASME BPVC SEC VIII D1. The tank must be of sufficient volume so that no more than six compressor starts per hour are required with the starting pressure switch differential set at 140 kPa 20 psi. The tank must be provided with an automatic condensate drain trap with manual override feature. Provide drain valve and piping routing the drainage to a floor sink or other safe and visible drainage location.

]PART 3 EXECUTION

3.1 INSTALLATION

3.1.1 General Installation Requirements

Perform the installation under the supervision of competent technicians regularly employed in the installation of DDC systems.

3.1.1.1 Device Mounting Criteria

All devices must be installed in accordance with manufacturer's recommendations and as specified and indicated. Control devices to be installed in piping and ductwork must be provided with required gaskets, flanges, thermal compounds, insulation, piping, fittings, and manual valves for shutoff, equalization, purging, and calibration. Strap-on temperature sensing elements must not be used except as specified. Spare thermowells must be installed adjacent to each thermowell containing a sensor and as indicated. Devices located outdoors must have a weathershield.

3.1.1.2   Labels and Tags

Match labels and tags to the unique identifiers indicated on the As-Built drawings. Label all enclosures and instrumentation. Tag all sensors and actuators in mechanical rooms. Tag airflow measurement arrays to show flow rate range for signal output range, duct size, and pitot tube AFMA flow coefficient. Tag duct static pressure taps at the location of the pressure tap. Provide plastic or metal tags, mechanically attached directly to each device or attached by a metal chain or wire. Labels exterior to protective enclosures must be engraved plastic and mechanically attached to the enclosure or instrumentation. Labels inside protective enclosures may attached using adhesive, but must not be hand written.

3.1.2   Weathershield

Provide weathershields for sensors located outdoors. Install weathershields such that they prevent the sun from directly striking the sensor and prevent rain from directly striking or dripping onto the sensor. Install weather shields with adequate ventilation so that the sensing element responds to the ambient conditions of the surroundings. When installing weathershields near outside air intake ducts, install them such that normal outside air flow does not cause rainwater to strike the sensor.

3.1.3   Room Instrument Mounting

****

NOTE: All facilities are required to follow ADA standards unless the building is for able-bodied military personnel with no handicapped visitors. Buildings must be constructed to ADA standards. For more information, please refer to the following website.
http://www.ada.gov/regs2010/2010ADAStandards/2010ADAstandards.htm#pgfId-1008

****

Mount room instruments, including but not limited to wall mounted non-adjustable space sensor modules and sensors located in occupied spaces, [1.5][1.2] meters [60][48] inches above the floor unless otherwise indicated. Install adjustable devices to be ADA compliant unless otherwise indicated on the Room Sensor Schedule:

a. Space Sensor Modules for Fan Coil Units may be either unit or wall mounted but not mounted on an exterior wall.

b. Wall mount all other Space Sensor Modules.

3.1.4   Indication Devices Installed in Piping and Liquid Systems

****

NOTE: Coordinate with the project site for preference on the use of programmable controllers or multiple application specific controllers in cases where a single application specific controller for the application is not available.

****

Provide snubbers for gauges in piping systems subject to pulsation. For gauges for steam service use pigtail fittings with cock. Install thermometers and temperature sensing elements in liquid systems in thermowells. Provide spare Pressure/Temperature Ports (Pete's Plug) for all temperature and pressure sensing elements installed in liquid systems for calibration/testing.

3.1.5 Occupancy Sensors

****

NOTE: Choose the preferred location and type of for Occupancy Sensors (coordinate with the project site to determine preference of O&M Staff).

****

Provide a sufficient quantity of occupancy sensors to provide complete coverage of the area (room or space). Occupancy sensors are to be ceiling mounted. Install occupancy sensors in accordance with NFPA 70 requirements and the manufacturer's instructions. Do not locate occupancy sensors within 2 m 6 feet of HVAC outlets or heating ducts, or where they can "see" beyond any doorway. Installation above doorway(s) is preferred. Do not use ultrasonic sensors in spaces containing ceiling fans. Install sensors to detect motion to within 600 mm 2 feet of all room entrances and to not trigger due to motion outside the room. Set the off-delay timer to [15][_____] minutes unless otherwise indicated. Adjust sensors prior to beneficial occupancy, but after installation of furniture systems, shelving, partitions, etc. For each controlled area, provide one hundred percent coverage capable of detecting small hand-motion movements, accommodating all occupancy habits of single or multiple occupants at any location within the controlled room.

3.1.6 Switches

****

NOTE: Wall mounted thermostats and similar control system components containing user input devices in ADA compliant facilities and spaces are required to be mounted 1200 mm 48 inches above the floor for forward reach and 1300 mm54 inches for side reach. Note the mounting height and location for these system components on the drawings or revise the following paragraph accordingly.

****

3.1.6.1 Temperature Limit Switch

Provide a temperature limit switch (freezestat) to sense the temperature at the location indicated. Provide a sufficient number of temperature limit switches (freezestats) to provide complete coverage of the duct section but no less than 3 m 1 foot in length per square meter square foot of cross sectional area. Install manual reset limit switches in approved, accessible locations where they can be reset easily. Install temperature limit switch (freezestat) sensing elements in a side-to-side (not top-to-bottom) serpentine pattern with the relay section at the highest point and in accordance with the manufacturer's installation instructions.

3.1.6.2 Hand-Off Auto Switches

Wire safety controls such as smoke detectors and freeze protection thermostats to protect the equipment during both hand and auto operation.

3.1.7 Temperature Sensors

Install temperature sensors in locations that are accessible and provide a good representation of sensed media. Installations in dead spaces are not acceptable. Calibrate and install sensors according to manufacturer’s instructions. Select sensors only for intended application as designated or recommended by manufacturer.

3.1.7.1 Room Temperature Sensors

Mount the sensors on interior walls to sense the average room temperature at the locations indicated. Avoid locations near heat sources such as copy machines or locations by supply air outlet drafts. Mount the center of all user-adjustable sensors [1.5 m 5 feet above the finished floor][1220 mm 48 inches above the floor to meet ADA requirements][at the height[s] indicated]. Non user-adjustable sensors can be mounted as indicated in paragraph ROOM INSTRUMENT MOUNTING.

3.1.7.2 Duct Temperature Sensors

3.1.7.2.1 Probe Type

Place tip of the sensor in the middle of the airstream or in accordance with manufacturer's recommendations or instructions.Provide a gasket between the sensor housing and the duct wall. Seal the duct penetration air tight. When installed in insulated duct, provide enclosure or stand off fitting to accommodate the thickness of duct insulation to allow for maintenance or replacement of the sensor and wiring terminations. Seal the duct insulation penetration vapor tight.

3.1.7.2.2 Averaging Type

Weave the sensing element in a serpentine fashion from side to side perpendicular to the flow, across the duct or air handler cross-section, using durable non-metal supports in accordance with manufacturer's installation instructions. Avoid tight radius bends or kinking of the sensing element. Prevent contact between the sensing element and the duct or air handler internals. Provide a duct access door at the sensor location. The access door must be hinged on the side, factory insulated, have cam type locks, and be as large as the duct will permit, maximum 18 by 18 inches. For sensors inside air handlers, the sensors must be fully accessible through the air handler's access doors without removing any of the air handler's internals.

3.1.7.3 Immersion Temperature Sensors

Provide thermowells for sensors measuring piping, tank, or pressure vessel temperatures. Locate wells to sense continuous flow conditions. Do not install wells using extension couplings. When installed on insulated piping, provide stand enclosure or stand off fitting to accommodate the thickness of the pipe insulation and allow for maintenance or replacement of the sensor or wiring terminations. Where piping diameters are smaller than the length of the wells, provide wells in piping at elbows to sense flow across entire area of well. Wells must not restrict flow area to less than 70 percent of pipe area. Increase piping size as required to avoid restriction. Provide the sensor well with a heat-sensitive transfer agent between the sensor and the well interior ensuring contact between the sensor and the well.

3.1.7.4   Outside Air Temperature Sensors

Provide outside air temperature sensors on the building's north side with a protective weather shade that does not inhibit free air flow across the sensing element, and protects the sensor from snow, ice, and rain. Location must not be near exhaust hoods and other areas such that it is not influenced by radiation or convection sources which may affect the reading. Provide a shield to shade the sensor from direct sunlight.

3.1.8   Air Flow Measurement Arrays (AFMA)

Locate Outside Air AFMAs downstream from the Outside Air filters.

Install AFMAs with the manufacturer's recommended minimum distances between upstream and downstream disturbances. Airflow straighteners may be used to reduce minimum distances as recommended by the AFMA manufacturer.

3.1.9   Duct Static Pressure Sensors

****
NOTE: Recommend that the designer of record determine the preferred location. It is desirable to have more than one terminal device downstream of the sensor to prevent a single device from having too much authority over the control loop.
****

Locate the duct static pressure sensing tap at 75 percent of the distance between the first and last air terminal units [as indicated on the design documents]. If the transmitter output is a 0-10Vdc signal, locate the transmitter in the same enclosure as the air handling unit (AHU) controller for the AHU serving the terminal units. If a remote duct static pressure sensor is to be used, run the signal wire back to the controller for the air handling unit.

3.1.10   Relative Humidity Sensors

Install relative humidity sensors in supply air ducts at least 3 m 10 feet downstream of humidity injection elements.

3.1.11   Meters

3.1.11.1   Flowmeters

Install flowmeters to ensure minimum straight unobstructed piping for at least 10 pipe diameters upstream and at least 5 pipe diameters downstream of the flowmeter, and in accordance with the manufacturer's installation instructions.

3.1.11.2   Energy Meters

Locate energy meters as indicated. Connect each meter output to the DDC system, to measure both instantaneous demand/energy and other variables as indicated.

3.1.12 Dampers

3.1.12.1 Damper Actuators

Provide spring return actuators which fail to a position that protects the served equipment and space on all control dampers related to freeze protection or force protection. For all outside, makeup and relief dampers provide dampers which fail closed. Terminal fan coil units, terminal VAV units, convectors, and unit heaters nay be non-spring return unless indicated otherwise. Do not mount actuators in the air stream. Do not connect multiple actuators to a common drive shaft. Install actuators so that their action seal the damper to the extent required to maintain leakage at or below the specified rate and so that they move the blades smoothly throughout the full range of motion.

3.1.12.2 Damper Installation

Install dampers straight and true, level in all planes, and square in all dimensions. Dampers must move freely without undue stress due to twisting, racking (parallelogramming), bowing, or other installation error. External linkages must operate smoothly over the entire range of motion, without deformation or slipping of any connecting rods, joints or brackets that will prevent a return to it's normal position. Blades must close completely and leakage must not exceed that specified at the rated static pressure. Provide structural support for multi-section dampers. Acceptable methods of structural support include but are not limited to U-channel, angle iron, corner angles and bolts, bent galvanized steel stiffeners, sleeve attachments, braces, and building structure. Where multi-section dampers are installed in ducts or sleeves, they must not sag due to lack of support. Do not use jackshafts to link more than three damper sections. Do not use blade to blade linkages. Install outside and return air dampers such that their blades direct their respective air streams towards each other to provide for maximum mixing of air streams.

3.1.13 Valves

****

NOTE: Three-way valve port markings vary from one manufacturer to another. Before installing a three-way valve, note the inlets and outlets, note which port is normally open, which is normally closed, and which is the common port. On butterfly valves, limit the valve travel to 70 percent (60 degrees) open position to achieve design flow.

****

Install the valves in accordance with the manufacturer's instructions.

3.1.13.1 Valve Actuators

Provide spring return actuators on all control valves where freeze protection is required. Spring return actuators for terminal fan coil units, terminal VAV units, convectors, and unit heaters are not required unless indicated otherwise.

3.1.14 Thermometers and Gauges

[3.1.14.1 Local Gauges for Actuators

****
NOTE: Remove this bracketed paragraph if pneumatic devices are not required.
****

Provide a pressure gauge at each pneumatic control input and output. Pneumatic actuators must have an accessible and visible pressure gauge installed in the tubing lines at the actuator as indicated.

]3.1.14.2 Thermometers

Mount devices to allow reading while standing on the floor or ground, as applicable.

3.1.15 Wire and Cable

****
NOTE: Coordinate with the project site and indicate whether all wiring needs to be in raceways or whether low-voltage wiring can be run without raceways.

Note that requiring all wiring to be run in raceways will increase the project cost.
****

Provide complete electrical wiring for the Control System, including wiring to transformer primaries. Wire and Cable must be installed without splices between control devices and in accordance with NFPA 70 and NFPA 90A. Instrumentation grounding must be installed per the device manufacturer's instructions and as necessary to prevent ground loops, noise, and surges from adversely affecting operation of the system. Test installed ground rods as specified in IEEE 142. Cables and conductor wires must be tagged at both ends, with the identifier indicated on the shop drawings. Electrical work must be as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM and as indicated. Wiring external to enclosures must be run in raceways[, except low-voltage control and low-voltage network wiring may be installed as follows:

a. plenum rated cable in suspended ceilings over occupied spaces may be run without raceways

b. nonmetallic-sheathed cables or metallic-armored cables may be installed as permitted by NFPA 70.]

Install control circuit wiring not in raceways in a neat and safe manner. Wiring must not use the suspended ceiling system (including tiles, frames or hangers) for support. Where conduit or raceways are required, control circuit wiring must not run in the same conduit/raceway as power wiring over 50 volts. Run all circuits over 50 volts in conduit, metallic tubing, covered metal raceways, or armored cable.

3.1.16 Copper Tubing

Provide hard-drawn copper tubing in exposed areas and either hard-drawn or annealed copper tubing in concealed areas. Use only tool-made bends. Use only brass or copper solder joint type fittings, except for connections to apparatus. For connections to apparatus use brass compression type fittings.

3.1.17   Plastic Tubing

Install plastic tubing within covered raceways or conduit except when otherwise specified. Do not use plastic tubing for applications where the tubing could be subjected to a temperature exceeding 55 degrees C 130 degrees F. For fittings, use brass or acetal resin of the compression or barbed push-on type for instrument service. Except in walls and exposed locations, plastic multitube instrument tubing bundle without conduit or raceway protection may be used where a number of air lines run to the same points, provided the multitube bundle is enclosed in a protective sheath, is run parallel to the building lines and is adequately supported as specified.

[3.1.18   Pneumatic Lines

****
NOTE: Remove this bracketed paragraph if pneumatic devices are not required.
****

Run tubing concealed in finished areas, run tubing exposed in unfinished areas like mechanical rooms. For tubing enclosed in concrete, provide rigid metal conduit. Run tubing parallel and perpendicular to building walls. Use1.5 m 5 foot maximum spacing between tubing supports. With the compressor turned off, test each tubing system pneumatically at 1.5 times the working pressure and prove it air tight, locating and correcting leaks as applicable. Caulking joints is not permitted. Do not run tubing and electrical power conductors in the same conduit.

a. Install pneumatic lines must such that they are not exposed to outside air temperatures. Conceal pneumatic lines except in mechanical rooms and other areas where other tubing and piping is exposed.

b. Install all tubes and tube bundles exposed to view in lines parallel to the lines of the building. Route tubing in mechanical/electrical so that the lines are easily traceable.

c. Purge air lines of dirt, impurities and moisture before connecting to the control equipment. Number-code or color-code air lines and key the coding in the As-Built Drawings for future identification and servicing the control system.

3.1.18.1   Pneumatic Lines In Mechanical/Electrical Spaces

In mechanical/electrical spaces, use plastic or copper tubing for pneumatic lines. Install horizontal and vertical runs of plastic tubing or soft copper tubing min raceways or rigid conduit dedicated to tubing. Support dedicated raceways, conduit, and hard copper tubing not installed in raceways every 2 m 6 feet for horizontal runs and every 2.4 m 8 feet for vertical runs.

3.1.18.2   Pneumatic Lines External to Mechanical/Electrical Spaces

External to mechanical/electrical spaces, use plastic tubing in raceways not containing power wiring or copper tubing with sweat fittings. Support raceways and tubing not in raceways every 2.4 m 8 feet. For pneumatic lines concealed in walls use hard-drawn copper tubing or plastic tubing in rigid conduit. Plastic tubing in a protective sheath, run parallel to the building lines and supported as specified, may be used above accessible ceilings and in other concealed but accessible locations.

3.1.18.3 Terminal Single Lines

For terminal single lines use hard-drawn copper tubing, except when the run is less than 300 mm 12 inches in length, flexible polyethylene may be used.

3.1.18.4 Connection to Liquid and Steam Lines

Use [copper][Series 300 stainless steel] with [brass compression][stainless-steel compression] fittings for connection of sensing elements and transmitters to liquid and steam lines.

3.1.18.5 Connection to Ductwork

Use plastic tubing for connections to sensing elements in ductwork.

3.1.18.6 Tubing in Concrete

Install tubing in concrete in rigid conduit. Install tubing in walls containing insulation, fill, or other packing materials in raceways dedicated to tubing.

3.1.18.7 Tubing Connection to Actuators

For final connections to actuators use plastic tubing no more than 300 mm 12 inches long and unsupported at the actuator.

]3.1.19 Compressed Air Stations

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NOTE: If possible, foundations and housekeeping pads should be specified in Section 23 30 00 HVAC AIR DISTRIBUTION.

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Mount the air compressor assembly on vibration eliminators, in accordance with ASME BPVC SEC VIII D1 for tank clearance. Connect the air line to the tank with a flexible pipe connector. Provide compressed air station specialties with required tubing, including condensate tubing to a floor drain. Compressed air stations must deliver control air meeting the requirements of ISA 7.0.01. Provide foundations and housekeeping pads for the HVAC control system air compressors [in accordance with the air compressor manufacturer's instructions][as specified in Section 23 30 00 HVAC AIR DISTRIBUTION].

-- End of Section --