UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2021
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DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING (HVAC)

SECTION 23 09 53.00 20

SPACE TEMPERATURE CONTROL SYSTEMS

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USACE / NAVFAC / AFCEC / NASA	**UFGS-23 09 53.00 20 (February 2010)** **Change 2 - 08/17**
Preparing Activity: NAVFAC	**Superseding** **UFGS-23 09 53.00 20 (April 2006)**

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SECTION 23 09 53.00 20

SPACE TEMPERATURE CONTROL SYSTEMS
02/10, CHG 2: 08/17

****
NOTE: This guide specification covers the requirements for space temperature control systems of the electric, analog electronic, and pneumatic type for heating, ventilating, and cooling system.

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).
****

****
NOTE: If there are questions concerning system design, The Engineering Field Division, Naval Facilities Engineering Command, Mechanical Engineering and Design Branch, and Electrical Engineering and Design Branch should be consulted.
****

****
NOTE: The following information shall be shown on the project drawings:

1. Complete HVAC mechanical flow diagram depicting individual HVAC components being controlled. Relative position of sensors and actuators, including dampers, valves, thermostats, and wall mounted switches.

2. Complete ATC schematics including flow diagrams, connection diagrams, wiring interlock diagrams, setpoints, and sequences of operation. Indicate control and operating ranges to clarify control sequences. Indicate manual-off-auto local controls on the locally mounted motor starters and in control panel(s) for remote motor starters; wire all safety controls to protect during both local manual and auto operation. Indicate electric elementary diagrams of motor starters, control device actuators, and control sensors.

3. Location and types of automatic dampers, including smoke dampers, e.g., opposed or parallel blade.

4. Control valve nominal sizes, flow capacities, inlet pressures, controlled fluid, maximum and minimum pressure drops at the designed flow, and calculated Cv. Select valves for smallest Cv within available pressure constraints, pipe velocities, economy of design, and noise criteria.

5. Required controller parameters:

a. Throttling range, setpoint, and controller action, direct or reverse.

b. Differential for two-position controllers.

c. Specify the dead-band range for heating and cooling applications and the cascade control range or remote setpoint adjustment.

6. Special controller parameters:

a. Fixed setpoint and fixed differential controllers.

b. Adjustable damping and damping rate.

c. Proportional-integral-derivative mode constant settings.

7. Scale the range of temperature and pressure indicators. Location of temperature wells and pressure taps.

8. Initial time switch settings for each zone.

9. Smoke detection systems and location of key-operated override switches, when required, along with the zoning arrangements for these systems.

10. Define which indicators and gages are mounted on the panel face and which are located inside the panel. Provide a complete layout of the panel faces

where a unique arrangement is necessary for efficient operation.

11. Location of room sensors and outdoor sensors.

12. Location of pneumatic compressors and refrigerated air dryers when required.

13. Write sequence of operation to include conventional control operations (e.g., temperature and pressure control loops), time clock operations, energy management functions (e.g., night setback and reset schedules), pushbutton overrides, safety devices, and emergency conditions.

****

PART 1 GENERAL

1.1 REFERENCES

****

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.

****

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

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

ASHRAE FUN IP	(2017) Fundamentals Handbook, I-P Edition
ASHRAE FUN SI	(2017) Fundamentals Handbook, SI Edition

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B16.1	(2020) Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250
ASME B16.5	(2017) Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B16.15	(2018) Cast Copper Alloy Threaded Fittings Classes 125 and 250
ASME B16.18	(2018) Cast Copper Alloy Solder Joint Pressure Fittings
ASME B16.22	(2018) Standard for Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
ASME B16.26	(2018) Standard for Cast Copper Alloy Fittings for Flared Copper Tubes
ASME B16.34	(2017) Valves - Flanged, Threaded and Welding End
ASME B31.1	(2020) Power Piping
ASME B31.5	(2020) Refrigeration Piping and Heat Transfer Components
ASME B40.100	(2013) Pressure Gauges and Gauge Attachments
ASME BPVC	(2010) Boiler and Pressure Vessels Code

ASTM INTERNATIONAL (ASTM)

ASTM A126	(2004; R 2019) Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings
ASTM B32	(2020) Standard Specification for Solder Metal
ASTM B75/B75M	(2020) Standard Specification for Seamless Copper Tube
ASTM B88	(2020) Standard Specification for Seamless Copper Water Tube
ASTM B88M	(2020) Standard Specification for Seamless Copper Water Tube (Metric)
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

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2018) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA ST 1	(1988; R 1994; R 1997) Specialty Transformers (Except General Purpose Type)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2020; ERTA 20-1 2020; ERTA 20-2 2020; TIA 20-1; TIA 20-2; TIA 20-3; TIA 20-4) National Electrical Code
NFPA 90A	(2021) Standard for the Installation of Air Conditioning and Ventilating Systems

SHEET METAL AND AIR CONDITIONING CONTRACTORS' NATIONAL ASSOCIATION (SMACNA)

SMACNA 1780	(2002) HVAC Systems - Testing, Adjusting and Balancing, 3rd Edition
SMACNA 1966	(2005) HVAC Duct Construction Standards Metal and Flexible, 3rd Edition

U.S. FEDERAL COMMUNICATIONS COMMISSION (FCC)

FCC Part 15	Radio Frequency Devices (47 CFR 15)

UNDERWRITERS LABORATORIES (UL)

UL 508	(2018) UL Standard for Safety Industrial Control Equipment
UL 555S	(2014; Reprint Oct 2020) UL Standard for Safety Smoke Dampers
UL 916	(2015) Standard for Energy Management Equipment

1.2 SUBCONTRACTOR SPECIAL REQUIREMENTS

Perform all work in this section in accordance with the paragraph SUBCONTRACTOR SPECIAL REQUIREMENTS in Section 01 30 00 ADMINISTRATIVE REQUIREMENTS. The paragraph specifies that all contract requirements of this section shall be accomplished directly by a first tier subcontractor. No work required shall be accomplished by a second tier subcontractor.

1.3 SYSTEM DESCRIPTION

Provide [new and modify existing] space temperature control systems complete and ready for operation.

1.4 SYSTEM REQUIREMENTS

****
NOTE: Indicate which control systems or control devices must be of a particular type for reasons of safety, control accuracy, or other technical reasons.
****

Provide control systems composed of any combination of electric, analog electronic or pneumatic devices. Indicated control system devices of a particular type do not intend a requirement for the device unless the requirement is specifically indicated. Requirements apply to field installed control systems.

****
NOTE: Regarding the text below, indicate the manufacturer's name when there is an existing control system.
****

[Existing control system was manufactured by [_____]. Provide new equipment compatible with the existing control system to the extent that the direct interface uses the same control signal type and level over the same calibrated range as the existing equipment.
]

****
NOTE: Regarding the text below, indicate portions of existing systems that are to be reused.
****

[Inspect and test reused portions of existing control systems, and furnish a report to the Government identifying all inoperative components or system deficiencies. The report shall include a cost estimate to correct deficiencies, scheduled need dates for equipment shutdown for repairs and connection to existing controls and systems. Proceed with repairs only after receipt of Government approval. Diagnose and report any malfunctions of existing control system device that occurs after the work commences. The Government is responsible for maintenance and repair of Government equipment. The Contractor shall be held responsible for repair costs due to Contractor negligence or abuse of Government equipment.

]1.5 CENTRALIZED DIRECT DIGITAL CONTROL (DDC) SYSTEMS

****
NOTE: If DDC is being used, use Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC in lieu of this section.
****

DDC systems are not permitted. Microprocessor-based single-loop controllers, unitary control system, variable-air-volume (VAV) boxes, and room thermostats may be used provided that the devices are manually configurable by the use of device firmware and require no software written

by the Contractor for their application and use.

1.6 PERFORMANCE REQUIREMENTS

Provide control systems to maintain the required heating, ventilating, and cooling (HVAC) conditions by performing the functions and sequences of operations indicated. Control systems shall be complete, including all equipment and appurtenances, and ready for operation. Control systems shall be furnished, installed, tested, calibrated, and started up by, or under the supervision of trained technicians certified by the Contractor as qualified and regularly employed in such work. Control system equipment, valves, panels and dampers shall bear the manufacturer's nameplate.

1.7 DESIGN REQUIREMENTS

1.7.1 Control System Diagrams

For each system, indicate HVAC process flow and location of devices relative to flow and to the HVAC control panel, the connections of control devices in control loops, references of control device contacts and device operating coils to line numbers of a ladder diagram and sequencing diagrams showing the operation of valves, dampers, and contacts relative to controller output, and HVAC process variables.

1.7.2 Ladder Diagram

Indicate connections and interlocks to control system devices and other devices such as starters, drives, HVAC control system panels, and HVAC equipment panels. Diagram shall be coordinated by line number and device number with each control system diagram.

1.7.3 Operating Parameters

Indicate operating parameters for devices shown on the control system diagram such as setpoints, ranges, limits, differentials, outside air temperature schedules, contact operating points, and HVAC equipment operating time schedules.

1.7.4 Automatic Control Valve Schedules

Indicate valve size, Cv, flow rate, pressure drop, top size, spring range, positioner range, operating signal characteristics, and power source.

1.7.5 Damper Schedules

Indicate damper sizes, quantities and sizes of actuators, spring ranges, positioner ranges, operating signal characteristics, and power source.

1.7.6 Wiring Diagram

Indicate terminal blocks, wire marker identification, connections to control system devices, external and internal power sources, and connections to external devices, starters, drives, control panels, jumpers, and ground connections.

1.7.7 Compressed Air Station Schematic

Indicate compressors, motors and horsepower rating, voltage, starter,

isolators, manual bypasses, tubing sizes, drain piping and drain traps, reducing valves, dryer, manufacturers' names and model numbers, mounting, access, and clearance requirements. Also include control panel schematics for pneumatic control.

1.7.8 Sequence of Operation

Sequence of operation for each HVAC control system coordinated with device identifiers on control system diagram and ladder diagram.

1.7.9 Arrangement Drawing

Arrangement diagram of each HVAC control system panel coordinated with device identifiers on the control system diagram and the ladder diagram.

1.8 SUBMITTALS

****

NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force, and NASA projects, or choose the second bracketed item for Army projects.

****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that

will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Control System Diagrams for each HVAC system; G[, [_____]]

Ladder Diagram; G[, [_____]]

Operating Parameters; G[, [_____]]

Automatic Control Valve Schedules; G[, [_____]]

Damper Schedules; G[, [_____]]

Sequence of Operation; G[, [_____]]

Arrangement Drawing; G[, [_____]]

Wiring Diagram; G[, [_____]]

Compressed Air Station Schematic; G[, [_____]]

Control Panel Schematics for pneumatic control; G[, [_____]]

SD-03 Product Data

Actuators; G[, [_____]]

Valves; G[, [_____]]

Dampers; G[, [_____]]

Fire Protection Devices; G[, [_____]]

Sensors; G[, [_____]]

Thermostats; G[, [_____]]

Sunshields; G[, [_____]]

Pressure Switches; G[, [_____]]

Indicating Devices; G[, [_____]]

Controllers; G[, [_____]]

Pressure Gages; G[, [_____]]

Control Panels; G[, [_____]]

Air Compressor; G[, [_____]]

Refrigerated Air Dryer; G[, [_____]]

Air Filtration System; G[, [_____]]

Compressed Air Station Specialties; G[, [_____]]

VAV Terminal Unit Controls; G[, [_____]]

SD-06 Test Reports

Commissioning Procedures; G[, [_____]]

Calibration Adjustment And Commissioning Reports; G[, [_____]]

Site Testing Procedures Identifying Each Item Tested and Describing Each Test; G[, [_____]]

Performance Verification Test plans and procedures; G[, [_____]]

SD-07 Certificates

Certification of Completion; G[, [_____]]

SD-08 Manufacturer's Instructions

Training Course Documentation; G[, [_____]]

SD-10 Operation and Maintenance Data

Space Temperature Control System, Data Package 3; G[, [_____]]

Submit in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

SD-11 Closeout Submittals

Qualified Service Organization List; G[, [_____]]

1.9 QUALITY ASSURANCE

1.9.1 Standard Products

a. Material and equipment shall be standard products of manufacturers regularly engaged in the manufacturing of such products, using similar materials, design and workmanship. The standard products shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year use shall include applications of similarly sized equipment and materials used under similar circumstances.

   The 2 years experience must be satisfactorily completed by a product which has been sold or is offered for sale on the commercial market through advertisements, manufacturers' catalogs, or brochures. Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation, for not less than 6000 hours exclusive of the manufacturer's factory tests, can be shown.

b. The equipment items shall be supported by a service organization.

1.9.2 Nameplates and Tags

a. Provide nameplates bearing legends as shown and tags bearing device unique identifiers as shown shall have engraved or stamped characters. Nameplates shall be mechanically attached to HVAC

control panel doors.

b. A plastic or metal tag shall be mechanically attached directly to each field-mounted device or attached by a metal chain or wire.

c. Each airflow measurement station shall have a tag showing flow rate range for signal output range, duct size, and device identifier where shown.

1.9.3 Verification of Dimensions

Contractor shall become familiar with details of work, shall verify dimensions in the field, and shall advise Contracting Officer of any discrepancy before performing work.

1.9.4 Modification of References

Accomplish work in accordance with ASME B31.1, ASME B31.5, NFPA 70, and NFPA 90A, except as modified herein or indicated otherwise for equipment, materials, installation, examination, inspection, and testing. Consider the advisory or recommended provisions to be mandatory, as though the word "shall" had be substituted for the words "should" or "could" or "may," wherever they appear. Interpret reference to "authority having jurisdiction" and "owner" to mean the Contracting Officer.

1.9.5 Site Testing Procedures

Indicate test equipment to be used including manufacturers' names and model numbers, date of last calibration, and accuracy of calibration.

1.9.6 Commissioning Procedures

Define procedures specific to each control system including instructions on how to set control parameters and setpoints, proportional, integral and derivative mode constants, contact output settings, positioner range adjustments, and calibration checks of transmitters

1.9.7 Calibration Adjustment and Commissioning Reports

Submit specific to each HVAC control system, including settings adjustments and results of calibration checks

1.9.8 Space Temperature Control System

In addition to the requirements specified in the paragraph SUBMITTALS, meet the following requirements. Submit Operation and Maintenance Manuals for items of equipment listed under paragraph PRODUCT DATA. Manual shall contain full hardware support documentation, which shall include but not be limited to the following:

a. General description and specifications

b. Installation and initial checkout procedures

c. Detailed electrical and logical description

d. Troubleshooting procedures, diagrams, and guidelines

e. Alignment and calibration procedures for components

f. Preventive maintenance requirements and a maintenance checklist

g. Detailed schematics and assembly drawings

h. Spare parts list data, including required tool kits and suggested method of repairs such as field repair, factory repair, or item replacement

i. Signal identification and timing diagrams

j. Complete as-built control drawings, schedules, and sequence of operation

k. Controller configuration and parameter setting procedures

l. Step-by-step procedures required for each HVAC control systems startup, operation, shutdown, recovery, and fault diagnosis

m. Manufacturer supplied operator manuals for equipment

n. Qualified service organization list

PART 2 PRODUCTS

****

NOTE: In order to comply with UFC 1-200-02, designs must achieve energy consumption levels that are at least 30 percent below the baseline established in the 2010 publication of ASHRAE 90.1. The Designer of Record must design control systems that assist in achieving this requirement.

****

2.1 COMPONENTS

****

NOTE: Indicate control devices that must be in enclosures with more stringent requirements than that covered by NEMA 250 Type 1 and state the requirements.

****

Provide components factory ordered for this project. Rebuilt equipment, warehoused equipment, or earlier generation equipment shall not be acceptable. Electrical, electronic, and electropneumatic devices not located within control panels shall have a NEMA 250 Type 1 enclosure in accordance with NEMA 250 unless otherwise specified. Actuators and positive positioners, and transmitters shall operate within temperature limit ratings of plus 2 to 66 degrees C 35 to 150 degrees F. Panel mounted instruments shall operate within limit ratings of 2 to 49 degrees C 35 to 120 degrees F and 10 percent to 95 percent relative humidity, noncondensing. Devices installed outdoors shall operate within limit ratings of minus 2 to 66 degrees C 35 to 150 degrees F.

2.2 ACTUATORS

Provide pneumatic, electric, or electronic actuators. Actuators shall function as required within 85 to 110 percent of their power supply

rating. Actuators shall fail to their spring return positions on signal or power failure unless indicated as timed, power return actuators. Actuators shall have visible position indicators. Where actuators do not have positive spring returns for fail-safe operation, provide capacity tanks, restrictors, check valves, and relays, or reserve power as required to achieve proper timed positioning for up to 4 minutes after primary power failure. Actuators shall open or close the devices to which they are applied within 60 seconds after a full scale signal input change. Pneumatic actuators shall be rated for 172 kPa (gage) 25 psig operating pressure except for high pressure cylinder type actuators.

2.2.1 Damper Actuators

Damper actuators shall be rated for at least 125 percent of the motive power necessary to operate the connected damper. The actuator stroke shall be limited by an adjustable stop in the direction of the return stroke. Actuators shall be provided with mounting and connecting hardware.

2.2.2 Valve Actuators

Valve actuators shall be rated for at least 125 percent of the motive power necessary to operate the valves over their full range of operation against the total and differential pressures.

2.2.3 Positive Positioners

Positive positioners shall be pneumatic relays with mechanical feedback mechanisms, adjustable operating ranges, and starting points.

2.3 AUTOMATIC CONTROL VALVES

Provide automatic control valves.

****

NOTE: Avoid selection of oversized control valves. Select valve Cv so that maximum pressure drops are used within constraints of available pressures, pipe velocities, economy of design, and noise criteria. Select steam valves using critical pressure drop (.45 of absolute pressure) where available, and select connected equipment using resultant pressure on downstream side of valve. List calculated Cv and flow rate in schedules (not manufacturer's listed Cv) to allow bidders to personally select valves.

****

2.3.1 Valve Assembly

Valves shall have stainless steel stems and stuffing boxes with extended necks to clear the piping insulation. Valve bodies shall be designed for not less than 862 kPa (gage) 125 psig working pressure or 150 percent of the system operating pressure, whichever is greater. Maximum rated shutoff pressure of the valve shall exceed the rated deadhead pressure of the pump that supplies it. Valve leakage rating shall be 0.01 percent of rated Cv for soft-seated valves and 0.05 percent for metal-to-metal seated valves. Class 125 copper alloy valve bodies and Class 150 steel or stainless steel valves shall conform to ASME B16.5 as a minimum. Components of cast iron valves shall conform to ASTM A126 Class B or C as

a minimum.

2.3.2 Butterfly Valve Assembly

Butterfly valves shall be threaded lug type suitable for dead-end service, and for modulation to the fully closed position, with carbon steel bodies or cast iron Class 125 and noncorrosive discs, stainless steel shafts supported by bearings, and EPDM seats suitable for temperatures from minus 29 degrees to plus 121 degrees C.20 degrees to plus 250 degrees F. Valves shall have a manual means of operation independent of the actuator.

2.3.3 Two-Way Valves

Two-way modulating valves shall have equal percentage characteristics.

2.3.4 Three-Way Valves

Three-way valves shall provide constant total flow throughout full plug travel.

2.3.5 Duct-Coil and Terminal-Unit-Coil Valves

Control valves with either flare-type or solder-type ends shall be provided for duct or terminal-unit coils. Flare nuts shall be provided for each flare-type end valve.

2.3.6 Valves for Chilled Water, Condenser Water, and Glycol Service

ASME B16.1. Bodies for valves 50 mm 2 inches and smaller shall be brass or bronze, with threaded-end or union-end connections. Bodies for valves from 65 mm 2.5 inches and larger shall be cast iron. Bodies for valves 65 mm 2.5 inches and larger shall have flanged-end connections. Internal valve trim shall be brass or bronze except that valve stems may be Type 316 stainless steel. Water valves shall be sized for a [21 kPa] [3 psi] [_____] differential through the valve at rated flow, except as indicated otherwise. Select valve flow coefficient (Cv) for an actual pressure drop not less than 50 percent or greater than 125 percent of the design pressure drop at design flow. Valves 100 mm 4 inches and larger shall be butterfly valves.

2.3.7 Valves for Hot Water Service

Valves for hot water service below 121 degrees C 250 Degrees F shall conform to ASME B16.1. Bodies for valves 50 mm 2 inches and smaller shall be brass or bronze, with threaded-end or union-end connections. Bodies for valves 65 mm 2.5 inches and larger shall be cast iron. Bodies for 65 mm 2.5 inches and larger shall have flanged-end connections. Water valves shall be sized for a [21 kPa] [3 psi] [_____] differential through the valve at rated flow, except as indicated otherwise. Select valve flow coefficient (Cv) for an actual pressure drop not less than 50 percent or greater than 125 percent of the design pressure drop at design flow. Internal trim, including seats, seat rings, modulating plugs, and springs, of valves controlling water hotter than 99 degrees C 210 degrees F shall be Type 316 stainless steel. Internal trim for valves controlling water 99 degrees C 210 degrees F or less shall be brass or bronze. Non-metallic parts of hot water control valves shall be suitable for a minimum continuous operating temperature of 121 degrees C or 10 degrees C 250 degrees F or 50 degrees F above the system design temperature, whichever is higher. Valves 100 mm 4 inches and larger shall be butterfly valves.

2.3.8 Valves for Steam Service

ASME B16.1. Bodies for valves 40 mm 1.5 inches and smaller shall be brass or bronze, with threaded or union ends. Bodies for valves 50 to 80 mm 2 to 3 inches inclusive shall be brass, bronze, or cast iron. Bodies for valves 100 mm 4 inches and larger shall be cast iron. Bodies for 50 mm 2 inch valves shall have threaded ends. Bodies for valves 65 mm 2.5 inches and larger shall be provided with flanged-end connections. Internal valve trim shall be Type 316 stainless steel. Steam valves shall be sized for [103 kPa (gage)] [15 psig] [_____] inlet steam pressure with a maximum [90 kPa] [13 psi] [_____] differential through the valve at rated flow, except as indicated otherwise.

2.3.9 Valves for High Temperature Hot Water Service

Valves for high temperature hot water service above 121 degrees C 250 degrees F. Valve bodies shall conform to ASME B16.34 Class 300. Valve and actuator combination shall be normally closed. Bodies shall be carbon steel, globe type with welded ends on valves 25 mm one inch and larger. Valves smaller than 25 mm one inch shall have socket-weld ends. Packing shall be virgin polytetrafluoroethylene (PTFE). Internal valve trim shall be Type 316 stainless steel. Water valves shall be sized for a [21 kPa] [3 psi] [_____] differential pressure through the valve at rated flow, except as indicated otherwise. Select valve flow coefficient (Cv) for an actual pressure drop not less than 50 percent or greater than 125 percent of the design pressure drop at design flow.

2.3.10 Valves for Compressed Air Service

Valves used for switching compressed air supplied to pneumatic systems shall be brass body, three-way valves which shall conform to ASME B16.15 Class 250.

2.4 DAMPERS

Provide dampers in air ducts.

****
NOTE: Use parallel blade dampers for mixing boxes and where two-position control is required. Use opposed blade dampers for modulating applications for face and bypass control.
****

2.4.1 Damper Assembly

Damper shall conform to SMACNA 1966. A single damper section shall have blades no longer than 1219 mm 48 inches and shall be no higher than 1829 mm 72 inches. Maximum damper blade width shall be 200 mm 8 inches. Larger sizes shall consist of a combination of sections. Dampers shall be steel or other materials where indicated. Flat blades shall be made rigid by folding the edges. Provide blades with compressible seals at points of contact. Provide channel frames of dampers with jamb seals to minimize air leakage. Dampers shall not leak in excess of 51 L/s per square meter 10 cfm per square foot at 996 Pa 4 inches water gage static pressure when closed. Seals shall be suitable for an operating temperature range of minus 40 degrees C to 93 degrees C 40 degrees F to 200 degrees F. Dampers shall be rated at not less than 10 m/s 2000 fpm air velocity. Moving

parts of the operating linkage in contact with each other shall consist of dissimilar materials. Damper axles shall be 13 mm 0.5 inch minimum plated steel rods supported in the damper frame by stainless steel or bronze bearings. Blades mounted vertically shall be supported by a non-ferrous dissimilar thrust bearings. Pressure drop through dampers shall not exceed 12 Pa 0.05 inch water gage at 5 m/s 1,000 fpm in the wide-open position. Frames shall not be less than 51 mm 2 inches wide. Dampers shall be tested in accordance with AMCA 500-D.

2.4.2 Operating Links

Operating links external to dampers, such as crankarms, connecting rods, and line shafting for transmitting motion from damper actuators to dampers, shall withstand a load equal to at least twice the maximum required damper-operating force. Rod lengths shall be adjustable. Links shall be brass, bronze, zinc-coated steel, or stainless steel. Mating parts shall consist of dissimilar materials. Working parts of joints and clevises shall be brass, bronze, or stainless steel. Adjustments of crankarms shall control the open and closed position of dampers.

2.5 FIRE PROTECTION DEVICES

Provide smoke detectors in return and supply air ducts on the downstream side of the filters in accordance with NFPA 90A, except as otherwise indicated. Provide UL listed or FM approved detectors for duct installation.

2.5.1 Smoke Detectors

****
NOTE: Choose one of the following options.
****

****
NOTE: Regarding the text below, use this paragraph if project has [Section 28 31 60 INTERIOR FIRE ALARM SYSTEM, NON-ADDRESSABLE] [Section 28 31 66 INTERIOR FIRE ALARM AND MASS NOTIFICATION SYSTEM, NON-ADDRESSABLE] [Section 28 31 70 INTERIOR FIRE ALARM SYSTEM, ADDRESSABLE] [Section 28 31 76 INTERIOR FIRE ALARM AND MASS NOTIFICATION SYSTEM, ADDRESSABLE].
****

[Provide in each air-handling system with supply air capacity greater than 944 L/s 2000 cfm in accordance with NFPA 90A. Locate downstream of the supply air filters and prior to any branch connection in accordance with NFPA 72. Provide in each air-handling system, serving more than one story, and having a return air capacity greater than 7079 L/s 15000 cfm in accordance with NFPA 90A. Locate at each story prior to connection to common return and at return connection to air handler prior to any fresh air inlet connection and prior to any recirculation connection in accordance with NFPA 72. Smoke control and exhaust systems shall have provision for automatic and manual operation by means of a key-operated switch to override any other shutdown features and shall be located [adjacent to the fire alarm system control panel] [as indicated].
]

****
NOTE: Regarding the text below: Use this paragraph

if building has an existing fire evacuation alarm system. For connection to existing system, designer must determine if the existing fire alarm control panel is compatible with smoke detectors and has spare zone capacity. Edit accordingly. When in doubt leave choice of connection to fire alarm panel or a separate control unit in paragraph. For some antiquated alarm systems, it may be necessary to replace the control panel in which case [Section 28 31 60 INTERIOR FIRE ALARM SYSTEM, NON-ADDRESSABLE] [Section 28 31 66 INTERIOR FIRE ALARM AND MASS NOTIFICATION SYSTEM, NON-ADDRESSABLE] [Section 28 31 70 INTERIOR FIRE ALARM SYSTEM, ADDRESSABLE] [Section 28 31 76 INTERIOR FIRE ALARM AND MASS NOTIFICATION SYSTEM, ADDRESSABLE] must be included in project and the first option should be used.
****

[Provide in each air-handling system with supply air capacity greater than 944 L/s 2000 cfm in accordance with NFPA 90A. Locate downstream of the supply air filters and prior to any branch connection in accordance with NFPA 72.

Provide in each air-handling system, serving more than one story, and having a return air capacity greater than 7079 L/s 15000 cfm in accordance with NFPA 90A. Locate at each story prior to connection to common return and at return connection to air handler prior to any fresh air inlet connection and prior to any recirculation connection in accordance with NFPA 72. Design for detection of abnormal smoke densities by the [ionization] [or] photoelectric principle, responsive to both invisible and visible particles of combustion, and not susceptible to undesired operation by changes to relative humidity.

Provide UL listed or FM approved detectors for duct installation. Provide duct detectors with an approved duct housing, mounted exterior to the duct, and with perforated sampling tubes extending across the width of the duct. Provide permanent descriptive zone labels indicating in which air-handling units the detectors in alarm are located.

Provide detectors with a test port [, test switch] [and] [or] [, remote keyed test device]. Provide control and power modules required for operation of detectors [in their own control unit] [or] [integral with the main building fire alarm control panel]. A ground fault or single break or open condition in electrical circuitry to any detector or its control or power units shall cause activation of building fire alarm control panel trouble signals.

Electrical supervision of wiring used exclusively for air-handling unit shutdown is not required provided a break in wiring would cause shutdown of the associated unit. Equipment and devices shall be compatible and operable in all respects with, and shall in no way impair reliability or operational functions of, the existing building fire alarm system. The existing fire alarm control panel was manufactured by [_____].

Smoke control and exhaust systems shall have provisions for [automatic and] manual operation by means of a key-operated switch to override any other shutdown features and shall be located [adjacent to the fire alarm system control panel] [as indicated].

]

****

NOTE: Regarding the text below: Use this paragraph only with specific approval of the Engineering Field Division Fire Protection Engineer. Approval will normally be granted only if the building has no fire alarm system and none is required. When in doubt, contact the Fire Protection Engineer.

****

[Provide in each air-handling system with supply air capacity greater than 944 L/s 2000 cfm in accordance with NFPA 90A. Locate downstream of the supply air filters and prior to any branch connection in accordance with NFPA 72. Provide in each air-handling system, serving more than one story, and having a return air capacity greater than 7079 L/s 15000 cfm in accordance with NFPA 90A. Locate at each story prior to connection to common return and at return connection to air handler prior to any fresh air inlet connection and prior to any recirculation connection in accordance with NFPA 72.

Design for detection of abnormal smoke densities by the [ionization] [or] [photoelectric] principle, responsive to both invisible and visible particles of combustion, and not susceptible to undesired operation by changes in relative humidity. Provide UL listed or FM approved detectors for duct installation. Provide duct detectors with an approved duct housing, mounted exterior to the duct, and with perforated sampling tubes extending across the width of the duct.

Provide 115 Vac power supply unit integral with duct housing. Obtain power from [the source to the air-handling unit or air-handling unit controls] [the location indicated]. Detectors shall have test port or test switch. [Provide remote alarm indicator [and keyed test] device at [_____] [the location indicated].] Provide each detector with a visible indicator lamp that lights when the detector is activated.

Activation of duct detector shall cause shutdown of the associated air-handling unit [and closing of dampers] [and shall sound an alarm bell, with minimum 152 mm 6 inch diameter, in a normally occupied area] located [as directed] [as indicated]. [Provide a separate bell with an engraved plastic or metal label indicating which unit each bell annunciates for each air-handling unit.]

]2.5.2 Smoke Dampers [and Combination Smoke/Fire Dampers]

****

NOTE: Use combination smoke/fire dampers only where required by NFPA and design manuals.

****

Smoke dampers and actuator assemblies as required in accordance with NFPA 90A shall meet the Class II leakage requirements of UL 555S. Dampers shall be factory fabricated, galvanized steel or stainless steel with lubricated bearings, linkages, and seals to withstand temperatures from minus 29 to 121 degrees C 20 to 250 degrees F. Provide replaceable seals. [Combination smoke/fire dampers shall have a UL 1.5 hour rating and shall be equipped with electric/thermal links which close the damper at 74 degrees C 165 degrees F and then automatically reset after normal temperature is restored by cycling damper actuator.] Equip dampers with pneumatic or electric actuators which close smoke dampers tightly when

activated. After the smoke has cleared, the dampers shall automatically reset.

2.6 SENSORS

****
NOTE: Use smallest span sufficient to cover the operating range. Use 0.06 degrees C 0.10 degree F allowable tolerance sensors where small temperature changes will have large impact on energy consumption; e.g., chilled water, where the span is nominally 4.44 to 6.67 degrees C 8 to 12 degrees F. The normal 0.28 degree C 0.5 degree F sensor would have an error of 3 to 6 percent: 0.28 degree C 0.5 degree F divided by 4.44 degree C 8 degrees F equals .06 or 6 percent.
****

****
NOTE: Indicate outside air sensors mounted on a north wall if possible; a fan-type air aspirator if necessary to avoid effects of wind, rain, solar radiation, and building outside air film; and also indicate a power source for the aspirator.
****

2.6.1 Spans and Ranges

Transmitters shall be calibrated to provide an electric or electronic output signal of 4 to 20 mA electric or electronic and 21 to 103 kPa 3 to 15 psi output for pneumatics over the indicated span or range.

[a. Conditioned space temperature, from 10 to 38 degrees C 50 to 100 degrees F.

][b. Duct temperature, from 4 to 60 degrees C 40 to 140 degrees F.

][c. High temperature hot-water temperature, from 93 to 260 degrees C 200 to 500 degrees F.

][d. Chilled water temperature, from minus one to 27 degrees C 30 to 80 degrees F.

][e. Dual temperature water, from minus one to 116 degrees C 30 to 240 degrees F.

][f. Heating hot water temperature, from 38 to 121 degrees C 100 to 250 degrees F.

][g. Condenser water temperature, from minus one to 54 degrees C 30 to 130 degrees F.

][h. Outside air temperature, from minus 34 to 54 degrees C 30 to 130 degrees F.

][i. Relative humidity, from 0 to 100 percent for high/low limit applications; from 20 to 80 percent for space applications.

][j. Differential pressure for VAV supply duct static pressure from 0

to 498 Pa 0 to 2.0 inches water gage.

][k. Pitot tube airflow measurement station and transmitter, from 0 to 25 Pa 0 to 0.1 inch water gage for flow velocities of 2.50 to 6 m/s 500 to 1200 fpm, 0 to 62 Pa 0 to 0.25 inch water gage for velocities of 2.50 to 9 m/s 500 to 1800 fpm, or 0 to 124 Pa 0 to 0.5 inch water gage for velocities of 2.50 to 13 m/s 500 to 2500 fpm, or 0 to 374 Pa 0 to 1.5 inches water gage for velocities of 7.5 to 23 m/s 1500 to 4500 fpm, or 0 to 498 Pa 0 to 2 inches water gage for velocities of 15 to 30 m/s 3000 to 6000 fpm as required by the duct system.

][l. Electronic airflow measurement station and transmitter, from 0.64 to 13 m/s 125 to 2500 fpm, 7.5 to 23 m/s 1500 to 4500 fpm, or 15 to 30 m/s 3000 to 6000 fpm as required by the duct system.

]2.6.2 Temperature Sensors

2.6.2.1 Resistance Temperature Detectors (RTD's)

RTD shall be platinum with a tolerance of plus or minus 0.25 percent at 0 degrees C 32 degrees F, and shall be encapsulated in epoxy, Series 300 stainless steel, anodized aluminum, or copper. RTD shall be furnished with RTD transmitter as specified, integrally-mounted unless otherwise indicated.

2.6.2.2 Continuous Averaging RTD's

Continuous averaging RTD's shall have a tolerance of plus or minus 0.55 degrees C 1.0 degrees F at the reference temperature, and shall be of sufficient length to ensure that the resistance represents an average over the cross section in which it is installed. Sensing element shall have a bendable copper sheath. Averaging RTD shall be furnished with RTD transmitter as specified, to match the resistance range of the averaging RTD. Element length shall be a minimum of 3280 mm per square meter one linear foot per square foot of coil face area.

2.6.2.3 RTD Transmitter

****

NOTE: Indicate where transmitters are required and not required.

****

RTD transmitter shall be selected to match the resistance range of the RTD. Transmitter shall be a two-wire, loop-powered device. Transmitter shall produce a linear 4 to 20 mA dc output corresponding to required temperature measurement. Output error shall not exceed 0.1 percent of the calibrated measurement. Transmitter shall include offset and span adjustments.

2.6.2.4 Pneumatic Temperature Transmitter

****

NOTE: Use smallest span sufficient to cover operating range. This provides smallest allowable deviation, improving control accuracy.

****

Transmitting sensing elements shall be bi-metal, averaging element and capillary, rod and tube, or bulb and capillary. Transmitters shall operate within the range of 4 to 116 degrees C 40 to 240 degrees F. Provide the following spans and allowable deviations for applications listed.

a. Room sensors, minus 4 degrees C 25 degrees F, plus or minus 0.28 degrees C 0.5 degrees F

b. Room, chilled water, dew point, return air sensors, 10 degrees C 50 degrees F, plus or minus 0.42 degree C 0.75 degree F

c. Outside air, hot water, coil discharge sensors, 38 degrees C 100 degrees F, plus or minus 0.56 degree C 1.0 degree F

d. High temperature hot water, chilled hot water system sensors, 93 degrees C 200 degrees F, plus or minus 1.11 degrees C 2.0 degrees F.

2.6.3 Relative Humidity Instruments

2.6.3.1 Relative Humidity Sensor

****

NOTE:

1. Measuring dew point temperature and relative humidity with accuracy and repeatability using "commercial" controls is difficult. It is recommended that the designer plan the control system to eliminate the need to control dew point temperature or relative humidity including eliminating enthalpy control. Dry bulb temperatures should be used to control outside, return, and exhaust air dampers in economizer applications. Only use humidity control when the space has specific humidity requirements.

2. Indicate a fan powered type aspirating cabinet, an electronic relative humidity sensing element, a transmitter for outside air relative humidity sensing applications, and a power source for the cabinet.

****

Provide relative humidity sensor. Use nonsaturating sensing elements capable of withstanding a saturated condition without permanently affecting calibration or sustaining damage. Sensing elements shall be bulk polymer or thin film polymer. Sensing elements shall have an accuracy of plus or minus 2 percent of full scale within the range of 20 to 80 percent relative humidity. Provide a two-wire, loop-powered transmitter located at the sensing elements to convert the sensing elements output to a linear 4 to 20 mA dc output corresponding to required humidity measurement. Output error shall not exceed 0.1 percent of calibrated measurement. Transmitter shall include offset and span adjustments. Transmitter shall have ability to be calibrated electronically by using a one-point, in-situ method which allows for error correction with a single potentiometer.

2.6.4 Dew Point Instruments

****

NOTE: Provide 2 degrees C 3 degree F dew point allowable deviation for normal control, as in commissary refrigerated display case, anti-sweat heater controls; provide a 0.55 degree C one degree F deviation for critical occupied space, as in computer rooms.

****

Provide analog salt-phase transition or dual chilled, mirror type sensor. Sensor shall have an allowable deviation of plus or minus [0.55] [2] degrees C [one] [3] degrees F dew point over the range of minus 12 to plus 27 degrees C 10 to 80 degrees F dew point.

2.6.5 Airflow Sensors

Provide airflow sensors.

****

NOTE: Use only where necessary. Airflow sensors are high maintenance items.

****

2.6.5.1 Electronic Airflow Measurement Stations and Transmitters

a. Stations shall contain an array of velocity sensing elements and straightening vanes inside a flanged sheet metal casing. Velocity sensing elements shall be RTD or thermistor type, with linearizing means. Sensing elements shall be distributed across the duct cross section in the quantity and pattern set forth for measurements and instruments in accordance with ASHRAE FUN SI ASHRAE FUN IP and SMACNA 1780, for traversing of ducted airflows. Resistance to airflow through the airflow measurement station shall not exceed 20 Pa 0.08 inch water gage at airflow of 10 m/s 2000 fpm. Station construction shall be suitable for operation at airflows of up to 25.40 m/s 5000 fpm over a temperature range of 4 to 49 degrees C 40 to 120 degrees F, and accuracy shall be plus or minus 3 percent over a range of 0.64 to 12.70 m/s 125 to 2500 fpm scaled to air volume. Use stations if required velocity measurement is below 2.50 meters per second 500 feet per minute.

b. Transmitters shall produce a linear, temperature compensated 4 to 20 mA dc output corresponding to required velocity pressure measurement. Transmitters shall be a two-wire, loop-powered device. Output error of transmitters shall not exceed 0.5 percent of calibrated measurement. Transmitters shall have offset and span adjustments.

2.6.5.2 Pitot Tube Airflow Measurement Stations and Transmitters

a. Stations shall contain an array of velocity sensing elements and straightening vanes inside a flanged sheet metal casing. Velocity sensing elements shall be multiple pitot tube type with averaging manifolds. Sensing elements shall be distributed across the duct cross section in the quantity and pattern set forth for measurements and instruments in accordance with ASHRAE FUN SI ASHRAE FUN IP or SMACNA 1780, for traversing of ducted airflows.

Resistance to airflow through the airflow measurement station shall not exceed 20 Pa 0.08 inch water gage at airflow of 10 m/s 2000 fpm. Station construction shall be suitable for operation at airflows of up to 25.40 m/s 5000 fpm over a temperature range of 4 to 49 degrees C 40 to 120 degrees F, and accuracy shall be plus or minus 3 percent over a range of 2.5 to 12.7 m/s 500 to 2500 fpm scaled to air volume. Do not use stations if required velocity measurement is below 2.50 meters per second 500 feet per minute.

b. Transmitters shall produce a linear 4 to 20 mA dc output corresponding to the required velocity pressure measurement. Each transmitter shall have a low-range differential pressure sensing element and a square root extractor. The transmitter shall be a two-wire, loop powered device. Sensing element accuracy shall be plus or minus 1 percent of full scale, and overall transmitter accuracy shall be plus or minus 0.25 percent of the calibrated measurement. Each transmitter shall have offset and span adjustments.

2.6.6 Pressure Sensors

****

NOTE: Indicate spare pressure taps where in-piping calibration is required.

****

Provide electronic pressure sensor and transmitter. Sensor shall be a pressure transmitter with an integral sensing element. Sensor over pressure rating shall be 172 kPa (gage) 25 psig above its normal operating range. Sensing element accuracy shall be plus or minus one percent of full scale. Transmitter accuracy shall be plus or minus 0.1 percent of the calibrated measurement. Transmitter shall be a two-wire, loop-powered device. Transmitter shall produce a linear 4 to 20 mA dc output corresponding to required pressure measurement. Transmitter shall have offset and span adjustments.

2.7 THERMOWELLS

Provide brass or Series 300 stainless steel thermowells with threaded brass plug and chain, 50 mm 2 inch lagging neck and extension type well, and inside diameter and insertion length as required for the application. Provide thermowells for immersion sensors with conducting material inside the well.

2.8 THERMOSTATS

Provide thermostats.

****

NOTE:

1. Use a recessed aspirating type mounting in public areas where it is necessary to make the thermostat less obvious to minimize vandalism. Do not use aspirating or concealed mountings in family housing. Use adjustable thermostats in family housing.

2. Locate room thermostats on interior walls where

they will respond to average conditions in the rooms. Thermostats shall not be mounted on exterior walls if other locations are available. If mounted on exterior walls, thermostats shall be indicated with an insulating subbase. Thermostats for comfort cooling that are occupant controlled (indicate the limits) shall have fixed factory temperature limits. Indicate centerline of room thermostat at 1.50 meters 5 feet above finished floor.

3. Indicate switch differential for each contact and between each contact on multistage switches; also, indicate whether the differential is adjustable or fixed.

****

2.8.1 Ranges

Thermostat ranges shall be selected so that the setpoint is adjustable [without tools] between plus or minus 5 degrees C plus or minus 10 degrees F of the setpoint indicated.

2.8.2 Nonmodulating Electric Room Thermostats

Contacts shall be single-pole double-throw (SPDT), hermetically sealed, and wired to identified terminals. Maximum differential shall be one degree C 2 degrees F. Thermostat covers shall consist of locking metal or heavy-duty plastic, and shall be capable of being locked by an Allen wrench or special tool. Thermostats shall have manual switches as required by the application and a minimum range of 13 to 32 degrees C 55 to 90 degrees F.

2.8.3 Microprocessor-Based Room Thermostats

****

NOTE: Use thermostats only for small split systems and packaged single-zone units.

****

Microprocessor-based room thermostats shall have built-in keypads for scheduling of day and night temperature settings. [Access to the scheduling mode shall be by password control code.] When out of the scheduling mode, thermostats shall have continuous 12-hour time display, with AM and PM indication, continuous display of day of the week, and either continuous display of room temperature with display of temperature setpoint on demand, or continuous display of temperature setpoint with display of room temperature on demand. In the programmable mode, use the display for setting and interrogating time program ON-OFF setpoints for each day of the week. The time program shall allow two separate temperature setback intervals per day. Thermostats shall have a means for temporary and manual override of program schedule, with automatic program restoration on the following day. Thermostats shall have a replaceable battery to maintain timing and to maintain the schedule in memory for one year in the event of a power outage. Maximum differential shall be one degree C 2 degrees F. Where used for heat pump applications, thermostat shall have an emergency heat switch.

2.8.4 Nonmodulating Capillary Thermostats and Aquastats

a. Thermostat shall have a capillary length of at least 1 1/2 meters 5 feet, adjustable direct reading scales for both setpoint and differential, and a differential adjustable from 3 to 9 degrees C 6 to 16 degrees F.

b. Aquastats shall be strap-on type, with 5.50 degrees C 10 degrees F fixed differential.

2.8.5 Low-Temperature Protection Thermostats (Freezestats)

****

NOTE: Indicate capillary serpentined in a plane perpendicular to airflow to uniformly sense entire airflow.

****

Low-temperature protection thermostats shall be manually reset low-temperature safety thermostats, with NO and NC contacts or a two-position pneumatic output signal and a 6 meters 20 foot element which shall respond to the coldest 456 mm 18 inch segment.

2.8.6 Modulating Capillary Thermostats

Thermostats shall have either one output signal, two output signals operating in unison, or two output signals operating in sequence, as required for the application. Thermostats shall have adjustable throttling ranges of 2 to 4 degrees C 4 to 8 degrees F for each output.

2.8.7 Modulating Pneumatic Room Thermostats

Two-temperature combination thermostats shall be adjustable proportioning type with dual setpoints containing two temperature sensing elements: one for heating control and one for cooling control; two for heating control or two for cooling control. Changeover for two-temperature combination thermostats shall be accomplished by a change in control air supply pressure which selects proper setpoint and proper controller action. Single-temperature thermostats shall be adjustable proportioning type with one temperature sensing element: one setpoint and proper controller action. "Dead-band" thermostats shall have one adjustable proportioning type controller with two setpoints, adjustable dead-band, and one controller output or two adjustable proportioning type controllers mounted on a common backplate with two setpoints, adjustable dead-band, and two controller outputs. Temperature sensing elements shall be selected for proper controller action. Individual temperature-sensing elements shall have a separate adjustable throttling range of one to 5.50 degrees C 2 to 10 degrees F; thermostat shall have a minimum range of 13 to 32 degrees C 55 to 90 degrees F and minimum safe air input pressure of 172 kPa (gage) 25 psig. Dead-band setting shall have a minimum adjustable range of 2 to 8 degrees C 4 to 15 degrees F. Room thermostat shall have concealed setpoint dial [, covers with Allen screws] [, aspirator type wall box with flush plate and locking screws] [, built-in concealed thermometers] [, exposed adjustment covers with visible thermometers for family housing], and plug-in gage ports.

2.8.8 Modulating, Insertion, Immersion, & Averaging Pneumatic Thermostats

****

NOTE: Indicate remote bulb return air thermostats in lieu of room thermostats where acceptable.
****

Thermostats shall be two-pipe, pilot-operated type with pneumatic feedback, proportional action and shall have an adjustable throttling range of one to 55 degrees C 2 to 100 degrees F with a minimum range of minus 12 to plus 121 degrees C 10 to 250 degrees F. Averaging elements shall be 825 mm 1 foot in length for each square meter 4 square feet of ductwork cross-sectional area with a minimum length of 2.44 meters 8 feet.

2.8.9 Nonmodulating Pneumatic Thermostats

Thermostats shall have integral positive acting relays, zero or maximum output pressure. Remote element thermostats shall have standard or averaging bulbs. Averaging bulbs shall be 825 mm one foot in length for each square meter 4 square feet of ductwork cross-sectional area and a minimum length of 2.44 meters 8 feet. Differential ranges shall be field adjustable. Remote element thermostat differential range shall be one to 14 degrees C 2 to 25 degrees F with minimum control ranges of minus 23 to plus 121 degrees C minus 10 to plus 250 degrees F. Room thermostat differential range shall be one to 5.50 degrees C 2 to 10 degrees F with minimum control ranges of 13 to 32 degrees C 55 to 90 degrees F.

2.9 SUNSHIELDS

Provide sunshields for outside air temperature sensing elements to prevent the sun from directly striking temperature sensing elements. Provide sunshields with adequate ventilation so that the sensing element responds to the ambient temperature of surroundings. The top of each sunshield shall have galvanized metal or aluminum rainshield projecting over the face of the sunshield. Sunshields shall be painted white or shall be unpainted aluminum.

2.10 PRESSURE SWITCHES AND SOLENOID VALVES

Provide pressure switches and solenoid valves.

2.10.1 Pressure Switches

Switches shall have an adjustable setpoint with visible setpoint scale. Range shall be as indicated. Differential adjustment shall span 20 to 40 percent of the range of the device.

2.10.2 Differential Pressure Switches

Switches shall be an adjustable diaphragm-operated device with [two SPDT] [one SPDT] contacts, with taps for sensing lines to be connected to duct pressure fittings designed to sense air pressure. Fittings shall be angled-tip type with tips pointing into the airstream. [Range shall be 125 to 1494 Pa 0.5 to 6 inches water gage. Differential shall be a maximum of 37 Pa 0.15 inch water gage at the low end of the range and 87 Pa 0.35 inch water gage at the high end of the range.]

2.10.3 Pneumatic Electric (PE) Switches

Switches shall have an adjustable setpoint range of 21 to 138 kPa (gage) 3 to 20 psig, and differential adjustable from [14 to 41] [7to 14] [2 to 7] kPa [2 to 6] [1 to 2] [0.25 to 1] psi.

2.10.4 Solenoid Operated Pneumatic (EP) Valves

Valves shall have three-port operation: common, normally open, and normally closed. Valves shall have an outer cast aluminum body. The air connection shall be a 6 mm 1/4 inch NPT threaded connection. Valves shall be rated for 345 kPa (gage) 50 psig where used in a control system which operates at 172 kPa (gage) 25 psig or less, or 1034 kpa (gage) 150 psig where used in a control system which operates in the range of 172 to 689 kPa (gage) 25 to 100 psig.

2.11 INDICATING DEVICES

Provide indicating devices.

2.11.1 Thermometers

a. Thermometers for insertion in ductwork and piping systems shall have brass, malleable iron, or aluminum alloy case and frame, clear protective face, and permanently stabilized glass tube with an indicating fluid column, white face, black numbers, and a 229 mm 9 inch scale.

b. Thermometers for piping systems shall have rigid stems with straight, angular, or inclined pattern.

c. Thermometer stems shall have expansion heads as required to prevent breakage at extreme temperatures. On rigid stem thermometers, the space between bulb and stem shall be filled with a heat transfer medium.

d. Air duct thermometers shall have perforated stem guards and 45 degree adjustable duct flanges with locking mechanisms.

e. Averaging thermometers shall have 90 mm 3.5 inch (nominal) dial, with black legend on white background, and pointer traveling through a 270 degree arc.

f. Thermometers shall have an accuracy of plus or minus one percent of scale range. Thermometers shall have the following ranges:

(1) Mixed air temperature: minus 18 to plus 38 degrees C in 1/2 degree C 0 to 100 degrees F in 1 degree F graduations.

(2) Return air temperature: minus 18 to plus 38 degrees C in 1/2 degrees C 0 to 100 degrees F in 1 degree F graduations.

(3) Cooling coil discharge temperature: minus 18 to plus 38 degrees C in 1/2 degree C 0 to 100 degrees F in 1 degree F graduations.

(4) Heating coil discharge temperature: minus one to plus 82 degrees C in one degree C 30 to 180 degrees F in 2 degree F graduations.

(5) Hydronic heating systems below 104 degrees C 220 degrees F: 4 to 116 degrees C in one degree 40 to 240 degrees F in 2 degree graduations.

(6) Chilled water temperature: minus 18 to plus 38 degrees C in 1/2 degree C 0 to 100 degrees F in one degree F graduations.

(7) Condenser water temperature: 4 to 60 degrees C in 1/2 degree C 40 to 140 degrees in one degree F graduations.

(8) Glycol temperature: minus 18 to plus 38 degrees C 0 to 100 degrees Ffor cooling service in 1/2 degree C one degree F graduations, and 4 to 116 degrees C 40 to 240 degrees F for heating service in one degree C 2 degree F graduations.

(9) High temperature hot water: 38 to 288 degrees C in 3 degree C 100 to 550 degrees F in 5 degree F graduations.

2.11.2 Pressure Gages

Provide pressure gages with gage cock, snubber, and syphon.

a. ASME B40.100. Gages shall be 65 mm 2 1/2 inch (nominal) size, back-connected, suitable for field or panel mounting as required, shall have black legend on white background, and shall have a pointer traveling through a 270 degree arc. Accuracy shall be plus or minus 3 percent of scale range.

b. Gages for indicating signal output to pneumatic actuators and main air gages shall have scale of 0 to 210 kPa (gage) in 10 kPa 0 to 30 psig in 1 psig graduations.

c. Gages for air storage tanks and for use before and after dirt and oil filters or dryers, shall have a scale of [0 to 1100] [_____] kPa (gage) [0 to 160] [_____] psig with 15 Kpa (gage) 2 psig graduations.

d. Gages for [hydronic] [and] [steam] system applications shall have ranges and graduations as indicated.

e. Pneumatic transmission receiver gages shall have a range to match the respective transmitters.

2.12 LOW-DIFFERENTIAL PRESSURE GAGES

Gages for low-differential pressure measurements shall be 115 mm 4 1/2 inch (nominal) size with two seats of pressure taps, and shall have a diaphragm-actuated pointer, white dial with black figures, and pointer zero adjustment. Gages shall have ranges and graduations as indicated. Accuracy shall be plus or minus 2 percent of scale range.

2.13 CONTROLLERS

****
NOTE: Indicate which type of controller is required for each application.
****

2.13.1 Single-Loop Controllers

****
NOTE: Indicate single-loop controllers for applications where proportional-integral (PI) modes

or proportional-integral-derivative (PID) modes are required or where the need for either mode is anticipated. Indicate single-loop controllers where one or two contact outputs are required to be operated in response to changes in process variable input signals for control application.
****

2.13.1.1 Controller Features

Controller shall be a microprocessor-based, single-loop device that does not require Contractor-generated software. Controller shall conform to FCC Part 15. Controller panel cutout shall be 92 by 92 mm 3.62 by 3.62 inches. Controller shall have field selectable range for process variables, a remote setpoint analog input and analog output with adjustable high and low end limits, and proportional control manual reset adjustment. Analog output shall result from PID control. Analog output shall be configurable as direct acting and reverse acting. Controller shall have keyboard, display, auto/manual selection for control of analog output, and remote setpoint adjustment/local setpoint adjustment selection. Controller shall have adjustable high-end and low-end limits, ratio, and bias adjustments on remote setpoint input; operator initiated self-tune/manual-tune selection, anti-reset wind-up feature, and two configurable independent SPDT with adjustable system contact closure outputs. Controller shall be configurable to power-up in manual with local setpoint control, in automatic with local setpoint control, and in automatic with remote setpoint control. Contact closures shall be activated by a process variable and by a process variable deviation from setpoint as configured. The range of hysteresis adjustment shall not be smaller than 1 percent to 5 percent of process variable input span. Controller shall power the analog output loop to 20 mA where connected to a load of 600 ohms. Controller shall have 5-year battery backup or shall have nonvolatile memory to store operating parameters.

2.13.1.2 Controller Parameter Input and Display

Control parameters shall be entered and displayed directly, in the correct engineering units, through a series of keystrokes on a front panel display with a 3 1/2-digit, seven-segment display, with decimal point and polarity indication. Use of the display shall allow manual interrogation of setpoint, mode constants, and values of process variables and outputs.

2.13.1.3 Controller Electrical Requirements

Controller shall be powered by 120 Vac. Controller shall provide electrical noise isolation, not less than 100 dB at 60 Hz common mode rejection ratio, and not less than 60 dB at 60 Hz normal mode rejection ratio between ac power line and process variable input, remote setpoint input, and output signals.

2.13.1.4 Controller Accuracy

Controller shall have an accuracy of plus or minus 0.30 percent of input span, plus or minus one digit.

2.13.1.5 Controller Self Tuning

Controller self-tuning operation shall apply proportional, integral, and derivative modes of control; mode constants shall be modified as

required. Self tuning shall only operate when selected from the front panel.

2.13.1.6 Controller Manual Tuning

Controller manual tuning operation shall provide proportional, integral, and derivative control modes, or any combination thereof, by means of individual mode constant adjustments. Adjustments shall be set for the appropriate value if a particular control mode action is desired, or to zero for the particular mode not desired. The proportional mode constant shall be adjustable from 0 to 200 percent of input signal range; the integral mode constant shall be adjustable from 0 to 20 repetitions per minute; and the derivative mode constant shall be adjustable from 0 to 5 minutes.

2.13.2 Pneumatic Controllers

****

NOTE: Indicate on drawings in sequence of operation, the following controller characteristics:

1. Type of setpoint adjustment: local or remote. Specify "field selectable" where future provisions for remote setpoint may be foreseen, or where similar units, a portion of which requires remote adjustment, are to be used at remote job sites.

2. Type of input ports: single or dual.

3. Type of inputs: primary with single input ports, or primary and secondary with dual input ports.

****

Controllers shall be two-pipe devices which use main air supplied to controller and pneumatic relay to produce the controller output signal. Controllers shall have field selectable local and remote adjustable setpoints, and an adjustable proportional band for analog (proportional) control or an adjustable differential for binary (two-position or floating) control. Controllers shall have single- or dual-input ports as required for the application and field selectable direct or reverse action for inputs. Dual input controllers shall have adjustable secondary input authority. Controllers shall have integral gage or test connections for testing or indication of input and output signals.

2.13.3 Analog Electronic Controllers

Controllers shall be solid-state electronic devices which sense the difference between input sensor analog values (resistance or voltage) and setpoint adjustment analog values (resistance or voltage), and shall amplify the difference signal to provide the output signal. Controllers shall include the following:

a. Proportional band: 2.5 to 33 percent of input device span.

b. Authority: minimum of 33 to 200 percent.

c. Inputs: thermistor, resistance, transmitter, or output of other electronic controllers.

d. Outputs: within the range of minus 5 to 20 Vdc or a 4 to 20 mA dc current loop.

e. Remote setpoint adjustment (SPA): plus or minus 10 percent of input device span.

2.13.4 Unitary Control Systems

****

NOTE: Energy-efficient temperature control systems should be used for small systems as well as large systems. Systems that otherwise are not cost effective may use programmable controllers that are commercially available for HVAC applications. These are chiefly staging type controllers but some do incorporate modulating outdoor air damper control. Controllers are available to control cooling in two steps with either two or four heating steps, and in three cooling steps with three heating steps.

****

Unitary control systems shall be energy-efficient, micro-processor-based temperature controllers and associated devices that do not require Contractor-generated software. Provide control systems with [integral] [or] [remote] sensor as indicated. Controllers shall operate heating, cooling, and ventilating modes with independent occupied and unoccupied settings for each of 7 consecutive days. Cooling shall be controlled in [two] [three] steps and heating shall be controlled in [two] [three] [four] steps with modulating control provided for the ventilation mode. Provide temperature changeover control to limit the ventilation mode when outdoor air temperature is not sufficiently low for "free-cooling." Provision shall be made for [automatic] [manual] changeover between heating and cooling modes, providing a one minute minimum time delay between the start and stop operation of heating and cooling stages upon startup and after power failure to prevent short cycling and power surges. Provide an optimum startup program to minimize warm-up or cool-down periods prior to the occupied mode. Outside air dampers shall be closed during the optimum startup program unless outside air is beneficial for cool-down in lieu of mechanical cooling. Fan shall operate continuously during the occupied mode and shall cycle during the unoccupied mode for heating or cooling. Provide battery backup to retain programs and maintain clock operation for 48 hours minimum during power outages. Controller shall have a self-diagnostic program to indicate errors and locking covers to prevent unauthorized program entries. Provide a convenient means to restore the occupied mode of operation for a minimum 2-hour period without removing covers. An indexing switch shall allow operation in a continuous unoccupied mode during abnormal periods without changing normal programs. [Servicing tool required to place the unitary control system in use shall be a hand-held device used to adjust and monitor setpoints, controlled device positions, input sensor values, and other control system parameters.]

2.13.5 Pneumatic Low-Range Pressure Controllers for Ductwork Applications

Controllers shall provide two-pipe, pilot-operated control with pneumatic feedback and proportional action. Sensing elements shall be differential type with pressure ranges appropriate for intended service. One element shall measure the variable while the other element measures the standard

reference. Static pressure controllers shall have slack diaphragms with standard ranges between 0 to 1494 Pa 0 to 6 inches water gage and an adjustable throttling range of 5 to 125 Pa 0.02 to 0.5 inch water gage. Sensing element shall be mountable in ductwork and shall measure static pressure without pulsations.

2.13.6 Pneumatic Differential Pressure Controllers for Liquid Applications

Differential pressure controllers shall have a minimum range of 0 to 345 kPa (gage) or 0 to 1724 kPa (gage) 0 to 50 psig or 0 to 250 psig as specified or required for the application and shall have an adjustable throttling range of 7 to 172 kPa (gage) 1 to 25 psig. Sensing element shall be filled diaphragm type with three-valve manifold for isolation and nulling. Provide syphons and pressure snubbers.

2.14 CONTROL DEVICES AND ACCESSORIES

Provide control devices and accessories.

2.14.1 Function Modules

Function modules shall accept mA dc analog input signals to produce analog output signals or contact output signals. Modules shall have zero and span adjustments for analog outputs, and setpoint adjustments for contact outputs.

2.14.1.1 Minimum Position Switches and Temperature Setpoint Devices

Minimum position switches and temperature setpoint devices shall accept manual input and shall produce steady analog output. Switches and devices shall be suitable for recessed wall mounting or panel mounting and shall have a graduated dial.

2.14.1.2 Signal Inverter Modules

Signal inverter modules shall accept analog input signal and produce analog output signal that linearly reverses the direction of signal change of input versus output.

2.14.1.3 High-Low Signal Selector Modules

High-low signal selector modules shall accept analog input signals and select either the highest or the lowest input signal as the output signal.

2.14.1.4 Sequencer Modules

Sequencer modules shall provide fixed time delayed sequencing of one or more contact transfers from an analog input signal. Sequencers shall return contacts to their zero input signal condition when power is interrupted.

2.14.2 Relays

Relays shall be two-pole, double-throw (DPDT) with a 10-ampere resistive rating at [120] [24] Vac, and shall have an enclosed coil. Provide with a light indicator which is lit when the coil is energized and is not lit when the coil is not energized.

2.14.3 Time-Delay Relays

Time-delay relays shall be DPDT with octal connectors and dust covers. The adjustable timing range shall be [0 to 3 minutes] [_____].

2.14.4 Time Clocks

****
NOTE: Indicate time clock to automatically index to day or night thermostats; control system shall function on Saturday and Sunday as specified for night cooling and heating. The second clock circuit of the same clock that controls HVAC air delivery system timing shall be used to maintain outside air dampers closed from beginning of night period through the morning warm-up period.
****

Time clocks shall be a 24-hour, 365-day programmable timing device with two independently timed circuits. Clocks shall have a manual scheduling keypad and alphanumeric display of timing parameters. Timing parameters shall include Gregorian calendar date for month, day and day-of-month indication; and 24-hour time-of-day display, with one-minute resolution for programming the ON and OFF times for each circuit. Circuits shall have programmable timed override from 1 to 99 minutes. Clocks shall have capacity for programming four ON events and four OFF events for each circuit. Programmed events shall be assignable to a 365-day schedule. Clocks shall have automatic standard time and daylight saving time adjustments, keyed to input of appropriate dates. Provide clocks with 4-day battery backup.

2.14.5 Override Timer

****
NOTE: Mechanical override timer, when activated, shall bypass the time clock and activate the day heating or cooling and ventilation controls for assigned units. Upon expiration of timer operation, the control system shall return to normal mode.
****

Override timers shall be manually set, mechanically driven timers, or electronic timers, without a "hold" feature. Time intervals shall be selectable for up to 12 hours of operation and shall expire unless reset.

2.14.6 Current-to-Pneumatic (IP) Transducers

Transducers shall be two-wire transmitters which convert an input signal to 21 to 103 kPa (gage) or 103 to 21 kPa (gage) 3 to 15 psig or 15 to 3 psig pneumatic output, with a conversion accuracy of plus or minus 2 percent of full scale, including linearity and hysteresis. Air consumption shall not be greater than 0.12 L/s 0.25 scfm.

2.14.7 Regulated Power Supplies

Power supplies shall provide a 24-Vdc linear supply at not less than 2 amperes, with regulation to 0.05 percent of output voltage. Power supplies shall have a fused input, and shall be protected from voltage surges and power-line transients. Power supply output shall be protected

against overvoltage and short circuits. Power supply loading shall not be greater than 1.2 amperes.

2.14.8 Transformers

****
NOTE: Indicate a backup transformer connected to an alternate voltage supply for systems connected to critical areas where continuous operation is necessary.
****

UL 508 and NEMA ST 1 as applicable. Transformers, other than transformers in bridge circuits, shall have primaries wound for available voltage and secondaries wound for correct control circuit voltage. Transformers shall be sized so that connected loads equal 80 percent of rated capacity. Transformers shall be enclosed in rustproof, galvanized steel cabinets with conduit connections. Disconnect switch shall be provided on the primary side, and a fuse cutout on the secondary side. [For systems serving] [_____] [or] [as indicated], provide backup power supply including transformers connected to [the emergency power source] [_____]. [Provide for automatic switchover and alarm upon failure of primary control circuit.]

2.14.9 Pilot Lights and Manual Switches

Device illumination shall be by light-emitting diode (LED) or neon lamp. Switches shall have operating levers and index plates showing switch positions and names of apparatus controlled or other appropriate designations.

2.15 HVAC SYSTEM CONTROL PANELS

Provide HVAC system control panels.

2.15.1 Panel Assembly

Panel shall be fabricated for bottom entry connection for control system electric power, control system main air source, control system wiring, pneumatic tubing, interconnection of control systems, interconnection of starters, and external shutdown devices. Panel shall have an operating temperature rise of not greater than 11 degrees C 20 degrees F above an ambient temperature of 38 degrees C 100 degrees F.

2.15.2 Panel Electrical Requirements

Control panel shall be powered by nominal 120 Vac terminating at panel on terminal blocks. Instrument cases shall be grounded. Interior and exterior panel enclosures shall be grounded.

2.15.3 Enclosures

****
NOTE: Indicate NEMA class for each panel.
****

Enclosures for each panel shall be a single door, wall-mounted box conforming to NEMA 250 with a continuous hinged and gasketed exterior door with a print pocket, key lock, and interior back panel. Inside finish

shall be white enamel, and outside finish shall be gray primer over phosphatized surfaces.

2.15.4 Mounting and Labeling

Provide pilot lights, switches, panel-mounted control devices, and pressure gages shall be mounted on the door. Power conditioners, fuses, and duplex outlets shall be mounted on the interior of the cabinet. Other components housed in the panel shall be mounted on the interior back panel surface of the enclosure and shall be identified by plastic or metal nameplates which are mechanically attached to the panel. Lettering shall be cut or stamped into the nameplate to a depth of not less than 0.4 mm 1/64 inch, and shall have contrasting color, produced by filling with enamel or lacquer or by use of laminated material. Painting of lettering directly on the surface of the door or interior back panel is not permitted.

2.15.5 Wiring and Tubing

a. Pneumatic device inputs and outputs shall be piped to bulkhead fittings in the bottom of the panel with a 50 mm 2 inch loop to facilitate replacement. Electric, electronic, and electropneumatic device signals entering and leaving the panel shall be wired to identified terminal blocks.

b. Wiring shall be installed in wiring ducts so that devices can be added or replaced without disturbing existing wiring that is not affected by the change. Wiring to single-loop controllers shall have a 100 mm 4 inch wiring loop in the horizontal wiring duct at each wiring connection. There shall be no wiring splices within the control panel. Interconnections required for power or signals shall be made on device terminals, if available, or panel terminal blocks, with not more than two wires connected to each terminal.

c. Instrument signal grounds at the same reference level shall end at a grounding terminal connected to a common ground point for that level. Wiring shield grounds at the same reference level shall end at a grounding terminal connected to a common ground point for that level. Grounding terminal blocks shall be identified by reference level.

d. Wiring connected to controllers shall be identified by function and polarity, e.g., process variable input and remote setpoint input and output.

2.16 COMPRESSED AIR STATIONS

Provide compressed air stations.

2.16.1 Air Compressor Assembly

****

NOTE: In that are additions to existing control systems, do not add additional loads or reuse existing control compressor unless it is verified by the designer that it has ample capacity and is dependable. If existing compressor is to be reused, so specify and indicate its location on drawings.

****

[a. Compressor shall be equipped with an electric motor with a totally enclosed belt guard, operating pressure switch, safety relief valves, gages, intake filter, and intake silencer. Compressor shall have combination type magnetic starter with undervoltage protection and thermal overload protection for each phase. Compressor shall be supported by a steel base mounted on an air storage tank. Air compressor shall be sized to supply compressed air required by the control system while operating not more than one-third of the time.

]

****

NOTE: Regarding the text below, provide duplex air compressors for systems having greater than 50 control air users or greater than 0.71 L/s 1.5 cubic feet per minute of free air.

****

[b. Compressor shall be a duplex machine. Compressor shall be equipped with an electric motor with a totally enclosed belt guard, operating pressure switch, safety relief valve, cylinder unloader or solenoid unloader, intake filter, and intake silencer. Provide an alternator and two magnetic starters with undervoltage protection and thermal overload protection for each phase. Compressors shall be supported on a steel base mounted on an air storage tank. Compressor shall be sized to the control system compressed air requirement while operating not more than one-half of the time.

] c. Compressed air storage tank shall be fabricated for working pressure of not less than 1379 kPa (gage) 200 psig, and constructed and certified in accordance with ASME BPVC. Tank shall be of sufficient volume so that no more than six compressor starts per hour are required with the starting pressure switch differential set at 138 kPa 20 psi differential. Tank shall be provided with an automatic condensate drain trap with a manual override feature.

2.16.2 Compressed Air Station Specialties

a. Pressure regulator and refrigerated air dryer shall be provided in the air outlet line of the air storage tank. Dryer shall be sized for full air delivery capacity of compressor. Air shall be dried at a pressure of not less than 483 kPa (gage) 70 psig to a temperature not greater than 2 degrees C 35 degrees F. Dryer shall be provided with an automatic condensate drain trap with a manual override feature.

b. Two parallel combination dirt and coalescing type oil filters with shutoff valves and pressure regulators shall be provided in the dryer discharge. Air filtration system shall be rated for full delivery capacity of compressor. Filter shall be 100 percent efficient for particle diameters down to 0.3 microns. Filter bowl shall be rated for 1034 kPa (gage) 150 psig maximum working pressure. One of the filters shall serve as a standby. Pressure regulator and safety valve shall be provided downstream of the filter.

c. Flexible pipe connectors shall be designed for 1034 kPa (gage) and

121 degrees C 150 psi and 250 degrees F service, and shall be constructed of rubber, tetrafluoroethylene resin, or braided corrosion-resistant steel, bronze, monel, or galvanized steel. Connectors shall be suitable for service intended and may have threaded or soldered ends. Length of connectors shall be as recommended by the manufacturer for service intended.

d. Vibration isolation units shall be standard products with published loading ratings, and shall be single rubber-in-shear, double rubber-in-shear, or spring type.

2.17 ELECTRONIC VARIABLE AIR VOLUME VAV TERMINAL UNIT CONTROLS

Provide electronic VAV terminal unit controls.

2.17.1 VAV Terminal Units

****
NOTE: For NAVFAC LANT projects that use the regional specifications, refer to NAVFAC LANT regional specification NFGS 23 73 33.00 22 HEATING, VENTILATING AND COOLING SYSTEMS.
****

VAV terminal units shall be as specified in Section 23 30 00 HVAC AIR DISTRIBUTION.

2.17.2 Terminal Unit Controls

a. UL 916 and FCC Part 15. Controls for pressure independent boxes shall consist of a velocity sensing device in the primary air entering box, a room temperature sensing element, a damper actuator, and an adjustable microprocessor-based VAV box controller. Controls shall operate a damper for cooling [and a duct coil for heating]. Actuator shall open or close the device to which it is applied within 6 minutes.

b. Controls for pressure independent boxes with recirculating fans shall consist of a velocity sensing device in the primary air entering the box, a room temperature sensing element, an adjustable microprocessor-based VAV box controller, a damper with actuator, and a duct pressure switch to operate the recirculation fan. Controller shall operate the damper for cooling and the recirculating fan [and duct coil] for heating.

c. One hand-held communication and programming device with an instruction manual, plus one additional hand-held communication device and instruction manual per 100 terminal units, shall be provided. Communication and programming device shall connect directly to the controller or to a jack at the room temperature sensing element location. Communication and programming device shall be used to read and set minimum velocity, maximum velocity, heating setpoint, and cooling setpoint, and to read air velocity and space temperature.

2.18 CONTROL TUBING AND WIRING

Provide HVAC control tubing and wiring.

2.18.1 Tube and Fittings

****
NOTE: Systems that are critical and required for smoke removal operation shall have tubing of noncombustible material only.
****

2.18.1.1 Copper Tubing

ASTM B75/B75M or ASTM B88M ASTM B88. Tubing 10 mm 0.375 inch outside diameter and larger shall have a minimum wall thickness equal to ASTM B88M ASTM B88, Type M. Tubing less than 10 mm 0.375 inch outside diameter shall have a minimum wall thickness of 0.64 mm 0.025 inch. Concealed tubing shall be hard or soft copper; multiple tubing shall be racked or bundled. Exposed tubing shall be hard copper; rack multiple tubing. Tubing for working pressures greater than 206 kPa (gage) 30 psig shall be hard copper. Bundled tubing shall have each tube numbered each 2.0 meters six feet minimum. Racked and individual tubes shall be permanently identified at each end. Fittings shall be solder type ASME B16.18 or ASME B16.22, using ASTM B32, Plumbing Code approved lead-free solder, or compression type ASME B16.26.

2.18.1.2 Polyethylene Tubing

****
NOTE: If the building has crawl spaces or ceilings with openings to the outside, such as vent louvers, prohibit use of bare polyethylene tubing in these areas.
****

Polyethylene tubing shall be provided only for systems with working pressure of 206 kPa (gage) 30 psig or less. Provide flame-resistant, multiple polyethylene tubing in flame-resistant protective sheath with Mylar barrier, or unsheathed flame-resistant 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, except prohibited in crawl spaces, attics, and above-ceiling spaces that are vented to the outdoors. Do not provide polyethylene tubing for [systems indicated as critical and] smoke removal systems. Number each tube in sheathing each two feet minimum. Permanently identify unsheathed tubing at each end. Provide compression or barbed push-on type fittings. Extruded seamless polyethylene tubing shall conform to the following:

a. Minimum burst pressure requirements: 690 kPa (gage) at 24 degrees C to 172 kPa (gage) at 66 degrees C 100 psig at 75 degrees F to 25 psig at 150 degrees F.

b. Stress crack resistance: ASTM D1693, 200 hours minimum.

c. Tensile strength (minimum): ASTM D638,ASTM D638, 7583 kPa 1100 psi.

d. Flow rate (average): ASTM D1238, 0.30 decigram per minute.

e. Density (average): ASTM D792, 920 kg/m3 57.5 pounds per cubic feet.

f. Burn rate: ASTM D635.

2.18.2 Wiring

a. Terminal blocks shall be insulated, modular, feed-through, clamp style with recessed captive screw-type clamping mechanisms. Terminal blocks shall be rail mounted, and shall have end plates, partition plates or enclosed sides for separation.

b. Control wiring for 24-V circuits shall be 18 AWG minimum and shall be rated for 300-V service.

c. Wiring for circuits operating at more than 100 V shall be 14 AWG minimum and shall be rated for 600-V service.

d. Analog signal wiring circuits within control panels shall not be less than 20 AWG and shall be rated for 300-V service.

e. Instrumentation cable shall be 18 AWG, stranded copper, single or multiple twisted, minimum 2-inch lay of twist, 100 percent shielded pairs, and shall have 300-V insulation. Each pair shall have a 20-AWG tinned copper drain wire, individual pair, and overall insulation. Cables shall have an overall aluminum polyester or tinned overall copper cable shield tape, 20-AWG tinned-copper cable drain wire, and overall cable insulation.

f. Nonconducting wiring ducts in control panels shall have slotted side snap-on covers, fittings for connecting ducts, mounting clips for securing ducts, and wire retaining clips.

PART 3 EXECUTION

3.1 INSTALLATION

****
NOTE: Indicate access doors where required for servicing mounted devices.
****

Perform installation under the supervision of competent technicians regularly employed in the installation of control systems. Provide components for a complete and operational control system. Provide control system complete and ready for operation, as specified and indicated. Provide dielectric isolation where dissimilar metals are used for connection and support. Penetrations through and mounting holes in the building exterior shall be watertight. Control system installation shall provide adequate clearance for control system maintenance by maintaining access spaces between coils, to mixed-air plenums, and as required to calibrate, remove, repair, or replace control system devices. Control system installation shall not interfere with the clearance requirements for mechanical and electrical system maintenance. Install devices mounted in or on piping or ductwork, on building surfaces, in mechanical and electrical spaces, or in occupied space ceilings in accordance with manufacturer's recommendations and as indicated on contract documents. Provide control devices to be installed in piping and ductwork with required gaskets, flanges, thermal compounds, insulation, piping, fittings, and manual valves for shutoff, equalization, purging, and calibration. Certify that installation of control system is complete and technical requirements of this section have been met.

3.1.1 Sensors

Provide sensors in locations to sense the appropriate condition. Install sensor and transmitter where easily accessible and serviceable without special tools. Sensors shall be calibrated to the accuracy specified in the contract, and operate correctly when installed. Do not install sensors designed for one application in the place of another application (e.g., replacing a duct sensor with a room sensor).

3.1.1.1 Room Sensors

Provide on interior walls to sense average room conditions. Avoid locations which may be covered by office furniture. Do not mount room sensors on exterior walls if other locations are available. Mount centerline of sensor 1 1/2 meters 5 feet above finished floor.

3.1.1.2 Duct Temperature Sensors

Provide sensors in ductwork in general locations as indicated. Select specific sensor location within duct to accurately sense appropriate air temperatures. Locate sensor connection boxes in position not obstructed by ducts or equipment. Install gaskets between sensor housing and duct wall. Seal duct and insulation penetrations. Install duct averaging sensors between two rigid supports in serpentine position to sense average conditions. Sensor shall have a total minimum length of 825 mm per square meter one linear foot per 4 square feet of duct area. Sensor shall be mounted a minimum of 80 mm 3 inches from outside wall surface. Thermally isolate temperature sensing elements from supports. Provide duct access doors to averaging sensors.

3.1.1.3 Immersion Temperature Sensors

****
NOTE: Indicate pipe size increases for thermowells in small diameter piping.
****

Provide thermowells for sensors measuring temperatures in liquid applications or pressure vessels. Locate wells to sense continuous flow conditions. Do not install wells using extension couplings. Where piping diameters are smaller than the length of the wells, provide wells in piping at elbows to effect proper flow across entire area of the well. Wells shall not restrict flow area to less than 70 percent of pipe area. Increase piping size as required to avoid restriction. Temperature sensors shall be installed in thermowells with thermal transmission material to speed the response of temperature measurement. Provide thermowells with sealing nuts to contain thermal transmission material.

3.1.1.4 Strap-on Temperature Sensors

Strap-on temperature sensors, using helical screw stainless steel clamps, shall be permitted on new hot water piping for on-off operation, and for existing hot water piping sizes not greater than 80 mm 3 inches. Clean the pipe to bright metal. Insulate strap-on bulb and pipe after installation. Provide other liquid temperature sensors with thermowells. Provide NEMA 250 Type 4 enclosures for outdoor installations. Provide brushed aluminum or brushed stainless steel enclosures for sensors located in finished spaces.

3.1.1.5 Outside Air Temperature Sensors

Provide outside air temperature sensor on north side of building, away from exhaust hoods, air intakes, and other areas which may affect temperature readings. Install sunshields to protect outside air temperature sensor from direct sunlight.

3.1.1.6 Low-Temperature Protection Thermostats (Freezestats)

Provide thermostat for each [7.5 square meter] [80 square feet] [_____] of coil-face area to sense the temperature at location indicated. Install thermostat sensing element in serpentine pattern.

3.1.2 Thermometers

Provide thermometers which are installed in liquid systems in thermowells with thermal transmitting materials within the well to speed the response of temperature measurement.

3.1.3 Pressure Sensors

3.1.3.1 Duct Static Pressure

Duct static pressure sensor shall be located where indicated on drawings. If no location is indicated, it should be located approximately two-thirds of distance from supply fan to the end of duct with greatest pressure drop.

3.1.3.2 Steam Pressure

Provide snubbers and isolation valves on steam pressure sensing applications.

3.1.4 Pressure Gages

Provide snubbers for gages in piping systems subject to pulsation. Gages for steam service shall have pigtail fittings with cocks. Install pressure gages at locations indicated. Pneumatic output lines shall have pressure gages mounted near the control panel.

3.1.5 Valves

Provide valve with stems upright where possible but with stems not lower than horizontal. Provide positioners where indicated and where necessary to prevent overlap of heating and cooling where one controller operates more than one pneumatic device and to maintain the proper dead band between heating and cooling.

3.1.6 Damper Actuators

Provide damper actuators so that the damper sealing action is smooth and sufficient to maintain leakage at or below specified leakage rate. Multiple actuators operating a common damper shall be connected to a common drive shaft. Provide positioners where indicated and where necessary to prevent overlap of heating and cooling where one controller operates more than one pneumatic device and to maintain the proper dead band between heating and cooling.

3.1.7 Access Doors

Provide access doors in ductwork to service airflow monitoring devices, devices with averaging elements, and low-temperature protection thermostats (freezestats).

3.1.8 Tubing

a. Provide control system so that pneumatic lines are not exposed to air temperatures below minus 4 degrees C 25 degrees F. Install tubes and tube bundles exposed to view neatly in lines parallel to lines of the building. Route tubing between panels and actuators in mechanical and electrical spaces so that lines are easily traceable. Tubes shall be permanently tagged on both ends with an identifier indicated on shop drawings. Install concealed tubing in finished areas, and install exposed tubing in unfinished areas such as mechanical equipment rooms.

b. Pneumatic lines in mechanical and electrical spaces shall be plastic tubing or copper tubing. Install horizontal and vertical runs of plastic tubes or soft copper tubing in raceways dedicated to tubing. Dedicated raceways shall be supported every 2 meters 6 feet of horizontal run and every 2.44 meter 8 feet for vertical runs. Tubing not installed in raceways shall be hard-drawn copper tubing with sweat fittings and valves, supported every 2 meter 6 feet of horizontal run and every 2.44 meters 8 feet for vertical runs.

c. Tubing for connecting sensing elements and transmitters to liquid and steam lines shall be [copper] [Series 300 stainless steel] with [brass compression] [stainless steel compression] fittings.

d. Tubing for final connection of sensing elements and transmitters to ductwork shall be plastic with a maximum length of 305 mm 12 inches.

e. Tubing external to mechanical and electrical spaces, where run in plenum ceilings, shall be soft copper with sweat fittings, supported every 2.44 meters 8 feet. Tubing not in plenum spaces shall be soft copper with sweat fittings supported every 2.44 meters 8 feet or shall be plastic tubing in raceways dedicated to tubing.

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

g. Final connections to actuators shall be plastic tubing, a maximum of 305 mm 12 inches long and unsupported at the actuator.

h. Provide a manual valve at each HVAC control panel to allow shutoff of main air. Pneumatic connections to HVAC control panels shall be made using bulkhead fittings except where bundled tubing is being used.

i. Final connections to HVAC control panel bulkhead fittings shall be exposed tubing approximately 305 mm 12 inches long.

j. Tubing and two insulated copper phone wires for installation

checkout may be run in the same conduit. Tubing and electrical power conductors shall not be run in the same conduit. Control circuit conductors, 24 V or less, may be run in the same conduit as polyethylene tubing.

3.1.9 Wiring

a. Provide wiring external to control panels, including low-voltage wiring, in metallic raceways. Install wiring without splices between sensors, transmitters, control devices, and HVAC control panels. Install instrumentation grounding as necessary to prevent ground loops, noise, and surges adversely affecting operation of the system. Tag cables, conductors, and wires at both ends, with identifiers indicated on shop drawings.

b. Other electrical work shall be specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide step-down transformers where control equipment operates at lower than line circuit voltages. Transformers serving individual heating, ventilating, and air-conditioning units shall be fed from fan motor leads, or fed from the nearest distribution panelboard or motor control center, using circuits provided for that purpose.

c. Ground control panels and cabinets as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Grounding of the green ac ground wire at the breaker panel alone is not adequate. Install ground wire from each control panel to adequate building ground.

3.1.10 Foundations and Housekeeping Pads

Provide 80 mm 3 inch high concrete foundations and housekeeping pads for the HVAC control system air compressors.

3.1.11 Compressed Air Stations

Mount air compressor assembly on vibration eliminators, in accordance with ASME BPVC for tank clearance. Connect air line to the tank with a flexible pipe connector. Install compressed air station specialties with required tubing, including condensate tubing to a floor drain.

3.1.12 Control Drawings

Post laminated copies of as-built control system drawings in each mechanical room.

3.2 ADJUSTMENTS

Calibrate instrumentation and controls, and verify specified accuracy using test equipment traceable to National Institute for Science and Technology (NIST) standards. Adjust controls and equipment to maintain conditions indicated, to perform the functions indicated, and to operate in the sequence specified.

3.3 FIELD QUALITY CONTROL

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NOTE: Include Section 23 05 93 TESTING, ADJUSTING AND BALANCING.

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a. Demonstrate compliance of HVAC control systems. Furnish personnel, equipment, instrumentation, and supplies necessary to perform calibration and site testing. Calibrate test equipment in accordance with NIST standards. Ensure that tests are performed or supervised by competent employees of the control system installer or the control system manufacturer regularly employed in testing and calibration of control systems.

b. Testing shall include field tests and the performance verification test. Field tests shall demonstrate proper calibration of instrumentation, input and output devices, and operation of specific equipment. The performance verification test shall ensure proper execution of sequence of operation and proper tuning of control loops.

c. The plan for each phase of field acceptance testing shall be approved in writing before beginning that phase of testing. Furnish written notification of planned testing to Contracting Officer at least 21 days prior to testing. Include proposed test procedures with notification. The Contractor will not be allowed to start testing without written Government approval of test procedures. Test procedures shall consist of detailed instructions for complete testing to prove the performance of heating, ventilating, and air-conditioning system and control system. Include the following tests in test procedures.

d. Submit original copies of data produced, including results of each test procedure, to the Government at the conclusion of each phase of testing. Tests are subject to supervision and approval by Contracting Officer. Do not perform testing during scheduled seasonal off-periods of heating and cooling systems.

3.3.1 Test Reporting

After completion or termination of field tests and again after the performance verification test, identify, determine causes, replace, repair, or calibrate equipment which fails to meet the specification; and deliver a written report to the Government. The report shall document test results, explain in detail the nature of each failure, and corrective action taken. After delivering the performance verification test report, the Contractor shall convene a test review meeting at the job site to present results and recommendations to the Government. As a part of the test review meeting, the Contractor shall demonstrate by performing appropriate portions of field tests or the performance verification test that failures have been corrected. Based on Contractor's report and test review meeting, the Government will determine either the restart point or successful completion of testing. Do not commence required retesting until after receipt of written notification by the Government. At the conclusion of retesting, repeat the assessment.

3.3.2 Contractor's Field Testing

Calibrate field equipment and verify equipment and system operation before system is placed on-line. Include the following tests in field testing.

3.3.2.1 Tubing and Wiring Integrity Tests

Test tubing system pneumatically at 1.5 times the design working pressure

for 24 hours. Allowable leakage rate is that which produces a pressure drop 7 kPa (gage) 1 psig in 24 hours with compressed air supply turned off. Test wiring for continuity, ground faults, and open and short circuits.

3.3.2.2 System Inspection

Observe HVAC control system in shutdown condition. Check dampers and valves for proper normal positions. Document positions for the performance verification test report.

3.3.2.3 Calibration Accuracy and Operation of Input Test

Verify correct calibration and operation of input instrument. For each sensor and transmitter, including for temperature, pressure, relative humidity, and dew point inputs, record the reading at the sensor or transmitter location using calibrated test equipment. Record the output reading provided by that sensor or transmitter. Document each of these location and output readings for the performance verification test report. The test equipment shall have been calibrated within one year of the date of use in the field. Test equipment calibration shall be traceable to the measurement standard of the National Institute of Standards and Technology.

3.3.2.4 Operation of Output Test

Check the operation of output to verify correct operation. Operate analog device to minimum range (e.g., 4 mA) and maximum range (e.g., 20 mA), and measure and record actual output values.

3.3.2.5 Actuator Range Adjustment

With the controller, apply a control signal to each actuator and verify that the actuator operates properly from its normal position through to the full range of stroke position. Record actual spring ranges and normal positions for modulating control valves and dampers.

3.3.3 Coordination With HVAC System Balancing

Tune the control system after air and hydronic systems have been balanced, minimum damper positions have been set, and a report has been issued.

3.3.4 Field Test Documentation

Before scheduling the performance verification test, provide field test documentation and written certification of completion to Contracting Officer and the Naval Energy and Environmental Support Activity (NEESA), that the installed system has been calibrated, tested, and is ready to begin the performance verification test. Do not start the performance verification test prior to receiving written permission from the Government.

3.3.5 Performance Verification Test

Conduct the performance verification tests to demonstrate that the control system maintains setpoints and that the control loops are tuned for the correct sequence of operation. Conduct the performance verification test during one week of continuous HVAC and control systems operation and before final acceptance of work. Specifically, the performance

verification test shall demonstrate that the HVAC system operates properly through the complete sequence of operation (e.g., seasonal, occupied and unoccupied, warm up, etc.), for specified control sequences. Demonstrate proper control system response for abnormal conditions for which there is a specified system or controls response by simulating these conditions. Demonstrate that hardware interlocks and safety devices work as designed. Demonstrate that the control system performs the correct sequence of control.

3.3.6 Opposite Season Test

Repeat the performance verification test during an opposite season to the first performance verification test.

3.4 TRAINING

Provide a qualified instructor to conduct training courses for designated personnel in maintenance and operation of HVAC and control systems. Orientate training to the specific system being installed under the contract. Furnish audiovisual equipment and other training materials and supplies. A training day is defined as 8 hours of classroom or lab instruction, including two 15-minute breaks and excluding lunch time, Monday through Friday, during the daytime shift in effect at the training facility. For guidance, assume that the attendees have a high school education and are familiar with HVAC systems. Submit planned training schedule, agenda, and class materials to the Government at least 45 days prior to training.

3.4.1 Training Course Documentation

Training shall be based on the operation and maintenance manuals and control system training manual. Deliver manuals for each trainee with two additional sets for archiving at the project site. Include an agenda, defined objectives, and a detailed description of subject matter for each lesson.

3.4.2 Operator Training I

The first class shall be taught for a period of 5 consecutive training days at least 1 month prior to the scheduled performance verification test. The first course shall be taught in a Government-provided facility on base. Training shall be classroom instruction, but have hands-on operation of similar digital controllers. Maximum of [5] [_____] personnel shall attend the course. Upon completion of course, each student, using appropriate documentation, shall be able to perform elementary operations, with guidance, and describe general hardware and functionality of the system. Course shall include but not be limited to description of hardware and operation of the system.

3.4.3 Operator Training II

The second course shall be taught in the field, using the operating equipment at project sites for a total of 16 hours of instruction per student, in blocks of 4 hours. Maximum of [5] [_____] personnel shall attend the course. Include hands-on training under constant monitoring of instructor. Course content shall duplicate the Operator Training I course as applied to the installed system. Instructor shall determine the level of the password to be issued to each student before each session. Upon completion of the course, students shall be proficient in system

operation. Prepare a written report describing the skill level of each student at the end of the course.

3.4.4 Operator Training III

The third course shall be taught in the field, at the project site, for a period of 3 training days no later than 6 months after completion of endurance test. Maximum of [5] [_____] personnel shall attend the course. Course shall be structured to address specific topics that the students need to discuss and to answer questions concerning operation of the system. Upon completion of the course, students shall be proficient in system operation and shall have no unanswered questions regarding operation of the installed system.

3.4.5 System Maintenance Training

Course shall be taught at the project site within one month after completion of endurance test for a period of 2 training days. Maximum of [_____] personnel shall attend the course. Course shall include but not be limited to the following:

a. Physical layout for each piece of hardware

b. Troubleshooting and diagnostics procedures

c. Repair instructions

d. Preventive maintenance procedures and schedule

e. Calibration procedures

3.5 QUALIFIED SERVICE ORGANIZATION LIST

The qualified service organization list shall include names and telephone numbers of organizations qualified to service HVAC control systems.

3.6 COMMISSIONING

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NOTE: If commissioning procedures are required beyond the scope of those described in Section 23 05 93 TESTING, ADJUSTING AND BALANCING, include procedures in this paragraph.
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Commissioning of control systems is specified in the pre-field TAB engineering report described in Section 23 05 93 TESTING, ADJUSTING AND BALANCING.

3.7 SCHEDULE

Some metric measurements in this section are based on mathematical

conversion of inch-pound measurements, and not on metric measurements commonly agreed on by the manufacturers or other parties. The inch-pound and metric measurements shown are as follows:

Products	Inch-Pound	Metric
a. Pneumatic Actuators: Operating Pressure	= 25 psig	= 172 kPa (gage)
b. Transmitters: Output Signal	= 3 to 15 psi	= 21 to 103 kPa
c. Thermostat: Minimum Ranges	= 55 to 90 degrees F	= 13 to 32 degrees C
d. Thermometers: Scales	= 9 inches	= 229 mm
e. Pressure Gages: Diameter	= 2 1/2 inches	= 65 mm
f. Compressed Air Storage Tank: Minimum Working Pressure	= 200 psig	= 1379 kPa (gage)

-- End of Section --