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Preparing Activity:    NASA                      Superseding  
   UFGS-23 81 43.00 40 (April 2006)  
   NASA-15740S (December 2005)

## UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 9 October 2006

Latest change indicated by CHG tags

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DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING

SECTION 23 81 43.00 40

AIR-SOURCE UNITARY HEAT PUMPS

06/06

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AIR-SOURCE UNITARY HEAT PUMPS  
06/06

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NOTE: Delete, revise, or add to the text in this section to cover project requirements. Notes are for designer information and will not appear in the final project specification.

This mediumslope section provides minimum requirements for Heat Pump Air-Conditioning Systems for small, stand-alone facilities or buildings. The following Sections were edited and condensed to produce this Section and should not be needed:

Section 23 05 00.00 40 COMMON WORK RESULTS FOR HVAC

Section 22 10 00.00 40 PLUMBING PIPING AND PUMPS

Section 23 05 48.00 40 VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT

Section 22 07 19.00 40 PLUMBING PIPING INSULATION

Section 23 23 16.00 40 REFRIGERANT PIPING SPECIALTIES

Section 23 74 33.00 40 PACKAGED, OUTDOOR, HEATING AND COOLING MAKEUP AIR-CONDITIONERS

Section 23 31 11.11 40 DUCTS, LOW PRESSURE

Section 23 37 13.00 40 DIFFUSERS, REGISTERS, AND GRILLS

Section 23 41 13.00 40 PANEL FILTERS

Section 23 09 33.00 40 ELECTRIC AND ELECTRONIC CONTROL SYSTEM FOR HVAC

Section 23 05 93.00 40 TESTING, ADJUSTING, AND BALANCING FOR HVAC SYSTEMS

Section 26 18 39.00 40 MEDIUM-VOLTAGE MOTOR  
CONTROLLERS

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.

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PART 1 GENERAL

1.1 REFERENCES

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

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

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

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

AIR DIFFUSION COUNCIL (ADC)

ADC Standards Manual (2002-2005) Flexible Duct Performance and Installation Standards

AIR-CONDITIONING AND REFRIGERATION INSTITUTE (ARI)

ARI 210/240 (2005) Standard for Unitary Air-Conditioning and Air-Source Heat Pump Equipment

ARI 270	(1995) Standard for Sound Rating of Outdoor Unitary Equipment
ARI 340/360	(2004) Standard for Commercial and Industrial Unitary Air-Conditioning Equipment and Heat Pump Equipment
ARI 620	(2004) Standard for Self Contained Humidifiers for Residential Applications
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)	
ASHRAE 90.1	(2004; R 2005a) Energy Standard for Buildings Except Low-Rise Residential Buildings, I-P Edition
AMERICAN WELDING SOCIETY (AWS)	
AWS A5.8/A5.8M	(1992; R 2004) Specification for Filler Metals for Brazing and Braze Welding
ASME INTERNATIONAL (ASME)	
ASME B16.22	(2001) Standard for Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
ASTM INTERNATIONAL (ASTM)	
ASTM A 269	(2004) Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
ASTM A 653/A 653M	(2004a) Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM B 280	(2003) Standard Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
ASTM B 62	(2002) Standard Specification for Composition Bronze or Ounce Metal Castings
ASTM C 1071	(2000) Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material)
ASTM C 534	(2005) Standard Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form
ASTM C 547	(2003) Standard Specification for Mineral Fiber Pipe Insulation
ASTM D 1785	(2005) Standard Specification for Poly(Vinyl Chloride) (PVC), Plastic Pipe,

Schedules 40, 80, and 120

- ASTM D 2466 (2005) Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40
- ASTM D 2564 (2004) Standard Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems
- ASTM D 2855 (1996; R 2002) Standard Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings
- ASTM D 579 (2004) Standard Specification for Greige Woven Glass Fabrics

NATIONAL ENVIRONMENTAL BALANCING BUREAU (NEBB)

- NEBB TABES (2005) Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

- NFPA 220 (2006) Standard on Types of Building Construction
- NFPA 255 (2005 Ed) Standard Method of Test of Surface Burning Characteristics of Building Materials
- NFPA 70 (2005) National Electrical Code
- NFPA 90A (2002) Standard for the Installation of Air Conditioning and Ventilating Systems

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

- SMACNA 1117 (2003) Fibrous Glass Duct Construction Standards
- SMACNA 1481 (1995e2) HVAC Duct Construction Standards - Metal and Flexible

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)

- SAE J513 (1999) Refrigeration Tube Fittings - General Specifications

U.S. DEPARTMENT OF DEFENSE (DOD)

- MS MIL-A-24179 (1987a) Adhesive, Flexible Unicellular-Plastic Thermal Insulation
- MS MIL-A-3316 (1990c) Adhesives, Fire-Resistant, Thermal Insulation

U.S. DEPARTMENT OF ENERGY (DOE)

DOE CE-4 (2000) How to Buy an Energy-Efficient  
Commercial Heat Pump

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FS HH-B-100 (Rev B) Barrier Material Vapor (for Pipe,  
Duct, and Equipment Thermal, Insulation)

FS HH-I-558 (Rev C) Insulation, Blocks, Boards,  
Blankets, Felts, Sleeving (Pipe and Tube  
Covering), and Pipe Fitting Covering,  
Thermal (Mineral Fiber, Industrial Type)

UNDERWRITERS LABORATORIES (UL)

UL 181 (2005) Standard for Factory-Made Air Ducts  
and Air Connectors

UL 1995 (2005) Standard for Heating and Cooling  
Equipment

UL 555 (2002; R 2005) Standard for Fire Dampers

1.2 SYSTEM DESCRIPTION

Control Diagrams shall be submitted for heat pump air conditioning systems showing the physical and functional relationship of equipment, electrical diagrams showing size, type, and capacity of the systems, and pneumatic diagrams for air and gas systems.

Contractor shall furnish labor, materials, equipment and services to construct, install, and test a system in accordance with the contract documents having the following design specifications:

	Outdoor	Indoor
Winter	[3] [38] [_____] degrees C F DB	[20.0] [68] [_____] degrees C F DB
Summer	[32] [90] [_____] degrees C F DB [26] [78] [_____] degrees C F WB	[26] [78] [_____] degrees C F DB [57] [_____] percent RH

1.3 SUBMITTALS

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NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the

submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation 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.

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

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Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are [for Contractor Quality Control approval.] [for information only. When used, a designation following the "G" designation 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

Connection diagrams shall be submitted indicating the relations and connections of the following items. Drawings shall indicate the general physical layout of all controls, and internal tubing and wiring details.

Pipe  
Ductwork  
Heat Pump  
Humidifiers  
Controls and Instrumentation

Control Diagrams shall be submitted in accordance with paragraph entitled, "System Description," of this section.

#### SD-03 Product Data

Equipment and Performance Data shall be submitted in accordance with paragraph entitled, "General Requirements," of this section.

Manufacturer's catalog data shall be submitted for the following items in sufficient detail and scope to verify compliance with the requirements of the contract documents.

Heat Pump  
Ductwork  
Air-Diffusion Devices  
Filters  
Insulation  
Vibration Isolation



## Spare Parts

### SD-04 Samples

Manufacturer's Standard Color Chips shall be submitted in accordance with paragraph entitled, "General Requirements," of this section.

### SD-06 Test Reports

Test reports shall be submitted for the following tests in accordance with the paragraph entitled, "Tests," of this section.

Pressure Tests  
System Tests  
Operating Tests

### SD-07 Certificates

Certificates shall be submitted for the following showing conformance with the referenced standards contained in this section.

Heat Pump  
Ductwork  
Air-Diffusion Devices  
Filters  
Insulation  
Vibration Isolation  
Spare Parts

### SD-08 Manufacturer's Instructions

Manufacturer's Instructions for installation of heat pump air conditioning systems shall be submitted showing the manufacturer's recommended method and sequence of installation.

### SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals shall be submitted in accordance with paragraph entitled, "Operation and Maintenance," of this section.

## 1.4 GENERAL REQUIREMENTS

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NOTE: If Section 23 31 13.20 40 WELDING METAL DUCTWORK is not included in the project specification, applicable requirements therefrom should be inserted and the first paragraph deleted.  
If Section 26 18 39.00 40 MEDIUM-VOLTAGE MOTOR CONTROLLERS is not included in the project specification, applicable requirements therefrom should be inserted and the second paragraph deleted.  
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Section 23 31 13.20 40 WELDING METAL DUCTWORK applies to work specified in this section.

[Section 26 18 39.00 40 MEDIUM-VOLTAGE MOTOR CONTROLLERS applies to this section.]

Equipment and Performance Data shall be submitted for heat pump air conditioning systems consisting of air capacities and distribution, efficiencies and operating pressures and temperatures.

Manufacturer's Standard Color Chips samples shall be submitted by the Contractor for heat air conditioning systems.

## PART 2 PRODUCTS

### 2.1 MATERIALS

Spare parts lists and information shall be submitted meeting referenced standards within this section.

#### 2.1.1 Ductwork Materials

##### 2.1.1.1 Galvanized Steel Ductwork Materials

[Steel ductwork shall be hot dip galvanized carbon steel of lock forming quality, with regular spangle type zinc coating conforming to ASTM A 653/A 653M, Z275 G-90. Construction, metal gauge and reinforcement thickness shall conform to SMACNA 1481.]

##### 2.1.1.2 Rigid Fibrous Glass Ductwork Materials

[Rigid fibrous glass ductwork shall not be used on this project.]

[Rigid fibrous glass duct system, including tapes, adhesives, vapor barriers and joint sealers, shall have a minimum density of 80 kilogram per cubic meter 5 pounds per cubic foot, conform to requirements of NFPA 90A, and be labeled as having FM approval and UL 181, Class 1 airduct listing. System shall have a thermal conductivity of [0.45] [0.26] [\_\_\_\_\_] at 24 degrees C 75 degrees F mean temperature, a noise reduction coefficient of 0.070, and a vapor transmission rate less than 0.02 nanogram per pascal per meter 0.02 grains per square foot per hour per inch of mercury pressure differential for 25 millimeter thickness 1 inch thickness (perm). Materials shall be odorless and nonallergenic when in service. Vapor barrier shall be factory applied, and construction shall be in accordance with SMACNA 1117.]

##### 2.1.1.3 Flexible Duct

[Wire reinforced flexible duct runouts to air outlets shall consist of a factory fabricated chloroprene or vinyl impregnated and coated fibrous glass cloth bonded to and supported by a corrosion protected spring steel helix. Fabric may be a laminate of metallic film and fibrous glass. Runout shall not exceed [\_\_\_\_\_] millimeter feet in length and shall comply with NFPA 90A and UL 181. Working pressure rating of ducting shall be not less than three times maximum system pressure, and temperature range shall be minus 29 to plus 79 degrees C 20 to plus 175 degrees F.]

#### 2.1.2 Insulation - Ductwork and Pipe

Thermal insulation system materials shall be non-combustable, as defined by NFPA 220. Adhesives, coatings, jacketing, and other thermal insulating materials, except cellular elastomers, shall have a flame spread

classification not to exceed [25] [\_\_\_\_], and a smoke developed classification not to exceed [50] [\_\_\_\_], as determined in accordance with NFPA 255. Adhesives, coatings, and sealants shall have published or certified temperature ratings suitable for the range of temperatures normal for the surfaces to which they are to be applied.

#### 2.1.2.1 Acoustic Duct Lining

Acoustic duct lining shall be [50] [2] [\_\_\_\_] millimeter inch thick fibrous glass conforming to ASTM C 1071. Liner composition shall be deeply impregnated with chloroprene on the surface exposed to the airstream and shall conform to fire hazard requirements of NFPA 90A. Air stream side of the liner shall be capable of withstanding air velocities of 20.32 meter per second 4,000 feet per minute without delamination or erosion.

Mineral fiber shall conform to FS HH-I-558, Form A, Class 1 for rigid boards, and Form B, Class 6 for flexible blankets.

Mineral fiber pipe insulation shall conform to ASTM C 547, Class 1, [jacketed] [plain].

Cellular elastomer shall conform to ASTM C 534, except that the water vapor permeability shall not exceed 17 nanogram per pascal second square meter 0.30 perms.

#### 2.1.2.2 Adhesives

Fire resistant adhesive for attaching fibrous glass insulation to metal surfaces shall be a nonflammable solvent base, synthetic rubber type, conforming to MS MIL-A-3316, Class 2.

Fire resistant adhesive for bonding fibrous glass cloth to itself and to other fibrous glass insulation materials shall conform to MS MIL-A-3316, Class 1.

Adhesive for cellular elastomer insulation shall be a solvent cutback chloroprene elastomer conforming to MS MIL-A-24179, Type II, Class 1, and shall be a type approved by the insulation manufacturer.

#### 2.1.2.3 Jacketing and Vapor Barriers

Jacketing for mineral fiber duct insulation shall be a 3-ply laminate of 155 newton 35 pound white bleached kraft bonded to not less than 0.025 millimeter 1-mil thick aluminum foil and reinforced with glass fiber. With foil exposed, flame spread rating shall be [5] [\_\_\_\_] and smoke developed rating shall be [0] [\_\_\_\_]. With kraft exposed, flame spread rating shall be [25] [\_\_\_\_] and smoke developed rating shall be [15] [\_\_\_\_]. Water vapor permeance of the composite shall be 1.15 nanogram per pascal second square meter 0.02 perm.

Vapor barrier material for mineral fiber pipe insulation shall conform to FS HH-B-100, Type I (low vapor transmission, high puncture resistance).

Glass reinforcing cloth shall conform to ASTM D 579.

### 2.2 AIR SOURCE UNITARY HEAT PUMP

Unit shall be a split type, factory made assembly, consisting of an indoor section and an outdoor section, designed to work together to provide year

round heating and cooling, air-circulating, ventilating, air-cleaning, and dehumidifying functions. The separate sections shall be standard commercial products of the same manufacturer, and shall have ratings based on their being used as matched assemblies.

Unit shall be certified as complying with provisions of ARI 210/240, ARI 270, ARI 340/360, and UL 1995, as applicable. Minimum [Coefficient of Performance (COP)] [Energy Efficiency Ratio (EER)] shall be in accordance with the recommended levels specified in DOE CE-4 when tested in accordance with ARI 210/240 or ARI 340/360, as applicable. Rating shall be at unit maximum speed. Refrigerant shall be non-CFC.

#### 2.2.1 Indoor Section

Indoor section shall be a factory assembled unit consisting of indoor coil, centrifugal blower with forward [\_\_\_\_\_] sloped blades, motor, motor controls, filters, [electric resistance heaters,] enclosure, and condensate pan, with controls, relief devices, piping, wiring, controls and accessories required for operation. [Plenum chamber and grille] [Provision for connecting the unit to a duct system] shall be provided for delivery of air to the conditioned space. Section shall be of double-wall construction.

#### 2.2.2 Outdoor Section

Outdoor section shall be a factory assembled unit consisting of outdoor coil, propeller type fans arranged for vertical [\_\_\_\_\_] discharge, refrigerant circuit with filter-dryer, and [\_\_\_\_\_] hermetically sealed compressor with crankcase heater, internal overload protection and pressure relief valve, all contained in a weather resistant outer casing. Defrost controls, and necessary tubing, piping, controls, control circuits, and required accessories shall be provided.

Time delay relays shall be provided for sequence starting where two or more compressors are used, and to prevent short cycling or rapid restart after shut down. System shall be factory precharged with oil and refrigerant.

Outer casing shall be provided with [lifting attachments and have] easily removable panels for access to all parts of the equipment. Air inlet and discharge grilles with birdscreens shall be provided. [Outdoor section to be treated for use in coastal environment.]

#### 2.2.3 Electrical Requirements

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NOTE: Ability to open and/or remove access covers is required for maintenance activities. In addition, access may be required to inspect this device while circuits are energized (for example, using infrared imaging). Minimum distances to energized circuits is specified in OSHA Standards Part 1910.333 (Electrical - Safety-Related work practices). OSHA Standards are available on the internet.  
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Each section shall be equipped with a main power panel and shall include complete branch circuit protection for every electrical component. Main power panel shall completely protect the unit from primary single phasing and overcurrent. Fuses and protective devices shall be provided by the

manufacturer and installed at the factory. Components shall be designated with a code and shall be called out on a wiring diagram for servicing of the power panel. Panel shall have terminal blocks, with the terminals clearly identified for easy connection, for the main power supply and all auxiliary connections.

Access to the main power panel shall be possible without interrupting the operation of the unit. Access shall be sufficient to safely check the voltage and current of each component. There shall be separate doors for access to the main power terminal block and the auxiliary terminals. All components of the main power panel and all control devices shall be UL listed. Power and control devices, including motor starters, relays, timers, fuses, circuit breakers, switches, and other electrical devices shall be in accordance with section 26 05 73.00 40 OVERCURRENT PROTECTIVE DEVICE COORDINATION STUDY. Internal wiring shall be not less than [No. 14 AWG, 105 degree C, 1.984 millimeter 5/64 inch insulation, appliance type] [\_\_\_\_\_] wire for power wiring, and not less than [No. 18 AWG, 105 degree C, 0.794 millimeter 2/64 inch insulation] [\_\_\_\_\_] wire for control wiring. Wiring shall be in accordance with UL and NFPA 70 requirements. Each wire shall be identified at every termination with a wire number matching the wiring diagram and control schematic. Wire identification shall utilize preprinted heat-shrink wire sleeves. Hand lettering or marking is not acceptable.

All motors shall have copper windings, be equipped with [heavy duty ball bearings] [sealed permanently lubricated bearings], have internal overload protection, have protection against primary single phasing, and be UL listed. Motors shall be sized by the manufacturer and be rated in accordance with the requirements of section 26 18 39.00 40 MEDIUM-VOLTAGE MOTOR CONTROLLERS.

Equipment shall operate on [208] [230] [\_\_\_\_\_] volt, [single] [3] phase, 60 hertz electrical service.

## 2.3 HUMIDIFIERS

[Self contained, atomizing, electrically operated humidifiers conforming to ARI 620 shall be provided.]

## 2.4 DUCTWORK COMPONENTS AND ACCESSORIES

### 2.4.1 Flexible Connectors

Connectors shall be UL listed, 6.10 kilogram per square meter 20 ounce, fire-retardant, airtight, woven fibrous glass cloth impregnated with chloroprene. Clear width, not including clamping section, shall be 80 to 125 millimeter 3 to 5 inches.

### 2.4.2 Dampers

Manual volume damper construction shall conform to SMACNA 1481, unless otherwise specified. Damper shall be equipped with an indicating quadrant regulator, with a locking feature externally located and easily accessible for adjustment. Where damper rod lengths exceed 760 millimeter 30 inches, a quadrant regulator shall be provided at each end of the damper shaft.

NFPA 90A fire dampers, constructed and labeled in accordance with UL 555 shall be provided at firewall barriers as indicated. For link loads in excess of 90 newton 20 pounds, UL-approved quartzoid links shall be

provided.

#### 2.4.3 Air Diffusion Devices

Diffusers, registers, and grilles shall be identified on the drawings and shall be listed in latest [ADC Standards Manual](#), or be certified as having been tested and rated in accordance with [ADC Standards Manual](#).

Construction and mounting shall prevent flutter, rattle, or vibration. Gaskets shall be provided for terminal supply air devices mounted in finished surfaces.

[Color selection shall [match architectural background] [be from manufacturer's standard color chips.]]

##### 2.4.3.1 Round Ceiling Diffusers

Round, [adjustable pattern,] stamped or spun, multicore type diffuser to discharge air in 360 degree pattern, with sectorizing baffles where indicated. Project diffuser collar [not more than [25 millimeter one inch](#)] above ceiling face and connect to duct with duct ring. [In plaster ceilings, provide plaster ring and ceiling plaque.] Fabricate of steel with factory applied baked enamel [off white] [\_\_\_\_\_] finish. Provide [radial opposed blade] [butterfly] [combination splitter] damper and multi-louvered equalizing grid with damper adjustable from diffuser face.

##### 2.4.3.2 Rectangular Ceiling Diffusers

Rectangular, [adjustable pattern,] stamped, multicore type diffuser to discharge air in 360 degree pattern with sectorizing baffles where indicated. Provide [surface mount] [snap in] [inverted T-bar] [spline] type frame. [In plaster ceilings, provide plaster frame and ceiling frame.] Fabricate of steel with factory applied baked enamel [off white] [\_\_\_\_\_] finish. Provide [radial opposed blade] [butterfly] [combination splitter] damper and multi-louvered equalizing grid with damper adjustable from diffuser face.

##### 2.4.3.3 Perforated Face Ceiling Diffusers

Perforated face with fully adjustable pattern and removable face. Provide [surface mount] [snap in] [inverted T-bar] [spline] type frame. [In plaster ceilings, provide plaster frame and ceiling frame.] Fabricate of steel with steel or aluminum frame and factory applied baked enamel [off white] [\_\_\_\_\_] finish. Provide [radial opposed blade] [butterfly] [combination splitter] damper and multi-louvered equalizing grid with damper adjustable from diffuser face.

##### 2.4.3.4 Modified Light Troffer Diffusers

[Single] [Double] plenum type constructed independent of light troffers with volume and pattern controllers, [[100](#)] [[125](#)] [[150](#)] [millimeter](#) [[4](#)] [[5](#)] [[6](#)] [inch](#) round or oval [top] [side] air inlet. Match diffusers to light troffers and connect in airtight connection without tools. Fabricate of galvanized steel with welded or soldered joints and finish matte black inside.

##### 2.4.3.5 Ceiling Supply Registers/Grilles

Streamlined and individually adjustable curved blades to discharge air

along face of grille, [one-way] [two-way] deflection. Fabricate [25] [32] millimeter [1] [1-1/4] inch margin frame with [countersunk screw] [concealed] mounting and gasket. Fabricate of aluminum extrusions with factory applied [clear lacquer] [prime coat] [\_\_\_\_\_] finish. Provide integral, gang-operated opposed blade dampers with removable key operator, operable from face.

#### 2.4.3.6 Ceiling Exhaust and Return Registers/Grilles

Streamlined blades, depth of which exceeds 20 millimeter 3/4 inch spacing, with spring or other device to set blades, [vertical] [horizontal] face. Fabricate [25] [32] millimeter [1] [1-1/4] inch margin frame with [countersunk screw] [concealed] mounting. Fabricate of steel with 1.0 millimeter 20-gage minimum frames and 0.85 millimeter 22-gage minimum blades, steel and aluminum with 1.0 millimeter 20-gage minimum frame, or aluminum extrusions, with factory applied [baked enamel] [prime coated] [clear lacquer] [\_\_\_\_\_] finish. Where not individually connected to exhaust, provide integral, gang-operated opposed blade campers with removable key operator, operable from face. In gymnasiums, blades shall be front pivoted, welded in place or securely fastened to be immobile.

#### 2.4.3.7 Ceiling Grid Core Exhaust and Return Registers/Grilles

Fixed grilles shall have 13 by 13 by 13 millimeter 1/2 by 1/2 by 1/2 inch louvers. Fabricate [25] [32] millimeter [1] [1-1/4] inch margin frame with [countersunk screw mounting.] [concealed mounting.] [lay-in frame for suspended grid ceilings.] Fabricate of aluminum with factory applied [clear lacquer] [baked enamel] finish. Where not individually connected to exhaust fans, provide integral, gang-operated opposed blade dampers with removable key operator, operable from face.

#### 2.4.3.8 Ceiling Linear Exhaust and Return Grilles

Streamlined blades shall have 90 degree [one-way] [two-way] deflection, 3 by 20 millimeter on [6] [15] millimeter 1/8 by 3/4 inch on [1/4] [1/2] inch centers. Fabricate [25] [32] millimeter [1] [1-1/4] inch [\_\_\_\_\_] margin frame [extra heavy for floor mounting,] with [countersunk screw] [concealed] mounting. Fabricate of steel with 1.0 millimeter 20-gage minimum frames and 0.85 millimeter 22-gage minimum blades, steel and aluminum with 1.0 millimeter 20-gage minimum frame, or aluminum extrusions, with factory applied [baked enamel] [prime coated] [clear lacquer] [\_\_\_\_\_] finish. Where not individually connected to exhaust fans, provide integral, gang-operated opposed blade dampers with removable key operator, operable from face.

#### 2.4.3.9 Ceiling Slot Diffusers

Continuous [13] [20] [25] millimeter [1/2] [3/4] [1] inch wide slot, [one] [two] [three] [four] slots wide, with adjustable vanes for left, right, or vertical discharge. Fabricate of aluminum extrusions with factory applied [clear lacquer] [baked enamel] [\_\_\_\_\_] finish. Fabricate [25] [32] millimeter [1] [1-1/4] inch margin frame with [countersunk screw] [concealed] [support clips for suspension system] [support clips for T-bar] mounting and gasket, [mitered end border.] [open end construction.] [end cap.]

#### 2.4.3.10 Wall Supply Registers/Grilles

Streamlined and individually adjustable blades, depth of which exceeds 20

millimeter 3/4 inch maximum spacing with spring or other device to set blades, [vertical] [horizontal] face, [single] [double] deflection. Fabricate [25] [32] millimeter [1] [1-1/4] inch margin frame with [countersunk screw] [concealed] mounting and gasket. Fabricate of steel with 1.0 millimeter 20-gage minimum frames and 0.85 millimeter 22-gage minimum blades, steel and aluminum with 1.0 millimeter 20-gage minimum frame, or aluminum extrusions, with factory applied [baked enamel] [prime coat] [clear lacquer] [\_\_\_\_\_] finish. Provide integral, gang-operated opposed blade dampers with removable key operator, operable from face. In gymnasiums, blades shall be front pivoted, welded in place or securely fastened to be immobile.

#### 2.4.3.11 Wall Supply Registers/Grilles

Streamlined and individually adjustable curved blades to discharge air along face of grille, [one-way] [two-way] deflection. Fabricate [25] [32] millimeter [1] [1-1/4] inch [\_\_\_\_\_] margin frame with [countersunk screw] [concealed] mounting and gasket. Fabricate of aluminum extrusions with factory applied [clear lacquer] [prime coat] [\_\_\_\_\_] finish. Provide integral, gang-operated opposed blade dampers with removable key operator, operable from face.

#### 2.4.3.12 Wall Exhaust and Return Registers/Grilles

Streamlined blades, depth of which exceeds 20 millimeter 3/4 inch spacing, with spring or other device to set blades, [vertical] [horizontal] face. Fabricate [25] [32] millimeter [1] [1-1/4] inch [\_\_\_\_\_] margin frame with [countersunk screw] [concealed] mounting. Fabricate of steel with 1.0 millimeter 20-gage minimum frames and 0.85 millimeter 22-gage minimum blades, steel and aluminum with 1.0 millimeter 20-gage minimum frame, or aluminum extrusions, with factory applied [baked enamel] [prime coated] [clear lacquer] [\_\_\_\_\_] finish. Where not individually connected to exhaust fans, provide integral, gang-operated opposed blade dampers with removable key operator, operable from face.

#### 2.4.3.13 Wall Grid Core Exhaust and Return Registers/Grilles

Fixed grilles of 13 by 13 by 13 millimeter 1/2 by 1/2 by 1/2 inch louvers. Fabricate [25] [32] millimeter [1] [1-1/4] inch [\_\_\_\_\_] margin frame with [countersunk screw mounting.] [concealed mounting.] [lay-in frame for suspended grid ceilings.] Fabricate of aluminum with factory applied [clear lacquer] [baked enamel] finish. Where not individually connected to exhaust fans, provide integral, gang-operated opposed blade dampers with removable key operator, operable from face.

#### 2.4.3.14 Linear Wall Registers/Grilles

Streamlined blades with [0] [15] degree deflection, 3 by 20 millimeter on [6] [15] millimeter 1/8 by 3/4 inch on [1/4] [1/2] inch centers. Fabricate of aluminum extrusions, with factory applied [clear lacquer] [prime coat] [\_\_\_\_\_] finish. Fabricate [25] [32] millimeter [1] [1-1/4] inch [\_\_\_\_\_] margin frame with [countersunk screw] [concealed] mounting and gasket. Provide integral [gang-operated opposed blade] [hinged single blade] damper with removable key operator, operable from face.

#### 2.4.3.15 Linear Floor Supply Registers/Grilles

Streamlined blades with [0] [15] degree deflection, 3 by 20 millimeter 1/8 by 3/4 inch on [6] [15] millimeter on [6] [15] millimeter [1/4] [1/2] inch



on [1/4] [1/2] inch centers. Fabricate of aluminum extrusions with factory applied clear lacquer finish. Fabricate [25] [32] millimeter [1] [1-1/4] inch [\_\_\_\_\_] margin heavy frame with [countersunk screw mounting] [concealed mounting and gasket] [, and mounting frame.] Provide integral [gang-operated opposed blade] [hinged single blade] damper with removable key operator, operable from face.

#### 2.4.3.16 Floor Supply Registers/Grilles

Individually adjustable blades, wide stamped border, single or double blade damper with set screw adjustment. Fabricate of steel, welded construction, with factory applied baked enamel finish.

#### 2.4.3.17 Door Grilles

V-shaped louvers of 1.0 millimeter 20-gage steel, one inch deep on 13 millimeter 1/2 inch centers. Provide 1.0 millimeter 20-gage steel frame with auxiliary frame to give finished appearance on both sides of door, with factory applied prime coat finish.

#### 2.4.4 Duct Hangers

Duct hangers and mill rolled steel in contact with galvanized surfaces shall be galvanized steel or painted with inorganic zinc.

### 2.5 FILTERS

Filters shall be a [25] [50] millimeter [1] [2] inch thick panel, installed in a filter box at the air handler for such purpose or installed in a return air filter grille and must be easily replaceable having throw away frames and media, standard dust holding capacity, and 1.778 meter per second 350 feet per minute (fpm) maximum face velocity. [A stiffener bar shall be provided for additional support.]

[Air filter gages or manometers shall be provided for each type filter assembly. Gages shall be the dial indicator type, graduated to read 0 to 500 pascal 0 to 2 inches wg.]

### 2.6 PIPE, VALVES AND SPECIALTIES

#### 2.6.1 Pipe

##### 2.6.1.1 Refrigeration Piping and Specialties

Refrigerant piping shall be as follows:

Tubing:

0-22.3 millimeter outside diameter (od)	Annealed seamless copper tubing temper O60 conforming to ASTM B 280
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Over 22.3 millimeter od	Hard drawn "ACR" seamless copper tubing temper H58 conforming to ASTM B 280
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Fittings:

0-22.3 millimeter od	Flared type conforming to SAE J513 or copper socket joint type conforming to ASME B16.22
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Over 22.3 milli-meter od	Copper socket joint type conforming to ASME B16.22
0-7/8 inch outside diameter (od)	Annealed seamless copper tubing temper O60 conforming to ASTM B 280
Over 7/8 inch od	Hard drawn "ACR" seamless copper tubing temper H58 conforming to ASTM B 280

Fittings:

0-7/8 inch od	Flared type conforming to SAE J513 or copper socket joint type conforming to ASME B16.22
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Over 7/8 inch od	Copper socket joint type conforming to ASME B16.22
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Soldered joints shall be preformed using 15 percent silver solder brazing alloy conforming to AWS A5.8/A5.8M.

Condensate drain pipe shall be [PVC] [copper].

[Humidifier dispersion piping shall be [copper] [stainless steel].]

#### 2.6.1.2 Stainless Steel Tubing

Stainless steel tubing shall be AISI Type 304, conforming to ASTM A 269.

#### 2.6.1.3 Polyvinyl Chloride (PVC) Pipe

PVC pipe shall be Schedule 40, and conform to ASTM D 1785.

Fittings shall be Socket Type, Schedule 40, PVC material conforming to ASTM D 2466.

Solvent cement for pipe and fittings shall conform to ASTM D 2564. Thread lubricant shall be as recommended by manufacturer of pipe and fittings.

#### 2.6.2 Valves

Valve bodies, DN50 2 inch iron pipe size (ips) and smaller, shall be bronze with screwed end connections. Valve bodies, DN65 2 1/2 inch ips and larger, shall be cast iron with flanged end connections.

Valves shall be single seated for dead-end service except where otherwise indicated or specified.

Drain, vent, and gauge cocks shall be T-head or lever handle, ground key type, with washer and screw, constructed of polished ASTM B 62 bronze, and rated 862 kilopascal 125-psi working steam pressure (wsp). End connections shall suit the service, with or without union and nipple, as required.

#### 2.7 VIBRATION ISOLATION PROVISIONS

Equipment vibration isolation shall be [as recommended by the equipment manufacturer.] [closed spring mount with top and bottom housing separated with neoprene rubber stabilizers.] [open spring mount with stiff springs (horizontal stiffness equal to vertical stiffness.)] [open spring mount with springs, heavy mounting frame, and limit stop.] [closed spring mount with stiff springs and limit stop.] [closed spring hanger with acoustic washer.] [closed spring hanger with 25 millimeter one inch thick acoustic

isolator.] [elastomer mount with threaded insert and hold down holes.] [neoprene jacketed pre-compressed molded glass fiber.] [rubber waffle pads, 30 durometer, minimum 13 millimeter 1/2 inch thick, maximum loading 275 kilopascal 40 psi. Use neoprene in oil or exterior locations.] [ 13 millimeter 1/2 inch thick rubber waffle pads bonded to each side of 6 millimeter 1/4 inch thick steel plate.]

Rubber shall be natural rubber. Elastomer shall be chloroprene. Shore A durometer measurement of both materials shall range between 40 and 60.

Inorganic materials such as precompressed, high-density, fibrous glass encased in resilient moisture impervious membrane may be provided in lieu of natural rubber and elastomers.

\*\*\*\*\*  
NOTE: Refer to Section 23 05 48.00 40 VIBRATION AND  
SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT if  
design may induce vibration considerations.  
\*\*\*\*\*

## 2.8 CONTROLS AND INSTRUMENTATION

Automatic temperature and humidity control systems shall include all equipment, instruments, and accessories required for proper operation. Controls may be electric, pneumatic, electronic, or any combination thereof. Thermostat shall be low voltage type with Fan Auto-Off and Heat-Off-Cool settings for heating and cooling temperature control. Thermostat location shall be as indicated. Thermostat shall conform to requirements established by ASHRAE 90.1.

Duct humidistats shall be insertion, proportioning type, reverse acting, with adjustable minimum throttling range no greater than 2 percent relative humidity, and shall be capable of maintaining relative humidity within this range for relative humidity of 20 to 80 percent and temperatures to 66 degrees C 150 degrees F.

## 2.9 COATINGS

Finish coating for cellular elastomer insulation shall be a polyvinyl chloride lacquer approved by the insulation manufacturer.

## PART 3 EXECUTION

### 3.1 GENERAL INSTALLATION REQUIREMENTS

Equipment shall be installed in accordance with manufacturer's printed instructions and recommendations.

Except where shown in dimensional detail, exact locations of mechanical equipment, ducts, and piping are not shown on design drawings. Materials, including offsets, bends, elbows, or other elements that may be required for the work shall be provided and installed by the Contractor, subject to approval by the Contracting Officer.

[Brass] [Aluminum] [\_\_\_\_\_] identification tags carrying manufacturer's name, address, equipment type or style, catalog number or model, and serial number, shall be securely attached to major equipment components.

### 3.2 DUCTWORK

Duct strength shall be adequate to prevent distortion under pressure or vacuum created by fast closure of ductwork devices. Ducts shall be secured to the building and shall be supported to prevent vibration and pulsation under operating conditions.

For metal duct sizes through 300 millimeter 12 inches, corner seams shall be Pittsburgh lock or button-punch snap lock, unless duct manual indicates Pittsburgh lock. For metal duct sizes 330 millimeter 13 inches and larger, only Pittsburgh corner locks shall be used. Acme lock shall be used for sheet joining where sheets are not cross broken.

Flanged joints shall be gasketed with chloroprene full face gaskets.

Turning vanes shall be installed at 90 degree elbows.

Where the size or shape of a duct changes, the transition shall not exceed 15 degrees from the straight run of duct connected thereto.

Manual balancing dampers of the splitter, butterfly, or multilouver type, shall be provided where indicated to balance each respective main and branch duct.

Fan inlets and outlets shall be connected to upstream and downstream components by treated woven cloth connectors. Connectors shall be installed only after system fans are operative and vibration isolators have been adjusted.

Duct supports shall be vibration isolated from structure. Selection of the hanging system shall, in general, be at the Contractor's option. After system startup, any duct support device that vibrates or could cause failure of a member or damage to ducting shall be replaced, or the condition alleviated, at no added cost to the government.

#### 3.2.1 Metal Ductwork

Sheet metal ductwork installation shall be in accordance with SMACNA 1481, NFPA 90A, and as indicated.

Dampers located behind architectural intake or exhaust louvers shall be enclosed by a rigid sheet metal collar and sealed to building construction with elastomers for complete air tightness.

Outside air intake ducts and plenums shall be sheet metal and shall have soldered watertight joints.

Access door construction shall be in accordance with SMACNA 1481. Doors that leak shall be made airtight at no additional cost to the government.

Friction rod assemblies and perforated strap hangers are not acceptable.

#### 3.2.2 Fibrous Glass Ductwork

[Fibrous glass ductwork shall not be used on this project.]

Fibrous glass ductwork shall be in accordance with SMACNA 1117, NFPA 90A, and manufacturer's instructions.

Minimum thickness of rectangular duct shall be 25 millimeter. 1 inch. Duct reinforcement shall be in accordance with SMACNA 1117.

Cut ends and edges of duct to be joined in the field shall be coated with a suitable mastic or cement to prevent delamination or erosion. Longitudinal joints shall appear as straight lines.

Control rods and similar shaft penetrations shall be made through sheet metal reinforcements on both sides of duct.

Rectangular ducts shall be supported either from joint reinforcement or by trapeze hangers installed to prevent edge cutting of duct.

Fibrous glass duct shall have internal metal reinforcement around entire duct perimeter at points of access, and openings shall be framed with sheet metal.

### 3.2.3 Flexible Ductwork

Flexible duct runouts shall be no longer than necessary for the application, [\_\_\_\_\_] millimeter feet maximum, and shall be fully extended when installed.

Flexible duct shall be joined and attached in accordance with SMACNA 1481.

### 3.2.4 Air Diffusion Device Installation

Wall mounted supply registers shall be mounted 150 millimeter 6 inches below ceiling.

Wall mounted return registers shall be mounted 150 millimeter 6 inches above the finished floor.

Registers and grilles installed in vertical surfaces shall have horizontal face bars set downward at approximately 35 degrees from vertical.

Registers and grilles installed in horizontal surfaces shall have face bars set straight and parallel to short dimension.

Where an air-diffusion device is shown as being installed on the side, top, or bottom of a duct, and whenever a branch takeoff is not of the splitter type, radius tap-ins shall be constructed in accordance with SMACNA 1481.

## 3.3 PIPE INSTALLATION

Connections between steel and copper piping shall be electrically isolated from each other with dielectric couplings (or unions), or flanged with gaskets rated for the service.

Final connections to equipment shall be made with unions or flanges.

Sleeves shall be provided where piping passes through roofs and masonry or concrete walls and floors. Sleeves shall be caulked watertight.

PVC piping shall be installed as indicated and in accordance with the manufacturer's installation instructions. Joints shall be threaded or solvent cemented in conformance with ASTM D 2855.

Piping, including that which is painted, insulated, or concealed in

accessible spaces, shall be labeled to designate service and flow direction.

Condensate drain piping shall be provided with a P-trap.

### 3.4 INSULATION

Insulation shall not be applied to system or component surfaces until they have been tested and approved.

Materials shall be applied in accordance with the recommendations of the manufacturer, except as otherwise specified.

Surfaces shall be clean and free of oil and grease before insulation adhesives or mastics are applied.

Contours on exposed work shall be smooth and continuous. Adhesives shall be applied for full coverage.

Insulation shall not impede access to duct covers/doors used for duct cleaning and/or maintenance.

#### 3.4.1 Acoustic Duct Lining

Acoustic duct lining shall be applied in cut to size pieces attached to the interior of sheetmetal ductwork with fire resistant adhesive. Top and bottom pieces shall lap the side pieces and, in addition, shall be secured with pins and speed washers or cup head pins 300 millimeter 12 inches on center, maximum, and within 50 millimeter 2 inches of each edge. Pins and washers shall be flush with the surface of the duct liner, and all breaks and punctures of the liner shall be sealed with fire-resistant adhesive. Exposed edges of the coated liner, and at joints where the lining will be subject to erosion, shall be heavily brush-coated with adhesive and, where necessary, with metal nosing to prevent delamination of the glass fibers. Duct liner may also be applied to flat sheet metal with fire-resistant adhesive prior to forming duct through the sheet metal brake. At top and bottom surfaces of the duct, lining shall be secured by pins or adhered clips as specified for cut to size pieces. Lining shall not be used in the first 3000 millimeter 10 feet air handler.

#### 3.4.2 Cellular Elastomer

Refrigerant suction line piping surfaces [and] [condensate drains] [and] [humidifier dispersion piping] shall be covered with [10] [13] millimeter [3/8] [1/2] inch thick flexible cellular elastomer preformed insulation. Vapor seal shall be maintained. Insulation shall be cemented into continuous material with a solvent cutback chloroprene adhesive applied for 100 percent coverage to both surfaces.

[Surfaces exposed to view or ultraviolet light shall be finished with a 0.051 millimeter 2 mil minimum dry film thickness of a polyvinyl chloride lacquer, with a minimum of 2 coats.]

#### 3.4.3 Flexible Mineral Fiber with Jacket

Sheet metal duct not lined internally with acoustic duct lining shall be covered with flexible mineral fiber duct insulation with factory attached vapor barrier jacket. Vapor seal shall be maintained. Jacket overlap shall not be less than 50 millimeter 2 inches.

[Insulation shall be cemented to sheet metal surfaces with vapor-barrier adhesive.]

Insulation on rectangular or square ducting with side or bottom surface dimensions over 760 millimeter 30 inches shall be cemented and impaled on pins secured to the duct surface, then locked by means of flush pin caps. Pins shall be clipped flush with face of cap. Pins shall be 300 millimeter 12 inches on center, placed not more than 50 millimeter 2 inches from duct edges, with 2 rows of pins per surface minimum. Pins shall be sealed with outdoor vapor barrier coating and vapor barrier duct tape.

When insulation is in place, total thickness shall not be reduced by more than 12.7 millimeter 0.5 inches, and no condensation shall appear on any surface while the system is operating.

Jackets, jacket flaps, and bands shall be securely cemented in place with vapor barrier adhesive. Jacketing bands for butt joints shall be not less than 100 millimeter 4 inches wide. In lieu of jacketing bands, pressure sensitive vapor barrier tape not less than 80 millimeter 3 inches wide may be used to seal horizontal and transverse seams.

[Rigid board mineral fiber insulation shall be used where penetrations through sleeves or prepared openings occur.]

Duct insulation at fire dampers shall be as indicated.

Duct insulation terminating at insulated or uninsulated sheet metal and equipment surfaces, supports, damper fittings, walls and similar penetration and construction points shall be sealed with outdoor vapor barrier coating and, where lengths exceed 610 millimeter 24 inches, be flashed with glass cloth tape and sheet metal trimming. Glass cloth tape shall be in 2 layers with minimum overlap of 80 millimeter 3 inches imbedded in 1.58 millimeter 1/16 inch minimum dry-film thickness of outdoor vapor barrier coating.

### 3.5 VIBRATION ISOLATION

Air conditioning equipment shall be vibration isolated from building structure using vibration isolators and from connecting ductwork using flexible connectors as specified.

### 3.6 CONTROLS AND INSTRUMENTATION

Duct humidistats shall be mounted [on outside of duct, with sensing element within duct] [as indicated].

Tubing shall be concealed, except in mechanical rooms or areas where other piping is exposed.

Hard drawn copper tubing shall be used in all exposed areas. Hard drawn or annealed tubing shall be used when concealed. Tubing shall be cut square, burrs removed, and surfaces cleaned before assembly of joints. Copper tubing shall be pressure tested. Copper joints that fail pressure tests shall be remade with new materials, including pipe or tubing fittings and filler metal.

Terminal single lines shall be hard-drawn copper tubing, except that where the run is less than 300 millimeter 12 inches, plastic tubing may be used.

Plastic tubing, in mechanical rooms or other spaces where copper tubing is exposed, shall be run within adequately supported metal raceways or in metallic or plastic electric conduit.

### 3.7 TESTS

\*\*\*\*\*  
NOTE: The Systems Engineer/Condition Monitoring Office/Predictive Testing Group should inspect the installation during acceptance testing using advanced monitoring technologies such as Infrared Imaging or Ultrasonic Listening. These technologies can identify insulation voids, insulation settling, and system/pressure/vacuum leaks.  
\*\*\*\*\*

Entire system shall be tested and balanced per NEBB TABES to provide specified quantities of air, plus or minus 10 percent, and to ensure that each piece of equipment and each system operates in accordance with the manufacturer's instructions.

Fire dampers shall be tested for proper operation in presence of the Contracting Officer, by activating fusible link with localized heat.

The HVAC system, when properly installed, shall be tested and balanced per NEBB TABES to deliver air flows from each supply register within 10 percent of design specification.

Final test reports shall be provided to the Contracting Officer. Reports shall have a cover letter/sheet clearly marked with the System name, Date, and the words "Final Test Reports - Forward to the Systems Engineer/Condition Monitoring Office/Predictive Testing Group for inclusion in the Maintenance Database."

Pressure Tests, System Tests and Operating Tests shall be performed.

### 3.8 OPERATION AND MAINTENANCE

Contractor shall submit [6] [\_\_\_\_\_] copies of the Operation and Maintenance Manuals 30 calendar days prior to testing the heat pump air conditioning systems. Data shall be updated and resubmitted for final approval no later than 30 calendar days prior to contract completion.

-- End of Section --