

UFGS-23 31 13 (February 2009)

3.3 APPLICATION

- 3.3.1 Low Pressure Sheet Metal Ducts
 - 3.3.1.1 Longitudinal Duct Seams
 - 3.3.1.2 Joints and Gaskets
 - 3.3.1.3 Flexible Duct Joints
 - 3.3.1.4 Square Elbows
 - 3.3.1.5 Radius Elbows
 - 3.3.1.6 Outlets, Inlets, And Duct Branches
 - 3.3.1.7 Duct Transitions
 - 3.3.1.8 Branch Connections
 - 3.3.1.9 Access Openings
 - 3.3.1.10 Plenum Construction
 - 3.3.1.11 Manual Volume Dampers
 - 3.3.1.12 Flexible Connectors For Sheet Metal
 - 3.3.2 Rectangular Sheet Metal Ducts
 - 3.3.2.1 Medium-Pressure Gages, Joints, And Reinforcement
 - 3.3.2.2 Medium- And High-Pressure Branches, Inlets, Outlets
 - 3.3.2.3 High-Pressure Gages, Joints, And Reinforcement
 - 3.3.3 Round Sheet Metal Ducts
 - 3.3.3.1 Duct Gages, Joints, And Reinforcement
 - 3.3.3.2 Duct Transitions
 - 3.3.4 Round, High Pressure, Sheet Metal Duct Installation
 - 3.3.4.1 Joints
 - 3.3.4.2 Insulation Ends
 - 3.3.5 Transverse Reinforcement Joints
 - 3.3.6 Joint Gaskets
 - 3.3.7 Radius Elbows
 - 3.3.8 Plenum Connections
 - 3.3.9 Access Openings
 - 3.3.10 Duct Supports
 - 3.3.11 Flexible Connectors For Steel Metal
 - 3.3.12 Insulation Protection Angles
 - 3.3.13 Duct Probe Access
 - 3.3.14 Openings In Roofs And Walls
- 3.4 FIELD QUALITY CONTROL
 - 3.4.1 Fire Damper Tests
 - 3.4.2 Ductwork Leakage Tests
 - 3.4.3 Inspection
 - 3.5 DUCTWORK CLEANING PROVISIONS
 - 3.6 OPERATION AND MAINTENANCE

-- End of Section Table of Contents --

USACE / NAVFAC / AFCEA / NASA UFGS-23 31 13.00 40 (February 2011)

Preparing Activity: NASA Superseding
UFGS-23 31 13 (February 2009)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2012

SECTION 23 31 13.00 40

METAL DUCTS 02/11

NOTE: This guide specification covers the requirements for low, medium and high pressure ductwork for air conditioning systems.

Drawings should supplement specifications by showing limits of round and rectangular duct and duct pressure classification; support provisions; type branch take-offs; elbows used for attenuation; location of dampers, linings, air diffusion devices; curbing at duct floor penetrations; framing or flanged duct segments at wall penetrations; vibration isolation of ducting. Refer to Section 23 05 48.00 40 VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT.

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 items(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).

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 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.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

- | | |
|----------|---|
| AISC 325 | (2011) Steel Construction Manual |
| AISC 360 | (2010) Specification for Structural Steel Buildings |

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

- | | |
|----------------------|---|
| ASHRAE EQUIP IP HDBK | (2008; Errata 1 2010) Handbook, HVAC Systems and Equipment (IP Edition) |
| ASHRAE EQUIP SI HDBK | (2008; Errata 1 2010) Handbook, HVAC Systems and Equipment (SI Edition) |
| ASHRAE FUN IP | (2009; Errata 2010) Fundamentals Handbook, I-P Edition |
| ASHRAE FUN SI | (2009; Errata 2010) Fundamentals Handbook, SI Edition |

AMERICAN WELDING SOCIETY (AWS)

- | | |
|----------------|--|
| AWS A5.8/A5.8M | (2011) Specification for Filler Metals for Brazing and Braze Welding |
|----------------|--|

ASTM INTERNATIONAL (ASTM)

- | | |
|-----------------|---|
| ASTM A123/A123M | (2009) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products |
| ASTM A36/A36M | (2008) Standard Specification for Carbon Structural Steel |
| ASTM A653/A653M | (2011) Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or |

Zinc-Iron Alloy-Coated (Galvannealed) by
the Hot-Dip Process

ASTM A924/A924M (2010a) Standard Specification for General
Requirements for Steel Sheet,
Metallic-Coated by the Hot-Dip Process

ASTM C1071 (2012) Standard Specification for Fibrous
Glass Duct Lining Insulation (Thermal and
Sound Absorbing Material)

ASTM D257 (2007) Standard Test Methods for D-C
Resistance or Conductance of Insulating
Materials

ASTM E90 (2009) Standard Test Method for Laboratory
Measurement of Airborne Sound Transmission
Loss of Building Partitions and Elements

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 90A (2012) Standard for the Installation of
Air Conditioning and Ventilating Systems

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

SMACNA 1966 (2005) HVAC Duct Construction Standards
Metal and Flexible, 3rd Edition

SMACNA 1987 (2006) HVAC Duct Systems Inspection Guide,
3rd Edition

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)

SAE AMS 2480 (2009; Rev H) Phosphate Treatment, Paint,
Base

THE SOCIETY FOR PROTECTIVE COATINGS (SSPC)

SSPC Painting Manual (2002) Good Painting Practice, Steel
Structures Painting Manual, Volume 1

UNDERWRITERS LABORATORIES (UL)

UL 181 (2005; Reprint Oct 2008) Factory-Made Air
Ducts and Air Connectors

UL 555 (2006; Reprint May 2012) Standard for Fire
Dampers

1.2 DESIGN REQUIREMENTS

NOTE: If Section 23 00 00 AIR SUPPLY, DISTRIBUTION,
VENTILATION, AND EXHAUST SYSTEMS is not included in
the project specification, applicable requirements
therefrom should be inserted and the first paragraph
deleted. If Section 23 05 48.00 40 VIBRATION AND

SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT is not included in the project specification, applicable requirements therefrom should be inserted and the second paragraph deleted. If Section 40 17 30.00 40 WELDING GENERAL PIPING is not included in the project specification, applicable requirements therefrom should be inserted and the third paragraph deleted.

[Section 23 00 00 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEMS apply to work specified in this section.]

[Section 23 05 48.00 40 VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT applies to work in this section.]

[Section 40 17 30.00 40 WELDING GENERAL PIPING applies to work specified in this section.]

Submit [equipment and performance data](#) for medium/high pressure ductwork systems consisting of use life, system functional flows, safety features, and mechanical automated details. Submit test response and performance characteristics curves for certified equipment.

Submit [design analysis and calculations](#) for medium/high pressure ductwork systems indicating the manufacturer's recommended air velocities, maximum static pressure, and temperature calculations.

1.3 SCOPE OF WORK

Encompass low-pressure systems ductwork and plenums where maximum air velocity is [10.1 meter per second](#) [2,000 feet per minute \(fpm\)](#) and maximum static pressure is [500 pascal](#) [2 inches water gage \(wg\)](#), positive or negative.

Submit [connection diagrams](#) for low pressure ductwork systems indicating the relation and connection of devices and apparatus by showing the general physical layout of all controls, the interconnection of one system (or portion of system) with another, and internal tubing, wiring, and other devices.

Submit [design analysis and calculations](#) for low pressure ductwork systems indicating the manufacturer's recommended air velocities, maximum static pressures, temperature calculations and acoustic levels.

Encompass high velocity systems ductwork where:

Minimum air velocity exceeds [10 meter per second](#) [2,000 feet per minute \(fpm\)](#) or static pressure exceeds [500 pascal](#) [2 inches water gage \(wg\)](#).

[Medium static pressure ranges from over [500 pascal](#) through [750 pascal](#) [2 inches wg](#) through [3 inches wg](#), positive or negative, or over [750 pascal](#) through [1500 pascal](#) [3 inches wg](#) through [6 inches wg](#) positive.]

[High static pressure ranges from over [1500 pascal](#) through [2500 pascal](#) [6 inches wg](#) through [10 inches wg](#), positive.]

Do not use rigid fibrous-glass ductwork.

1.4 SUBMITTALS

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.

The Guide Specification technical editors have designated 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 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.

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-01 Preconstruction Submittals

Submit [Material, Equipment, and Fixture Lists](#) and [Records of Existing Conditions](#) in accordance with paragraph entitled, "General Requirements," of this section.

SD-02 Shop Drawings

Submit the following in accordance with paragraph entitled, "Drawings," of this section.

[Connection Diagrams](#)

[Record Drawings](#)

SD-03 Product Data

Submit [Equipment and Performance Data](#) for medium/high pressure ductwork systems in accordance with paragraph entitled, "Design Requirements," of this section.

Submit manufacturer's catalog data for the following items:

[Galvanized Steel Ductwork Materials](#)

[Brazing Materials](#)

[Mill-Rolled Reinforcing and Supporting Materials](#)

[Round Sheet Metal Duct Fittings](#)

[Round, High-Pressure, Double-Wall Sheet Metal Ducts](#)

[Turning Vanes](#)

[Sound Traps](#)

[Flexible Connectors](#)

[Flexible Duct Materials](#)

[Power Operated Dampers](#)

[Flexible Connectors](#)

[Fire Dampers and Wall Collars](#)

[Gravity Backdraft and Relief Dampers](#)

[Manual Volume Dampers](#)

[SD-05 Design Data](#)

Submit [Design Analysis and Calculations](#) for medium/high pressure ductwork systems in accordance with paragraph entitled, "Design Requirements," of this section.

[SD-06 Test Reports](#)

Submit test reports for medium/high pressure ductwork systems in accordance with the paragraphs entitled, "Ductwork Leakage Tests" and "Fire Damper Tests," of this section.

[Ductwork Leakage Tests](#)

[Operational Tests](#)

[SD-07 Certificates](#)

[Listing of Product Installations](#) for medium/high pressure ductwork systems in accordance with paragraph entitled, "Installation," of this section.

Submit certificates, showing conformance with the referenced standards contained in this section for:

Galvanized Steel Ductwork Materials

Brazing Materials

Mill-Rolled Reinforcing and Supporting Materials

Round Sheet Metal Duct Fittings

Round, High-Pressure, Double-Wall Sheet Metal Ducts

Turning Vanes

Dampers

Sound Traps

Flexible Connectors

SD-10 Operation and Maintenance Data

Submit [Operation and Maintenance Manuals](#) in accordance with paragraph entitled, "Operation and Maintenance," of this section.

Power Operated Dampers

Fire Dampers and Wall Collars

1.5 GENERAL REQUIREMENTS

Submit [records of existing conditions](#) consisting of the results of Contractor's survey of work area conditions and features of existing structures and facilities within and adjacent to the jobsite. Commencement of work constitutes acceptance of existing conditions.

Include the manufacturer's style or catalog numbers, specification and drawing reference numbers, warranty information, and fabrication site information within [material, equipment, and fixture lists](#).

1.6 DRAWINGS

Submit [connection diagrams](#) for medium/high pressure ductwork systems indicating the relation and connection of devices and apparatus by showing the general physical layout of all controls, the interconnection of one system (or portion of system) with another, and internal tubing, wiring, and other devices.

Provide [record drawings](#) with current factual information including deviations from, and amendments to, the drawings and concealed or visible changes in the work, for medium/high pressure ductwork systems. Label drawings "As-Built".

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Galvanized Steel Ductwork Materials

Galvanized steel ductwork sheet metal shall be carbon steel, of lock-forming quality, hot-dip galvanized, with regular spangle-type zinc

coating, conforming to [ASTM A924/A924M](#) and [ASTM A653/A653M](#), Designation G90. Treat duct surfaces to be painted by phosphatizing.

Conform to [ASHRAE EQUIP SI HDBK](#) [ASHRAE EQUIP IP HDBK](#), Chapter 16, [ASHRAE FUN SI](#) [ASHRAE FUN IP](#), Chapter 32 and [SMACNA 1966](#) for sheet metal thickness gages and reinforcement thickness.

Low pressure ductwork minimum standards are as follows:

MINIMUM SHEET METAL THICKNESS

<u>DUCT WIDTH</u> <u>MILLIMETER</u>	<u>THICKNESS</u> <u>MILLIMETER</u>
0 - 305	0.45
330 - 762	0.61
787 - 1524	0.76

MINIMUM SHEET METAL GAGE

<u>DUCT WIDTH</u> <u>INCHES</u>	<u>GAGE</u>
0 - 12	26
13 - 30	24
31 - 60	22

2.1.2 [Brazing Materials](#)

Brazing materials shall be silicon bronze conforming to [AWS A5.8/A5.8M](#).

2.1.3 [Mill-Rolled Reinforcing And Supporting Materials](#)

Conform to [ASTM A36/A36M](#) for mill-rolled structural steel and, wherever in contact with sheet metal ducting galvanize to commercial weight of zinc or coated with materials conforming to [ASTM A123/A123M](#) [[SSPC Painting Manual](#)].

Equivalent strength, proprietary design, rolled-steel structural support systems may be submitted for approval in lieu of mill-rolled structural steel.

2.2 COMPONENTS

2.2.1 [Round Sheet Metal Duct Fittings](#)

Shop fabricate fittings.

Manufacture as separate fittings, not as tap collars welded or brazed into duct sections.

Submit for approval offset configurations.

Miter elbows shall be two-piece type for angles less than 31 degrees, three-piece type for angles 31 through 60 degrees, and five-piece type for angles 61 through 90 degrees. Centerline radius of elbows shall be 1-1/2 times fitting cross section diameter.

Crosses, increasers, reducers, reducing tees, and 90-degree tees shall be

conical type.

Cutouts in fitting body shall be equal to branch tap dimension or, where smaller, excess material shall be flared and rolled into smooth radius nozzle configuration.

2.2.2 Round, High-Pressure, Double-Wall Sheet Metal Ducts

Shop fabricate ducts and fittings.

Construction comprises of an airtight, vapor barrier, outer pressure shell, a 25 millimeter 1 inch insulation layer, and a metal inner liner that completely covers the insulation throughout the system.

Conform to NFPA 90A and ASTM C1071 for insulation with thermal conductivity in accordance with ASTM D257.

2.2.3 Reinforcement

Support inner liners of both duct and fittings by metal spacers welded in position to maintain spacing and concentricity.

2.2.4 Fittings

Make divided flow fittings as separate fittings, not tap collars into duct sections, with the following construction requirements:

Sound, airtight, continuous welds at intersection of fitting body and tap

Tap liner securely welded to inner liner, with weld spacing not to exceed 75 millimeter 3 inches

Pack insulation around the branch tap area for complete cavity filling.

Carefully fit branch connection to cutout openings in inner liner without spaces for air erosion of insulation and without sharp projections that cause noise and airflow disturbance.

Continuously braze seams in the pressure shell of fittings. Protect galvanized areas that have been damaged by welding with manufacturer's standard corrosion-resistant coating.

Submit for approval offset configurations.

Elbows shall be two-piece type for angles through 35 degrees, three-piece type for angles 36 through 71 degrees, and five-piece type for angles 72 through 90 degrees.

NOTE: Delete the following paragraph if
low-friction loss thru conical fittings is not a
design factor.

[Crosses, increasers, reducers, reducing tees, and 90-degree tees shall be conical type.]

2.2.5 Turning Vanes

Turning vanes shall be double-wall type, commercially manufactured for high-velocity system service.

2.2.6 Dampers

Low pressure drop, high-velocity manual volume dampers, and high-velocity fire dampers shall be constructed in accordance with ASHRAE EQUIP SI HDBK, ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN SI HDBK, Chapter 32 and SMACNA 1966.

2.2.7 Sound Traps

[Provide sound traps.]

NOTE: Retain for high-velocity, high-pressure systems or delete when not applicable to the project.

Drawings must supplement following specifications with data sufficient for the manufacturer to properly select sound traps. Data must include cubic meter per second, feet per minute; total static pressure; maximum permissible static pressure drop; air movement data (AMD) configuration; system velocities; type motor if in airstream; sound power level measurement point, in millimeter feet, from terminus where applicable; etc.

Indicate sound traps for all fans operating at static pressures in excess of 1000 pascal 4-inches water gage. Provide traps at fan discharge and inlet where required, also in return air systems.

No standards exist for testing prefabricated sound traps. ASTM E90 is based on static methods. Rewrite where acoustic testing is based on dynamic insertion loss method.

Factory fabricate sound traps, and acoustic confirmation of cataloged attenuation made by an independent laboratory in accordance with ASTM E90. Confirm pressure drop measurements in accordance with ASHRAE EQUIP SI HDBK, ASHRAE EQUIP IP HDBK, Chapter 18. Noise-reduction data shall include effects of flanking paths and vibration transmission. Testing shall be with standard metal inlet and outlet connections under indicated capacity flow.

NOTE: Select the following paragraph when sound attenuation in decibels (dB) RE 0.0002 microbar is given under the following paragraph for each midfrequency for all octave bands.

Attenuation required should provide present and future needs at least 5 dB excess attenuation in the 250 hertz, third octave band, midfrequency, when compared to specified noise criteria curve for the

area.

[Attenuation shall be in accordance with ASHRAE FUN SI ASHRAE FUN IP. Certification shall include a graphic system noise spectrum indicating proposed fan sound power level. Attenuation of ducting system proposed for installation based on ASHRAE FUN IP for bends, branches, and other duct system construction details; sound pressure level without sound trap; attenuation required; and excess attenuation compared to specific noise criteria curve.]

NOTE: Select the following paragraph only when no noise criteria are given and when required by project conditions; otherwise determine performance criteria after analysis of fans and downstream duct work.

[Sound trap shall reduce fan-rated sound-power level to not less than 65 decibels in the 250-hertz third octave band when measured at trap discharge end.]

Pressure drop at rated flow shall not exceed ratings in accordance with ASHRAE EQUIP SI HDBK ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN SI ASHRAE FUN IP, Chapter 32 and SMACNA 1966 or design criteria.

Trap shall be airtight when operating under an internal pressure of 2600 pascal 0.37 pound per square inch. Air-side surface shall be capable of withstanding air velocities of 50 meter per second 10,000 feet per minute without any particulate matter leaving the trap and being carried downstream.

Sound traps shall be double-metal walled, [round] [rectangular]. Sheet metal shall be mill-galvanized steel with commercial weight of zinc, conforming to ASTM A653/A653M. Exterior metal shall act as a vapor barrier, and metal thickness shall be not less than that required for the pressure service, in accordance with ASHRAE EQUIP SI HDBK ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN SI ASHRAE FUN IP, Chapter 32 and SMACNA 1966, but not less than 0.85 millimeter 22-gage. Absorbing material, on the sound-impinging side, shall be covered with formed perforated mill-galvanized steel of not less than 0.70 millimeter 24-gage. Exterior sheet joints shall be continuously welded or made with lockseams filled, prior to forming, with a chloroprene mastic.

Interior surfaces shall be spot welded not more than 75 millimeter 3 inches on center. Connections to duct transitions shall be flanged with through-bolted 3 by 25 millimeter 1/8 inch by 1 inch continuous rubber gasketing. Supports shall be trapeze type, vibration isolated.

Absorption material shall be fibrous glass. [Surface exposed to airstream shall be chloroprene coated or protected with woven fibrous-glass cloth conforming to ASTM C1071.] Total compressed thickness shall provide required attenuation and thermal insulation to preclude condensation on exterior surface under operating conditions normal to installed location. Compressed material density shall be approximately 72 kilogram per cubic meter 4.5 pounds per cubic foot. Material shall conform to fire hazard requirements of NFPA 90A.

2.2.8 Flexible Connectors For Sheet Metal

Connectors shall be UL listed, 915 gram per square meter 30-ounce per square foot, waterproof, fire-retardant, airtight, woven fibrous-glass cloth, double coated with chloroprene. Clear width, not including clamping section, shall be 150 to 200 millimeter 6 to 8 inches.

[Leaded vinyl sheet shall be provided as a second layer for sound attenuation. Leaded vinyl shall be not less than 1.4 millimeter 0.055 inch thick, shall weigh not less than 4.25 kilogram per square meter 0.87 pound per square foot, and shall be capable of approximately 10-decibel attenuation in the 10- to 10,000-hertz range.]

2.2.9 Duct Hangers

Duct hangers in contact with galvanized duct surfaces shall be [galvanized] [black carbon] steel painted with inorganic zinc.

2.2.10 Mill-Rolled Reinforcing And Supporting Materials

Mill-rolled structural steel shall conform to ASTM A36/A36M and, whenever in contact with sheet metal ducting, shall be galvanized in accordance with ASTM A123/A123M.

Equivalent strength, proprietary-design, rolled-steel structural support systems may be submitted for approval in lieu of mill-rolled structural steel.

2.2.11 Flexible Duct Materials

Flexible duct connectors shall be in accordance with UL 181, Class 1 material and shall comply with NFPA 90A.

[Metal duct shall be bendable through 180 degrees without damage, with an inside bend radius not greater than one-half the diameter of duct. Metal shall be [aluminum] [carbon steel] zinc-coated ASTM A123/A123M.]

[Wire-reinforced cloth duct shall consist of a [chloroprene] [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. Working pressure rating of ducting shall be not less than three times maximum system pressure, and temperature range shall be 29 to plus 79 degrees C minus 20 to plus 175 degrees F.]

[Wire-reinforced fibrous-glass duct shall consist of a minimum [4] [_____] 16 Kg/cubic meter [1] [_____] 1 pound/cubic foot density fibrous glass bonded to and supported by corrosion-protected spring helix. Vapor barrier shall be a [0.102] [_____] millimeter [4] [_____] mil minimum, pigmented polyvinylchloride film. Duct shall be bendable without damage through 180 degrees with an inside bend radius not greater than two duct diameters. Minimum wall thickness shall be [25] [_____] millimeter [1] [_____] inch. Thermal conductivity shall be not greater than [0.40 watt per meter per degrees C] [0.23] Btu per hour per square foot per degrees F [_____] at 24 degrees C 75 degrees F mean. Permeance shall be not greater than [5.7] nanogram per pascal second square meter [0.10 perm] [_____] . Working pressure range shall be from minus [124] [_____] pascal [1/2] [_____] inch wg to plus [373] [_____] pascal [1-1/2] [_____] inches wg. Working temperature shall range from 29 to plus 121 degrees C minus 20 to plus 250

degrees F. Minimum sustained velocity without delamination shall be [12.19] [_____] meter per second [2,400] [_____] fpm. Materials shall conform to NFPA 90A.

2.2.12 Manual Volume Dampers

Conform to SMACNA 1966 for volume damper construction.

Equip dampers with an indicating quadrant regulator with a locking feature externally located and easily accessible for adjustment and standoff brackets to allow mounting outside external insulation. Where damper rod lengths exceed [760] millimeter [30] inches [_____] , provide a regulator at each end of damper shaft.

All damper shafts shall have two-end bearings.

Splitter damper shall be [[0.76] millimeter[22]-gauge [_____] sheet metal] [0.25 millimeter[2] gages [_____] heavier than duct in which installed]. Hinges shall be [full length piano-type] [3 millimeter1/8 inch thick door type].

Damper shaft shall be full length and shall extend beyond damper blade. A [10] millimeter [3/8] inch [_____] square shaft shall be used for damper lengths up to [500] millimeter [20] inches [_____] and a [15] millimeter [1/2] inch square shaft shall be used for damper lengths [500] millimeter [20] inches [_____] and larger. Where necessary to prevent damper vibration or slippage, adjustable support rods with locking provisions external to duct shall be provided at damper blade end.

Dampers in ducts having a width perpendicular to the axis of the damper that is greater than [300] millimeter [12] inches [_____] shall be multiblade type having a substantial frame with blades fabricated of [1.6] millimeter [16]-gauge [_____] metal. Blades shall not exceed [250] millimeter [10] inches [_____] in width and [1220] millimeter [48] inches [_____] in length and shall be [pinned] [welded] to [15] millimeter [1/2] inch [_____] diameter shafts. Dampers greater than [1220] millimeter [48] inches [_____] in width shall be made in two or more sections with intermediate mullions, each section being mechanically interlocked with the adjoining section or sections. Blades shall have [graphite-impregnated nylon] [oil-impregnated sintered bronze] bearings and shall be connected so that adjoining blades rotate in opposite directions.

2.2.13 Gravity Backdraft And Relief Dampers

NOTE: The following paragraphs do not cover
light-duty equipment.

Frame shall be constructed of not less than [40 by 100 millimeter1-1/2- by 4 inch] [_____] reinforced [1.6] millimeter [16]-gauge [_____] galvanized carbon steel. Frames and mullions shall be solidly secured in place and sealed with elastomer caulking against air bypass.

Maximum blade width shall be [230] millimeter [9] inches [_____] , and maximum blade length shall be [900] millimeter [36] inches [_____] . Blade material shall be [1.6 millimeter16-gauge galvanized steel] [1.99 millimeter14-gauge [6063] [5052] alloy aluminum] [1.2 millimeter18-gauge AISI 18-8 corrosion-resistant steel]. Blades shall be provided with

mechanically retained seals and 90-degree limit stops.

Dampers used for relief service shall have blades linked together to open not less than 30 degrees on 12 pascal 0.05 inch wg differential pressure.

Shaft bearings shall be [graphite-impregnated nylon] [oil-impregnated bronze].

Counterbalanced dampers shall be equipped with fixed or adjustable counterbalancing weights.

Gravity backdraft dampers in sizes [460 by 460 18 by 18] [_____] millimeter inches or smaller, when furnished integral with air moving equipment, may be equipment manufacturer's standard construction.

2.2.14 Power-Operated Dampers

Dampers shall conform to applicable requirements specified under Section 23 09 33.00 40 ELECTRIC AND ELECTRONIC CONTROL SYSTEM FOR HVAC.

2.2.15 Fire Dampers And Wall Collars

Fire damper locations shall be in accordance with NFPA 90A.

Fire dampers in ductwork shall be provided at firewall barriers.

Fire dampers shall be constructed and labeled in accordance with UL 555 to provide damper and mounting fire-resistance that equals or exceeds fire-resistance of the construction in which installed. For link loads in excess of [90] newton [20] pounds [_____] , UL-approved quartzoid links shall be provided.

Wall collars shall be constructed in accordance with UL 555.

PART 3 EXECUTION

3.1 PREPARATION

Provide sheet metal construction in accordance with the recommendations for best practices in ASHRAE EQUIP SI HDBK ASHRAE EQUIP IP HDBK, Chapter 16, SMACNA 1966, NFPA 90A, and ASHRAE FUN SI ASHRAE FUN IP, Chapter 32.

Where construction methods for certain items are not described in the referenced standards or herein, perform the work in accordance with recommendations for best practice defined in ASHRAE EQUIP SI HDBK ASHRAE EQUIP IP HDBK.

Clean free of oil, grease, and deleterious substances sheet metal surfaces to be painted and surfaces to which adhesives are to be applied.

Duct strength shall be adequate to prevent failure under service pressure or vacuum created by fast closure of duct devices. Provide leaktight, automatic relief devices.

Supplementary steel shall be designed and fabricated in accordance with AISC 360 and AISC 325.

3.2 INSTALLATION

Within **listing of product installations** for medium/high pressure ductwork systems include identification of at least 5 units, similar to those proposed for use, that have been in successful service for a minimum period of 5 years. Include purchaser, address of installation, service organization, and date of installation.

Fabricate airtight and include reinforcements, bracing, supports, framing, gasketing, sealing, and fastening to provide rigid construction and freedom from vibration, airflow-induced motion and noise, and excessive deflection at specified maximum system air pressure and velocity.

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

Provide outside air-intake ducts and plenums made from sheet metal with soldered watertight joints.

Provide offsets and transformations as required to avoid interference with the building construction, piping, or equipment.

Wherever ducts pass through firewalls or through walls or floors dividing conditioned spaces from unconditioned spaces, provide a flanged segment in that surface during surface construction.

Clean free of oil, grease, and deleterious substances sheet metal surfaces to be painted or surfaces to which adhesives will be applied.

Where interiors of ducting may be viewed through air diffusion devices, construct the viewed interior with sheet metal and paint flat black.

Make plenum anchorage provisions, sheet metal joints, and other areas airtight and watertight by caulking mating galvanized steel and concrete surfaces with a two-component elastomer.

**NOTE: Retain only the following sub-parts covering
duct types required for the project.**

3.3 APPLICATION

3.3.1 Low Pressure Sheet Metal Ducts

Weld angle iron frames at corners and ends, whenever possible. Angle iron reinforcements shall be riveted or welded to ducts not more than **[150] millimeter [6] inches [_____]** on center, with not less than **[two] [_____]** points of attachment. Spot welding, where used, shall be **75 millimeter 3 inches** on center.

Standard seam joints shall be sealed with an elastomer compound to comply with **SMACNA 1966** Seal Class A, B or C as applicable.

Crossbreaking shall be limited to **[1220] millimeter [4] feet [_____]** and shall be provided on all ducts **[200] millimeter [8] inches [_____]** wide and wider. Bead reinforcement shall be provided in lieu of crossbreaking where panel popping may occur. Where rigid insulation will be applied,

crossbreaking is not required.

3.3.1.1 Longitudinal Duct Seams

Corner seams shall be Pittsburgh lock [____].

3.3.1.2 Joints and Gaskets

Companion angle flanges shall be bolted together with [6] millimeter [1/4] inch [____] diameter bolts and nuts spaced [150] millimeter [6] inches [____] on center. Flanged joints shall be gasketed with chloroprene full-face gaskets [3] millimeter [1/8] inch [____] thick, with Shore A 40 durometer hardness. Gaskets shall be one piece and [vulcanized] [dovetailed] at joints.

3.3.1.3 Flexible Duct Joints

Joints between flexible duct without sheet metal collars and round metal ductwork connections shall be made by trimming the ends, coating the inside of the flexible duct for a distance equal to depth of insertion with elastomer caulk, and by securing with sheet metal screws or binding with a strap clamp.

3.3.1.4 Square Elbows

[Provide single-vane duct turns in accordance with SMACNA 1966, and may be used on ducts 300 millimeter 12 inches wide and narrower.]

[Provide double-vane duct turns in accordance with SMACNA 1966.]

3.3.1.5 Radius Elbows

Conform to SMACNA 1966 for radius elbows. Provide an inside radius equal to the width of the duct. Where installation conditions preclude use of standard elbows, the inside radius may be reduced to a minimum of [0.25] [____] times duct width and install turning vanes in accordance with the following schedule.

WIDTH OF ELBOWS MILLIMETER	RADIUS OF TURNING VANES IN PERCENT OF DUCT WIDTH		
	VANE NO. 1	VANE NO. 2	VANE NO. 3
Up to 406	56	--	--
430 to 1220	43	73	--
1245 and over	37	55	83

WIDTH OF ELBOWS INCHES	RADIUS OF TURNING VANES IN PERCENT OF DUCT WIDTH		
	VANE NO. 1	VANE NO. 2	VANE NO. 3
Up to 16	56	--	--
17 to 48	43	73	--
49 and over	37	55	83

Where two elbows are placed together in the same plane in ducts 30 inches

760 millimeter wide and larger, the guide vanes shall be continuous through both elbows rather than spaced in accordance with above schedule.

3.3.1.6 Outlets, Inlets, And Duct Branches

Install branches, inlets, and outlets so that air turbulence will be reduced to a minimum and air volume properly apportioned. Install adjustable splitter dampers at all supply junctions to permit adjustment of the amount of air entering the branch. Wherever 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, a commercially manufactured 45 degree side-take-off (STO) fitting with manual; provide volume damper to allow adjustment of the air quantity and to provide an even flow of air across the device or duct it services.

Where a duct branch is to handle more than [25] [_____] percent of the air handled by the duct main, use a complete 90-degree increasing elbow with an inside radius of [0.75] [_____] times branch duct width. Size of the leading end of the increasing elbow within the main duct shall have the same ratio to the main duct size as the ratio of the related air quantities handled.

Where a duct branch is to handle [25] [_____] percent or less of the air handled by the duct main, the branch connection shall have a 45 degree side take-off entry in accordance with SMACNA 1966.

3.3.1.7 Duct Transitions

Where the shape of a duct changes, the angle of the side of the transition piece shall not exceed [15] [_____] degrees from the straight run of duct connected thereto.

Where equipment is installed in ductwork, the angle of the side of the transition piece from the straight run of duct connected thereto shall not exceed [15] [_____] degrees on the upstream side of the equipment and [22-1/2] [_____] degrees on the downstream side of the equipment.

3.3.1.8 Branch Connections

Construct radius tap-ins in accordance with SMACNA 1966.

3.3.1.9 Access Openings

Install access doors and panels in ductwork [upstream from coils] [upstream and downstream from coils] [adjacent to fire dampers] [at controls or at any item requiring periodic inspection, adjustment, maintenance, or cleaning] [where indicated], and every 20 feet 6.1M for indoor air quality housekeeping purposes.

Minimum size of access opening shall be [305 by 460 12 by 18] [_____] millimeter [_____] inches , unless precluded by duct dimensions or otherwise indicated.

Construct access door in accordance with SMACNA 1966, except that sliding doors may be used only for special conditions upon prior approval. Insulated doors shall be double-panel type.

Access doors that leak shall be made airtight by adding or replacing hinges and latches or by construction of new doors adequately reinforced, hinged,

and latched.

NOTE: Select the following paragraph when there is
need for frequent duct cleaning.

[Duct access shall be particularly suitable for commercial duct cleaning methods utilizing vacuum devices. Space access openings with a frequency and at points which will permit ready access to duct internals with essentially no duct or insulation cutting. Where access through an air-diffusion device or through access doors specified herein is not available at a specific point, [200] millimeter [8] inch [_____] diameter, [1.5] millimeter [16]-gage [_____] provide access plates not more than [3048] millimeter [10] feet [_____] on center. Where duct is insulated and vapor-sealed, provide mastic seals around circumference of access. When access plate is in place and insulated, externally identify the location.]

3.3.1.10 Plenum Construction

NOTE: This version is preferred as a supplement to
the SMACNA 1966 and provides for heavy sheet metal.

Intake and discharge plenum shall have companion angle joints with the following minimum thickness of materials:

<u>LONGEST ANGLES SIDE MILLIMETER</u>	<u>SHEET METAL USS GAGE ALL SIDES</u>	<u>COMPANION ANGLES MILLIMETER</u>	<u>REINFORCEMENT INCHES, 610 MM ON CENTER MAXIMUM</u>
To 1220	1.0	40 by 40 by 3	40 by 40 by 3
1245 to 2135	1.3	50 by 50 by 3	50 by 50 by 4.7
2160 to 3048	1.6	50 by 50 by 3	50 by 50 by 3
3075 and larger	2.0	50 by 50 by 4.7	50 by 50 by 4.7

<u>LONGEST ANGLES SIDE INCHES</u>	<u>SHEET METAL USS GAGE ALL SIDES</u>	<u>COMPANION ANGLES INCHES</u>	<u>REINFORCEMENT INCHES, 24 INCHES ON CENTER MAXIMUM</u>
To 48	20	1-1/2 by 1-1/2 by 1/8	1-1/2 by 1-1/2 by 1/8
49 to 84	18	2 by 2 by 1/8	2 by 2 by 3/16
85 to 120	16	2 by 2 by 1/8	2 by 2 by 1/8
121 and larger	14	2 by 2 by 3/16	2 by 2 by 3/16

At the floor line and other points where plenums join masonry construction, panels shall be bolted [300] millimeter [12] inches [_____] on center to [50 by 50 by 4.72- by 2- by 3/16] [_____] millimeter [_____] inch thick

hot-dip galvanized steel angle that has been secured to the masonry with masonry anchors and bolts [600] millimeter [24] inches [_____] on center and caulked tight to the masonry.

Panels shall be anchored to curbing by not less than [50 by 50 by 4.72- by 2- by 3/16] [_____] millimeter [_____] inch thick hot-dip galvanized steel angle iron. Concrete curbing shall include angle iron nosing with welded studs for the anchoring of panels. Nosing shall be level at curb height within plus or minus [1] millimeter [1/16] inch [_____].

Plenum access doors shall be constructed in accordance with SMACNA 1966 except that access doors smaller than man-access doors shall have door openings framed with angle iron that is one commercial size smaller than specified panel reinforcement.

Man-access door size shall be per SMACNA 1966 and paragraph entitled, "Access Openings," of this section. Insulated and uninsulated construction shall be per SMACNA 1966. Door openings shall be framed with channel iron. Doors shall be framed with angle iron. Channel iron and angle iron shall be approximately the same size as specified panel reinforcement. Exterior door skin shall be [1.6] millimeter [16] gage [_____]. Latches shall be fabricated steel, hinges shall be at least [100] millimeter [4] inches [_____] long, and bolting shall be at least [10] millimeter [3/8] inch [_____] diameter.

Angle iron and channel iron shall have welded and ground miter corners.

3.3.1.11 Manual Volume Dampers

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

Dampers regulated through ceilings shall have regulator concealed in box mounted in the ceiling, with a cover finish aesthetically compatible with ceiling surface. Where ceiling is of removable construction, regulators shall be above ceiling, and location shall be marked on ceiling in a manner acceptable to the Contracting Officer.

3.3.1.12 Flexible Connectors For Sheet Metal

Air handling equipment, ducts crossing building expansion joints, and 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 isolation mountings have been adjusted. When system fans are operating, connectors shall be free of wrinkle caused by misalignment or fan reaction. Width of surface shall be curvilinear.

3.3.2 Rectangular Sheet Metal Ducts

3.3.2.1 Medium-Pressure Gages, Joints, And Reinforcement

Minimum sheet metal gages, joints, and reinforcements between joints shall be in accordance with ASHRAE EQUIP SI HDBK ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN SI ASHRAE FUN IP, Chapter 32 and SMACNA 1966.

Sheet metal minimum thickness, transverse reinforcement between joints, and joints of ducts shall be in accordance with the following:

LONGEST SIDE (mm)	SHEET METAL THICKNESS ALL SIDES	COMPANION ANGLE (mm)	REINFORCEMENT ANGLES INCHES, 600 (mm) ON CENTER MAXIMUM (BACK TO BACK)
2450 to 2750	1.6	50 by 50 by 3, two tie rods along angle	Two 50 by 50 by 3, two tie rods along angle
2451 to 3350	1.6	50 by 50 by 5, two tie rods along angle	Two 50 by 50 by 5, two tie rods along angle
3351 and longer	2.0	50 by 50 by 5, with tie rods every 1200 mm	Two 50 by 50 by 5, with tie rods every 1200 mm
LONGEST SIDE INCHES	SHEET METAL GAGE ALL SIDES	COMPANION ANGLE INCHES	REINFORCEMENT ANGLES INCHES, 24 INCHES ON CENTER MAXIMUM (BACK TO BACK)
97 to 108	16	2 by 2 by 1/8, two tie rods along angle	Two 2 by 2 by 1/8, two tie rods along angle
109 to 132	16	2 by 2 by 3/16, two tie rods along angle	Two 2 by 2 by 3/16, two tie rods along angle
133 and longer	14	2 by 2 by 3/16, with tie rods every 48 inches	Two 2 by 2 by 3/16, with tie rods every 48 inches

3.3.2.2 Medium- And High-Pressure Branches, Inlets, Outlets

Install branches, inlets, and outlets to minimize air turbulence and to ensure proper airflow.

Install dampers so that the amount of air entering duct mains can be adjusted.

Provide commercially manufactured air extractors to allow adjustment of the air quantity and to provide an even flow of air across the device or duct served.

Where a duct branch is to handle over 25 percent of the air handled by the duct main, a complete 90-degree increasing elbow shall be used, with an inside radius of 0.75 times duct branch width. Size of the trailing end of the increasing elbow within the main duct shall be in the same ratio to the main duct size as the ratio of the relative air quantities handled.

Where a duct branch is to handle 25 percent or less of the air handled by the duct main, the branch connection shall have an inside radius of 0.75 times branch duct width, a minimum arc length of 45 degrees, and an outside radius of 1.75 times duct branch width. Arc shall be tangent to duct main.

3.3.2.3 High-Pressure Gages, Joints, And Reinforcement

Sheet metal minimum thickness, joints, and reinforcement between joints shall be in accordance with ASHRAE EQUIP SI HDBK ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN SI, ASHRAE FUN IP, Chapter 32 and SMACNA 1966.

The following types of ASHRAE EQUIP SI HDBK ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN SI ASHRAE FUN IP, Chapter 32 and SMACNA 1966 transverse joints shall be used:

Welded flange joint [with] [without] angle

Companion angle flanged joint

The following types of longitudinal seams shall be used:

Approved lock seams, back brazed, or continuously brazed seams for ducts with largest dimension up to 1800 millimeter 72 inches

Continuously welded or brazed seams for ducts with largest dimension greater than 1800 millimeter 72 inches

Sheet metal minimum thickness, transverse reinforcement between joints, and companion angle joints of ducts with longest side greater than 2550 millimeter 96 inches shall be in accordance with the following:

LONGEST SIDE (mm)	SHEET METAL THICKNESS ALL SIDES	COMPANION ANGLE (mm)	REINFORCEMENT ANGLES INCHES, 600 (mm) ON CENTER MAXIMUM (BACK TO BACK)
2450 to 2750	1.6	50 by 50 by 3, two tie rods along angle	Two 50 by 50 by 3, two tie rods along angle
2451 to 3350	1.6	50 by 50 by 5, two tie rods along angle	Two 50 by 50 by 5, two tie rods along angle
3351 and longer	2.0	65 by 65 by 5, with tie rods every 600 mm	Two 65 by 65 by 5, with tie rods every 600 mm

LONGEST SIDE INCHES	SHEET METAL GAGE ALL SIDES	COMPANION ANGLE INCHES	REINFORCEMENT ANGLES INCHES, 24 INCHES ON CENTER MAXIMUM (BACK TO BACK)
97 to 108	16	2 by 2 by 1/8, two tie rods along angle	*Two 2 by 2 by 1/8, two tie rods along angle
109 to 132	16	2 by 2 by 3/16, two tie rods along angle	*Two 2 by 2 by 3/16, two tie rods along angle
133 and longer	14	2-1/2 by 2-1/2 by 3/16, with tie rods every 24 inches	*Two 2-1/2 by 2-1/2 by 3/16, with tie rods every 24 inches

3.3.3 Round Sheet Metal Ducts

3.3.3.1 Duct Gages, Joints, And Reinforcement

Sheet metal minimum thickness, joints, and reinforcement between joints shall be in accordance with [ASHRAE EQUIP SI HDBK](#) [ASHRAE EQUIP IP HDBK](#), Chapter 16, [ASHRAE FUN SI](#), [ASHRAE FUN IP](#), Chapter 32 and [SMACNA 1966](#).

Longitudinal duct joint shall be manufactured by machine, with spiral lockseams to and including [1500 millimeter](#) [60 inch](#) diameters, and to dimensional tolerances compatible with fittings provided.

Ducts shall have supplemental girth angle supports, riveted with [solid rivets [150 millimeter](#) [6 inches](#) on center] [tack welded] [brazed] to duct. Girth angles shall be located as follows:

<u>DIAMETER, MILLIMETER</u>	<u>REINFORCEMENT-MAXIMUM SPACING, MILLIMETER</u>
625 to 915	32 by 32, 3.2 thick, 1825 millimeter on center
916 to 1270	32 by 32, 3.2 thick, 1525 millimeter on center
1271 to 1525	38 by 38, 3.2 thick, 1220 millimeter on center
<u>DIAMETER, INCHES</u>	<u>REINFORCEMENT-MAXIMUM SPACING, INCHES</u>
25 to 36	1-1/4 by 1-1/4, 1/8 thick, 72 inches on center
37 to 50	1-1/4 by 1-1/4, 1/8 thick, 60 inches on center
51 to 60	1-1/2 by 1-1/2, 1/8 thick, 48 inches on center

DIAMETER, INCHES

REINFORCEMENT-MAXIMUM SPACING, INCHES

Draw band girth joints are not acceptable.

Slip joints shall be made up by coating the male fitting with elastomer sealing materials, exercising care to prevent mastic from entering fitting bore, leaving only a thin annular mastic line exposed internally. Sheet metal screws shall be used to make assembly rigid, not less than four screws per joint, maximum spacing 150 millimeter 6 inches. Pop rivets shall not be used. All joints shall be taped and heat sealed.

Bolt heads and nuts shall be hex-shaped, M8 5/16 inch diameter for ducts up to 1270 millimeter 50 inch diameter, and M10 3/8 inch diameter for 1271 millimeter 51 inch diameter ducts and larger.

Flanges shall be [continuously welded] [brazed] to duct on outside of duct and intermittently welded with 25 millimeter 1 inch welds every 100 millimeter 4 inches on inside joint face. Excess filler metal shall be removed from inside face. Galvanized areas that have been damaged by welding shall be protected with manufacturer's standard corrosion-resistant coating.

3.3.3.2 Duct Transitions

NOTE: Rectangular duct with transitions specified
below should be used wherever building construction
or equipment are limiting factors.

[Where the shape of a duct changes, the angle of the side of the transition piece shall not exceed 15 degrees from the straight run of duct connected thereto.]

Where equipment is installed in ductwork, the angle of the side of the transition piece from the straight run of duct connected thereto shall not exceed 15 degrees on the upstream side of the equipment and 22-1/2 degrees on the downstream side of the equipment.

3.3.4 Round, High Pressure, Sheet Metal Duct Installation

3.3.4.1 Joints

An inner coupling shall be provided to align the inner lining to maintain good airflow conditions equivalent to standard round high-pressure duct joints. Butt joints are not suitable for the inner liner. This alignment shall be accomplished by [extending the liner of the fitting for slip joint into the pipe] [by the use of a double concentric coupling with the two couplings held by spacers for rigidity and wall spacing]. For ducts over 860 millimeter 34 inches inside diameter, provide a separate coupling for inner alignment, with the pressure shells joined by angle-ring flanged connections.

3.3.4.2 Insulation Ends

At the end of an uninsulated section or run where internally insulated duct connects to uninsulated spiral duct, fitting, fire damper or flexible duct, install an insulated end-fitting to bring the outer pressure shell down to

nominal size.

3.3.5 Transverse Reinforcement Joints

Transverse reinforcements shall be [riveted with solid rivets to duct sides 150 millimeter 6 inches on center] [spot welded 100 millimeter 4 inches on center]. Transverse reinforcement shall be welded at [all corners] [ends] to form continuous frames.

3.3.6 Joint Gaskets

Flanged joints shall be gasketed with chloroprene full-face gaskets 3.2 millimeter 1/8 inch thick, Shore A 40 durometer hardness. Gaskets shall be one piece, [vulcanized] [dovetailed] at joints.

3.3.7 Radius Elbows

Fabricate elbow proportions and radius elbows in accordance with ASHRAE EQUIP SI HDBK ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN SI ASHRAE FUN IP, Chapter 32 and SMACNA 1966.

3.3.8 Plenum Connections

Round duct connections shall be welded joint bellmouth type.

Rectangular duct connections shall be bellmouth type, constructed in accordance with ASHRAE EQUIP SI HDBK ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN IP ASHRAE FUN SI, Chapter 32 and SMACNA 1966.

3.3.9 Access Openings

Install access panels in ductwork adjacent to fire dampers.

Minimum size of access opening shall be 300 by 450 millimeter 12 by 18 inches, unless precluded by duct dimension.

Access openings shall be framed by welded and ground miter joint, 4 millimeter 1/8 inch thick [strap steel] [angle iron], with [7] [10] millimeter [1/4] [3/8] inch studs welded to frame. Cover plate shall be not less than[1.6 millimeter 16-gage, reinforced as necessary for larger sizes] [constructed of 2.8 millimeter 12-gage metal].

In lieu of access doors, readily accessible flanged duct sections may be provided upon approval. Provide stable hanger supports for disconnected duct termini.

3.3.10 Duct Supports

NOTE: Areas of seismic activity require seismically
braced ducts per SMACNA.

Install duct support in accordance with ASHRAE EQUIP SI HDBK ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN SI ASHRAE FUN IP, Chapter 32 and SMACNA 1966. Duct hangers shall meet the minimum size specified in ASHRAE EQUIP SI HDBK ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN SI ASHRAE FUN IP, Chapter 32 and SMACNA 1966. Provide two hangers where necessary to eliminate sway. Support attachment to duct surfaces, shall be

by [solid rivet] [bolt] [welding] 100 millimeter 4 inches on center.

NOTE: Delete following paragraph if double-wall
ducts are not required.

[Round, double-wall duct supports shall be as recommended by the manufacturer except that minimum hanger ring and strap size shall be 40 by 4 millimeter 1-1/2 inches by 1/8 inch.]

Selection of hanging system shall be at the Contractor's option, and shall take into account the location and precedence of work under other sections, interferences of various piping and electrical conduit, equipment, building configuration, structural and safety factor requirements, vibration, and imposed loads under normal and abnormal service conditions. Support sizes, configurations, and spacings are given to show the minimal type of supporting components required. If installed loads are excessive for the specified hanger spacing, hangers, and accessories [heavier-duty components shall be provided] [hanger spacing shall be reduced]. After system startup, any duct support device which, due to length, configuration, or size, vibrates or causes possible failure of a member, shall be replaced or the condition shall otherwise be alleviated. Special care shall be exercised to preclude cascade-type failures.

Hanger rods, angles, and straps shall be attached to beam clamps. Concrete inserts, masonry anchors, and fasteners shall be approved for the application.

NOTE: The following devices are an acceptable
fastener in office buildings where unusual
conditions do not occur.

Hardened high-carbon spring-steel fasteners fitted onto beams and miscellaneous structural steel are acceptable upon prior approval of each proposed application and upon field demonstration of conformance to specification requirements. Fasteners shall be made from steel conforming to AISI Type [1055] [1070], treated and finished in conformance with SAE AMS 2480, Type Z (zinc phosphate base), Class 2 (supplementary treatment). A 72-hour load-carrying capacity shall be verified by a certified independent laboratory.

Hanger spacing shall provide a 20-to-1 safety factor for supported load.

Maximum load supported by any two fasteners shall be 45 kilogram 100 pounds.

Friction rod assemblies are not acceptable.

[Where support from metal deck systems is involved, support requirements shall be coordinated with installation of metal deck.]

Ductwork and equipment shall not be hung from roof deck, piping, or other ducts or equipment. Maximum span between any two points shall be 3000 millimeter 10 feet, with lesser spans as required by duct assemblies, interferences, and permitted loads imposed.

There shall be not less than one set of hangers for each point of support.

Hangers shall be installed on both sides of all duct turns, branch fittings, and transitions.

Hangers shall be sufficiently cross braced to eliminate sway vertically and laterally.

Rectangular ducts up to 900 millimeter 36 inches shall be supported by strap-type hangers attached at not less than three places to not less than two duct surfaces in different planes.

Perforated strap hangers are not acceptable.

Rectangular ducting, 900 millimeter 36 inches and larger, shall be supported by trapeze hangers. Ducts situated in unconditioned areas and required to have insulation with a vapor-sealed facing shall be supported on trapeze hangers. Hangers shall be spaced far enough out from the side of the duct to permit the duct insulation to be placed on the duct inside the trapeze. Duct hangers shall not penetrate the vapor-sealed facing.

Where trapeze hangers are used, the bottom of the duct shall be supported on angles sized as follows:

<u>WIDTH OF DUCT, MILLIMETER</u>	<u>MINIMUM BOTTOM ANGLE SIZE, MILLIMETER</u>
760 and smaller	32 by 32 by 3.2
761 to 1200	38 by 38 by 3.2
1201 to 1830	38 by 38 by 4.8
1831 to 2440	50 by 50 by 6.4
2441 and wider	75 by 75 by 6.4
<u>WIDTH OF DUCT, INCHES</u>	<u>MINIMUM BOTTOM ANGLE SIZE, INCHES</u>
30 and smaller	1-1/4 by 1-1/4 by 1/8
31 to 48	1-1/2 by 1-1/2 by 1/8
49 to 72	1-1/2 by 1-1/2 by 3/16
73 to 96	2 by 2 by 1/4
97 and wider	3 by 3 by 1/4

Where ductwork system contains heavy equipment, excluding air-diffusion devices and single-leaf dampers, such equipment shall be hung independently of the ductwork by means of rods or angles of sizes adequate to support the load.

Ducting, when supported from roof purlins, shall not be supported at points greater than one-sixth of the purlin span from the roof truss. Load per hanger shall not exceed 875 kilogram 400 pounds when support is from a single purlin or 1750 kilogram 800 pounds when hanger load is applied halfway between purlins by means of auxiliary support steel provided under this section. When support is not halfway between purlins, the allowable hanger load shall be the product of 400 times the inverse ratio of the longest distance to purlin-to-purlin spacing.

When the hanger load exceeds the above limits, provide reinforcing of purlin(s) or additional support beam(s). When an additional beam is used, the beam shall bear on the top chord of the roof trusses, and bearing shall be over gusset plates of top chord. Beam shall be stabilized by connection to roof purlin along bottom flange.

Purlins used for supporting fire-protection sprinkler mains, electrical lighting fixtures, electrical power ducts, or cable trays shall be considered fully loaded, and supplemental reinforcing or auxiliary support steel shall be provided for these purlins.

**NOTE: When vibration isolation is required, retain
applicable portions of the following two paragraphs.**

[Duct supports shall be vibration isolated from structure at points indicated. Refer to Section 23 05 48.00 40 VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT.]

[Provide vibration isolators in discharge ducting system for a distance not less than 15 meter 50 feet beyond the air handling unit. Deflection of duct and equipment mountings shall be coordinated.]

3.3.11 Flexible Connectors For Steel Metal

Air-handling equipment, ducts crossing building expansion joints, and fan inlets and outlets shall be connected to upstream and downstream components by treated woven-cloth connectors.

Install connectors only after system fans are operative and all vibration isolation mountings have been adjusted. When system fans are operating, connectors shall be free of wrinkles caused by misalignment or fan reaction. Width of surface shall be curvilinear.

3.3.12 Insulation Protection Angles

Galvanized 1 millimeter thick 20-gage sheet, formed into an angle with a 50 millimeter 2 inch exposed long leg with a 10 millimeter 3/8 inch stiffening break at outer edge, and with a variable concealed leg, depending upon insulation thickness, shall be provided.

Install angles over all insulation edges terminating by butting against a wall, floor foundation, frame, and similar construction. Fasten angles in place with blind rivets through the protection angle, insulation, and sheet metal duct or plenum. Install angles after final insulation covering has been applied.

3.3.13 Duct Probe Access

Provide holes with neat patches, threaded plugs, or threaded or twist-on caps for air-balancing pitot tube access. Provide extended-neck fittings where probe access area is insulated.

3.3.14 Openings In Roofs And Walls

Building openings are fixed and provide equipment to suit.

3.4 FIELD QUALITY CONTROL

3.4.1 Fire Damper Tests

[Perform [operational tests](#) on each fire damper in the presence of the Contracting Officer by energizing fusible link with localized heat. Provide new links and install after successful testing.]

3.4.2 Ductwork Leakage Tests

Contractor shall conduct complete leakage test of new ductwork in accordance with Section [23 05 93](#) TESTING, ADJUSTING, AND BALANCING FOR HVAC. Tests shall be performed prior to installing ductwork insulation.

NOTE: Delete the following paragraph and title if inspections are not required.

3.4.3 Inspection

[Ductwork shall be inspected in accordance with [SMACNA 1987](#).]

3.5 DUCTWORK CLEANING PROVISIONS

Open ducting shall be protected from construction dust and debris in a manner approved by the Contracting Officer. Dirty assembled ducting shall be cleaned by subjecting all main and branch interior surfaces to airstreams moving at velocities two times specified working velocities, at static pressures within maximum ratings. This may be accomplished by: filter-equipped portable blowers which remain the Contractor's property; wheel-mounted, compressed-air operated perimeter lances which direct the compressed air and which are pulled in the direction of normal airflow; and other means approved by the Contracting Officer. Compressed air used for cleaning ducting shall be water- and oil- free. After construction is complete, and prior to acceptance of the work, construction dust and debris shall be removed from exterior surfaces. [[SMACNA 1987](#).]

3.6 OPERATION AND MAINTENANCE

Contractor shall submit [6] [_____] copies of the [operation and maintenance manuals](#) 30 calendar days prior to testing the medium/high pressure ductwork systems. Data shall be updated and resubmitted for final approval no later than 30 calendar days prior to contract completion.

Operation and Maintenance Manuals shall be consistent with manufacturer's standard brochures, schematics, printed instructions, general operating procedures and safety precautions.

-- End of Section --