Preparing Activity: NASA Superseding
UFGS-23 31 13.00 40 (May 2016)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2023
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DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING (HVAC)

SECTION 23 31 13.00 40

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SECTION 23 31 13.00 40

METAL DUCTS
08/22

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; and 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 item(s) or insert appropriate information.

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

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

PART 1 GENERAL

NOTE: If Section 23 30 00 HVAC AIR DISTRIBUTION is not included in the project specification, applicable requirements therein 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 therein 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 therein should be inserted and the third paragraph deleted.
****

[Section 23 30 00 HVAC AIR DISTRIBUTION 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.

]1.1 REFERENCES

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

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

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

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

AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

AISC 325	(2017) Steel Construction Manual
AISC 360	(2016) Specification for Structural Steel Buildings

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

ASHRAE EQUIP IP HDBK	(2012) Handbook, HVAC Systems and Equipment (IP Edition)

ASHRAE EQUIP SI HDBK	(2012) Handbook, HVAC Systems and Equipment (SI Edition)
ASHRAE FUN IP	(2021) Fundamentals Handbook, I-P Edition
ASHRAE FUN SI	(2021) Fundamentals Handbook, SI Edition

AMERICAN WELDING SOCIETY (AWS)

AWS A5.8/A5.8M	(2019) Specification for Filler Metals for Brazing and Braze Welding

ASTM INTERNATIONAL (ASTM)

ASTM A36/A36M	(2019) Standard Specification for Carbon Structural Steel
ASTM A123/A123M	(2017) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A653/A653M	(2023) Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM A924/A924M	(2022a) Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process
ASTM C1071	(2019) Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material)
ASTM D257	(2014) Standard Test Methods for D-C Resistance or Conductance of Insulating Materials
ASTM E477	(2020) Standard Test Method for Laboratory Measurements of Acoustical and Airflow Performance of Duct Liner Materials and Prefabricated Silencers

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 90A	(2024) Standard for the Installation of Air Conditioning and Ventilating Systems

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST HB 150	(2016) National Voluntary Laboratory Accreditation Program Procedures and General Requirements
NIST HB 150-8	(2018) NVLAP Acoustical Testing Services

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

SMACNA 1966	(2020) HVAC Duct Construction Standards Metal and Flexible, 4th Edition
SMACNA 1987	(2006) HVAC Duct Systems Inspection Guide, 3rd Edition

SOCIETY FOR PROTECTIVE COATINGS (SSPC)

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

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)

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

UNDERWRITERS LABORATORIES (UL)

UL 181	(2013; Reprint Dec 2021) UL Standard for Safety Factory-Made Air Ducts and Air Connectors
UL 555	(2006; Reprint Aug 2016) UL Standard for Safety Fire Dampers

1.2 SUBMITTALS

****

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

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

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification

and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

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

****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Material, Equipment, and Fixture Lists; G[, [____]]

Records of Existing Conditions; G[, [____]]

SD-02 Shop Drawings

Connection Diagrams; G[, [____]]

Offset Fitting Configurations; G[, [____]]

SD-03 Product Data

Equipment and Performance Data

Galvanized Steel Ductwork Materials; G[, [____]]

Brazing Materials

Mill-Rolled Reinforcing and Supporting Materials

Round Sheet Metal Duct Fittings; G[, [____]]

Round, High-Pressure, Double-Wall Sheet Metal Ducts; G[, [____]]

Turning Vanes; G[, [____]]

Sound Attenuators; G[, [____]]

Flexible Connectors; G[, [____]]

Flexible Duct Materials

Power-Operated Dampers; G[, [____]]

Fire Dampers and Wall Collars; G[, [____]]

Gravity Backdraft and Relief Dampers; G[, [____]]

Manual Volume Dampers; G[, [____]]

SD-05 Design Data

Design Analysis and Calculations; G[, [____]]

SD-06 Test Reports

Ductwork Leakage Tests; G[, [____]]

Operational Tests; G[, [____]]

SD-07 Certificates

Listing of Product Installations

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 Attenuators

Flexible Connectors

SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals; G[, [____]]

Power Operated Dampers; G[, [____]]

Fire Dampers and Wall Collars; G[, [____]]

SD-11 Closeout Submittals

Record Drawings; G[, [____]]

1.3 QUALITY CONTROL

When furnishing the listing of product installations for medium and 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.

PART 2 PRODUCTS

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.

2.1 SYSTEM DESCRIPTION

Provide low-pressure systems ductwork and plenums where maximum air

velocity is 10 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.

High velocity systems ductwork encompass systems where:

a. 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).

[b. 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.

][c. High static pressure ranges from over 1500 pascal through 2500 pascal 6-inches wg through 10-inches wg, positive.

] d. Do not use rigid fibrous-glass ductwork.

2.1.1 Design Requirements

Submit records of existing conditions including the results of a survey consisting of work area conditions, and features of existing structures and facilities within and adjacent to the jobsite.

Submit equipment and performance data for medium and 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 ductwork systems indicating the manufacturer's recommended air velocities, maximum static pressure, and temperature calculations.

2.2 COMPONENTS

2.2.1 Round Sheet Metal Duct Fittings

Submit offset fitting configurations for approval. Shop fabricate fittings.

2.2.1.1 Fittings Construction

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

Provide two-piece type miter elbows 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. Ensure centerline radius of elbows is 1-1/2 times fitting cross section diameter.

Provide conical type crosses, increasers, reducers, reducing tees, and 90-degree tees.

Ensure cutouts in fitting body are equal to branch tap dimension or, where smaller, excess material is 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.

Provide insulation conforming to NFPA 90A and ASTM C1071 for 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:

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

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

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

d. 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.

Construct two-piece type elbows 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.

****

[Provide conical type crosses, increasers, reducers, reducing tees, and 90-degree tees.

]2.2.5 Turning Vanes

Provide double-wall type turning vanes, commercially manufactured for high-velocity system service.

2.2.6 Dampers

Construct low pressure drop, high-velocity manual volume dampers, and high-velocity fire dampers in accordance with ASHRAE EQUIP SI HDBK ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN SIASHRAE FUN IP, Chapter 32 and SMACNA 1966.

2.2.7 Sound Attenuators

[Provide sound attenuators.

] Ensure the pressure drop at the rated flow does 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.

Ensure the sound attenuators is airtight when operating under an internal pressure of 2600 pascal 0.37 pounds per square inch. Provide an air-side surface capable of withstanding air velocities of 50 meters per second 10,000-feet per minute without any particulate matter leaving the trap and being carried downstream.

****

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

Supplement specifications with data on drawings sufficient for the manufacturer to properly select sound attenuators. Include data for: cubicmeter per second feet per minute, total static pressure, maximum permissible static pressure drop, air movement data (AND) configuration; system velocities, type motor if in airstream, sound power level measurement point, in millimeter feet, from terminus where applicable, and any additional data required.

Indicate sound attenuators 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 attenuators. ASTM E90 is based on static methods. Rewrite where acoustic testing is based on the dynamic insertion loss method.

****

2.2.7.1 Attenuation

Factory fabricate sound attenuators. Confirm pressure drop measurements in accordance with ASHRAE EQUIP SI HDBKASHRAE EQUIP IP HDBK, Chapter 18. Units shall be tested in accordance with ASTM E477 silencer test standard in aero-acoustical test facility which is NVLAP accredited for ASTM E477 standard. Submit copy of laboratory's NVLAP accreditation certificate on dynamic insertion loss, self-noise power levels, and aerodynamic performance according to the requirements of NIST HB 150 and NIST HB 150-8. Conduct tests 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.

****

[Ensure attenuation is in accordance with ASHRAE FUN SIASHRAE FUN IP. Include a graphic system noise spectrum certification indicating proposed fan sound power level. Attenuation of ducting system proposed for installation is based on ASHRAE FUN SIASHRAE FUN IP for bends, branches, and other duct system construction 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.

****

Reduce fan-rated sound-power level to not less than 65 decibels in the 250-hertz third octave band when measured at the sound attenuation discharge end.

2.2.7.2 Construction of Sound Attenuators

Provide double-metal walled, [round] [rectangular] sound attenuators. Provide mill-galvanized sheet metal steel with commercial weight of zinc, conforming to ASTM A653/A653M. Exterior metal acts as a vapor barrier. Metal thickness is not less than that required for the pressure service, in accordance with ASHRAE EQUIP SI HDBK ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN SIASHRAE FUN IP, Chapter 32 and SMACNA 1966, but not less than 0.85 millimeter 22-gage. Cover absorbing material, on the sound-impinging side, with formed perforated mill-galvanized steel of not less than 0.70 millimeter 24-gage. Ensure all exterior sheet joints are continuously welded, or construct with locksets filled with neoprene mastic prior to forming.

Spot weld interior surfaces not more than 75 millimeter 3-inches on center. Ensure all connections to duct transitions are flanged with through-bolted 3 by 25 millimeter 1/8-inch by 1-inch continuous rubber gasketing. Provide vibration isolated trapeze type supports.

Provide fibrous glass absorption material. [Ensure surfaces exposed to airstream are neoprene coated or protected with woven fibrous-glass cloth conforming to ASTM C1071.]Ensure the total compressed thickness gives the required attenuation, and thermal insulation to preclude condensation on exterior surface under normal operating conditions. Compressed material density is approximately 72 kilograms per cubic meter 4.5 pounds per cubic foot. Select materials conforming to fire hazard requirements of NFPA 90A.

2.2.8 Flexible Connectors for Sheet Metal

Use UL listed connectors, 915 gram per square meter 30-ounce per square yard, waterproof, fire-retardant, airtight, woven fibrous-glass cloth, double coated with neoprene. Clear width, not including clamping section, is 150 to 200 millimeter 6 to 8-inches.

[Provide leaded vinyl sheets as a second layer for sound attenuation. Ensure leaded vinyl is not less than 1.4 millimeter 0.055-inch thick, weighing not less than 4.25 kilogram per square meter 0.87 pound per square foot, and capable of approximately 10-decibel attenuation in the 10- to 10,000-hertz range.

]2.2.9 Duct Hangers

For duct hangers in contact with galvanized duct surfaces, provide [galvanized] [black carbon] steel painted with inorganic zinc.

2.2.10 Mill-Rolled Reinforcing and Supporting Materials

Provide mill-rolled structural steel conforming to ASTM A36/A36M. Whenever in contact with sheet metal ducting, provide galvanized steel in accordance with ASTM A123/A123M.

In lieu of mill-rolled structural steel, submit equivalent strength, proprietary-design, rolled-steel structural support systems for approval.

2.2.11 Flexible Duct Materials

Ensure flexible duct connectors comply with NFPA 90A, and conform with UL 181, Class 1 material.

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

][Provide wire-reinforced cloth duct consisting of a [neoprene] [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. Ensure working pressure rating of ducting is not less than three times maximum system pressure, and the temperature range is 29 to plus 79 degrees C minus 20 to plus 175 degrees F.

][Provide wire-reinforced fibrous-glass duct consisting 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 barriers are a minimum of [0.102] [_____] millimeter [4] [_____] mil, pigmented polyvinylchloride film. Ensure duct is bendable without damage through 180 degrees with an inside bend radius not greater than two duct diameters. Minimum wall thickness is [25] [_____] millimeter [1][_____]-inch. Thermal conductivity is 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 temperature. Ensure permeance is not greater than [5.7] nanogram per pascal second square meter [0.10 perm] [_____]. Working pressure range is from minus [124] [_____] pascal [1/2][_____]-inch wg to plus [373] [_____] pascal [1-1/2][_____]-inches wg. Working temperature ranges from 29 to plus 121 degrees C minus 20 to plus 250 degrees F. Minimum sustained velocity without delamination is [12.19] [_____] meter per second [2,400] [_____] fpm. Use materials

conforming 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.

2.2.12.1 Damper Construction

Provide all damper shafts with two-end bearings.

Ensure splitter damper is[[0.76] [_____] millimeter [22] [_____]-gage sheet metal][and is [0.25] [_____] millimeter [2] [_____] gages heavier than duct in which installed]. Hinges are [full length piano-type][3 millimeter 1/8-inch thick door type].

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

Provide dampers in ducts having a width perpendicular to the axis of the damper that is greater than [300] [_____] millimeters [12] [_____]-inches of multiblade type having a substantial frame with blades fabricated of [1.6] [_____] millimeter [16] [_____]-gage metal. Provide blades not exceeding [250] [_____] millimeters [10] [_____]-inches in width and [1220] [_____] millimeters [48] [_____]-inches in length, [pinned] [welded] to [15] [_____] millimeter [1/2] [_____]-inch diameter shafts. Ensure dampers greater than [1220] [_____] millimeters [48] [_____]-inches in width are made in two or more sections with intermediate mullions, each section being mechanically interlocked with the adjoining section or sections. Provide blades with [graphite-impregnated nylon] [oil-impregnated sintered bronze] bearings and connect 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.
****

Construct frames of not less than [40 by 100] [_____] millimeter [1-1/2-by 4-inch] [_____] reinforced [1.6] [_____] millimeter [16-gage] [_____] galvanized carbon steel. Solidly secure frames and mullions in place and seal with elastomer caulking against air bypass.

Provide shaft bearings with [graphite-impregnated nylon] [oil-impregnated bronze].

Equip counterbalanced dampers with fixed or adjustable counterbalancing

weights.

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

2.2.13.1 Blade Construction

Maximum blade width is [230] [_____] millimeters [9] [_____] inches, and maximum blade length is [900] [_____] millimeters [36] [_____]-inches. Blade material is[1.6 millimeters 16-gage galvanized steel][1.99 millimeters 14-gage [6063] [5052] alloy aluminum][1.2 millimeters 18-gage AISI 18-8 corrosion-resistant steel]. Provide blades with mechanically retained seals and 90-degree limit stops.

Blades linked together for relief service dampers are to open not less than 30 degrees on 12 pascal 0.05-inch wg differential pressure.

2.2.14 Power-Operated Dampers

Ensure dampers 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

Ensure fire damper locations are in accordance with NFPA 90A.

Provide fire dampers in ductwork at firewall barriers.

Construct and label fire dampers 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] Newtons [20] pounds[_____], provide UL-approved quartzoid links.

Construct wall collars in accordance with UL 555.

2.3 MATERIALS

2.3.1 Galvanized Steel Ductwork Materials

Provide hot-dip galvanized carbon steel ductwork sheet metal of lock-forming quality, with regular spangle-type zinc coating, conforming to ASTM A924/A924M and ASTM A653/A653M, Designation G90. Treat duct surfaces to be painted by annealing.

Conform to ASHRAE EQUIP SI HDBKASHRAE 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 thicknesses are:

MINIMUM SHEET METAL THICKNESS	
DUCT WIDTH MILLIMETER	THICKNESS MILLIMETER

MINIMUM SHEET METAL THICKNESS	
0-305	0.45
330-762	0.61
787-1524	0.76

MINIMUM SHEET METAL THICKNESS	
DUCT WIDTH INCHES	GAGE
0-12	26
13-30	24
31-60	22

2.3.2 Brazing Materials

Provide silicon bronze brazing materials conforming to AWS A5.8/A5.8M.

2.3.3 Mill-Rolled Reinforcing and Supporting Materials

Conform to ASTM A36/A36M for mill-rolled structural steel. Wherever in contact with sheet metal ducting, galvanize to conforming with ASTM A123/A123M [SSPC Painting Manual].

In lieu of mill-rolled structural steel, submit for approval, equivalent strength, proprietary design, rolled-steel structural support systems.

[2.3.4 Manufactured [Round][Round Or Flat Oval] Ductwork (Positive Pressure)

Duct and fittings suitable to positive 2500 Pascals10 inches WG. Ducts shall be machine formed round and/or flat oval as shown on drawings, constructed of G90 galvanized steel. Use spiral lockseam construction. Longitudinal seam construction may be used for ductwork over 2032 millimeters80 inches diameter with minimum 1.50 millimeters16 ga. Use fittings as indicated on drawings, as specified, and as required in accordance with manufacturer's published data.

Unless otherwise indicated, connection shall be slip type with minimum 50 millimeters2 inches insertion length or flanged joint in accordance with manufacturer's recommendations. When flange joints are required, use Van Stone angle rings welded to duct. Internal bracing is not allowed.

]PART 3 EXECUTION

3.1 PREPARATION

For sheet metal surfaces to be painted, and surfaces to which adhesives are to be applied, clean surface of oil, grease, and deleterious substances.

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

3.1.1 Construction Standards

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

Design and fabricate supplementary steel in accordance with AISC 360 and AISC 325.

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.

3.2 INSTALLATION

Fabricate an airtight system. 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.

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

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.

3.2.1 Jointing

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.

3.2.2 Ducts

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.

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

3.2.2.1 Ductwork Cleaning Provisions

Protect open ducting from construction dust and debris in a manner approved by the Contracting Officer. Clean dirty assembled ducting 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; or other means approved by the Contracting Officer. Use water- and oil- free compressed air for cleaning ducting. After construction is complete, and prior to acceptance of the work, remove construction dust and debris from exterior

surfaces. [Clean in conformance with SMACNA 1987.]

3.3 APPLICATION

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

3.3.1 Low Pressure Sheet Metal Ducts

Weld angle iron frames at corners and ends, whenever possible. Rivet or weld angle iron reinforcements to ducts not more than [150] millimeters [6]-inches [_____] on center, with not less than [two] [_____] points of attachment. Spot welding, where used, is 75 millimeters 3-inches on center.

Seal standard seam joints with an elastomer compound to comply with SMACNA 1966 Seal Class A, B or C as applicable.

Limit crossbreaking to [1220][_____] millimeters [4][_____]-feet and provide on all ducts [200][_____] millimeters [8][_____]-inches wide and wider. Provide bead reinforcement in lieu of crossbreaking where panel popping may occur. Where rigid insulation is applied, crossbreaking is not required.

3.3.1.1 Longitudinal Duct Seams

Provide Pittsburgh lock [_____] corner seams.

3.3.1.2 Joints and Gaskets

Bolt companion angle flanges together with [6] [_____] millimeters [1/4] [_____]-inch diameter bolts and nuts spaced [150] [_____] millimeters [6] [_____]-inches on center. Gasket flanged joints with neoprene full-face gaskets [3] [_____] millimeters [1/8] [_____]-inch thick, with Shore A 40 durometer hardness. Use one piece gaskets, [vulcanized] [dovetailed] at joints.

3.3.1.3 Flexible Duct Joints

Between flexible duct without sheet metal collars and round metal ductwork connections make joints 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[, use on ducts 300 millimeters 12 inches in width 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. Install turning vanes in accordance with the following schedule.

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

	RADIUS OF TURNING VANES IN PERCENT OF DUCT WIDTH		
WIDTH OF ELBOWS INCHES	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 for ducts 760 millimeters 30-inches wide and larger, continue the guide vanes 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 is 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 take-off is not of the splitter type; provide a commercially manufactured 45 degree side-take-off (STO) fitting with manual 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 with 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, construct the branch connection with 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, ensure the angle of the side of the transition piece does not exceed [15] [_____] degrees from the straight run of duct connected thereto.

Where equipment is installed in ductwork, ensure the angle of the side of

the transition piece from the straight run of duct connected thereto does 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

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

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 6.1 meters 20-feet for indoor air quality housekeeping purposes.

Minimum access opening size is [305 by 460] [_____] millimeters [12 by 18] [_____]-inches, unless precluded by duct dimensions or otherwise indicated.

Make airtight access doors that leak by adding or replacing hinges and latches or by construction of new doors adequately reinforced, hinged, and latched.

[3.3.1.10 Duct Access for Cleaning

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

Make duct access particularly suitable for commercial duct cleaning methods utilizing vacuum devices. Space access openings with a frequency and at points that permits 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, provide [200] [_____] millimeters [8] [_____]-inch diameter, [1.5] [_____] millimeters [16] [_____]-gage access plates not more than [3] [_____] meters [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.

]3.3.1.11 Plenum Construction

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

Provide intake and discharge plenum companion angle joints with the following minimum thickness of materials:

LONGEST ANGLES SIDE MILLIMETER	SHEET METAL USS GAGE ALL SIDES	COMPANION ANGLES MILLIMETER	REINFORCEMENT 610 MM ON CENTER MAXIMUM
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

LONGEST ANGLES SIDE INCHES	SHEET METAL USS GAGE ALL SIDES	COMPANION ANGLES INCHES	REINFORCEMENT 24 INCHES ON CENTER MAXIMUM
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, bolt panels [300] [_____] millimeters [12] [_____]-inches on center to [50 by 50 by 4.72- by 2- by 3/16] [_____] millimeters [_____]-inch thick hot-dip galvanized steel angle that has been secured to the masonry with masonry anchors and bolts [600][_____] millimeters [24][_____]-inches on center and caulked tight to the masonry.

Anchor panels to curbing with hot-dip galvanized steel angle iron of a size not less than [50 by 50 by 4.7] [_____] millimeters [2- by 2- by 3/16] [_____]-inch thick. Concrete curbing includes angle iron nosing with welded studs for the anchoring of panels. Level nosing at curb height within plus or minus [1] [_____] millimeter [1/16] [_____]-inch.

Weld and grind miter corners for angle iron and channel iron.

3.3.1.12 Plenum Door Construction

Construct plenum access doors in accordance with SMACNA 1966 except that access doors smaller than man-access doors have door openings framed with angle iron that is one commercial size smaller than the specified panel reinforcement.

Ensure man-access door size conforms to SMACNA 1966 and paragraph ACCESS OPENINGS. Insulated and uninsulated construction is per SMACNA 1966. Frame door openings with channel iron. Frame doors with angle iron. Size channel iron and angle iron approximately the same size as specified panel reinforcement. Provide exterior door skin [1.6] [_____] millimeters [16] [_____] gage. Fabricate latches from steel with hinges at least [100] [_____] millimeters [4] [_____]-inches long, and bolts at least [10] [_____] millimeters [3/8] [_____]-inch diameter.

3.3.1.13 Manual Volume Dampers

Provide balancing dampers of the splitter, butterfly, or multilouver type, to balance each respective main and branch duct.

For dampers regulated through ceilings provide a regulator concealed in a box mounted in the ceiling, with a cover finish aesthetically compatible with ceiling surface. Where ceiling is of removable construction, set regulators above the ceiling, and mark the location on ceiling in a manner acceptable to the Contracting Officer.

3.3.1.14 Flexible Connectors for Sheet Metal

Connect air handling equipment, ducts crossing building expansion joints, and fan inlets and outlets to upstream and downstream components by treated woven-cloth connectors.

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

3.3.2 Rectangular Sheet Metal Ducts

3.3.2.1 Medium-Pressure Gages, Joints, and Reinforcement

Ensure minimum sheet metal gages, joints, and reinforcements between joints are in accordance with ASHRAE EQUIP SI HDBKASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN SI ASHRAE FUN IP, Chapter 32 and SMACNA 1966.

Ensure sheet metal minimum thickness, transverse reinforcement between joints, and joints of ducts are in accordance with the following:

LONGEST SIDE (mm)	SHEET METAL THICKNESS ALL SIDES	COMPANION ANGLE (mm)	REINFORCEMENT ANGLES 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 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

LONGEST SIDE (INCHES)	SHEET METAL GAGE ALL SIDES	COMPANION ANGLE (INCHES)	REINFORCEMENT ANGLES 24 INCHES ON CENTER MAXIMUM (BACK TO BACK)
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 is adjustable.

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.

3.3.2.3 Duct Branch Transition

Where a duct branch handles over 25 percent of the air transported by the duct main, use a complete 90-degree increasing elbow, with an inside radius of 0.75 times duct branch width. Ensure the size of the trailing end of the increasing elbow within the main duct has 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, provide a branch connection with 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. Place arc tangent to duct main.

3.3.2.4 High-Pressure Gages, Joints, and Reinforcement

Ensure sheet metal minimum thickness, joints, and reinforcement between joints are in accordance with ASHRAE EQUIP SI HDBK ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN SI, ASHRAE FUN IP, Chapter 32 and SMACNA 1966.

Use 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 joints and seams:

Transverse Joints:

a. Welded flange joint [with] [without] angle

b. Companion angle flanged joint

Longitudinal Seams:

a. Approved lock seams, back brazed, or continuously brazed seams for ducts with largest dimension up to 1800 millimeters 72-inches

b. Continuously welded or brazed seams for ducts with largest dimension greater than 1800 millimeters 72-inches

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

LONGEST SIDE (mm)	SHEET METAL THICKNESS ALL SIDES	COMPANION ANGLE (mm)	REINFORCEMENT ANGLES 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 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 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.

Provide ducts with supplemental girth angle supports, riveted with [solid rivets 150 millimeters 6 inches on center] [tack welded] [brazed] to duct. Locate girth angles as follows:

DIAMETER, MILLIMETER	REINFORCEMENT-MAXIMUM SPACING, MILLIMETER
625 to 915	32 by 32, 3.2 thick, 1825 millimeters on center
916 to 1270	32 by 32, 3.2 thick, 1525 millimeters on center
1271 to 1525	38 by 38, 3.2 thick, 1220 millimeters on center

DIAMETER, INCHES	REINFORCEMENT-MAXIMUM SPACING INCHES
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

Use hex-shaped bolt heads and nuts, M8 5/16-inch diameter for ducts up to 1270 millimeters 50-inch diameter, and M10 3/8-inch diameter for 1271 millimeters 51-inch diameter ducts and larger.

[Continuously weld] [Braze] flanges to duct on outside of duct and intermittently welded with 25 millimeters 1-inch welds every 100 millimeters 4-inches on inside joint face. Remove excess filler metal from inside face. Protect galvanized areas that have been damaged by welding with manufacturer's standard corrosion-resistant coating.

3.3.3.2 Duct Joints

Provide duct joints manufactured by machine, with spiral locksets up to and including 1500 millimeters 60-inch diameters, and to dimensional tolerances compatible with fittings provided. Draw-band girth joints are not acceptable.

Prepare slip joints by coating the male fitting with elastomer sealing materials, exercising care to prevent mastic from entering fitting bore. Leave only a thin annular mastic line exposed internally. Use sheet metal screws to make assembly rigid, not less than four screws per joint, maximum spacing 150 millimeters 6-inches. Do not use pop rivets. Tape and heat seal all joints.

3.3.3.3 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, ensure the angle of the side of the transition piece does not exceed 15 degrees from the straight run of duct connected thereto.

] Where equipment is installed in ductwork, ensure the angle of the side of the transition piece from the straight run of duct connected thereto does 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

Provide an inner coupling 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. Accomplish this alignment by [extending the liner of the fitting for slip joint into the pipe] [the use of a double concentric coupling with the two couplings held by spacers for rigidity and wall spacing]. For ducts over 860 millimeters 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

Provide transverse reinforcements that are [riveted with solid rivets to duct sides 150 millimeters 6 inches on center] [spot welded 100 millimeters 4 inches on center]. Weld transverse reinforcement at [all corners] [ends] to form continuous frames.

3.3.6 Joint Gaskets

For flanged joints, use neoprene full-face gaskets 3.2 millimeters 1/8-inch thick, with Shore A 40 durometer hardness. Use one-piece gaskets, [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

Ensure round duct connections are welded joint bellmouth type.

Ensure rectangular duct connections are 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 is 300 by 450 millimeters 12 by 18 inches, unless precluded by duct dimension.

Frame access openings with welded and ground miter joints, 4 millimeters 1/8-inch thick [strap steel] [angle iron], with [7] [10] millimeters [1/4] [3/8]-inch studs welded to frame. Ensure cover plates are not less than[1.6 millimeters 16-gage, reinforced as necessary for larger sizes] [constructed of 2.8 millimeters 12-gage metal].

In lieu of access doors, use readily accessible flanged duct sections upon approval. Provide stable hanger supports for disconnected duct terminal.

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. Meet the minimum size for duct hangers as 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 by [solid rivet] [bolt] [welding] 100 millimeters 4-inches on center.

Take the following into account in selection of a hanging system:

a. Location and precedence of work under other sections

b. Interferences of various piping and electrical conduit

c. Equipment, and building configuration

d. Structural and safety factor requirements

e. Vibration, and imposed loads under normal and abnormal service conditions

Support sizes, configurations, and spacing are given to show the minimal type of supporting components required. If installed loads are excessive for the specified hanger spacing, hangers, and accessories [provide heavier-duty components] [reduce hanger spacing]. After system startup, replace any duct support device which due to length, configuration, or size, vibrates or causes possible failure of a member. Do not use a ductwork support system that allows a cascade-type failure to occur.

Do not hang ductwork and equipment from roof deck, piping, or other ducts or equipment. Maximum span between any two points is 3 meters 10-feet, with lesser spans as required by duct assemblies, interferences, and permitted loads imposed.

[Where support from metal deck systems is involved, coordinate support requirements with installation of metal deck.

][3.3.10.1 Double-wall Ducts

****

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

****

Provide round, double-wall duct supports as recommended by the manufacturer except that minimum hanger ring and strap size is 40 by 4 millimeters 1-1/2 inches by 1/8 inch.

]3.3.10.2 Hangars

Attach hanger rods, angles, and straps to beam clamps. Receive approval from the Contracting Officer for concrete inserts, masonry anchors, and fasteners 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. Make fasteners 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). Verify a 72-hour load-carrying capacity by a certified independent laboratory.

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

Cross-brace hangers to preclude swaying both vertically and laterally.

3.3.10.3 Installation

Ensure hanger spacing gives a 20-to-1 safety factor for supported load.

Maximum load supported by any two fasteners is 45 kilograms 100 pounds.

Install hangers on both sides of all duct turns, branch fittings, and transitions.

Friction rod assemblies are not acceptable.

3.3.10.4 Strap-type Hangars

Support rectangular ducts up to 900 millimeters 36-inches 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.

3.3.10.5 Trapeze Hangars

Support rectangular ducting, 900 millimeters 36-inches and larger, by trapeze hangers. Support ducts situated in unconditioned areas and required to have insulation with a vapor-sealed facing on trapeze hangers. Space hangers far enough out from the side of the duct to permit the duct insulation to be placed on the duct inside the trapeze. Do not penetrate the vapor-sealed facing with duct hangers.

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

WIDTH OF DUCT, MILLIMETER	MINIMUM BOTTOM ANGLE SIZE, MILLIMETER
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	50 by 50 by 6.4

WIDTH OF DUCT, INCHES	MINIMUM BOTTOM ANGLE SIZE, INCHES
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

3.3.10.6 Purlins

Do not support ducting from roof purlins at points greater than one-sixth of the purlin span from the roof truss. Do not exceed 875 kilograms 400 pounds load per hanger.

If the hanger load must exceed the above limit, provide reinforcing of purlin(s) or additional support beam(s). When an additional beam is used, have the beam bear on the top chord of the roof trusses, and also bear over the gusset plates of top chord. Stabilize the beam 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 are considered fully loaded. Provide supplemental reinforcing or auxiliary support steel for these purlins when used to support ductwork.

3.3.10.7 Vibration Isolation

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

[Isolate the structure from duct support vibration 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. Coordinate deflection of duct and equipment mountings.

]3.3.11 Flexible Connectors for Steel Metal

Connect air-handling equipment, ducts crossing building expansion joints, and fan inlets and outlets to upstream and downstream components with 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, ensure connectors are free of wrinkles caused by misalignment or fan reaction. Width of surface is curvilinear.

3.3.12 Insulation Protection Angles

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

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

Existing building openings are fixed in size and cannot be resized without authorization. Provide equipment to suit existing opening size.

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 enervating a fusible link with localized heat. Provide and install new links after successful testing.

]3.4.2 Ductwork Leakage Tests

Conduct complete leakage test of new ductwork in accordance with Section 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC. Perform tests prior to installing ductwork insulation.

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

[3.4.3 Inspection

Inspect ductwork in accordance with SMACNA 1987.

]3.5 CLOSEOUT ACTIVITIES

3.5.1 Operation and Maintenance

Submit [6] [_____] copies of the operation and maintenance manuals 30 calendar days prior to testing the medium and high pressure ductwork systems. Update data and resubmit for final approval no later than 30 calendar days prior to contract completion.

Ensure operation and maintenance manuals are consistent with manufacturer's standard brochures, schematics, printed instructions, general operating procedures and safety precautions.

3.5.2 Record Drawings

Provide record drawings with current factual information. Include deviations from, and amendments to, the drawings. Include concealed or visible changes in the work. Label drawings "As-Built".

-- End of Section --