SECTION 233113 - METAL DUCTS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

1. GENERAL
   * + 1. RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

* + - * 1. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.
      1. SUMMARY
         1. Section Includes:

Single-wall rectangular ducts and fittings.

Double-wall rectangular ducts and fittings.

Single-wall round[**and flat-oval**] ducts and fittings.

Double-wall round[**and flat-oval**] ducts and fittings.

Sheet metal materials.

Duct liner.

Sealants and gaskets.

Hangers and supports.

Seismic-restraint devices.

* + - 1. SUBMITTALS
         1. Submittals for this section are subject to the re-evaluation fee identified in Article 4 of the General Conditions.
         2. Manufacturer’s installation instructions shall be provided along with product data.
         3. Submittals shall be provided in the order in which they are specified and tabbed (for combined submittals).
         4. Product Data: For each type of the following products:

Liners and adhesives.

Sealants and gaskets.

Seismic-restraint devices.

USE PARAGRAPH BELOW WITH EPD REQUIREMENT WHEN PROJECT ESTIMATE IS $1M OR MORE.

* + - * 1. Submit an Environmental Product Declaration (EPD) from the manufacturer for steel sheets within this specification section, if available. A statement of the contractor’s good faith effort to obtain the EPD shall be provided if not available.

Manufacturer-provided EPDs must be Product Specific Type III (Third-Party Reviewed), in adherence with ISO 14025 *Environmental labels and declarations*, ISO 14044 *Environmental management – Life cycle assessment*, and ISO 21930 *Core rules for environmental product declarations of construction products and services.*

"Product Data" subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes. Coordinate with requirements for adhesives.

Product Data: For adhesives, indicating VOC content.

"Laboratory Test Reports" subparagraph below applies to LEED 2009 for Schools, LEED v4, IgCC, ASHRAE 189.1, and Green Globes. Coordinate with requirements for adhesives.

Laboratory Test Reports: For adhesives, indicating compliance with requirements for low-emitting materials.

"Product Data" subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes. Coordinate with requirements for sealants.

Product Data: For sealants, indicating VOC content.

"Laboratory Test Reports" subparagraph below applies to LEED 2009 for Schools, LEED v4, IgCC, ASHRAE 189.1, and Green Globes. Coordinate with requirements for sealants.

Laboratory Test Reports: For sealants, indicating compliance with requirements for low-emitting materials.

Retain "Laboratory Test Reports" below if factory-applied "Antimicrobial Coating" is retained under "Inside Casing Wall" paragraph below.

"Laboratory Test Reports" subparagraph below applies to LEED 2009 for Schools, LEED v4, IgCC, ASHRAE 189.1, and Green Globes. Coordinate with requirements for adhesives and sealants.

Laboratory Test Reports: For antimicrobial coatings, indicating compliance with requirements for low-emitting materials.

* + - * 1. Shop Drawings:

Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.

Factory- and shop-fabricated ducts and fittings.

Duct layout indicating sizes, configuration, liner material, and static-pressure classes.

Elevation of top [**and bottom**]of ducts.

Dimensions of [**main**] [**all**] duct runs from building grid lines.

Fittings.

Reinforcement and spacing.

Seam and joint construction.

Penetrations through fire-rated and other partitions.

Equipment installation based on equipment being used on Project.

Locations for duct accessories, including dampers, turning vanes, and access doors and panels.

Hangers and supports, including methods for duct and building attachment[**, seismic restraints,**] and vibration isolation.

<**Insert lists of areas or systems requiring Shop Drawings**>.

Retain "Delegated-Design Submittal" paragraph below if design services have been delegated to Contractor.

* + - * 1. Delegated-Design Submittal:

Sheet metal thicknesses.

Joint and seam construction and sealing.

Reinforcement details and spacing.

Materials, fabrication, assembly, and spacing of hangers and supports.

Retain "Design Calculations" subparagraph below if Work of this Section is required to withstand specific design loads and design responsibilities have been delegated to Contractor as another way to verify compliance with performance requirements.

Retain "Coordination Drawings" paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation if products and materials by separate installers. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

Retain "Welding certificates" paragraph below if retaining "Welding Qualifications" paragraph in "Quality Assurance" Article.

* + - * 1. Welding certificates.
        2. Field quality-control reports.
      1. QUALITY ASSURANCE

Retain one or more options in "Welding Qualifications" paragraph below if shop or field welding is required. If retaining, also retain "Welding certificates" paragraph in "Informational Submittals" Article.

* + - * 1. Welding Qualifications: Qualify procedures and personnel in accordance with the following:

[**AWS D1.1, "Structural Welding Code - Steel," for hangers and supports.**]

[**AWS D1.2, "Structural Welding Code - Aluminum," for aluminum supports.**]

[**AWS D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.**]

Retain "Mockups" paragraph below for special construction. Mockups are normally required only for static-pressure classes in excess of 3-inch wg (750 Pa) when verification of maximum allowable leakage is important. If retaining, indicate location, size, and other details of mockups on Drawings and retain "Leakage Tests" paragraph in "Field Quality Control" Article.

Consider building a mockup of typical portions of the system that can be inspected and tested early in the construction process.

* + - * 1. Mockups:

Before installing duct systems, build mockups representing static-pressure classes in excess of [**3**] <**Insert static-pressure class**> inch wg. Build mockups to comply with the following requirements, using materials indicated for the completed Work:

[**Five**] <**Insert number**> transverse joints.

[**One**] <**Insert number**> access door(s).

[**Two**] <**Insert number**> typical branch connections, each with at least one elbow.

[**Two**] <**Insert number**> typical flexible duct or flexible-connector connections for each duct and apparatus.

[**One**] <**Insert number**> 90-degree turn(s) with turning vanes.

[**One**] <**Insert number**> fire damper(s).

[**One**] <**Insert number**> smoke damper(s).

Perform leakage tests specified in "Field Quality Control" Article. Revise mockup construction and perform additional tests as required to achieve specified minimum acceptable results.

Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

1. PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or Deltek. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications.

* + - 1. PERFORMANCE REQUIREMENTS

Retain "Delegated Duct Design" paragraph below if Contractor is required to assume responsibility for duct construction design. Some jurisdictions may have more stringent requirements than SMACNA. Consult authorities having jurisdiction.

* + - * 1. Delegated Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and with performance requirements and design criteria indicated in "Duct Schedule" Article.

Retain seismic options and design criteria in "Structural Performance" paragraph below that are approved by authorities having jurisdiction.

* + - * 1. Structural Performance: Duct hangers and supports[**and seismic restraints**] shall withstand the effects of gravity[**and seismic**] loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" [**and**] [**ASCE/SEI 7**] <**Insert applicable building code**>. [**Seismically brace duct hangers and supports in accordance with**] [**SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."**] <**Insert reference document.**>

Retain "Seismic Hazard Level (SHL)" and "Connection Level" subparagraphs and one of options below if retaining SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems" or SMACNA's "Seismic Restrain Manual: Guidelines for Mechanical Systems - OSHPD Edition" option in "Structural Performance" paragraph above. If using other seismic design criteria, delete first two subparagraphs below and insert applicable requirement. First and second SHL options below are only options available in the OSHPD Edition version.

Seismic Hazard Level (SHL): [**AA**] [**A**] [**B**] [**C**] [**D**].

Retain "Connection Level" subparagraph below for OSHPD jurisdiction.

Connection Level: [**1**] [**2**].

<**Insert requirement**>.

Retain "Airstream Surfaces," "ASHRAE Compliance," or "ASHRAE/IES Compliance" paragraph below to comply with sustainable design schemes that require compliance with ASHRAE 62.1 and ASHRAE/IES 90.1.

* + - * 1. Airstream Surfaces: Surfaces in contact with airstream shall comply with requirements in ASHRAE 62.1.
        2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment," and Section 7 - "Construction and System Startup."
        3. ASHRAE/IES Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."
        4. Duct Dimensions: Unless otherwise indicated, all duct dimensions indicated on Drawings are inside clear dimensions and do not include insulation or duct wall thickness.
      1. SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

See "Static-Pressure Classes" and "Leakage and Seal Classes" articles in the Evaluations for discussion on fabrication.

* + - * 1. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

Construct ducts of galvanized sheet steel unless otherwise indicated.

For ducts exposed to weather, construct of [**Type 304**] [**Type 316**] stainless steel indicated by manufacturer to be suitable for outdoor installation.

* + - * 1. Transverse Joints: Fabricate joints in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

For ducts with longest side less than 36 inches, select joint types in accordance with Figure 2-1.

For ducts with longest side 36 inches or greater, use flange joint connector Type T-22, T-24, T-24A, T-25a, or T-25b. Factory-fabricated flanged duct connection system may be used if submitted and approved by Director’s Representative.

[**Where specified for specific applications, all joints shall be welded.**]

* + - * 1. Longitudinal Seams: Select seam types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."[**All longitudinal seams shall be Pittsburgh lock seams unless otherwise specified for specific application.**]

[**Where specified for specific applications, all joints shall be welded.**]

* + - * 1. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Ch. 4, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
      1. DOUBLE-WALL RECTANGULAR DUCTS AND FITTINGS

Retain manufacturer list to require factory-fabricated, double-wall rectangular ducts and fittings; delete to allow shop-fabricated ducts and fittings.

* + - * 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:

McGill AirFlow LLC.

MKT Metal Manufacturing.

Sheet Metal Connectors, Inc.

Approved equivalent.

* + - * 1. Rectangular Ducts: Fabricate ducts with indicated dimensions for clear internal dimensions of the inner duct.
        2. Outer Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

Construct ducts of galvanized sheet steel unless otherwise indicated.

For ducts exposed to weather, construct outer duct of [**Type 304**] [**Type 316**] stainless steel indicated by manufacturer to be suitable for outdoor installation.

* + - * 1. Transverse Joints: Select joint types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

For ducts with longest side less than 36 inches, select joint types in accordance with Figure 2-1.

For ducts with longest side 36 inches or greater, use flange joint connector Type T-22, T-24, T-24A, T-25a, or T-25b. Factory-fabricated flanged duct connection system may be used if submitted and approved by Director’s Representative.

[**Where specified for specific applications, all joints shall be welded.**]

* + - * 1. Longitudinal Seams: Select seam types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."[**All longitudinal seams shall be Pittsburgh lock seams unless otherwise specified for specific application.**]

[**Where specified for specific applications, all joints shall be welded.**]

Retain one of two "Interstitial Insulation" paragraphs below. If the objective of interstitial insulation includes achievement of both thermal performance and sound absorption, then ducts may need additional external insulation to achieve the thermal portion of the objective. See Section 230713 "Duct Insulation" for applicable duct insulation and installation requirements for external duct application.

* + - * 1. Interstitial Insulation: Fibrous-glass liner complying with ASTM C1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

Retain "Maximum Thermal Conductivity" subparagraph below to require thermal conductivity exceeding requirements in ASTM C1071. Retaining subparagraph may create a restrictive proprietary specification. Verify availability of performance with manufacturers.

Maximum Thermal Conductivity: [**0.27 Btu x in./h x sq. ft. x deg F**] <**Insert conductivity**> at 75 deg F mean temperature.

Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.

Coat insulation with antimicrobial coating.

Retain subparagraph below for additional protection of airstream.

Cover insulation with polyester film complying with UL 181, Class 1.

* + - * 1. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C534, Type II for sheet materials, and with NFPA 90A or NFPA 90B.

Retain "Maximum Thermal Conductivity" subparagraph below to require thermal conductivity exceeding requirements in ASTM C1071. Retaining subparagraph may create a restrictive proprietary specification. Verify availability of performance with manufacturers.

Maximum Thermal Conductivity: [**0.25 Btu x in./h x sq. ft. x deg F**] <**Insert conductivity**> at 75 deg F mean temperature.

* + - * 1. Inner Duct: Minimum 24-gauge [**perforated galvanized sheet steel having 3/32-inch- diameter perforations, with overall open area of 23 percent**] [**solid galvanized sheet steel**].
      1. SINGLE-WALL ROUND[**AND FLAT-OVAL**] DUCTS AND FITTINGS

See "Static-Pressure Classes" and "Leakage and Seal Classes" articles in the Evaluations for discussion on fabrication.

* + - * 1. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Ch. 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.

Construct ducts of galvanized sheet steel unless otherwise indicated.

For ducts exposed to weather, construct of [**Type 304**] [**Type 316**] stainless steel indicated by manufacturer to be suitable for outdoor installation.

Retain manufacturer list to require factory-fabricated, single-wall round and flat-oval ducts and fittings; delete to allow shop-fabricated ducts and fittings.

Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:

Elgen Manufacturing.

Linx Industries (formerly Lindab).

McGill AirFlow LLC.

MKT Metal Manufacturing.

Nordfab Ducting.

SEMCO, LLC; part of FlaktGroup.

Set Duct Manufacturing.

Sheet Metal Connectors, Inc.

Spiral Manufacturing Co., Inc.

Stamped Fittings Inc.

Approved equivalent.

* + - * 1. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension).
        2. Transverse Joints: Select joint types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

Option in subparagraph below is SMACNA's requirement. Insert smaller dimension for more stringent requirement.

Transverse Joints in Ducts Larger Than [**60**] <**Insert dimension**> Inches in Diameter: Flanged.

* + - * 1. Longitudinal Seams: Select seam types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.

Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.

* + - * 1. Tees and Laterals: Select types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
      1. DOUBLE-WALL ROUND[**AND FLAT-OVAL**] DUCTS AND FITTINGS

Retain manufacturer list to require factory-fabricated, double-wall round and flat-oval ducts and fittings; delete to allow shop-fabricated ducts and fittings.

* + - * 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:

Linx Industries (formerly Lindab).

McGill AirFlow LLC.

MKT Metal Manufacturing.

SEMCO, LLC; part of FlaktGroup.

Set Duct Manufacturing.

Sheet Metal Connectors, Inc.

Approved equivalent.

* + - * 1. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension) of the inner duct.

Outer Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Ch. 3, "Round, Oval, and Flexible Duct," based on static-pressure class unless otherwise indicated.

Construct ducts of galvanized sheet steel unless otherwise indicated.

For ducts exposed to weather, construct outer duct of [**Type 304**] [**Type 316**] stainless steel indicated by manufacturer to be suitable for outdoor installation.

Transverse Joints: Select joint types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

Option in subparagraph below is SMACNA's requirement. Insert smaller dimension for more stringent requirement.

Transverse Joints in Ducts Larger Than [**60**] <**Insert dimension**> Inches in Diameter: Flanged.

Longitudinal Seams: Select seam types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.

Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.

Tees and Laterals: Select types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

* + - * 1. Inner Duct: Minimum 24-gauge[**perforated galvanized sheet steel having 3/32-inch-diameter perforations, with overall open area of 23 percent**] [**solid galvanized sheet steel**].

Retain one of two "Interstitial Insulation" paragraphs below. If the objective of interstitial insulation includes achievement of both thermal performance and sound absorption, then ducts may need additional external insulation to achieve the thermal portion of the objective. See Section 230713 "Duct Insulation" for applicable duct insulation and installation requirements for external duct application.

* + - * 1. Interstitial Insulation: Fibrous-glass liner complying with ASTM C1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

Retain "Maximum Thermal Conductivity" subparagraph below to require thermal conductivity exceeding requirements in ASTM C1071. Retaining subparagraph may create a restrictive proprietary specification. Verify availability of performance with manufacturers.

Maximum Thermal Conductivity: [**0.27 Btu x in./h x sq. ft. x deg F**] <**Insert conductivity**> at 75 deg Fmean temperature.

Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.

Coat insulation with antimicrobial coating.

Cover insulation with polyester film complying with UL 181, Class 1.

* + - * 1. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C534/C534M, Type II for sheet materials, and with NFPA 90A or NFPA 90B.

Retain "Maximum Thermal Conductivity" subparagraph below to require thermal conductivity exceeding requirements in ASTM C1071. Retaining subparagraph may create a restrictive proprietary specification. Verify availability of performance with manufacturers.

Maximum Thermal Conductivity: [**0.25 Btu x in./h x sq. ft. x deg F**] <**Insert conductivity**> at 75 deg F mean temperature.

* + - 1. SHEET METAL MATERIALS
         1. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

See "Sheet Metal Materials" Article in the Evaluations for discussion on applicable materials and coatings in "Galvanized Sheet Steel"; "PVC-Coated, Galvanized Sheet Steel"; "Carbon-Steel Sheets"; "Stainless-Steel Sheets"; and "Aluminum Sheets" paragraphs below.

* + - * 1. Galvanized Sheet Steel: Comply with ASTM A653.

Galvanized Coating Designation: [**G90**].

Finishes for Surfaces Exposed to View: Mill phosphatized.

* + - * 1. PVC-Coated, Galvanized Sheet Steel: Comply with ASTM A653.

Galvanized Coating Designation: [**G90**].

Most sheet metal suppliers can provide a 4-mil- thick coating on both sides.

Minimum Thickness for Factory-Applied PVC Coating: 4 mils thick [**on sheet metal surface of ducts and fittings exposed to corrosive conditions, and minimum 1 mil thick on opposite surface**].

Coating Materials: Acceptable to authorities having jurisdiction for use on ducts listed and labeled by an NRTL for compliance with UL 181, Class 1.

* + - * 1. Carbon-Steel Sheets: Comply with ASTM A1008, with oiled, matte finish for exposed ducts.
        2. Stainless-Steel Sheets: Comply with ASTM A480, Type 304 or 316, as indicated in "Duct Schedule" Article; cold rolled, annealed, sheet. Exposed surface finish shall be No. 2B, No. 2D, No. 3, or No. 4 as indicated in "Duct Schedule" Article.
        3. Aluminum Sheets: Comply with ASTM B209 Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view.

Antimicrobial coating in "Factory- or Shop-Applied Antimicrobial Coating" paragraph below is an optional feature and usually applied only after fabrication to ducts fabricated with galvanized sheet steel. See the Evaluations for discussion on coatings.

* + - * 1. Factory- or Shop-Applied Antimicrobial Coating:

Apply to the surface of sheet metal that will form the interior surface of the duct. An untreated clear coating shall be applied to the exterior surface.

Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.

Coating containing the antimicrobial compound shall have a hardness of 2H, minimum, when tested in accordance with ASTM D3363.

Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested in accordance with UL 723; certified by an NRTL.

Shop-Applied Coating Color: [**Black**] [**White**].

Antimicrobial coating on sheet metal is not required for duct containing liner treated with antimicrobial coating.

* + - * 1. Reinforcement Shapes and Plates: ASTM A36, steel plates, shapes, and bars; black and galvanized.

Where black- and galvanized-steel shapes and plates are used to reinforce aluminum ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials.

* + - * 1. Tie Rods: Galvanized steel, 1/4-inch-minimum diameter for lengths 36 inches or less; 3/8-inch-minimum diameter for lengths longer than 36 inches
      1. DUCT LINER

If the objective of duct liner includes achievement of both thermal performance and sound absorption, then ducts may need additional external insulation to achieve the thermal portion of the objective. See Section 230713 "Duct Insulation" for applicable duct insulation and installation requirements for external duct application.

Sustainable design schemes require that duct insulation R-value comply with ASHRAE/IES 90.1 tables titled "Minimum Duct Insulation R-Value." If using liner alone to satisfy thermal requirements, verify that material selected is available in thickness needed to provide thermal performance without jeopardizing other requirements.

Type I duct liner is available in thicknesses of 1/2 to 2 inches in 1/2-inch increments; Type II duct liner is available in thicknesses of 1 to 2 inches in 1/2-inch increments. Indicate thicknesses on Drawings or in "Duct Schedule" Article.

When specifying duct liner by referencing ASTM C1071, specifiers are assured of product qualifications for corrosiveness, water-vapor sorption, fungi resistance, temperature resistance, erosion resistance, odor emission, surface-burning characteristics, apparent thermal conductivity, sound absorption coefficients, bacteria resistance, and combustion characteristics.

* + - * 1. Fibrous-Glass Duct Liner: Comply with ASTM C1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:

CertainTeed Corporation; Saint-Gobain North America.

Johns Manville; a Berkshire Hathaway company.

Knauf Insulation.

Owens Corning.

Voltek; a division of Sekisui America Corp.

Approved equivalent.

Retain "Maximum Thermal Conductivity" subparagraph below to require thermal conductivity exceeding minimum requirements in ASTM C1071. Retaining subparagraph may create a restrictive proprietary specification.

Maximum Thermal Conductivity:

Option for thermal conductivity in first two subparagraphs below exceeds values in ASTM C1071. If retaining, verify availability of performance with duct liner manufacturers.

Type I, Flexible: [**0.27 Btu x in./h x sq. ft. x deg F**] <**Insert conductivity**> at 75 deg F mean temperature.

Type II, Rigid: [**0.23 Btu x in./h x sq. ft. x deg F**] <**Insert conductivity**> at 75 deg F mean temperature.

Antimicrobial coating in "Antimicrobial Erosion-Resistant Coating" subparagraph below is an optional feature for duct liner.

Antimicrobial Erosion-Resistant Coating: Apply to the surface of the liner that will form the interior surface of the duct to act as a moisture repellent and erosion-resistant coating. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.

[**Solvent**] [**Water**]-Based Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C916.

Subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes. VOC content limit is that for fiberglass.

Adhesive shall have a VOC content of 80 g/L or less.

Subparagraph below applies to LEED 2009 for Schools Credit IEQ 4.1.

Adhesive shall comply with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

Duct liner in "Flexible Elastomeric Duct Liner" paragraph below is not suitable for temperatures higher than 220 deg F (104 deg C).

* + - * 1. Flexible Elastomeric Duct Liner: Preformed, cellular, closed-cell, sheet materials complying with ASTM C534, Type II, Grade 1; and with NFPA 90A or NFPA 90B.

Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:

Aeroflex USA.

Armacell LLC.

Ductmate Industries, Inc.

K-Flex USA.

Voltek; a division of Sekisui America Corp.

Approved equivalent.

Available thicknesses for flexible elastomeric duct liner are 3/8, 1/2, 3/4, and 1 inch. Indicate thickness on Drawings or in "Duct Schedule" Article.

Characteristics in "Surface-Burning Characteristics" subparagraph below are available in limited thicknesses. Verify maximum thickness with manufacturers.

Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested in accordance with UL 723; certified by an NRTL.

Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

Subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes. VOC content limit is that for contact adhesive.

Adhesive shall have a VOC content of 80 g/L or less.

Subparagraph below applies to LEED 2009 for Schools Credit IEQ 4.1.

Adhesive shall comply with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

* + - * 1. Fiberglass-Free Duct Liner: Made from partially recycled cotton or polyester products and containing no fiberglass. Airstream surface overlaid with fire-resistant facing to prevent surface erosion by airstream, complying with NFPA 90A or NFPA 90B. Treat natural-fiber products with antimicrobial coating.

Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:

Acoustical Surfaces, Inc.

Ductmate Industries, Inc.

Approved equivalent.

Available thicknesses for natural-fiber duct liner are 1/2 and 1 inch. Indicate thickness on Drawings or in "Duct Schedule" Article.

Maximum Thermal Conductivity: [**0.24 Btu x in./h x sq. ft. x deg F**] <**Insert conductivity**> at 75 deg F mean temperature when tested in accordance with ASTM C518.

Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested in accordance with ASTM E84; certified by an NRTL.

Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

Subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes. VOC content limit is that for contact adhesive.

Adhesive shall have a VOC content of 80 g/L or less.

Subparagraph below applies to LEED 2009 for Schools Credit IEQ 4.1.

Adhesive shall comply with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

* + - * 1. Insulation Pins and Washers:

Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, [**0.106-inch-**] [**0.135-inch-**] diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.

Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- thick [**galvanized steel**] [**aluminum**] [**stainless steel**]; with beveled edge sized as required to hold insulation securely in place, but not less than 1-1/2 inches in diameter.

* + - * 1. Shop Application of Duct Liner: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 7-11, "Flexible Duct Liner Installation."

Adhere a single layer of indicated thickness of duct liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of duct liner is prohibited.

Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.

Butt transverse joints without gaps, and coat joint with adhesive.

Fold and compress liner in corners of rectangular ducts or cut and fit to ensure butted-edge overlapping.

Do not apply liner in rectangular ducts with longitudinal joints, except at corners of ducts, unless duct size and dimensions of standard liner make longitudinal joints necessary.

Delete first subparagraph below if air velocities do not exceed 2500 fpm (12.7 m/s).

Apply adhesive coating on longitudinal seams in ducts with air velocity of 2500 fpmor greater.

Securing method in first subparagraph below is for ducts with air velocities of 2500 fpm (12.7 m/s) and lower. Use caution when designing lined ducts with air velocities higher than 2500 fpm (12.7 m/s). See SMACNA for requirements.

Secure liner with mechanical fasteners 4 inches from corners and at intervals not exceeding 12 inches transversely; at 3 inches from transverse joints and at intervals not exceeding 18 inches longitudinally.

Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or "Z" profiles or are integrally formed from duct wall. Fabricate edge facings at the following locations:

Fan discharges.

Intervals of lined duct preceding unlined duct.

Upstream edges of transverse joints in ducts where air velocities are higher than 2500 fpm or where indicated.

Retain first subparagraph below if ducts with air velocities higher than 4000 fpm (20.3 m/s) are anticipated; indicate locations of double-wall ducts on Drawings. Use solid-metal (unperforated) inner ducts for material-handling exhaust systems.

Secure insulation between perforated sheet metal inner duct of same thickness as specified for outer shell. Use mechanical fasteners that maintain inner duct at uniform distance from outer shell without compressing insulation.

Sheet Metal Inner Duct Perforations: 3/32-inch diameter, with an overall open area of 23 percent.

Terminate inner ducts with buildouts attached to fire-damper sleeves, dampers, turning vane assemblies, or other devices. Fabricated buildouts (metal hat sections) or other buildout means are optional; when used, secure buildouts to duct walls with bolts, screws, rivets, or welds.

* + - 1. SEALANT AND GASKETS
         1. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested in accordance with UL 723; certified by an NRTL.

See SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for discussion on seam and joint sealing methods and their applications. Retain one or more of "Two-Part Tape Sealing System," "Water-Based Joint and Seam Sealant," and "Solvent-Based Joint and Seam Sealant" paragraphs below; identify which sealing system applies to which duct system in "Duct Schedule" Article.

* + - * 1. Two-Part Tape Sealing System:

Tape: Woven cotton fiber impregnated with mineral gypsum and modified acrylic/silicone activator to react exothermically with tape to form hard, durable, airtight seal.

Tape Width: [**3 inches**] [**4 inches**] [**6 inches**].

Sealant: Modified styrene acrylic.

Water resistant.

Mold and mildew resistant.

Maximum Static-Pressure Class: 10 inch wg, positive and negative.

Service: Indoor and outdoor.

Service Temperature: Minus 40 to plus 200 deg F.

Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum.

Subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes.

Sealant shall have a VOC content of 420 g/L or less.

Subparagraph below applies to LEED 2009 for Schools Credit IEQ 4.1.

Sealant shall comply with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

Retain "Water-Based Joint and Seam Sealant" or "Solvent-Based Joint and Seam Sealant" paragraph below. If retaining second paragraph, verify acceptability with authorities having jurisdiction.

* + - * 1. Water-Based Joint and Seam Sealant:

Application Method: Brush on.

Solids Content: Minimum 65 percent.

Shore A Hardness: Minimum 20.

Water resistant.

Mold and mildew resistant.

VOC: Maximum 75 g/L (less water).

Maximum Static-Pressure Class: 10 inch wg, positive and negative.

Service: Indoor or outdoor.

Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

* + - * 1. Solvent-Based Joint and Seam Sealant:

Application Method: Brush on.

Base: Synthetic rubber resin.

Solvent: Toluene and heptane.

Solids Content: Minimum 60 percent.

Shore A Hardness: Minimum 60.

Water resistant.

Mold and mildew resistant.

Subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes.

Sealant shall have a VOC content of 420 g/L or less.

Subparagraph below applies to LEED 2009 for Schools Credit IEQ 4.1.

Sealant shall comply with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

Maximum Static-Pressure Class: 10-inch wg, positive or negative.

Service: Indoor or outdoor.

Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

* + - * 1. Flanged Joint Sealant: Comply with ASTM C920.

General: Single-component, acid-curing, silicone, elastomeric.

Type: S.

Grade: NS.

Class: 25.

Use: O.

Subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes.

Sealant shall have a VOC content of 420 g/L or less.

Subparagraph below applies to LEED 2009 for Schools Credit IEQ 4.1.

Sealant shall comply with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

* + - * 1. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

O-ring seals are generally available for duct fittings 3 to 24 inches (76 to 610 mm) in diameter.

* + - * 1. Round Duct Joint O-Ring Seals:

Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg and shall be rated for10-inch wg static-pressure class, positive or negative.

Retain one or both subparagraphs below. These are proprietary seals provided on factory-fabricated, round duct fitting joints and constructed with specific dimensions to ensure a proper seal.

EPDM O-ring to seal in concave bead in coupling or fitting spigot.

Double-lipped, EPDM O-ring seal, mechanically fastened to factory-fabricated couplings and fitting spigots.

* + - 1. HANGERS AND SUPPORTS

Indicate extent of corrosive environment on Drawings.

* + - * 1. Hanger Rods for Noncorrosive Environments: Galvanized-steel rods and nuts.
        2. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.
        3. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct."
        4. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A603.
        5. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A492.
        6. Steel Cable End Connections: Galvanized-steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.
        7. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
        8. Trapeze and Riser Supports:

Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.

Supports for Stainless-Steel Ducts: Stainless-steel shapes and plates.

Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

* + - 1. SEISMIC-RESTRAINT DEVICES

Coordinate specifications for seismic-restraint components in this article with structural engineer and with Drawings. See "Seismic Considerations" Article in the Evaluations for discussion on seismic restraints.

* + - * 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:

B-line; Eaton, Electrical Sector.

CADDY; nVent.

Ductmate Industries, Inc.

Elgen Manufacturing.

Hilti, Inc.

Kinetics Noise Control, Inc.

Mason Industries, Inc.

Unistrut; Atkore International.

Approved equivalent.

See the Evaluations in Section 230548 "Vibration and Seismic Controls for HVAC" for discussion on seismic-restraint capacities and rating services.

* + - * 1. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by [**an evaluation service member of the ICC Evaluation Service**] [**an agency acceptable to authorities having jurisdiction**].

Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least [**four**] <**Insert number**> times the maximum seismic forces to which they will be subjected.

* + - * 1. Channel Support System: Shop- or field-fabricated support assembly made of slotted steel channels rated in tension, compression, and torsion forces and with accessories for attachment to braced component at one end and to building structure at the other end. Include matching components and corrosion-resistant coating.
        2. Restraint Cables: [**ASTM A603, galvanized**] [**ASTM A492, stainless**]-steel cables with end connections made of galvanized-steel assemblies with brackets, swivel, and bolts designed for restraining cable service; and with an automatic-locking and clamping device or double-cable clips.

Retain "Hanger Rod Stiffener" paragraph below for strengthening resistance of hanger rods against seismic forces that may cause rods to buckle. Use with either channel- or cable-type bracing assemblies. Detail fabrication and indicate locations on Drawings.

* + - * 1. Hanger Rod Stiffener: [**Steel tube or steel slotted-support-system sleeve with internally bolted connections**] [**Reinforcing steel angle clamped**] to hanger rod.
        2. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type. Select anchor bolts with strength required for anchor and as tested in accordance with ASTM E488.

1. EXECUTION
   * + 1. DUCT INSTALLATION

Coordinate duct layout and duct accessory arrangement with Drawings.

* + - * 1. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and coordination drawings.
        2. Install ducts in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.
        3. Install ducts in maximum practical lengths with fewest possible joints.
        4. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.
        5. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.
        6. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.
        7. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.
        8. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.
        9. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches.
        10. Install fire[**, combination fire/smoke,**] and smoke dampers where indicated on Drawings and as required by code, and by local authorities having jurisdiction. Comply with requirements in Section 233300 "Air Duct Accessories" for fire and smoke dampers and specific installation requirements of the damper UL listing.
        11. Install heating coils, cooling coils, air filters, dampers, and all other duct-mounted accessories in air ducts where indicated on Drawings.
        12. Protect duct interiors from moisture, construction debris and dust, and other foreign materials both before and after installation.[**Comply with SMACNA's "IAQ Guidelines for Occupied Buildings Under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."**]
        13. Elbows: Use long-radius elbows wherever they fit.

Fabricate 90-degree rectangular mitered elbows to include turning vanes.

Fabricate 90-degree round elbows with a minimum of three segments for 12 inches and smaller and a minimum of five segments for 14 inches and larger.

* + - * 1. Branch Connections: Use lateral or conical branch connections.
      1. INSTALLATION OF EXPOSED DUCTWORK
         1. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.
         2. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.
         3. Grind welds to provide smooth surface free of burrs, sharp edges, and weld splatter. When welding stainless steel with a No. 3 or 4 finish, grind the welds flush, polish the exposed welds, and treat the welds to remove discoloration caused by welding.
         4. Maintain consistency, symmetry, and uniformity in arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.
         5. Repair or replace damaged sections and finished work that does not comply with these requirements.
      2. ADDITIONAL INSTALLATION REQUIREMENTS FOR TYPE 1 COMMERCIAL KITCHEN GREASE HOOD EXHAUST DUCT
         1. Install ducts in accordance with NFPA 96, "Ventilation Control and Fire Protection of Commercial Cooking Operation"; SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; and SMACNA's "Kitchen Ventilation Systems and Food Service Equipment Fabrication and Installation Guidelines" unless otherwise indicated.
         2. Install all ducts without dips and traps that may hold grease, and sloped a minimum of 2 percent to drain grease back to the hood.
         3. All ducts exposed to view shall be constructed of stainless steel as per "Duct Schedule" Article. All ducts concealed from view shall be [**stainless**] [**carbon**] steel as per "Duct Schedule" Article.
         4. All joints shall be welded and shall be telescoping, bell, or flange joint as per NFPA 96.
         5. Install fire-rated access panel assemblies at each change in direction and at maximum intervals of [**20**] [**12**] <**Insert dimension**> feet in horizontal ducts, and at every floor for vertical ducts, or as indicated on Drawings.
         6. Do not penetrate fire-rated assemblies except as allowed by applicable building codes and authorities having jurisdiction.
      3. ADDITIONAL INSTALLATION REQUIREMENTS FOR EXHAUST DUCTS SERVING COMMERCIAL DISHWASHERS AND OTHER HIGH-HUMIDITY LOCATIONS
         1. Install dishwasher exhaust ducts and other exhaust ducts from wet, high-humidity locations without dips and traps that may hold water. Slope ducts a minimum of 2 percent back to dishwasher or toward drain.
         2. Provide a drain pocket at each low point and at the base of each riser with a 1-inchtrapped copper drain from each drain pocket to open site floor drain.
         3. Minimize number of transverse seams.
         4. Do not locate longitudinal seams on bottom of duct.
      4. ADDITIONAL INSTALLATION REQUIREMENTS FOR LABORATORY EXHAUST AND FUME HOOD EXHAUST DUCTS
         1. Install ducts in accordance with NFPA 45, "Fire Protection for Laboratories Using Chemicals."
         2. Install exhaust ducts without dips and traps that may hold water. Slope ducts a minimum of 2 percent back to hood or inlet. Where indicated on Drawings, install trapped drain piping.
         3. Connect duct to fan, fume hood, and other equipment indicated on Drawings.
      5. DUCTWORK EXPOSED TO WEATHER
         1. All external joints are to [**be welded**] [**have secure watertight mechanical connections**]. Seal all openings to provide weatherproof construction.
         2. Construct ductwork to resist external loads of wind, snow, ice, and other effects of weather. Provide necessary supporting structures.
         3. Single Wall:

Retain one of first two subparagraphs below.

Ductwork shall be [**Type 304**] [**Type 316**] stainless steel.

Ductwork shall be galvanized steel.

If duct outer surface is uninsulated, protect outer surface with suitable paint. Paint materials and application requirements are specified in Section 099113 "Exterior Painting."

Where ducts have external insulation, provide weatherproof aluminum jacket. See Section 230713 "Duct Insulation."

* + - * 1. Double Wall:

Ductwork shall comply with requirements in "Double-Wall Rectangular Ducts and Fittings" or "Double-Wall Round [**and Flat-Oval**]Ducts and Fittings" Article.

Ductwork outer wall shall be [**Type 304**] [**Type 316**] stainless steel indicated by manufacturer to be suitable for outdoor installation.

Provide interstitial insulation.

* + - 1. DUCT SEALING

Retain one of two paragraphs below. Retain first paragraph if retaining subparagraphs for seal class and leakage class in "Duct Schedule" Article; otherwise, delete first and retain second paragraph.

* + - * 1. Seal ducts for duct static-pressure, seal classes, and leakage classes specified in "Duct Schedule" Article in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

Retain paragraph below for compliance with ASHRAE/IES 90.1, in which Section 6.4.4.2.1 - "Duct Sealing" requires a minimum seal class for various duct locations and pressures indicated in paragraph.

* + - * 1. Seal ducts at a minimum to the following seal classes in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible":

Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

Outdoor, Supply-Air Ducts: Seal Class A.

Outdoor, Exhaust Ducts: Seal Class C.

Outdoor, Return-Air Ducts: Seal Class C.

Unconditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg and Lower: Seal Class B.

Unconditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class A.

Unconditioned Space, Exhaust Ducts: Seal Class C.

Unconditioned Space, Return-Air Ducts: Seal Class B.

Conditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg and Lower: Seal Class C.

Conditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class B.

Conditioned Space, Exhaust Ducts: Seal Class B.

Conditioned Space, Return-Air Ducts: Seal Class C.

* + - 1. HANGER AND SUPPORT INSTALLATION
         1. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."

Verify attachment selection and spacing in "Building Attachments" and "Hanger Spacing" paragraphs below with structural engineer.

* + - * 1. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

Where practical, install concrete inserts before placing concrete.

Install powder-actuated concrete fasteners after concrete is placed and completely cured.

Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches thick.

Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.

Retain subparagraph below for projects that require seismic restraints.

Do not use powder-actuated concrete fasteners for seismic restraints.

* + - * 1. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.
        2. Hangers Exposed to View: Threaded rod and angle or channel supports.
        3. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at a maximum intervals of 16 feet.
        4. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.
      1. SEISMIC-RESTRAINT-DEVICE INSTALLATION
         1. Install ducts with hangers and braces designed to support the duct and to restrain against seismic forces required by applicable building codes. Comply with [**SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."**] [**ASCE/SEI 7.**]

Options for 40 and 80 feet in first subparagraph below are recommended by SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems." Revise these dimensions based on the configuration of duct and the seismic hazard.

Space lateral supports a maximum of [**40**] <**Insert dimension**> feet o.c., and longitudinal supports a maximum of [**80**] <**Insert dimension**> feet o.c.

Brace a change of direction longer than 12 feet.

* + - * 1. Select seismic-restraint devices with capacities adequate to carry present and future static and seismic loads.
        2. Install cables so they do not bend across edges of adjacent equipment or building structure.
        3. Install cable restraints on ducts that are suspended with vibration isolators.
        4. Install seismic-restraint devices using methods approved by [**an evaluation service member of the ICC Evaluation Service**] [**an agency acceptable to authorities having jurisdiction**].
        5. Attachment to Structure: If specific attachment is not indicated, anchor bracing and restraints to structure, to flanges of beams, to upper truss chords of bar joists, or to concrete members.
        6. Drilling for and Setting Anchors:

Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify Director’s Representative if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.

Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.

Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.

Set anchors to manufacturer's recommended torque, using a torque wrench.

Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

* + - 1. CONNECTIONS

Coordinate duct installations and specialty arrangements with Drawings.

* + - * 1. Make connections to equipment with flexible connectors complying with Section 233300 "Air Duct Accessories."
        2. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.
      1. PAINTING
         1. Paint interior of metal ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."
      2. FIELD QUALITY CONTROL
         1. Perform tests and inspections.

Retain "Leakage Tests" paragraph below for ducts in pressure classes 3-inch wg (750 Pa) and higher or if applying for sustainable design certification. It may not be economically practical to test ducts in pressure classes less than 3-inch wg (750 Pa).

* + - * 1. Leakage Tests:

Comply with SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.

Test the following systems:

Sustainable design requiring compliance with ASHRAE/IES 90.1 must comply with requirements of Section 6.4.4.2.2 - "Duct Leakage Tests," which requires leak testing of at least 25 percent of total installed duct area with a pressure class in excess of 3-inch wg (750 Pa). Retain "Ducts with a Pressure Class Higher Than 3-Inch wg (750 Pa)" subparagraph below for minimum requirements if applying for sustainable design certification or complying with ASHRAE/IES 90.1. To define more stringent requirements, retain subsequent subparagraphs as applicable and delete "Ducts with a Pressure Class Higher Than 3-Inch wg (750 Pa)" subparagraph. Consider cost impact when specifying extent of duct area to be tested. It is not common to leak test all ducts or ducts with a pressure class less than 3-inch wg (750 Pa).

Ducts with a Pressure Class Higher Than 3-Inch wg: Test representative duct sections[**, selected by Director’s Representative from sections installed,**] totaling no less than 25 percent of total installed duct area for each designated pressure class.

Supply Ducts with a Pressure Class of [**2-**] [**3-**] [**4-**] <**Insert number**> Inch wg or Higher: Test representative duct sections[**, selected by Director’s Representative from sections installed,**] totaling no less than [**50**] [**100**] <**Insert number**> percent of total installed duct area for each designated pressure class.

Return Ducts with a Pressure Class of [**2-**] [**3-**] [**4-**] <**Insert number**> Inch wg or Higher: Test representative duct sections[**, selected by Director’s Representative from sections installed,**] totaling no less than [**50**] [**100**] <**Insert number**> percent of total installed duct area for each designated pressure class.

Exhaust Ducts with a Pressure Class of [**2-**] [**3-**] [**4-**] <**Insert number**> Inch wg or Higher: Test representative duct sections[**, selected by Director’s Representative from sections installed,**] totaling no less than [**50**] [**100**] <**Insert number**> percent of total installed duct area for each designated pressure class.

Outdoor-Air Ducts with a Pressure Class of [**2-**] [**3-**] [**4-**] <**Insert number**> Inch wg or Higher: Test representative duct sections[**, selected by Director’s Representative from sections installed,**] totaling no less than [**50**] [**100**] <**Insert number**> percent of total installed duct area for each designated pressure class.

Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.

Testing of each duct section is to be performed with access doors, coils, filters, dampers, and other duct-mounted devices in place as designed. No devices are to be removed or blanked off so as to reduce or prevent additional leakage.

Test for leaks before applying external insulation.

Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure.

Give [**seven**] <**Insert number**> days' advance notice for testing.

Retain "Duct System Cleanliness Tests" paragraph below if duct cleaning is required or if applying for sustainable design certification. Sustainable design requiring compliance with ASHRAE 62.1 must comply with requirements of Section 7.2.4 - "Ventilation System Start-up," which requires that distribution systems be clean of dirt and debris. Text was taken from NADCA ACR, dated 2013.

* + - * 1. Duct System Cleanliness Tests:

Visually inspect duct system to ensure that no visible contaminants are present.

Test sections of metal duct system, chosen randomly by Director’s Representative, for cleanliness in accordance with "Description of Method 3 - NADCA Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."

Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.

* + - * 1. Duct system will be considered defective if it does not pass tests and inspections.
        2. Prepare test and inspection reports.
      1. DUCT CLEANING

Retain this article for applications where construction dust and debris in duct system must be removed before air-system operation, or if applying for sustainable design certification.

Sustainable design requiring compliance with ASHRAE 62.1 must comply with requirements of Section 7.2.4 - "Ventilation System Start-up," which requires that distribution systems be clean of dirt and debris.

This Section includes cleaning of new ductwork only. Where a project requires cleaning of portions of an existing duct system as well as all new work, those portions of existing system requiring cleaning must be accurately identified. This action is best done by indicating on a floor plan the duct portions to be cleaned. If cleaning of existing systems is required, include Section 230130.52 "Existing HVAC Air Distribution System Cleaning."

* + - * 1. Clean new duct system(s) before testing, adjusting, and balancing.
        2. For cleaning of existing ductwork, see Section 230130.52 "Existing HVAC Air Distribution System Cleaning."
        3. Use duct cleaning methodology as indicated in NADCA ACR.
        4. Use service openings for entry and inspection.

Provide openings with access panels appropriate for duct static-pressure and leakage class at dampers, coils, and any other locations where required for inspection and cleaning access. Provide insulated panels for insulated or lined duct. Patch insulation and liner as recommended by duct liner manufacturer. Comply with Section 233300 "Air Duct Accessories" for access panels and doors.

Disconnect and reconnect flexible ducts as needed for cleaning and inspection.

Remove and reinstall ceiling to gain access during the cleaning process.

* + - * 1. Particulate Collection and Odor Control:

When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.

When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

* + - * 1. Clean the following components by removing surface contaminants and deposits:

Air outlets and inlets (registers, grilles, and diffusers).

Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.

Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.

Coils and related components.

Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.

Supply-air ducts, dampers, actuators, and turning vanes.

Dedicated exhaust and ventilation components and makeup air systems.

* + - * 1. Mechanical Cleaning Methodology:

Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.

Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.

Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.

Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.

Clean coils and coil drain pans in accordance with NADCA ACR. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.

Provide drainage and cleanup for wash-down procedures.

Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents in accordance with manufacturer's written instructions after removal of surface deposits and debris.

* + - 1. STARTUP

Sustainable design requiring compliance with ASHRAE 62.1 should be coordinated with requirements of Section 7 - "Construction and System Start-up."

* + - * 1. Air Balance: Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
      1. DUCT SCHEDULE
         1. Fabricate ducts with galvanized sheet steel except as otherwise indicated and as follows:

Fabricate all ducts to achieve SMACNA pressure class, seal class, and leakage class as indicated below.

Underground Ducts: Concrete-encased, [**galvanized sheet steel**] [**PVC-coated, galvanized sheet steel with thicker coating on duct exterior**] [**stainless steel**].

<**Insert requirements**>.

Retain applicable subparagraphs in this article to set criteria for pressure class, duct seal-class level, and duct-leakage class; or delete subparagraphs and indicate pressure class, duct seal-class level, and duct-leakage class on Drawings. If retaining duct seal and leakage requirements in this article, retain first paragraph in "Duct Sealing" Article. Both seal class and leakage class are included in this article and either one can be deleted, or both can remain if they are consistent.

Paragraphs below are examples of broad system classifications. Revise to suit Project or indicate requirements on Drawings if a more refined classification is required.

See ASHRAE duct leakage recommendations in 2016 ASHRAE HANDBOOK - "HVAC Systems and Equipment," Ch. 19, "Duct Construction."

Sustainable design requiring compliance with ASHRAE/IES 90.1 must comply with requirements of Section 6.4.4.2.1 - "Duct Sealing," which requires a minimum seal-class level (A, B, or C) for various duct locations and pressures and specifies seal-class levels for joints and seams in ducts located outdoors, in unconditioned spaces, and in conditioned spaces. Retain second paragraph in "Duct Sealing" Article if applying for sustainable design certification and requirements are not defined in this article or indicated on Drawings.

* + - * 1. Supply Ducts:

Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units <**Insert equipment**>:

Pressure Class: Positive [**1-**] [**2-**] <**Insert number**>inch wg.

Minimum SMACNA Seal Class: [**A**] [**B**] [**C**].

SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].

SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

Ducts Connected to Constant-Volume Air-Handling Units <**Insert equipment**>:

Pressure Class: Positive [**2-**] [**3-**] <**Insert number**>inch wg.

Minimum SMACNA Seal Class: [**A**] [**B**].

SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].

SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

Ducts Connected to Variable-Air-Volume Air-Handling Units <**Insert equipment**>:

Pressure Class: Positive [**3-**] [**4-**] <**Insert number**>inch wg.

Minimum SMACNA Seal Class: [**A**] [**B**].

SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].

SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

Ducts Connected to Equipment Not Listed Above:

Pressure Class: Positive [**2-**] [**3-**] [**4-**] <**Insert number**>inch wg.

Minimum SMACNA Seal Class: [**A**] [**B**] [**C**].

SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].

SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

* + - * 1. Return Ducts:

Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units <**Insert equipment**>:

Pressure Class: Positive or negative [**1-**] [**2-**] <**Insert number**>inch wg.

Minimum SMACNA Seal Class: [**A**] [**B**] [**C**].

SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].

SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

Ducts Connected to Air-Handling Units <**Insert equipment**>:

Pressure Class: Positive or negative [**2-**] [**3-**] <**Insert number**>inch wg.

Minimum SMACNA Seal Class: [**A**] [**B**] [**C**].

SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].

SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

Ducts Connected to Equipment Not Listed above:

Pressure Class: Positive or negative [**2-**] [**3-**] [**4-**] <**Insert number**>inch wg.

Minimum SMACNA Seal Class: [**A**] [**B**] [**C**].

SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].

SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

* + - * 1. Exhaust Ducts:

Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:

Pressure Class: Negative [**1-**] [**2-**] [**3-**] <**Insert number**>inch wg.

Minimum SMACNA Seal Class: [**A**] [**B**] [**C**] if negative pressure, and A if positive pressure.

SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].

SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

Ducts Connected to Air-Handling Units <**Insert equipment**>:

Pressure Class: Positive or negative [**2-**] [**3-**] <**Insert number**>inch wg.

Minimum SMACNA Seal Class: [**A**] [**B**] [**C**] if negative pressure, and [**A**] [**B**] [**C**] if positive pressure.

SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].

SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

Ducts Connected to Commercial Kitchen Hoods: Comply with NFPA 96.

Exposed to View: Type 304, stainless-steel sheet, [**No. 4**] [**No. 3**] <**Insert finish**> finish.

Concealed: [**Type 304, stainless-steel sheet, No. 2D finish**] [**Carbon-steel sheet**].

Welded seams and joints.

Pressure Class: Positive or negative [**2-**] [**3-**] [**4-**] <**Insert number**>inch wg.

Airtight/watertight.

Ducts Connected to Dishwashers, Dishwasher Hoods, and Other High-Humidity Locations:

Type 304, stainless-steel sheet.

Exposed to View: [**No. 4**] [**No. 3**] <**Insert finish**> finish.

Concealed: [**No. 2D**] <**Insert finish**> finish.

Welded longitudinal seams; welded or flanged transverse joints with watertight EPDM gaskets.

Pressure Class: Positive or negative [**2-**] [**3-**] <**Insert number**>inch wg.

Airtight/watertight.

Ducts Connected to Fans Exhausting Fume Hood, Laboratory, and Process (ASHRAE 62.1, Class 3 and Class 4) Air:

Retain one of first two subparagraphs below. Determine from system users what chemicals are to be exhausted; verify suitable exhaust duct materials. Also consider Section 233116 "Nonmetal Ducts."

[**Type 316**] [**Type 304**], stainless-steel sheet.

Exposed to View: [**No. 4**] [**No. 3**] <**Insert finish**> finish.

Concealed: [**No. 2B**] [**No. 2D**] <**Insert finish**> finish.

PVC-coated, galvanized sheet steel with thicker coating on duct interior.

Pressure Class: Positive or negative [**3-**] [**4-**] [**6-**] <**Insert number**>inch wg.

[**Minimum SMACNA Seal Class A**] [**Welded seams and joints**].

Retain "SMACNA Leakage Class 2" subparagraph below if retaining "Minimum SMACNA Seal Class A" option in last subparagraph above. Retain "Airtight/watertight" subparagraph below if retaining "Welded seams and joints" option above.

[**SMACNA Leakage Class 2.**]

[**Airtight/watertight.**]

Ducts Connected to Equipment Not Listed above:

Pressure Class: Positive or negative [**2-**] [**3-**] [**4-**] <**Insert number**>inch wg.

Minimum SMACNA Seal Class: [**A**] [**B**] if negative pressure; A if positive pressure.

SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].

SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

* + - * 1. Outdoor-Air (Not Filtered, Heated, or Cooled) Ducts:

Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units <**Insert equipment**>:

Pressure Class: Positive or negative [**1-**] [**2-**] <**Insert number**>inch wg.

Minimum SMACNA Seal Class: [**A**] [**B**] [**C**].

SMACNA Leakage Class for Rectangular: [**8**] [**16**].

SMACNA Leakage Class for Round and Flat Oval: [**8**] [**16**].

Ducts Connected to Air-Handling Units <**Insert equipment**>:

Pressure Class: Positive or negative [**2-**] [**3-**] <**Insert number**>inch wg.

Minimum SMACNA Seal Class: [**A**] [**B**].

SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].

SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

Ducts Connected to Equipment Not Listed Above:

Pressure Class: Positive or negative [**2-**] [**3-**] [**4-**] <**Insert number**>inch wg.

Minimum SMACNA Seal Class: [**A**] [**B**].

SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].

SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

* + - * 1. Intermediate Reinforcement:

Galvanized-Steel Ducts: [**Galvanized steel**] [**Carbon steel coated with zinc-chromate primer**] [**Galvanized steel or carbon steel coated with zinc-chromate primer**].

PVC-Coated Ducts:

Exposed to Airstream: Match duct material.

Not Exposed to Airstream: [**Galvanized**] [**Match duct material**].

Stainless-Steel Ducts:

Exposed to Airstream: Match duct material.

Not Exposed to Airstream: [**Galvanized**] [**Match duct material**].

Aluminum Ducts: [**Aluminum**] [**or**] [**galvanized steel coated with zinc chromate**].

* + - * 1. Liner:

Sustainable design requiring compliance with ASHRAE/IES 90.1 must have duct insulation with an R-value that complies with tables titled "Minimum Duct Insulation R-Value, Cooling and Heating Only Supply Ducts and Return Ducts" and "Minimum Duct Insulation R-Value, Combined Heating and Cooling Supply Ducts and Return Ducts." If using liner alone to satisfy thermal requirements, verify that material selected is available in thickness needed to provide thermal performance without jeopardizing other requirements.

Flexible elastomeric insulation is available in thicknesses through 1-1/2 inches, which comply with NFPA 90A. Some options in subparagraphs below may create a restrictive proprietary specification. Verify availability of performance with manufacturers.

Retain one option for material and one option for thickness, or insert another thickness, in each of six subparagraphs below.

Supply-Air Ducts: [**Fibrous glass, Type I**] [**Flexible elastomeric**] [**Natural fiber**], [**1**] [**1-1/2**] [**2**] <**Insert dimension**> inch(es) thick.

Return-Air Ducts: [**Fibrous glass, Type I**] [**Flexible elastomeric**] [**Natural fiber**], [**1**] [**1-1/2**] [**2**] <**Insert dimension**> inch(es) thick.

Exhaust-Air Ducts: [**Fibrous glass, Type I**] [**Flexible elastomeric**] [**Natural fiber**], [**1**] <**Insert dimension**> inch(es) thick.

Supply Fan Plenums: [**Fibrous glass, Type II**] [**Flexible elastomeric**] [**Natural fiber**], [**1**] [**1-1/2**] [**2**] <**Insert dimension**> inch(es) thick.

Return- and Exhaust-Fan Plenums: [**Fibrous glass, Type II**] [**Flexible elastomeric**] [**Natural fiber**], [**2**] <**Insert dimension**> inches thick.

Transfer Ducts: [**Fibrous glass, Type I**] [**Flexible elastomeric**] [**Natural fiber**], [**1**] [**1-1/2**] [**2**] <**Insert dimension**> inch(es) thick.

Sustainable design requiring compliance with ASHRAE/IES 90.1 must have duct insulation with an R-value that complies with tables titled "Minimum Duct Insulation R-Value, Cooling and Heating Only Supply Ducts and Return Ducts" and "Minimum Duct Insulation R-Value, Combined Heating and Cooling Supply Ducts and Return Ducts." If using interstitial insulation alone to satisfy thermal requirements, verify that material selected is available in thickness needed to provide thermal performance without jeopardizing other requirements.

* + - * 1. Double-Wall Duct Interstitial Insulation:

Supply-Air Ducts: [**1**] [**1-1/2**] [**2**] <**Insert dimension**> inch(es) thick.

Return-Air Ducts: [**1**] [**1-1/2**] [**2**] <**Insert dimension**> inch(es) thick.

Exhaust-Air Ducts: [**1h**] [**1-1/2**] [**2**] <**Insert dimension**> inch(es) thick.

* + - * 1. Elbow Configuration:

Retain one of two "Rectangular Duct" subparagraphs below. Retain first subparagraph to set different requirements for various velocities; second, to set the same requirements for all velocities.

Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."

Velocity 1000 fpm or Lower:

Radius Type RE 1 with minimum 0.5 radius-to-diameter ratio.

Mitered Type RE 4 without vanes.

Velocity 1000 to 1500 fpm:

Radius Type RE 1 with minimum 1.0 radius-to-diameter ratio.

Radius Type RE 3 with minimum 0.5 radius-to-diameter ratio and two vanes.

Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

Velocity 1500 fpm or Higher:

Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.

Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.

Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."

Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.

Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.

Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "Round Duct Elbows."

Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 3-1, "Mitered Elbows." Elbows with less than 90-degree change of direction have proportionately fewer segments.

Retain "Velocity 1000 fpm (5 m/s) or Lower," "Velocity 1000 to 1500 fpm (5 to 7.6 m/s)," and "Velocity 1500 fpm (7.6 m/s) or Higher" subparagraphs below, or delete all and retain "Radius-to Diameter Ratio" subparagraph.

Velocity 1000 fpm or Lower: 0.5 radius-to-diameter ratio and three segments for 90-degree elbow.

Velocity 1000 to 1500 fpm: 1.0 radius-to-diameter ratio and four segments for 90-degree elbow.

Velocity 1500 fpm or Higher: 1.5 radius-to-diameter ratio and five segments for 90-degree elbow.

Radius-to Diameter Ratio: 1.5.

Round Elbows, [**12**] <**Insert dimension**> Inches and Smaller in Diameter: Stamped or pleated.

Round Elbows, [**14**] <**Insert dimension**> Inches and Larger in Diameter: [**Standing seam**] [**Welded**].

Delete "Branch Configuration" paragraph below if branch fittings are indicated on Drawings.

* + - * 1. Branch Configuration:

Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-6, "Branch Connection."

Rectangular Main to Rectangular Branch: 45-degree entry.

Rectangular Main to Round Branch: Conical spin in.

Round and Flat Oval: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees." Saddle taps are permitted in existing duct.

Velocity 1000 fpm or Lower: 90-degree tap.

Velocity 1000 to 1500 fpm: Conical tap.

Velocity 1500 fpm or Higher: 45-degree lateral.

END OF SECTION 233113