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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.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 1. Single-wall rectangular ducts and fittings.
 2. Double-wall rectangular ducts and fittings.
 3. Single-wall round[**and flat-oval**] ducts and fittings.

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4. Double-wall round[**and flat-oval**] ducts and fittings.
5. Sheet metal materials.
6. Antimicrobial Protective Coating.
7. Duct liner.
8. Sealants and gaskets.
9. Hangers and supports.
10. Seismic-restraint devices.

B. Related Sections:

Retain Sections in subparagraphs below that contain requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 230593 "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing requirements for metal ducts.
2. Section 233116 "Nonmetal Ducts" for fibrous-glass ducts, thermoset fiber-reinforced plastic ducts, thermoplastic ducts, PVC ducts, and concrete ducts.
3. Section 233119 "HVAC Casings" for factory- and field-fabricated casings for mechanical equipment.

Antimicrobial Coating should be applied to portions of duct accessories exposed to the air stream. This ensures the interior of the system is completely coated so as not to allow anywhere for microbial growth. Duct accessories with portions to be coated include: volume control dampers; turning vanes; purchased taps; round couplers; duct access doors (airstream side only); flat strip (one side only); standing slip lock; and conduit ties.

Do not apply Antimicrobial Coating to flexible duct and the following duct accessories: fire dampers; smoke dampers; combination fire/smoke dampers; motor dampers; and backdraft dampers. UL Listed components are precision and often moving parts that require complete mobility. Since they are typically purchased and not fabricated by those applying antimicrobial coating, they should not be coated in order to maintain design integrity.

4. Section 233300 "Air Duct Accessories" for dampers, sound-control devices, duct-mounting access doors and panels, turning vanes, and flexible ducts. Includes Antimicrobial Coating of duct accessory surfaces exposed to the airstream.

1.3 PERFORMANCE REQUIREMENTS

Retain first paragraph below if Contractor is required to assume responsibility for duct construction design.

- A. 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 performance requirements and design criteria indicated in "Duct Schedule" Article.

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

- B. 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

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described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" [and] [ASCE/SEI 7.] [SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."] <Insert document.>

Retain one of three subparagraphs below if retaining "SMACNA's 'Seismic Restraint Manual: Guidelines for Mechanical Systems'" option in paragraph above. If using other seismic design criteria, delete three subparagraphs below.

1. Seismic Hazard Level A: Seismic force to weight ratio, 0.48.
2. Seismic Hazard Level B: Seismic force to weight ratio, 0.30.
3. Seismic Hazard Level C: Seismic force to weight ratio, 0.15.

Retain paragraph below to comply with LEED Prerequisite IEQ 1.

- C. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of the following products:

1. Liners and adhesives.
2. Sealants and gaskets.
3. Seismic-restraint devices.

- B. LEED Submittals:

1. Product Data for Prerequisite IEQ 1: Documentation indicating that duct systems comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
2. Product Data for Prerequisite EA 2: Documentation indicating that duct systems comply with ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

Retain first subparagraph below if leak testing is retained in "Field Quality Control" Article.

3. Leakage Test Report for Prerequisite EA 2: Documentation of work performed for compliance with ASHRAE/IESNA 90.1, Section 6.4.4.2.2 - "Duct Leakage Tests."

Retain first subparagraph below if retaining "Duct Cleaning" Article.

4. Duct-Cleaning Test Report for Prerequisite IEQ 1: Documentation of work performed for compliance with ASHRAE 62.1, Section 7.2.4 - "Ventilation System Start-up."

"Product Data for Credit IEQ 4.1" Subparagraph below applies to LEED-NC, LEED-CI, and LEED-CS; coordinate with requirements for adhesives and sealants.

5. Product Data for Credit IEQ 4.1: For adhesives and sealants, documentation including printed statement of VOC content.

"Laboratory Test Reports for Credit IEQ 4" Subparagraph below applies to LEED for Schools.

6. Laboratory Test Reports for Credit IEQ 4: For adhesives and sealants, documentation indicating that products comply with the testing and product requirements of the

California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. Shop Drawings:

1. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
2. Factory- and shop-fabricated ducts and fittings.
3. Duct layout indicating sizes, configuration, liner material, and static-pressure classes.
4. Elevation of top of ducts.
5. Dimensions of main duct runs from building grid lines.
6. Fittings.
7. Reinforcement and spacing.
8. Seam and joint construction.
9. Penetrations through fire-rated and other partitions.
10. Equipment installation based on equipment being used on Project.
11. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.
12. Hangers and supports, including methods for duct and building attachment[, **seismic restraints,**] and vibration isolation.
13. **<Insert lists of areas or systems requiring Shop Drawings.>**

Paragraph below is defined in Section 013300 "Submittal Procedures" as a "Delegated-Design Submittal." Retain with "Performance Requirements" Article if design responsibilities have been delegated to Contractor.

D. Delegated-Design Submittal:

1. Sheet metal thicknesses.
2. Joint and seam construction and sealing.
3. Reinforcement details and spacing.
4. Materials, fabrication, assembly, and spacing of hangers and supports.

Retain 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. Professional engineer qualifications are specified in Section 014000 "Quality Requirements."

5. Design Calculations: Calculations[, **including analysis data signed and sealed by the qualified professional engineer responsible for their preparation**] for selecting hangers and supports[**and seismic restraints**].

1.5 INFORMATIONAL SUBMITTALS

Retain first paragraph below if Drawings do not include detailed plans or if Project involves unusual coordination requirements.

- A. Coordination Drawings: Plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

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1. Duct installation in congested spaces, indicating coordination with general construction, building components, and other building services. Indicate proposed changes to duct layout.
2. Suspended ceiling components.
3. Structural members to which duct will be attached.
4. Size and location of initial access modules for acoustical tile.
5. Penetrations of smoke barriers and fire-rated construction.
6. Items penetrating finished ceiling including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. Perimeter moldings.
 - g. <Insert item>.

Retain first paragraph below if retaining procedures for welder certification in "Quality Assurance" Article.

- B. Welding certificates.
- C. Field quality-control reports.

1.6 QUALITY ASSURANCE

Retain one of first two paragraphs below if welding is required. If retaining, also retain "Welding certificates" Paragraph in "Informational Submittals" Article. Retain first paragraph if only one AWS standard is applicable. Retain second paragraph if more than one AWS standard is referenced.

- A. Welding Qualifications: Qualify procedures and personnel according to [AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.] [AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports.] [AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.]
- B. Welding Qualifications: Qualify procedures and personnel according to the following:

Retain applicable subparagraphs below.

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports.
3. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.

Retain first two paragraphs below if applying for LEED certification or if requiring compliance with ASHRAE or ASHRAE/IESNA.

LEED Prerequisite IEQ 1 requires compliance with requirements in ASHRAE 62.1.

- C. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-up."

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LEED Prerequisite EA 2 requires compliance with requirements in ASHRAE/IESNA 90.1.

- D. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

Retain 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.

ASHRAE/IESNA 90.1 requires leakage testing for representative sections totaling no less than 25 percent of installed duct area for ducts designated to operate at a static-pressure class in excess of 3-inch wg (750 Pa). Consider building a mockup of typical portions of the system that can be tested early in the construction process. This standard, as enforced by some authorities having jurisdiction, requires duct systems with static-pressure classes in excess of 3-inch wg (750 Pa) to be identified on Drawings.

- E. Mockups:

1. Before installing duct systems, build mockups representing static-pressure classes in excess of [3-inch wg (750 Pa)] <Insert static-pressure class>. Build mockups to comply with the following requirements, using materials indicated for the completed Work:
 - a. [Five] <Insert number> transverse joints.
 - b. [One] <Insert number> access door(s).
 - c. [Two] <Insert number> typical branch connections, each with at least one elbow.
 - d. [Two] <Insert number> typical flexible duct or flexible-connector connections for each duct and apparatus.
 - e. [One] <Insert number> 90-degree turn(s) with turning vanes.
 - f. [One] <Insert number> fire damper(s).
 - g. Perform leakage tests specified in "Field Quality Control" Article. Revise mockup construction and perform additional tests as required to achieve specified minimum acceptable results.

Retain subparagraph below if mockups are installed as part of building rather than erected separately and the intention is to make an exception to the default requirement in Section 014000 "Quality Requirements" for demolishing and removing mockups when directed unless otherwise indicated.

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

PART 2 - PRODUCTS

2.1 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

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

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- A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.
- B. Transverse Joints: Select joint types and fabricate according to 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."
- C. Longitudinal Seams: Select seam types and fabricate according to 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."
- D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 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."

2.2 DOUBLE-WALL RECTANGULAR DUCTS AND FITTINGS

Retain first paragraph below to require factory-fabricated, double-wall rectangular ducts and fittings; delete to allow shop-fabricated ducts and fittings.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, **[provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:**
 - 1. McGill AirFlow LLC.
 - 2. Sheet Metal Connectors, Inc.
 - 3. **<Insert manufacturer's name>**.
- B. Rectangular Ducts: Fabricate ducts with indicated dimensions for the inner duct.
- C. Outer Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.
- D. Transverse Joints: Select joint types and fabricate according to 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."

- E. Longitudinal Seams: Select seam types and fabricate according to 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."

Retain one of first two 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.

- F. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

Retain first subparagraph below to require thermal conductivity exceeding the requirements in ASTM C 1071. Retaining subparagraph may create a restrictive proprietary specification. Verify availability of performance with manufacturers.

1. Maximum Thermal Conductivity: [**0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K)** <Insert conductivity> at **75 deg F (24 deg C)** mean temperature.
2. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.

Retain subparagraph below for additional protection of airstream.

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

- G. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C 534, Type II for sheet materials, and with NFPA 90A or NFPA 90B.

Retain subparagraph below to require thermal conductivity exceeding the requirements in ASTM C 1071. Retaining subparagraph may create a restrictive proprietary specification. Verify availability of performance with manufacturers.

1. Maximum Thermal Conductivity: [**0.25 Btu x in./h x sq. ft. x deg F (0.034 W/m x K)** <Insert conductivity> at **75 deg F (24 deg C)** mean temperature.

For double wall insulated ductwork: In instances when perforated interior is required over solid inner wall, the recommended application would be to coat the interior solid wall below the perforated material due to the excess oil found on perforated steel prior to fabrication. While coating using Silver Bullet AM on perforated steel is not impossible, it is somewhat impractical due to additional steps required to prep the surface of the perforated steel.

- H. Inner Duct: Minimum **0.028-inch (0.7-mm)** [**perforated galvanized sheet steel having 3/32-inch- (2.4-mm-) diameter perforations, with overall open area of 23 percent**] [**solid sheet steel**].

Retain "Antimicrobial Coating" subparagraph below if first option is selected in paragraph above.

1. Antimicrobial Coating: Shop-applied to interior solid wall below perforated material.

- I. Formed-on Transverse Joints (Flanges): Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Traverse 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."
- J. Longitudinal Seams: Select seam types and fabricate according to 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."

2.3 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.

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

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

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain subparagraph and list of manufacturers below. See Section 016000 "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, **[provide products by one of the following]** **[available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:**
 - a. Lindab Inc.
 - b. McGill AirFlow LLC.
 - c. SEMCO Incorporated.
 - d. Sheet Metal Connectors, Inc.
 - e. Spiral Manufacturing Co., Inc.
 - f. **<Insert manufacturer's name>**.
- B. 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).
- C. Transverse Joints: Select joint types and fabricate according to 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.

1. Transverse Joints in Ducts Larger Than [**60 Inches (1524 mm)**] <Insert dimension> in Diameter: Flanged.
- D. Longitudinal Seams: Select seam types and fabricate according to 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."
 1. Fabricate round ducts larger than **90 inches (2286 mm)** in diameter with butt-welded longitudinal seams.
 2. Fabricate flat-oval ducts larger than **72 inches (1830 mm)** in width (major dimension) with butt-welded longitudinal seams.
- E. Tees and Laterals: Select types and fabricate according to 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."

2.4 DOUBLE-WALL ROUND[**AND FLAT-OVAL**] DUCTS AND FITTINGS

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

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:
 1. Lindab Inc.
 2. McGill AirFlow LLC.
 3. SEMCO Incorporated.
 4. Sheet Metal Connectors, Inc.
 5. <Insert manufacturer's name>.
- B. 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.
- C. Outer Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on static-pressure class unless otherwise indicated.
 1. Transverse Joints: Select joint types and fabricate according to 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.

- a. Transverse Joints in Ducts Larger Than **[60 Inches (1524 mm)]** <Insert dimension> in Diameter: Flanged.
2. Longitudinal Seams: Select seam types and fabricate according to 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."
 - a. Fabricate round ducts larger than **90 inches (2286 mm)** in diameter with butt-welded longitudinal seams.
 - b. Fabricate flat-oval ducts larger than **72 inches (1830 mm)** in width (major dimension) with butt-welded longitudinal seams.
3. Tees and Laterals: Select types and fabricate according to 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."

For double wall insulated ductwork: In instances when perforated interior is required over solid inner wall, the recommended application would be to coat the interior solid wall below the perforated material due to the excess oil found on perforated steel prior to fabrication. While coating using Silver Bullet AM on perforated steel is not impossible, it is somewhat impractical due to additional steps required to prep the surface of the perforated steel.

- D. Inner Duct: Minimum **0.028-inch (0.7-mm)** [perforated galvanized sheet steel having **3/32-inch- (2.4-mm-)** diameter perforations, with overall open area of 23 percent] [solid sheet steel].

Retain "Antimicrobial Coating" subparagraph below if first option is selected in paragraph above.

1. Antimicrobial Coating: Shop-applied to interior solid wall below perforated material.

Retain one of two 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.

- E. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

Retain first subparagraph below to require thermal conductivity exceeding the requirements in ASTM C 1071. Retaining subparagraph may create a restrictive proprietary specification. Verify availability of performance with manufacturers.

1. Maximum Thermal Conductivity: **[0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K)]** <Insert conductivity> at **75 deg F (24 deg C)** mean temperature.

2. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
 3. Cover insulation with polyester film complying with UL 181, Class 1.
- F. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C 534, Type II for sheet materials, and with NFPA 90A or NFPA 90B.

Retain subparagraph below to require thermal conductivity exceeding the requirements in ASTM C 1071. Retaining subparagraph may create a restrictive proprietary specification. Verify availability of performance with manufacturers.

1. Maximum Thermal Conductivity: **[0.25 Btu x in./h x sq. ft. x deg F (0.034 W/m x K)]** **<Insert conductivity>** at **75 deg F (24 deg C)** mean temperature.

2.5 SHEET METAL MATERIALS

- A. 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 first six paragraphs below.

- B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
1. Galvanized Coating Designation: **[G60 (Z180)] [G90 (Z275)]**.
 2. Finishes for Surfaces Exposed to View: Mill phosphatized.
- C. PVC-Coated, Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
1. Galvanized Coating Designation: **[G60 (Z180)] [G90 (Z275)]**.

Most sheet metal suppliers can provide a 4-mil- (0.10-mm-) thick coating on both sides.

2. Minimum Thickness for Factory-Applied PVC Coating: **4 mils (0.10 mm)** thick **[on sheet metal surface of ducts and fittings exposed to corrosive conditions, and minimum 1 mil (0.025 mm) thick on opposite surface]**.
 3. Coating Materials: Acceptable to authorities having jurisdiction for use on ducts listed and labeled by an NRTL for compliance with UL 181, Class 1.
- D. Carbon-Steel Sheets: Comply with ASTM A 1008/A 1008M, with oiled, matte finish for exposed ducts.

Agion Silver Bullet AM with stainless steel metal flake applied to sheet metal provides and alternative to stainless-steel.

- E. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304 or 316, as indicated in the "Duct Schedule" Article; cold rolled, annealed, sheet. Exposed surface finish shall be No. 2B, No. 2D, No. 3, or No. 4 as indicated in the "Duct Schedule" Article.

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- F. Aluminum Sheets: Comply with **ASTM B 209 (ASTM B 209M)** Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view.
- G. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.
 - 1. 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.
- H. Tie Rods: Galvanized steel, **1/4-inch (6-mm)** minimum diameter for lengths **36 inches (900 mm)** or less; **3/8-inch (10-mm)** minimum diameter for lengths longer than **36 inches (900 mm)**.

Antimicrobial coating in Article below is an optional feature and shop applied to ducts fabricated with galvanized sheet steel at the time of fabrication. See Evaluations for discussion on coatings.

Bio Shield Tech specializes in the supply of Agion Antimicrobial Protective "Shop Applied" coating which "suppresses" the growth of mold and mildew, while controlling the spread and growth of many types of bacteria, such as Staphylococcus aureus (MRSA), Escherichia coli, and Legionella pneumophila.

Silver Bullet AM manufactured by Burke Industrial Coatings and supplied by Bio Shield Tech, LLC are Made in the USA. Silver Bullet AM is a registered trademark of Burke Industrial Coatings.

2.6 Shop-Applied Antimicrobial Coating:

Retain "with stainless steel metal flake" option in subparagraph below for coatings applied to sheet metal where stainless-steel sheet would otherwise be used.

- A. Basis-of-Design Product: Subject to compliance with requirements, provide Bio Shield Tech; Silver Bullet AM containing Agion antimicrobial silver ion compounds [**and stainless steel metal flake**] or comparable product by one of the following:
 - 1. **<Insert manufacturer's name>**.
- B. Apply Agion Antimicrobial Protected Coating to the surface of sheet metal that will form 100 percent the interior solid surface of the duct.

Bio Shield Tech supplied Agion protected coatings recommends the application of a minimum of 0.5 mils of dry film thickness. To achieve this, a minimum of 1.5 mils wet film is typically advised, subject to shop conditions.

- C. Thickness: Minimum of 1.5 mils of wet film thickness applied to all fabricated sheet metal components to achieve minimum of 0.5 mils dry film thickness.
- D. EPA for use in HVAC systems.
- E. Coating containing the antimicrobial compound shall have a hardness of 2H, minimum, when tested according to ASTM D 3363.
- F. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.

In "Shop-Applied Coating Color" subparagraph below, retain "Stainless steel gray" option for coatings applied to sheet metal where stainless-steel sheet would otherwise be used.

- G. Shop-Applied Coating Color: **[Black] [White] [Clear] [Stainless steel gray]**.

2.7 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.

LEED Prerequisite EA 2 requires that duct insulation R-value comply with ASHRAE/IESNA 90.1 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.

Type I duct liner is available in thicknesses of 1/2 to 2 inches (13 to 50 mm) in 1/2-inch (13-mm) increments; Type II duct liner is available in thicknesses of 1 to 2 inches (25 to 50 mm) in 1/2-inch (13-mm) increments. Indicate thicknesses on Drawings or in the "Duct Schedule" Article.

When specifying duct liner by referencing ASTM C 1071, 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.

When liner is required regardless of type, it should not be considered equal to a quality shop applied antimicrobial coating. Hard surface AM coatings such as Silver Bullet AM are used in a variety of industries such as food processing equipment, ambulances interiors, waste water treatment plants, among others due to its longevity and effectiveness under harsh conditions. While liners can provide R-value for insulation or Sound attenuation it is not practical or possible to line a complete HVAC system. Conversely, an entire enhanced HVAC system can be coated with a shop-applied antimicrobial coating such as Silver Bullet AM with the use of liners in areas as needed. (Example: Liner used 20 ft outside of air handling unit)

To achieve maximum benefit of Agion antimicrobial protected coatings on sheet metal duct, liners of any material should be avoided. If the duct needs to be conditioned for either R-value or sound, these could be achieved in one of the following ways. If the duct needs to be thermally protected in an unconditioned space, it should be wrapped with insulation. If the duct needs to be thermally protected and sound reduced, the duct can be made "double wall perforated". The inner wall of the duct would use Agion antimicrobial shop-applied coatings on sheet metal that has been perforated to allow sound attenuation.

- A. Fibrous-Glass Duct Liner: Comply with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain one of first two subparagraphs and list of manufacturers below. See Section 016000 "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, **[provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:**

To exceed the minimum requirements set by ASTM C 1071, verify that a particular manufacturer's product can meet the requirements, retain the "Basis-of-Design Product" Subparagraph below, and insert the manufacturer's name and product designation.

2. Basis-of-Design Product: Subject to compliance with requirements, provide [**product indicated on Drawings**] <Insert manufacturer's name; product name or designation> or comparable product by one of the following:
 - a. CertainTeed Corporation; Insulation Group.
 - b. Johns Manville.
 - c. Knauf Insulation.
 - d. Owens Corning.
 - e. <Insert manufacturer's name>.

Retain first subparagraph below to require thermal conductivity exceeding the minimum requirements in ASTM C 1071. Retaining subparagraph may create a restrictive proprietary specification.

- f. Maximum Thermal Conductivity:

Option for thermal conductivity in first two subparagraphs below exceeds the values in ASTM C 1071. If retaining, verify availability of performance with duct liner manufacturers.

- 1) Type I, Flexible: [**0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K)**] <Insert conductivity> at 75 deg F (24 deg C) mean temperature.
- 2) Type II, Rigid: [**0.23 Btu x in./h x sq. ft. x deg F (0.033 W/m x K)**] <Insert conductivity> at 75 deg F (24 deg C) mean temperature.

Antimicrobial coating in first subparagraph below is an optional feature for duct liner.

Antimicrobial coatings such as Silver Bullet AM should not be compared to generic "antimicrobial" coatings used on porous surfaces such as fibrous duct liner. The Agion silver/copper ion compounds used in Silver Bullet AM reside in an extremely robust resin system that is formulated for hard non porous substrates (such as G90 Steel/Aluminum, etc.) which when fully cured will dry to a pencil hardness of 6H. This type of coating is designed to house a maximum reservoir of available silver/copper ions that can sustain years, and more likely decades, of antimicrobial efficacy in a contained HVAC environment.

3. 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.
4. [**Solvent**] [**Water**]-Based Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C 916.

One or both subparagraphs below may be required to comply with Project requirements or authorities having jurisdiction. Retain first subparagraph below if required for LEED-NC, LEED-CI, or LEED-CS Credit IEQ 4.1.

- a. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

Retain subparagraph below if required for LEED for Schools Credit IEQ 4.

- b. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile

Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

Flexible elastomeric duct liner in first paragraph below is not suitable for temperatures higher than 220 deg F (104 deg C).

- B. Flexible Elastomeric Duct Liner: Preformed, cellular, closed-cell, sheet materials complying with ASTM C 534, Type II, Grade 1; and with NFPA 90A or NFPA 90B.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain one of first two subparagraphs and list of manufacturers below. See Section 016000 "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, **[provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:**

To exceed the minimum requirements set by ASTM C 1071, verify that a particular manufacturer's product can meet the requirements, retain the "Basis-of-Design Product" Subparagraph below, and insert the manufacturer's name and product designation.

2. Basis-of-Design Product: Subject to compliance with requirements, provide **[product indicated on Drawings] <Insert manufacturer's name; product name or designation>** or comparable product by one of the following:
- Aeroflex USA Inc.
 - Armacell LLC.
 - Rubatex International, LLC
 - <Insert manufacturer's name>**.

Available thicknesses for flexible elastomeric duct liner are 3/8, 1/2, 3/4, and 1 inch (10, 13, 19, and 25 mm). Indicate thickness on Drawings or in the "Duct Schedule" Article.

Surface-burning characteristics in first 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 according to UL 723; certified by an NRTL.
- Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

One or both subparagraphs below may be required to comply with Project requirements or authorities having jurisdiction. Retain first subparagraph below if required for LEED-NC, LEED-CI, or LEED-CS Credit IEQ 4.1.

- For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

Retain subparagraph below if required for LEED for Schools Credit IEQ 4.

- Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

- C. Natural-Fiber Duct Liner: 85 percent cotton, 10 percent borate, and 5 percent polybinding fibers, treated with a microbial growth inhibitor and complying with NFPA 90A or NFPA 90B.

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain one of first two subparagraphs and list of manufacturers below. See Section 016000 "Product Requirements."

1. Manufacturers: Subject to compliance with requirements, **[provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:**

To exceed the minimum requirements set by ASTM C 1071, verify that a particular manufacturer's product can meet the requirements, retain the "Basis-of-Design Product" Subparagraph below, and insert the manufacturer's name and product designation.

2. Basis-of-Design Product: Subject to compliance with requirements, provide **[product indicated on Drawings] <Insert manufacturer's name; product name or designation>** or comparable product by one of the following:
 - a. Bonded Logic, Inc.
 - b. Reflectix Inc.
 - c. **<Insert manufacturer's name>**.

Available thicknesses for natural-fiber duct liner are 1/2 and 1 inch (13 and 25 mm). Indicate thickness on Drawings or in the "Duct Schedule" Article.

3. Maximum Thermal Conductivity: **[0.24 Btu x in./h x sq. ft. x deg F (0.034 W/m x K)] <Insert conductivity>** at **75 deg F (24 deg C)** mean temperature when tested according to ASTM C 518.
4. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to ASTM E 84; certified by an NRTL.
5. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

One or both subparagraphs below may be required to comply with Project requirements or authorities having jurisdiction. Retain first subparagraph below if required for LEED-NC, LEED-CI, or LEED-CS Credit IEQ 4.1.

- a. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

Retain subparagraph below if required for LEED for Schools Credit IEQ 4.

- b. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

- D. Insulation Pins and Washers:

1. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, **[0.106-inch- (2.6-mm-)] [0.135-inch- (3.5-**

- mm-)]** diameter shank, length to suit depth of insulation indicated with integral **1-1/2-inch (38-mm)** galvanized carbon-steel washer.
2. Insulation-Retaining Washers: Self-locking washers formed from **0.016-inch- (0.41-mm-)** 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 (38 mm)** in diameter.
- E. Shop Application of Duct Liner: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 7-11, "Flexible Duct Liner Installation."
1. 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.
 2. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.
 3. Butt transverse joints without gaps, and coat joint with adhesive.
 4. Fold and compress liner in corners of rectangular ducts or cut and fit to ensure butted-edge overlapping.
 5. 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).

6. Apply adhesive coating on longitudinal seams in ducts with air velocity of **2500 fpm (12.7 m/s)**.

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.

7. Secure liner with mechanical fasteners **4 inches (100 mm)** from corners and at intervals not exceeding **12 inches (300 mm)** transversely; at **3 inches (75 mm)** from transverse joints and at intervals not exceeding **18 inches (450 mm)** longitudinally.
8. 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:
 - a. Fan discharges.
 - b. Intervals of lined duct preceding unlined duct.
 - c. Upstream edges of transverse joints in ducts where air velocities are higher than **2500 fpm (12.7 m/s)** 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.

9. 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.
 - a. Sheet Metal Inner Duct Perforations: **3/32-inch (2.4-mm)** diameter, with an overall open area of 23 percent.

10. 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.

2.8 SEALANT AND GASKETS

- A. 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 according to 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 first three paragraphs below, and identify which sealing system applies to which duct system in the "Duct Schedule" Article.

- B. Two-Part Tape Sealing System:

1. Tape: Woven cotton fiber impregnated with mineral gypsum and modified acrylic/silicone activator to react exothermically with tape to form hard, durable, airtight seal.
2. Tape Width: [3 inches (76 mm)] [4 inches (102 mm)] [6 inches (152 mm)].
3. Sealant: Modified styrene acrylic.
4. Water resistant.
5. Mold and mildew resistant.
6. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive and negative.
7. Service: Indoor and outdoor.
8. Service Temperature: Minus 40 to plus 200 deg F (Minus 40 to plus 93 deg C).
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum.

One or both subparagraphs below may be required to comply with Project requirements or authorities having jurisdiction. Retain first subparagraph below if required for LEED-NC, LEED-CI, or LEED-CS Credit IEQ 4.1.

10. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

Retain subparagraph below if required for LEED for Schools Credit IEQ 4.

11. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

Retain one of first two paragraphs below. If retaining second paragraph, verify acceptability with authorities having jurisdiction.

- C. Water-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Solids Content: Minimum 65 percent.
3. Shore A Hardness: Minimum 20.
4. Water resistant.

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5. Mold and mildew resistant.
6. VOC: Maximum 75 g/L (less water).
7. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive and negative.
8. Service: Indoor or outdoor.
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

D. Solvent-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Base: Synthetic rubber resin.
3. Solvent: Toluene and heptane.
4. Solids Content: Minimum 60 percent.
5. Shore A Hardness: Minimum 60.
6. Water resistant.
7. Mold and mildew resistant.

One or more of three subparagraphs below may be required to comply with Project requirements or authorities having jurisdiction. Retain first subparagraph if required for LEED-NC, LEED-CI, or LEED-CS Credit IEQ 4.1.

8. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
9. VOC: Maximum 395 g/L.

Retain subparagraph below if required for LEED for Schools Credit IEQ 4.

10. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
11. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive or negative.
12. Service: Indoor or outdoor.
13. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

E. Flanged Joint Sealant: Comply with ASTM C 920.

1. General: Single-component, acid-curing, silicone, elastomeric.
2. Type: S.
3. Grade: NS.
4. Class: 25.
5. Use: O.

One or both subparagraphs below may be required to comply with Project requirements or authorities having jurisdiction. Retain first subparagraph below if required for LEED-NC, LEED-CI, or LEED-CS Credit IEQ 4.1.

6. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

Retain subparagraph below if required for LEED for Schools Credit IEQ 4.

7. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

- F. 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.

- G. Round Duct Joint O-Ring Seals:

1. Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg (0.14 L/s per sq. m at 250 Pa) and shall be rated for 10-inch wg (2500-Pa) 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.

2. EPDM O-ring to seal in concave bead in coupling or fitting spigot.
3. Double-lipped, EPDM O-ring seal, mechanically fastened to factory-fabricated couplings and fitting spigots.

2.9 HANGERS AND SUPPORTS

Indicate the extent of corrosive environment on Drawings.

- A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.
- B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.
- C. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1 (Table 5-1M), "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct."
- D. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A 603.
- E. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A 492.
- F. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.
- G. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
- H. Trapeze and Riser Supports:
1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.
 2. Supports for Stainless-Steel Ducts: Stainless-steel shapes and plates.
 3. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

2.10 SEISMIC-RESTRAINT DEVICES

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

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain first paragraph and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, **[provide products by one of the following] [available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following]:**
1. Cooper B-Line, Inc.; a division of Cooper Industries.
 2. Ductmate Industries, Inc.
 3. Hilti Corp.
 4. Kinetics Noise Control.
 5. Loos & Co.; Cableware Division.
 6. Mason Industries.
 7. TOLCO; a brand of NIBCO INC.
 8. Unistrut Corporation; Tyco International, Ltd.
 9. **<Insert manufacturer's name>**.

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

- B. 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] [the Office of Statewide Health Planning and Development for the State of California] [an agency acceptable to authorities having jurisdiction]**.
1. 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.
- C. 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.
- D. Restraint Cables: **[ASTM A 603, galvanized] [ASTM A 492, stainless]**-steel cables with end connections made of cadmium-plated 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 first 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.

- E. Hanger Rod Stiffener: **[Steel tube or steel slotted-support-system sleeve with internally bolted connections] [Reinforcing steel angle clamped]** to hanger rod.

- F. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

Coordinate duct layout and duct accessory arrangement with Drawings.

- A. 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.
- B. Install ducts according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.
- C. Install round[**and flat-oval**] ducts in maximum practical lengths.
- D. Install ducts with fewest possible joints.
- E. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.
- F. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.
- G. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.
- H. Install ducts with a clearance of **1 inch (25 mm)**, plus allowance for insulation thickness.
- I. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.
- J. 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 (38 mm)**.
- K. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers. Comply with requirements in Section 233300 "Air Duct Accessories" for fire and smoke dampers.
- L. Protect duct interiors from moisture, construction debris and dust, and other foreign materials.[**Comply with SMACNA's "IAQ Guidelines for Occupied Buildings Under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."**]

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3.2 INSTALLATION OF EXPOSED DUCTWORK

- A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.
- B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.
- C. 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.
- D. Maintain consistency, symmetry, and uniformity in the arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.
- E. Repair or replace damaged sections and finished work that does not comply with these requirements.

3.3 ADDITIONAL INSTALLATION REQUIREMENTS FOR COMMERCIAL KITCHEN HOOD EXHAUST DUCT

Delete this article if exhaust ducts for commercial kitchen hoods are specified in Section 235100 "Breechings, Chimneys, and Stacks."

- A. Install commercial kitchen hood exhaust ducts without dips and traps that may hold grease, and sloped a minimum of 2 percent to drain grease back to the hood.
- B. Install fire-rated access panel assemblies at each change in direction and at maximum intervals of [20 feet (6 m)] [12 feet (3.7 m)] <Insert dimension> in horizontal ducts, and at every floor for vertical ducts, or as indicated on Drawings. Locate access panel on top or sides of duct a minimum of 1-1/2 inches (38 mm) from bottom of duct.
- C. Do not penetrate fire-rated assemblies except as allowed by applicable building codes and authorities having jurisdiction.

3.4 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.

- A. Seal ducts for duct static-pressure, seal classes, and leakage classes specified in "Duct Schedule" Article according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

LEED Prerequisite EA 2 requires compliance with ASHRAE/IESNA 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 below.

- B. Seal ducts to the following seal classes according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible":

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1. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
2. Outdoor, Supply-Air Ducts: Seal Class A.
3. Outdoor, Exhaust Ducts: Seal Class C.
4. Outdoor, Return-Air Ducts: Seal Class C.
5. Unconditioned Space, Supply-Air Ducts in Pressure Classes **2-Inch wg (500 Pa)** and Lower: Seal Class B.
6. Unconditioned Space, Supply-Air Ducts in Pressure Classes Higher Than **2-Inch wg (500 Pa)**: Seal Class A.
7. Unconditioned Space, Exhaust Ducts: Seal Class C.
8. Unconditioned Space, Return-Air Ducts: Seal Class B.
9. Conditioned Space, Supply-Air Ducts in Pressure Classes **2-Inch wg (500 Pa)** and Lower: Seal Class C.
10. Conditioned Space, Supply-Air Ducts in Pressure Classes Higher Than **2-Inch wg (500 Pa)**: Seal Class B.
11. Conditioned Space, Exhaust Ducts: Seal Class B.
12. Conditioned Space, Return-Air Ducts: Seal Class C.

3.5 HANGER AND SUPPORT INSTALLATION

- A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."

Verify attachment selection and spacing in first two paragraphs below with structural engineer.

- B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.
1. Where practical, install concrete inserts before placing concrete.
 2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
 3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than **4 inches (100 mm)** thick.
 4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than **4 inches (100 mm)** thick.

Retain subparagraph below for Projects that require seismic restraints.

5. Do not use powder-actuated concrete fasteners for seismic restraints.
- C. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," **Table 5-1 (Table 5-1M)**, "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 (610 mm)** of each elbow and within **48 inches (1200 mm)** of each branch intersection.
- D. Hangers Exposed to View: Threaded rod and angle or channel supports.
- E. 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 (5 m)**.

METAL DUCTS

- F. 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.

3.6 SEISMIC-RESTRAINT-DEVICE INSTALLATION

- A. 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 (12 and 24 m) 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.

1. Space lateral supports a maximum of [**40 feet (12 m)**] <Insert dimension> o.c., and longitudinal supports a maximum of [**80 feet (24 m)**] <Insert dimension> o.c.
 2. Brace a change of direction longer than **12 feet (3.7 m)**.
- B. Select seismic-restraint devices with capacities adequate to carry present and future static and seismic loads.
- C. Install cables so they do not bend across edges of adjacent equipment or building structure.
- D. Install cable restraints on ducts that are suspended with vibration isolators.
- E. Install seismic-restraint devices using methods approved by [**an evaluation service member of the ICC Evaluation Service**] [**the Office of Statewide Health Planning and Development for the State of California**] [**an agency acceptable to authorities having jurisdiction**].
- F. 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.
- G. Drilling for and Setting Anchors:
1. 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 the Architect if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
 2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
 3. 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.
 4. Set anchors to manufacturer's recommended torque, using a torque wrench.
 5. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

3.7 CONNECTIONS

METAL DUCTS

Coordinate duct installations and specialty arrangements with Drawings.

- A. Make connections to equipment with flexible connectors complying with Section 233300 "Air Duct Accessories."
- B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.8 PAINTING

Painting can be omitted if antimicrobial coatings are applied in black color. Silver Bullet AM is available in Black, White, and Clear. Black is typically the color of choice due to the stark contrast in color from the metal substrate. It also does not require the additional step for painting the visible areas at the grills and registers. In the instances when white AM coating is used as a primary color, small amounts of black AM coating can be used on visible areas through grills and registers. This can be applied over the top of the white AM coating.

- A. 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."

3.9 FIELD QUALITY CONTROL

- A. Perform tests and inspections.

Retain first paragraph below for ducts in pressure classes 3-inch wg (750 Pa) and higher or if applying for LEED credits. It may not be economically practical to test ducts in pressure classes less than 3-inch wg (750 Pa).

- B. Leakage Tests:

- 1. Comply with SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.
- 2. Test the following systems:

LEED Prerequisite EA 2 requires compliance with ASHRAE/IESNA 90.1, in which Section 6.4.4.2.2 - "Duct Leakage Tests" 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 first subparagraph below for minimum requirements if applying for LEED certification or complying with ASHRAE/IESNA 90.1. To define more stringent requirements, retain subsequent subparagraphs as applicable and delete first subparagraph. Consider cost impact when specifying the 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).

- a. Ducts with a Pressure Class Higher Than **3-Inch wg (750 Pa)**: Test representative duct sections[, **selected by Architect from sections installed,**] totaling no less than 25 percent of total installed duct area for each designated pressure class.
- b. Supply Ducts with a Pressure Class of [**2-Inch wg (500 Pa)**] [**3-Inch wg (750 Pa)**] [**4-Inch wg (1000 Pa)**] <Insert value> or Higher: Test representative duct

METAL DUCTS

- sections[, **selected by Architect from sections installed,**] totaling no less than [50] [100] <Insert value> percent of total installed duct area for each designated pressure class.
- c. Return Ducts with a Pressure Class of [**2-Inch wg (500 Pa)**] [**3-Inch wg (750 Pa)**] [**4-Inch wg (1000 Pa)**] <Insert value> or Higher: Test representative duct sections[, **selected by Architect from sections installed,**] totaling no less than [50] [100] <Insert value> percent of total installed duct area for each designated pressure class.
 - d. Exhaust Ducts with a Pressure Class of [**2-Inch wg (500 Pa)**] [**3-Inch wg (750 Pa)**] [**4-Inch wg (1000 Pa)**] <Insert value> or Higher: Test representative duct sections[, **selected by Architect from sections installed,**] totaling no less than [50] [100] <Insert value> percent of total installed duct area for each designated pressure class.
 - e. Outdoor Air Ducts with a Pressure Class of [**2-Inch wg (500 Pa)**] [**3-Inch wg (750 Pa)**] [**4-Inch wg (1000 Pa)**] <Insert value> or Higher: Test representative duct sections[, **selected by Architect from sections installed,**] totaling no less than [50] [100] <Insert value> percent of total installed duct area for each designated pressure class.
3. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
 4. Test for leaks before applying external insulation.
 5. 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.
 6. 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 LEED certification. LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, in which Section 7.2.4 - "Ventilation System Start-up" requires that distribution systems be clean of dirt and debris. Text was taken from NADCA ACR, dated 2005.

C. Duct System Cleanliness Tests:

1. Visually inspect duct system to ensure that no visible contaminants are present.
2. Test sections of metal duct system, chosen randomly by Owner, for cleanliness according to "Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."
 - a. Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

- D. Duct system will be considered defective if it does not pass tests and inspections.
- E. Prepare test and inspection reports.

3.10 DUCT CLEANING

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

LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1, in which Section 7.2.4 - "Ventilation System Start-up" requires that distribution systems be clean of dirt and debris.

- A. Clean **[new]** **[and]** **[existing]** duct system(s) before testing, adjusting, and balancing.
- B. Use service openings for entry and inspection.
 - 1. Create new openings and install access panels appropriate for duct static-pressure class if required for 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.
 - 2. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.
 - 3. Remove and reinstall ceiling to gain access during the cleaning process.
- C. Particulate Collection and Odor Control:
 - 1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
 - 2. 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.
- D. Clean the following components by removing surface contaminants and deposits:
 - 1. Air outlets and inlets (registers, grilles, and diffusers).
 - 2. 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.
 - 3. 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.
 - 4. Coils and related components.
 - 5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
 - 6. Supply-air ducts, dampers, actuators, and turning vanes.
 - 7. Dedicated exhaust and ventilation components and makeup air systems.
- E. Mechanical Cleaning Methodology:
 - 1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
 - 2. 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.
 - 3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.

4. 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.
5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
6. Provide drainage and cleanup for wash-down procedures.

The below referenced antimicrobial agents and coatings should not be compared to the EPA-registered Agion Silver Ion antimicrobial compound found in Silver Bullet AM. AM coatings, such as Silver Bullet AM, are designed for OEM use, meaning at the time of manufacture to assure a uniform and permanent coating on the surface which provides years of residual antimicrobial efficacy. Aftermarket antimicrobial agents applied through access panels or introduced to airstream are not intended for long term residual antimicrobial activity.

Silver Bullet AM is available for touch-up in 12 oz. aerosol cans, or two-part epoxy that can be mixed on site as needed.

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

3.11 START UP

LEED Prerequisite IEQ 1 requires compliance with ASHRAE 62.1; see Section 7 - "Construction and System Start-up."

- A. Air Balance: Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC."

3.12 DUCT SCHEDULE

- A. Fabricate ducts with galvanized sheet steel except as otherwise indicated and as follows:
 1. Underground Ducts: Concrete-encased, [**galvanized sheet steel**] [**PVC-coated, galvanized sheet steel with thicker coating on duct exterior**] [**stainless steel**].
 2. <Insert requirements>.

Retain applicable subparagraphs in this article to set criteria for pressure class, duct seal-class level, and duct-leakage class; or delete applicable 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 2005 ASHRAE HANDBOOK - "Fundamentals," Chapter 35, "Duct Design," Table 7, "Recommended Ductwork Leakage Class by Duct Type."

METAL DUCTS

LEED Prerequisite EA 2 requires compliance with ASHRAE/IESNA 90.1, in which Section 6.4.4.2.1 - "Duct Sealing" 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 LEED certification and requirements are not defined in this article or on Drawings.

As with any best practice, it is advised that all "Metal" surfaces exposed to the airstream be coated with Silver Bullet AM antimicrobial coating. Building a better duct by design and coating "ALL" of the interior surfaces assures bacteria, virus, mold, mildew, and fungi cannot, and will not, grow or multiply on the coated surface and will provide antimicrobial efficacy for the useful life of the product.

B. Supply Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units <Insert equipment>:
 - a. Pressure Class: Positive [1-inch wg (250 Pa)] [2-inch wg (500 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B] [C].
 - c. SMACNA Leakage Class for Rectangular: [12] [24] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [12] [24] <Insert value>.
2. Ducts Connected to Constant-Volume Air-Handling Units <Insert equipment>:
 - a. Pressure Class: Positive [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B].
 - c. SMACNA Leakage Class for Rectangular: [6] [12] [24] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [6] [12] [24] <Insert value>.
3. Ducts Connected to Variable-Air-Volume Air-Handling Units <Insert equipment>:
 - a. Pressure Class: Positive [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B].
 - c. SMACNA Leakage Class for Rectangular: [3] [6] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [3] [6] <Insert value>.
4. Ducts Connected to Equipment Not Listed Above:
 - a. Pressure Class: Positive [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B].
 - c. SMACNA Leakage Class for Rectangular: [3] [6] [12] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [3] [6] [12] <Insert value>.

C. Return Ducts:

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

- a. Pressure Class: Positive or negative [**1-inch wg (250 Pa)**] [**2-inch wg (500 Pa)**] **<Insert value>**.
 - b. Minimum SMACNA Seal Class: [A] [B] [C].
 - c. SMACNA Leakage Class for Rectangular: [12] [24] **<Insert value>**.
 - d. SMACNA Leakage Class for Round and Flat Oval: [12] [24] **<Insert value>**.
2. Ducts Connected to Air-Handling Units **<Insert equipment>**:
- a. Pressure Class: Positive or negative [**2-inch wg (500 Pa)**] [**3-inch wg (750 Pa)**] **<Insert value>**.
 - b. Minimum SMACNA Seal Class: [A] [B].
 - c. SMACNA Leakage Class for Rectangular: [6] [12] [24] **<Insert value>**.
 - d. SMACNA Leakage Class for Round and Flat Oval: [6] [12] [24] **<Insert value>**.
3. Ducts Connected to Equipment Not Listed Above:
- a. Pressure Class: Positive or negative [**2-inch wg (500 Pa)**] [**3-inch wg (750 Pa)**] [**4-inch wg (1000 Pa)**] **<Insert value>**.
 - b. Minimum SMACNA Seal Class: [A] [B].
 - c. SMACNA Leakage Class for Rectangular: [3] [6] [12] **<Insert value>**.
 - d. SMACNA Leakage Class for Round and Flat Oval: [3] [6] [12] **<Insert value>**.
- D. Exhaust Ducts:
1. Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:
 - a. Pressure Class: Negative [**1-inch wg (250 Pa)**] [**2-inch wg (500 Pa)**] [**3-inch wg (750 Pa)**] **<Insert value>**.
 - b. Minimum SMACNA Seal Class: [A] [B] [C] if negative pressure, and A if positive pressure.
 - c. SMACNA Leakage Class for Rectangular: [12] [24] **<Insert value>**.
 - d. SMACNA Leakage Class for Round and Flat Oval: [6] [12] [24] **<Insert value>**.
 2. Ducts Connected to Air-Handling Units **<Insert equipment>**:
 - a. Pressure Class: Positive or negative [**2-inch wg (500 Pa)**] [**3-inch wg (750 Pa)**] **<Insert value>**.
 - b. Minimum SMACNA Seal Class: [A] [B] if negative pressure, and A if positive pressure.
 - c. SMACNA Leakage Class for Rectangular: [6] [12] [24] **<Insert value>**.
 - d. SMACNA Leakage Class for Round and Flat Oval: [3] [6] [12] [24] **<Insert value>**.
- [Retain first subparagraph below unless fire-rated, factory-fabricated grease ducts for Type I commercial kitchen hoods are specified in Section 235100 "Breechings, Chimneys, and Stacks." Factory-fabricated and -insulated grease ducts can be installed with reduced clearance to combustible construction.](#)
3. Ducts Connected to Commercial Kitchen Hoods: Comply with NFPA 96.
 - a. Exposed to View: Type 304, stainless-steel sheet, [No. 4] [No. 3] **<Insert finish>** finish.

- b. Concealed: [Type 304, stainless-steel sheet, No. 2D finish] [Carbon-steel sheet].
 - c. Welded seams and joints.
 - d. Pressure Class: Positive or negative [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] <Insert value>.
 - e. Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.
 - f. SMACNA Leakage Class: 3.
4. Ducts Connected to Dishwasher Hoods:
- a. Type 304, stainless-steel sheet.
 - b. Exposed to View: [No. 4] [No. 3] <Insert finish> finish.
 - c. Concealed: [No. 2D] <Insert finish> finish.
 - d. Welded seams and flanged joints with watertight EPDM gaskets.
 - e. Pressure Class: Positive or negative [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] <Insert value>.
 - f. Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.
 - g. SMACNA Leakage Class: 3.
5. Ducts Connected to Fans Exhausting Laboratory and Process (ASHRAE 62.1, Class 3 and 4) Air:

Retain one of first two subparagraphs below.

- a. [Type 316] [Type 304], stainless-steel sheet.
 - 1) Exposed to View: [No. 4] [No. 3] <Insert finish> finish.
 - 2) Concealed: [No. 2B] [No. 2D] <Insert finish> finish.
 - b. PVC-coated, galvanized sheet steel with thicker coating on duct interior.
 - c. Pressure Class: Positive or negative [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] [6-inch wg (1500 Pa)] <Insert value>.
 - d. Minimum SMACNA Seal Class: [A] [Welded seams, joints, and penetrations].
 - e. SMACNA Leakage Class: 3.
6. Ducts Connected to Equipment Not Listed Above:
- a. Pressure Class: Positive or negative [2-inch wg (500 Pa)] [3-inch wg (750 Pa)] [4-inch wg (1000 Pa)] <Insert value>.
 - b. Minimum SMACNA Seal Class: [A] [B] if negative pressure, and A if positive pressure.
 - c. SMACNA Leakage Class for Rectangular: [6] [12] [24] <Insert value>.
 - d. SMACNA Leakage Class for Round and Flat Oval: [3] [6] [12] [24] <Insert value>.
- E. Outdoor-Air (Not Filtered, Heated, or Cooled) Ducts:
- 1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units <Insert equipment>:

- a. Pressure Class: Positive or negative [**1-inch wg (250 Pa)**] [**2-inch wg (500 Pa)**] **<Insert value>**.
 - b. Minimum SMACNA Seal Class: [A] [B] [C].
 - c. SMACNA Leakage Class for Rectangular: [12] [24] **<Insert value>**.
 - d. SMACNA Leakage Class for Round and Flat Oval: [6] [12] [24] **<Insert value>**.
2. Ducts Connected to Air-Handling Units **<Insert equipment>**:
- a. Pressure Class: Positive or negative [**2-inch wg (500 Pa)**] [**3-inch wg (750 Pa)**] **<Insert value>**.
 - b. Minimum SMACNA Seal Class: [A] [B].
 - c. SMACNA Leakage Class for Rectangular: [6] [12] [24] **<Insert value>**.
 - d. SMACNA Leakage Class for Round and Flat Oval: [3] [6] [12] [24] **<Insert value>**.
3. Ducts Connected to Equipment Not Listed Above:
- a. Pressure Class: Positive or negative [**2-inch wg (500 Pa)**] [**3-inch wg (750 Pa)**] [**4-inch wg (1000 Pa)**] **<Insert value>**.
 - b. Minimum SMACNA Seal Class: [A] [B].
 - c. SMACNA Leakage Class for Rectangular: [3] [6] [12] **<Insert value>**.
 - d. SMACNA Leakage Class for Round and Flat Oval: [3] [6] [12] **<Insert value>**.
- F. Intermediate Reinforcement:
1. Galvanized-Steel Ducts: [**Galvanized steel**] [**Carbon steel coated with zinc-chromate primer**] [**Galvanized steel or carbon steel coated with zinc-chromate primer**].
 2. PVC-Coated Ducts:
 - a. Exposed to Airstream: Match duct material.
 - b. Not Exposed to Airstream: [**Galvanized**] [**Match duct material**].
 3. Stainless-Steel Ducts:
 - a. Exposed to Airstream: Match duct material.
 - b. Not Exposed to Airstream: [**Galvanized**] [**Match duct material**].
 4. Aluminum Ducts: [**Aluminum**][**or galvanized sheet steel coated with zinc chromate**].
- G. Antimicrobial Coating:
1. Supply Ducts: Shop-applied antimicrobial protective coating as indicated.
 2. Return Ducts: Shop-applied antimicrobial protective coating as indicated.
 3. Transfer Air Ducts: Shop-applied antimicrobial protective coating as indicated.
 4. Exhaust Ducts: Antimicrobial protective coating not required.
 5. Outside Air Ducts: Shop-applied antimicrobial protective coating as indicated.

When liner is required regardless of type, it should not be considered equal to a quality shop applied antimicrobial coating. Hard surface AM coatings such as Silver Bullet AM are used in a variety of industries such as food processing equipment, ambulances interiors, waste water treatment plants, among others due to its longevity and effectiveness under harsh conditions. While liners can provide R-value for

insulation or Sound attenuation it is not practical or possible to line a complete HVAC system. Conversely, an entire enhanced HVAC system can be coated with a shop-applied antimicrobial coating such as Silver Bullet AM with the use of liners in areas as needed. (Example: Liner used 20ft outside of air handling unit).

To achieve maximum benefit of Agion antimicrobial protected coatings on sheet metal duct, liners of any material should be avoided. If the duct needs to be conditioned for either R-value or sound, these could be achieved in one of the following ways. If the duct needs to be thermally protected in an unconditioned space, it should be wrapped with insulation. If the duct needs to be thermally protected and sound reduced, the duct can be made "double wall perforated". The inner wall of the duct would use Agion antimicrobial shop-applied coatings on sheet metal that has been perforated to allow sound attenuation.

H. Liner:

LEED Prerequisite EA 2 requires that duct insulation R-value comply with ASHRAE/IESNA 90.1 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 (38 mm), 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.

1. Supply Air Ducts: [**Fibrous glass, Type I**] [**Flexible elastomeric**] [**Natural fiber**], [**1 inch (25 mm)**] [**1-1/2 inches (38 mm)**] [**2 inches (51 mm)**] <Insert thickness> thick.
2. Return Air Ducts: [**Fibrous glass, Type I**] [**Flexible elastomeric**] [**Natural fiber**], [**1 inch (25 mm)**] [**1-1/2 inches (38 mm)**] [**2 inches (51 mm)**] <Insert thickness> thick.
3. Exhaust Air Ducts: [**Fibrous glass, Type I**] [**Flexible elastomeric**] [**Natural fiber**], [**1 inch (25 mm)**] <Insert thickness> thick.
4. Supply Fan Plenums: [**Fibrous glass, Type II**] [**Flexible elastomeric**] [**Natural fiber**], [**1 inch (25 mm)**] [**1-1/2 inches (38 mm)**] [**2 inches (51 mm)**] <Insert thickness> thick.
5. Return- and Exhaust-Fan Plenums: [**Fibrous glass, Type II**] [**Flexible elastomeric**] [**Natural fiber**], [**2 inches (51 mm)**] <Insert thickness> thick.
6. Transfer Ducts: [**Fibrous glass, Type I**] [**Flexible elastomeric**] [**Natural fiber**], [**1 inch (25 mm)**] [**1-1/2 inches (38 mm)**] [**2 inches (51 mm)**] <Insert thickness> thick.

LEED Prerequisite EA 2 requires that duct insulation R-value comply with ASHRAE/IESNA 90.1 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.

I. Double-Wall Duct Interstitial Insulation:

1. Supply Air Ducts: [**1 inch (25 mm)**] [**1-1/2 inches (38 mm)**] [**2 inches (51 mm)**] <Insert thickness> thick.

2. Return Air Ducts: [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (51 mm)] <Insert thickness> thick.
3. Exhaust Air Ducts: [1 inch (25 mm)] [1-1/2 inches (38 mm)] [2 inches (51 mm)] <Insert thickness> thick.

J. Elbow Configuration:

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

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."
 - a. Velocity 1000 fpm (5 m/s) or Lower:
 - 1) Radius Type RE 1 with minimum 0.5 radius-to-diameter ratio.
 - 2) Mitered Type RE 4 without vanes.
 - b. Velocity 1000 to 1500 fpm (5 to 7.6 m/s):
 - 1) Radius Type RE 1 with minimum 1.0 radius-to-diameter ratio.
 - 2) Radius Type RE 3 with minimum 0.5 radius-to-diameter ratio and two vanes.
 - 3) 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."
 - c. Velocity 1500 fpm (7.6 m/s) or Higher:
 - 1) Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
 - 2) Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
 - 3) 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."
2. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."
 - a. Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
 - b. Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
 - c. 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."
3. Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "Round Duct Elbows."
 - a. 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 first three subparagraphs below, or delete and retain fourth subparagraph.

- 1) Velocity **1000 fpm (5 m/s)** or Lower: 0.5 radius-to-diameter ratio and three segments for 90-degree elbow.
 - 2) Velocity **1000 to 1500 fpm (5 to 7.6 m/s)**: 1.0 radius-to-diameter ratio and four segments for 90-degree elbow.
 - 3) Velocity **1500 fpm (7.6 m/s)** or Higher: 1.5 radius-to-diameter ratio and five segments for 90-degree elbow.
 - 4) Radius-to Diameter Ratio: 1.5.
- b. Round Elbows, [**12 Inches (305 mm)**] <Insert dimension> and Smaller in Diameter: Stamped or pleated.
 - c. Round Elbows, [**14 Inches (356 mm)**] <Insert dimension> and Larger in Diameter: [**Standing seam**] [**Welded**].

Delete paragraph below if branch fittings are detailed on Drawings.

K. Branch Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-6, "Branch Connection."
 - a. Rectangular Main to Rectangular Branch: 45-degree entry.
 - b. Rectangular Main to Round Branch: Spin in.
2. 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.
 - a. Velocity **1000 fpm (5 m/s)** or Lower: 90-degree tap.
 - b. Velocity **1000 to 1500 fpm (5 to 7.6 m/s)**: Conical tap.
 - c. Velocity **1500 fpm (7.6 m/s)** or Higher: 45-degree lateral.

END OF SECTION 233113