

SECTION 23 31 10 - METAL DUCTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- 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 metal ducts and accessories for various types of air distribution systems.

1.3 SUBMITTALS

- A. Coordination Drawings: Coordination drawings are required. Refer to the applicable Division 1 Specification Section, for the work required by the HVAC Contractor in preparing Coordination Drawings.
- B. Provide submittal data for Cable Support Systems with SMACNA STRI verification.
- C. Submit results of duct system leakage tests.
- D. Product data for each of the following products:
 - 1. Duct liner and adhesives.
 - 2. Duct sealants.

1.4 PERFORMANCE REQUIREMENTS

- A. 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 as indicated in Part 3 of this specification.
- B. Refer to the contract drawings for any notes that indicate requirements for duct construction that may differ from the SMACNA standard requirements. Where indicated provide duct construction that meets requirements.

1.5 QUALITY ASSURANCE

- A. Comply with the requirements of NFPA 90A and 90B.
- B. The installation of all ductwork shall comply with the requirements of the 2018 International Mechanical Code and all applicable local codes and code amendments.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Protect all ductwork, accessories and purchased products from damage during shipping, storage and handling. Prevent dirt and moisture from entering ducts and duct fittings. Store ductwork in an area which is protected from the weather. All ductwork shall be shipped with a protective polyethylene film or other water tight covering at the ends of all ducts and fittings. To prevent condensation in the ducts, the covering shall not be added while excessive moisture is present in the duct.
- B. While ducts are stored on-site the protective covering shall remain in place with the ducts stores on skids and placed such that the duct openings are not subject to water infiltration.

PART 2 - PRODUCTS

2.1 SINGLE WALL RECTANGULAR DUCTS AND FITTINGS

- A. Refer to and comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 2, "Rectangular Duct Construction," for fabrication of ducts based on the static-pressure class indicated in Part 3 of this specification.
- B. Unless otherwise indicated on the drawings fabricate ducts with a gauge thickness per the requirements of Chapter 2.
- C. Longitudinal Seam, Traverse Joints and Reinforcements: Select and fabricate seam, joint, reinforcement types and sealing requirements and according to the requirements in Chapter 2 for required static-pressure class, applicable sealing requirements, duct-support intervals, and other provisions in the SMACNA Standard."
- D. Duct fittings: fabricate elbows, turning vanes, branch connectors, offsets and transitions in accordance with Chapter 4 of the SMACNA "HVAC Duct Construction Standards - Metal and Flexible."
 - 1. Radius elbows: type RE 1 with a center line radius equal to 1.5 times the duct width.
 - 2. Square throat elbows: type RE 2 with turning vanes per figure 4-3 and 4.4.
 - 3. Branch connections: 45-degree entry.

2.2 SINGLE WALL ROUND DUCTS AND FITTINGS

- 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.
- B. Unless otherwise indicated on the drawings fabricate ducts with a gauge thickness per the requirements of Chapter 3.
- C. Longitudinal Seam, Traverse Joints and Reinforcements: Select seam, joint, reinforcement types and sealing requirements and fabricate according to the requirements in Chapter 3 for required static-pressure class, applicable sealing requirements, duct-support intervals, and other provisions in the SMACNA Standard."
- D. Duct fittings: fabricate elbows and tees in accordance with Chapter 3.
 - 1. Elbows: fabricate with a center line radius equal to 1.5 times the duct diameter.
 - 2. Tees and laterals: fabricate per figure 3-5

2.3 SPIRAL SEAM SINGLE WALL ROUND AND FLAT-OVAL DUCTS AND FITTINGS

- 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.
- 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. Unless otherwise indicated on the drawings fabricate ducts with paintable G60 galvanized steel. Duct gauge thickness to be per the requirements of Chapter 3.
- D. Longitudinal Seam shall be a spiral lock seam per figure 3-2 of Chapter 3.
- E. Traverse Joints and Reinforcements: Select seam, joint, reinforcement types and sealing requirements and fabricate according to the requirements in Chapter 3 for required static-pressure class, applicable sealing requirements, duct-support intervals, and other provisions in the SMACNA Standard."
- F. Duct fittings: fabricate elbows and tees in accordance with Chapter 3.
 - 1. Elbows: fabricate with a center line radius equal to 1.5 times the duct diameter.
 - 2. Conical tees and laterals: fabricate per figure 3-6.
- G. Provide spiral duct and fittings with a PVC coating, where indicated on the drawings. PVC coating to be 4 mils thick and applied to the interior and exterior of the ducts and fittings.

2.4 SPIRAL SEAM DOUBLE-WALL ROUND AND OVAL DUCTS AND FITTINGS

- 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.
- 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 requirements in Chapter 3. based on indicated static-pressure class unless otherwise indicated. Unless otherwise indicated on the drawings fabricate ducts with paintable G60 galvanized steel. Duct gauge thickness to be per the requirements of Chapter 3.
- D. Longitudinal Seam shall be a spiral lock seam per figure 3-2.
- E. Traverse Joints and Reinforcements: Select seam, joint, reinforcement types and sealing requirements and fabricate according to the requirements in Chapter 3 for required static-pressure class, applicable sealing requirements, duct-support intervals, and other provisions in the SMACNA Standard."
- F. Duct fittings: fabricate elbows and tees in accordance with Chapter 3.
 - 1. Elbows: fabricate with a center line radius equal to 1.5 times the duct diameter.
 - 2. Conical tees and laterals: fabricate per figure 3-6.
- G. Inner Duct: Minimum 0.028-inch perforated galvanized sheet steel having 3/32-inch-diameter perforations, with overall open area of 23 percent.
- H. Interstitial Insulation: Fibrous-glass liner as indicated in paragraph 2.6.

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.
- B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
 - 1. Galvanized Coating Designation: G60 for interior ductwork conveying non-hazardous materials; G90 for interior ductwork conveying hazardous materials; G90 for exterior ducts without exterior insulation.
 - 2. Finishes for Surfaces Exposed to View: Mill phosphatized and suitable for painting.
- C. PVC-Coated, Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
 - 1. Galvanized Coating Designation: G90.
 - 2. Minimum Thickness for Factory-Applied PVC Coating: 4 mils thick on sheet metal surface of ducts and fittings exposed to corrosive conditions.
 - 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.
- 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.
- 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 minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.6 DUCT LINER

- A. Fibrous-Glass Duct Liner: Comply with, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following manufacturers:
 - a. CertainTeed Corporation.
 - b. Johns Manville.
 - c. Knauf Insulation.
 - d. Owens Corning.

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2. Materials: ASTM C 1071; surfaces exposed to airstream shall have a factory applied coating to prevent erosion of glass fibers and a factory applied coating on the edge of the liner.
 - a. Thickness: 1 inch or as noted on the drawings.
 - b. Density: 2.0 pcf.
 - c. Thermal performance: "R" equals 4.2 for 1" thick; 6.0 for 1.5" thick; 8.0 for 2" thick.
 - d. Sound Absorption Coefficient (NRC): 0.70 for 1" thick; 0.80 for 1.5" thick; 0.85 for 2" thick.
 - e. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.
 - f. Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C 916.
 - g. 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.
- B. Shop Application of Duct Liner: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," and manufacturer's instructions.
 1. Where lined ducts are indicated, the duct dimensions indicated on the drawings are the metal size. The net free area size of the duct is the metal size minus the liner thickness.
 2. Adhere to a single layer of liner with adhesive coverage per the manufacturer's recommendations.
 3. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.
 4. Butt transverse joints without gaps, and coat joint with adhesive.
 5. Fold and compress liner in corners of rectangular ducts or cut and fit to ensure butted-edge overlapping.
 6. Secure liner with mechanical fasteners per SMACNA standards and the manufacturer's recommendations.
 7. 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.
 8. 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.

2.7 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.
- B. 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.
 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.

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

C. 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.
8. For indoor applications, use sealant that has 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.
10. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive or negative.
11. Service: Indoor or outdoor.
12. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

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

E. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

F. 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.
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.

2.8 HANGERS AND SUPPORTS

- 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," "Rectangular Duct Hangers Minimum Size," - "Minimum Hanger Sizes for Round Duct."
- D. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
- E. 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.
- F. Cable Support Systems: Provide cable support systems and accessories that have been verified through the SMACNA Testing and Research Institute (STRI).
1. Manufacturer's:
 - a. Duro Dyne.
 - b. Gripple Hang-Fast Systems.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

- A. Fabricate, install and support ductwork and accessories according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.
- B. The installing contractor is required to field verify all duct locations and elevations prior to fabrication of the ductwork.
- C. 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.
- D. Electrical Equipment Spaces: Route ducts to avoid passing through transformer vaults and electrical equipment spaces and enclosures. Do not locate ducts over electrical panels.
- E. Ship and store all ductwork with a protective closure at the ends of all ducts and fittings. During construction, provide temporary polyethylene film enclosures at all openings in the duct systems, at the time of ductwork installation, to prevent entrance of dust and debris until final connections are completed.
 1. Protective film shall be applied only after excessive moisture has been removed from ductwork, including moisture generated from sealants and adhesives. If moisture levels are not acceptable within the sealed ductwork, provide relief vent in temporary film.
 2. Failure to protect duct systems from construction dust and debris will result in the installing contractor being required to Mechanically Clean the affected duct system(s) as indicated in this specification.
- F. Install round and flat-oval ducts in maximum practical lengths.
- G. Install ducts with fewest possible joints. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.
- H. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.
- I. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.
- J. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.

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- K. Where ducts pass through non-fire-rated interior masonry or drywall partitions and any type of exterior wall(s), 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.
- L. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers. Comply with requirements in Division 23 Section "Duct Accessories" for fire and smoke dampers. Provide firestopping as specified in Section 233300.
- M. Paint interiors of metal ducts that do not have duct liner for 24 inches upstream of registers and grilles. Apply one coat of flat, black, latex finish coat over a compatible galvanized-steel primer.
- N. Refer to contract drawings for locations where sprinklers are to be located within various duct systems. Coordinate locations with the sprinkler installer. Refer to contract drawing details for work required for a complete duct installation.

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 INSTALLATION REQUIREMENTS FOR COMMERCIAL KITCHEN HOOD EXHAUST DUCT

- A. Install ducts per the requirement indicated in Chapter 5 of the International Mechanical Code.
- B. Refer the International Mechanical Code, Chapter 5; 506.3.2.5 and provide all testing, as stated, for grease ducts and systems prior to use or concealment. Report results of the testing to the Owner's representative and the code official, if required.
- C. Grease duct supports shall be of noncombustible material securely attached to the structure. Any attachments or fasteners shall not penetrate the grease duct.
- D. Install commercial kitchen hood exhaust ducts without dips and traps that may hold grease, and at a minimum of 2 percent slope to the hood. Where the length of horizontal grease duct exceeds 75 feet, the slope shall not be less than 8.3 percent.
- E. Provide vibration connector where the exhaust duct connects to the fan. Connector to be listed and labeled for the application.
- F. Provide horizontal cleanouts as required by the International Mechanical Code.

3.4 DUCT SEALING

- 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."

3.5 HANGER AND SUPPORT INSTALLATION

- A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports and the requirements of the International Mechanical Code Section 603. Support spacing of all hangers shall be per SMACNA standards but in no case shall hangers be spaced at more than 10'-0" intervals.
- B. Supports for Clothes Dryer exhaust ducts shall be at a maximum spacing of 4'-0".
- C. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," "Rectangular Duct Hangers Minimum Size," and "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.
- D. 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 maximum intervals of 12 feet.
- E. 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 thick.
 - 4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.
- 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.
- G. Cable Support Systems: Where ducts are exposed to view in finished areas provide cable duct support systems installed per the manufacturer's installation instructions.

3.6 CONNECTIONS

- A. Make connections to equipment with flexible connectors complying with Division 23 Section "Air Duct Accessories."
- B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.7 FIELD QUALITY CONTROL

- A. Leakage Tests: Provide duct leakage testing complying with SMACNA's "HVAC Air Duct Leakage Test Manual." Notify the Owner's representative a minimum of 7 days before leak testing is to begin. Test the following systems:

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1. All duct systems with a Pressure Class of 3-Inch w.g. or higher: Test representative duct sections totaling no less than 25 percent of total installed duct lineal feet of duct for each designated pressure class.
 2. All Variable Air Volume supply systems from the air handling unit outlet to the entry connection at all variable air volume terminal units.
 3. All duct systems located on the exterior of the building.
- B. Disconnect, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
- C. Perform all leak testing prior to the application of external insulation.
- D. Conduct tests at static pressures equal to maximum design pressure of system. If static-pressure classes are not indicated, test system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure. Duct leak rate shall not exceed SMACNA Standard Seal Class B / Leakage Class 12, for all rectangular ducts. All duct leak testing shall be performed in accordance with the SMACNA HVAC Duct Leakage Test Manual.
- E. If leak testing indicates the duct system(s) leakage is greater than the allowed amount, the installing contractor is required to provide labor to reseal and / or reinstall the system(s) to provide a system that will meet the allowable leakage rate.
- F. All leak testing may be witnessed by the Owner's representative. The Owner's Testing, Adjusting and Balancing firm will be responsible for leak testing verification.
- G. Provide test results upon completion of testing.

3.8 DUCT CLEANING

- A. Where indicated on the contract drawings mechanically clean all ductwork connected to existing systems as described in this specification section.
- B. New duct system installations: manually clean ductwork internally, section by section as it is installed, of dust and debris. Clean external surfaces of foreign substances which might cause corrosive deterioration of metal or, where ductwork is to be painted, might interfere with painting or cause paint deterioration.
- C. 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 Division 23 Section "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.
- D. 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.
- E. Clean the following components by removing surface contaminants and deposits:

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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.

3.9 MECHANICAL DUCT CLEANING METHODOLOGY

- A. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
- B. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
- C. 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.
- D. 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.
- E. 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.
- F. Provide drainage and cleanup for wash-down procedures.
- G. 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.

3.10 DUCT SCHEDULE

- A. Fabricate ducts with G90 galvanized sheet steel unless otherwise indicated in the following:
 1. Type I range hood exhaust duct construction: comply with the requirements of the Section 506 of the 2018 International Mechanical Code (IMC) and NFPA 96.
 - a. Concealed ducts: minimum 14-gauge carbon steel with liquid tight welded joints.
 - b. Exposed ducts: minimum 14-gauge Type 304 stainless steel with liquid tight welded joints.
 2. Dishwasher exhaust ducts: Type 304 stainless steel. Provide watertight joints and slope ducts to allow drainage to the dishwasher.
 3. Shower area exhaust ducts: Aluminum ducts and fittings with sealed watertight joints.
 4. Science hood exhaust ducts: PVC coated G90 galvanized ducts and fittings.
 5. Clothes dryer exhaust ducts: Minimum 28-gauge aluminum. Installation to comply with all requirements indicated in the 2018 International Mechanical Code; Chapter 5, Section 504.

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B. Supply Ducts:

1. Ducts Connected to the discharge of Fan Coil Units, Cabinet Heaters, and Terminal Units:
 - a. Pressure class: positive 1-inch wg.
 - b. Minimum SMACNA seal class: B.
2. Ducts Connected to the discharge of Modular and Packaged Air-Handling Units:
 - a. Pressure class: positive 2-inch wg.
 - b. Minimum SMACNA seal class: B.
3. Ducts Connected to the discharge of Variable Air Volume Air-Handling Units:
 - a. Pressure class: positive 4-inch wg.
 - b. Minimum SMACNA seal class: A.
 - c. SMACNA leakage class for rectangular ducts: 4.
 - d. SMACNA leakage class for round and oval ducts: 2.

C. Return Ducts:

1. Pressure Class: Positive or negative 2-inch wg.
 - a. Interior ducts: minimum SMACNA seal class B.
 - b. Exterior ducts: minimum SMACNA seal class B.
2. Exterior Ducts: Pre-insulated double wall shop fabricated ducts.

D. Exhaust Ducts:

1. Pressure Class: Positive or negative 1-inch wg.
 - a. Minimum SMACNA seal class: B if negative pressure, and B if positive pressure.

E. Outdoor-Air:

1. Pressure Class: positive or negative 1-inch wg.
 - a. Minimum SMACNA Seal Class: B.

F. Elbow Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."
 - a. Radius Elbows: type RE-1 with a center line radius of $R = (3W)/2$
 - b. Square (mitered) Elbows: type RE-2 with the fitting width (W) equal.
2. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners."
3. Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "Round Duct Elbows."

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- 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.

- 1) Radius-to Diameter Ratio = 1.5.

G. Branch Configuration:

- 1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-5, "Divided Flow Branches."
 - a. Type 2 or 3 as indicated on the contract drawings.
- 2. 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.
- 3. 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." Provide fittings as indicated on the contract drawings.

END OF SECTION 23 31 10