

SECTION 23 3114 - DUCTWORK

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Specification Book 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.
4. Double-wall round and flat-oval ducts and fittings.
5. Laboratory exhaust ductwork.
6. Sheet metal materials.
7. Duct cleaning and contamination protection.
8. Sealants and gaskets.
9. Hangers and supports.

- B. Related Sections:

1. Section 23 0529 "Mechanical Supporting Devices."
2. Section 23 0550 "Vibration Isolation."
3. Section 23 0553 "Mechanical Systems Identification."
4. Section 23 0594 "Testing, Adjusting, and Balancing (TAB)."
5. Section 23 0700 "Mechanical System Insulation."
6. Section 23 3314 "Ductwork Specialties" for dampers, sound-control devices, duct-mounting access doors and panels, turning vanes, flange connectors, flexible connectors, duct accessory hardware, louvers, and flexible ducts.

1.3 PERFORMANCE REQUIREMENTS

- 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 the "Duct Schedule" Article and on the drawings.
- B. Structural Performance: Duct hangers and supports shall withstand the effects of gravity loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- C. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

- D. SMACNA's 3rd Edition, 2005, "HVAC Duct Construction Standards - Metal and Flexible," as referenced herein.

1.4 ACTION SUBMITTALS/INFORMATION

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

1. Factory fabricated ductwork and fittings.
2. Factory fabricated hangers and supports.
3. Transverse joint components.
4. Sealants and gaskets.

- B. Delegated-Design Information (for Contractor Use and University Reference, Not For Engineer Approval) :

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

1.5 INFORMATIONAL SUBMITTALS (For Use Amongst the Contractors and For Owner Reference, Not For Engineer Approval)

- 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:

1. Duct installation in congested spaces, indicating coordination with general construction, building components, and other building services. Indicate proposed changes to duct layout.
2. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
3. Factory and shop fabricated ducts and fittings.
4. Duct layout indicating sizes, configuration, liner material, and static-pressure classes.
5. Elevation of tops or bottoms of ducts.
6. Dimensions of main duct runs from building grid lines.
7. Fittings.
8. Reinforcement and spacing.
9. Seam and joint construction.
10. Penetrations through fire-rated and other partitions.
11. Equipment installation based on equipment being used on Project.
12. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.
13. Hangers and supports, including methods for duct and building attachment and vibration isolation.
14. Suspended ceiling components.
15. Structural members to which duct will be attached.
16. Size and location of initial access modules for acoustical tile.
17. Penetrations of smoke barriers and fire-rated construction.
18. 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.

B. Welding certificates.

C. Field quality-control reports.

1.6 QUALITY ASSURANCE

A. Welding Qualifications: Qualify procedures and personnel according to the following:

- 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.

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

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

1.7 SPECIAL WARRANTIES

A. Five (5) years, see Division 01.

PART 2 - PRODUCTS

2.1 FIBROUS GLASS (DUCTBOARD) DUCTS

A. Not allowed.

2.2 LINED DUCTWORK

A. Not allowed.

2.3 ELBOWS, TRANSITIONS, OFFSETS, BRANCH CONNECTIONS, LATERALS, AND OTHER DUCT CONSTRUCTION REQUIREMENTS

A. Fabricate and install all duct fittings, branches, inlets, outlets, transitions, take-offs, laterals, offsets, and elbows to minimize air turbulence and resistance and to ensure proper airflows.

B. Extractors and splitter dampers not allowed.

C. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and

Flexible," Chapters 3 and 4, for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible." But:

1. Mitered elbows with turning vanes not permitted, use radius elbows.
2. Radius elbows shall have minimum centerline radius to width or diameter ratio of 1.5. If 1.5 ratio elbows do not fit, use 1.0 radius elbows. Where 1.0 radius elbows do not fit, use square throat elbows with turning vanes.
3. Pleated or adjustable elbows not allowed.
4. No straight taps, branch or lateral take-offs, or connections, all to be expanded or conical, and taken off at an angle $< 90^\circ$ if possible.
5. No bullhead tees for either diverging or converging flow.
6. For transitions, where the shape of the duct changes, ensure the angle of the side of the transition piece does not exceed 15° from the straight run of duct connected thereto. Where equipment is installed in the ductwork, ensure the angle of the side of the transition piece from the straight run of duct connected thereto does not exceed 15° on the upstream side of the equipment and 22.5° on the downstream side of the equipment.
7. Special duct branch requirements: Where a duct branch handles over 25% of the air transported by the duct main, use a complete 90° increasing elbow, with an inside radius of 0.75 times the duct branch width. Ensure the size of the trailing end of the increasing elbow within the duct main is in the same ratio to the main duct size as the ratio of the relative air quantities being handled. Where a duct branch is to handle 25% or less of the air handled by the duct main, provide a branch connection with an inside radius of 0.75 times the branch duct width, a minimum arc length of 45° , and an outside radius of 1.75 times the duct branch width. Place arc tangent to the duct main.
8. Saddle taps are not allowed on new or existing ducts.
9. See more information and requirements in PART 3 herein.

2.4 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

- A. General Fabrication Requirements: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated. But, duct wall thickness to be minimum 22 gage except where any welding other than longitudinal seams is performed, then the minimum thickness shall be 18 gage, and, no crimp joints allowed.
- B. Transverse Joints: Select joint types and fabricate according to SMACNA's 2005 "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." But, transverse (girth) joints T-4, 9, 17 through 20, and 23 not permitted.
- C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's 2005 "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." But, button punch snaplock seams are not permitted.

2.5 DOUBLE-WALL RECTANGULAR DUCTS AND FITTINGS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. McGill AirFlow LLC.
 2. SEMCO.
- B. General Fabrication Requirements: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated. Duct wall thickness to be minimum 22 gage except where any welding other than longitudinal seams is performed, then the minimum thickness shall be 18 gage.
- C. Contractor Fabricated Ductwork: Ductwork of this section (2.5) may be fabricated by the contractor if it can be demonstrated that it meets or exceeds the performance of the manufacturer's products listed directly above.
- D. Rectangular Ducts: Fabricate ducts with indicated dimensions for the inner duct. But, duct wall thicknesses to be minimum 22 gage except where any welding other than longitudinal seams is performed, then the minimum thickness shall be 18 gage.
- E. Outer Duct: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.
- F. Transverse Joints: Select joint types and fabricate according to SMACNA's 2005 "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." But, transverse (girth) joints T-4, 9, 17 through 20, and 23 not permitted.
- G. Longitudinal Seams: Select seam types and fabricate according to SMACNA's 2005 "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." But, button punch snaplock seams are not permitted.
- H. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
1. Maximum Thermal Conductivity: 0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K) at 75 deg F mean temperature.
 2. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
 3. Coat insulation with antimicrobial coating.
 4. Cover insulation with polyester film complying with UL 181, Class 1.
 5. Insulation Thickness: See PART 3.
- I. Inner Duct: Minimum 0.028-inch thick solid sheet galvanized steel.
- J. 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/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible." But, transverse (girth) joints T-4, 9, 17 through 20, and 23 not permitted.

2.6 SINGLE-WALL ROUND AND FLAT-OVAL DUCTS AND FITTINGS

- A. General Fabrication Requirements: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated but, only spiral seam or fully welded longitudinal seam duct is to be used. And, longitudinal seam ductwork not to be used if exposed.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. McGill AirFlow LLC.
 - b. SEMCO Incorporated.
 - c. Spiral Manufacturing Co., Inc.
- B. Contractor Fabricated Ductwork: Ductwork of this section (2.6) may be fabricated by the contractor if it can be demonstrated that it meets or exceeds the performance of the manufacturer's products listed directly above.
- C. 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). SMACNA Type 1 reinforcement (Figure 3-6 of SMACNA's Duct Construction Standards) is not allowed.
- D. Transverse Joints: Select joint types and fabricate according to SMACNA's 2005 "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 2005 "HVAC Duct Construction Standards - Metal and Flexible." But, no crimp joints allowed.
1. Transverse Joints in Ducts Larger Than 60 Inches in Diameter: Flanged.
- E. Longitudinal Seams: Select seam types and fabricate according to SMACNA's 2005 "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 2005 "HVAC Duct Construction Standards - Metal and Flexible." But, snaplock seams not allowed.
1. Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.
 2. Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.

2.7 DOUBLE-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 but, only spiral seam or fully welded longitudinal seam duct is to be used. And, longitudinal seam ductwork not to be used if exposed.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. McGill AirFlow LLC.
 - b. SEMCO Incorporated.
 - c. Spiral Manufacturing Co., Inc.
- B. Contractor Fabricated Ductwork: Ductwork of this section (2.7) may be fabricated by the contractor if it can be demonstrated that it meets or exceeds the performance of the manufacturer's products listed directly above.
- C. 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. SMACNA Type 1 reinforcement (Figure 3-6 of SMACNA's Duct Construction Standards) is not allowed.
- D. Outer Duct: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on static-pressure class unless otherwise indicated.
- E. Transverse Joints: Select joint types and fabricate according to SMACNA's 2005 "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 2005 "HVAC Duct Construction Standards - Metal and Flexible." And, no crimp joints allowed.
1. Transverse Joints in Ducts Larger Than 60 Inches in Diameter: Flanged.
- F. Longitudinal Seams: Select seam types and fabricate according to SMACNA's 2005 "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 2005 "HVAC Duct Construction Standards - Metal and Flexible." But, no snaplock seams allowed.
1. Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.
 2. Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.
- G. Inner Duct: Minimum 0.028-inch thick solid sheet steel. Factory fabricated, insulated round duct to be McGill Airflow, Acoustic K-27, or approved equal by SEMCO or Spiral Manufacturing Co., Inc.
- H. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
1. Maximum Thermal Conductivity: 0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K) at 75 deg F mean temperature.
 2. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
 3. Thickness for ducts inside the building minimum 1.5", 3" thickness for ducts outside.

2.8 LABORATORY EXHAUST DUCTWORK

- A. Ductwork and shall be all welded Type 316 stainless steel, minimum 18 gage.

2.9 SHEET METAL MATERIALS

- A. General Material Requirements: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Duct wall thickness to be minimum 22 gage except where any welding other than longitudinal seams is performed, then the minimum thickness shall be 18 gage.
- B. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.
- C. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
 - 1. Galvanized Coating Designation: G90 (Z275).
 - 2. Finishes for Surfaces Exposed to View: Mill phosphatized.
- D. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304 or 316 (Type 316 only for Lab exhaust), 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.
- E. 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.
- F. Reinforcement Shapes and Plates for Galvanized Ducts: 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 or stainless steel ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials.
- G. 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.

2.10 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.
 - 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, 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.
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 (SMACNA Joints T-24, T-25, and proprietary slip-on flanges) 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, sealant shall have 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. Pressure Sensitive Tapes for Primary Sealing of Ducts: Not allowed.

G. Duct Sealer Manufacturers/Products: United Airseal - United Duct Seal, Mon-Eco Industries 44/48, or Foster 32.

H. Lab Exhaust Duct/System Sealant: For any non-welded joints or connections, sealants shall be custom selected for the duty, including proper chemical resistance against whatever is to be transported in the duct system.

2.11 HANGERS AND SUPPORTS

A. Shall be in accordance with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible" except non-engineered wire hangers are not permitted. Engineered cable support systems may be used if they meet SMACNA, Ductmate or approved equal.

B. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.

C. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.

D. Strap and Rod Sizes: Comply with SMACNA's 2005 "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."

- E. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A 603.
- F. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A 492.
- G. 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.
- H. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
- I. 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.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

- 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 2005 "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.
- C. Install round 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, 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.

- K. Where ducts pass through fire and/or smoke and/or fire/smoke rated surfaces, install appropriate safety dampers. Comply with requirements in Section 23 3314 "Duct Specialties" for safety 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."

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

- 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 10 feet in horizontal ducts, and at every floor for vertical ducts, or as indicated on Drawings.
- C. Install access openings at each change in direction and at intervals defined by NFPA 96; locate on sides of duct a minimum of 1-1/2 inches from bottom; and fit with grease-tight fire rated covers of same material as duct.
- D. Do not penetrate fire-rated assemblies except as allowed by applicable building codes and authorities having jurisdiction.

3.4 DUCT SEALING AND CONTAMINATION PROTECTION

- A. Contamination Protection: Ductwork shall be sealed at the point of fabrication/manufacture, and remain sealed until installed. Ductwork must be sealed at all times, even if being worked on. Seals can be removed only during immediate installation and must be restored immediately upon non-work activity. Ductwork being worked on shall be sealed at the end of each work day.
- B. Seal ducts for duct static-pressure, seal classes, and leakage classes specified in "Duct Schedule" Article according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible."

- C. **Seal all ducts to Seal Class A according to SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible."**

3.5 HANGER AND SUPPORT INSTALLATION

- A. Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."
- 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 thick.
 - 4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.
 - 5. Do not use powder-actuated concrete fasteners for seismic restraints.
- C. Hanger Spacing: Comply with SMACNA's 2005 "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 of each elbow and within 48 inches 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.
- 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 CONNECTIONS

- A. Make connections to equipment with flexible connectors complying with Section 23 3314 "Duct Specialties."
- B. Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections, and see drawings/details.

3.7 PAINTING

- A. Prime and 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.

3.8 FIELD QUALITY CONTROL

- A. Perform tests and inspections.

B. Leakage Tests:

1. Leakage tests shall be conducted in accordance with 1985, 1st Edition, of SMACNA's "HVAC Air Duct Leakage Test Manual," Sections 3 and 5. Positive pressure ductwork to be tested under positive pressure. Negative pressure ductwork to be tested under positive and negative pressure. Submit a test report for each test.
2. Test the following systems:
 - a. Supply Ducts with a Pressure Class of 3-Inch wg (750 Pa) or Higher: Test representative duct sections, selected by Engineer from sections installed, totaling no less than 50 percent of total installed duct area for each designated pressure class.
 - b. All Lab exhaust ductwork.
3. Leakage tests to be witnessed by the University.
4. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
5. Test for leaks before applying external insulation and before ducts are concealed.
6. 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.
7. Give seven days' advance notice for testing.
8. Leakage shall not exceed the values in the following Table 23-3114-3:

Table 23-3114-3 – Allowable Leakage Rates, cfm/100 ft ² Surface Area				
Location	Test Pressure in. wg	Rectangular Ductwork	Round Ductwork	Flat Oval Ductwork
Low Pressure Ductwork ^a	2	9.4	4.7	4.7
All Other Ductwork ^b	4	14.8	7.4	7.4

a. Supply Ductwork: Ductwork downstream of VAV/CAV Terminals, Return Ductwork: Ductwork upstream of VAV/CAV Terminals.

b. Supply, Return, and Exhaust Ductwork

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.

D. Duct system will be considered defective if it does not pass tests and inspections.

- E. Prepare test and inspection reports.

3.9 DUCT CLEANING

- A. Clean new duct system(s) before testing, adjusting, and balancing.
- B. Clean existing ducts 10' each direction which become open due to equipment or duct removal, and clean before testing, adjusting, and balancing.
- 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 Section 23 3314 "Duct Specialties" 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:
 - 1. Air outlets and inlets (registers, grilles, and diffusers).
 - 2. Supply, return, and exhaust fans including fan housings, plenums, scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
 - 3. Air-handling unit internal surfaces and components including mixing box, coil section, condensate drain pans, humidifiers, 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.
- F. 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.
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.

3.10 START UP

- A. Air Balance: Comply with project TAB requirements.

3.11 DUCT SCHEDULE AND OTHER REQUIREMENTS

- A. Fabricate ducts with galvanized sheet steel unless called for as another material on drawings, or if Lab exhaust, dishwasher exhaust, and any other high humidity applications or areas, ducting to be stainless steel, sloped, and drained.
- B. For outdoor ducts exposed to wind forces, anchor and brace as required.
- C. Flat-oval ducts shall not be used for exhaust.
- D. Fabricate underground 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>**.
- E. Supply Ducts:
 1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units:
 - a. Pressure Class: Positive **2-inch wg (500 Pa)**.
 - b. Minimum SMACNA Seal Class: A.
 - c. SMACNA Leakage Class for Rectangular: 12.
 - d. SMACNA Leakage Class for Round and Flat Oval: 12.
 2. Ducts Connected to Constant-Volume Air-Handling Units <Insert equipment>:
 - a. Pressure Class: Positive **3-inch wg (750 Pa)** <Insert value>.
 - b. Minimum SMACNA Seal Class: A.
 - c. SMACNA Leakage Class for Rectangular: 6.
 - d. SMACNA Leakage Class for Round and Flat Oval: 6.
 3. Ducts Connected to Variable-Air-Volume Air-Handling Units <Insert equipment>:
 - a. Pressure Class: Positive **4-inch wg (1000 Pa)** <Insert value>.
 - b. Minimum SMACNA Seal Class: A.
 - c. SMACNA Leakage Class for Rectangular: 3.
 - d. SMACNA Leakage Class for Round and Flat Oval: 3.
 4. Ducts Connected to Equipment Not Listed Above:

- a. Pressure Class: Positive **2-inch wg (500 Pa)** <Insert value>.
- b. Minimum SMACNA Seal Class: A.
- c. SMACNA Leakage Class for Rectangular: 6.
- d. SMACNA Leakage Class for Round and Flat Oval: 6.

F. Return Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units <Insert equipment>:
 - a. Pressure Class: Positive or negative **2-inch wg (500 Pa)**.
 - b. Minimum SMACNA Seal Class: A.
 - c. SMACNA Leakage Class for Rectangular: 12.
 - d. SMACNA Leakage Class for Round and Flat Oval: 12.
2. Ducts Connected to Air-Handling Units <Insert equipment>:
 - a. Pressure Class: Positive or negative **3-inch wg (750 Pa)**.
 - b. Minimum SMACNA Seal Class: A.
 - c. SMACNA Leakage Class for Rectangular: 6.
 - d. SMACNA Leakage Class for Round and Flat Oval: 6.
3. Ducts Connected to Equipment Not Listed Above:
 - a. Pressure Class: Positive or negative **3-inch wg (750 Pa)**.
 - b. Minimum SMACNA Seal Class: A.
 - c. SMACNA Leakage Class for Rectangular: 6.
 - d. SMACNA Leakage Class for Round and Flat Oval: 6.

G. Exhaust Ducts:

1. Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:
 - a. Pressure Class: Negative **3-inch wg (750 Pa)**.
 - b. Minimum SMACNA Seal Class: A if negative pressure, and A if positive pressure.
 - c. SMACNA Leakage Class for Rectangular: 6.
 - d. SMACNA Leakage Class for Round and Flat Oval: 6.
2. Ducts Connected to Air-Handling Units <Insert equipment>:
 - a. Pressure Class: Positive or negative **3-inch wg (750 Pa)**.
 - b. Minimum SMACNA Seal Class: A if negative pressure, and A if positive pressure.
 - c. SMACNA Leakage Class for Rectangular: 6.
 - d. SMACNA Leakage Class for Round and Flat Oval: 6.
3. Ducts Connected to Commercial Kitchen Hoods: Comply with NFPA 96.
 - a. Exposed to View: Type 304, stainless-steel sheet, No. 4 finish.
 - b. Concealed: Carbon-steel sheet.
 - c. Welded seams and joints.
 - d. Pressure Class: Positive or negative **3-inch wg (750 Pa)**.
 - 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 finish.**
 - c. **Concealed: No. 2D finish.**
 - d. **Welded seams and flanged joints with watertight EPDM gaskets.**
 - e. **Pressure Class: Positive or negative 3-inch wg (750 Pa).**
 - 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:**
 - a. **Type 316, stainless-steel sheet.**
 - 1) **Exposed to View: No. 4.**
 - 2) **Concealed: No. 2B finish.**
 - b. **Pressure Class: Positive or negative 4-inch wg (1000 Pa).**
 - c. **Minimum SMACNA Seal Class: A, Welded seams, joints, and penetrations.**
 - d. **SMACNA Leakage Class: 3.**

6. **Ducts Connected to Equipment Not Listed Above:**
 - a. **Pressure Class: Positive or negative 3-inch wg (750 Pa).**
 - b. **Minimum SMACNA Seal Class: A if negative pressure, and A if positive pressure.**
 - c. **SMACNA Leakage Class for Rectangular: 3.**
 - d. **SMACNA Leakage Class for Round and Flat Oval: 3.**

- H. **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 2-inch wg (500 Pa).**
 - b. **Minimum SMACNA Seal Class: A.**
 - c. **SMACNA Leakage Class for Rectangular: 6.**
 - d. **SMACNA Leakage Class for Round and Flat Oval: 3.**

 2. **Ducts Connected to Air-Handling Units <Insert equipment>:**
 - a. **Pressure Class: Positive or negative 3-inch wg (750 Pa).**
 - b. **Minimum SMACNA Seal Class: A.**
 - c. **SMACNA Leakage Class for Rectangular: 6.**
 - d. **SMACNA Leakage Class for Round and Flat Oval: 3.**

 3. **Ducts Connected to Equipment Not Listed Above:**
 - a. **Pressure Class: Positive or negative 3-inch wg (750 Pa).**
 - b. **Minimum SMACNA Seal Class: A.**
 - c. **SMACNA Leakage Class for Rectangular: 6.**
 - d. **SMACNA Leakage Class for Round and Flat Oval: 6.**

I. Intermediate Reinforcement:

1. **Galvanized-Steel Ducts: Galvanized steel.**
2. **PVC-Coated Ducts:**
 - a. **Exposed to Airstream: Match duct material.**
 - b. **Not Exposed to Airstream: Match duct material.**
3. **Stainless-Steel Ducts:**
 - a. **Exposed to Airstream: Match duct material.**
 - b. **Not Exposed to Airstream: Match duct material.**
4. **Aluminum Ducts: Aluminum.**

J. Double-Wall Duct Interstitial Insulation:

1. **Supply Air Ducts: 2 inches (51 mm) thick.**
2. **Return Air Ducts: 2 inches (51 mm) thick.**
3. **Exhaust Air Ducts: 2 inches (51 mm) thick.**

K. Elbow Configurations To Be Use, Unless More Stringent Requirements Are Required Per PART 2 of This Section:

1. **Rectangular Duct: Comply with SMACNA's 2005 "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 1.5 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 1.5 radius-to-diameter ratio.**
 - 2) **Radius Type RE 3 with minimum 1.5 radius-to-diameter ratio and two vanes.**
 - 3) **Mitered Type RE 2 with vanes complying with SMACNA's 2005 "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 1.5 radius-to-diameter ratio and two vanes.**
 - 3) **Mitered Type RE 2 with vanes complying with SMACNA's 2005 "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 2005 "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 1.5 radius-to-diameter ratio and two vanes.**

- c. Mitered Type RE 2 with vanes complying with SMACNA's 2005 "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 2005 "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 2005 "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) Velocity 1000 fpm (5 m/s) or Lower: 1.5 radius-to-diameter ratio and three segments for 90-degree elbow.
 - 2) Velocity 1000 to 1500 fpm (5 to 7.6 m/s): 1.5 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) and Smaller in Diameter: Stamped.
 - c. Round Elbows, 14 Inches (356 mm) and Larger in Diameter: Welded.
- L. Branch Configurations To Be Use, Unless More Stringent Requirements Are Required Per PART 2 of This Section:
 - 1. Rectangular Duct: Comply with SMACNA's 2005 "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: 45-degree entry and transition.
 - 2. Round and Flat Oval: Comply with SMACNA's 2005 "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees."
 - a. Velocity 1000 fpm (5 m/s) or Lower: 90-degree tap, conical.
 - 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 23 3113

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