PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes:

1. Metal ductwork.
2. Duct liner.
3. Duct sealants.
4. Duct hangers and supports.
5. Wire rope hanging system.
6. Manufactured ductwork and fittings.
7. Factory-fabricated grease exhaust ductwork.
8. Snap-Lock duct system.

1.02 REFERENCE STANDARDS

A. ASHRAE (FUND) - ASHRAE Handbook - Fundamentals.

B. ASTM A36/A36M - Standard Specification for Carbon Structural Steel.

C. ASTM A90 - Standard Specification for Weight [Mass] of Coating on Iron and Steel Articles with Zinc of Zinc-Alloy Coatings.

D. ASTM A480/A480M - Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip.

E. ASTM A653/A653M - Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.

F. ASTM A700 - Standard Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment.

G. ASTM A924 - Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process.

H. ASTM A1008/A1008M - Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable.

I. ASTM B209/B209M - Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate.

J. ASTM C423 - Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method.

K. ASTM C534 - Standard Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form

L. ASTM C1071 - Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material).

M. ASTM E84 - Standard Test Method for Surface Burning Characteristics of Building Materials.

N. ASTM E90 - Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements.

O. ASTM E119 - Standard Test Methods for Fire Tests of Building Construction and Materials.

P. ASTM E814 - Standard Test Method for Fire Tests of Penetration Firestop Systems, 2013

Q. AWS D1.1 - Structural Welding Code - Steel

R. AWS D9.1 - Sheet Metal Welding Code

S. ICC-ES AC01 - Acceptance Criteria for Expansion Anchors in Masonry Elements.

T. ICC-ES AC106 - Acceptance Criteria for Predrilled Fasteners (Screw Anchors) in Masonry Elements.

U. ICC-ES AC193 - Acceptance Criteria for Mechanical Anchors in Concrete Elements.

V. ICC-ES AC308 - Acceptance Criteria for Post-Installed Adhesive Anchors in Concrete Elements.

W. NADCA ACR-2002 - Assessment, Cleaning & Restoration of HVAC Systems; National Air Duct Cleaners Association

X. NAIMA - Duct Cleaning Guide; North American Insulation Manufacturers Association

Y. NFPA 90A - Standard for the Installation of Air-Conditioning and Ventilating Systems.

Z. NFPA 90B - Standard for the Installation of Warm Air Heating and Air-Conditioning Systems.

AA. NFPA 96 - Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations.

BB. SMACNA (DCS) - HVAC Duct Construction Standards Metal and Flexible.

CC. SMACNA (KVS) - Kitchen Ventilation Systems and Food Service Equipment Fabrication and Installation Guidelines.

DD. SMACNA (LEAK) - HVAC Air Duct Leakage Test Manual.

EE. TIMA AHC-101; Thermal Insulation Manufacturers Association

FF. UL 181 - Standard for Factory-Made Air Ducts and Air Connectors; current edition, including all revisions.

GG. UL 723 - Standard for Test for Surface Burning Characteristics of Building Materials; Current Edition, Including All Revisions.

HH. UL 1978 - Grease Ducts; Current Edition, Including All Revisions.

II. UL 2221 - Tests of Fire Resistive Grease Duct Enclosure Assemblies; Current Edition, Including All Revisions.

1.03 DEFINITIONS

A. Sealing Requirements Definitions: For the purposes of duct systems sealing requirements specified in this Section, the following definitions apply:

1. Seams: A seam is defined as joining of two longitudinally (in the direction of airflow) oriented edges of duct surface material occurring between two joints. All other duct surface connections made on the perimeter are deemed to be joints.

2. Joints: Joints include girth joints; branch and subbranch intersections; so-called duct collar tap-ins; fitting subsections; louver and air terminal connections to ducts; access door and access panel frames and jambs; duct, plenum, and casing abutments to building structures.

1.04 SYSTEM PERFORMANCE REQUIREMENTS

A. The duct system design, as indicated, has been used to select and size air moving and distribution equipment and other components of the air system. Changes or alterations to the layout or configuration of the duct system must be specifically approved in writing. Accompany requests for layout modifications with calculations showing that the proposed layout will provide the original design results without increasing the system total pressure.

1.05 SUBMITTALS

A. Product data including details of construction relative to materials, dimensions of individual components, profiles, and finishes for the following items:

1. Duct Liner.
2. Sealing Materials.
3. Fire-Stopping Materials.
4. Duct Cleaning Products.

B. Shop drawings from duct fabrication shop, drawn to a scale not smaller than 1/4 inch equals 1 foot, on drawing sheets same size as the Contract Drawings, detailing:

1. Fabrication, assembly, and installation details, including plans, elevations, sections, details of components, and attachments to other work.
2. Duct layout, indicating pressure classifications, duct gauge and sizes in plan view. For exhaust ducts systems, indicate the classification of the materials handled as defined in this Section.
3. Fittings.
4. Reinforcing details and spacing.
5. Seam and joint construction details.
6. Penetrations through fire-rated and other partitions.
7. Terminal heating and cooling unit, coil, humidifier and duct silencer installations.
8. Locations of fire and fire/smoke dampers and associated duct access doors.
9. Locations of cleanout and access doors in grease exhaust ducts.
10. Location of manual balancing dampers.
11. Duct smoke detector locations. Refer to electrical drawings for general locations and coordinate locations with the electrical contractor.

12. Hangers and supports, including methods for building attachment, vibration isolation, and duct attachment.

C. Coordination drawings for ductwork installation in accordance with Division 23 Section "General Mechanical Requirements." In addition to the requirements specified in "General Mechanical Requirements" show the following:

1. Coordination with ceiling suspension members.
2. Spatial coordination with other systems installed in the same space with the duct systems.
3. Coordination of ceiling- and wall-mounted access doors and panels required to provide access to dampers and other operating devices.
4. Coordination with ceiling-mounted lighting fixtures and air outlets and inlets.

D. Leak Test certificate for all grease duct joints and fittings in compliance with the locally adopted IMC.

E. Record drawings including duct systems routing, fittings details, reinforcing, support, and installed accessories and devices, in accordance with Division 23 Section "General Mechanical Requirements" and Division 1.

F. Welding certificates including welding procedures specifications, welding procedures qualifications test records, and welders' qualifications test records complying with requirements specified in "Quality Assurance" below.

G. Duct Cleaning Plan: Submit written work plan including the following information:

1. Scope of work identifying components that will be cleaned.
2. Identify specific environmental engineering controls required for area of work.
3. Detail the cleaning work means and methods.

1.06 QUALITY ASSURANCE

A. Manufacturer Qualifications: Company specializing in manufacturing the type of products specified in this section, with minimum three years of documented experience.

B. Installer Qualifications: Company specializing in performing the type of work specified in this section, with minimum three years of documented experience.

C. Qualify welding processes and welding operators in accordance with AWS D1.1 "Structural Welding Code - Steel" for hangers and supports and AWS D9.1 "Sheet Metal Welding Code."

D. Qualify each welder in accordance with AWS qualification tests for welding processes involved. Certify that their qualification is current.

E. NFPA Compliance: Comply with the following NFPA Standards:

1. NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems," except as indicated otherwise.
2. NFPA 90B, “Standard for the Installation of Warm Air Heating and Air Conditioning Systems.
3. NFPA 96, "Standard for the Installation of Equipment for the Removal of Smoke and Grease-Laden Vapors for Commercial Cooking Equipment," Chapter 3, "Duct System," for kitchen hood duct systems, except as indicated otherwise.

F. Sheet Metal and Air Conditioning Contractors’ National Association, Inc. (SMACNA): Provide ductwork systems in conformance with “HVAC Duct Construction Standards – Metal and Flexible,” latest edition.

G. Underwriter’s Laboratories (UL): Comply with the UL standards listed within this section. Provide mastic and tapes that are listed and labeled in accordance with UL 181A and marked according to type.

H. National Air Duct Cleaners Association, Inc. (NADCA): Clean ductwork systems in accordance with the standard Assessment, Cleaning and Restoration of HVAC Systems (ACR 2002).

1.07 PROTECTION AND REPLACEMENT

A. Protect ductwork during shipping and storage from dirt, debris and moisture damage. Provide plastic covers over ends of ductwork during shipping, storage and installation.

B. Replace duct liner that is damaged and cannot be repaired satisfactorily, including insulation with vapor barrier damage and insulation that has been exposed to moisture during shipping, storage, or installation. Drying the insulation is not acceptable. Dry surfaces prior to installing new duct liner.

1.08 FIELD CONDITIONS

A. Do not install duct sealants when temperatures are less than those recommended by sealant manufacturers.

B. Maintain temperatures within acceptable range during and after installation of duct sealants.

PART 2 - PRODUCTS AND MATERIALS

2.01 DUCT ASSEMBLIES

A. Ducts: Galvanized steel, unless otherwise indicated. Provide sheet metal in thickness indicated (minimum 26 gauge), packaged and marked as specified in ASTM A700.

B. Primary Supply Air Ducts (upstream of terminal boxes in multizone VAV systems): 4 inches water gauge.

C. Secondary Supply Air Ducts (downstream of terminal boxes in multizone VAV systems): 2 inches water gauge

D. Return and Relief: 2 inch w.g. pressure class, galvanized steel.

E. General Exhaust: 2 inch w.g. pressure class, galvanized steel.

F. Dishwasher Hood Exhaust Ducts: 2 inch w.g. pressure class.

1. Type 304, stainless steel, minimum 18 gauge, with finish to match kitchen equipment and range hood. Provide continuously welded seams on top or sides of duct and flanged joints with watertight EPDM gaskets.
2. Aluminum, with longitudinal seams and laps arranged on top of duct. Seal joints with silicone sealant to provide watertight joint.

G. Type I (Grease) Hood Exhaust Ducts: 2 inch w.g. pressure class, comply with NFPA 96.

1. Concealed: Carbon-steel sheet, minimum 16 gauge.
2. Exposed:

a) Interior to the Building: Type 304, stainless steel, minimum 18 gauge, with finish to match kitchen equipment and range hood.

b) Exterior to the Building:

1) Type 304, stainless steel, minimum 18 gauge.
2) Carbon-steel sheet, minimum 16 gauge, coated with an exterior rated, high temperature corrosion resistant paint.

3. Weld and flange seams and joints.
4. At Contractor's option, a UL listed concentric ductwork package may be used in lieu of the welded carbon or stainless steel duct for connecting hood to exhaust fan. Provide manufacturers UL listing number and verification certificate as a part of the shop drawing submittal. Install duct package in strict conformance with manufacturer's instructions and recommendations.

H. Outside Air Intake: 2 inch w.g. pressure class, galvanized steel.

I. Combustion Air: 2 inch w.g. pressure class, galvanized steel, aluminum or stainless steel.

J. Transfer Air and Sound Boots: 1/2 inch wg pressure class, galvanized steel.

K. Exterior Ductwork: Ductwork installed exterior to the building shall be minimum #18 gauge with longitudinal and transverse joints welded or sealed airtight as specified under Paragraph “Seam and Joint Sealing”.

L. Duct Liner Application: Provide duct liner on the following interior air ducts and where specified on the drawings.

1. Supply Ductwork:

a) Exposed rectangular ductwork.
b) Exposed round ductwork.
c) Above open slat ceiling ductwork.
d) First 50 feet of ductwork downstream of equipment outlets.

2. Return Ductwork.

a) Exposed rectangular ductwork.
b) Exposed round ductwork.
c) Above open slat ceiling ductwork
d) First 50 feet of ductwork upstream of equipment outlets.

2.02 MATERIALS

A. Sheet Metal, General: Provide sheet metal in thickness indicated (minimum 26 gauge), packaged and marked as specified in ASTM A 700.

B. Galvanized Steel for Ducts: Hot-dipped galvanized steel sheet, ASTM A653/A653M FS Type B, lock-forming quality with G90/Z275 coating.. Provide mill phosphatized or galvanized finish for surfaces of ducts exposed to view that is to be field painted. Provide bright galvanized finish for ductwork that is exposed to view and not field painted.

C. Carbon Steel for Ducts: ASTM A1008/A1008M, Designation CS (commercial steel), cold-rolled, with oiled, exposed matte finish.

D. Aluminum for Ducts: ASTM B209 (ASTM B209M); aluminum sheet, alloy 3003-H14. Aluminum Connectors and Bar Stock: Alloy 6061-T651 or of equivalent strength, with standard, one-side bright finish where ducts are exposed to view, and mill finish for concealed ducts.

E. Stainless Steel for Ducts: ASTM A 480, Type 316, with No. 4 finish on exposed surface for ducts exposed to view; Type 304, sheet form, with No. 1 finish for concealed ducts.

F. PVC-Coated Galvanized Steel: UL-181 Class 1 Listing. Hot-dipped galvanized steel sheet, ASTM A653/A653M FS Type B, lock-forming quality with G90/Z275 coating. Provide with factory-applied, 4-mil, PVC coating on exterior of ducts and fittings for underground applications, and the interior of ducts and fittings for fume-handing applications and 2-mil PVC coating on the reverse side of the ducts and fittings.

G. Duct Liner

1. General:

   a) Comply with NFPA Standard 90A and North American Insulation Manufacturers Association (NAIMA) Standard AHC-101.
   b) Liner shall have a flame spread rating of not more than 25 without evidence of continued progressive combustion and a smoke developed rating of no higher than 50, when tested in accordance with ASTM E84 or UL 723.
   c) Duct sizes on mechanical plans indicate clear inside airflow dimensions. Sheet metal sizes for ductwork with duct liner shall be increased accordingly to account for liner thickness.

2. Fiberglass: ASTM C1071, Type I or II, glass fibers firmly bonded together with a thermosetting resin with surface exposed to airstream coated to prevent erosion of glass fibers. Liner surface shall serve as a barrier against infiltration of dust and dirt, shall meet ASTM C 1338 for fungi resistance and shall be cleanable using duct cleaning methods and equipment outlined

by NAIMA Duct Cleaning Guide. Duct liner shall be rated for air velocity of 6,000 fpm.

a) Rectangular fiberglass duct liner shall be Certainteed ToughGard T, JohnsManville Linacoustic RC, Knauf Atmosphere, Owens Corning QuietR or approved equal.

1) Thickness and Density:

a) 1 inch, 1-1/2 pounds per cubic foot.

b) Round fiberglass duct liner shall be Certainteed ToughGard UltraRound, JohnsManville Spiracoustic Plus, Owens Corning QuietZone Spiral, or approved equal.

1) Thickness and Density:

a) 1 inch, 4 pound per cubic foot.

c) Thermal Performance: Meet minimum "K-Factor" equal to 0.28 (Btu·in/h·sq ft·F) or better, at a mean temperature of 75°F and rated in installed condition in accordance with ASTM C518 and/or ASTM C177.

d) Noise Reduction Coefficient (NRC): Meet the following minimum NRC in accordance with ASTM C423 Type A Mounting:

1) 1 Inch Thick: NRC 0.65.

e) Liner Adhesive: Comply with NFPA Standard 90A /UL 181 classified with flame spread/smoke development less than 25/50 and ASTM C 916. Adhesive shall be a minimum 50% solid content, water-based, non-oxidizing and have a service temperature of –20 to 200 F. Water-based adhesive shall be one of the following:

1) Armacell LLC Armaflex 520 BLV low VOC.
2) Design Polymerics DP 2502.
3) Duro Dyne WIT.
4) Foster 85-60.
5) Childers CP-127.
6) Johns Manville SuperSeal HV.
7) Hardcast 951.
8) United McGill Uni-Tack.

f) Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct.

1) Fastener Pin Length: As required for thickness of insulation, and without projecting more than 1/8 inch into the airstream.

2) Adhesive For Attachment of Mechanical Fasteners: Comply with the "Fire Hazard Classification" of duct liner system.

3. Flexible Elastomeric Acoustical and Conformable Duct Liner: Compliance with ASTM C 534 Grade 1, Type II or ASTM C 1534, NFPA 90A or NFPA 90B, Thickness: 1/2 inch and 1 inch, Thermal Conductivity: 0.25 BTU-in/hr sq ft F at 75 F mean temp, ASTM C 518, Noise Reduction Coefficient: 0.6, ASTM C 423, Sound Transmission Class (STC) 25, ASTM E 90, EPA registered anti-microbial additive to inhibit mold and mildew, ASTM G21.

   a) Manufacturers:

      1) Aeroflex USA, Inc PLUS Acoustical Duct Liner.
      2) Armacell LLC, AP Coilflex.
      3) Approved equal.

4. Polyester Duct Liner: Duct liner shall be an engineered nonwoven, thermally bonded polyester with a smooth and durable FSK facing. Liner shall have a noise reduction coefficient of at least 0.65 per ASTM C423 and have thermal values greater or equal to an R-5 at 1 inch, R-6 at 1-1/2 inch and R-8 at 2 inch, respectively. Polyester liner must be able to withstand a constant internal temperature up to 250 F, must be compliant with Greenguard Environmental Institute, and contain zero VOCs per ASTM D5116. Liner must comply with NFPA 90A, NFPA 90 B and UL 181. Liner must meet ASTM C518 for thermal conductance properties and ASTM G-21 for fungal resistance properties. Liner must consist of at least 25 percent recycled content.

   a) Manufacturers:

      1) Ductmate Industries “PolyArmor.”
      2) Approved equal.

H. Joint Sealers and Sealants: Non-hardening, water resistant, mildew and mold resistant.

1. Type: Heavy mastic or liquid used alone or with tape, suitable for joint configuration and compatible with substrates, and recommended by manufacturer for pressure class of ducts.
2. Surface Burning Characteristics: Sealants shall be ASTM E84 or UL 723 listed with a flame spread index not more than 25 and a smoke-developed index not more than 50.
3. For Use with Flexible Ducts: UL labeled.
4. The term sealant used here is not limited to materials of adhesive or mastic nature, but also includes tapes and combinations of open weave fabric strips and mastics. Duct tape shall not be used as a sealant on any ducts.
5. Joint and Seam Tape: 2 inches wide, glass-fiber-reinforced fabric.

6. Tape Sealing System: Woven-fiber tape impregnated with a gypsum mineral compound and a modified acrylic/silicone activator to react exothermically with the tape to form a hard, durable, airtight seal.
7. Solvent-Based Joint and Seam Sealant: One-part, non-sag, solvent-release-curing, polymerized butyl sealant complying with FS TT-S-001657, Type I; formulated with a minimum of 70 percent solids. Approved products: Childers CP-140, Duro Dyne SGD, Fosters 32-14, or approved equal.
8. Water-Based Joint and Seam Sealant: Non-Fibrated: UL 181 listed. Sealant shall be rated to ±15 inches w.g. Sealant shall have a service temperature of –25 to 200 F and be freeze/thaw stable through 5 cycles. Approved products: Childers CP-146, Design Polymerics DP 1010, Ductmate Proseal/Fiberseal, Duro Dyne Duroseal, Fosters 32-1, United Duct Sealer (Water Based), and Hardcast 601.
9. Flanged Joint Mastics: One-part, acid-curing, silicone elastomeric joint sealants, complying with ASTM C 920, Type S, Grade NS, Class 25, Use O.
10. Flanged Gasket Tapes: Butyl gasket shall be UL 181 classified. Gasket size shall be minimum 5/8 inch x 3/16 inch and have nominal 100 percent solid content. It shall be non-oxidizing, non-skinning and have a service temperature of –25 to 180 F. Approved Products: Design Polymerics DP 1040, Ductmate 440, and Hardcast 1104.

I. Fire Stopping

1. Fire-Resistant Sealant: Two-part, foamed-in-place, fire-stopping silicone sealant formulated for use in a through-penetration fire-stop system for filling openings around duct penetrations through walls and floors, having fire-resistance ratings indicated as established by testing identical assemblies per ASTM E 814 by Underwriters Laboratory, Inc. or other testing and inspecting agency acceptable to authorities having jurisdiction.
2. Fire-Resistant Sealant: One-part elastomeric sealant formulated for use in a through-penetration fire-stop system for filling openings around duct penetrations through walls and floors, having fire-resistance ratings indicated as established by testing identical assemblies per ASTM E 814 by Underwriters Laboratory, Inc. or other testing and inspecting agency acceptable to authorities having jurisdiction.
3. Products: Subject to compliance with requirements, provide one of the following:

    a) "3M Fire Stop Foam"; 3M Corp.
    b) "SPECSEAL Pensil 200 Silicone Foam"; Specify Technology, Inc.
    c) 3M Fire Stop Sealant"; 3M Corp.
    d) "3M Fire Barrier Caulk CP-25"; Electrical Products Div./3M.
    e) "Fyre Putty"; Standard Oil Engineered Materials Co.
    f) “FS-ONE”, Hilti, Inc.

J. Hangers and Supports

1. Hanger Rod: ASTM A36/A36M; steel, galvanized; threaded both ends, threaded one end, or continuously threaded.
2. Hanger Fasteners: Attach hangers to structure using appropriate fasteners, as follows:

    a) Concrete Wedge Expansion Anchors: Complying with ICC-ES AC193.
    b) Masonry Wedge Expansion Anchors: Complying with ICC-ES AC01.
    c) Concrete Screw Type Anchors: Complying with ICC-ES AC193.
    d) Masonry Screw Type Anchors: Complying with ICC-ES AC106.
    e) Concrete Adhesive Type Anchors: Complying with ICC-ES AC308.

3. Building Attachments: Concrete inserts, powder actuated fasteners, or structural steel fasteners appropriate for building materials. Do not use powder actuated concrete fasteners for lightweight aggregate concrete or for slabs less than 4 inches thick.
4. Hangers: Galvanized sheet steel, or round, uncoated steel, threaded rod.

    a) Hangers Installed In Corrosive Atmospheres: Electro-galvanized, all-thread rod or hot-dipped-galvanized rods with threads painted after installation.
    b) Straps and Rod Sizes: Conform with SMACNA HVAC Duct Construction Standards, 2005 Edition, for sheet steel width and gauge and steel rod diameters.

5. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
6. Trapeze and Riser Supports: Steel shapes conforming to ASTM A 36.

    a) Where galvanized steel ducts are installed, provide hot-dipped-galvanized steel shapes and plates.
    b) For stainless steel ducts, provide stainless steel support materials.
    c) For aluminum ducts, provide aluminum support materials, except where materials are electrolytically separated from ductwork.

7. Wire Rope Hanging Systems:

    a) General: Wire rope hanger system shall have a minimum 5 to 1 safety factor based upon the applied working load being supported.
    b) Source Limitations: Furnish associated fittings, accessories, and hardware produced by a single manufacturer.
    c) Wire Rope: Zinc coated or galvanized steel, with wire thread type as required to support the applied working load being supported.

Provide same size wire for all applications based on worst case loading.

d) Cable Lock: Cast zinc housing with steel spring with wedge grip, selected to meet the vertical load applied to the hanging system and wire thread. Do not exceed the working load limit.

e) Accessories: Hanger attachments and structural attachments shall be compatible with wire rope hanger system and shall be by the same manufacturer as the wire rope hanger system.

f) Manufacturers:

1) ASC Engineered Solutions.
2) Ductmate Industries, Inc; Clutcher Cable Hanging System.
3) Duro Dyne.
4) Gripple.

K. Reinforcement Shapes and Plates: Unless otherwise indicated, provide galvanized steel reinforcing where installed on galvanized sheet metal ducts. For aluminum and stainless steel ducts provide reinforcing of compatible materials.

L. Tie Rods: Same material as the duct, 1/4-inch minimum diameter for 36-inch length or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.03 DUCTWORK FABRICATION

A. Fabricate and support duct in accordance with latest edition of SMACNA (DCS).

B. Provide duct material, gauges, reinforcing, and sealing for operating pressures indicated.

1. Fabricate rectangular ductwork of minimum 26 gauge sheet metal.
2. Fabricate ducts in lengths appropriate to reinforcement and rigidity class required for pressure classification.

C. Provide materials that are free from visual imperfections such as pitting, seam marks, roller marks, stains, and discolorations.

D. Field Painted Ductwork: Provide mill phosphatized finish on exposed surfaces of rectangular ductwork and duct fittings to be field painted.

E. Crossbreaking or Cross Beading: Crossbreak or bead duct sides that are 19 inches and larger and are 20 gauge or less, with more than 10 sq. ft. of unbraced panel area, as indicated in SMACNA "HVAC Duct Construction Standards," 2005 Edition, Figure 2-9, unless they are lined or are externally insulated.

F. Fabricate elbows, transitions, offsets, branch connections, and other duct construction in accordance with SMACNA "HVAC Metal Duct Construction Standard," 2005 Edition, Figures 4-1 through 4-8. Unless otherwise noted on drawings, provide prefabricated 45 degree, high efficiency, rectangular/round branch duct takeoff fittings with manual balancing damper, 3/8 inch square shaft, U-bolt, nylon bushings, locking quadrant, and 2 inch insulation build-out for branch duct connections and take-offs to individual diffusers, registers and grilles. 45 degree, high efficiency, rectangular/round branch duct takeoff fittings shall be Flexmaster STO with model BO3 damper or equal.

G. Provide radius elbows, turns, and offsets with a minimum centerline radius of 1-1/2 times the duct width. Where space does not permit full radius elbows, provide short radius elbows with a minimum of two continuous splitter vanes. Vanes shall be the entire length of the bend. The use of square throat, radius heel elbows is prohibited. Remove and replace all installed elbows of this type with an approved elbow at no additional cost to the owner.

H. Provide mitered elbows where space does not permit radius elbows, where shown on the drawings, or at the option of the contractor with the engineer's approval. The contractor shall obtain approval to substitute mitered elbows in lieu of radius elbows prior to fitting fabrication. Mitered elbows less than 45 degrees shall not require turning vanes. Mitered elbows 45-degrees and greater shall have single thickness turning vanes of same material and gauge as ductwork, rigidly fastened with guide strips in ductwork. Vanes for mitered elbows shall be provided in all supply and exhaust ductwork and in return and outside air ductwork that has an air velocity exceeding 1000 fpm. Do not install vanes in grease ductwork. Refer to Section "Ductwork Accessories" for turning vane construction and mounting.

I. Provide full radius elbows for ductwork installed in noise critical spaces. Refer to Section "Basic Mechanical Materials and Methods" for noise critical spaces. Where space does not permit the installation of radius elbows, provide mitered elbows with sound attenuating, acoustical turning vanes. Refer to Section "Ductwork Accessories" for acoustical turning vanes.

J. Increase duct sizes gradually, not exceeding 15 degrees divergence wherever possible; maximum 30 degrees divergence upstream of equipment and 45 degrees convergence downstream.

K. Where ducts are connected to exterior wall louvers and duct outlet is smaller than louver frame, provide blank-out panels sealing louver area around duct. Use same material as duct, painted black on exterior side; seal to louver frame and duct.

L. Round and Flat Oval Duct Fabrication

1. General: "Basic Round Diameter" as used in this article is the diameter of the size of round duct that has a circumference equal to the perimeter of a given sized of flat oval duct. Except where interrupted by fittings, provide round and flat oval ducts in lengths not less than 12 feet.

    a) Fabricate round and flat oval ductwork of minimum 26 gauge sheet metal.

M. Round Ducts: Fabricate round supply ducts using seam types identified in SMACNA "HVAC Duct Construction Standards," 2005 Edition, Figure 3-2, RL-1, RL-4, or RL-5 except where diameters exceed 72 inches. Seam Types RL-2 or RL-3 may be used for ducts smaller than 72 inches in diameter if spot-welded on 1-inch intervals. Fabricate ducts having diameters greater than 72 inches with longitudinal butt-welded seams. Comply with SMACNA "HVAC Duct Construction Standards," 2005 Edition, Table 3-5 through 3-13 for galvanized steel gauges. For round duct with static pressure classification of 2 inches water gauge or lower, round supply ducts may be fabricated using snaplock seam types identified in SMACNA "HVAC Duct Construction Standards," 2005 Edition, Figure 3-2, RL-6A, RL-6B, RL-7 or RL-8.

N. Flat Oval Ducts: Fabricate flat oval supply ducts with standard spiral lockseams (without intermediate ribs) or with butt-welded longitudinal seams in gauges listed in SMACNA "HVAC Duct Construction Standards," 2005 Edition, Table 3-15.

O. Double-Wall (Insulated) Ducts: Fabricate double-wall insulated ducts with an outer shell, insulation, and an inner liner as specified below. Dimensions indicated on internally insulated ducts are nominal inside dimensions.

1. Outer Shell: Base outer shell gauge on actual outer shell dimensions. Provide outer shell lengths 2 inches longer than inner shell and insulation, and in gauges specified above for single-wall duct.
2. Insulation: Unless otherwise indicated, provide 1-inch-thick. 1.5 pounds per cubic foot density fiber-glass insulation with thermal conductivity performance of 0.27 Btu/sq.ft./°F/inch-thickness at 75°F mean temperature. Provide insulation ends where internally insulated duct connects to single-wall duct or non-insulated components. The insulation end shall terminate the insulation and reduce the outer shell diameter to the nominal single-wall size.
3. Perforated Inner Liner: Construct round and flat oval inner liners with perforated sheet metal of the gauges listed below. Provide 3/32-inch-diameter perforations, with an overall open area of 23 percent. For flat oval ducts, the diameter indicated below is the "basic round diameter."

    a) 3 to 8 inches: 28 gauge with standard spiral construction.
    b) 9 to 42 inches: 28 gauge with single-rib spiral construction.
    c) 44 to 60 inches: 26 gauge with single-rib spiral construction.

d) 62 to 88 inches: 22 gauge with standard spiral construction.

4. Maintain concentricity of liner to outer shell by mechanical means. Retain insulation from dislocation by mechanical means.

P. Round and Flat Oval Fittings Fabrication

1. 90-Degree Tees and Laterals and Conical Tees: Fabricate to conform to SMACNA "HVAC Duct Construction Standards," 2005 Edition, Figures 3-5, 3-6 and 3-7 and with metal thickness specified for longitudinal seam straight duct.
2. Diverging-Flow Fittings: Fabricate with a reduced entrance to branch taps with no excess material projecting from the body onto branch tap entrance.
3. Elbows: Unless elbow construction type is indicated, provide elbows meeting the following requirements:

a) Fabricate in die-formed, gored, pleated, or mitered construction. Fabricate the bend radius of die-formed, gored, and pleated elbows 1.5 times the elbow diameter.

1) Elbows in Round Duct: Provide full radius elbows.
2) Elbows in Flat Oval Duct: Provide full radius elbows. Where space limits the installation of full radius elbows, short radius elbows with a minimum of two continuous splitter vanes shall be installed. Vane length shall be the entire length of the bend or 36 inches whichever is greater.
3) The use of square throat, radius heel elbows is prohibited. Remove and replace all installed elbows of this type with an approved elbow at no additional cost to the owner.
4) Provide full radius elbows for ductwork installed in noise critical spaces or where shown on the drawings. Refer to Section “Basic Mechanical Materials and Methods” for noise critical spaces.

b) Mitered Elbows: Fabricate mitered elbows with welded construction in gauges specified below.

1) Mitered Elbows Radius and Number of Pieces: Unless otherwise indicated, construct elbow to comply with SMACNA "HVAC Duct Construction Standards," 2005 Edition, Table 3-1.
2) Round Mitered Elbows: Solid welded and with metal thickness listed below for pressure classes from minus 2 inches to plus 2 inches:

a) 3 to 26 inches: 24 gauge.
b) 27 to 36 inches: 22 gauge.

c) 37 to 50 inches: 20 gauge.
d) 52 to 60 inches: 18 gauge.
e) 62 to 84 inches: 16 gauge.

3) Round Mitered Elbows: Solid welded and with metal thickness listed below for pressure classes from 2 inches to 10 inches:

a) 3 to 14 inches: 24 gauge.
b) 15 to 26 inches: 22 gauge.
c) 27 to 50 inches: 20 gauge.
d) 52 to 60 inches: 18 gauge.
e) 62 to 84 inches: 16 gauge.

4) Flat Oval Mitered Elbows: Solid welded and with the same metal thickness as longitudinal seam flat oval duct.

5) 90-Degree, 2-Piece, Mitered Elbows: Use only for supply systems, or exhaust systems for material handling classes A and B; and only where space restrictions do not permit the use of 1.5 bend radius elbows. Fabricate with a single-thickness turning vane.

c) Round Elbows - 8 Inches and Smaller: Die-formed elbows for 45- and 90-degree elbows and pleated elbows for 30, 45, 60, and 90 degrees only. Fabricate nonstandard bend angle configurations or 1/2-inch-diameter (e.g. 3-1/2- and 4-1/2-inch) elbows with gored construction.

d) Round Elbows - 9 Through 14 Inches: Gored or pleated elbows for 30, 45, 60, and 90 degrees, except where space restrictions require a mitered elbow. Fabricate nonstandard bend angle configurations or 1/2-inch-diameter (e.g. 9-1/2- and 10-1/2-inch) elbows with gored construction.

e) Round Elbows - Larger Than 14 Inches and All Flat Oval Elbows: Gored elbows, except where space restrictions require a mitered elbow.

f) Die-Formed Elbows for Sizes Through 8 Inches and All Pressures: 20 gauge with 2-piece welded construction.

g) Round Gored Elbows Gauges: Same as for non-elbow fittings specified above.

h) Flat Oval Elbows Gauges: Same as longitudinal seam flat oval duct.

i) Pleated Elbows Sizes Through 14 Inches and Pressures Through 10 Inches: 26 gauge.

4. Double-Wall (Insulated) Fittings: Fabricate double-wall insulated fittings with an outer shell, insulation, and an inner liner as specified below. Dimensions indicated on internally insulated ducts are nominal inside dimensions.

a) Outer Shell: Base outer shell gauge on actual outer shell dimensions. Provide outer shell lengths 2 inches longer than inner shell and insulation. Gauges for outer shell shall be same as for uninsulated fittings specified above.

b) Insulation: Unless otherwise indicated, provide 1-inch-thick. 1.5 pounds per cubic foot density fiber-glass insulation with thermal conductivity performance of 0.27 Btu/sq.ft./°F/inch-thickness at 75°F mean temperature. Provide insulation ends where internally insulated duct connects to single-wall duct or non-insulated components. The insulation end shall terminate the insulation and reduce the outer shell diameter to the nominal single-wall size.

c) Perforated Inner Liner: Construct round and flat oval inner liners with perforated sheet metal of the gauges listed below. Provide 3/32-inch-diameter perforations, with an overall open area of 23 percent. For flat oval ducts, the diameter indicated in the table below is the "basic round diameter."

1) 3 to 34 inches: 24 gauge.
2) 35 to 58 inches: 22 gauge.
3) 60 to 88 inches: 20 gauge.

d) Maintain concentricity of liner to outer shell by mechanical means. Retain insulation from dislocation by mechanical means.

5. PVC-Coated Elbows and Fittings: Fabricate elbows and fittings as follows:

a) Round Elbows 4 to 8 Inches: 2-piece, die stamped, with longitudinal seams spot welded, bonded, and painted with a PVC aerosol spray.
b) Round Elbows 9 to 26 Inches: Standing seam construction.
c) Round Elbows 28 to 60 Inches: Standard gore construction, riveted and bonded.
d) Other Fittings: Riveted and bonded joints.
e) Couplings: Slip-joint construction with a minimum of a 2-inch insertion length.

Q. Shop Application of Liner in Rectangular Ducts

1. Adhere a single layer of indicated thickness of duct liner with 90 percent coverage of adhesive at liner contact surface area. Multiple layers of insulation to achieve indicated thickness is prohibited.
2. Apply a coat of adhesive to liner facing in direction of airflow not receiving 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 assure butted edge overlapping.

5. Longitudinal joints in rectangular ducts shall not occur except at corners of ducts, unless the size of the duct and standard liner product dimensions make longitudinal joints necessary.

    a) Apply an adhesive coating on longitudinal seams in ducts exceeding 2,500 FPM air velocity.

6. Secure liner with mechanical fasteners 4 inches from corners and at intervals not exceeding 12 inches transversely around perimeter; at 3 inches from transverse joints and at intervals not exceeding 18 inches longitudinally.
7. Secure transversely oriented liner edges facing the airstream with metal nosings that are either channel or "Z" profile or are integrally formed from the duct wall at the following locations:

    a) Fan discharge.
    b) Intervals of lined duct preceding unlined duct.
    c) Upstream edges of transverse joints in ducts where duct velocity is greater than 2,500 FPM.

8. Secure insulation liner with perforated sheet metal liner of the same gauge specified for the duct, secured to ducts with mechanical fasteners that maintain metal liner distance from duct without compressing insulation. Provide 3/32-inch-diameter perforations, with an overall open area of 23 percent.
9. Terminate liner with duct buildouts installed in ducts to attach dampers, turning vane assemblies, and other devices. Fabricated buildouts (metal hat sections) or other buildout means are optional; when used, secure buildouts to the duct wall with bolts, screws, rivets, or welds. Terminate liner at fire dampers at connection to fire damper sleeve through fire separation.

2.04 MANUFACTURED DUCTWORK AND FITTINGS

A. General: At the Contractor’s option, factory-manufactured ductwork can be provided instead of fabricated ductwork for round and oval ductwork. The round duct system shall consist of fittings that are factory fitted with a sealing gasket and spiral duct which, when installed according to the manufacturer's instructions, will seal the duct joints without the use of duct sealer. The oval duct system shall be sealed with duct sealer as specified.

1. Ducts shall be calibrated to manufacturer's published dimensional tolerance standard.
2. All duct 14" diameter and larger shall be corrugated for added strength and rigidity.
3. Spiral seam slippage shall be prevented by means of a flat seam and a mechanically formed indentation evenly spaced along the spiral seam.

4. Ducts shall be constructed using spiral lock seam sheet metal construction.
5. Ductwork to be installed in exposed locations shall have the surface prepared in the factory for field painting.

B. Duct Construction

1. Unless otherwise noted, all duct and fittings shall be constructed from galvanized steel in accordance with SMACNA's Duct Construction Standards for +10" water gauge pressure with minimum wall thickness as shown in the following tables:

Single Wall Round Duct:

Diameter (Inches)	Galvanized Spiral Duct (ga)	Galvanized Fittings (ga)
3-14	28	24
15-24	26	24
26-42	24	22
42-60	22	20

Double Wall Round Duct:

Diameter (Inches)	Galvanized Spiral Duct (ga)		Galvanized Fittings (ga)	
	Inner	Outer	Inner	Outer
3-14	28	28	24	24
16-24	26	26	24	24
26-42	24	24	22	22
44-60	22	22	20	20

Oval Duct:

Major Axis (Inches)	Galvanized Spiral Duct (ga)	Galvanized Fittings (ga)
3-24	24	20
25-38	22	20
37-48	22	18
49-60	20	18
61-70	20	16
71 and large	18	16

2. Duct shall be calibrated to manufacturer's published dimensional tolerance standard.
3. Ducts shall be constructed using spiral lock seam sheet metal construction.
4. Ductwork to be installed in exposed locations shall be factory-prepared for field painting, i.e. mill-phosphatized..

C. Fittings:

1. All fitting ends for round duct and transitions and divided flow fittings smaller than 24” diameter that convert oval duct to round duct shall come factory equipped with a double lipped, U-profile, EPDM rubber gasket. Gasket shall be manufactured to gauge and flexibility so as to ensure that system will meet all of the performance criteria set forth in the manufacturer's literature. Gasket shall be classified by Underwriter's Laboratories to conform to ASTM E84-91a and NFPA 90A flame spread and smoke developed ratings of 25/50.
2. All fittings shall be calibrated to manufacturer's published dimensional tolerance standard and associated spiral duct.
3. All fitting ends from 5" to 60" diameter shall have rolled over edges for added strength and rigidity.
4. All elbows from 5" to 12" diameter shall be 2 piece die stamped and continuously stitch welded. All elbows 14" diameter and larger shall be standing seam gorelock construction and internally sealed.
5. The radius of all 90° and 45° elbows shall be 1.5 times the elbow diameter, unless otherwise noted on the contract documents to be 1.0. The radius of all 15°, 30° and 60° elbows shall be minimum 1.0 times the elbow diameter.
6. All fittings that are of either spot welded or button punched construction shall be internally sealed. When contract documents require divided flow fittings, only full body fittings will be accepted. The use of duct taps is unacceptable except for retrofit installations.
7. Double wall duct and fittings shall consist of a perforated or solid inner liner, a 1 inch, 1.50 pounds per cubic foot (unless otherwise specified) layer of fiberglass insulation and a solid outer pressure shell. Perforated inner liner shall have a retaining fabric wrapped between the perforated inner and the fiberglass insulation. This fabric shall provide fiberglass tear retention while maintaining the desired acoustical properties. For 1 inch thick insulation, the outer pressure shell diameter shall be 2 inches larger than the inner liner.
8. All double wall fittings for round duct shall be furnished with the manufacturer’s standard gasket on the outer shell. The inner shell on all double wall fittings shall extend a minimum of 1 inch past the outer shell.
9. Double wall to single wall transitions shall be provided where insulated duct connects to non-insulated, single wall duct. Transitions shall also act as insulation ends reducing the double wall outer shell diameter to the inner shell diameter.
10. All double wall duct and fittings shall be furnished with both an inner liner and an outer pressure shell coupling. The inner liners shall not be fastened tighter to allow for expansion and contraction.
11. All volume dampers shall be Lindab Safe type DRU, DSU or DTU or equal by an acceptable manufacturer. Damper shall be fitting sized to slip into spiral duct. Damper shall have the following features:

    a) Locking quadrant with blade position indicator.
    b) 2" sheet metal insulation stand-off.

c) Integral shaft/blade assembly.
d) Shaft mounted, load bearing bushings.
e) Gasketed shaft penetrations to minimize leakage.

D. Manufacturers:

1. Hercules Industries.
2. Lewis & Lambert.
3. Lindab Safe.
4. Linx Industries, Inc.
5. Semco.

2.05 SNAP-LOCK DUCT SYSTEM

A. General: At Contractor's option, snap-lock round ductwork can be provided instead of fabricated ductwork for round ductwork up to 14" in diameter in air systems with pressures between negative 1" and positive 2" w.c..

B. Duct Construction:

1. Material:

a) Galvanized steel conforming to ASTM A653 and A924 with G-60 galvanized coating conforming to ASTM A653 and ASTM A90.

2. Duct shall be minimum 26 gauge. Duct shall be self-locking and incorporate a factory applied gasket in the longitudinal seam and the female end of the traverse joint to provide a system that meets SMACNA Seal Class A.
3. Fittings: Minimum 26 gauge. All high-efficiency take-offs, conicals, and collars shall have a factory applied gasket along all rivets, co-latches, and flanges. Dampered fittings shall have low leakage hardware with closed-end bearings.

C. Gaskets: Gaskets shall be made of butyl and EPDM rubber that meets flame spread index of 25 and smoke spread index of 50 according to ASTM E84.

D. Manufacturers:

1. Ductmate GreenSeam.
2. Approved equal.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install, support, and seal ducts in accordance with SMACNA (DCS).

B. Install products in accordance with manufacturer's instructions.

C. Install ducts with the fewest possible joints.

D. Seal duct joints with the appropriate sealing material.

E. Use fabricated fittings for all changes in directions, changes in size and shape, and connections.

F. Install couplings tight to duct wall surface with projections into duct at connections kept to a minimum.

G. Locate ducts, except as otherwise indicated, vertically and horizontally, parallel and perpendicular to building lines; avoid diagonal runs. Install duct systems in shortest route that does not obstruct useable space or block access for servicing building and its equipment.

H. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

I. Provide clearance of 1 inch where furring is shown for enclosure or concealment of ducts, plus allowance for insulation thickness, if any.

J. Install insulated ducts with 1-inch clearance outside of insulation.

K. Conceal ducts from view in finished and occupied spaces by locating in mechanical shafts, hollow wall construction, or above suspended ceilings. Do not encase horizontal runs in solid partitions, except as specifically shown.

L. Coordinate layout with suspended ceiling and lighting layouts and similar finished work.

M. Exposed Ductwork: Exposed ductwork shall be free of defects, dents or blemished surfaces to provide a smooth, finished appearance. Any damaged material shall be

replaced with new material. Ductwork that is to be field painted shall have surfaces wiped clean of lubricant, dirt, or fil prior to priming and painting. Apply primer and paint of type as recommended by paint manufacturer for duct material and finish.

N. Electrical Equipment Spaces: Route ductwork to avoid passing through transformer vaults and electrical equipment spaces and enclosures.

O. Non-Fire-Rated Partition Penetrations: Where ducts pass interior partitions and exterior walls, and are exposed to view, conceal space between construction opening and duct or duct insulation with sheet metal flanges of same gauge as duct. Overlap opening on 4 sides by at least 1-1/2 inches.

P. Acoustical Barrier Penetrations: Where a duct passes through a wall, ceiling or floor slab of a noise critical space, provide a clear annular space of 1-inch between the duct and the structure. Refer to Section "Common Work Results for HVAC" for noise critical spaces. The Contractor shall check the clearance and, if clearance is acceptable, shall install the duct and pack the voids full depth with mineral fiber batt insulation. Contractor shall caulk both ends with a non-aging, non-hardening sealant backed by a polyethylene foam rod or permanently flexible firestop material. Where there is insufficient clearance space, Contractor shall place a short stub duct in the wall, pack and caulk around it and then attach the inlet and outlet ducts to each end.

Q. Cover ducts openings during construction with duct caps or three-mil plastic to protect inside of (installed and delivered) ductwork from exposure to dust, dirt, paint and moisture. Do not use duct tape on ducts that will be exposed or painted.

R. Duct Liner Installation

1. Fiberglass Duct Liner:

a) Attach fiberglass duct liner using fasteners that do not damage the liner when applied as recommended by the manufacturer, that do not cause leakage in the duct, and will indefinitely sustain a 50-pound tensile dead load test perpendicular to the duct wall.

2. Flexible Elastomeric Duct Liner:

a) Install liner in accordance with the manufacturer's installation instructions or ASTM C 1710.
b) Attach flexible elastomeric duct liner to clean, oil-free sheet metal surfaces with adhesive as recommended by the liner manufacturer.
c) Seal all longitudinal seams and end joints with manufacturer's recommended adhesive and install compression joints in accordance

with manufacturer's instructions to eliminate any openings in insulation that would allow passage of air to duct surface being insulated.

3. Polyester Duct Liner:

   a) Install polyester duct liner per SMACNA Manual, "HVAC Duct Construction Standards, Metal and Flexible," unless otherwise specified.
   b) Attach polyester duct liner using a nonflammable, low VOC water based adhesive.
   c) Apply a nonflammable, low VOC water based lagging adhesive to the exposed leading edge of the insulation.
   d) Install fasteners per SMACNA HVAC Duct Liner installation instructions.

S. Kitchen Hood Exhaust

1. Provide for thermal expansion of ductwork through 2,000°F temperature range.
2. Install without dips or traps that may collect residues, except where traps have continuous or automatic residue removal.
3. Horizontal Ducts:

   a) Provide at least one opening that is minimum size of 20 inches by 20 inches for personnel entry. Where an opening of this size is not possible, provide access openings at each change in direction and at 12-foot intervals. Locate openings on sides of duct 1-1/2 inches minimum from bottom, and fit with grease-tight covers of same material as duct. Support systems for ducts 24 inch and larger in any dimension shall be designed for the weight of the duct plus 800 pounds at any point in the duct system.
   b) Slope horizontal ductwork serving a Type I hood back toward the hood or local grease reservoir a minimum of 1/4 inch per foot. Horizontal ducts that exceed 75 feet in length shall be sloped not less than 1 inch per foot.

4. Vertical Ducts:

   a) For ducts larger than 24 inches by 24 inches, provide a 20 inch by 20 inch access opening for personnel entry at the top of the vertical riser.
   b) For ducts smaller than 24 inches by 24 inches, provide an access opening at each floor level in a location that is accessible and not higher than 12 feet above finished floor.

c) Supports for ducts large enough for personnel entry shall be designed for the weight of the duct plus 800 lbs at any point in the duct system.

5. Provide transition at connection to fan with opening size equal to or greater than the venturi opening of the fan inlet. Provide gasket at flanged connection to fan rated for 1500 F and grease applications.
6. Do not penetrate fire-rated assemblies without providing shaft, field-applied or factory-built enclosure.

T. Dishwasher Exhaust Duct Installations

1. Install dishwasher exhaust duct systems in accordance with SMACNA "HVAC Duct Construction Standards," 2005 Edition, Figure 10-2.
2. Slope horizontal ductwork back towards dishwasher hood a minimum of 1/4" per foot. Where distance does not allow continuous slope in ductwork, provide low point drains with the following:

a) Drip leg with 3/4 inch plenum rated drain tubing routed to discharge at code approved location.
b) Pigtail trap or U-trap sized for system pressure.

U. Provide openings in ductwork where required to accommodate thermometers and controllers. Provide pilot tube openings where required for testing of systems, complete with metal can with spring device or screw to ensure against air leakage. Where openings are provided in insulated ductwork, install insulation material inside a metal ring.

V. Locate ducts with sufficient space around equipment to allow normal operating and maintenance activities.

W. Use crimp joints with or without bead for joining round duct sizes 8 inch and smaller with crimp in direction of air flow.

X. Seam and Joint Sealing

1. General: Seal duct seams and joints as follows:

a) All transverse joints, longitudinal seams, and duct wall penetrations shall be sealed to meet SMACNA Seal Class A.
b) Seal class shall apply to all supply, return, outdoor air, and exhaust ductwork, regardless if the duct is positively or negatively pressurized. Transfer air ducts and sound boots do not need to be sealed.

2. Seal externally insulated ducts prior to insulation installation.

3. Ductwork installed exterior to the building shall have longitudinal and transverse joints welded or sealed airtight with weatherproof heavy liquid sealant applied according to manufacturer's instructions.

Y. HANGING AND SUPPORTING

1. Install rigid round, rectangular, and flat oval metal duct with support systems per SMACNA standards.
2. The use of wire rope hanging systems is an acceptable alternate hanging method when installed in strict accordance with manufacturer's instructions. Wire rope hanger spacing shall not exceed 8 feet. Supported load shall not exceed manufacturer's recommended load rating.

    a) Where approved by local code authority, the loop system may be swaged directly on to a seismic approved bracket or appropriate end fixing.

3. Support horizontal ducts within 2 feet of each elbow and within 4 feet of each branch intersection.
4. Support vertical ducts at a maximum interval of 16 feet and at each floor.
5. Upper attachments to structures shall have an allowable load not exceeding 1/4 of the failure (proof test) load but are not limited to the specific methods indicated. Hangers and supports shall be fastened to building joists or beams. Do not attach hangers and supports to the above floor slab or roof with sheet metal screws.
6. Install concrete insert prior to placing concrete.
7. Install powder actuated concrete fasteners after concrete is placed and completely cured.
8. Provide double nuts and lock washers on threaded rod supports.
9. 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.

Z. Penetrations

1. Fire Barrier Penetrations: Where ducts pass though fire-rated walls, partitions, ceilings, and floors, maintain the fire-rated integrity.
2. Underground Exterior Wall Penetrations: Seal duct penetrations through underground exterior walls with sleeves, packing, and sealant. Refer to Division 23 Section "Basic Piping Materials and Methods" for additional information.
3. Elevated Floor Penetrations of Waterproof Membrane, Interior Penetrations of No-Fire Rated Walls and Concrete Slab on Grade Penetrations: Seal ducts that pass through waterproof floors, non-fire rated walls, partitions and ceilings or concrete slab on grade. Refer to Division 23 Section "Basic Piping Materials and Methods" for special sealers and materials.

AA. CONNECTIONS

1. Equipment Connections: Connect equipment with flexible connectors in accordance with Division 23 Section "Air Duct Accessories."
2. Branch Connections: Comply with SMACNA "HVAC Duct Construction Standards".
3. Outlet and Inlet Connections: Comply with SMACNA "HVAC Duct Construction Standards". Where a 90-degree elbow is required at the connection to air devices, provide a rigid duct elbow or, at Contractor's option, a flexible elbow assembly as specified in Division 23 Section "Air Duct Accessories."
4. Fan Connections: Comply with SMACNA "HVAC Duct Construction Standards".

3.02 FIELD QUALITY CONTROL

A. Remake leaking joints as required and apply sealants to achieve specified maximum allowable leakage.

B. General Duct Systems: Perform leakage tests in accordance with ASHRAE and SMACNA standards.

1. Disassemble, reassemble, and seal segments of the systems as required to accommodate leakage testing, and as required for compliance with test requirements.
2. Conduct tests, in the presence of the Architect, at static pressures equal to the maximum design pressure of the system or the section being tested. If pressure classifications are not indicated, test entire system at the maximum system design pressure. Do not pressurize systems above the maximum design operating pressure. Give 7 days' advanced notice for testing. Submit a letter report to the Owner and Engineer summarizing the test procedures followed, systems tested and the results of the leakage tests.
3. Determine leakage from entire system or section of the system by relating leakage to the surface area of the test section.
4. Maximum Allowable Leakage: As described in ASHRAE 2005 Handbook, "Fundamentals" Volume, Chapter 35, Table 9 and Figure 13. Comply with requirements for leakage classification 3 for round and flat oval ducts, leakage classification 12 for rectangular ducts in pressure classifications less than and equal to 2 inches water gauge (both positive and negative pressures), and leakage classification 6 for pressure classifications greater than 2 inches water gauge and less than and equal to 10 inches water gauge.
5. Remake leaking joints as required and apply sealants to achieve specified maximum allowable leakage.
6. Leakage Test: Perform volumetric measurements and adjust air systems as described in ASHRAE 2003 "HVAC Applications" Volume, Chapter 37

and ASHRAE 2005 "Fundamentals" Volume, Chapter 14, and Division 23 Section "TESTING, ADJUSTING, AND BALANCING FOR HVAC."

C. Ductwork with Pressure Rating > 3" W.C.: Ducts and plenums shall be leak tested in accordance with SMACNA HVAC Air Duct Leakage Test Manual to prove they meet leakage classification less than or equal to 6. Submit test reports to the Engineer of Record demonstrating that at least 25 percent of the installed duct area has been tested and pass this test.

D. Grease Duct Leakage Test: All portions of grease duct systems shall be tested for leakage in accordance with Chapter 5, Section 506 of the locally adopted IMC. Leakage tests shall be by light or other equivalent test methods as approved by the local code official to verify that all joints are liquid tight. Tests shall be performed in the presence of the local code official. Any joints found defective shall be repaired and retested until satisfactory results are obtained. The contractor shall submit a copy of the grease duct leakage test report to the Architect and Engineer complete with the approval signature of the local code official.

3.03 ADJUSTING, STARTUP AND CLEANING

A. Adjust volume control devices as required by the testing and balancing procedures to achieve required air flow. Refer to Division 23 Section "TESTING, ADJUSTING, AND BALANCING FOR HVAC" for requirements and procedures for adjusting and balancing air systems.

B. Vacuum duct systems prior to final acceptance to remove dust and debris.

C. Remove temporary protection devices over ductwork prior to starting equipment and turning the system over to the owner.

D. If permanent HVAC equipment is used during the construction period, provide temporary filters at all openings in the ductwork and at inside equipment to protect the system from dust, dirt, paint, and moisture. Replace and maintain filters when needed, but not less than every month. On the day of substantial completion, clean the duct system and provide a new set of filters in the HVAC unit.

1. Refer to Division 23 Section 234100 Particulate Air Filtration for filter requirements.

3.04 CLEANING NEW SYSTEMS

A. Contractor shall clean the HVAC systems in accordance with NADCA.

B. Mark position of dampers and air-directional mechanical devices before cleaning, and perform cleaning before air balancing.

C. Use service openings, as required, for physical and mechanical entry and for inspection.

1. Create other openings to comply with duct standards.

a) Do not degrade structural, thermal or functional system integrity of the duct.
b) Provide access doors complying with UL 181 to cover new openings. Refer to Division 23 Section “Air Duct Accessories”.
c) Seal openings with tape and sealant complying with UL 181A.

2. Disconnect flexible ducts as needed for cleaning and inspection.
3. Remove and reinstall ceiling sections to gain access during the cleaning process.

D. Vent vacuuming system to the outside. Provide filtration and/or containment systems to keep debris removed from HVAC systems from contaminating other spaces. Locate exhaust down wind and away from air intakes and other points of entry into building.

E. Clean the following metal duct systems 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, and actuators except in ceiling plenums and mechanical equipment rooms.
6. Supply and outdoor 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 while the system is under negative pressure; do not permit duct liner to get wet.
5. Clean coils and coil drain pans according to ACR 2002. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.

G. Disposal: Debris collected from the HVAC system shall be disposed of in accordance with applicable federal, state and local requirements.

H. Cleanliness Verification:

1. Visually inspect metal ducts for contaminants.
2. Where contaminants are discovered, re-clean and re-inspect ducts.

END OF SECTION