SECTION 23 08 90 - AIR DISTRIBUTION

The General Conditions, any Supplementary General Conditions, and Division 1 - General Requirements are hereby made a part of this Section as fully as if repeated herein.

PART 1 - GENERAL

1.01 SCOPE

A. Furnish and install all materials, labor, equipment, and accessories for the installation of a complete system of air distribution, including supply, return, relief, exhaust, transfer, and outdoor air.

B. System shall include, but not necessarily be limited to:

1. Low-pressure sheet metal ductwork
2. Medium pressure sheet metal ductwork
3. Low-pressure aluminum ductwork
4. Low-pressure fabric ductwork
5. Flexible ducts
6. Commercial cooking and dishwasher exhaust ductwork and hood(s)
7. Round and/or flat oval ductwork
8. Ductwork insulation
9. Variable air volume boxes/terminal units
10. Airflow measuring dampers
11. Sound attenuators
12. All ductwork accessories, supports/hangers, coordination, supervision, etc.

1.02 RELATED SECTIONS

A. 23 00 10 - General Requirements for Mechanical Work

B. 23 01 00 - Basic Materials and Methods for Mechanical Work

C. 23 02 00 - Piping Systems Insulation

D. 23 07 90 - Air Coils

E. 23 08 58 - Custom Air Handling Units

F. 23 08 60 - Fans

G. 23 08 80 - Filters and Accessories

H. 23 09 51 - Controls and Instrumentation

I. 23 09 70 - Divisions 22 and 23 Testing, Adjusting, and Balancing

1.03 STANDARDS

A. At a minimum, install all duct and insulation systems in accordance with applicable SMACNA standards for fabrication and installation of duct systems. Exceed those minimum requirements where indicated by drawings or specifications.

Refer to Part 3 below for additional information pertaining to duct hangers and installation of externally wrapped duct systems.

B. Install fire and smoke dampers in accordance with SMACNA's latest editions of Fire Damper and Heat Stop Guide, U.L.'s Fire Resistance Directory, and manufacturer’s written instructions.

C. Conform to NFPA 90A - Installation of Air Conditioning and Ventilation Systems, and NFPA 90B - Installation of Warm Air Heating and Air Conditioning Systems.

D. Conform to NFPA 96 - Installation of Equipment for the Removal of Smoke and Grease-Laden Vapors from Commercial Cooking Equipment.

E. Duct Systems Sealing and Leak Testing:

1. Seal and test all duct systems: All positive and negative pressure ducts shall be sealed and pressure tested according to SMACNA HVAC Air Duct Leakage Test Manual.

a. Provide SMACNA duct sealing Class A and leakage testing Class 6 for all duct systems.

2. Seal/Test entire system: The entire system of ductwork shall be tested up to the necks of air devices, equipment connections, or similar termination points.

a. Supply systems: Medium pressure conditions shall apply up through the terminal unit assembly (e.g., terminal units including integral heating coil, or as otherwise applicable). Low-pressure conditions shall apply downstream of the terminal assembly.

b. Exhaust/return systems: Medium pressure conditions shall apply from the terminal unit where applicable and otherwise from the manual balancing device to the AHU, fan, or similar equipment connection. Low-pressure conditions shall apply upstream of the terminal assembly or manual damper, as may apply.

3. Include in the leak testing: terminal boxes, heating coils (i.e. the tube penetrations of casings), damper shaft penetrations of ductwork, access door assemblies (between frames and ducts), duct taps and runouts, flexible duct connections,

instrumentation taps, safing/closure "donuts" between inner/outer liners of double wall duct (typically at connections to single wall duct), and at other fittings and appurtenances.

4. Schedule reviews/inspections: The contractor shall inform the project inspector/commissioning authority when the joints may be visually inspected for voids, splits, or improper sealing of the joints.

5. Make corrections as needed: Contractor shall effect remedial work for any system or segment thereof which does not achieve the specified leakage limitations, and shall then retest. This procedure shall occur as many iterations as is necessary to achieve compliance.

6. Submit leakage test results; include as found conditions, and after any corrections have been made.

7. Spot checks/verifications: Spot testing to verify performance shall be performed in random sections of duct as selected by the Architect/Engineer or the Commissioning Authority. Approximately 25% will be verified, subject to all tests demonstrating acceptable performance.

1.04 SUBMITTALS

A. **General: Provide submittals for all products specified herein, including:**

1. factory ductwork, flexible ducts, ,

2. fabric ductwork, including size and placement of dispersion units, performance data for each fabric system including airflow rate, design static pressure, inlet velocity, and isothermal throw.

3. terminal units, airflow measuring dampers,

4. fire dampers, smoke dampers, fire/smoke dampers, fire/smoke/control dampers each as indicated by the drawings

5. insulations, mastics, sealants

6. duct sealing materials,

7. air devices, taps to trunk/branch ducts

8. sound attenuators,

9. all duct accessories/appurtenances, including duct thermometers, duct access doors, remote/concealed damper operators,

10. other products occasioned by the project/specifications or requested by the Architect/Engineer

11. detailed installation requirements of each (including approved UL details for fire and fire/smoke dampers).

B. **Terminal units table summary: Terminal unit (including airflow measuring dampers) submittals shall be** an AHU by AHU tabular presentation with each box in the project included (not just box "mark"). As applicable, the tabulation shall include: unique tag number; type (mark); maximum rated CFM; minimum recommended CFM; design CFM setpoint; minimum CFM setpoint; inlet size; pressure drop at maximum rated CFM; NC level at maximum rated CFM and at minimum recommended CFM when operating with an inlet static of 1.5” w.c.; rows heating coil and gpm and resultant MBH; 2-way or 3-way valve.

C. **Mock-ups**

1. Provide field mock-up of example terminal units, including ducting/equipment connections; sealing/insulation assembly for coils, u-bends, etc.; piping connections and supply/return piping up to isolation valving; piping system insulation.

2. Provide example fabrication per field mock-up/installation of zone guillotine damper and control damper assembly. Obtain Architect/Engineer's acceptance prior to fabricating additional assemblies.

3. Provide additional mockups as indicated by the drawings.

D. **Submit specification copy mark-ups as required by Section 23 00 10.**

PART 2 - PRODUCTS

2.01 DUCTWORK AND INSULATION - GENERAL

A. Low Pressure

1. For purposes of this specification, low-pressure ductwork classification shall be for the following service: up to 2.0-inch water column (positive or negative) static pressure and less than 2,000 feet per minute velocity.

2. The following ductwork shall be considered low pressure:

a. Supply ductwork downstream of terminal units,

b. return duct runouts serving individual or pairs of grilles,

c. exhaust ductwork systems:

1) upstream of exhaust pressure control dampers

d. transfer air ductwork

3. Ductwork for low-pressure duct systems shall be:

a. Galvanized sheet metal

1) Supply duct systems

2) Return duct systems

3) General building exhaust systems

b. Aluminum where so indicated

B. Medium Pressure

1. For the purpose of this specification, medium pressure ductwork classification shall be constructed for the following service: up to 6.0-inch water column positive, 6.0-inch water column negative static pressure, or greater than 2,000 feet per minute velocity.

2. The following ductwork shall be considered medium pressure:

a. All supply ductwork systems upstream of terminal units (through the heating coils where applicable) where the maximum duct pressure does not exceed 6.0-inches water column,

b. Return air trunk and branch duct systems where the maximum duct pressure does not exceed 6.0-inches water column negative,

c. Exhaust ductwork systems:

1) Downstream of exhaust pressure control dampers

d. All relief and outside air ductwork.

e. Plenums and casings over 36" in any dimension in otherwise low-pressure service.

3. Ductwork for medium pressure environmental air duct systems shall be:

a. Galvanized sheet metal

1) Supply duct systems

2) Return duct systems

3) General building exhaust systems

b. Aluminum where so indicated

C. Special duct service:

1. Flexible ducts may be used for branch take-offs to supply air devices and at other locations shown on the drawings.

2. Ductwork for kitchen hood exhaust system shall be welded black steel, minimum thickness 16-gauge or stainless steel as indicated in the appropriate subsection below. Provide with two-hour fire/smoke blanket approved by the building official.

3. Ductwork for dishwasher exhaust shall be 316 stainless steel.

D. Insulation

1. For interior sheet metal duct:

    a. external duct insulation

    b. internal thermal/acoustical liner (rectangular supply/return duct, only where specifically allowed per drawings and these specifications)

2. For exterior sheet metal duct:

    a. high-density fiberglass insulation system

    b. phenolic foam board insulation system

    c. flexible elastomeric sheet insulation system

    d. internal thermal/acoustical liner

3. Refer also to duct insulation specifications of this air distribution section.

E. Refer also to following subsections for complete specification.

F. Dimensions for ductwork as shown on drawings are clear inside dimensions. Adjust fabrication dimensions as needed to accommodate lined duct or ductboard where allowed.

2.02 SHEET METAL DUCTWORK (LOW AND MEDIUM PRESSURE)

A. Low and medium-pressure sheet metal ductwork:

1. Factory fabricate in accordance with the materials, service, and pressures and velocities presented in 2.01 above. Minimum thickness shall be 26-gauge.

    a. Approved Manufacturers of factory fabricated ducts: United Sheet Metal, Spiral Pipe of Texas, Semco, Lindab, Sheet Metal Products Co., or equal accepted by Architect/Engineer.

2. Shop Fabricated Rectangular Ducts - Single wall: Construct of materials presented in 2.01 above in accordance with the recommended construction for the duct pressures and velocities encountered. Gauges of metal, bracing of joints, joint construction, internal and external intermediate bracing and installation shall be according to the 2008 ASHRAE HVAC System and Equipment Handbook, Chapter 18, and the latest edition of SMACNA HVAC Duct Construction Standards - Metal and Flexible. Minimum thickness shall be 26-gauge.

Refer to Part 3 below for additional requirements pertaining to duct hangers and installation of external duct insulation.

B. Duct Sealing

1. Single wall: Seal all transverse and longitudinal joints/seams in all rectangular, single wall round/flat oval, and double wall round/flat oval (outer wall) ductwork via “hardcasting” with indoor/outdoor adhesive (indoor only adhesive not acceptable):

a. Carlisle Two Part II sealing system with RTA-50 sealant and DT5300/5400 mineral impregnated tape, conforming to LEED requirements.

b. Where brush-on sealant is accepted as a substitution or voluntary alternate (only), it shall thoroughly and completely be worked into the duct joint. Skim coats or thick coats merely brushed over the surface shall not be acceptable and shall be cause for overcoating of hardcast at the Architect/Engineer's directive. Note: brush on sealants shall not be permitted for ductwork exposed in finished/occupied areas.

2. Double wall: Seal all transverse joints in double wall round ductwork at the inner and outer walls when solid inner walls are used, and at all flanged/TDC or similar joints. (Solid inner walls shall serve as primary air/moisture barrier.)

a. Inner wall: Carlisle Iron Grip 601, water-based indoor/outdoor duct sealant.

b. Outer wall: per 'B.1' above

3. Painting under this Section:

a. All duct sealant applied outside: epoxy based paint matching/simulating adjacent duct surface color,

b. Duct sealant applied inside in finished areas: Latex based paint matching adjacent duct surfaces, to be used as a primer/substrate for finishes applied by other Divisions/trades. Coordinate materials and applications with Architectural and Division 9 trades.

4. For projects subject to LEED or Green Building Program requirements (refer to Section 23 00 10), sealants, mastics, glass, and tapes shall comply with South Coast Air Quality Management District (SCAQMD) Rule #1168 standards for Volatile Organic Compounds (VOC's) emission of 250 gm per liter.

2.03 FABRIC DUCTWORK

A. General

1. Section includes continuous, tubular, fabric air-distribution devices.

2. Continuous tubular diffuser materials shall be listed and labeled as complying with [**UL 2518**] [**UL 723**] [**NFPA 90A**] [**NFPA 90B**

B. Basis of Design: FabricAir Combi 80 SonicFlow with Type 8 All in One Hanger System

1. Other Acceptable Manufacturers:

a. DuctSox with SkeleCore FTS

b. K.E. Fibertec

C. Description

1. Fabric: 100% Flame Retardant Polyester, factory treated with an EPA approved antimicrobial agent

2. Shape: Round

3. Base Permeability: 2 cfm/sf at 0.5” WG per ASTM D737, verified by the Frazier Permeability Test

4. Air-Outlet Configuration: refer to drawings.

5. Color: White

D. System Fabrication Requirements

1. The system is made with sewn in, but still removable, aluminum hoops. The rods support the shape of the fabric system by 180° (8”-48”), 120° (49”-60”), 90° (61”-68”) and 60° (69”-80”). Hoops must be pre-installed from factory, no installation at sight. Diameter of hoops and distance between as specified by manufacturer.

2. Air dispersion shall be accomplished with linear or polar arrays of laser cut orifices. Size of laser cut orifices shall be from 0.12" to 0.55" diameter. Due to exact throw requirements and NC requirements alternative flow models are not acceptable.

3. Number, spacing, and size of linear arrays of laser cut orifices shall be determined by the manufacturer.

4. Fabric system shall include connectors to attach to suspension system listed below.

5. Provide system in sections optimized for maintenance, connected by zippers. Zippers shall provide closure completely around the circumference to prevent leakage. Required number of zippers shall be specified by the manufacturer.

6. Each section to have a unique tag including information about manufacturers order number, position, diameter of section, length of section, maintenance instruction, code compliance and contact details for spare parts.

E. Hangers and Supports:

1. Type 8: One row H-rail/cable system located 2" above 12 o'clock of FabricAir® system. Hardware to include H-rail joint, eye bolt, end cap H-rail, cable, tie down strap and H-rail as required. FabricAir® system shall be attached to hardware using one single row of plastic sliders located 12 o'clock spaced 20 inches.

2. Hardware: Anodized Aluminum H-Rails - With PVC coated Galvanized Steel suspension cable. Suspension cable clamps, H-rail suspension eyebolts, and all other factory supplied metal components shall be Galvanized Steel.

F. Installation

1. Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop.

G. Warranty: Manufacturer shall provide a 10-year warranty.

H. Cleaning:

1. Clean air handling unit and other ductwork prior to the FabricAir® system as it is installed. Ensure that all construction debris, including dust, is removed from the air handling unit and other ductwork before connecting the FabricAir® system.

2. If the FabricAir® system becomes soiled during the installation, it should be removed and cleaned following the manufacturers cleaning instructions.

2.04 ROUND AND/OR FLAT OVAL DUCTWORK

A. General

1. Construct of spiral lockseam helical joint (without standing rib).

2. Dimensions: Dimensions for round and/or flat oval ductwork as shown on the drawings are interior dimensions. In coordinating clearances, installation, etc. include allowances for internal lining and inner/outer walls.

B. Single wall: Round and/or flat oval spiral wound single wall ductwork shall be constructed of materials and for classifications/services as noted in 2.01 above.

C. Double wall: Round and/or flat oval spiral wound double wall ductwork shall be constructed of materials and for classifications/service as noted below. Exception: external wall shall be constructed as high pressure (for dent resistance).

1. At a minimum, inner wall shall be constructed in accordance with the recommended construction for medium duct pressure. Inner wall shall be:

a. Solid in the following services:

1) supply duct systems in exposed areas

b. Perforated in the following services:

1) return ducts where indicated by drawings.

2. Entire system of round double wall duct and fittings shall be provided by a single manufacturer.

3. Interior duct shall have factory installed insulation between inner wall and outer wall. Insulation shall have a K-Factor not exceeding 0.27 BTUH-IN/(hr-ft^2-F). Where manufacturers use “blanket” (duct wrap) insulation systems, said insulation shall comply with this Section. In addition, said insulation shall be a minimum of 50% thicker than finished insulation thickness, the finished insulation thickness being achieved by compression of the insulation during the duct manufacturing process (e.g., 2” finished thickness achieved by compressing 3” insulation between inner and outer walls). Finished insulation thickness shall be:

a. Interior duct: 2”

b. Exterior duct: 3”

4. Fittings/Drops/taps shall be of sizes as shown on the plans and, where installed in the finished areas, shall be factory installed and continuously welded to duct trunk or branch lines. Insulation and inner wall shall be continuous from interior of duct through fitting/drop/tap.

D. Jointing and sealing: single wall

1. Joints shall be by use of a coupling with a tapered wedge effect as the duct nears the bead stop. A generous bead of duct sealer shall be placed at both the inner liner and outer wall around the edges of the coupler and duct about 1/2" from the end. Upon insertion of the coupler, the duct will be fully sealed without affecting the exterior visual appearance.

a. Additional externally field-applied sealant shall not be required of these coupling style joints where installed in strict accordance with this specification and with manufacturer’s written instructions, provided duct leakage tests satisfy the specified requirement.

2. Alternatively, factory system of self-sealing ducts/fittings incorporating two double lipped U profile EPDM gaskets per joint may be used (Lindab “Spirosafe”).

a. Field-applied sealant shall not be required of this system where installed in strict accordance with manufacturer’s written instructions, provided duct leakage tests satisfy the specified requirement.

3. Refer also to sealing requirements in 2.02 above.

E. Jointing and Sealing: double wall

1. Provide factory system of flange style connectors “T-24” or equal.

a. Connectors shall be sealed at inner and outer walls for ducts with solid inner wall.

b. For supply ducts, provide field applied 1” thick engineered polymer insulation of joints to prevent through metal penetration and protect against condensation.

c. Prime and paint field applied insulation to match finished duct appearance.

2. Note: For solid interior walls, it is imperative that a full and complete seal of both the inner and outer walls be provided as part of the installation.

F. Exposed Ductwork in finished areas:

1. Duct shall have a phosphatized mill surface etch treatment or other suitable factory preparation acceptable to Architect/Engineer to create a paintable surface without field preparation. After installation, galvanized ductwork shall be primed using galvanized primer (Glidden #5229 or as selected by Architect/Engineer) and then painted with durable top coat compatible with duct sealant materials, product and color as selected by the Architect/Engineer.

2. Division 9 coordination: All finish painting/coating of round/flat oval ductwork and accessories (galvanized, aluminum, and/or others that apply) indicated to be painted in this Section are to be painted under Division 9. **Coordinate proposal, submittals, and execution with Division 9.**

G. All ductwork and fittings shall be stored, handled, shipped, and installed/supported as a decorative grade job to avoid water or dirt exposure, dents, dings, and to minimize scratches. Failure to comply shall be cause for extensive cleaning or rejection.

H. Provide complete factory ductwork system with all fittings, appurtenances, balancing devices, control devices, (dampers, blast gates where shown, etc.), etc. as required by the drawings and appropriate for field conditions.

I. Round and flat oval exposed duct hangers

1. Uninsulated ducts:

a. Single point with not less than 1" wide band completely circumscribing duct and minimum of 3/8" rod from top center line. All hangers, fasteners, escutcheons, etc. shall be painted to match ductwork. Increase band/strap width and hanger rod diameter as required to comply with drawing details and/or weights of duct.

b. If duct sizes or field conditions require duct supported from the bottom, install with saddles and other features as required to prevent dents at the bottom/support points. Use angle rings or other accessories as required to achieve compliance.

2. Insulated ducts: Refer to Drawings for intended insulation to maintain uninterrupted insulation and vapor barriers at hanger locations.

J. Approved Manufacturers:

1. Bases of Design

a. United Sheetmetal (K-27)

b. Equal products by Spiral Pipe of Texas, Semco, and Gowco.

c. Lindab “Spirosafe” self-sealing round ductwork system.

2.05 FLEXIBLE DUCTS

A. Inside dimensions shown: Dimensions shown on the drawings for flexible duct are nominal inside dimensions.

B. Length limitation: Unless specifically illustrated in the drawings, flexible duct runs shall not exceed eight (8) feet in length. Provide sheet metal duct extensions as required to comply with this directive.

C. Flexible air duct: UL listed 181 Class I pre-insulated duct. Duct shall conform to NFPA 90A and 90B. Installation shall conform to the Air Diffusion Council Manual “Flexible Duct

Performance and Installation Standards." Pressure ratings and approved manufacturers shall be as follows:

1. Low-Pressure Duct Systems:

   a. 10-inches water column (in. w.c.) positive pressure for all sizes; 5.0 in. w.c. negative pressure through 16" dia.; 1.0 in. w.c. negative pressure for 18" and 20" dia.; jacket permeance rating of 0.05 perms or less; minimum R-value of 8.0. Basis of Design: Flexmaster Type 1M (black interior liner).

   b. This flex duct type shall be allowed only downstream of all terminal (VAV, mixing) boxes and at return air device connections to return air duct where indicated on drawings.

2. Medium and High-Pressure Duct Systems Upstream of Terminal Boxes:

   a. 20-inches water column (in. w.c.) positive pressure for all sizes; 10 in. w.c. negative pressure through 12" dia.; 5 in. w.c. negative pressure for 14" and 16" dia.; 1 in. w.c. negative pressure for 18" and 20" dia.; jacket perm rating of 0.05 or less; minimum R-value of 8.0. Basis of Design: Flexmaster Type 3M.

   b. 12 in. w.c. positive pressure for all sizes; 12 in. w.c. negative pressure for all sizes; jacket perm rating of 0.05 or less; minimum R-value of 8.0. Basis of Design: Flexmaster SS-I-TL.

   c. These flex types shall be used upstream of all supply terminal units (downstream of all return terminal units or control dampers). Maximum lengths of two feet and used for minor misalignments only, at terminal unit supply.

   d. NOTE: Substitute medium or high-pressure flexible ducts which have any "similarities" in liner appearance or construction to low-pressure flexible ducts shall not be allowed.

3. Exhaust Systems: Flexible ducts shall not be allowed on exhaust systems unless and where: specifically shown on drawings; or where required by field conditions, with written acceptance of the Architect/Engineer.

   a. If used, flexible ducts for exhaust systems shall be

      1) As specified in C.2 above for medium and high-pressure options

      2) Or: rated for (-) 12" negative pressure thru 16" and for (-) 4" negative pressure for sizes 18" and 20". Insulate with min. R-6 wherever run in unconditioned or semi-conditioned spaces. Insulation may be omitted if run in completely conditioned spaces. Basis of Design: Flexmaster TL-M (insulated) or NI-TL (non-insulated).

2.06 BRANCH TAP CONNECTORS

A. Connectors/take-offs: Branch tap connectors and flexible duct take-offs shall be made with flanged connections/joints to trunk duct, fully sealed as specified, and with elevated manual volume dampers with standoffs and heavy duty adjustable quadrants.

1. Take-offs from Rectangular Duct: Provide low loss tee (lateral), similar or equal to Flexmaster LDS, or rectangular to round 45° connectors, similar or equal to Flexmaster STO45, for all branch taps except those to individual air devices.

a. Except where indicated in drawings, branch taps to individual air devices may be round with conical or 45° connections.

2. Take-offs from single-wall Round Duct: Provide low loss saddle taps, similar or equal to Flexmaster STO ST 90°, or round 45° connectors, similar or equal to Flexmaster STO ST 45°.

3. Spin-in substitutions: Spin-in connectors may be allowed as a substitution in low-pressure ducts only under prior acceptance by Architect/Engineer, and provided they are securely installed and thoroughly sealed to create a strong, airtight connection meeting leak testing specified. **Submit mock-up (field preparation acceptable) showing installation, sealing, and insulation.**

a. At each flexible duct branch take-off from rectangular duct to air devices: spin-in connector with elevated integral balancing damper; similar and equal to:

1) Rainier 84 MTD or Flexmaster FLD for sheet metal ducts

2) Rainier DBTD or Flexmaster DBD for fibrous glass ducts.

b. At each take-off to VAV boxes, mixing boxes, or similar terminal devices, conical bellmouth connector similar and equal to:

1) Sheet Metal Ducts: Rainier No. 84MT, Style A, or Flexmaster SOG

2) Fibrous Glass Ducts: Rainier No. 84DBT, Style A

3) Provide above spin-ins with integral elevated dampers where VAV boxes, mixing boxes, etc. are pressure dependent and where mixing boxes are used in constant volume systems.

4. Carefully cut duct so as to yield no gaps between trunk/branch duct and connectors, and effectively and thoroughly seal all such taps/connections.

B. Blade orientation: NOTE: All taps shall be provided/installed so that the integral damper blade(s) when in the open position is parallel to the flow direction in the trunk duct.

1. Exception: if otherwise required due to field conditions or use of remote damper operators.

2.07 COMMERCIAL COOKING EXHAUST DUCTWORK & HOOD

A. Ducts and plenums serving a kitchen hood for collecting and removing grease and smoke shall be double wall factory fabricated constructed of not less than 0.035-inch type 304

stainless steel inner wall and 0.025-inch aluminized steel. Ducts are to be rated for zero-inch (0") clearance to combustibles. Grease duct system to be a complete installed system with all components required for fully functioning grease duct system including but not limited to anchors, supports, guides, adjustable length sections (for assembly and expansion compensation), cleanouts, elbows transitions, through penetration firestops, etc.

1. Acceptable Manufacturers:

   a. Basis of Design: Selkirk Metalbestos 'zero clearance – Z3'

   b. Duravent DIS3Z

   c. Ampco Z3

Submit plan and section shop drawings detailing the proposed assembly and obtain approval of the local authority having jurisdiction prior to fabrication/installation.

B. Joints and seams shall be made with a continuous liquid-tight weld or braze made on the external surface of the duct system. Any vibration isolation connector used shall consist of noncombustible packing in a metal sleeve joint of approved design.

C. Joints and seams shall be constructed in accordance with the manufacturer's requirements to maintain UL listing. Any vibration isolation connector used shall consist of noncombustible packing in a metal sleeve joint of design approved by duct manufacturer.

D. Duct bracing and supports shall be of noncombustible material securely attached to the structure and designed to carry gravity and lateral loads within the stress limitations of the Building Code. Bolts, screws, rivets and other mechanical fasteners shall not penetrate duct walls.

C. Duct bracing and supports shall be installed in accordance with the grease duct manufacturers requirements, and be of noncombustible material securely attached to the structure and designed to carry gravity and lateral loads within the stress limitations of the Building Code. Bolts, screws, rivets and other mechanical fasteners shall not penetrate duct walls.

D. Prevention of Grease Accumulation: Duct systems serving a kitchen hood for collecting and removing grease and smoke shall be so constructed and installed that grease cannot become pocketed in any portion thereof, and the system shall slope not less than 1 inch per linear foot toward the hood or toward an approved grease reservoir.

   1. When a centrifugal fan is used it shall be positioned so the discharge outlet is in a bottom horizontal position and the air shall be so diverted that there will be no impingement on the roof, other equipment or parts of the structure.

E. Air Velocity: Duct systems serving a Type I hood shall be designed and installed in a manner to provide an air velocity within the duct system of not less than 500 feet per minute (at minimum airflow condition) and not to exceed 2,500 feet per minute.

F. Kitchen Exhaust Hood

1. Provide cooking equipment hood of size, quantity and air volume as indicated on plans. Hood shall be of the full caption, backshelf type. The bottom of the hood shall be installed to have a minimum clearance of 6'-8" above finished floor (7'-0" where ceiling height allows). Make-up air to be provided through transfer air from the space (no make-up at hood).

    a. Exception: Chick fil A hoods provided with Capture Jet Air to be mounted with the front face of the hood at 5’-4” above finished floor.

2. Hood shall be constructed with 18-gauge, type 304 stainless steel interior liner and with 18-gauge, type 304 stainless steel exterior panels. The assembly at joints and seams on the hood shall be liquid tight. The exposed external welds shall be ground down, smoothed and highly polished. Internal construction shall include galvanized structural steel framing member as required to prevent flexing and fatigue of the inner liner and outer shell. All unexposed interior surfaces shall be constructed of minimum 18-gauge galvanized steel including, but not limited to: duct, plenums, framings, and brackets.

3. The hood shall include a filter housing constructed of same material as the interior liner and be complete with U.L. classified stainless steel grease filters of sufficient numbers and sizes to ensure optimum performance as specified by the filter manufacturer. The filter housing shall terminate into an internally pitched full-length grease trough which shall drain into a removable recessed grease drawer.

4. Vapor proof, U.L. listed, marine light fixtures shall be installed at no less than 3-foot centers. The lights shall be pre-wired to a junction box situated at the top of the hood for field connection to power. The wiring shall conform to the requirements of the National Electrical Code.

5. A control panel shall be flush-mounted on the front face of the canopy. This panel shall include one or more on/off toggle-type switches for the control of hood lights and fans. There shall be an indicator lamp located next to each fan and heater control switch for positive function status identification.

    a. For variable volume hoods provided with DCV, a separate, remote mounted control panel shall be provided and located according to the plans.

6. The hood shall be fabricated in accordance with N.F.P.A. Bulletin #96 and shall bear the National Sanitation Foundation Seal of Approval (NSF). Hood shall be U.L. listed or classified as required.

7. All sequences and setpoints for the hood ventilation control system are to be field coordinated/adjusted by ventilation control system manufacturer with the Owner present. Setpoints will be determined based on current cooking operations and are subject to change if/as cooking operations change.

8. Provide BAS interface via hood control system manufacturer gateway, with all status, points, and alarms communicated with BAS. Coordinate with controls contractor for connection and communication of system.

9. Refer to plans and controls drawings/sequences for additional system requirements.

10. Acceptable manufacturers:

    a. Halton

    b. Gaylord

11. The kitchen hood manufacturer shall be responsible for approved fire suppression system for the kitchen hood, Ansul R-102 or approved equal.

    a. The hood fire suppression system shall be the pre-engineered, liquid agent, cartridge-operated type with a fixed nozzle agent distribution network. It shall be listed with Underwriters Laboratories, Inc. (UL).

    b. The system shall be capable of automatic detection via fusible link detection system and actuation with local (pushbutton on the release mechanism) or remote manual actuation by a mechanical pull station. Accessories shall be provided for gas line shut-off applications.

    c. Provide remote manual pull station as for manual actuation of suppression system. Pull station shall be of the break rod type and shall be connected to the release mechanism trip lever by means of 1/16” diameter stainless steel rope and ½” conduit.

    d. Provide UL listed gas line shut off valve. Valve shall be mechanical type, adapted to the release mechanism cartridge receiver by means of a pneumatic piston type air cylinder. Valve shall have resilient seating with aluminum body and stainless steel internal parts.

    e. The system shall have fire suppression capabilities for the following kitchen hazard areas as applicable: ventilating structures including hoods, ducts, plenums, filters, fryers, griddles, range tops, broilers, charbroilers, and ovens.

    f. A system owner's manual shall be provided containing basic information pertaining to system operation. A detailed technical manual shall be supplied including system description, design, installation, recharge, and maintenance procedures, plus accessory installation and reset instructions.

2.08 ALUMINUM DUCTWORK (LOW PRESSURE)

A. Dimensions for aluminum ductwork as shown on drawings are sheet metal dimensions.

B. Aluminum ductwork shall be constructed of alloy 3003-H14 sheets in accordance with the recommended construction for the duct pressures and velocities encountered. Thickness of aluminum, bracing of joints, joint construction, and installation shall be according to the 1985 SMACNA HVAC Duct Construction Standards - Metal and Flexible. Minimum thickness shall be 0.040 inches.

C. Construction and installation for low-pressure ducts shall be in accordance with the pressures and velocities presented in 2.01 above.

D. Seal all transverse and longitudinal seams. Refer to 2.02 above.

E. All construction and support materials (i.e. screws, bracing, angles, bars, tie rods, hangers, etc.) shall be of aluminum construction.

2.09 DUCTWORK AND EQUIPMENT INSULATION

A. General:

1. Scope:

a. Insulate all supply air and outdoor air ductwork as specified herein.

b. Insulate return, exhaust, and relief ductwork systems where indicated on the drawings or specified herein.

c. Insulate all uninsulated equipment (terminal boxes, fans, dampers, hoods, etc.) as specified or as otherwise required to control condensation and/or noise.

2. Qualifications: Work shall be performed by a qualified contractor or subcontractor regularly engaged in the insulation field, and having a minimum of ten years' experience in insulation systems as indicated herein.

3. LEED: For LEED or Green Building Program projects, all mastics, sealants, etc. used inside the building must meet the standards of South Coast Air Quality Management Division for volatile organic compounds (VOC) emission of and insulation products must be formaldehyde-free. **Submit documentation demonstrating compliance.**

4. Complete system: Finished insulation system shall provide complete thermal barrier throughout the equipment and air distribution system, including effective and durable vapor barriers and vapor stops for any system or condition potentially subject to condensation.

a. Vapor barriers and vapor stops: Insulation system shall be provided to prevent condensation or potential thereof, to prevent transmission of water vapor into the insulation system (vapor barriers), and to prevent transmission of water vapor within the insulation system should vapor barrier compromises occur during operation/maintenance of the building (vapor stops).

B. Internal Thermal / Acoustical Duct Liner Insulation: Internally insulated/ acoustically lined ductwork shall be allowed only where indicated by the drawings, and only for rectangular ductwork and plenums. Where required, it shall be provided as follows:

1. Acceptable Manufacturers

a. Basis of Design: Certainteed "ToughGard T" Textile Duct Liner Type 300

b. Other acceptable manufacturers: Johns Manville and Owens Corning.

2. Unless otherwise indicated on drawings, nominal thickness shall be 1". Provide other thicknesses if/as indicated on plans. At a minimum, duct liners shall meet the following characteristics.

THERMAL PERFORMANCE			
Nominal thickness	**K-Value**	**C-Value**	**R-Value**
in.	**$\frac{Btu*in}{h*ft.^2*°F}$**	**$\frac{Btu}{h*ft.^2*°F}$**	**$\frac{h*ft.^2*°F}{Btu}$**
½	0.24	0.48	2.1
1		0.23	4.4
1 ½		0.16	6.3
2		0.12	8.3

ACOUSTICAL PERFORMANCE							
Nominal thickness	**Sound Absorption Coefficients @ Octave Frequencies (Hz)**						**NRC**
in.	**125**	**250**	**500**	**1000**	**2000**	**4000**	
½	0.06	0.15	0.33	0.56	0.76	0.91	0.45
1	0.10	0.33	0.65	0.86	0.94	0.96	0.70
1 ½	0.20	0.46	0.82	0.94	0.95	0.91	0.80
2	0.27	0.72	1.04	1.02	0.96	0.92	0.95

3. The airstream surface shall contain an EPA registered anti-microbial agent to reduce the potential for microbial growth.

4. Product shall have factory applied edge coating to assure sealing of transverse edges per SMACNA and NAIMA installation standards. All exposed edges shall be sealed/coated. Provide metal nosing where recommended by the manufacturer.

    a. Installation shall be in accordance with manufacturer's recommendations for velocities up to 6,000 FPM, regardless of actual duct velocity.

5. In addition, wrap any lined supply ducts with external insulation as specified below.

6. Keep ductwork sealed and the liner protected and clean throughout the construction/installation process.

7. Coat liners in supply duct systems with Foster 40-30 (black) anti-microbial coating in strict compliance with manufacturers written instructions.

C. External Thermal / Acoustical Insulation

1. Concealed Ductwork inside envelope of building, including round and rectangular sheet metal ductwork serving:

    a. Outside Air; Supply Air; Return Air (where not indicated to be lined above);

    b. Ductwrap insulation shall be foil faced 2-inch thick duct wrap, 1.0 lb/cu.ft. density, K factor 0.26 BTUH-in/(hr-sq.ft.-F) or less. Basis of Design:

CertainTeed “soft touch” duct wrap with Foil-Skrim-Kraft composite vapor barrier.

c. Secure joints with outward clenching staples at 6” O.C. max. Seal all joints and seams using glass fabric embedded in generous coat of mastic (Childers CP-30 low odor, white, vapor barrier mastic, or equal), with a second coat of mastic applied after embedment and curing of first coat.

1) Alternative to glass fabric/mastic sealing: Where acceptable to Owner, after stapling, tape joints with Venture Clad 1525 CW FSK tape (UL 723 listed), only after cleaning and drying surfaces.

2) Note: Provide inserts at all hanger/support locations between the hanger and ductwork.

3) Insert materials:

a) Where generous (adequate) space occurs for installation of duct and other above ceiling systems, insert shall be 2” thick x min. 12” length x duct width, Owens Corning “Pipe and Tank” vertical fiber fiberglass insulation with compressive strength at 10% deformation no less than 125 lb/ft^2, with FSK jacket.

b) At Contractor’s option, insert may be: 6.0 pcf fiberglass insulation board with FSK jacket; triple layers of specified duct wrap where concealed and not subject to tight/limited clearances; or in lieu of inserts, install 1” Armaflex SS or Imcolock (slit-tube) over the duct hanger. (Refer also to drawings.)

3) Refer also to Part 3 and to drawings.

d. For hard (sheet metal) round duct branches/takeoffs to air devices and for hard (sheet metal) round ducts upstream of terminal units, provide insulation via:

1) manufactured insulation sleeve with metalized outer jacket having permeance rating of 0.05 perms or less; minimum R-value of 8.0; Basis of Design: Flexmaster Thermosleeve Type TSM.

2) or duct wrap as specified above.

e. For ducts with flange style or standing seams/joints, or angle iron stiffeners exceeding 1" outside of the duct surface, provide 1” thick fiberglass board 6" wide on both sides of protrusion to prevent loss of thermal insulation value due to compression of insulation.

f. For inordinately restricted space field conditions where above insulation approach does not accomplish thorough and complete vapor barriers and vapor stops as specified, one of the following alternates shall be used.

1) Insulation board/Venture Clad: Apply 1" thick, K factor not exceeding 0.23 BTUH-in/(hr-sq. ft-F), 3 pcf fiberglass insulation board (FSK) lengthwise with ducts such that the number of insulation joints is minimized (but with joints no longer than 12' intervals). Adhere to duct at appropriate intervals to secure in place. Vapor stop at 12' intervals and vapor seal at each joint using Venture Clad 1577CW, overlapping each joint/seam minimum of 6". Where conditions allow return to more standard insulation approaches (e.g., at sides and bottom of duct with restricted space above top of duct), vapor seal joints of lengthwise wrap or board to the traverse wrap or board using Venture Clad 1577CW, minimum 6" wide for 3" overlap on both sides of joint/seam.

2) Imcosheet/Venture Clad: Apply minimum 1" Imcosheet lengthwise with ducts similar to description in "1)" above. Extend minimum of 3" beyond duct corners (both sides), miter cut, and fold over to adjoining sides of duct, sealing to adjoining sides with 100% adhesive coverage. Where return to duct wrap or similar insulation, join and vapor seal with Venture Clad 1577CW or Venture Tape 1577CW, minimum 6" wide for 3" overlap on both sides.

3) Other techniques and materials as recommended/proposed by the Contractor and acceptable to the Architect/Engineer.

g. See below for insulation of ductwork within mechanical rooms.

h. Thermal breaks: Install insulation before conduit, controls, electrical devices, duct smoke detectors, etc. are installed so that no such elements are enclosed by the insulation (or coordinate to provide "stand-offs" for conduit, etc. to accomplish same). Coordinate with other trades as required.

i. Reference Part 3 for **important** installation requirements.

2. Exposed Rectangular Ductwork:

a. Exposed in finished areas: Insulation board for supply sheet metal ductwork: shall be 2" thick, 3-pound density, fiberglass insulation board with white all service composite vapor barrier jacket, K factor not exceeding 0.23 BTU-in/hr-ft^2-°F at 75°F. Basis of Design: CertainTeed "CB300" board.

1) Provide matching glass fabric to finish off and seal joints with Childer Chil-Perm CP-30 Low Odor (white) indoors (Chil Perm WB CP-35 for LEED or Green Building Program projects).

2) Provide vapor barrier and vapor stop conditions through all systems potentially subject to condensation.

3) Paint with one coat suitable primer and one coat suitable enamel (exterior grade for exterior exposed duct) to match adjacent finishes as directed by/selected by Architect/Engineer.

3. Exposed Round Ductwork:

a. Insulation wrap for round ductwork and round or rectangular transitions shall be minimum 2" thick, 25-pound density, fiberglass insulation with white all service composite vapor barrier jacket, K factor not exceeding 0.24 BTU-in/hr-ft^2-°F at 75°F. Basis of Design: Certainteed "Crimp Wrap," or equal approved by Architect/Engineer.

1) Apply with 100 percent adhesive coverage and bands 24 inches on center.

2) Cover joints/seams/edges with glass fabric and two coats Chil Perm CP-30 Low Odor mastic (white) (Chil Perm WB CP-35 for LEED or Green Building Program projects).

3) Provide vapor barriered and vapor stopped conditions through all systems subject to condensation.

4) Paint with one coat suitable primer and one coat suitable exterior enamel to match adjacent finishes as directed by/selected by Architect/Engineer.

b. Alternatively, 1/2" thick Armaflex AP sheet applied with 100% adhesive coverage.

1) Miter or square cut joints, avoiding close radius bends of insulation.

2) Provide two coats of Armaflex finish and two coats suitable finish enamel to match adjacent finishes as directed by/selected by Architect/Engineer. (Verify color with Architect/Engineer prior to painting.)

4. Insulation for Exterior Sheet Metal Ductwork and for Blank-Off Plates/Safing at Louvers

a. Blank-offs/Louvers: insulation shall be minimum 2-inch thick "FoamGlas" insulation board, K factor 0.31 BTUH-in/(hr-sq. ft.-F) or less, with FSK jacket. Basis of Design: "Foamglas" insulation board.

1) Apply with 100 percent adhesive coverage and pins 24 inches on center.

2) Cover joints/seams/edges with glass fabric, and two coats of Pittseal 444N or 727 or equal joint sealant/mastic. Must meet 25/50 flame spread/smoke developed ratings.

3) Skim coat with manufacturer's float: Paint with one coat suitable primer and one coat suitable exterior enamel. Colors to be as selected by/directed by Architect/Engineer.

b. Insulation for rectangular ductwork, round ductwork, and round or rectangular transitions: minimum 2 inches thick, and 2.5-pound density fiberglass insulation with FSK jacket. Basis of Design: Certainteed "Crimp Wrap," or equal approved by Architect/Engineer.

1) Apply with 100 percent adhesive coverage and bands or pins 24 inches on center.

2) Cover joints/seams/edges with glass fabric and two coats of Childers (Chil Perm CP-30 Low Odor (white) or Chil Perm WB CP-35 for LEED or Green Building Program projects mastic.

3) Paint with one coat suitable primer and one coat suitable exterior enamel. Colors to be as selected by/directed by Architect/Engineer.

c. Louvers and ductwork alternative: 2" thick Armaflex AP sheet applied with 100% adhesive coverage.

1) Miter or square cut joints, avoiding close radius bends of insulation.

2) Provide two coats of Armaflex finish and two coats suitable finish enamel in color as selected by Architect/Engineer.

d. Refer also to "Duct Accessories-Louvers" below.

5. External Insulation for Ductwork Within Mechanical Rooms

a. Mechanical rooms: Where external insulation (duct wrap) is to be provided for duct systems within the building, the insulation on duct within mechanical rooms shall be:

1) Armacell "ArmaTuff Plus II – Silver" sheet insulation laminated with 16 mil puncture resistant blended polymeric membrane, 1-1/2" thick, with:

a) 100% adhesive coverage applied and joints sealed with Armstrong 520 adhesive sealant.

b) Cover all joints with ArmaTuff Plus II – Silver seal tape.

c) Miter or square cut joints. Provide square cut joints/seams at all edges to prevent stressing, stretching, or tearing.

d) Avoid close radius bends of insulation at ductwork corners or similar conditions. (Alternatively, a "vee-cut" method of forming corners (similar to that used to form fiberglass

ductboard corners) may be used, pending Architect/Engineer's approval of a mock-up sample.)

2) Fiberglass insulation board for rectangular ducts, 1-1/2" thick, 6-pound density with 100% adhesive coverage and one of the following options applied to exterior surface:

a) 0.016" aluminum jacket;

b) Venture clad 1577CW;

c) glass fabric and two coats Chil Perm CP-30 LO mastic.

d) Round ductwork to be insulated similar to rectangular above except with conforming high-density insulation equal to Certainteed "Crimp Wrap," as specified in "3" above.

b. Install insulation before conduit, controls, electrical devices, etc. are installed so that no such elements are enclosed by the insulation (or coordinate to provide "stand-offs" for conduit, etc. to accomplish same).

c. LEED notice: Where external insulation (duct wrap) is to be provided for duct systems within the buildings subject to LEED requirements (refer to Section 23 00 10), the insulation on duct shall be: one layer of 2-inch thick duct wrap, 1.5 lb/cu.ft. density, K factor 0.25 BTUH-in/(hr-sq.ft.-F) or less. Insulation shall be similar and equal to Johns Manville Microlite formaldehyde-free fiberglass duct wrap with FSK composite vapor barrier.

1) Note: Provide "inserts" at all hanger locations between the hanger and ductwork.

3) Where generous (adequate) space occurs for installation of duct and other above ceiling systems, insert shall be 2" thick x min. 12" length x duct width, 3.0 pcf density Certainteed "Crimp Wrap" or equal fiberglass insulation with FSK jacket. At Contractor's option, insert may be 6.0 pcf fiberglass insulation board with FSK jacket; or triple layers of specified duct wrap where concealed and not subject to tight/limited clearances.

4) In other conditions of close tolerances and limited clearances, provide insert of 1" thick x min. 12" length x duct width, 6.0 pcf density fiberglass insulation board with FSK jacket.

5) After duct has been completely insulated, vapor sealed, vapor stopped, inspected by the insulation supervisor, and reviewed by the Architect/Engineer, provide additional layer of FSK jacketing. FSK jacketing shall have permeance of not greater than 0.02 perms and shall be non-supportive/immune to mold growth. Jacketing shall be similar and equal to Compac Corporation FB-1535, applied per manufacturers written instructions.

6. External Insulation for Uninsulated/Unlined Fans, Air Handling Units, VAV Boxes, Mixing Boxes, Dampers, Duct Coils, Filter Housings, and Other Equipment in Duct Systems.

    a. Where conditions call for uninsulated equipment to be used, said equipment shall be insulated with “Armcacell ArmaTuff Plus II” in accordance with that specified for "Ductwork Systems in Mechanical Rooms" above.

        1) Such insulation is to be provided, if directed by Architect/Engineer, on equipment in uninsulated duct systems for acoustical purposes.

        2) Install in sections conforming to equipment panels/sections and as otherwise necessary to accommodate future service and maintenance without damaging the insulation. (Suspend such equipment using angle or Unistrut and threaded rods.)

    b. Provide insulation segments to allow movement of surfaces where required (e.g., filter rack doors, hinges, panels, etc.).

D. Acoustical Lagging: As shown on drawings or where indicated in this or other specification sections, provide acoustical lagging per the following:

1. Where applied directly to sheet metal, provide decoupling layer covered by mass loaded acoustical barrier (lagging). The barrier shall be equal to Kinetics Noise Control Type KNM-100ALQ. Beneath the barrier, apply Kinetics Noise Control Type KFA, or equal, decoupling layer directly to the duct.

2. Where applied to externally insulated ducts, provide mass loaded acoustical barrier (lagging) only (decoupling layer not required). The barrier shall be equal to Kinetic Noise Control Type KNM-100ALQ.

3. Install per manufacturer’s installation instructions and use the manufacturer’s recommended adhesives, overlaps, fastening, etc.

4. Hanger specialties: Lagging may add significant weight to the duct system, requiring the Contractor’s evaluation of hanger support system. Determine what additional hangers and structure attachments are needed and **submit evidence that this item is addressed in planned installation.**

E. 2-Hour Fire Wrap: As shown on drawings or where indicated in this or other specification sections, provide 2-hour fire duct wrap system, listed for use in place of 2-hour shaft wall construction per the following:

1. Provide fire-wrap blanket insulation system equal to 3M Fire Barrier 615+. Install system and terminate to separations according to manufacturer’s UL Listed system details.

2. Where applied to conditions that are not detailed in manufacturer’s details, provide a rated assembly for termination of Fire Barrier system that is included in the manufacturer’s details. Once routinely encountered condition is the installation of air outlets, which require a fire damper. In this case, one option would be to provide

a small section of shaft wall for installation of the fire damper and termination of the Fire Barrier system.

2.10 VARIABLE AND CONSTANT VOLUME TERMINAL UNITS: PRESSURE INDEPENDENT

A. Furnish and install single duct, variable and constant volume terminal units of size and capacities shown in the plans.

B. Unit casing shall be:

1. 22-gauge galvanized steel, internally lined with 1", 1.9 lb/cu.ft. density foil faced fiberglass insulation system which complied with UL 181 and NFPA 90A. All exposed insulation edges shall be coated with NFPA 90 approved sealant. Lining system shall be securely fastened with spot welded “stick pins” and yield a non-porous and completely sealed condition acceptable to all applicable administrative authorities.

C. Volume/flow control devices shall be:

1. Heavy gauge metal damper with shaft rotating in self-lubricating bearings. Shaft shall be permanently marked (scored) on the end to indicate the damper blade position. Damper shall have a built-in stop to prevent overstroking and shall seal against a closed cell foam gasket to eliminate close-off leaking.

D. The terminal unit shall be leak tested to not exceed 1% of the nominal catalog flow at 3.0” w.g. inlet pressure.

E. Flow Sensing/Measurement:

1. Units shall include integral, multi-point, averaging flow sensing rings accurate to $\pm$ five percent (5%) of actual air flow, including errors from amplifiers and transducers, down to 500 FPM inlet velocity. Integral flow taps and calibration charts shall be provided on each unit (and shall not be covered, painted, or in any other way obscured by the contractor).

2. The sensor shall develop a differential pressure of 0.03” w.g. at an air velocity of 450 fpm. Brass balancing taps and airflow calibration charts shall be provided for field airflow measurements. Provide documentation indicating such in submittal.

F. Units shall have heating water reheat coils in accordance with the drawings. Coils shall be enclosed in a galvanized steel casing module matching the terminal unit casing. Tubes shall be 1/2" copper with 0.016” wall thickness with 0.0045” thick aluminum or copper fins mechanically fixed to the tubes. Tubes shall be expanded into fins and headers to provide a leaktight condition without soldering, brazing, or tinning.

1. Each coil shall be tested at a minimum of 350 psig under water.

G. Units shall have pressure independent direct digital control that shall be re-settable for air flow between zero and maximum catalogued CFM.

1. Airside actuators shall be furnished under this section in compliance with the requirements of Section 23 09 51 – Controls and Instrumentation, DDC.

2. Controllers and thermostats shall be furnished under Section 23 09 51.

H. The terminal unit shall be suitable for operation with an electronic controller temperature sensors from any approved control manufacturer.

I. Acceptable manufacturers:

1. Basis of Design: Titus

2. Other acceptable manufacturers:

a. Price

b. Trane

2.11 VAV PRESSURE INDEPENDENT AIRFLOW MEASURING/ CONTROL DAMPER MODULES – AFMD (TERMINAL UNITS)

A. Furnish and install variable volume airflow measuring/control modules of size and capacities shown in the plans.

B. Damper and Sleeve Assembly shall be:

1. Damper: Extruded aluminum damper frames not less than .080” thick and 4” deep. Provide extruded aluminum damper blade profiles. Blade seals shall be extruded EPDM or silicone. Frame seals shall be extruded silicone. Seals shall be secured in an integral slot within aluminum extrusions.

2. Bearings: Bearings shall be composed of Celcon inner bearing fixed 7/16” aluminum hexagon blade pin, rotating within polycarbonate outer bearing inserted in the frame, resulting in no metal-to-metal or metal-to-plastic contact. Linkage hardware shall be installed in the frame side and be constructed of aluminum and corrosion resistant, zinc-plated steel, complete with cup-point trunnion screws for slip-proof grip.

3. Leakage: Damper leakage shall not exceed 3 cfm/sf against 1” w.g. differential static pressure. Damper shall be either opposed blade or parallel blade in accordance with information presented in the drawings and made to size without blanking off free area.

4. Sleeve: Provide one or more damper sections for each location indicated on the plans. Damper section(s) shall be integral to the sleeve assembly: factory-assembled extruded aluminum sleeve, not less than 0.08” thick for each damper section. Entire sleeved assembly shall be provided with flanged connections for duct installation.

C. Flow Sensing/Measurement:

1. Provide thermal dispersion airflow/temperature measuring device (AFMD). Differential pressure-based devices, including pitot tubes and arrays, are not acceptable. Each AFMD shall have one or more factory-mounted, multi-point, measuring probes and microprocessor-based transmitter (remotely mounted by others). Each sensor probe shall consist of one to eight independent sensor nodes

in a gold anodized, extruded aluminum tube with aluminum mounting brackets. Each sensor node shall consist of two hermetically sealed bead-in-glass thermistors.

Each node shall have a calibrated accuracy of +/- 2% of reading, and the overall installed accuracy of the assembly shall be better than +/- 5%. The AFMD shall be capable of measuring flow rates over the full range of 0 to 5,000 fpm between -20 deg F and 160 deg F.

D. Units shall have pressure independent direct digital.

1. Airside actuators shall be furnished under this section in compliance with the requirements of Section 23 09 51 – Controls and Instrumentation, DDC.

2. Controllers and thermostats shall be furnished under Section 23 09 51.

E. Acceptable manufacturers:

1. Basis of Design: Tamco-Ebtron

2. Other acceptable manufacturers:

a. Ruskin

2.12 AIR DISTRIBUTION ACCESSORIES

A. Grilles, Registers, and Diffusers

1. Furnish and install all grilles, registers, and diffusers as shown and scheduled on the Drawings, to deliver the indicated volume of air without objectionable noise or draft. All grilles, registers, and diffusers shall have off-white electro-deposit paint finish unless otherwise scheduled on the drawings.

Note: Painting to match adjacent finishes, if required, shall be provided under Division 9.

2. Multi-cone ceiling diffusers shall have a minimum of three cones (for 2’x2’ module size), unless specifically scheduled otherwise, to restrict line of sight through the diffuser into the ductwork.

3. Where substitution air devices to those scheduled on the drawings are requested, substitutes shall be equal to those scheduled, including throw, NC levels, appearance, installation, materials of construction, operation, and other pertinent features as determined by the Architect/Engineer.

Submittals, including those for substitutions or voluntary alternates, shall provide comparative appearance, NC and Throw data summarized in a table.

Should a substitute device prove unsuitable in appearance, performance, or noise characteristics, the substitute shall be replaced as required to achieve desired conditions. Said replacement shall be at the contractor's expense. The Architect/Engineer shall retain sole authority in determining if replacements are required.

4. Contractor shall verify that scheduled air devices are correct for ceiling types (lay-in, gypsum, etc.) prior to submittal and purchase.

5. Acceptable manufacturers:

   a. Basis of Design: as scheduled on drawings

   b. Other acceptable manufacturers:

      1) Price

      2) Titus

      3) Anemostat

      4) Krueger

      5) Metal Aire

      6) Nailor

      7) Tuttle & Bailey

      8) As listed in schedules.

B. Manual Volume Dampers

1. Furnish and install manual volume dampers:

   a. in main trunk ducts of supply air, outside air, return air, exhaust air, and relief air;

   b. as required to balance branch ducts and/or runouts to individual air devices in supply, return, or exhaust systems;

   c. as required to balance flow or control noise from terminal devices/equipment;

   d. and where shown on the drawings.

2. Rectangular to 12”: For rectangular dampers not exceeding 12" in the smaller dimension, 24” in the larger dimension, or 2000 FPM velocity: factory damper blades shall be constructed of 16-gauge minimum galvanized steel securely fastened to square operating rod of adequate cross-section to prevent distortion, of length as required.

   Where installed for adjustment through air device (e.g., at hinging return/exhaust grilles in hard ceilings), construct with folds/flaps at ends riveted to duct for pivot operation. Secure with sheet metal screws in final (balanced) position.

3. Rectangular exceeding 12”: For rectangular dampers exceeding 12" in the smaller dimension or exceeding 2000 FPM velocity, use factory manufactured opposed blade dampers rated for the maximum velocities and pressures involved.

4. For low-pressure round dampers up to 24” diameter:

    a. Flanged frame, min 16-gauge, 6” deep (4”-8” duct), 8” deep (≥10” duct), 12-gauge flange; double skin blade (stiffened as required), with neoprene blade seals /stops; ½” plated steel shaft, stainless steel bearings pressed into frame; max static pressure difference (closed damper) of 4” w.g.; max operating temperature of 250 deg F; max velocity of 4000 fpm through 12” diameter, 2500 fpm from 13” to 24” diameter.

    b. Maximum leakage across damper blade at 1.0” w.c. differential to be 0.25% of max rated flow, not to exceed 6 cfm for 24” size.

    c. Basis of Design: Ruskin CDRS82

5. For low-pressure round dampers above 24” diameter:

    a. In accordance with “3” above, with square (rectangular) to round transitions on both sides.

    b. As Specified in “4” above, up to 36” max, but only if sufficient duct length does not exist for transitions to rectangular dampers.

6. For medium and high-pressure round dampers up to 24” diameter:

    a. Flanged frame, min 10-gauge, 8” deep, 10-gauge flange; min. 10-gauge blade (stiffened as required), with neoprene blade seals /stops; min. ½” plated steel shaft, stainless steel bearings pressed into frame; max static pressure difference (closed damper) of 8” w.g.; max operating temperature of 250 deg F; max velocity of 6000 fpm through 24” diameter.

    b. Maximum leakage across damper blade at 1.0” w.c. differential to be 0.13% of max rated flow, not to exceed 25 cfm for 24” size.

    c. Basis of Design: Ruskin CDR82

7. For medium and high-pressure round dampers above 24” diameter:

    d. In accordance with “3” above, with square (rectangular) to round transitions on both sides.

    e. As Specified in “6” above, up to 36” max, but only if sufficient duct length does not exist for transitions to rectangular dampers.

8. Accessibility: Locate dampers in an accessible position

    a. Examples:

        1) Above lay-in ceilings at elevations low enough to safely access through removable ceiling tiles or ceiling access doors, without grid removal.

        2) Above inaccessible ceilings, coordinate with Architect/Engineer for acceptable access panel locations).

Locate to avoid additional/objectionable noise (e.g., avoid locations near to air devices).

9. Where balancing will not require future adjustments, adjustable guillotine dampers or adjustable partial blank-offs may be used if approved by Architect/Engineer for specific application.

    a. Guillotine dampers shall be installed with track internal to ductwork and wiper seals where damper blade penetrates duct. Damper blade shall be minimum 16-gauge.

    b. After final adjustments, seal (hardcast) damper penetration into duct and insulate to conserve heat/cold and prevent condensation.

    c. Finish protruding portion (cut to approximately 4" beyond duct if/where directed by Architect/Engineer) with rounded corners, and paint protruding portion to mark final balance adjustment.

    d. Support duct immediately on both sides of the guillotine damper.

    e. Confer with Architect/Engineer for construction/installation in retrofit applications.

    f. Refer also to Section 23 09 51 - Controls and Instrumentation (DDC), for similar guillotine dampers installed at control dampers.

10. Damper adjustments:

    a. Accessible conditions: Where ductwork is exposed or accessible above ceilings, dampers shall be equipped with locking type quadrants.

    b. Concealed/inaccessible conditions: Where ductwork is concealed and not accessible above ceilings, dampers shall be equipped with adjustable cover concealed remote damper regulators installed flush and painted to match ceiling, or as otherwise indicated on drawings.

        1) MAT (Metropolitan Air Technology) RT-250 system with:

            a) Cabling (up to 60’), couplings, worm gear driver, and ceiling or wall adjustment.

            b) Ceiling or wall cups for access to point of adjustment.

            c) Tamper-proof screws where installed in psychiatric, detention, or other secure locations.

        2) Ventlok No. 666 with rods, couplings, u-joints, and gear assembly.

    c. Refer also to drawings. Coordinate/clarify with Architect/Engineer as required.

11. Installation:

a. Blade orientation-refer to Part 3.

b. Refer also to Section 23 09 70 – Division 23 Testing, Adjusting, and Balancing, and coordinate to provide all necessary balancing devices, whether or not specifically indicated on the drawings.

C. Turning Vanes

1. General: Install turning vanes in ductwork at non-radius (e.g., mitered) turns 50 degrees and greater and at other locations indicated by the drawings.

2. Mitered turns of 90 degrees: Turning vanes in 90 degree turns shall be airfoil double thickness type. Where they occur in acoustically lined ducts, they shall be set in metal frames sized to permit lining to be continuous.

3. Acoustical turning vanes (ATV): Turning vanes in 90-degree turns shall be the acoustical type

a. where indicated by drawings

b. where located within four duct fittings (elbows, splitters, etc.) of fans or equipment containing fans, except acoustical turning vanes (ATV's) shall not be used downstream of filters having greater than 90% efficiency

c. Basis of Design: acoustical type turning vanes similar and equal to acoustical turning vanes manufactured by Sheet Metal Connectors, Inc – Minneapolis, Minn.

4. Mitered turns of less than 90 degrees: Turning vanes in turns of less than 90 degrees shall be single thickness with long leaving edges, factory or shop fabricated for the specific degree of turn/elbow. Coordinate specifics with Architect/Engineer prior to fabrication.

D. Flexible Connections

1. Install flexible connections where shown on the drawings and at all connections between ductwork and equipment subject to vibration or movement. Connections shall have suitable metal collar frames at each end. Allow at least one-inch slack in each connection to assure no vibration is transmitted from fan to ductwork. Connections shall be not less than four inches long.

2. Basis of Design: Ventfabrics “Ventlon,” 10” water column positive or negative, fire resistant, weatherproof, UV, ozone, and mildew resistant fabric.

3. Provide external insulation (duct wrap inside, “Imcosheet” or equal outside) at flexible connections in supply air ductwork and at other locations subject to condensation. Install vapor tight. Insulation to extend a minimum of six inches beyond metal collars.

4. Install to provide access and easy removal for future service of equipment.

E. Thermometers

1. General: Provide supply, return, mixed air, and outside air thermometers at all air handler locations, and where shown in the drawings. Calibrate thermometers together in one environment (approximately 70 deg. F) prior to installation. **Submit statement/report to Architect/Engineer** certifying same and describing the range of adjustments needed/performed.

2. Duct/equipment (airside) thermometers: Thermometers shall be self-powered with 1% reading accuracy, digital readout, variable angle, -50◦ to 300◦ F range, -30◦F to 140◦F ambient operation at 100% relative humidity, stem length sufficient to extend a minimum of 25% into air stream, accessories to accommodate application, and installed for easy reading from the floor. Similar and equal to Weiss Digital Vari-Angle.

3. Provide threaded ductwork tap/flange to receive thermometer.

4. Under voluntary alternate/substitution only, if approved by Architect/Engineer: A fixed angle (back or bottom connection) bimetal thermometer may be substituted for the adjustable angle type where ductwork, equipment, etc., will allow easy reading from the floor without an adjustable angle. Similar and equal to Weksler BK (back connection) or 5BM (bottom connection).

    a. Thermometer range shall be suitable for the service and selected for the lowest possible span. Unless otherwise noted, the schedule below shall be used as a guideline.

Service	Thermometer Range (°F)
Supply/Return Mixed Air	25 to 125, 1° divisions
Outside Air	-40 to 120, 2° divisions

F. Flow Monitoring Stations

1. Flow monitoring stations (FMS) are to be provided by the controls contractor and installed by the mechanical contractor. Refer to Section 23 09 51 – Controls and Instrumentation (DDC).

    a. Exception: air flow measuring dampers specified in 2.01 above.

2. **Submit proposed installation detail in accordance with Part 3 below.**

G. Wall/Ceiling Access Panels

1. Provide access panels/doors in walls and ceilings as described in Section 23 01 00 Parts 2 and 3. Coordinate locations and installation with the General Contractor and Architect/Engineer.

H. Duct Access Doors

1. General Requirements:

    a. Accessible/functional locations: Install approximately full height/width access doors where indicated by the drawings AND as otherwise necessary to provide for easy service/maintenance access. Locate all access doors for convenient inspection, testing, and resetting. Plan work

and purchase of materials (e.g., smoke dampers, flow measurement stations) to locate materials needing access above accessible ceilings where possible. Locate downstream of fire and/or fire/smoke dampers unless upstream location is necessary to have access in lay-in ceilings is indicated on drawings, or is required due to duct detector location (to allow fire/smoke damper and duct detector to share access door).

b. Size guidelines:

1) Not serving fire/smoke dampers: Access doors shall be rectangular (square when duct sizes permit), with minimum sizes as follows: duct dimension less 2” for ducts up to 26” wide or high; 24” x 24” for ducts greater than 26” in installed dimension.

2) Serving fire and/or smoke dampers: rectangular (square when duct sizes permit), with minimum sizes as follows: duct dimensions less 2" for ducts up to 20" wide or high; 18" x 18" for larger duct dimensions.

c. Locations: At a minimum, provide access doors for:

1) inspection of fire/smoke dampers, control dampers, duct smoke detectors, and control equipment/sensors;

2) cleaning upstream face of coils, (including electric duct heaters);

3) Inspection and cleaning of louvers (leaving side)

4) removal of filters;

5) cleaning/inspection at upstream of flow measuring stations/ devices (including airflow measuring);

6) cleaning/inspection at upstream of sound attenuators;

7) cleaning/inspection minimum once every 100 ft of main duct run;

8) at other locations indicated by drawings or required by job conditions;

9) and/or as directed by the Architect/Engineer.

d. Double wall/thermal break construction: Construction and installation of access door shall prevent condensation in the installed field/operating condition. Doors in insulated duct systems shall be thermal break type double wall with insulation between walls of same thickness as on ductwork.

e. Suitable for duct systems/applications served: Access doors shall be constructed in accordance with SMACNA Duct Standard 56, and shall be appropriate for low, medium, or high-pressure duct systems as applicable.

f. Identification: Nameplate all access doors describing component they serve.

1) Nameplates at concealed locations may be stenciled, painted, or engraved. Nameplates at exposed locations in finished areas shall be engraved.

2) For all fire and combination fire/smoke dampers, nameplates shall be in red letters, minimum 1-1/2" high "Fire Damper" or "Smoke/Fire Damper" on access doors serving such dampers (near perimeter of access doors where clear view panel provided).

2. Low-pressure rectangular duct access doors shall be as follows:

a. Not serving fire/smoke dampers: Min. 22-gauge galvanized steel double wall construction with continuous piano hinge door, "Ventlok" 100 latches, insulation, and foam gasket seals. Basis of Design: Ruskin ADH22. (ADC22 with security chain acceptable where field conditions require removable door rather than a hinging door.)

b. Serving fire, smoke, or combination fire/smoke dampers: Min. 22-gauge galvanized steel double wall construction, with continuous piano hinged door, "Ventlok" 100 latches, insulation, insulating/ double layer of transparent plexiglass or reinforced wire glass panel, and foam gasket seals. Basis of Design: Ruskin ADHW22. (ADCW22 with security chain acceptable where field conditions require removable door rather than a hinging door.)

3. Medium and high-pressure rectangular duct access doors shall be as follows:

a. Positive pressures, not serving fire/smoke dampers: Min. 22-gauge galvanized steel double wall construction, continuous piano hinged door, "Ventlok" 100 latches, insulation, and foam gasket seals. Limited to pressures to 6" w.c. Basis of Design: Ruskin ADH24-HP. (ADC24-HP with security chain acceptable where field conditions require removable door rather than a hinging door.)

b. Positive pressures serving fire, smoke, or combination fire/smoke dampers: 16-gauge galvanized steel construction with reinforced corners, removable doors, spring latches, insulation, gasket seals, and reinforced insulating/double glazed wire glass view panel. Door shall be designed and rated for installation in duct systems with up to 12" w.g. pressure. Door shall be equipped with coiled spring latches (installed on outside of duct) and installed such that spring latches relieve excess negative pressures to protect against duct collapse. 12” x 12” maximum size. Basis of Design: Ruskin ADHP-3 Install on the downstream side of fire or smoke damper to provide vacuum collapse protection.

c. Negative pressures, all services: 22-gauge galvanized steel frame, 22-gauge galvanized steel double wall with 1” insulation, full-length continuous hinge, continuous door to frame closed cell neoprene gasketing, window see-through door panel, dual cam latches, minimum size 18" x 24". Basis of Design: Pottorff HAD.

1) Options for negative pressure duct systems:

a) negative pressures up to 4" w.c., not serving fire/smoke dampers: Ruskin ADH24-HP as specified in "3a" above.

b) negative pressures greater than 2" w.c. but less than 3" w.c., serving fire, smoke, or combination fire/smoke dampers: Ruskin ADHP-3 as specified in "3b" above, limited to 12" x 12" size.

c) negative pressures up to 2" w.c., serving fire, smoke, or combination fire/smoke dampers: Ruskin ADHP-3 as specified in "3b" above, limited to 18" x 18" size.

4. Round duct access door frames shall be approved duct fitting products provided by the duct manufacturer and suitable for the system pressures encountered.

a. For positive pressure duct systems: door frame shall be rectangular, double-wall/insulated fitting with flanged connection and continuous gasket shipped with fitting. Install above specified access door(s) mating with the flanged connection of the fitting.

For smoke dampers or combination smoke/fire dampers, access door (ADHP-3) installed in door frame (D-2) shall include reinforced (and double glazed in insulated systems) wire glass panel.

b. For negative pressure duct systems (not in fire/smoke damper applications) - door shall be rectangular, hinged, contoured to curvature of duct, and double-wall/insulated in insulated duct systems. Basis of Design: Semco D-40.

5. Refer also to Section 23 09 51 - Controls and Instrumentation DDC, Part 4.

I. Fire Dampers

1. General: Provide “dynamic rated” fire dampers at all penetrations of fire rated partitions and floors, and where indicated on drawings (exception: where riser stub-ups or other acceptable equivalency measures are indicated by the drawings). Fire dampers shall be constructed and tested in accordance with the latest UL Safety Standard 555. Damper assemblies shall be equipped for airflow in any direction (horizontal, vertical up or down), as required by the location. Dampers shall be marked “for use in dynamic systems.”

2. Ratings: Each fire damper shall have a fusible link, and shall include a factory applied, permanently affixed UL label showing the fire protection rating of the fire damper.

a. Unless otherwise noted, each fire damper shall have 1 ½-hour UL listed fire protection rating.

1) Exception: Rating shall be 3-hours where installed in 4-hour rated assembly.

b. Unless otherwise noted, provide 165˚ F fusible link.

1) Exception: Provide 212˚ F fusible link where so indicated.

3. Installation: Fire dampers shall be installed in partition and floor openings utilizing steel sleeves, angles, other materials, and practices required to provide an installation equivalent to that utilized by the manufacturer when dampers were tested at UL. Installation shall be in accordance with the damper manufacturer's written instructions and/or in accordance with the most recent edition of SMACNA's "Fire Damper and Heat Stop Guide for Air Handling Systems."

4. Basis of Design:

a. Curtain style: Ruskin DIBD2 (DIBD23 where 3-hour rating is required). Curtain shall be completely out of the air stream.

1) Provide style(s) B, C, CR, CO, LR, LO as required to accommodate the field conditions and particular assembly.

2) Provide style GA (grille access) where fire dampers are installed adjacent to sidewall air devices which are mounted in the rated position (not rated for horizontal/floor installation).

3) Provide style OW (out of wall or floor) where field conditions do not accommodate fire damper installation within the plane of the partition or floor.

4) Minimum size (verify for each model used): 4" x 4" for vertical installation; 6" x 6" for horizontal installation.

5) Maximum size, single section (verify for each model used): 33" W x 36" H for vertical installation; 24" W x 24" H for horizontal installation.

6) Maximum size, multiple sections (verify for each model used): 72" W x 48" H or 120" W x 24" H for vertical installation; 36" W x 48" H for horizontal installation.

7) Options/Accessories: Provide as indicated below, unless not required to satisfy system installation and performance, or to accommodate field conditions.

a) Factory sleeves

b) Stainless steel construction

c) Switch package to remotely indicate damper curtain position

d) Fast Angles for one-sided or two-sided installation, as applicable

e) MCP control panel for monitoring purposes.

b. Blade style: Ruskin FD35

1) Use where field conditions are insufficient to accept the out of air stream curtain, or where beneficial because of the larger maximum sizes for blade style dampers.

2) Provide style(s) B, C, CR, CO, LR, LO as required to accommodate the field conditions and particular assembly.

3) Provide style GA (grille access) where fire dampers are installed adjacent to sidewall air devices which are mounted in the rated position (not rated for horizontal/floor installation).

4) Provide style OW (out of wall or floor) where field conditions do not accommodate fire damper installation within the plane of the partition or floor.

5) Minimum size (verify for each model used): 8” x 6” for vertical or horizontal installation.

6) Maximum size, single section (verify for each model used): 36” W x 48” H for vertical or horizontal installation.

7) Maximum size, multi-section (verify for each model used): 120” W x 96” H for vertical or horizontal installation.

8) Options/Accessories: Provide as indicated below, unless not required to satisfy system installation and performance, or to accommodate field conditions.

a) Jamb seals and blade seals

b) Factory sleeves

c) Stainless steel construction

d) Switch package to remotely indicate damper blade position

e) Fast Angles for one-sided or two-sided installation, as applicable

f) MCP control panel for monitoring purposes.

g) Crank lever to assist with testing and fusible link replacement

J. Smoke Dampers

1. General: Provide “Dynamic Rated” smoke dampers at all penetrations of smoke walls/partitions, and where indicated by drawings. (Exception: in engineered smoke control systems.) Each damper shall be classified by Underwriter's Laboratories as a Leakage Rated Damper for Use in Smoke Control Systems

under the latest version of UL555S, and bear a UL label attesting to same. Damper manufacturer shall have tested, and qualified with UL, a complete range of damper sizes covering all smoke dampers required by this specification. Damper dimensions shall allow for no reduction in duct size at the damper.

2. Leakage, pressure, and velocity: The leakage rating under UL555S shall be no higher than leakage Class I (4 cfm/sq. ft. at 1 w.g.). As part of the UL qualification, smoke dampers shall have demonstrated a capacity to operate (to open and close) under HVAC system operating conditions, with pressures of at least 8" w.g. in the closed position, and 4000 fpm air velocity in the open position.

3. Actuators: Smoke dampers and actuators shall be qualified under UL555S to an elevated temperature of 250-350 degrees F. Appropriate electric operators shall be installed by the damper manufacturer at the time of damper fabrication; damper and operator shall be supplied as a single entity which meets all applicable UL555S qualifications for both smoke dampers and operators.

    a. Actuators shall be electric type operating on 120 VAC or 24 VAC 60 Hz, each as indicated by drawings, and shall be of the controlled closure spring return type such that damper will be closed in no faster than 7 to 15 seconds upon power interruption.

    b. Unless otherwise indicated, it is intended that actuators be mounted externally to the damper. Verify field conditions allow this intent, and confer with the Engineer should they not.

4. Accessible installation: Install where damper actuator is “easily” accessible:

    a. Provide access through lay-in ceilings, where possible.

    b. Provide ceiling access panel(s) were required to achieve access.

    c. Where actuator access is enhanced by actuators on the bottom of the assembly, provide same together with damper assemblies rated for vertical blade installation, to the extent such is achievable.

    d. Where portable ladder is required for access, ensure safe access is achievable or that ceiling tile removal is easily accomplished without affecting other ceiling systems (e.g., ceiling grid, lights, sprinkler heads, diffusers/grilles, speakers, smoke detectors, occupancy sensors, etc.).

    e. Install in accordance with the most recent edition of SMACNA's "Fire Damper and Heat Stop Guide for Air Handling Systems,” and with manufacturers product listing.

5. Basis of Design:

    a. Smoke Dampers: Ruskin Model SD50 (aluminum), Ruskin Model SD60 (galvanized steel), or Greenheck Model SMD-301 (galvanized steel).

        1) Provide style(s) C, CR, CD, and OW (out of wall) as required to accommodate the field conditions and particular assembly.

2) Minimum size (at 2000 fpm and 4" w.g., so verify for each model used): 8" W x 6" H.

3) Maximum size, single section (at 2000 fpm and 4" w.g., so verify for each model used) 48" W x 72" H

4) Maximum size, multi-section (at 2000 fpm and 4" w.g., so verify for each model used): 144" W x 96" H; 288" W x 48" H; 72" W x 192" H.

5) Options/accessories: Provide as indicated below, unless not required to satisfy system installation and performance, or to accommodate field conditions.

a) Jamb seals and blade seals

b) Factory sleeves compatible with field conditions

c) Stainless steel construction

d) Suntek package to remotely indicate damper blade position

e) Fast Angles for one-sided or two-sided installation, as applicable

f) MCP control panel for monitoring purposes.

g) Duct smoke detector (where not provided by other trades under Division 28)

h) Damper test switch for cycle testing

i) Switch package to remotely indicate damper blade position

j) MCP control panels for test purposes or smoke management systems

b. Combination Smoke/Control Dampers: Greenheck Model SMD-301M; or Ruskin Model SD60M (galvanized steel) where system velocities do not exceed 2,000 FPM, and system pressures do not exceed 4" w.c. Coordinate with controls trades, Section 23 09 51 to assure compatible actuator voltages.

1) Provide style(s) C, CR, CD as required to accommodate the field conditions and particular assembly.

2) Minimum size (at 2000 fpm and 4" w.g., so verify for each model used): 8" W x 6" H.

3) Maximum size, single section (at 2000 fpm and 4" w.g., so verify for each model used) 32" W x 50" H

4) Maximum size, multi-section (at 2000 fpm and 4” w.g., so verify for each model used): 128” W x 100” H.

5) 24 VAC actuator

6) Options/accessories

a) Factory sleeves compatible with field conditions

b) Duct smoke detector (where not provided by other trades under Division 28)

c) Damper test switch for cycle testing

d) Switch package to remotely indicate damper blade position

e) MCP control panels for test purposes or smoke management systems

f) Fast angles for one or two-sided installations

K. Combination Fire/Smoke Dampers

1. General: Furnish and install at fire/smoke rated partitions and floors, and locations shown on plans or as described in schedules, “Dynamic Rated” combination fire/smoke dampers meeting or exceeding the following specifications. Each combination fire/smoke damper shall be not less than 1 ½-hour fire rated under UL Standard 555, with dampers and operators shall be UL 555S to an elevated temperature of 250-350 degrees F. Dampers shall further be classified by Underwriter's Laboratories as a Leakage Rated Damper for Use in Smoke Control Systems under the latest version of UL555S, and bear a UL label attesting to same. Damper manufacturer shall have tested, and qualified with UL, a complete range of damper sizes covering all dampers required by this specification.

2. Leakage, Pressure, and Velocity: The leakage rating under UL 555S shall be no higher than leakage Class I (4 cfm/sq. ft. at 1" w.g.). As part of the UL qualification, dampers shall have demonstrated a capacity to operate (to open and close) under HVAC system operating conditions, with pressures up to 8" w.g. in the closed position, and velocities up to 4000 fpm air velocity in the open position.

3. Actuators: Appropriate 120 VAC or 24 VAC controlled closure (no faster than 7 to 15 seconds) spring return type electric operators shall be installed by the damper manufacturer at the time of damper fabrication; damper and operator shall be supplied as a single entity which meets all applicable UL555S qualifications for both dampers and operators.

a. Unless otherwise indicated, it is intended that actuators be mounted externally to the damper. Verify field conditions allow this intent, and confer with the Engineer should they not.

4. FireStat package: Each combination fire/smoke damper shall be equipped with a UL Classified FireStat equal to Ruskin model TS150. FireStat shall function to

electrically lock damper in a closed position when duct temperatures exceed 165 degrees F and still allow the appropriate authority to override FireStat and operate damper as may be required for smoke control functions.

a. FireStat package shall include two damper position indicator switches linked directly to damper blade to provide the capability of remotely indicating damper position. One switch shall close when damper is fully open; the other switch shall close when damper is fully closed.

b. FireStat and position indicator switches shall be capable of interfacing electrically with smoke detectors, building fire alarm systems, and remote indicating/control stations.

5. Electronic Fusible link (EFL): Each combination fire/smoke damper shall be equipped with a resettable link which shall cause the damper to close and lock in a closed position at 165 degrees F. Damper dimensions shall allow for no reduction in duct flow size at the damper.

6. Basis of Design:

a. Fire/Smoke Dampers: Ruskin Model FSD60LP (low profile/low-pressure drop) (galvanized steel) for sizes through 36” W x 14” H in service with velocities less than 2,000 fpm and pressures less than 4” w.g.; FSD60 for other sizes, velocities, and pressures.

1) Provide styles A, C, CR, CD, and OW (out of wall) as required to accommodate the field conditions and particular assembly.

2) Minimum size (at 2000 fpm and 4” w.g., so verify for each model used): 6” W x 6” H.

3) Maximum size, single section (at 2000 fpm and 4” w.g., so verify for each model used): 36” W x 14” H for FSD60LP; 30” W x 48” H for FSD60.

4) Maximum size, multi-section (at 2000 fpm and 4” w.g., so verify for each model used): 144” W x 96” H for FSD60.

5) EFL (Electric Fuse Link) heat activated controlled closed device, for closure in not less than 3 to 10 seconds (greater for some actuators). Requires manual reset of heat activation at actuator.

1) Options/Accessories: Provide as indicated below, unless not required to satisfy system installation and performance, or to accommodate field conditions.

a) Jamb seals and blade seals

b) Factory sleeves

c) Stainless steel construction

d) Suntek package to remotely indicate damper blade position

e) Fast Angles for one-sided or two-sided installation, as applicable

f) MCP control panel for monitoring purposes.

g) Crank lever to assist with testing and fusible link replacement

h) Factory sleeves compatible with field conditions, insulated where adjacent ducts are insulated, with vapor barrier where adjacent ducts are vapor-barriered

i) Duct smoke detector (where not provided by other trades under Division 28)

j) Damper test switch for cycle testing

k) Switch package to remotely indicate damper blade position

l) MCP control panels for test purposes or smoke management systems

m) TS-150 FireStat for remotely openable damper once the temperature fault condition has been restored to acceptable.

b. Combination Fire/Smoke/Control Dampers: Ruskin Model FSD60M (galvanized steel).

1) Provide styles A, C, CR, CD, and OW (out of wall) as required to accommodate the field conditions and particular assembly.

2) Minimum size (at 2000 fpm and 4” w.g., so verify for each model used): 8” W x 6” H.

3) Maximum size, single section (at 2000 fpm and 4” w.g., so verify for each model used): 32” W x 48” H.

4) Maximum size, multi-section (at 2000 fpm and 4” w.g., so verify for each model used): 120” W x 48” H.

5) 24 VAC Actuator

6) EFL (Electric Fuse Link) heat activated controlled closed device, for closure in not less than 3 to 10 seconds (greater for some actuators). Requires manual reset of heat activation at actuator.

7) Options/Accessories: Provide as indicated below, unless not required to satisfy system installation and performance, or to accommodate field conditions.

a) Jamb seals and blade seals

b) Factory sleeves

c) Stainless steel construction

d) Switch package to remotely indicate damper blade position

e) Fast Angles for one-sided or two-sided installation, as applicable

f) MCP control panel for monitoring purposes.

g) Crank lever to assist with testing and fusible link replacement

h) Factory sleeves compatible with field conditions, insulated where adjacent ducts are insulated, with vapor barrier where adjacent ducts are vapor-barriered

i) Duct smoke detector (where not provided by other trades under Division 28)

j) Damper test switch for cycle testing

k) Switch package to remotely indicate damper blade position

l) Fast angles for one or two-sided installations, as applicable

m) MCP control panels for test purposes or smoke management systems

n) TS-150 FireStat for remotely openable damper once the temperature faucet condition has been restored to acceptable.

7. Dampers shall be “DYNAMIC” rated. Rectangular damper shall be similar and equal to Ruskin FSD60LP. Out of wall rectangular fire/ smoke dampers shall be Ruskin FSD60OW or equal. Round damper shall be similar and equal to Greenheck SEFSDR-511.

8. Install where access to damper actuator is achieved through lay-in ceilings or other easily accessible space, where possible. Install in accordance with the most recent edition of SMACNA's "Fire Damper and Heat Stop Guide for Air Handling Systems," and with manufacturers product listing.

L. Nameplates on Finishes (ceilings, partitions, access panels, etc.) for Terminal Units, Fire Dampers, Smoke Dampers, and Combination Fire/Smoke Dampers, Combination Fire/Smoke/Control Dampers, etc.

1. For each terminal unit, fire or smoke damper, combination fire/smoke damper, or Combination Fire/Smoke/Control Dampers, etc., provide a nameplate visible from floor to mark the location of the damper.

a. For dampers above ceilings, nameplates shall be mounted directly below the damper on the ceiling T-bar, ceiling access panel, or adjacent partition.

b. For dampers at other locations, provide nameplates on access panel or other appropriate position.

2. Nameplates shall be 3/4" wide engraved plastic with 1/2" high red letters securely attached to T-bar, access panel, wall, etc. Nameplates shall read “VAV -,” "Fire Damper Above," "Fire/Smoke Damper Above," or as otherwise appropriate.

3. Obtain Architect/Engineer's approval of nameplate size, lettering, and color prior to purchase/installation.

PART 3 - EXECUTION

3.01 GENERAL

A. Seal all systems: Thoroughly, effectively, and completely seal all ductwork systems. Where insulated externally (e.g., duct wrap or board), seal ductwork prior to installing external insulations. Refer also to SMACNA seal/leak test requirements of Part 1 above. Include:

1. all joints, seams, connections to devices and equipment,

2. damper shafts/bearings, coil casings, duct access door frames,

3. controls/instrumentation devices duct /cabinet penetrations,

4. and other applicable elements of the air distribution system.

B. Accommodate accessories: Provide openings in ductwork where required to accommodate thermometers and controllers (openings to be threaded where needed). Provide pitot tube openings where required for testing of systems, complete with cap or screw plug to ensure against air leakage. Cover with removable insulation, providing vapor barrier conditions for cold surfaces.

C. Installation

1. Prior to fabrication and installation of air distribution systems, plan installation of systems carefully with all affected trades to avoid conflicts. Locate ducts high and near to structure (or near to piping, if applicable) above (or otherwise as high as possible) to allow for uniform clearance for light fixtures, refrigerant/hydronic piping, hydronic piping, fire protection piping, condensate drains, sanitary, storm drains, conduits, etc. (Accordingly, where required, apply external insulations

PRIOR TO raising duct tight to structure, at least at hanger locations or at top of duct.) Refer also to drawings for related information.

Ensure that safe access and service clearances are maintained for all systems, including above ceiling systems. Coordinate installation through coordination drawings and in the field with General Contractor and with plumbing, electrical, and fire protection trades.

2. Provide full coordination and cooperation with Testing, Adjusting, and Balancing (TAB) trade. Provide test ports, access panels, duct access doors, balancing dampers, etc. as required or requested by TAB trade. Provide craftsman/crew to support activities of those trades at all times work by TAB trade is occurring.

3. Where duct offsets are required to drop below beams or avoid other items (ducts, piping, etc.), fabricate offsets using elbows with a maximum of 45-degree turns.

4. In all cases, install duct systems to avoid conflict with needed access to mechanical, electrical, etc. equipment and systems, including controls.

5. Coordinate installation to avoid conflicts with storm, sanitary, vent, condensate, and other graded piping systems.

6. Keep ends of all duct on site (whether stored or installed) completely and effectively sealed during construction to prevent construction dust and/or other soiling of duct system.

   Failure to keep ducts sealed or failure to install and maintain pre-and-final filters prior to operation of supply system fans shall, at the Architect/Engineer's discretion, subject entire duct system to replacement and/or extensive cleaning in place per specifications or Engineer’s directives.

7. Avoid making taps to air devices within five (5) feet of rooftop units, air handlers, fans, terminal units, etc. Avoid bottom and side take-offs to air devices within ten (10) feet of rooftop units, air handlers, fans, terminal units, etc. unless absolutely required by field conditions.

   Where such taps are unavoidable and acceptable to the Architect/Engineer, provide taps in top of ducts, (or otherwise to prevent direct noise path from trunk) and route run out to accomplish 180º of long radius flex turns where possible.

8. Provide relocation of initial duct taps as required to obtain desired air flow and/or noise characteristics. (Such relocations shall be at contractor's expense.)

9. Install louvered face air devices to minimize line of sight through the device from normal location of room occupants. Confirm with Architect/Engineer, as needed.

10. Avoid routing ducts above/through electrical or elevator equipment rooms or spaces dedicated for electrical or elevator equipment. (Exception: where duct serves only the electrical or elevator equipment rooms/spaces). Adjust schematic routings shown on drawings as required to accomplish this directive.

11. Where ducts penetrate floors or walls/partitions of mechanical and other similar rooms, frame penetration with minimum 4" x 4” steel angles (outside and clear of

any fire damper installation details). Seal angles at floor with silicone caulk to provide a watertight barrier to water on floor.

12. Penetrations Through Ducts: If required by unavoidable field conditions and if accepted by Architect/Engineer prior to penetrations and if performed on a limited basis, penetrate ducts with pipe using sleeved and insulated penetrations details consistent with SMACNA Standards.

13. Flow measuring stations: Provide flanged installations with adjacent access doors for installation, service, and removal of airflow measuring stations.

14. Dampers: Where dampers are to be installed within 6 duct diameters (upstream or downstream) of a branch tap, elbow, splitter or similar fitting, align the damper blade(s)/shaft with the direction of airflow in the respective duct.

    a. For horizontal trunks/branches/taps, install dampers with blades/shafts in the horizontal position.

    b. For vertical trunks/branches, including those with horizontal tops, align blades/shafts in the vertical positions.

    c. Plan blade/shaft damper orientation and provide damper construction/models to accommodate vertical blades where applicable.

    d. Install to provide an accessible condition for adjustment (including remote operations where needed).

15. Streamers: Provide color-coded ribbons of bright nylon or other suitable material at all above ceiling/concealed locations of manual or automatic dampers. Streamers shall extend from the device to approximately 6” above the ceiling grid.

16. Ceiling markers: Provide approximately ¾” diameter color-coded adhesive markers on ceiling grids or ceiling access panel below manual or automatic dampers.

D. Cleaning, Lubrication, and Initial Adjustments

1. Before operation of fans, install temporary/construction filters (outdoor, return, and supply as applicable to the particular system) for all fans that are operated during construction as determined by ASHRAE 52.2-1999 (including temporary MERV-8 through 14 filters as applicable or required). During construction installation must meet or exceed the recommended Control Measures of SMACNA IAQ Guidelines for Occupied Buildings under Construction, 1995, Chapter 3. Exceed those requirements where systems or conditions indicate such.

   Failure to do so shall subject entire duct system to replacement and/or extensive cleaning in place.

   New filters shall be installed after all construction dirt has been removed.

2. Ducts, plenums, and casings shall be thoroughly cleaned of all debris and vacuumed or blown free of all small particles of rubbish and dust before installing diffusers, etc.

3. Equipment (and ducts, where required by the Architect/Engineer) shall be wiped clean, with all traces of oil, dust, dirt or paint spots removed.

4. Bearings shall be properly lubricated with oil or grease as recommended by the manufacturer. Belts shall be tightened and adjusted.

5. All control dampers and other miscellaneous equipment requiring adjustment shall be adjusted to settings indicated or as directed. Fans shall be adjusted to the speed indicated by the manufacturer to meet specified conditions. Coordinate adjustments with Test, Adjust, and Balance Contractor.

E. Fire and/or Smoke Rated Penetrations

1. Where ducts pass through floors, walls/partitions, or ceilings having a required fire and/or smoke-resistive rating, such penetrations shall be constructed to provide the required fire-resistive rating.

2. In all cases, such penetrations shall be listed and approved assemblies and shall be made in accordance with the latest published edition of U.L. Fire Resistance Directory and the latest edition of relevant SMACNA publication(s).

3. **The contractor shall submit the proposed penetration detail from the Fire Resistance Directory for the Architect/Engineer's review.** In addition, the contractor shall be responsible for securing approval of such methods from authorities having jurisdiction.

4. In general, above grade floors of all multi-story structures shall be a minimum of two-hour rated unless otherwise indicated in Architectural drawings. Walls/partitions shall be rated in accordance with architectural drawings.

   When not indicated as requiring one-hour fire resistance, penetration in corridor partitions shall be sealed to achieve smoke tight conditions. Use sealing materials noted herein for fire-rated penetrations.

   Contact Architect/Engineer for clarifications, as needed.

5. Materials shall be similar and equal to Specified Technologies Incorporated “SpecSeal series” or “Pensil series” firestop system yielding a permanently resilient/flexible condition which allows minor movement in ductwork systems without compromise to the fire resistance and without damage to the partition/floor, etc.: sealant; wrap strip; mortar; putty; etc.

6. Also provide: fire-rated gypsum and/or Pabco "Super Fire Temp"; steel channels and angles; and other members required for the particular fire resistance and penetration method involved.

3.02 KITCHEN HOOD SYSTEMS

Provide coordination and interfaces, as required, for automatic shutdown of gas supply and/or electrical supply to kitchen equipment upon activation of kitchen hood fire suppression system.

3.03 INSTALLATION OF INSULATION SYSTEMS

A. General: Install all insulations in accordance with manufacturer's written instructions, with applicable SMACNA standards, with these specifications, AND IN THE BEST PRACTICES OF THE TRADE.

B. Complete, unbroken system: Finished insulation system (external insulations and internal liners) shall provide complete and continuous thermal barrier throughout the equipment and air distribution system, including effective and durable vapor barriers and vapor stops for all elements subject to condensation. Insulation system shall be provided to prevent condensation or potential thereof, to prevent transmission of water vapor into the insulation system (vapor barrier), and to prevent transmission of water vapor within the insulation system should vapor barrier compromises occur during operation/maintenance of the building (vapor stops).

1. Exception: Where SMACNA or product listing installation requirements prohibit insulation of fire, smoke, or fire/smoke dampers, in which case refer to drawings details.

C. Vapor stops:

1. Provide vapor stop condition to prevent migration of water vapor within the insulation system: at all insulation joints along the length of duct runs; at all duct fittings (elbows, splitters, taps, etc.); and at all unavoidable penetrations of the insulation system (e.g., damper rods, duct smoke detectors, control sensors.)

2. Note that duct hangers shall not be permitted to penetrate the vapor barriers.

3. Vapor stop shall typically consist of sealing the insulation joint to the duct (heavy duty FSK facing tape equal to NASHUA FSK 10.5 mil.), overlapping the sealant joint by a minimum of 6”, and sealing to the next insulation segment of the vapor stopped insulation segment. Confer with Architect/Engineer as required.

4. Refer also to drawing details.

D. Termination of insulation:

1. Where insulation terminates at: equipment (e.g., air handlers, fan coils, fans, terminal units); sleeves of fire, smoke, or fire/smoke dampers; duct sections, or other appurtenances in the air distribution system, provide glass fabric/mastic terminations and assure adhesion to all surfaces and vapor stop/vapor barrier condition.

E. Hangers systems:

1. Hangers for wrapped round duct shall be continuous "saddles," minimum 4" wide, outside the insulation (and mass-loaded vinyl, as applicable).

2. Hangers for wrapped rectangular duct shall likewise be outside the insulation and shall be: trapeze type constructed of threaded rods with inserts/beam clamps and "Unistrut" or angles; or continuous strap, minimum 2" wide, across the entire length of the duct bottom. ("Hat" channels shall not be acceptable materials for the trapeze.)

Refer also to drawings/details for related requirements.

F. Inserts: Provide insulation inserts or cushions as described in Part 2 above and as indicated by drawings.

G. Sequencing installations:

1. Install external insulation systems (duct wrap, Armaflex, etc.) prior to hanging of duct (at least at hanger locations), and atop ducts where clearances from duct to surfaces above would otherwise prevent proper installation).

2. Coordinate with electrical, controls, fire alarm, and other trades as required to install external insulations prior to the attachment of boxes, sensors, conduit, and other devices (or provide standoffs such that insulation can be properly applied after attachment).

   For any detectors, damper actuators, or similar electrical components installed outdoors, provide sheet metal rain shield to protect sides, back, and top, while leaving face exposed and accessible.

H. Retaining pins: Provide pins for external duct insulation at 24" on center, for all rectangular wrapped duct where the duct dimension exceeds 24". Any and all penetrations and/or joints of insulation shall be thoroughly vapor sealed and shall have mastic applied.

I. Repair damaged insulation: All cuts, tears, or other breaks in insulation system shall be repaired in accordance with manufacturer's recommended procedures. Where directed by Architect/Engineer, such insulation shall be replaced rather than repaired, and at Contractor's expense.

J. Insulations to improve acoustics:

1. Provide duct liner or other suitable noise absorbing material where needed in unlined supply, return or exhaust duct to reduce noise to desired and acceptable levels. Install at the direction of Architect/Engineer during Substantial Completion review(s). Coordinate with Architect/Engineer as needed.

2. Where indicated on drawings or in Part 2 above, install acoustical barrier (lagging). Install per manufacturer’s installation instructions. (Seal all joints and seams per manufacturer’s recommendations.)

K. Flexible elastomeric duct insulation systems (e.g., Imcosheet, Armaflex): duct corners and other similar conditions shall have square or mitered joints/cuts. Continuous bends around such conditions shall not be allowed (insulation will tear).

1. Alternatively, a “vee-cut” method of forming mitered corners (similar to that used to form fiberglass ductboard corners) may be used, pending Architect/Engineer's approval of a mock-up sample.

L. Overlap systems as required: Where insulation changes from only internal to external within a duct run, external insulation shall overlap interior liner by a minimum of 24”.

3.04 TERMINAL BOXES (INCLUDING AFMD ASSEMBLIES)

A. Safe and accessible: Install terminal units to provide readily and safely accessible conditions to all associated components: controllers and actuators, balance valves, control valve, strainers, filters, and other similar appurtenances.

B. Removable: For actuators installed internally to the box, provide conditions which allow readily removable supply duct connectors and readily removable air valve/actuator conditions.

C. Subject to Architect/Engineer acceptance**: As part of the submittal process, provide field mock-up(s) of typically installed conditions for Architect/Engineer review.** Accommodate directives which may accompany the mock-up(s). Installed conditions shall be subject to acceptance by Architect/Engineer, and any remedial actions shall be at the Contractor's expense.

3.05 AIR DISTRIBUTION ACCESSORIES

A. General:

1. Refer to drawings and to Part 2 above.

2. Provide supplemental duct system sealing as may be required to achieve acceptable duct leakage test results (e.g., at access doors, damper shafts/seals, terminal boxes, terminal box coils). Confer with Architect/Engineer regarding specific measures at particular components/conditions.

3. Provide reinforcements for fire and/or smoke and/or control dampers, as required to ensure proper strength and minimal deflection in all conditions that the damper will experience (including closed against maximum rated static pressure). **Submit shop drawings of reinforcements**.

3.06 TESTING AND BALANCING

A. Refer to Section 23 09 70 – Division 23 Testing, Adjusting, and Balancing.

3.07 CONTRACTOR'S COMMISSIONING

A. Provide all testing indicated by this Section. **Submit report immediately pursuant to each test**, detailing the test, date, procedures, results, and any scheduling for re-test. Testing/reporting shall include, but not limited to:

1. Leak testing of all duct systems, on a system to system, section by section basis as applicable. **Submit with electronic drawing format distinguishing each section tested.**

2. Verification of proper and complete installation of all acoustics products indicated by the project:

a. Sound attenuators

b. De-coupling layer and mass loaded laggings

3. Verification of proper and complete installation and operation of all terminal units, including controls, dampers, valves, power and control wiring to each, and piping.

B. Refer also to Section 23 00 10 - General Requirements for Mechanical Work.

3.08 VERIFICATION OF CONTRACTOR'S TESTING

A. Contractor's testing shall be subject to partial or complete verifications with Owner's representative(s) or, including but not limited to, the Architect/Engineer.

B. Schedule, organize and assist testing verifications as required. Refer also to Section 20 08 00, and perform work as described therein.

END OF SECTION

SECTION 23 09 50 - VARIABLE FREQUENCY DRIVES

The General Conditions, any Supplementary General Conditions, and Division 1 - General Requirements are hereby made a part of this Section as fully as if repeated herein.

PART 1 - GENERAL

1.01 SCOPE

A. Provide all project VFDs under this Section.

1. Exception: Those contained within or as a part of manufactured equipment.

B. Coordinate VFDs with supplemental requirements which may exist in other Division 23 specification sections, including but not limited to the Related Sections identified in 1.04 below.

1.02 QUALITY ASSURANCE AND WARRANTY

A. Testing agency qualification: Accredited by NETA.

B. Refer also to Part 2 herein.

1.03 RESPONSIBILITY

A. Manufacturer approved applications: VFDs provided under this Section shall have their application(s) closely examined by the manufacturer, Manufacturer shall, by providing its product(s), warrant that they are suitable for the intended applications.

B. Controls Compatibility: It is intended that VFDs provided under this Section be an integral part of the Controls/Building Automation System (BAS). Accordingly, it is intended they be bid, submitted, and procured by the Building Automation Contractor (BAC) so that the BAC can assure the features and operation of the VFDs are consistent with its BAS.

1. If the VFDs are provided by a party other than the BAC, such party shall be responsible for assuming the coordination and compatibility intent is fully satisfied in accordance with the judgment of the Engineer of Record.

1.04 RELATED SETIONS INCLUDE, BUT ARE NOT NECESSARILY LIMITED TO:

A. Division 22 (Plumbing)

B. Division 23 01 00 – General Requirements for Mechanical Work

C. Division 23 01 00 - Basic Materials and Methods

D. Division 23 01 60 – Pumps

E. Division 23 08 58 – Custom Air Handling Units

F. Division 23 08 60 - Fans

1.05 REFERENCED STANDARDS AND GUIDELINES

A. IEEE 519-2014, IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems

B. Underwriters Laboratories (as appropriate to the application)

1. UL 508, 508A, 508C

2. UL 61800, 61800-5-1, 61800-5-2

3. UL 1995

C. The National Electric Manufacturers Association, NEMA ICS 7-2014, Adjustable Speed Drives

D. International Electrotechnical Commission, EN/IEC 61800

E. National Electric Code

F. CSA Group, CSA C22.2 No. 274

G. International Building Code, IBC 2018 Seismic – referencing ASCE 7-16 and ICC AC-156

1.06 SUBMITTALS

A. **General:** Refer to the requirements of Section 23 00 10-General Requirements for Division 23 work.

B. **Spec-copy Mark-ups: Submit annotated copies of these specifications (spec copy mark-ups) to demonstrate compliance and/or to clearly identify proposed departures from these specifications.**

C. **Product Data: Submit full catalog data, performance/summary specifications data sheet(s), and operating and maintenance (O&M) manuals.** Data shall include, but not be limited to:

1. Dimensions and finishes

2. Rated capacities, operating, characteristics and related specialties and accessories

3. Mounting and attachment details

4. Weights, loads, required installation and working clearances in all directions, method of field assembly (where applicable), and location and size of each field connection.

5. Diagrams for power, signal, and control wiring.

6. Shop drawings illustrating VFDs in intended/proposed locations.

PART 2 - PRODUCTS

2.01 COMMON REQUIREMENTS AMONGST VFDs

A. Units suitable for:

1. Operation of NEMA MG 1, Design A and Design B motors, as defined by NEMA MG 1, Section IV, Part 30, “Application Considerations for Constant Speed Motors Used on Sinusoidal Bus with Harmonic Content and General Purpose Motors Used with Adjustable-Voltage or Adjustable-Frequency Controls or Both”

2. Operation of inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, “Definite-Purpose Inverter-Fed Polyphase Motors”

B. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.

C. Design and Rating: Match load type, such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.

1. VFD shall be selected and sized to permit operation of respective motor into its service factor at any operating condition (typically 1.15 S.F.)

D. VFD Physical Size: The VFDs shall fit into the space allotted for them in the drawings. It shall be the joint responsibility of the manufacturer/vendor and contractor to verify such fit, with appropriate clearances, **prior to submittal**.

E. Integral Bypass System (included in VFD enclosure)

1. General

a. Application: all fans, pumps, and other driver equipment when in single or tandem/dual configuration.

1) Exception: bypasses are not required when there or more fans, pumps, and other drivers equipment are operated and controlled together and are designed for an “N + 1” redundancy.

b. Service nameplate: All VFDs with integral bypass shall have safety nameplate of manufacturer’s choice clearly prohibiting VFD service while operation in the bypass mode.

2. Two Contactor Manual Bypass. VFD and bypass package shall be NEMA 1 or 3R rated, according to the application, fully pre-wired as a packaged assembly and ready for installation as a single UL listed device. Bypass shall include the following:

a. Drive output and bypass contractors, to isolate the VFD from the motor, when the motor is running in the bypass mode. These contractors shall be electrically and software interlocked to ensure safe operation.

1) Soft start bypass

b. Main input circuit breaker with a pad-lockable handle operation mechanism, able to achieve a SCCR panel rating of 100kAIC.

c. 120 VAC control transformer, with fused primary.

d. Motor overload relay, to protect the motor while operating in the bypass mode.

e. Control and safety circuit terminal strip.

f. Current transformers on the output of the Drive/Bypass package for displaying motor current in both modes of operation as well as verification that the motor is running.

g. Provide BACnet, Metasys N2, Siemens P1 Apogee, and Modbus communication protocols as standard, with the ability to configure controller parameters view controller monitors, control I/O, clear faults and view controller status in both drive and bypass modes.

h. Door mounted control keypad with; Drive/Bypass selector keys, Hand/Off/Auto selector keys, Normal/Test selector keys.

i. Door mounted control keypad with LCD display for “Control Power”, “Drive Ready”, “Drive Run”, “Drive Selected”, “Drive Fault”, “Drive Test”, “Bypass Selected”, “Bypass Run”, “Motor OL”, “Safety Open”, “BAS Interlock”, “Auto Run”, Auto Transfer”, “Smoke Purge”, “Hand Mode”, “Off Mode”, and “Auto Mode”.

j. Hand/Off/Auto selector keys shall provide the following operation and be programmed to operate in any of these modes upon power-up:

    1) Hand Position – The drive is given a start command; operation is via the local speed input (digital operator/keypad). If in the bypass mode, the motor is running.

    2) Off Position – the start command is removed, all speed inputs are ignored, power is still applied to the drive. If in bypass mode, the motor is stopped.

    3) Auto Position – The drive is enabled to receive a start command and speed input from a building automation system. If in by bypass mode, the motor start/stop is controlled by the building automation system.

k. Eight programmable digital inputs (24Vdc, 8mA) shall be provided for Auto Transfer to bypass, Safety Interlock, BAS Interlock, and numerous other bypass specific functions.

l. Four Programmable form C relays (24Vdc/120 VAC, 2 Amp) for: “Motor Run”, “Damper Actuator”, “Auto Transfer”, “Drive Run”, “Hand Mode”, “Auto Mode”, “System Fault”, “Bypass Run” or “Serial Com Run”.

m. Damper control circuit with end of travel feedback capability. This circuit shall also include two adjustable wait time functions. One is a run delay time where the drive will operate at a preset speed before the damper opens to pressurize the system. The other time function is an interlock wait time, so if the damper has not fully opened within the specified time, a fault will be declared.

n. Line voltage sensors to monitor for brownout, blackout and single phase conditions.

o. Safety tag: Provide nameplate to instruct operating/service personnel not to perform maintenance on VFD when in bypass mode, even if the input circuit breaker is closed. Specific wording to be by manufacturer.

F. Multiple Motor Operation: Two motor “OR” control; Multiple motor “AND” control shall be provided.

a. Two motor “OR” control allows local or remote motor operation selection between two individual motors (motor #1 “OR” motor #2)

b. Multiple motor “AND” control allows the operation of several motors from one drive (motor #1, motor #2, “AND” motor #3 are operated at the same speed via the output from one drive).

G. Motor winding heater: All VFDs shall include motor winding heater function to prevent condensation in the motor, application includes chilled water pumps, condenser water pumps, AHUs processing outdoor air or operation in cooling mode, and other motors as may apply.

H. Other common features:

1. Serial communication capability for BAS protocols as apply (BACnet, Modbus, MetaSys, Echelon LonWorks and EtherNet/IP).

2. PC software and cable for parameter upload/download/graphing.

3. Drive Service Switch.

4. “Aegis” shaft grounding rings.

I. Qualifications

1. Drives shall be UL labeled as a complete assembly. The base VFD shall be UL listed for 100 kA SCCR when installed in accordance with the manufacturer’s guidelines.

2. The base drive shall be seismically certified and labeled as such in accordance with the latest published edition of International Building Code (IBC).

3. The base drive shall be SEMI-F47 certified. The drive must tolerate voltage sags to 50% for up to 0.2 seconds, sags to 70% for up to 0.5 seconds, and sags to 80% for up to one second.

4. Others as stated in these specifications.

J. Warranty

1. Warranty shall extend for one (1) year from the date of Substantial Completion. Warranty shall cover all parts and labor, including labor to test for harmonic compliance or other trouble shooting potentially involving the VFD(s).

2. Exception: Warranty shall extend for three (3) years from the date of Substantial Completion for compliance testing in accordance with 2.02.E.4.d.

2.02 VARIABLE FREQUENCY DRIVES: SIX PULSE WITH PASSIVE FILTER

A. General

1. Provide variable frequency drives (VFD) with microprocessor controlled PWM output as indicated on the drawings and as specified herein to control speed of: air handling units, fans, pumps, and other equipment indicated herein or on the drawings.

2. One enclosure: All standard and specified optional features shall be included within the VFD enclosure unless otherwise specified.

3. VFD shall be approved by the equipment and motor manufacturer for the particular product(s) and application(s) involved. **Submittal shall include evidence of such approval.**

4. One manufacturer: All the VFDs shall be supplied by one manufacturer.

5. Application: The variable frequency drive shall convert three-phase, 60 Hz input power to adjustable voltage and frequency, three-phase, AC power for stepless motor speed control for standard NEMA Design A and B induction/asynchronous and permanent magnet manufacturer shall verify compatibility of VFD with all motors driven by VFDs **prior to submittals**.

6. Voltage/disconnecting means: Input voltage shall be as specified on the drawings. VFDs shall satisfy requirements for disconnecting means required by the NEC, and shall be provided with lock-out/tag out functionality.

7. Compatible with driven motors: The drive shall produce an output volts/Hertz pattern to produce adequate starting torque under all conditions and operate smoothly at all operating speeds on variable torque load.

8. Enclosure and environmental: The VFD shall be self-contained totally enclosed in NEMA I ventilated cabinet, and rated for continuous operation in ambient conditions between 0 and 122°F (provide derated drive of larger size where required to achieve ambient operating conditions), 95% RH (noncondensing). Altitude 0 to 3300 feet.

a. NEMA 3R: Provide NEMA 3R enclosure where VFD is located outdoors or in wet areas.

9. EMI/RFI filters: All VFDs shall include EMI/RFI filters. The VFD shall comply standard EN 61800-3 for the First Environment, restricted level of up to 100' of motor cables. No Exceptions. Certified test lab test reports shall be **provided with the submittals**.

10. Enclosure, AIC ratings:

    a. All components shall be self-contained and totally enclosed factory mounted and wired on a dead-front, grounded, freestanding or wall mounted enclosure (minimum NEMA I) arranged for top or bottom conduit entry.

    b. VFD shall be listed for 100 KAIC without the need for input fuses or additional branch circuit protection.

11. Testing: The VFD and options shall be built and tested to ANSI/UL standard 508. The complete system shall be listed by a nationally recognized testing agency such as UL or ETL.

B. Operation/User Interface

1. General: All VFDs shall have the same customer interface, including digital display, and keypad/control panel, regardless of horsepower rating.

2. Advanced Control panel features shall include, but not be limited it, the following:

    a. Keypad: removable, capable of remote mounting (up to 100 ft.) and allow for uploading and downloading of parameter settings as an aid for start-up of multiple VFDs. Drive shall be capable of operation with keypad removed.

        1) If indicated, remote mount the control panel as shown on drawings.

    b. Plain English text: The display shall be in complete English words for programming and fault diagnostics (alpha-numeric codes are not acceptable).

    c. Keys/control selections: Four navigation keys and two soft keys; Hand-off-Auto selections and manual speed control; fault reset and help keys.

    d. Multiple Home View screens: capable of displaying up to 21 points of information.

    e. A single screen display of: output frequency, output current, reference signal, drive name, time, and operating mode.

    f. A built-in time clock: with a battery backup with 10 years minimum life span.

    g. I/O Summary display with a single screen

1) The status/values of all inputs, and outputs. Drives that require access to internal or live components to measure these values, are not acceptable.

2) The programmed function of all inputs, outputs.

3) The ability to force individual digital I/O high or low and individual analog I/O to desired value, for increased personal protection during drive commissioning and troubleshooting. Drives that require access to internal or live components to perform these functions, are not acceptable.

h. Automatic backup parameters: Backup files shall include a time and date stamp. In the event of a drive failure, the control panel of the original drive can be installed on the replacement drive, and parameters from that control panel can be downloaded into the replacement drive.

i. Local technical support display: provides contact information as part of drive fault status.

j. Stored screen shots: downloadable via USB.

k. Start-up assistants: specifically designed to facilitate start-up. Include: First Start Assistant, Basic Operation, Basic Control, and PID Assistant.

l. Bluetooth Control: support of a Bluetooth Advanced Control Panel which is FCC and QDL (Qualified Design Listing) certified.

C. Standard hardware features/characteristics:

1. Analyze inputs: minimum of two (2) programmable analog inputs using current or voltage signals. Drives that require access to internal components to perform these functions are not acceptable.

2. Analyze outputs: minimum of two (2) programmable analog outputs, at least one of which shall be adjustable for current or voltage signal. Drives that require access to internal components to perform these functions, are not acceptable.

3. Digital inputs: minimum of six (6) programmable digital inputs.

a. All digital inputs shall be programmable to support both active high and active low logic, and shall include adjustable on/off time delays. The digital input shall be capable of accepting both 24 VDC and 24 VAC.

4. Relay outputs: minimum of three (3) programmable Form-C relay outputs rated for a continuous current rating of 2 Amps. Maximum switching voltage of 250 VAC/30VDC.

a. Open collector and Form-A relays are not acceptable.

b. Drives that have less than (3) Form-C relay outputs shall provide an option card to provide additional relay outputs.

5. Terminal blocks: color coded for easy identification of function.

6. USB interface: isolated USB port for interface between the drive and a laptop. A non-isolated USB port is not acceptable.

7. Auxiliary: rated at 24 VDC, 250 mA.

D. Standard software/characteristics:

1. Fault Logger: stores the last 16 faults in non-volatile memory.

2. Event Logger: stores the last 16 warnings or events that occurred, in non-volatile memory.

3. Programmable start method: selectable based on the application: Normal start, Flying-start, and Brake-on-start (stopping reverse rotation before accelerating forward).

4. Programmable loss-of-load (broken belt/ coupling) indication: selectable as a control panel warning, relay output, or over network communications. Includes a programmable time delay to mitigate false loss-of-load indications.

5. Power metering: Advanced functionality with the following minimum data points:

a. Input Current (A); Input Voltage (V); Input Power (kW), also broken down by active, reactive, and apparent power components.

b. Total power broken down by kWh, MWh, and GWh units of measurement.

c. Time-based kWh metering for: current hour, previous hour, current day, and previous day.

d. Energy saving calculation that shows the energy and dollars saved by the drive.

6. Motor flux optimization: optimization circuit that automatically reduces applied motor voltage to the motor to optimize energy consumption and reduces audible motor noise.

7. Run permissive circuit: for damper or valve control. Regardless of the source of a run command, the Drives shall provide a dry contact closure that will signal the damper to open. When the damper is fully open, an end-switch shall close, allowing the drive to run the motor. The drive shall also include a programmable start delay, for when and end-switch is not provided.

8. Start interlock circuit: Four separate start interlock (safety) inputs. When any safety is opened, the motor shall be commanded to stop. The control panel displays the specific safety(s) that are open. The status of each safety shall be transmitted over the network communications. Wiring multiple safeties in series is also acceptable if so indicated by the drawings.

9. External fault circuit: Three separate external fault input circuits shall have the same features and functionality as the start interlock circuit, except it shall require a manual reset before the drive is allowed to operate the motor.

10. Frequency switching control circuit: reduces the switching frequency based on actual drive temperature, and allows higher switching frequency settings without derating the drive. Adjustable minimum and a target switching frequency.

11. Visual block adaptive programming: allows custom control schemes, without external controllers. A free software tool shall be used to configure adaptive programming.

12. Automatic re-start: after an over-current, over-voltage, under-voltage, external fault, over temperature or loss of input signal protective trip. Restart attempts, trial time, and time between attempts shall be programmable. Faults may have automatic restart individually disabled.

13. Lockout ranges: three (3) programmable critical frequency lockout ranges to prevent the drive from operating the load continuously at an unstable speed/load.

14. Preset frequencies: seven (7) programmable preset frequencies/speeds.

15. Acceleration/deceleration: two independently adjustable accel and decel ramps with 1-1800 seconds adjustable time ramps.

16. PID functionality: Include: programmable “Sleep” and “Wake up” functions to allow the drive to be started and stopped based on the level of a process feedback signal, and; an independent PID loop for customer use, assigned to an Analog Output.

17. Parameter memory/recall: at least 4 parameter user sets that can be saved to the permanent memory and recalled using digital input, timed function, or supervision function.

18. External power source/UPS functionality: drive shall allow the control board to be powered from an external 24 VDC/VAC source, allowing the drive control to remain powered by a UPS during an extended power outage.

19. USB powered laptop interface: computer-based software tool shall allow a laptop to program the drive, supporting programming without the need for line voltage.

20. Fire override mode: Upon receipt of a contact closure from the Fire Alarm System, the drive shall operate in a dedicated Override mode distinct and separate from the drive’s Normal operation mode. The following features shall be available in the drive override function:

    a. Secured by password to prevent changes once programmed.

    b. Ignore external inputs and commands not defined as part of the override function.

    c. Selectable between: signal frequency, multiple fixed frequencies, follow an analog input signal, PID control, or come to a forced stop.

d. High priority safeties shall stop the drive and lower priority safeties shall be ignored in Override mode.

e. Drive faults shall be defined in Critical and low priority groups. Critical faults shall stop the drive. Low priority faults shall be reset. Reset trials and timing shall be programmable.

f. Configurable to receive from 1 to 3 discrete digital input signals and operate at up to three discrete speeds.

21. Intelligent multi-motor functionality: The drive shall have multi-pump (or fan) functionality and an intelligent master/follower configuration for controlling up to 8 parallel pumps equipped with drives.

E. Harmonic mitigation

1. Harmonic mitigation hardware shall be provided to limit the current and voltage distortion to 3% total harmonic current distortion, when measured at the lugs of the drive. The harmonic mitigation hardware shall be internal to the drive package and include, at a minimum, the following characteristics:

a. An active front end, IGBT based design, shall be used for mitigation of low frequency harmonics.

b. Each phase of the drive shall be constructed with an input T-Series LCL (inductor-capacitor-inductor) line filter to remove high frequency harmonics.

c. The drive shall provide full motor nameplate voltage while operating the motor at nameplate RPM. The output IGBTs must be modulating and in control of the motor during this 100% speed/load operating condition. The specified 3% current and voltage distortion and 1.0 displacement power factor shall be achievable during this operating condition.

d. The hardware structure of the front end shall boost the DC bus voltage by 10% during low line conditions. Active front end solutions without a boost feature are not acceptable.

e. Displacement power factor shall be 1.0 throughout the speed range. The displacement power factor shall also be programmable to provide a specific leading or lagging power factor value, based on the system needs.

f. The combined harmonic content of all the drives on the project must be small enough to not interfere with an emergency generator’s voltage regulator. Drives capable of regeneration shall not be allowed on applications with a generator.

2. Supplemental requirements regarding line noise, filters, reactors, and harmonics

a. The VFD shall not emit either conducted or radiated RFI in excess of the limitations set forth in the FCC Rules and Regulations. The VD shall not cause objectionable acoustical motor noise, or as determined by the Owner or Engineer.

b. Total effective source impedance of harmonic mitigation devices shall not exceed 8% at full load.

c. Individual or simultaneous operation of all VFD's provided in this project shall not add more than 5% total harmonic voltage or current distortion while operating a full load and speed from the utility source, or from standby generator. (Maximum input voltage unbalance shall be 0.5% as defined in NEMA MG 1 section 14.35.2.)

3. Part load/speed harmonics: In addition to the requirements for 100% speed/load operation in E.1 above, the maximum allowable harmonic current and voltage demand distortion limits for part speed/part load conditions shall not exceed the following (with pint of common coupling at the lugs of the drive.

a. 75% load: 8% total distortion (based on 60 Hz full load operation)

b. 50% load: 52% total distortion (based on 60 Hz full load operation)

c. 25% load: 95% total distortion (based on 60 Hz full load operation)

4. Manufacturer's harmonic analysis:

a. The VFD manufacturer shall perform full load/full speed harmonic analysis based on the electrical one-line/riser diagram and approximate feeder/conductor lengths established by the Contractor. **Results shall be included in VFD submittals.**

b. If short circuit current is unknown: The short circuit current used for harmonic calculations shall be estimated by the VFD Manufacturer, but shall not be less than the total full load current with all VFD's operating multiplied by twenty (Example: (5) 100 HP VFD's full load current = 5 x 126 amps x 20 = 12,600.

c. Filters: If harmonic filters are required to meet these requirements, the VFD manufacturer must provide, as a minimum, 5^{th}, 7^{th}, and 11^{th} harmonic filters and is responsible for the design and manufacturing of the filters. The vendor must supply cabling and installation for the filter. The filters are to be provided with a separate contactor such that the VFD can operate in the event of a filter failure. Failure of a filter shall not cause the entire drive system to shut down. **Where total electrical distribution system is new, a preliminary harmonic analysis must be submitted by the VFD manufacturer with the submittal, which includes all voltage and current harmonics up to the 99^{th}. Failure to supply this harmonic analysis will result in rejection/resubmittal.**

d. Compliance: If directed by the Architect/Engineers, harmonic compliance shall be verified with onsite field measurements by the Manufacturer of both the voltage and current harmonic distortion at the drive input terminals with and without the VFD's operating. A recording type Fluke 41 or equivalent harmonic analyzer displaying individual and total harmonic currents and voltages shall be utilized. Such direction may be given by Architect/Engineer or by Owner's Commissioning Authority (CxA) prior to Substantial Completion, or at any time within three years after substantial

completion, if potentially related problems are suspected or have occurred. Such verification shall be at the Contractor's Manufacturer's cost as part of the manufacturer's warranty.

5. VFD system shall maintain a 0.95 minimum true power factor throughout the entire speed range.

6. Submittals shall include analysis with written statement of compliance with harmonics, distortions, power factor and noise requirements of IEEE 519 and those specifications.

F. Self-protection and reliable operation features: At a minimum include:

1. Overcurrent protection: Inverse- time overcurrent protection when current exceeds setting.

2. Undervoltage protection: trip to protect the inverter from non-momentary power or phase loss. Trip shall activate automatically when the line voltage drops 10 – 20% (adjustable, initially set at 10%) below rated input voltage.

3. Overvoltage protection: trip to protect the inverter due to voltage levels in excess of 10 – 20% (adjustable, initially set at 10%) above nominal line voltage.

4. Over temperature protection: trip to protect the inverter from elevated temperatures in excess of component rating. Trip indicator illuminates continuously.

5. Power loss safe shutdown: with automatic return to normal operation and restart (without component damage) on resumption of power.

6. Short circuit/phase loss safe shutdown: without component damage where safe operation cannot continue with remaining phases.

7. Power component failure protection: Integral protection against damage due to input or output power contactor, disconnect switch, or circuit breaker being opened or closed while the control is activated.

8. Input transient voltage spikes.

9. Over voltage on the DC bus.

10. Output short circuit and motor winding shorting to case faults.

11. Display for indication of individual fault conditions.

12. No load operation – Controller shall be able to operate continuously without motor or any other equipment connected to the inverter output to facilitate start-up and troubleshooting and to allow abnormal operation, without damage to the VFD.

For VFD's with multi-motor operation, VFD able to operate with any combination of motor outputs disconnected or placed in the off position (for example, at disconnects external to the VFD).

Include provisions (input and output) to operate with a 4-20ma or 0-10VDC as needed (now or in future), under this Section.

G. Manufacturer's Testing

1. To ensure quality and minimize infantile failures at the job site, the VFD shall be burned in by the manufacturer. The VFD shall operate a dynamometer at full load and the load and speed shall by cycled during the test.

2. All optional and special features shall be functionally tested at the factory for proper operation.

3. **Records of this factory testing shall be provided with VFD shipment and in Records for Owner.**

4. Refer also to 2.02.E.4.d for on-site compliance testing.

H. Contractor's Commissioning – Factory Start-up

1. Provide factory startup by factory authorized personnel.

2. Start-up shall occur after pre-functional testing has demonstrated start-up readiness, and before initiation of contractor's functional performance testing. Sales personnel shall not be acceptable. **Provide and submit a certified report on the start-up**, listing the drive and motor nameplate data, name of the driven equipment (e.g. AHU-1, Fan-1, CHWP-1 etc.), and start-up data pertinent to proper drive operation.

3. Start-up report shall be signed by the certified service technician performing the start-up **and reports shall be submitted in the same quantity and to the same contractor as other submittals of this section**.

4. **Start-up report submittal shall be required prior to scheduling the Substantial Completion Site Visit.** Coordinate submittal with TAB submittal to occur prior to Substantial Completion Site Visit.

I. Parts and Spare Parts

1. VFD parts and service must be available on a local or regional (within 100 mile radius) basis.

2. Spare Parts: for all VFD's, provide spare parts according to the following (excepting spare parts on bypass feature components):

a. One complete VFD assembly, including input reactors/filters and bypass features where applicable, for each size (hp) of VFD provided in the project.

J. Approved Manufacturers

1. Basis of Design: ABB 550 with Passive Filter

a. Provide with Active Front-End or indicated herein.

2. Substitute manufacturers:

   a. Siemens

   b. Yaskawa

   c. Danfoss

PART 3 – EXECUTION

3.01 EXAMINATION

A. Examine areas, surfaces, and substrates to receive VFDs, with manufacturer's technician present, for compliance with requirements for installation tolerances, and other conditions affecting performance of the Work.

B. Examine VFD before installation. Reject VFDs that are wet, moisture damaged, mold damaged, or cabinet damaged.

C. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFD installation.

D. **Prepare and submit written report, endorsed by manufacturer's start-up technician, listing any conditions not complying with manufacturer's installation instructions and conditions potentially detrimental to performance of the Work.**

E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.02 INSTALLATION

A. Wall-Mounted VFDs: Install with tops at uniform height and with disconnect operating handles not higher than 78 inches above finished floor, unless otherwise indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall. For controllers not on walls, provide freestanding racks.

B. Floor-Mounted VFDs: Install VFDs on 4-inch nominal thickness reinforced concrete base.

   1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base. Tile/secure dowel rods to pad reinforcement.

   2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.

   3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

   4. Install anchor bolts to elevations required for proper attachment to supported equipment.

C. Install fuses in each fusible-switch VFC.

D. Install fuses in control circuits if not factory installed.

E. Install heaters in thermal-overload relays. Select heaters based on actual nameplate full-load amperes after motors are installed.

F. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.

G. Comply with NECA 1.

3.03 CONTROL WIRING INSTALLATION

A. Install wiring between VFDs and remote devices and BAS, as applicable.

B. Bundle, train, and support wiring in enclosures.

C. Connect selector switches and other automatic-control devices where applicable.

1. Connect selector switches to bypass only those manual- and automatic-control devices that have no safety functions when switches are in manual-control position.

2. Connect selector switches with control circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor-overload protectors.

3.04 IDENTIFICATION

A. Identify VFDs, components, and control wiring. Comply with requirements for identification specified in Section 23 05 91 and in Division 26.

1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.

2. Label each VFD with engraved nameplate.

3. Label each enclosure-mounted control and pilot device.

B. Operating Instructions: Frame printed operating instructions for VFDs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFD units.

1. Oher means of installation may be acceptable if proposed by contractor and accepted by A/E.

3.05 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Contractor shall engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

B. **The factory-authorized service representative shall perform tests and inspections.**

1. Acceptance Testing Preparation:

   a. Test insulation resistance for each VFD element, bus, component, connecting supply, feeder, and control circuit.

   b. Test continuity of each circuit.

2. Tests and Inspections - at a minimum:

   a. Inspect VFD, wiring, components, connections, and equipment installation.

   b. Test insulation resistance for each VFD element, component, connecting motor supply, feeder, and control circuits.

   c. Test continuity of each circuit.

   d. Verify that voltages at VFD locations are within 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify **Contractor / Construction Manager** before starting the motor(s).

   e. Test each motor for proper phase rotation.

   f. Perform tests according to the Inspection and Test Procedures for Adjustable Speed Drives stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.

   g. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

   h. Warranty Phase Testing: Perform the following infrared (thermographic) scan tests and inspections, and prepare reports:

      1) Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each VFD. Remove front panels so joints and connections are accessible to portable scanner.

      2) Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each VFD 11 months after date of Substantial Completion.

      3) Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

      4) Refer also to compliance testing specified in 2.02.E.4.d.

   i. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

3. VFDs will be considered defective if they do not pass tests and inspections.

4. **Prepare and submit test and inspection reports.** Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

    a. Include a certified report in Warranty Phase that identifies the VFD and describes scanning results.

3.06 ADJUSTING

A. Program microprocessors for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after Commissioning Authority's (CxA) final acceptance testing and prior to Substantial Completion.

B. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.

C. Adjust the trip settings of instantaneous-only circuit breakers and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements unless recommended otherwise by the VFD and motor manufacturers:

1. Initially adjust to 6 times the motor nameplate full-load amperes and attempt to start motors several times, allowing for motor cool-down between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping.

2. Do not exceed 8 times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required).

3. Where these maximum settings do not allow starting of a motor, notify **Contractor/Construction Manager** before increasing settings.

D. Set the taps on reduced-voltage autotransformer controllers.

E. Set field-adjustable circuit-breaker trip ranges as indicated by Coordination Studies. Coordinate with Division 26 trades.

F. Set field-adjustable pressure switches where applicable.

3.07 PROTECTION

A. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until controllers are ready to be energized and placed into service.

B. Replace VFDs whose interiors have been exposed to water or other liquids prior to Substantial Completion.

END OF SECTION

SECTION 23 09 51 - CONTROLS AND INSTRUMENTATION

The General Conditions, any Supplementary General Conditions, and Division 1 - General Requirements are hereby made a part of this Section as fully as if repeated herein.

PART 1 - GENERAL

1.01 SCOPE

A. General

1. Complete System: Provide a complete working Building Automation System (BAS) of Direct Digital Controls (DDC), including any and all instrumentation necessary for a complete automatic control system as indicated by the requirements of the drawings and as specified herein. System shall be designed and installed so as to obtain all functions and results necessary or appropriate for the system(s), and as indicated by the Drawings and as hereinafter specified. System shall be based on most current/latest version of hardware and software of the particular manufacturer.

2. General BAS requirements: The automatic temperature control system shall be a microprocessor based, Direct Digital Control (DDC), Building Automation System (BAS) utilizing a combination of electric/electronic components, as indicated. The entire system shall be provided by a qualified Controls Contractor or Subcontractor, and shall be installed by competent technicians regularly employed in the specialty of HVAC controls.

a. Open protocol: BAS shall support BacNet open communication protocol and shall integrate a wide variety of third party devices, applications, and communication protocol.

b. System/installation shall include control devices/components, and all associated electrical conduit and conductors.

c. Shielded bus/cabling: The Controls Contractor/subcontractor shall provide all necessary shielding and installation techniques required for protection against interference by external voltages.

d. Proximity for service: The manufacturer shall maintain facilities within 100 miles of project site for installation, maintenance, and service, including 24 hour per day availability.

e. Equipment coordination and interface: Coordinate with equipment controls in other Sections to accomplish sequences, monitoring, and alarms as intended. Provide gateways for differing protocols between the BAS and the equipment.

3. Work includes, but is not necessarily limited to:

a. Delegated design of control system details

b. Submittals

c. DDC, electronic, and electric hardware

d. Control panels, with ventilation as required

e. Functionality: DDC data base/programming/interactive color graphics using communication described below, with appropriate security to prevent system intrusion by unauthorized parties

1) Owner's LAN communication where Owner provides and maintains a suitably secured and controlled network through its Information Technology system(s).

f. Installation: including all related electrical wiring, tubing, ports, wells, etc.

g. Testing/Commissioning Contractor's full and complete system commissioning/testing, including but not limited to:

1) Manufacturer's factory start up and calibration

2) All safeties, including hard-wired interlocks, BAS programmed safeties, and fire alarm interface/coordination safeties

3) Cooling season and heating season operation (separate procedure for each season as may be needed)

4) All sequences of operation, including:

a) event initiated sequences, reset sequences; failure recovery sequences, start-up, shutdown, and re-start sequences; and annunciations, alarms, and remote notifications.

b) All coordination with equipment manufacturer's for proper systems operation

5) Support to all of Prime Contractor's other/related systems commissioning activities as may apply to the particulars of the project

6) Completion of all commissioning requirements as identified in this Section, including Section 5.05- COMPLETION AND TESTING.

7) **Submission of report certifying completed testing and commissioning and proper operation for each season**.

8) Completion of all commissioning requirements as identified in Section 5.06– VERIFICATIONS OF CONTRACTOR'S COMMISSIONING. Verifications shall be subject to full and comprehensive scope, according to the discretion or the scope of those performing the verifications.

h. Owner instruction and training: including course development for the particular system and Owner.

i. Operating manuals as described in Section 5.07– OPERATION AND MAINTENANCE MANUALS AND CONSTRUCTION RECORDS

j. Warranty replacement and service including the monthly warranty work required by Part 4.

4. Work includes all electrical: ALL electrical work associated with this system shall be performed under this section of these specifications, including: any related 120V electrical work not indicated by electrical drawings (Division 26) that may require connections at panelboards (circuits dedicated for HVAC control, spare circuits with unassigned circuit breakers, and/or available spaces requiring installation of circuit breakers); and related distribution to and for the controls system.

a. Refer also to Section 2.02- ELECTRICAL.

5. Coordination: It shall be the responsibility of the Division 23 Contractor to ensure all controls work is properly coordinated.

B. Project-specific control work: Refer to other specification Sections, Part 3 herein, drawings (including control schematics and sequences of operation), and requirements of equipment manufacturers as may relate to the work of this Section.

C. Control System Overview

1. Provide a new building HVAC control system to interface with the existing campus controls system.

2. The system shall be fully current technology and performance, and of modular design consisting of:

a. Web Server/Interface; Network/Central Controllers (CC); equipment controllers (EC); device controllers; specific application, component, and terminal controllers (TCs); other controllers as needed/applicable

b. Meters, sensors, transmitters, transducers, actuators, etc. as herein specified and as otherwise required for a properly functioning system.

3. Full monitor and control and graphic functions with all related interactive color graphics are to be performable:

a. from an existing satellite work station located as coordinated with the Owner;

b. from Portable (Laptop computer) work station(s) via input into any controller

c. HVAC systems or building components shall be monitored at and controllable from the Campus BAS central systems.

4. The Work Station(s), Network/Central Controllers (CC), Equipment Controllers (EC), device controllers, and other controllers, shall be based on a distributed

system of fully intelligent, stand alone controllers, operating in a multi-tasking, multi-user environment

5. The system shall include all: computer hardware and software, operator input/output devices, power supplies, uninterruptible power supplies, controllers, bus cabling, local area networks, sensors, control devices, actuators, and all other necessary devices required in order to perform the HVAC sequences and monitoring/status/ alarm/programming intents indicated in this section, other sections, and the accompanying drawings.

   a. UPS – Uninterruptible Power Supply: Refer to 2.02R. Provide in ventilated cabinet.

6. LAN Operation:

   a. Provide a dedicated network communications trunk (NCT) between DDC panels and a separate LAN communications network between each terminal unit controller (or group of controllers) back to the DDC panel associated with the AHU which serves the terminal units (or with other respective equipment). In addition, the NCT shall be extended from the nearest Panel to an Owner-provided network drop(s) location.

   b. System hardware/software shall operate on a dedicated controls (BAS) Local Area Network of open protocol equal to certified BAC Net, Echelon “Lonmark”, or other open protocol acceptable to Owner. Provide building level controllers, switches, etc. with Ethernet IP connectivity capability via CAT-6 cable and port connection(s).

7. Connection and integration: The BAS contractor will be responsible for the connection and integration from the BAS in the building to:

   a. the Campus BAS software;

1.02 QUALITY ASSURANCE AND WARRANTY

A. General: The entire system shall be provided by an approved Controls Manufacturer/Contractor. It shall be designed by experienced engineers (degreed engineers acceptable, Professional Engineers not required) and installed by competent technicians, all of which are regularly employed in the specialty field of HVAC and building controls.

   1. Contract/subcontract assistance in these items shall be limited to Class I wiring systems (e.g., 120 VAC) and raceway systems.

B. Local Requirements

   1. Branch Office Proximity: The manufacturer shall maintain a Branch Office for design, installation, maintenance and service within approximately 100 miles of the project site. This office shall be staffed by not less than five (5) permanent technical (e.g., excluding sales management, and administration) personnel, at least three of which shall be previously trained and experienced sufficiently to deliver expected proficiency in the installation, service, and programming of the system (specific "generation" of the system used).

2. On-site support during construction and warranty: The manufacturer/contractor shall provide qualified and experienced DDC designer(s), programmer(s) and service technician(s), familiar with the details of this project/system, to serve the project throughout the warranty period. Such personnel shall be available on a 24-hour, seven day a week basis, and contractor/manufacturer shall provide equally qualified substitutes during such personnel's "absentee" periods. Response times shall be as specified in “Warranty” below.

3. **Names, resumes with detailed experience records, and project assignments shall be provided with submittals of this Section.** Qualifications and personnel shall be subject to Architect/Engineers/Owners review and acceptance. Accepted assignments shall not be modified during the course of the project and warranty period except for reasonable cause accepted by or required by the Engineer and Owner.

C. Minimum required experience: The Contractor shall have not less than a ten (10) year experience record in the design and installation of computerized building systems similar in geographic vicinity, scope, and performance to that specified herein.

D. Workmanship: Contractor shall use only thoroughly trained and experienced workmen completely familiar with the items required and with the manufacturer's recommended methods of installation. In all respects, the WORKMANSHIP (INCLUDING THAT IN WARRANTY PERIOD) SHALL BE OF THE HIGHEST GRADE, AND ALL CONSTRUCTION SHALL BE DONE ACCORDING TO THE BEST PRACTICES OF THE TRADE.

Any work not meeting these requirements, as determined solely by the Architect/Engineer, shall be replaced or rebuilt at the contractor's expense.

E. High quality products: Material and equipment shall be the high quality products of a manufacturer regularly engaged in the production of the devices specified. Control devices and equipment shall essentially duplicate that which has been in satisfactory service for at least two years prior to the proposal opening date. **Controls manufacturer shall submit written certification of this item with other controls submittals.**

F. Quality assurance for automatic controls systems shall be accomplished through the Contractor’s commissioning process consisting of at least the following:

1. pre-proposal review of system;

2. delegated design of controls system details in full compliance with these specifications and accompanying drawings, and fully compatible with the HVAC, plumbing, and electrical systems and equipment;

3. Owner’s BAS standards: Obtain and review Owner’s BAS standards and **prepare a “BAS Standards mark-up” submittal** which identifies:

a. Items not applicable to the project,

b. Recommended or necessary departures from the Standard, and

c. Elements of the standard not within the scope of the contract documents.

4. “90%” submittal package conference with Architect/Engineer/Owner;

5. **submittal containing all system particulars** indicated or intended;

6. continuous quality control and monitoring of construction/installation practices;

7. documented point-to-point and connectivity testing

8. **documented pre-functional testing** and initial checkout including point to point verifications;

9. **documented start-up testing;**

10. documented functional performance testing;

11. documented integrated systems testing;

12. **thorough report of contractor’s commissioning** in preparation for Owner’s Commissioning Verifications (CxV);

13. operator training; and

14. O&M documentation.

G. Qualification of lead programmer and lead installing technician:

1. Lead Programmer (LP): The majority of the programming for this project shall be completed by the lead programmer. The LP will personally review and approve any programming performed by others.

2. Lead Installation Technician (LIT): The automatic controls will be installed under the direct and continuous supervision of a lead technician who is an employee of the manufacturer or an approved representative of the manufacturer (approved by the manufacturer and acceptable to the Owner). Subcontractors to the manufacturer are acceptable.

H. The entire system shall be approved and listed by Underwriters' Laboratories, Inc., under UL916 for energy management systems.

I. The system shall be certified to comply with: NEC (NFPA70); FCC-Part J; ASHRAE/ANSI Standard 135-2008 (BACnet); and EIA 709.1 (LonTalk), or other protocol acceptable to Owner.

1.03 RESPONSIBILITY

A. Refer to sequences of operation – General, on controls drawing sheets.

1.04 EQUIPMENT AND SOFTWARE UPDATES/UPGRADES/REVISIONS

A. Equipment: All equipment, components, parts, materials, peripherals, etc. provided shall be the latest current versions offered by the respective manufacturer, and shall be fully compatible with all other equipment, etc.

B. Software:

1. Applied Software: All software used in/supplied to this system shall be the manufacturer's current/latest version, consistent with the Owner's existing service contract.

2. Upgrades and Licenses: All software upgrades and licenses applicable to system and offered by the manufacturer/contractor for this system shall be to the Owner consistent with the Owner's existing service contract. This upgrade shall include installation, programming, (sequence, interactive color graphics, reports, etc.) modifications to field equipment, data base revisions, etc., all as appropriate.

C. Revisions: Hardware/software revisions made related to correcting systems operation (refining sequences of control, adding monitoring/control/points, or other similar operations) shall be provided at the contractor's expense.

D. All project developed hardware and software shall become the property of the Owner. These properties include but are not limited to:

1. Project graphic images

2. Record drawings

3. Project database

4. Job-specific application programming code

5. All documentation

1.05 RELATED SECTIONS INCLUDE BUT ARE NOT NECESSARILY LIMITED TO:

A. 20 08 00 – MEP Systems Commissioning

B. Division 22 (Plumbing)

C. 23 00 10 - General Requirements for Mechanical Work

D. 23 01 00 - Basic Materials and Methods for Mechanical Work

E. 23 02 00 - Piping Systems Insulation

F. 23 08 58 - Custom Air Handling Units

G. 23 08 60 - Fans

H. 23 08 80 - Filters And Accessories

I. 23 08 90 - Air Distribution

J. 23 09 70 - Division 23 Testing, Adjusting, Balancing

K. Division 26 (Electrical)

L. Division 28 (Fire Alarm)

1.06 SYSTEM PERFORMANCE

A. At a minimum, the systems shall conform to the following minimum performance standards:

1. Graphic Display. The system shall display a graphic with a minimum of 80 dynamic points. All current data shall be displayed within 5 seconds of the request.

2. Graphic Refresh. The system shall update all dynamic points with current data within 5 seconds.

3. Object Command. The maximum time between the command of a binary object by the operator and the reaction by the device shall be 5 seconds. Analog objects shall start to adjust within 5 seconds.

4. Object Scan. All changes of state and change of analog values shall be transmitted over the high-speed network such that any data used or displayed at a controller or workstation will be current, within the prior 10 seconds.

5. Alarm Response Time. The maximum time from when an object goes into alarm to when it is annunciated at the workstation shall not exceed 5 seconds.

6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 seconds. The contractor shall be responsible for selecting execution times consistent with the mechanical process under control.

7. Performance. Programmable Controllers shall be able to execute DDC PID (and PI) control loops at a selectable frequency from at least once every 5 seconds. The controller shall scan and update the process value and output generated by this calculation at this same frequency.

8. Multiple Alarm annunciation. All workstations on the network shall receive alarms within 5 seconds of each other.

9. Stability: All elements and entire system shall provide stable operation without overshoot or hunting.

10. Event recovery: Controls shall accomplish a rapid, stable, and repeatable recovery from an “event” condition (e.g., start/stop, override, safety, failure occurrence, transfer to emergency/standby power, resumption of normal power, or other programmed or unexpected event).

11. Increasing/decreasing conditions: Where sequences describe controls for a rise in a sensed or control variable (or another form of increasing condition), provide proper control for the return sequence experiencing a fall in a sensed or control variable (or other form of decreasing condition). Provide PID tuning, delays on make or break, and other supplemental controls as required.

B. Reporting Accuracy.

1. Minimum acceptable reporting accuracies for all values reported by the specified system are as follows. Note: Reported accuracies shall be maximum allowed deviation from actual measurement/condition.

2. Where amplifiers or transducers or other devices are interposed in the measurement system, reported accuracies shall include the performance/accuracy of the transducer or other device.

3. Where transducers are specified in Part 2 which have accuracies different than those required to meet reporting accuracies below, provide the transducer according to the better accuracy requirement.

Measure Variable	Reported Accuracy
Space temperature	±0.4 °F
Ducted air temperature	±0.4 °F
Outside air temperature	±0.4 °F
Water temperature	±0.4 °F
Delta-T	±0.4 °F
Relative humidity/Dewpoint/Wet bulb	±1%RH/±1 °F/±1 °F
Water flow	±2% of reading
T.U. Air flow (terminal VAV box, including transducers/reporting)	±5% of actual air flow (from 10% to 100% of full scale)
Air flow (measuring stations)	±3% of actual reading
Air pressure (ducts)	±0.01” W.G.
Air pressure (space)	±0.0003” W.G.
Water pressure	±1% of full scale (absolute and differential)
Electrical power	±3% of reading (excluding utility supplied meters)
wCarbon Monoxide (CO)	±50 PPM
Carbon Dioxide (CO_2)	±(30 PPM + 2% of reading)
Methane (NG), Propane (LP), Hydrogen (H2)	Combustible Gas Range 0-50% LEL
Others	As indicated herein

1.07 DRAWINGS, MANUALS, AND OTHER SUBMITTALS

A. Refer also to the Requirements of Section 23 00 10, including those for **submitting annotated copies of these specifications (spec copy mark-ups).**

B. **Pre-Submittal Meeting**

1. Building Automation Contractor (BAC) roles:

a. Meeting preparation: Controls Contractor/Manufacturer shall prepare “90% complete” submittals and shall schedule a pre-submittal review meeting with Engineer at the Engineer’s office (or at project site if compatible with Engineer’s routinely scheduled site visits and not causing delay in submittals process). Controls contractor/manufacturer shall prepare for this meeting so that its proposed control system is concisely presented, and so that any questions, recommended deviations,

presumed clarifications, and specification copy mark-ups are brought to the meeting in writing as a published agenda.

b. Meeting lead and documentation: The meeting will be led by the Controls Contractor/Manufacturer. Discussions will occur as applicable by the Contractor/Manufacturer, the Engineer, the Division 23 Contractor, the Construction Manager/General Contractor, and the Owner (should it so desire), all of whom shall be included in the meeting invitations/solicitations made by the Controls Contractor/Manufacturer. The controls contractor shall take notes of the topics discussed and conclusion reached, and shall **include minutes of the meeting in the submittals.**

2. Meeting intent: The intent of this meeting is to create mutual efficiency for the Owner, Contractor and Engineer in order to expedite submittals reviews and progress of the work. The intent is not to provide a platform for multiple contractor deviations which may lessen the quality of the installed and operating control system.

a. Owner's BAS standards mark-ups: Include mark-ups indicated in subsection 1.02 F above where applicable.

C. Submittal acceptance prerequisite to installation: Installation shall not begin until shop drawings, control drawings, and other submittals are reviewed and accepted without re-submittal requirements. Installation shall agree with the more stringent of accepted submittals and these specifications and accompanying drawings.

D. Most stringent conditions apply: Should differences in the submittals, specifications, and drawings be discovered at a subsequent period through the warranty, repairs/replacements using the most stringent condition with regards to cost shall govern.

1. Exceptions

a. where otherwise directed by the Architect/Engineer

b. unless the differences were explicitly enumerated in "summary of Deviations and Clarifications" in the **submittals** and explicitly accepted by the Architect/Engineer. In such case, however, the Architect/Engineer's acceptance shall not relieve the Contractor from providing a fully and properly functioning system.

E. **Shop Drawings: The Control Contractor/Manufacturer shall submit shop drawings of the entire control system complete with specification data sheets for all controllers, instrumentation, control cabinets, control valves, control dampers, and system appurtenances and peripherals etc., before starting work. Shop drawings shall be neat and professionally prepared, and shall include, but not necessarily be limited to:**

1. **Flow diagram(s)** showing all equipment and controls in the system:

a. air systems

b. water systems

2. **Electrical diagrams**. Each as applicable, provide the following:

   a. A tabular or other suitable summary of power requirements for all system components served by a controller or control panel,

   b. "Bus" wiring/cabling routes and materials,

   c. electric ladder diagram(s) and connection diagram(s),

   d. electronic connection diagram(s), each as applicable.

   e. Note: Conform to acceptable routing of conduit, cables, etc. as provided in Section 23 09 51, 1.01.A.4 above, and Division 26.

3. Detailed control sequence(s):

   a. designate each control device/variable in the system and describing its function.

   b. include all DDC system control strategies;

   c. as applicable to the system particulars, include:

      1) start-up, shut down, overrides, event initiations, failure/upset recovery, alarm reporting/test, remote notifications (e.g., email, voice, text, etc.)

      2) initiation of emergency/standby power and return to normal power,

      3) and other special sequence conditions applicable.

4. **Controllers:** All network/central controllers, equipment controllers, device controllers, and other controllers used in the system. For each, provide a summary of input/output quantity required of the system, explicitly enumerating all spaces and certifying compliance with specified spares of each type (binary/digital, analog).

5. **Material list(s)** covering each device coded to match flow and connection diagrams. Field and panel located hardware shall be clearly identified.

6. **Control valve schedule** complete with:

   a. C_V values and pressure drops at design GPM's

   b. valve/actuator close-off ratings tabulated and illustrating such ratings meet those specified herein.

   c. normally open/normally closed position

   d. position feedback provided (or position based on control output where permitted)

   e. actuators applied to each

f. Note: Where ball type control valves are provided, include “valve only” Cv and “geometry-corrected” Cv incorporating reducing fittings, nipples, etc.

7. **Control damper schedule** complete with:

   a. "effective" damper size

   b. damper type (parallel, opposed, combination);

   c. damper leakage data

      1) Flange connected dampers shall be the default basis of design.

      2) Where specifically allowed, slip-in dampers with frames thoroughly sealed to ducts.

   d. air pressure drop curves for dampers, showing pressure drop as a function of face velocity and percentage damper open position.

   e. maximum static pressure ratings across closed dampers for the particular blade length/damper size

8. **Control panels:** Sizes, locations, and internal layouts. Include independent/separated high voltage sections (120 VAC or above), low voltage sections (nominally 24 VAC or below), wiring/tubing paths and containment, all internal field devices and controllers, terminal strips and spaces designated for future additions or changes in device/controller sizes.

   a. 120V section(s) in control panels shall be separated from low voltage (e.g. 24 VAC) areas of panelboards by suitable partitions and covers. Alternatively, 120 V sections may be provided as separate (small) power panels installed adjacent to the control panel(s). 120V sections shall include, at a minimum: transformers and/or other power supplies to DDC panel sections; and convenience receptacles (minimum of two duplex).

   b. All conduit penetrations of control panels shall be located in the bottom, not top or side.

9. **Initial (pre-commissioning) settings:** Indicate on diagrams and/or sequences, all initial set points, throttling ranges, differential settings, reset schedules and control valve and damper operator voltage/milliamperage ranges.

10. **All proposed graphics presentations** (color) and report/alarm formats. (These items are subject to approval by Owner and Architect/Engineer.)

    a. Initial/draft graphics may be submitted subsequently to shop drawings/ submittals, but prior to Contractor’s commissioning. If permitted by Owner and Engineer, submission may be by means of on-site reviews prior to or during Owner’s or Engineer’s commissioning verifications. When so provided, document results using submission of “screen shots”.

b. Make graphics modifications as may be identified by the A/E, the CxA, or the Owner.

11. **Detailed resumes and contact information** of all engineers, designers, lead programmer, programmers, lead installers, and lead service personnel assigned to the project. Refer also to 1.02 above, and include/repeat LP and LIT submittals here-in. Once approved, these personnel shall be active in their respective capacities throughout the project, and supervisory work shall be performed strictly by only these individuals.

12. **Material and equipment lists** including manufacturer, model number, diagram device designation and a clearly identified product data sheet with applicable portions highlighted.

13. **Drawing details and/or mock-ups** showing insulation and vapor barrier/vapor stop compliance with installation requirements of 2.01E and 5.01 G herein.

14. Submittal of spec section mark-ups as prescribed in Part 1 of Section 23 00 10 – General Requirements for Mechanical Work.

15. **A DDC system points list** with input/output/function summary.

F. **Departures from Contract Documents:** Where departures from the contract plans and specifications are deemed necessary or advisable by the Control Manufacturer/Contractor, details of such departures shall be indicated with annotations to the control drawings and specifications, including the reasons therefor. Such changes in this work or in related portions of the project shall be made without additional cost in accordance with control manufacturer's/contractor's responsibility. Refer also to 1.03 above.

G. **Records for Owner:**

1. **Record Drawings:** Refer to Division 1 requirements.

2. **Operating instructions** and as-built system flow diagrams and other complete controls drawings shall be prepared, bound, and mounted in a binder, frame or cabinet in each mechanical equipment room. Each actuator, relay, transducer, switch, motor, controller, indicator (when inside panel) other control system device, and item of equipment, etc., shall be identified with a unique number or mark identical to one which shall be tagged on each item. Large items of equipment may be identified by a suitable symbol listed in a legend on the control diagram. Drawings/operating instructions shall be reduced to an easily legible 11" x 17" format for placement in the mechanical rooms, (or may be prepared in that format initially).

3. Service Manuals: Unless Owner determines only electronically produced owning, operating, and service manuals are required, provide manuals in both hard copy and electronic formats. (Minimum number of hard copies shall be six.) Cover the entire controls system, as described below.

a. Organize manuals: Each O & M manual shall be organized with bookmarks (electronically) and with labeled tabs (hard copy). Organize into logical separations of elements and subsystems, and shall contain the manufacturer's complete, detailed operating and maintenance instructions

with equipment data for each piece of installed material and equipment under this contract.

b. Each hard copy manual shall be composed of 8-1/2" x 11" instruction sheets with full size (not less than 11" x 17") drawing sheets folded in and having a reinforced margin.

c. Data shall clearly indicate information for specific material or equipment installed with extraneous material crossed out or removed.

d. The O & M manual shall include, but not be limited to, the following information.

1) Record Layouts: Provide as-built system layouts showing equipment, conduit routing, piping, valves, controls, test ports, terminals, control boxes, panels, and field devices, and sizes and locations as applicable. Indicate component piece or identity as tagged on layouts.

2) Thoroughly documented: As-built wiring and control diagrams to include schematics with data and narratives to explain the detailed operation and control of each component.

3) Component schedules: Control schedules of all control components providing data for proper system operation and performance of maintenance.

4) Sequences: Detailed control sequences describing start up, operation, shut down, and special sequences/alarms as identified in “E” above.

5) Programs and flow charts: A complete list (hard copy) of all controls programs and a flow chart of the entire controls program.

6) Service details: Operating and maintenance instructions for each piece of equipment, including troubleshooting, check lists, repair and adjustment.

7) Equipment data sheets: Manufacturer's bulletins, data sheets, descriptive data and serial number, wiring diagrams and control schematics for equipment with self-contained controls which are interfaced to the temperature control system (Examples: terminal units, coils, smoke detectors, smoke dampers, fire alarm panels [circuits which may disable air handling unit fans] etc., each as may be applicable to the project/control system).

8) Parts/spare parts: Parts lists and recommended spare parts with complete detailed ordering information correlated to tagged identification on system layouts.

9) Safety instructions.

1.08 APPROVED CONTROLS MANUFACTURER/CONTRACTORS

A. Portions of this specification are based upon system equipment, terminology and/or performance as available from Siemens, Schneider Electric/Andover Controls, Johnson Controls, Trane Controls and/or others. Such information are intended as a standard of performance, but not as a means of approving these manufacturers or of excluding other candidate control manufacturers/contractors.

B. Acceptable Manufacturers/Contractors:

1. Siemens

2. Johnson Controls

C. Acceptance authority: The Architect/Engineer shall reserve all authority regarding approval, conditional approval, or rejection of the systems not fully complying with these specifications.

PART 2 - PRODUCTS

2.01 GENERAL

A. Minimum number of manufacturers: Unless otherwise specified, all products shall be of single manufacturer wherever possible. Should a single manufacturer not have all products available from its product line, a minimum number of manufacturers shall be used. Each manufacturer, and quantity of manufacturers, shall be subject to the acceptance of the Architect/Engineer. In all cases, all like devices/equipment shall be of a single manufacturer.

B. Complete system components:

1. Provide all sensors, thermostats, control valves, control dampers (control and control/smoke), operators, microprocessors, controllers, transducers, switches, indicating devices, interface equipment, transformers, power supplies, fuses, terminal boxes, wiring, cabling, and other devices/apparatus required to properly operate mechanical system and to perform functions specified and intended.

2. UPS –Uninterruptible Power Supply: Refer to 2.02 R. Provide in ventilated cabinet.

C. Modulating components: Unless otherwise indicated, all modulating components shall be fully proportional, proportional/integral or proportional/integral/derivative as required for the particular controls involved.

1. All temperature, humidity, flow, and pressure sensors/controllers shall be analog.

2. All modulating control devices shall be driven by voltage analog (not pulse width or floating point) control signals. Differential pressure switching may be digital (binary) where appropriate and so indicated for the particular control involved.

D. Environmental

1. General: The system and all component products shall be designed, rated, and warranted for continuous operation in the environments to be possibly encountered. At a minimum this environment shall:

   a. range from 32 °F to 120 °F/95% RH (non-condensing) for equipment located in conditioned or ventilated/freeze protected interior spaces;

   b. range from -40 °F to 158 °F for equipment located outdoors or in outdoor panel enclosures;

   c. and be protected or immune from dust and other air contaminants typical of the locale and process.

2. Outdoors: All outdoor products and installation shall be weatherproof and sunlight resistant. At a minimum, system and all control devices installed outdoors shall be rated for or shall be installed to provide an approved NEMA 3R or NEMA 4 condition.

E. Supports

1. Supported and secured: All panels, controls devices, field devices, conduit, etc. shall be properly and securely supported independently of vessels, piping, ducts, and other systems or equipment. (Exception: approved devices intended for securing in or to tanks, piping, ducts, etc.)

2. Insulated elements: Note special requirements to coordinate details of mounting methods when applied to insulated elements. Mounting must maintain thermal and vapor barrier separations between mounted device and pipe, duct, etc.

3. Racks, etc.: Provide support racks, stanchions, hangers, clips, etc. as required, subject to approval of Architect/Engineer, of galvanized "Unistrut", piping, or channels.

4. Plan/install to maintain service clearances: Carefully plan for installation/location of supports to allow ready access and service to controls and instrumentation and to all other materials/equipment or access/service thereto.

2.02 ELECTRICAL

A. General: All electrical wire, cable, fittings, connectors, conduit, power voltage (e.g., 120VAC, 277 VAC) connections and distribution to panelboards, associated circuit breakers, interconnection/interlock wiring, interconnection/interface wiring with fire suppression system(s) and with fire alarm systems (from fire alarm system relays to Division 23 components such as fans, air units, VFDs, dampers, etc.) and control devices, etc., associated with the systems under this Section of the specifications shall be furnished and installed complete under this section of the specifications.

1. UPS – Uninterruptible Power Supply: Refer to “R” below. Provide in ventilated cabinet.

2. Exception: Where specifically indicated on electrical drawings or in Division 26 specifications, Division 26 work may be used to the extent that it serves adequately. Supplement Division 26 work in this section as required.

B. Separate Ground: Where recommended by controls manufacturer for the system/application involved, DDC system/components shall employ and maintain a separate, "clean earth" grounding protection. "Mixing" of grounding systems shall be prohibited. (Isolate DDC controls conduits/metal boxes from other raceway systems using isolation bushings and other measures as necessary.)

C. Conduit: Except as noted below, all wire/cable (in walls, partitions, shafts, chases, crawlspaces, mechanical rooms/cabinets, on roofs, below grade, below slabs, above ceilings, etc.) shall be run in conduit, min. ¾".

1. Conduit types shall match those in Division 26 with regard to types (e.g. RGS, IMC, EMT) in particular spaces.

2. Conduit fill limit shall not exceed 40% in any portion of the conduit system.

3. Exception: Control wire/cable may be run outside conduit if all the following conditions prevail:

a. located above accessible ceilings or other accessible and concealed locations;

b. plenum rated cable is used;

c. Class II wiring (less than 24 VAC or 24 VDC nominal and served by no greater than 100 VA transformer) is used;

d. where allowed by all applicable administrative authorities;

e. cabling employs unique color coding from others in the facility;

f. where labeled "controls";

g. and where supported in accordance with Part 5.01.

D. Color Codes and Labels:

1. Control conduits and wires and cables outside of conduits shall be of consistent color codes and polarity throughout the project. Coordinate with Division 26 to provide unique color codes different than Division 26 systems (examples: 480/277V, 208/120V, fire alarm, nurse call, medical gas, communications, etc., each as applicable to the project/system).

2. All controls wire/cable and all conduit/boxes housing controls wire/cable shall be permanently labeled "CONTROLS" to distinguish it from power, lighting, data, communications, etc. systems.

3. All controls conduits shall be colored in accordance with Division 26 conduits requirements. Junction/pull boxes covers shall be painted according to this color code, and labeled regarding the contents/device served. Refer also to Division 26 Part 4.01 below.

E. Provide all wiring to electric (e.g. 120V, nominally 24 VAC or 24 VDC) and electronic control devices. Include power wiring to terminal units, and other terminal device controllers and actuators.

F. Controls Power Supplies: Provide transformer(s), power supply(ies), etc. as required. Locate transformers “grouped” in available control panel spaces of mechanical or electrical rooms (i.e. not dispersed above ceilings), and label each according to the area(s) and terminal units it serves. Refer also to drawings.

1. Locate heat producing components and other heat producing equipment in mechanically ventilated controls cabinets.

2. Control transformer circuits/ sizes (VA) shall not exceed NEC Class II wiring system allowables (100 VA at 24 VAC per circuit).

3. Uninterruptible power supply: Refer to “R” below. Provide in ventilated cabinet.

G. Standards: Materials and installation shall be in accordance with the requirements of NFPA, the National Electrical Code, and the electrical division (Division 26) of this specification. All electrical work included under this section shall be complete with labor, materials and installations.

H. Gold contacts: Where required for proper operation with electronic controls interfacing, provide relays and other devices with low impedance gold contacts.

I. Conductor sizes: Where required to maintain proper relay operation, increase minimum control wire gauges specified herein. Coordinate relay and voltage drop characteristics to ensure proper operation.

J. Minimum Wire Sizes:

1. AC wiring (e.g. 277VAC, 120VAC) - 12 gauge or larger conductors, solid, with THHN insulation, properly fused or protected by circuit breakers.

2. "Bus" wiring/cable (e.g. Network Communications Trunk, Terminal controller LAN networks) - minimum 18 gauge shielded/ twisted with protective jacket meeting 25/50 plenum requirements;

a. Cabling shall not exceed 12.5 pf capacitance per foot, wire to wire, and not exceed 6 twists per foot.

3. thermostat/sensor/transmitter and other analog wiring/cabling - minimum 18 gauge shielded/twisted with drain wire, with protective jacket meeting 25/50 plenum requirements;

4. 24V control "power" wiring to actuators and controllers - properly fused 16 gauge or larger conductors, solid or stranded, with THHN insulation;

5. Digital output wiring (DO) – min 14 gauge THHN.

6. Increase the above minimum requirements if/as needed for the particular application.

7. Exceptions: **Where manufacturer, in letter contained in the front of submittals, recommends that smaller size** (higher gauge) and/or unshielded cabling for the particular system/application be provided, including considerations/provisions for all future system expansion/installation.

K. Systems allowed in common conduits:

1. Class 2 Digital Input (D.I.) wiring may be run in a common conduit with Class 2 Digital Output (D.O.) wiring.

2. Analog Input (A.I.), Analog Output (A.O.) Class 2 Digital Input (D.I.), and common "bus" cabling (e.g. Network Communications Trunk (N.C.T)) wiring may be run in common conduit.

a. Specified restrictions: Class 2 Digital Output (D.O.) wiring run in a common conduit with Analog (A.I.), Analog Output (A.O.), or common "bus" cabling (e.g. Network Communications Trunk (N.C.T)) is not permitted under any circumstances.

b. Performance restrictions: Other common conduit restrictions shall be in "force" should they adversely affect specified minimum performance.

L. Wiring between DDC Panels:

1. CAT-6 Assemblies: Provide and terminate individual CAT-6 cable assemblies to interconnect each BAS panel. Pass data through a CAT-6 Ethernet switch before continuing to its destination to other main building panels and to the front end.

a. Each cable shall originate and terminate within one designated DDC panel in each mechanical room.

b. Additionally, provide and terminate individual CAT-6 cable assemblies to connect each DDC panel within the mechanical room(s), with others in that same room, as engineered by the BAS Contractor.

2. Cable lengths: All cable runs between mechanical room and/or DDC panels shall be no longer than allowed as specified in Division 27 (e.g. teledata and IT requirements). Should Div 27 scope not be included in project, maximum length shall be as set by the more restrictive of industry standards and manufacturers written standards.

a. Should runs be required that will be longer than allowable in "2" above, provide an additional enclosure near the midpoint (coordinate location with architect), to be used as a network junction box, complete with 120VAC emergency/standby power source (where available). Terminate and label the cables within this junction box and show the location on the as built control drawing, as directed for each DDC panel

b. UPS power: Refer to "R" below. Where UPS is required, 120VAC power to network junction boxes shall be powered through UPS.

M. Connections, extension, and interlocks:

1. Provide and connect all interlock wiring power for sensors (if required), and line and low voltage wiring external and internal to DDC panels.

2. All wiring shall be clearly and permanently labeled.

N. Field devices required 4-20mA DC input signal shall be non-ground referenced.

O. Independent junction boxes: In order to facilitate maintenance, where multiple sensors or devices are connected to a common raceway or conduit, each sensor or device shall be individually connected to a common (non-sensor or device) junction box, which shall then be attached to common conduit. Under no circumstances shall sensor or device wiring or tubing be routed through any other sensor or device's specific enclosure or junction box.

P. Wire Labeling:

1. All wiring shall be labeled at both ends and at any spliced joint in between. Wire shall be tagged using a system similar to the Panduit P1 Self Laminating System that utilizes a thermal transfer (or equivalent) printer with a minimum font size of Arial 10.

2. In addition to tagging at filed device end and at spliced joints, a tag shall be placed approximately 6 inches after entering each DDC panel and within approximately 6" of panel device.

3. **Identification and tag information shall be included in engineering/wiring submittal** which must be submitted for Owner and Architect/Engineer review prior to beginning work**.**

4. Tag information shall coincide with equipment/point information as written in the specification input/output summary.

5. Each BAS DDC panel shall include a paper wiring document, in a clear sleeve permanently attached to the inside door that shows the name of each point and what terminal they are connected to.

Q. Electrical Equipment: Hand-Off-Auto Switches and Motor Starter Auxiliary Contacts

1. Motor starters/disconnects with HOA switches for equipment/fans are generally provided under Division 26 or by equipment manufacturers under other sections of Division 23.

a. Verify and coordinate with other related Division 23 sections and with Division 26 drawings and specifications to ensure HOA/starters/disconnects meet the needs of the specified controls.

b. Provide additional HOA's and auxiliary contacts under this Section if/as required to achieve the intended controls.

R. BAS Power Source: Entire DDC controls system shall be powered:

1. Dedicated Circuits: Through dedicated circuits ("DDC controls" only) fed from designated panelboards.

2. UPS: Through uninterruptible power supplies (UPS), selected for not less than 30 minutes operation under loss of normal and emergency/standby power.

a. Provide UPS's as required with continuous, regulated output power without using its batteries including during brown-out, surge, and spike conditions. UPS shall be sized such that the load it serves does not exceed 75% of the rated capacity of the UPS, including power factor of the connected loads. Larger capacity UPS's or multiple UPS's shall be required for systems with larger controls connected loads. Battery shall be sealed lead-acid type and maintenance free.

b. Input voltage: single phase, 120 VAC, +20 to -33 %. Minimum 0.97 power factor at full load.

c. Output voltage: single phase, 120VAC, +/- 3%, steady state with rated output current of 8.3A, 25.0A peak.

d. Inverter overload capacity shall be minimum 130% for 10 seconds. Recharge time shall be maximum 8 hours to 90% capacity.

e. UPS bypass shall be automatic during fault or overload conditions.

f. Provide UPS with connector option card as required for dry contact communication to the BAS system of fault condition and battery operation

g. Provide minimum 1-year on-site warranty which covers all material and labor.

h. Connect UPS to emergency/standby branch of electrical grid of electrical power.

i. Provide tower models installed in NEMA 1 hinged, ventilated, lockable cabinets or rack models installed on matching racks, as applicable to the particular installation location and space availability/configuration.

j. Acceptable Manufacturer: Toshiba Series 1000, Liebert, or approved equal.

2.03 CONTROL VALVES

A. General

1. Sizing guidelines for stable control: Water valves shall be sized by the control manufacturer to produce linear characteristics/stable control at the required capacity.

a. For water valves serving air handling unit or fan coil unit coils, size a pressure loss of approximately 4 psig, but not greater than a 5 psig pressure loss,

b. For terminal unit coils, size for a pressure drop of approximately 3 psig, but not greater than 4 psig.

c. Valve Constant (Cv) Charts: Controls submittals/shop drawings shall indicate the design pressure drop and the valve constant (Cv rating) of all valves used so that the valve pressure drop may be used for balancing and performance tests.

1) Note: Ball type controls valves, 2-way and 3-way, are acceptable under this specification. However, when submitting Cv and pressure drop data, provide not only the valves data but also the "geometry corrected" Cv data for the valves and associated reducers and short nipples.

2. Body pressure rating: Nominal body rating shall be not less than 125 psig (greater where required for the particular service). However, the valve body and packing selected shall be designed to withstand the system pressure static head plus the maximum pump head for water systems) and the maximum temperature of control medium (chilled water, heating water, run-around water, and/or steam, each as may be applicable).

3. Single-seated valves shall be rated for tight shut-off and shall have close-off ratings equal to or in excess of the system pressure encountered (the maximum upstream pressure).

a. Exception: Double-seated valves will be permitted where tight shut-off is not required, but the leakage shall be limited to maximum five percent (5%) while in the closed position and subjected to the maximum system pressure.

4. Close-off: Two-way and three-way modulating and two position valves shall have close-off ratings equal to or in excess of the maximum pressure difference, at any load condition, between either the two inlets and outlet (or between the inlet and either of the two outlets for diverting valves). Each valve shall be equipped with proper packing to assure there will be no leakage at the valve stem.

5. Dual valve/ actuators: Where single valve and actuator combinations cannot achieve these close-off requirements due to valve sizes, provide:

a. dual valves and/or tandem actuators as required and arrange for sequencing operation, or

b. 120 VAC actuators.

6. Butterfly control valves: Provide in accordance with Section 23 01 00 - Basic Materials and Methods.

7. Select valves to fail safe in normally open or closed position as dictated by freeze, humidity, fire, or temperature protection. VERIFY this intent with any normally closed/normally open descriptions offered in the sequences of operation.

B. Modulating ball type control valves: commercial quality 2 way and 3 way.

1. Acceptable Manufacturers: Belimo, Siemens, or JCI, similar to Belimo Series B2/B3-VSS.

a. Control valve using characterized disk

b. Body size

1) 2-way: Y2" - 3"

2) 3-way: Y2" – 2"

c. Cv range

1) 2-way: 0.8-240

2) 3-way: 0.3-83.

d. Materials: stainless steel body, ball, and trim; PFTE seals/seats; EPOM O-rings; Tefzel characterized disk

e. Class 300 valve acceptance with minimum of 400 psig pressure rating

f. Connections: threaded or flanged.

g. Temperature range: to 250 F

h. Flow characteristic: equal percentage

i. Close-off rating: to 2"-200 psig; above 2", 100 psig.

j. Leakage rating: ANSI class IV.

k. Suitable for chilled water, heating water

l. Provide actuator stand-off/air gap and/or thermal isolating actuator adapter to accommodate insulation

m. Note: Select valve size to match pipe size where Cv options allow.

2. Optional Basis of Design: Valve Solutions Inc VSI "Unimizer."

a. Control valve with characterized flow optimizer

b. Body size: Y2"-3" (2-way and 3-way)

c. Cv range

1) 2-way: 0.4 to 266

2) 3-way: 0.3 to 200

d. Materials:

1) 2-way: forged brass body; stainless steel ball and stem – PFTE seals and EPOM O-rings; glass-filled polymer flow optimizer.

2) 3-way: same as 2-way except brass stem and nickel plated brass ball

e. Class 300 valve acceptance with minimum of 360 psig pressure rating.

f. Connections: threaded or flanged

g. Temperature range; up to 250F

h. Flow characteristic: equal percentage

i. Close off rating:

1) 2-way: minimum of 100 psig

2) 3-way: minimum of 40 psig

j. Leakage rating: class IV

k. Suitable for chilled water, heating water

l. Provide actuator stand-off/air gap and/or thermal isolating actuator adapter to accommodate insulation

m. Note: select valve size to match pipe size where Cv options allow.

C. Valves Installation

1. Install with unions or flanges on both sides of control valve to permit service/replacement

2. Select valves to fail safe in normally open or closed position as dictated by freeze, humidity, fire, or temperature protection. VERIFY this intent with any normally closed/normally open descriptions offered in the sequences of operation

3. As required by field conditions to achieve best access, and accepted by the Architect/Engineer, valves and actuators in horizontal piping shall be installed:

a. In upright (top of pipe) or horizontal (side of pipe) position. Underside valve installation (actuators on bottom) shall not be permitted. Determine best position for access and visual inspection, especially if actuator is equipped with visual indicator.

b. Verify specific application examples with Architect/Engineer via mock-up submittal required per Section 23 00 10.

4. Insulation mock-ups: Coordinate with insulation mock-up requirements of Section 23 02 00, and **submit mock-up of insulation for each type of valve/actuator assembly used in chilled water service.**

2.04 DAMPERS

A. General: All automatic dampers shall be sized and furnished by the temperature control manufacturer under this section. (Exception: where dampers are integral to equipment or packaged assemblies.)

1. Blade Style: Provide parallel blade, opposed blade, and combination blade style dampers as required to achieve stable control without excessive pressure drop.

2. Control/smoke and control/fire/smoke: Where indicated, provide dampers also UL rated for:

a. Combination control/smoke service

b. Combination control/smoke/fire service

c. Refer also to and coordinate with Section 23 08 90 for combination smoke/control and smoke/fire/control dampers specification.

3. Construction:

a. Flanged connection type, with neoprene or similar seals on two edges and spring steel or other acceptable seals at jambs and shall be designed to shut off tight. Adhesive applied or clip-on blade seals are not acceptable

b. Unless otherwise indicated, frames shall be constructed of min. 16 gauge galvanized sheet steel formed into channels and welded for maximum strength Blades shall be constructed to assure non-slip pivoting of the blades when a damper is used as a single module or is interconnected with others.

c. Bearings shall be stainless steel, molded synthetic or oil impregnated sintered bronze construction, and shall provide constant lubrication.

d. Dampers operating with blades in vertical orientation shall be provided with thrust washers.

e. Damper shafts shall be squared, keyed, or otherwise machined to ensure durable, tight, and non-slipping condition with actuator and/or linkage. Set-screw or compression fitted actuator/damper couplings shall not be acceptable under this specification.

f. Where dampers types and/or manufacturers are indicated by drawings (e.g. notes or schedules), comply with requirements therein or with equal acceptable to Architect/Engineer.

4. Damper types and sizes: Where suggested damper types and sizes are indicated on the drawings or in these specifications, it shall be the **responsibility of the Controls Contractor to verify these sizes and types prior to submittal.**

5. Duct System/Pressure Compatibility: Refer to Section 23 08 90 – Air Distribution for duct system pressure ratings (e.g., low, medium, high). Select dampers compatible with those ratings, including duct velocities and closed damper pressure differential ratings (e.g., blade length).

6. Blade lengths and centers: Dampers shall be arranged so that blades are set at no greater than nine inch (9") centers (less where indicated in 'E' above) and shall be a maximum of 48 inches long for low pressure dampers, 42" log for medium pressure dampers, and 60" long for high pressure dampers.

    a. A minimum of one damper actuator shall be furnished for each 24 square feet of damper area, or for each independently sequenced damper section.

7. Allowable section sizes: Unless otherwise indicated or allowed by damper pressure limitations:

    a. Single section dampers; dampers 24 square feet and smaller shall be constructed in a single section and shall be driven by an externally mounted damper actuator.

        1) Internally mounted damper actuators may be used in exterior applications, provided duct or AHU access doors are also provided (unless specifically requested in **Submittal memorandum** and approved by the Architect/ Engineer).

    b. Dampers larger than 24 square feet shall be constructed in multiple sections, with each section driven and sequenced independently by a separate externally mounted (unless field conditions do not permit) damper actuator.

        1) Multi-section dampers shall have independently sequenced actuators operating smoothly and positively and in accordance to the sequence of operations. Cross-linking over millions or other obstructions will not be acceptable.

8. Damper linkage: Linkage which shall provide a linear flow characteristic shall be provided with damper actuator for all mixing or control damper application (constant pressure drop).

9. Vertical blades: Install dampers with blades in vertical orientation (perpendicular to fan shaft) where located at fan discharge and where adjacent to vertical risers (e.g., shafts). Verify particular damper model/size is recommended for this application.

    a. Note: Vertical blade damper may be subject to shorter blade length, depending on duct pressures and velocities, and on manufacturer limitation.

10. **Submit sizes and types to be used complete with technical backup. (size, pressures ratings, pressure drops, leakage test data, flow characteristic curves, close-off with proposed actuator, etc**

B. Dampers in low pressure/low velocity duct systems:

1. For zone control dampers (excluding those in terminal units which are specified elsewhere): maximum 4" (open) width; 16 gauge galvanized steel or heavy gauge aluminum frame; leakage not to exceed 6 cfm/sq. ft. @ 4" s.p. (24"x24" damper).

a. Basis of Design: Ruskin CD40 Thinline or Greenheck VCD-40 Narrowline (not for use with blades in vertical).

2. Where damper length in ductwork is unconfined:

a. V-groove blades: maximum 8" (open) width; min. 16 gauge galvanized steel blades; leakage not to exceed 10 cfm/sq. ft. @ 4" s.p. (24"x24" damper).

1) Basis of Design: Ruskin CD 356 or Johnson D1300 with double-piece blades, or Greenheck VCD-23.

C. Dampers in medium pressure duct systems:

1. Related applications:

a. At AHU connections where AHU is specified to have leakage and deflection tests not exceeding 6" w.c.

b. At dampers upstream of supply terminal units and downstream of exhaust/return terminal units

2. Airfoil blades: Maximum 6" (open) width; 16 gauge galvanized steel or heavy gauge aluminum frame; extruded aluminum airfoil blades; leakage not to exceed 7 cfm/sq. ft. @ 4" s.p. (24"x24" damper); rated to 122°F; maximum pressure drop at 1500 fpm of 0.3" w.c. (24"x24" damper).

a. Basis of Design: Ruskin CD50, Johnson D-1300 with airfoil blades, or Greenheck VCD-42 or 43.

3. Certain mixing applications: Where used in outdoor air/return air mixing with economizer control application (e.g. AHU mixing boxes, in ducted outdoor/return air situations, or ducted fan-driven relief situations), provide combination parallel blade/oppose blade dampers to produce approximately equal pressure drops through entire range of operation.

a. Basis of Design: Ruskin CD403, with OB/PB percentages selected for the particular application.

D. Dampers subject to condensation:

1. Related application: relief dampers in barometric relief hoods or at relief fans, and where otherwise indicated.

2. Airfoil blades with injected foam insulation: Maximum 6" (open) width; heavy gauge extruded aluminum frame; heavy gauge extruded aluminum airfoil blades; leakage not to exceed 4 cfm/sq. ft. @ 4" s.p. (24"x24" damper); foam injected blades with thermal break seals to prevent condensation/dripping in horizontal or vertical plane installation.

a. Basis of Design: Ruskin CDTI-50 (low temperature).

E. Air handling unit control dampers and other dampers also serving as smoke dampers.