PREFACE

PURPOSE OF THIS DOCUMENT

The intent of this document is to disseminate the San Francisco International Airport’s (SFO’s or Airport’s) expectations regarding the information presented to designers, engineers, general contractors and other industry specialists. The material provided in the following sections includes the minimal requirements, general information, design criteria, guide specifications and details for HVAC installed at SFO. While this document addresses major areas of concern to SFO, it is not an all-inclusive document.

HOW TO USE THIS DOCUMENT

This document should be used as a resource for the development of project specific design documents including drawings, details and specifications. It is the responsibility of the design, engineering and construction professionals to adhere to all codes and regulations related to the content presented.

SCOPE

This section contains the Standards and Criteria for HVAC. Any questions or concerns regarding the items or equals specified must be submitted to the Standards Committee in writing. All final decisions regarding products shall be made at the Airport’s discretion. If the Engineer of Record presents items that are not specified or named equals, they must be brought to the Standards Committee for evaluation of those products. The specifications are divided into two parts: This section is a narrative overview of the general scope of work, the other Division 23 Sections are technical specifications intended to establish the level of quality and utility of materials to be provided, requirements for procurement, installation, and testing of the mechanical work.

GENERAL INFORMATION

Please refer to Chapter 2 of Appendix A: SFO Mechanical Design Guidelines for the Airport Design Guidelines and standards.

DRAWING REQUIREMENTS

A. All design disciplines including the architectural/engineering sub-consultants and the trade bid package subcontracts shall prepare documents using Revit in the current version utilized by the Airport in compliance with the Airport’s Building Information Modeling (BIM) Requirements as described in Document 00 73 87: BIM Requirements, unless waived by the Chief Development Officer.

B. When Revit models may not be applicable, (for example, tasks with underground infrastructure beyond a building footprint), Civil 3D may be used to model utilities and applicable infrastructure if approved by the Chief Development Officer.

C. Refer to technical specifications for As-Built requirements.

D. Documents and plans submitted to SFO shall be searchable using PDFs with live text. This includes, but is not limited to, text and symbols. The document shall also provide the capability to turn layers on and off. Any project using legacy documents which may be composed image files shall be converted to live text via Optical Character Recognition (OCR).
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SECTION 23 05 00 – COMMON WORK RESULTS FOR HVAC

PART 1 – GENERAL

1.1 DESCRIPTION

A. General: Provide Basic Materials and Methods for Mechanical systems in accordance with the Contract Documents.

B. The requirements of this Section govern all sections pertinent sections.

C. This section includes the following:
   1. Piping materials and installation instructions common to most piping systems.
   2. Transition fittings.
   3. Dielectric fittings.
   4. Mechanical sleeve seals.
   5. Sleeves.
   7. Grout.
   8. Equipment installation requirements common to equipment sections.
   10. Concrete bases.
   11. Supports and anchorages.
   12. Seismic restrain/vibration isolation requirements.

1.2 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this Section shall comply with all Basic Mechanical Requirements, and the requirements of other Sections in Division 23 specified herein.

1.3 REFERENCES

A. Codes and Standards: Provide products conforming to the requirements of the following:

   1. American National Standards Institute (ANSI):
      a. A13.1 - Scheme for the Identification of Piping Systems
      b. B16.1 - Cast Iron Pipe Flanges and Flanged Fittings Class 25, 125, 250 and 800
      c. B16.3 - Malleable Iron Threaded Fittings Classes 150 and 300
      d. B16.4 - Cast Iron Threaded Fittings Classes 125 and 250
      e. B16.5 - Pipe Flanges and Flanged Fittings
      f. B16.9 - Factory-Made Wrought Steel Buttwelding Fittings
      g. B16.10 - Face-To-Face and End-To-End Dimensions of Valves
      h. B16.11 - Forged Steel Fittings, Socket-Welding and Threaded
i. B16.18 - Cast Copper Alloy Solder Joint Pressure Fittings  
  
j. B16.22 - Wrought Copper Alloy Solder Joint Pressure Fittings  
  
k. B16.24 - Bronze Pipe Flanges and Flanged Fittings Class 150 and 300  
  
l. B16.39 - Maleable Iron Threaded Pipe Unions Classes 150, 250, and 300  
  
m. B31.1 - Power Piping  
  
n. B31.9 - Building Services Piping  
  
  
  
b. A53 - Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded Seamless  
  
  
  
  
f. A183 - Standard Specification for Carbon Steel Track Bolts and Nuts  
  
g. A193/A193M - Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service  
  
h. A194/A194M - Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service  
  
i. A216/A216/M - Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service  
  
j. A276 - Standard Specification for Stainless and Heat-Resisting Steel Bars and Shapes  
  
k. A307 - Standard Specifications for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength  
  
l. A536 - Standard Specifications for Ductile Iron Castings  
  
m. A795 - Standard Specifications for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use  
  
n. B16 - Standard Specification for Free-Cutting Brass Rod, Bar and Shapes for Use in Screw Machines  
  
o. B32 - Standard Specification for Solder Metal  
  
p. B61 - Standard Specification for Steam or Valve Bronze Castings  
  
q. B62 - Standard Specification for Composition Bronze or Ounce Metal Castings  
  
r. D2000 - Standard Classification System for Rubber Product  
  
3. Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. (MSS):  
  
a. SP25 - Standard Marking System for Valves, Fittings, Flanges and Unions  
  
b. SP67 - Butterfly Valves  
  
c. SP70 - Cast Iron Gate Valves, Flanged and Threaded Ends
d.  SP71 - Cast Iron Swing Check Valves, Flanged and Threaded Ends  
e.  SP72 - Ball Valves with Flanged or Butt-Welding Ends for General Service  
f.  SP80 - Bronze Gate, Globe, Angle and Check Valves  
g.  SP84 - Steel Valves - Socket Welding and Threaded Ends  
h.  SP85 - Cast Iron Globe and Angle Valves Flanged and Threaded Ends

4. National Electrical Manufacturers Association (NEMA)  
a.  NEMA Standard MG 1 – Motors and Generators.  
b.  NEMA Standard ICS 2 – Industrial Control Devices, Controllers, and Assemblies.  
c.  NEMA Standard 250 – Enclosures for Electrical Equipment  
d.  NEMA Standard KS1 – Enclosed Switches.

5. National Fire Protection Association (NFPA): All work must comply with the current edition of the NFPA. See also the SFO A&E Standard for Division 21 – Fire Suppression.

6. CEC – California Electrical Code  
7. American Welding Society (AWS)

1.4 DEFINITIONS

A. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.

B. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.

C. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.

D. Concealed, Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and in duct shafts.

E. Concealed, Exterior Installations: Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.

F. The following are industry abbreviations for plastic materials:  
   2.  CPVC: Chlorinated polyvinyl chloride plastic.  
   3.  PE: Polyethylene plastic.  
   4.  PVC: Polyvinyl chloride plastic.

G. The following are industry abbreviations for rubber materials:  
   1.  EPDM: Ethylene-propylene-diene monomer rubber.  
   2.  NBR: Acrylonitrile-Butadiene rubber.

1.5 QUALITY ASSURANCE
A. Manufacturer’s Qualifications: Firms regularly engaged in manufacturing of the materials and products of types and sizes required, and whose products have been in satisfactory use in similar services for not less than 5 years.

B. Fabricator/Installer Qualifications: Regularly and successfully engaged in construction methods on projects of similar sizes using type of equipment and systems as specified herein, for a period of not less than 5 years.

C. Uniformity: All items of similar nature shall be by the same manufacturer. Trims and accessories for major items shall be by the same manufacturer.

D. Steel Support Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX, “Welding and Brazing Qualifications.”
   1. Comply with provisions in ASME B31 Series.
   2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

E. Electrical Characteristics for Mechanical Equipment: Equipment of higher electrical characteristics may be furnished provided such proposed equipment is approved in writing and connecting electrical services, circuit breakers, and conduit sizes are appropriately modified. If minimum energy ratings or efficiencies are specified, equipment shall comply with requirements.

1.6 SUBMITTALS

A. Prior to construction, submit for approval all materials and equipment as per requirements.

B. Product Data: Submit manufacturer’s standard technical product data indicating conformance to the stipulated reference specifications, construction materials, construction details, and test and operating pressures. Submit manufacturer’s product data on the following:
   1. Pipe Materials and fittings.
   2. Pipe specialties.
   3. Valves.
   4. Strainers.
   5. Supports, anchors, hangers, and seismic restraints.
   7. Gauges and thermometers.
   8. Electrical devices and motors.
   10. Dielectric fittings.
   11. Mechanical sleeve seals.
   12. Escutcheons.

C. Shop Drawings: Provide piping layout drawings, drawn to a scale of not less than \(\frac{1}{4}\)" to one foot showing the proposed layout of piping systems, including valves, fittings, equipment, hangers, grading, high points, low points, drain points, anchors, seismic loops, and expansion devices. Provide Shop drawing submittals shall include but not be limited to the following:
   1. Cut sheets on all materials.
   2. Shop drawings showing details of fabrication and construction methods.
   3. Samples of products.
   4. Mechanical rooms.
5. Congested areas above ceilings.
6. Cooling coils.
8. Sleeve locations.
9. Coordination of core holes.
10. Expansion compensation devices and seismic loops.

D. Welding certificates.

1.7 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver all materials in factory fabricated, water resistant, and shock-proof wrapping.

B. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.

C. Handle and store all material in accordance with manufacturer's recommendations.

D. Store plastic pipes protected from direct sunlight. Support to prevent sagging and bending.

1.8 COORDINATION

A. Notes:
   1. More detailed definition of the Design MEP peer review role shall be provided for submittal and post DD design phases.
   2. More information regarding furnishing and coordination shall be provided. “Furnishing, coordination with installing, and activation of pre-conditioned air units on passenger boarding bridges shall be considered part of Mechanical scope. PC air shall be equipped with status output to connected and observed during the current Airport Mechanical Maintenance EMCS (Energy Management Control System).”
   3. “Fall Protection systems shall be coordinated with and approved with Airport Mechanical Engineering and Safety and Health Departments. All associated engineering and structural work for the accepted system shall be included by structural steel subcontractor.”
   4. The engagement of the MEP subcontractors is very important is on a project of this nature. The sooner they are engaged in the process the better. SFO is looking into ways to engage them earlier in the process on future projects shall include a section regarding when to begin engaging the MEP subcontractor and how frequently to consult with the MEP subcontractor.

B. Arrange for pipe spaces, chases, slots, and openings in building structure during progress of construction, to allow for mechanical installations.

C. Coordinate installation of required supporting devices and set sleeves in poured in-place concrete and other structural components as they are constructed.

D. Coordinate requirements for access panels and doors for mechanical items requiring access that are concealed behind finished surfaces.
PART 2 – PRODUCTS

2.1 GENERAL

A. Furnish and install all new material, equipment, and apparatus hereinafter specified unless specifically noted otherwise. All material, equipment, and apparatus shall be identified by the manufacturer’s name, nameplate, and pertinent data.

B. Type M copper piping is not acceptable for any pressure water piping unless specifically noted otherwise. Type M copper may be used for condensate drains from cooling coils.

C. Manufacturers:
   1. All materials, equipment, and apparatus are mentioned as standards unless noted otherwise. The words “or approved equal” shall be considered to be subsequent to all manufacturers’ names used herein, unless specifically noted that substitutes are not allowed.
   2. In other Part 2 articles where subparagraph titles below introduce lists, the following requirements apply for product selection:
      a. Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the manufacturers specified.
      b. Manufacturers: Subject to compliance with requirements, provide products by the manufacturers specified.

2.2 PIPES, TUBES, AND FITTINGS

A. Refer to individual Division 23 piping Sections for pipe, tube, and fitting materials and joining methods.

B. Pipe Threads: ASME B2.20.1 for factory-threaded pipe and pipe fittings.

C. All pipes and fittings shall be manufactured domestically and shall bear “Made in USA” stamp. Pipe sizes indicated shall be carried full size to equipment served. Any change of size to match equipment connection shall be made within one foot of equipment. At temperature control valves with sizes smaller than connected lines, reduction shall be made immediately adjacent to valve.

D. Cast Iron
   1. Pressure:
      a. Pipe and Fittings: ANSI A21.6, 300 PSIG; bituminous external coated.
      b. Joints: ANSI A21.11, push-on or mechanical.
   2. Soil, Bell and Spigot:
      a. Pipe and Fittings: ANSI A112.5.2, service weight, bituminous coated interior and exterior.
      b. Joints: Bell and spigot, with neoprene compression gaskets.
   3. Soil, Plain End (No Hub):
      a. Pipe and Fittings: ANSI A112.5.1, hubless, service weight, bituminous coated interior and exterior.
E. Black Steel:

1. Threaded Malleable Iron:
   a. Pipe: ASTM A53, or ASTM A120, Schedule 40, black.
   c. Unions: MSS SP-76, 300 PSIG, black.

2. High Pressure, Threaded Malleable Iron:
   b. Fittings: ANSI B16.3, 300 PSIG Class, black.
   c. Unions: MSS SP-76, 300 PSIG, black.

3. Threaded Cast Iron:
   a. Pipe: ASTM A53 or ASTM A120, Schedule 40; black.
   b. Fittings: ANSI B16.4, black, 125 PSIG Class.

4. High Pressure, Threaded Cast Iron:
   a. Pipe: ASTM A53 or ASTM A120, Schedule 40; black.
   b. Fittings: ANSI B16.4, black, 250 PSIG Class.

5. Flanged Cast Iron:
   a. Pipe, 4" and Smaller: ASTM A53 or ASTM A120, Schedule 40; black.
   b. Pipe, 5" and Larger: ASTM A53, Schedule 40; black.
   c. Fittings and Flanges: ANSI B16.1, 125 PSIG Class, black; ANSI B16.21, non-metallic gasket.

6. High Pressure Flanged Cast Iron:
   b. Fittings and Flanges: ANSI B16.1, 250 PSIG Class, black; ANSI B16.21, non-metallic gasket.

7. Mechanical Joints:
   a. Pipe, 4" and Smaller: ASTM A53 or ASTM A120, Schedule 40; black.
   b. Pipe, 5" and Larger: ASTM A53, Schedule 40; black.
   c. Fittings: Gustin-Bacon Standard or Victualic Full Flow; black, grooved end.
   d. Couplings: Gustin-Bacon No. 100 or Victualic No. 77. Gasket material per manufacturer’s recommendations for service conditions of system.
   e. Grooves: Per manufacturer’s recommendations.

8. Buttweld:
   a. Pipe: ASTM A53, Schedule 40; black; seamless.
   b. Fittings: ANSI B16.9, ASTM A234, Schedule 40; buttweld.
   c. Flanges: ANSI B16.5, weld neck pattern; 150 PSIG Class.

F. Galvanized Steel:

1. Threaded Malleable Iron:
   a. Pipe, 4" and Smaller: ASTM A53 or ASTM A120, Schedule 40; galvanized.
2. High Pressure, Threaded Malleable Iron:
   b. Fittings: ANSI B16.3, 300 PSIG Class; galvanized.
   c. Unions: MSS SP-76, 300 PSIG Class; galvanized.

3. Flanged Cast Iron:
   a. Pipe, 4” and Smaller: ASTM A53 or ASTM A120, Schedule 40; galvanized.
   b. Pipe, 5” and Larger: ASTM A53, Schedule 40; galvanized.
   c. Fittings and Flanges: ANSI B16.1, 125 PSIG Class, galvanized; ANSI B16.21, non- metallic gasket.

4. High Pressure, Flanged Cast Iron:
   b. Fittings and Flanges: ANSI B16.1, 250 PSIG Class, galvanized; ANSI B16.21, non- metallic gasket.

5. Mechanical Joint:
   a. Pipe, 4” and Smaller: ASTM A53 or ASTM A120, Schedule 40; galvanized.
   b. Pipe, 5” and Larger: ASTM A53, Schedule 40; galvanized.
   c. Fittings: Gustin-Bacon Standard, or Victualic Full Flow; galvanized, grooved end.
   d. Couplings: Gustin-Bacon No. 100 or Victualic No. 77. Gasket material per manufacturer’s published recommendations for service conditions of system.
   e. Grooves: Per manufacturer’s published recommendations.

6. Drainage:
   a. Pipe: ASTM A120, Schedule 40; galvanized.
   b. Fittings: ANSI B16.12, black; coated.

G. Copper:

1. Drainage; Type DWV:
   b. Fittings: ANSI B16.23 cast bronze, or ANSI B16.29 wrought copper.
   c. Solder: ASTM B32, alloy grade 50A; lead-free solder.

2. Drainage; Type M:
   b. Fittings: ANSI B16.23 cast bronze, or ANSI B16.29 wrought copper.
   c. Solder: ASTM B32, alloy grade 50A; lead-free solder.

3. Pressure; Type L; Hard Temper:
   a. Joints; 95/5 Solder:
      1) Tubing: ASTM B88.
      2) Fittings: ANSI B16.22 wrought copper or ANSI B16.18 cast bronze.
4) Solder: ASTM B32, alloy grade 95TA; 95% tin, 5% antimony.

b. Joints; Silver Brazed:
   1) Tubing: ASTM B88.
   2) Fittings: ANSI B16.22 wrought copper or ANSI B16.18 cast bronze.
   4) Solder: Silver brazing alloy melting at or above 1100°F; 15% silver, 80% copper, 5% phosphorous.

4. Pressure, Type K; Hard Temper:
   a. Joints; Silver Brazed:
      1) Tubing: ASTM B88.
      2) Fittings: ANSI B16.22 wrought copper or ANSI B16.18 cast bronze.
      4) Solder: Silver brazing alloy melting at or above 1100°F; 15% silver, 80% copper, 5% phosphorous.

H. Stainless Steel:
   1. Welded:
      a. Pipe: ASTM A312, Schedule 40S, Type 304L, or where indicated, Schedule 10S, Type 304L.
      b. Fittings: ASTM A403, Schedule 40S, Type 304L, or where indicated, Schedule 10S, Type 304L.

I. Ductile Iron:
   1. Drainage:
      b. Fittings: Bell and Spigot ends for push-on joints.

J. Fiberglass Reinforced Resin Pipe:
   1. Pipe and Fittings: Fiberglass reinforced epoxy pipe conforming to ANSI Z-288.1; UL approved.
   2. Acceptable Manufacturers:
      a. Dualoy-3000/UL.
      b. Or approved equal.

K. Other Piping: As described in specific sections.

2.3 JOINING MATERIALS

A. Refer to individual Division 23 Piping Sections for special joining materials not listed below.

B. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.
   1. ASME B16.21, nonmetallic, flat, asbestos-free, 1/8” maximum thickness unless thickness or specific material is indicated.
      a. Full-Face Type: For flat-face, Class 125 cast-iron and cast-bronze flanges.
      b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.
   2. AWWA C110, rubber, flat face, 1/8” thick, unless otherwise indicated; and full-face or ring type,
C. Flange Bolts and Nuts: ASME B1821, carbon steel, unless otherwise indicated.

D. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer, unless otherwise indicated.

E. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.

F. Brazing Filler Metals: AWS A5.8, BcuP Series, copper-phosphorus alloys for general-duty brazing, unless otherwise indicated; and AWS A5.8, BAg1, silver alloy for refrigerant piping, unless otherwise indicated.

G. Welding Filler Metals: Comply with AWS D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

H. Solvent Cements for Joining Plastic Piping:
   1. ABS Piping: ASTMD 2235.
   2. CPVC Piping: ASTMF 493.
   3. PVC Piping: ASTM D 2564. Include primer according to ASTM F 656.
   4. PVC to ABS Piping Transition: ASTMD 3138.

I. Fiberglass Pipe Adhesive: As furnished or recommended by pipe manufacturer.

2.4 TRANSITION FITTINGS

A. AWWA Transition Couplings: Same size as, and with pressure rating at least equal to and with ends compatible with, piping to be joined.

   1. Acceptable Manufacturers:
      b. Dresser Industries, Inc.; DMD Div.
      c. Ford Meter Box Company, Incorporated (The); Pipe Products Div.
      d. JCM Industries.
      e. Smith-Blair, Inc.
      f. Viking Johnson.
      g. Or approved equal.

   2. Underground Piping NPS 1.5 and smaller: Manufactured fitting or coupling.


   4. Aboveground Pressure Piping: Pipe fitting.

B. Plastic-to-Metal Transition Fittings: CPVC and PVC one-piece fitting with manufacturer’s Schedule 80 equivalent dimensions; one end with threaded brass insert, and one solvent-cement-joint end.

   1. Acceptable Manufacturers:
      a. Eslon Thermoplastics.
      b. Or approved equal.

C. Plastic-to-Metal Transition Adaptors: One-piece fitting with manufacturer’s SDR 11 equivalent
dimensions; one end with threaded brass insert, and one solvent-cement-joint end.

1. Acceptable Manufacturers:
   a. Thompson Plastics, Inc.
   b. Or approved equal.

D. Plastic-to-Metal Transition Unions: MSS SP-107, [CPVC] [PVC] [CPVC and PVC] four-part union. Include brass end, solvent-cement-joint end, rubber O-ring, and union nut.

1. Acceptable Manufacturers:
   a. NIBCO, Inc.
   b. NIBCO, Inc.; Chemtrol Div.
   c. Or approved equal.

2.5 DIELECTRIC FITTINGS AND CONNECTIONS

A. Description: Combination fitting of copper alloy and ferrous materials with threaded, solder-joint, plain or weld-neck end connections that match piping system materials.

B. Insulating Material: Suitable for system fluid, pressure, and temperature.

C. Dielectric Unions: Factory-fabricated, union assembly, for 250-psig minimum working pressure at 180 °F.

1. Acceptable Manufacturers:
   a. Capitol Manufacturing Co.
   b. Central Plastics Company.
   c. Eclipse, Inc.
   d. Epco Sales, Inc.
      1) 2” and Smaller: EPCO Model FX; 250 WOG, with standard gaskets for plumbing and high temperature gaskets for heating.
      2) 2.5” and Larger: EPCO Model X; brass half-union, ANSI B16.1, 175 WOG, to flange
   g. Zurn Industries, Inc.; Wilkins Div.
   h. Or approved equal.

2.6 NOTE: Plastic/metal dielectric unions are not permitted. Use brass nipples in lieu of dielectric unions.

A. Dielectric Flanges: Factory-fabricated, companion-flange assembly for 150- or 300-psig minimum working pressure as required to suit system pressures.

1. Acceptable Manufacturers:
   a. Capitol Manufacturing Co.
   b. Central Plastics Company.
   c. Epco Sales, Inc.
   e. Or approved equal.

B. Dielectric-Flange Kits: Companion-flange assembly for field assembly. Include flanges, full- face- or ring-type neoprene or phenolic gasket, phenolic or polyethylene bolt sleeves, phenolic washers, and steel backing washers.
1. Acceptable Manufacturers:
   a. Advance Products & Systems, Inc.
   b. Calpico, Inc.
   c. Central Plastics Company.
   d. Pipeline Seal and Insulator, Inc.
   e. Or approved equal.

2. Separate companion flanges and steel bolts and nuts shall have 150- or 300-psig minimum working pressure where required to suit system pressures.

C. Dielectric Couplings: Galvanized-steel coupling with inert and noncorrosive, thermoplastic lining; threaded ends; and 300-psig minimum working pressure at 225 °F.

1. Acceptable Manufacturers:
   a. Calpico, Inc.
   b. Lochinvar Corp.
   c. Or approved equal.

D. Dielectric Nipples: Electroplated steel nipple with inert and noncorrosive, thermoplastic lining; plain, threaded, or grooved ends; and 300-psig minimum working pressure at 225 °F.

1. Acceptable Manufacturers:
   a. Perfection Corp.
   b. Precision Plumbing Products, Inc.
   c. Sioux Chief Manufacturing Co., Inc.
   d. Or approved equal.

E. Dielectric Connections:

1. General: Isolate ferrous from non-ferrous materials in piping systems and equipment connections with insulating couplings or dielectric unions.

2. Insulating Couplings:
   a. 2" and Smaller: Walter Vallett Company, V line
   b. 2.5" and Larger: EPCO, Model X, brass half-union; ANSI B16.1, 175 WOG; to flange.
   c. Or approved equal.

2.7 UNIONS

A. General: Provide and install in lines assembled with screwed and soldered fittings at points of connection to items of equipment and elsewhere as indicated or required to permit proper connections to be made or so that equipment may be removed. Unions shall also be provided in welded lines at the connections to items of equipment, where flanges are not provided.

1. Unions in steel lines assembled with screwed fittings shall be malleable iron screwed pattern unions with bronze seats. Unions in copper or brass lines shall be all brass, threaded pattern unions. Where unions are required by the above in steel lines assembled by welding, they shall consist of two mating welding flanges.

2. Unions in 2" and smaller in ferrous lines shall be Class 300 AAR malleable iron unions with iron to brass seats, and 2.5" and larger shall be ground flange unions. Unions in copper lines shall be 125 pounds ground joint brass unions or 150 pounds brass flanges if required by the mating item of equipment. Companion flanges on lines at various items of equipment, machines and pieces
of apparatus shall serve as unions to permit removal of the particular items.

2.8 FLANGES

A. General: All 125/150 pound and 250/300 pound ANSI flanges shall be weld neck and shall be domestically manufactured, forged carbon steel, conforming to ANSI B16.5 and ASTM A181 Grade I or II or A-105-71 as made by Tube Turn, Hackney or Ladish Company. Slip on flanges will not be acceptable. Each fitting shall be stamped as specified by ANSI B16.9 and, in addition, shall have the laboratory control number stenciled on each fitting for ready reference as to physical properties and chemical composition of the material. Complete test reports may be required for any fitting selected at random. Flanges which have been machined, remarked, painted or otherwise produced domestically from imported forgings or materials will not be acceptable. The flanges shall have the manufacturer's trademark permanently identified in accordance with MSS SP-25. Submit data for firm certifying compliance with these Specifications. Gaskets used shall be ring form, dimensioned to fit accurately within the bolt circle, shall be 1/16” thick, Manville service sheet packing Style 60. Inside diameter shall conform to the nominal pipe size. Bolts used shall be carbon steel bolts with semi-finished hexagon nuts of American Standard Heavy dimensions. All-thread rods will not be acceptable for flange bolts. Bolts shall have a tensile strength of 60,000 psi and an elastic limit of 30,000 psi. Flat faced flanges shall be furnished where required to match flanges on pumps, check valves, strainers, and similar items. Only one manufacturer of weld flanges will be allowed for on the project.

2.9 VALVES

A. General:
   1. All valves shall be domestically manufactured and shall bear “Made in USA” stamp.
   2. Pressure Ratings: Steam, unless otherwise indicated.
   3. Babbitt Sprocket Rims and Chains: Provide on all exposed valves installed over 7'-0” above floor. This includes, but is not limited to, all valves in mechanical, pump and fan rooms. Conform to accepted valve manufacturer’s published size schedule for type and size of valve.
   4. Ball Valves: Provide lever handles with position indicator and pointer.
   6. Motorized Gate Valves: Provide specified gate valves for the systems to be operated by actuators/motors (pneumatic or DDC) provided under Automation System. Coordinate exact requirement with Division 13 and provide all necessary features and attachments.

B. General Service Valves:
   1. Acceptable Manufacturers:
      a. Crane
      b. Demco
      c. Jenkins
      d. Keystone
      e. Nibco-Scott
      f. Powell
      g. Stockham
      h. Or approved equal.
Manufacturer numbers listed are Stockham:

2. Group 1A: 125 Class, 200 WOG, 2” and smaller, threaded ends.
   - Gate Valves: B-105
   - Ball Valves: S-216-BR-R-T
   - Globe Valve: B-13T screwed bonnet
   - Check Valve: B-319

3. Group 1B: 125 Class, 200 WOG, 2” and smaller, solder ends.
   - Gate Valves: B-109 screwed bonnet
   - Globe Valves: B-14T screwed bonnet
   - Check Valves: B-309

4. Group 2A: 150 Class, 300 WOG, 2” and smaller, threaded ends.
   - Gate Valves: B-120
   - Ball Valves: S-217-BR-R-T
   - Globe Valves: B-22
   - Check Valves: B-345

5. Group 2B: 150 Class, 300 WOG, 2” and smaller, solder ends.
   - Gate Valves: B-124
   - Globe Valves: B-24
   - Check Valves: B-345

6. Group 3A: 300 Class, 1000 WOG, 2” and smaller, threaded ends.
   - Gate Valves: B-145
   - Globe Valves: B-74
   - Check Valves: B-364

7. Group 4A: 125 Class, 200 WOG, IBBM, 2.5” and larger, flanged ends.
   - Gate Valves: G-623
   - Butterfly Valves: LD722-DS3-E
   - Globe Valves: G-512
   - Check Valves: G-931

8. Group 5A: 250 Class, 500 WOG, IBBM, 2.5” and larger, flanged ends.
   - Gate Valves: F-667
   - Globe Valves: F-532
   - Check Valves: F-947

9. Group 6A: 300 Class, 740 WOG, Cast Steel, 2.5” and larger, flanged ends.
   - Gate Valves: 30-OF
   - Globe Valves: 30-GSF
   - Check Valves: 30-SF

C. Plug Valves:

1. Acceptable Manufacturers:
a. Dezurik.
c. Rockwell.
d. Walworth.
e. Or approved equal.

Manufacturer numbers listed are Rockwell:

2. Wrenches: Provide selected manufacturer’s standard pattern on concealed valves and exposed valves less than 7' above floor.

3. Indicator and Adjustable Stop: Provide on valves installed on hydronic systems to indicate valve position at balance position.

4. Low Pressure: Semi-steel body, tapered lubricated plug, 200 PSIG WOG, 3 bolt cover minimum.
   a. 2” and smaller: Fig. 114, thread ed.
   b. 2.5” and 4”: Fig. 115, flanged.
   c. 5” to 6”: Fig. 165, flanged.
   d. 8” and larger: Fig. 169, flanged, gear operated.

5. High Pressure: Suitable for 400 °F and 500 PSIG pressure.

D. Pump Discharge Check Valves:

1. Sewage and Sump Pumps:
   a. Acceptable Manufacturers:
      1) Crane.
      2) Hammond.
      3) Jenkins.
      4) Kennedy.
      5) Nibco
      6) Scott.
      7) Powell.
      8) Stockham.
      9) Walworth.
     10) Or approved equal

Manufacturers numbers listed are Stockham:

b. Small Sump Pumps (2” Discharge and Smaller): B-316 bronze, 125 PSIG, lift check installed horizontally.

c. Sewage and Sump Pumps: G-931 L&W, iron body, bronze mounted, 125 PSIG, composition disc swing check with adjustable outside lever and weight.

2. Water Pumps:

   a. Manufacturers:
      1) Muessco.
      2) Clow.
      3) Or approved equal

Manufacturers numbers listed are Muessco.

   a) 2” and Smaller: Figure #203BP.
   b) 2.5” and Larger: Figure 105AP.
E. Combination Valve: Bell & Gossett Triple Duty Valve, Taco, Multipurpose, or Mueller No. 711 Control-Chek, combination shut-off, balancing, and check valve; angle and straight patterns as indicated; or approved equal.

F. Backflow and Anti-Syphon Valves:
   1. Acceptable Manufacturers:
      a. Clayton.
      b. Febco.
      c. Watts.
      d. Hersey.
      e. Or approved equal.
   3. Double Check Valve: Clayton Model D.
   4. Reduced Pressure Backflow Preventer: Clayton Model RP.

G. Water Pressure Reducing Valves:
   1. Acceptable Manufacturers:
      a. C.M. Bailey.
      b. A.W. Cash.
      c. Watts.
      d. Cash-Acme.
      e. Clayton
      f. Wilkins.
      g. Or approved equal.
   2. General Purpose: Cash Figure EB-24U with back pass and optimal union inlet.
   3. For Closed HVAC Systems: Cash Figure E-41.

H. Gas Pressure Reducing Valves:
   1. Manufacturers: Fisher, Reliance, Rockwell, or approved equal.
   2. Type: As indicated, or otherwise required.

I. Differential Pressure Relief Valves:
   1. Acceptable Manufacturers:
      a. C.M. Bailey.
      b. Clayton.
      c. Watts.
      d. Or approved equal. Pressure rating and connections, as specified for systems served.
   2. Pilot Operated: Watts Figure 116-25. Settings as shown on the drawings.

J. Safety and Relief Valves:
   1. Acceptable Manufacturers:
      a. Consolidated.
b. Kunkle.
c. Ladewig.
d. Or approved equal.

2. Types: Constructed, rated and stamped per ASME.
   b. Safety Relief Valves: Use for heated liquids.

3. Pressures and Ratings:
   a. General: Set pressures as indicated; not to exceed pressure rating of protected equipment.
   b. Temperature Rating: Suitable and rated for system temperatures on which installed. Safety relief valve minimum temperature rating is saturated steam temperature corresponding to pressure 10% higher than valve set pressure.

4. Capacities: Minimum capacity to relieve maximum energy while maintaining pressure in protected equipment within following:
   a. Unfired Pressure Vessels: 10% above vessel working pressure or 10% above

5. Test Tolerance: Maximum variation, under test, from set pressure as follows:
   a. Set Pressures 70 PSIG and Lower: Plus or minus 2 PSIG.
   b. Set Pressures Over 70 PSIG: Plus or minus 3%.

K. Solenoid Valves: ASCO, Hayes or approved equal. Normally open or close, as indicated in drawings. 200 PSIG WOG ratings. Coordinate electrical voltage and power requirements with Division 16.

2.10 PIPING SPECIALTIES

A. Thermometers:
   1. Acceptable Manufacturers:
      a. Trerice.
      b. Weksler.
      c. Weiss.
      d. Marsh.
      e. Or approved equal.

   2. Type: Industrial class, 9" scale, Aluminum case, glass front, magnified mercury column, separable well, straight, angle or adjustable to suit location installed.

   3. Scale Ranges:
      a. Chilled Water: 0 to 100 °F
      b. High Temperature Heating Water: 100 to 500 °F
      c. Heating Water: 20 to 240 °F
      d. Domestic Hot Water: 20 to 240 °F.

   4. Thermometer Wells: Ferrous piping; Type 316 stainless steel. Non-ferrous piping; brass or bronze. Working pressure as required for system. Provide cap and chain and lagging neck extensions to suit insulation thickness. Select properly for pressure ratings of piping systems.
5. Locate thermometer wells so the sensing bulb will give true and correct reading. Install thermometer wells as not to cause undue restriction in small piping. On overhead piping install thermometers such that they are readable from floor.

B. Pressure Gauges:
   1. Acceptable Manufacturers:
      a. Weksler.
      b. Trerice.
      c. Marsh.
      d. Weiss.
      e. Ashcroft.
      f. Or approved equal.
   
   2. Type: Weksler model BY14P, 4-1/2” diameter glycerin filled Grade A Bronze Bourdon tube with black numerals on white face. Markings both in psi and feet of water. Select dial range so that the normal operating pressure will occur close to midpoint of the dial range. Accuracy 1/2 of 1% of full scale. Micrometer type calibration adjustment screw. Select properly for pressure ratings of piping systems.

   3. Gauge Cocks: Provide BBV4 Brass Needle valves and pulsation dampener in pressure tube to gauge.

C. Test Fittings (PT Plugs):
   1. Acceptable Manufacturers:
      b. Flow Design.
      c. Or approved equal.

D. Type: Pete’s plug No. 110 with brass body and Nordel valve core suitable for 1000 PSIG and 275 °F. Locate where required for balancing and as indicated.

E. Strainers:
   1. Acceptable Manufacturers:
      a. Muessco.
      b. Bailey.
      c. Armstrong.
      d. Cash.
      e. Watts.
      f. Or approved equal.

   2. Y-Type:
      a. Ferrous piping: Muessco Model 751, cast iron body for chilled and heating water. Model 764 carbon steel body for high temperature hot water.
      b. Non-Ferrous piping: Muessco Model 351 for heating and chilled water, Model 581 cast steel body for high temperature heating water. Cast Bronze body with machined screen seats.
      c. Screen Perforations:
         1) 2” and Smaller: 20 mesh stainless steel screen.
2) 2.5” to 4”: 3/64” perforated stainless steel.
3) 5” and Larger: 1/8” perforated stainless steel.

   d. Blow-off connections: Provide all strainers with valved blow-off connection. Valves same size as plug or 1” maximum. Provide with 1” garden hose thread adapter and chain.

3. Basket Strainer: Muessco Model 165 cast iron body for heating and chilled water, Model 186 cast steel body for high temperature heating water. Perforation screen and blow-off connection similar to for “Y” strainers, unless otherwise indicated on drawings.

F. Air Vents

1. Manual Air Vents: Provide 0.25” globe valve, valve group as listed for system in which installed. Provide 0.25” U-tube and flexible copper tubing to drain in mechanical rooms and terminate above ceiling at accessible locations for other locations.

2. Automatic Air Vents: Sarco, Hoffman, Taco, or approved equal. Working pressure as required for systems. 0.75” inlet, cast iron body, bronze pilot mechanism and stainless steel hardware. Provide shut-off valve at inlet and pipe outlet to open sight floor drain or floor sink.

G. Balancing Devices:

1. Devices: Bell & Gossett Model CB Circuit Setter, or approved equal by Taco or Armstrong; 0.5” through 3”, bronze balancing valve calibrated and with provisions for quick connection to portable differential pressure meter; with integral degree of valve opening indicator; 125 PSIG working pressure at 250 °F.

2. Meter: Provide one Model RO-2 differential pressure meter suitable for quick connection to balancing devices and with differential pressure versus GPM curves for each device size.

H. Flow Measurement Devices:

1. Flow Elements:
   a. Fitting: Ellison, Sentinel, or approved equal, Annubar with brass nipples and fitting; other parts stainless steel; 300 PSIG at 250 °F; provide necessary fittings.
   
   b. Type:
      1) 2” and Smaller: Type 71.
      2) 2.5” - 3”: Type 73.
      3) 4” and Larger: Type 74.
   
   c. Meter: Provide one portable flow meter set including Type 705 valves and fittings, quick coupling hoses, carrying case, pressure differential to GPM chart, and instructions. Equipment suitable for 250 PSIG and 250 °F.
   
   d. Provide flow measuring device and plug valves where balancing device is shown for pipes 4” and larger.

I. Flow Control Valves:

1. Acceptable Manufacturers:
   a. Griswold.
   b. Flow Design.
   c. Or approved equal, suitable for pressure differential of 4 psi through 57 psi, +5% accuracy.
2. Type:
   a. 0.75” - 1.25”: Threaded, gray iron; 250 PSIG at 400 °F.
   b. 1.5” - 2.5”: Threaded, gray iron; 200 PSIG at 250 °F.
   c. 3” and Larger: Flanged.
      1) Gray Iron: 200 PSIG at 250 °F.
   d. Select with suitable pressure settings and ranges to provide water flows as scheduled at pressure differential expected at the device.

J. Flexible Pipe Connectors:

1. Acceptable Manufacturers:
   a. Mason.
   b. Flexonics.
   c. Metraflex.
   d. Or approved equal.

2. Type:
   a. Type A: At Pumps and at equipment connections on low pressure (200 PSI WOG) systems: Mason double sphere, EPDM Model “Superflex” MFTNC. 200 °F rated at 200 PSIG.
   b. Type B: At connection to Vibration Isolated equipment: Mason BSS type “GU” or “EM”, flexible stainless steel braided hose with threaded or flanged ends. Length and pressure ratings as required.
   c. Type C: For High Temperature Hot Water System: Flexonics 402H, Superdeluxe, high pressure double braided connector with 300 carbon steel flanges each end.

K. Air Separators:

1. Acceptable Manufacturers:
   a. Bell & Gossett.
   b. Taco.
   c. Armstrong.
   d. Or approved equal.

2. Construction: Tangential opening vessel with flanged inlet and outlet connections to create low velocity vortex thereby separating air from the circulating water. Internal stainless steel, perforated air collection tubes designed to direct accumulated air to the vent at top. Steel body with construction in accordance with ASME Boiler and Vessel code, stamped for 125 psig @ 350 °F. Provide with one shop coat of dry enamel at the factory. Provide with drain and vent connection.

3. Model, size, air collection efficiency and pressure drop as scheduled on drawings.

L. Expansion Tanks:

1. Acceptable Manufacturers:
   a. Bell & Gossett.
   b. Amtrol.
   c. Armstrong.
   d. Taco.
   e. Wessel.
f. Or approved equal.

M. Construction: Hydro-pneumatic, bladder type tank made per ASME Boiler and Vessel Code and Stamped 125 psi working pressure. California Code approved with water level sight glass and other accessories. Carbon steel, shell and heavy duty butyl rubber bladder containing all system water with no water contact with metal. Provide with system connection and drain and with a 0.302”-32 changing valve connection (standard tire valve) to facilitate on-site changing of the tank.

N. Type, size, operating pressures and volumes as scheduled on Drawings.

O. Adjust system pressure by adding or removing air at the start-up of systems.

P. Pipe Coating
   1. All above ground steel and copper pipe and fittings (not insulated or painted) in corrosive air environments shall be covered with one of the following methods:
   2. Two coats of 10 Mill Scotch Wrap No. 51.
   3. Prefabricated extruded plastic cover with joints sealed with two coats of 10 Mill Scotch Wrap No. 51.
   5. For above grade pipes coat clean pipe coal tar and allow to cure per manufacturer’s requirements Kop-Coat #Bit-50 or equal by Pittsburg.

2.11 MECHANICAL SLEEVE SEALS

A. Description: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.

   1. Acceptable Manufacturers:
      a. Thunderline Link Seal.
      b. Calpico, Inc.
      c. Metraflex, Co.
      d. Or approved equal.

   2. Sealing Elements: EPDM interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.

   3. Pressure Plates: Stainless Steel. Include two for each sealing element.

   4. Connecting Bolts and Nuts: Stainless steel of length required to secure pressure plates to sealing elements. Include one for each sealing element.

2.12 SLEEVES, FLASHINGS AND ESCUTCHEONS

A. General: Provide all pipes passing through floors, walls, partitions, beams, and girders with sleeves, types as specified below, of adequate diameter to allow minimum of 0.75” clearance around between sleeves and pipe. When piping is insulated, insulation shall pass continuously through sleeve with same clearance between insulation and sleeve. Insulation vapor barrier shall also pass through sleeve uninterrupted. Provide insulation protection shields at all penetrations of insulated piping.

B. Sleeves: Adjus-To-Crete, A.M.J. Products, or approved equal; 26-gauge minimum galvanized sheet
metal or plastic types as scheduled. Adjus-To-Crete used as basis of selection. Galvanized- Steel Sheet: 0.0239” minimum thickness; round tube closed with welded longitudinal joint.

1. Sleeve Schedule

<table>
<thead>
<tr>
<th>Concrete or masonry walls and concrete beams:</th>
<th>No. 100</th>
<th>(Remove)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaster or Drywall:</td>
<td>No. 11</td>
<td>(Do not remove)</td>
</tr>
<tr>
<td>Beams with poured concrete Fireproofing:</td>
<td>No. 100 or No.10</td>
<td>(Remove)</td>
</tr>
<tr>
<td>Concrete floors with metal under deck. (Spot weld to deck):</td>
<td>ATC</td>
<td>(Do not remove)</td>
</tr>
<tr>
<td>Concrete floors:</td>
<td>No. 10</td>
<td>(Remove)</td>
</tr>
</tbody>
</table>

2. Steel Pipe: ASTM A 53, Type E, Grade B, Schedule 40, galvanized, plain ends.

3. Cast Iron: Cast or fabricated “wall pipe” equivalent to ductile-iron pressure pipe, with plain ends and integral water stop, unless otherwise indicated.

4. Stack Sleeve Fittings: Manufactured, cast-iron sleeve with integral clamping flange. Include clamping ring and bolts and nuts for membrane flashing.
   a. Underdeck Clamp: Clamping ring with set screws.

5. Molded PVC: Permanent, with nailing flange for attaching to wooden forms.


7. Molded PE: Reusable, PE, tapered-cup shaped, and smooth-outer surface with nailing flange for attaching to wooden forms.

C. Sealing of Sleeves and Openings: Seal as follows:

1. Waterproof Walls and Floors: Provide Thunderline Corporation’s Link Seal, or approved equal.

2. Fire Rated Floors and Walls: Provide sleeves and insulation protection shields (See Paragraph 2.09 I) at penetrations and leave sufficient annular space between them so that fire stopping can be accomplished as specified under sections pertaining to “Firestopping.”

3. Non-Rated Floors and Walls: Provide glass fiber packing between sleeve and insulation protection shields, minimum 1.5 lb. density. Seal face of penetration with non-hardening sealant, type as specified under sections pertaining to “Sealants”.

D. Flashings:

1. Pipes through Roof: Flash with 6 lb. lead extending a minimum of 12” around pipe and up pipe under counter flashing. Provide counter flashing similar to Wade W-8780-CV.

2. Drains: Provide clamping ring and 6 lb. lead flashing extending a minimum of 12” around drain.

3. Ducts and Vents through Exterior Wall or Roof: Flash and counter flash per ductwork and accessories requirements.
E. Escutcheons:

1. Description: Manufactured wall and ceiling escutcheons and floor plates, with an ID to closely fit around pipe, tube, and insulation of insulated piping and an OD that completely covers opening.

2. Provide at exposed pipe and duct penetrations through walls, partitions, furring floors, and ceilings.

3. Types:
   a. Piping: Grinnell No. 10, Beaton and Cadwell, or approved equal; nickel plated.
   b. Ducts: Sheet metal angle sized to conceal edges of opening.

4. One-Piece, Deep-Pattern Type: Deep-drawn, box-shaped brass with polished chrome-plated finish.

5. One-Piece, Cast-Brass Type: With set screw.


7. One-Piece, Stamped-Steel Type: With set screw and chrome-plated finish.

8. Split-Plate, Stamped-Steel Type: With concealed hinge, set screw, and chrome-plated finish.

9. One-Piece, Floor-Plate Type: Cast-iron floor plate.

10. Split-Casting, Floor-Plate Type: Cast brass with concealed hinge and set screw.

2.13 HANGERS AND SUPPORTS

A. General: Comply with applicable codes pertaining to product materials and installation of supports and anchors, including, but not limited to, the following:

1. UL and FM Compliance: Provide products which are UL listed and FM approved.

2. MSS Standard Compliance: Manufacturer's Standardization Society (MSS).

3. SMACNA: Seismic Restraint Manual Guidelines for Mechanical Systems, including Appendix E where applicable.

4. NFPA: Pamphlet number 13 and 14 for fire protection systems.

5. Provide copper plated supports and attachments for copper piping systems or felt lined steel supports.

6. Comply with applicable requirements of ANSI B31.1.0 and B31.2 for piping.

7. Acceptable Manufacturers:
   a. B-Line.
   b. Grinnell.
   c. Superstrut.
   d. Or approved equal.

B. Properly support material, equipment, and apparatus. Hangers and supports shall have minimum safety factor of 5, based on ultimate tensile or compressive strength, as applicable, of material used. Turnbuckles shall have capacity of not less than attached rod. Use proper manufactured supports.
throughout; make-shift materials such as wire, tape, and wood blocks not permitted. Support weight of piping independent of equipment and provide supports on both sides of valves for piping 4” or larger. Supports and frequency of their installation are minimum requirements. Provide more frequent supports and/or supports with greater load ratings so that no support is loaded beyond its recommended limit. No water piping shall have direct contact with hanging and support system or the structure.

C. Supplemental Support Steel: Provide all additional steel members required to support the equipment, piping and ductwork in the arrangements shown on drawings. The examples for this requirement include but are not limited to the following:

2. Equipment supports where the load needs to be transferred to building structural members.
3. Duct and pipe riser supports in shafts.
4. Large pipes that cannot be supported by floor decks/slabs.
5. Pipe support racks in pipe trenches.
   a. The Contractor shall design all supplemental steel requirements, shall have a registered Structural Engineer provide the calculations, and shall submit fabrication details showing methods of attachments to building structure for approval by the Architect.
   b. Acceptable Manufacturers:
      1) Grinnell.
      2) B-Line.
      3) Elcen.
      4) Pipe Shields, Inc.
      5) Superstrut.
      6) Unistrut.
      7) Or approved equal.
      Grinnell catalog numbers specified unless noted otherwise.
   c. Attachments to Building Structure:
      6. Anchor Bolts: Material, diameters and lengths for 3,000 psi concrete.
      7. Concrete Inserts: Figure 282. Place reinforcing steel through insert as recommended by manufacturer for recommended loads.
      8. Poured-In-Place Concrete with Metal Deck: Superstrut figure C-475. Maximum allowable load 200 pounds at each support.
      10. Welded Beam Attachments: Figure 66.
      11. Side Beam Brackets: Figures 202 or 203.
      13. Hanger Rod Fixtures:
         a. Steel Turnbuckles: Figure 230. MSS Type 13. B-Line #B3202.
         b. Linked Eye Rod: Figure 278X.
c. Steel Clevis or J-Hangers: Figure 299. MSS Type 14 or MSS-SP-69.

D. Building Attachments: Except as otherwise indicated, provide factory-fabricated building attachments of one of the following MSS types listed:

2. Steel Brackets: One of the following for indicated loading:
4. Anchor Bolts: Heavy duty, drilled-in concrete expansion wedge anchor bolts; Hilti #TZ.

E. Saddles and Shields: Except as otherwise indicated, provide saddles or shields under piping hangers and supports, factory-fabricated, for all insulated piping. Size saddles and shields for exact fit to mate with pipe insulation.

2. Insulation Protection Shields: MSS Type 40, 18” minimum or of length recommended by manufacturer to prevent crushing of insulation. High density insulation insert lengths shall match or exceed shield length. B-Line #B3151.
3. Thermal Hanger Shields: Constructed of 360° insert of waterproofed calcium silicate (60 psi flexural strength minimum) encased in 360° sheet metal shield. Provide assembly of same thickness as adjoining insulation. Length of calcium silicate insert shall match or exceed shield length. B-Line #B13152.

F. Miscellaneous Materials:

1. Metal Framing: Provide products complying with NEMA STD ML1.
2. Steel Plates, Shapes, and Bars: Provide products complying with ASTM A36.
3. Cement Grout: Portland cement (ASTM C150, Type I or Type III) and clean uniformly graded, natural sand (ASTM C404, Size No. 2). Mix at a ratio of 1.0 part cement to 3.0 parts sand by volume, with minimum amount of water required for placement and hydration.
4. Heavy-Duty Steel Trapezes: Fabricate from steel shapes selected for loads required. Weld steel in accordance with AWS standards.
5. Pipe Guides: Provide factory-fabricated guides, of cast semi-steel or heavy fabricated steel, consisting of a bolted two-section outer cylinder and base with a two-section guiding spider bolted tight to pipe. Size guide and spiders to clear pipe and insulation (if any), and cylinder. Provide guides of length recommended by manufacturer to allow indicated travel.
2.14 PIPING SUPPORTS

A. General: For pipes supported on insulation shields, use spacing requirements recommended by insulation shield manufacturer or spacings specified, whichever is more stringent.

B. Acceptable Manufacturers:
   1. Grinnell.
   2. B-Line.
   3. Pipe Shields, Inc.
   4. Rilco.
   5. Elcen.
   7. Unistrut.
   8. Or approved equal.

Grinnell catalog numbers specified, unless otherwise noted.

C. Cast Iron Soil Pipe:

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Max. Span (ft)</th>
<th>Minimum Rod Size (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4” and smaller</td>
<td>10</td>
<td>1/2</td>
</tr>
<tr>
<td>5”</td>
<td>10</td>
<td>5/8</td>
</tr>
<tr>
<td>6”</td>
<td>10</td>
<td>3/4</td>
</tr>
<tr>
<td>8”-12”</td>
<td>10</td>
<td>7/8</td>
</tr>
<tr>
<td>15”</td>
<td>5</td>
<td>3/4</td>
</tr>
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</table>

D. Copper Pipe:

<table>
<thead>
<tr>
<th>Nominal Size</th>
<th>Maximum (Feet)</th>
<th>Span (inches)</th>
<th>Rod Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25” - 3/8”</td>
<td>4</td>
<td>3/8</td>
<td></td>
</tr>
<tr>
<td>1/2” - 0.75”</td>
<td>5</td>
<td>3/8</td>
<td></td>
</tr>
<tr>
<td>1” - 1-0.25”</td>
<td>6</td>
<td>3/8</td>
<td></td>
</tr>
<tr>
<td>1.5” - 2”</td>
<td>8</td>
<td>3/8</td>
<td></td>
</tr>
<tr>
<td>2.5” - 3”</td>
<td>9</td>
<td>1/2</td>
<td></td>
</tr>
<tr>
<td>4”</td>
<td>10</td>
<td>1/2</td>
<td></td>
</tr>
<tr>
<td>6”</td>
<td>10</td>
<td>5/8</td>
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</tr>
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</table>

E. Steel Pipe:

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<thead>
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<th>Nominal Size</th>
<th>Maximum (Feet)</th>
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</tr>
</thead>
<tbody>
<tr>
<td>0.25” - 0.5”</td>
<td>5</td>
<td>3/8</td>
<td></td>
</tr>
<tr>
<td>0.75”</td>
<td>6</td>
<td>3/8</td>
<td></td>
</tr>
<tr>
<td>1”</td>
<td>7</td>
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<td></td>
</tr>
<tr>
<td>1.25” - 1.5”</td>
<td>9</td>
<td>3/8</td>
<td></td>
</tr>
<tr>
<td>2”</td>
<td>10</td>
<td>3/8</td>
<td></td>
</tr>
<tr>
<td>2.5”</td>
<td>11</td>
<td>1/2</td>
<td></td>
</tr>
<tr>
<td>3”</td>
<td>12</td>
<td>1/2</td>
<td></td>
</tr>
<tr>
<td>4”</td>
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<td>5/8</td>
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</tr>
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<td>6”</td>
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<td>3/4</td>
<td></td>
</tr>
<tr>
<td>8”</td>
<td>19</td>
<td>7/8</td>
<td></td>
</tr>
<tr>
<td>10&quot;</td>
<td>22</td>
<td>2-3/4</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>----</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>12&quot;</td>
<td>23</td>
<td>2-3/4</td>
<td></td>
</tr>
<tr>
<td>14&quot;</td>
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<td>28</td>
<td>2-7/8</td>
<td></td>
</tr>
<tr>
<td>20&quot;</td>
<td>30</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

F. 14" and Larger: Attach to building structural beams or columns. Do not attach to floor construction.

G. Horizontal Pipe Attachments:
   1. Adjustable Clevis: Figure 260 or 300.
   2. U-Bolt: Figure 137.
   3. Stanchion: Figure 259.
   4. Sliding Supports:
      a. Where Required: All high temperature heating water piping, chilled and heating water piping, 6" and larger, and additionally where indicated.
      b. Rollers: B-Line Figure B3117SL, B3120 or B3122.
   5. Except as otherwise indicated, provide factory-fabricated hangers and supports of one of the following MSS types listed
      a. Adjustable Steel Swivel Band Hangers: MSS Type 10. B-Line #B3170NF.
      c. Pipe Slides and Slide Plates: MSS Type 35, including one of the following plate types:
         7. Plate: Guided type. B-Line #B3893 or #B3896.
      a. Pipe Saddle Supports: MSS Type 36, including steel pipe base support and cast iron floor flange. B-Line #B3095.
      b. Pipe Saddle Supports with U-Bolt: MSS Type 37, including steel pipe base support and cast iron floor flange. B-Line #B3090.
      c. Adjustable Pipe Saddle Supports: MSS Type 38, including steel pipe base support and cast iron floor flange. B-Line #B3093.
      e. Adjustable Roller Hangers: MSS Type 43. B-Line #B3110.
      f. Pipe Roll Stands: MSS Type 44. B-Line #B3117SL.
   H. Vertical Pipe Attachments:
      1. Locations: At each floor unless otherwise indicated.
      2. Concealed: Figure 261.
3. Exposed: Hang from underside of floor with two structural attachments, 2 rods and Figure 261 clamp.

4. Insulated Pipes: Pipe Shields, Inc. Series E-1000 to E-1300 or equal.


I. Insulation Protection Shield: Pipe Shields, Inc., Models A1000 through A9000, as suitable for application and load rating, or approved equal. Provide at supports of insulated piping and at all wall and floor penetrations for insulated piping. Length of shield, thickness and compressive strength of insulation to result in no noticeable deformation of shield or insulation at support and shall result in alignment with adjacent insulation. Provide vapor barrier integral with shield for insulation systems requiring a vapor barrier.

J. Isolators: Superstrut Series 715 or 716, or approved equal. Provide at all non-insulated copper tube supports.


2.15 SEISMIC RESTRAINT/VIBRATION ISOLATION REQUIREMENTS

A. All ductwork, equipment and piping shall be seismically braced per the California Building Code for maximum restraint for Seismic Zone 4 sizing.

B. The manufacturers of the seismic restraints for piping shall submit shop drawings for review prior to installation of piping. The shop drawings shall indicate the location and loading of each restraint.

C. Acceptable Manufacturers:
   1. B-Line.
   2. Grinnell.
   4. Superstrut.
   5. Mason.
   6. Or approved equal.

D. Anchor bolt and seismic restrain calculations, signed and stamped by a Civil or Structural Engineer licensed in California, shall be submitted showing adequacy of the bolts, sizing and type.

E. Restraint of rigidly mounted piping and ductwork conforming to “Seismic Restraint Manual Guidelines for Mechanical Systems” need not submit structural calculations for restraint systems strictly conforming to these guidelines.

F. Isolated Equipment:
   1. Spring type isolators shall be freestanding and laterally stable and complete with 0.25” neoprene acoustical friction pads or neoprene cup between the spring and the base plate. All mountings shall have leveling bolts. Springs shall have a minimum additional travel to solid equal to 50% of the rated deflection. Submittals shall include spring diameters, deflections compressed spring height and solid spring height. A steel housing shall be included to resist motion due to earthquake loads. A minimum clearance of 0.25” shall be maintained around restraining bolts and between the housing and the spring so as not to interfere with the spring.
action. The housing shall be out of contact during normal operations. Mountings used out of doors shall be hot dipped galvanized.

a. Manufacturer:
   1) Mason Industries #SLR series.
   2) Or approved equal.

2. All-directional seismic snubber restraints, with 1G load rating, shall consist of interlocking steel members restrained by a one-piece molded bushing or bridge bearing neoprene. A minimum air gap of 1/8” shall be incorporated in the snubber design in all directions before contact is made between the rigid and resilient surfaces. Snubber end shall be removable to allow inspection of internal clearances.

a. Manufacturer:
   1) Mason Industries #Z-122S.

3. Suspended isolated equipment and vessels shall be protected with cable restraints. Cables shall be installed to prevent excessive seismic motion and so arranged that they do not engage during normal operation, starting or stopping.

G. Isolator Types: Where equipment isolators are not provided by other sections of the specification or shown on drawings, provide factory fabricated isolator types sized by the manufacturer for the appropriate loading. Model numbers of Mason Industries products are listed below. Products of other manufacturers will be acceptable provided they comply with all of the requirements of this specification and the drawings.

1. Acceptable Manufacturers:
   a. Mason Industries.
   b. Amber-Booth.
   c. Caldyn.
   d. Peabody Noise Control.
   e. Or approved equal.

H. Seismic restraints may be omitted from the following installations with prior approval from the Airport.

1. All piping suspended by individual hangers 12” or less in length from the top of pipe to the bottom of the support for the hanger.

2. All ducts suspended by hangers 12” or less in length from the top of the duct to the bottom of the support for the hanger. Ducts must be positively attached to the hangers within 2” of the top of the duct with a minimum of two #10 sheet metal screws.

I. Submittals:

1. The seismic and vibration control manufacturer shall determine the number, size, and type of anchor bolts, cables, restraints, seismic snubbers, etc., for each piece of equipment and groups of pipes and ducts.

2. Complete engineering calculations and drawings stamped and signed by a Civil or Structural Engineer licensed in California for all vibration and seismic requirements for all equipment, piping and ductwork.

3. The type, size and deflection of each isolator proposed.

4. Details for all the isolators and seismic bracing with snubbers proposed.
5. Details for steel frames to be used in conjunction with the isolation and seismic restraint of the items.
6. Clearly outlined procedures for installing and adjusting the isolators, seismic bracing and snubbers.

2.16 THERMAL EXPANSION JOINTS

A. Acceptable Manufacturers:
   1. Barco-Hyspan.
   2. Flexonics.
   3. Centerflex.
   5. Keflex.
   6. Or approved equal.

B. General: Pressure ratings, minimum 150 psig or to conform with pressure ratings of the pipe system. End connections as specified for valves in the same system. Factory preset and compress expansion joints installed in chilled water systems.

C. Types:
   1. Guided expansion joints (Code “EJ-1”): Hyspan Series 3501 with externally pressurized guided, laminated bellows and flanges and guide rings. 4” axial compression with 1” axial extension.
   2. Pressure balanced and guided expansion joints (Code “EJ-2”): Hyspan Series 3501PB, flanged ends with second additional bellows to eliminate pressure thrust force at the anchors. 4” axial compression with 1” axial extension. Provide for all piping 6” and larger installed in the pipe trenches and additionally where shown on the drawings.
   3. Laminated bellows expansion joints (Code “EJ-3”): Hyspan Series 1500 laminated stainless steel type 304 bellows and stainless steel inner liner, welded 360°. Axial deflection 2” unless otherwise shown.
   4. Expansion compensators (Code “EJ-4”): Hyspan Series 8500 high pressure expansion compensators, working pressure 175 psi. 2” tube expansion, 1/2” tube contraction. Copper of steel construction as required.

D. Provide anchors and guides in accordance with manufacturer’s published recommendations.

2.17 FLEXIBLE (BALL TYPE) JOINTS

A. Acceptable Manufacturers:
   1. Barco-Hyspan.
   2. Or approved equal.

B. Types: The flexible ball joints shall be Barco Type N, flanged, bolted retainer type, Style I Ball Joints with 11N molded mineral filled composition seals unless otherwise shown, suitable for continuous operating temperatures of +525 °F without additional containment seals, injected sealants, or anti-bypass seals. Ball joints shall provide 360° rotation and 15° total angular flex. Provide 3 joints per set at each location for each pipe. For joint movement needs at each location and arrangement, see Drawings.
C. Materials and Construction:
   1. All pressure containing parts and bolting shall be designed and manufactured from materials conforming to code requirements of ASME Section II and ANSI B31.1.
   2. Carbon steel ball spheres shall be crack-free chrome plated with baked-on molybdenum disulfide coating.
   3. Ball joint pipe connection ends shall be beveled for welding to standard wall pipe or with (specified) ANSI forged steel weld neck flanges.
   4. All ball joints shall be domestically manufactured and shall bear “Made in USA” stamp.

D. Operating Conditions: The flexible ball joints shall be designed for continuous operation at the various operating conditions listed below:

<table>
<thead>
<tr>
<th>Operating Condition</th>
<th>Temperature</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>High temperature heating water</td>
<td>400 °F at 500 PSIG</td>
<td></td>
</tr>
<tr>
<td>Chilled and heating water</td>
<td>200 °F at 275 PSIG</td>
<td></td>
</tr>
<tr>
<td>Other piping</td>
<td>200 °F at 200 PSIG</td>
<td></td>
</tr>
</tbody>
</table>

E. Acceptance Testing:
   1. All flexible ball joints shall be capable of a hydrostatic test at one-and-one-half times design pressure.
   2. In addition to the hydrostatic test, each ball joint will be pressurized with 50 psig saturated steam, inspected for leakage and have bolts properly torqued prior to shipment.
   3. Ball joints shall be capable of certifying to meet Mil-Std-167 vibration test and Mil-S-901C shock test.
   4. Ball joints shall be installed in accordance with published recommendation of the manufacturer. Ball end of the joints shall be upstream side of flow to prevent build-up of entrained foreign matter at the joints. Manufacturer’s authorized representative shall be present for inspection of the installation and at start-up.
   5. Approval certification: Ball joints shall be FM approved or UL listed.

F. For additional features and requirements of specific systems, see the respective piping system sections.

2.18 ANCHORS, GUIDES AND EXPANSION LOOPS

A. Anchors:
   1. Locations: As indicated.
   2. Acceptable Manufacturers:
      a. Pipe Shields, Inc.
      b. Rilco.
      c. Or approved equal. Model numbers given are for Pipe Shields, Inc.
   3. Types:
      a. Horizontal Support Anchors:
         1) High temperature heating water - Series C4000 to C4300.
2) Chilled Water - Series C4000 to C4300.
3) Heating Water - Series C1000, C2000 or C2100.

b. Vertical Support Anchors:
   1) Chilled and Heating Water - Series E2000 to E2300.
   2) Provide anchors attached to resilient support mounts specified at location indicated in the drawings.

B. Pipe Guides:
   1. Locations: As indicated.
   2. Acceptable Manufacturers:
      a. Keflex.
      b. Flexonics.
      c. Metraflex.
      d. Mason.
      e. Or approved equal.
   3. Types: Keflex CP for insulated pipes; type PM for other piping. Continuous uninterrupted vapor barrier for chilled water pipes.

C. Expansion Loops: As indicated. Provide minimum of two guides on both sides of each expansion loop.

2.19 ACCESS PANELS AND ACCESS DOORS

A. Acceptable Manufacturers:
   1. Milcor, Karp
   2. Nystrom
   3. Elmdoor
   4. Or approved equal.

B. General: In non-public areas with non-accessible ceilings and walls, and where access panels are not provided under other Divisions, furnish access panels for concealed valves, equipment, dampers, and control devices. Provide all access doors and panels to serve equipment under this work including those which must be installed in finished architectural surfaces. Size for proper access, adjusting and maintenance, but not smaller than 12”x 12” for simple manual access or smaller than 24” x 24” where personnel must pass through, or as indicated. Installation under applicable sections.

C. Frame and door of 16-gauge steel, 1” flange width, continuous piano hinge, key operated, prime coated. Refer to Architectural specifications for the required product specification for each surface. Contractor to submit schedule of access panels for approval. Exact size, number and location of access panels are not necessarily shown on Plans. Access doors shall be of a size to permit removal of equipment for servicing. Access door shall have same rating as the wall or ceiling in which it is mounted. Provide access panel for each water hammer arrestor, trap primer, or concealed valve and install between 12” and 36” above furnished floor where possible.

D. Included under this work is the responsibility for verifying the exact location and type of each unit required to serve equipment under this work and in the proper sequence to keep in schedule with construction and with prior approval. Access doors in fire rated partitions and ceilings shall carry “B” label rating.
E. Refer to other specification sections for duct access panels and doors.

F. Type: Style to suit wall or ceiling construction, as follows:
   1. Plaster: Style K with 14-gauge panel.
   2. Masonry: Style M with 14-gauge panel.
   4. Fire Rated: 1.5-hour B label, UL listed and labeled, for fire rated surfaces. Provide in lieu of other styles where fire rating is required.

G. Locks:
   1. Wall: Cylinder locks, keyed alike. Provide 6 keys.
   2. Ceiling: Screwdriver cam lock.

2.20 FLUES, VENTS, STACKS AND BREECHING

A. General: Provide factory-manufactured, UL listed flue gas stack systems.

B. Acceptable Manufacturers:
   1. AMPCO.
   2. Metalbestos.
   3. Dura Vent.
   4. Or approved equal.

C. Diesel Engine Exhaust: AMPCO Model IVSI, Positive pressure venting system, double wall construction with space between walls filled with 2” high temperature, 11-pound density insulation. UL listed for 1000°F continuous.
   1. Construction: Inner wall - 20 gauge 304 Stainless Steel; Outer wall - 24 gauge 304 Stainless Steel.
   2. Inner Joints: Inner pipe joints shall be field sealed by use of containment bands and high temperature joint sealant (VS-2000).
   3. Accessories: Provide with the following accessories:
      a. Lined Bellow Expansion Joints, numbers as required,
      b. Stack Base Drain,
      c. Floor and Wall penetration assemblies,
      d. Roof Support Assembly,
      e. Tall Cone Flashing,
      f. Exhaust Flip Top.
   4. Installation: Erect per UL listing and manufacturer’s published recommendation. Provide written certification showing inspection and approval by the manufacturer of the completed installation.

2.21 DRAIN PANS

A. General: Provide 3” deep galvanized sheet metal auxiliary drain pans under all suspended horizontal air handling and fan coil units, duct mounted chilled water coils, suspended domestic water heaters located above ceilings and under any equipment and pipes where shown on the drawings. See specification for drain pans required for Air Handling Units and Fan Coil Units.

B. Construction: Drain pans shall be minimum 16 gauge galvanized steel with water tight soldered joints. Drain pans shall be at least 2” larger in each dimension than the equipment served and shall extend...
under control and isolation valves. Chain suspended drain pans under equipment served. Pan shall have a welded coupling of the same size as the unit condensate drain (minimum 0.75” FPT). Pan bottom shall be cross-broken and sloped to the drain connection.

C. Drain Lines: Auxiliary drain lines shall be routed through the ceiling in “tell-tale” fashion above a general use plumbing lavatory, janitors sink or as shown on drawings. Locations of “tell-tale” drains shall be approved by the Architect.

2.22 BELT DRIVES

A. Acceptable Manufacturers:
   1. Browning.
   2. Gates.
   3. Woods.
   4. Dayton.
   5. Or approved equal.

B. Belts: V-belt drives rated at 1.5 times the motor horsepower. Two belts, minimum.


D. 

<table>
<thead>
<tr>
<th>Motor HP</th>
<th>Fan RPM</th>
<th>Sheave</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>0-1800</td>
<td>Adjustable or Fixed</td>
</tr>
<tr>
<td>15 &amp; above</td>
<td>0-1800</td>
<td>Fixed</td>
</tr>
<tr>
<td>0-3</td>
<td>1801 &amp; Above</td>
<td>Adjustable or Fixed</td>
</tr>
<tr>
<td>5 &amp; above</td>
<td>1801 &amp; Above</td>
<td>Fixed</td>
</tr>
</tbody>
</table>

E. Adjustments: Fan static pressures on drawings and related RPM’s are only approximate. Adjust sheaves or change drives to obtain required performance.

F. Drive Guards:
   1. General: Comply with applicable safety code requirements. Provide holes in guards for tachometer readings and checking of belt tension. Guards removable.
   2. Indoor Belt Drives: 16 gauge expanded metal or wire screen enclosure with 70% free area and steel frame.
   3. Outdoor Belt Drives: 16 gauge galvanized sheet metal with stamped louvers near top and bottom for ventilation.
   4. Shaft and Coupling Guards: 16-gauge sheet metal, inverted “U” trough cover over entire length of exposed shaft. Cover shall extend to below bottom of shaft and coupling.

2.23 ELECTRICAL

A. General:
   1. All electrical material, equipment, and apparatus specified herein shall also conform to the electrical requirements.
   2. Provide all motors for equipment specified herein.
3. Set and align all motors and drives in equipment specified herein.

4. Specific electrical requirements (i.e., horsepower and electrical characteristics) for mechanical equipment are scheduled on the Drawings.

B. Quality Assurance:

1. Electrical components and materials shall be UL or ETL listed/labeled as suitable for location and use – no exceptions.

C. Motors:

1. The following are basic requirements for simple or common motors. For special motors, more detailed and specific requirements are specified in the individual equipment specifications.

2. Torque characteristics shall be sufficient to satisfactorily accelerate the driven loads.

3. Motor sizes shall be large enough so that the driven load will not require the motor to operate in the service factor range. Unless otherwise noted on plans, all motors ½ HP or larger shall be rated for 200 or 460 volt, 3-phase operation unless otherwise noted on plans, all motors less than ½ HP shall be rated for 120 volts, single phase operation.

4. Temperature Rating: Rated for 40°C environment with maximum 50°C temperature rise for continuous duty at full load (Class A Insulation).

5. Minimum Service Factor: 1.15 for poly-phase motors and 1.35 for single phase motors.

   a. Frames: NEMA Standard, use driven equipment manufacturer’s standards to suit specific application.
   b. Bearings:
      1) Ball or roller bearings with inner and outer shaft seals.
      2) Re-greasable, except permanently sealed where motor is normally inaccessible for regular maintenance.
      3) Designed to resist thrust loading where belt drives or other drives product lateral or axial thrust in motor.
      4) For fractional horsepower, light duty motors, sleeve type bearings are permitted.
   c. Enclosure Type:
      1) Open drip-proof motors for indoor use where satisfactorily housed or remotely located during operation.
      2) Guarded drip-proof motors where exposed to contact by employees or building occupants.
      3) Weather protected Type I for outdoor use, Type II where not housed.
   d. Overload Protection: Built-in thermal overload protection and, where indicated, internal sensing device suitable for signaling and stopping motor at starter.
   e. Noise Rating: “Quiet.”
   f. Efficiency: Where indicated, “Energy Efficient” motors shall have a minimum efficiency as scheduled in accordance with IEEE Standard 112 Test Standard Method B. If efficiency is not specified, motors shall have a higher efficiency than “average standard industry motors”, in accordance with IEEE Standard 112, test method B. Minimum guaranteed
efficiencies at motor full load rating for 1,750 RM motors shall be:

<table>
<thead>
<tr>
<th>HP</th>
<th>Percentage Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>78.5</td>
</tr>
<tr>
<td>1.5</td>
<td>81.5</td>
</tr>
<tr>
<td>2</td>
<td>84.0</td>
</tr>
<tr>
<td>3</td>
<td>88.5</td>
</tr>
<tr>
<td>5</td>
<td>88.5</td>
</tr>
</tbody>
</table>

g. Nameplate: Indicate the full identification of manufacturer, ratings, characteristics, construction, special features, and similar information.

h. Motors with other than 1,750 RPM shall be same type motors as would meet requirements for 1,750 RPM motors.

2.24 IDENTIFICATION MARKERS

A. Mechanical Identification Materials: Provide products of categories and types required for each application as referenced in other Division 23 sections. Where more than single type is specified for application, selection is installer's option, but provide single selection for each product category.

B. Plastic Pipe Markers:


2. Pressure Sensitive Type: Provide pre-printed, permanent adhesive, color coded, pressure sensitive vinyl pipe markers, complying with ANSI A13.1. Secure both ends of markers with color coded adhesive vinyl tape.

3. Insulation: Furnish 1" thick molded fiberglass insulation with jacket for each plastic pipe marker to be installed on uninsulated pipes subjected to fluid temperatures of 125°F (52°C) or greater. Cut length to extend 2" beyond each end of plastic pipe marker.

4. Arrows: Print each pipe marker with arrows indicating direction of flow, either integrally with piping system service lettering (to accommodate both directions), or as separate unit of plastic.

C. Plastic Duct Markers:

1. Provide 4.5 x 6” laminated plastic, ANSI A13.1 color coded duct markers with white core lettering.

2. Nomenclature: Include the following:
   a. Direction of air flow.
   b. Duct service (supply, return, exhaust, etc.).
   c. Duct origin (from).
   d. Duct destination (to).
   e. Design cfm.

D. Valve Tags

1. Brass Valve Tags: Provide 1.5" diameter 19-gauge polished brass valve tags with stamp-engraved piping system abbreviation in 0.25" high letters and sequenced valve numbers 0.5" high, and with 5/32” hole for fastener. Fill tag engraving with black enamel.
2. Plastic Laminate Valve Tags: Provide 3/32" thick engraved plastic laminate valve tags, with piping system abbreviations in 0.25” high letters and sequenced valve number 0.5” high, and with 5/32” hole for fasteners.

3. Valve Tag Fasteners: Provide solid brass chain (wire link or beaded type), or solid brass S-hooks of the sizes required for proper attachment of tags to valves, and manufactured specifically for that purpose.

4. Access Panel Markers: Provide 1/16” thick engraved plastic laminate access panel markers, with abbreviations and numbers corresponding to concealed valve. Include 1/8” center hole to allow attachment.

5. Valve Schedule Frames: For each page of valve schedule, provide glazed display frame, with screws for removable mounting on framed or masonry walls. Provide frames of finished hardwood or extruded aluminum, with SSB-grade sheet glass.

6. Plastic Equipment Signs:
   a. Provide 4.5” x 6” plastic laminate sign, ANSI A.13 color coded with engraved white core lettering.
   b. Fasteners: Self-tapping stainless steel screws, except contact-type permanent adhesive where screws cannot or should not penetrate the substrate. Nomenclature: Include the following, matching terminology on schedules as closely as possible:
      1) Name and plan number.
      2) Equipment service.
      3) Design capacity.
      4) Other design parameters, such as pressure drop, entering and leaving conditions, rpm, etc.

E. Acceptable Manufacturers:
   1. Craftmark.
   2. Seton.
   3. Brady.
   4. Brimar.
   5. Or approved equal.

PART 3 – EXECUTION

3.1 Notes:
   1) Mechanical equipment for base building/Airport shall not be located over tenant lease areas. Access for base building equipment shall outside of tenant area footprints.

3.2 GENERAL PIPING INSTALLATION

A. General: The Contractor shall provide all piping system components as shown on the Drawings or necessary to complete the working system in accordance with the intent of the Drawings and Specifications, a complete system of piping, all valves as indicated or as necessary to completely control the entire apparatus and all appurtenances. The Piping Drawings and schematics are diagrammatic and indicate the general location and connections. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations.
Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

B. Workmanship shall be performed by journeymen mechanics and shall result in an installation consistent with the best practices of the trade.

C. Follow manufacturers’ directions and recommendations in all cases where the manufacturers of articles used on this Contract furnish directions covering points not shown on the Drawings or covered in these Specifications.

D. Install according to Division 23 Sections specifying piping systems.

E. Install work uniform, level, and plumb, in relationship to lines of building. Do not install any diagonal or otherwise irregular work unless so indicated on the Drawings or approved by the Airport.

F. Coordinate the work between the various Mechanical Sections and with the work specified under other Divisions of the work or contracts toward rapid completion of the entire project. If any cooperative work must be altered due to lack of supervision or failure to make proper provisions in time, then the work hereunder shall include all expenses of such changes as are necessary in the work under other contracts, and such changes shall be directly supervised by and made to the satisfaction of the Owner. Also coordinate wall and ceiling work with the contractor and Contractors in locating ceiling air outlets, wall registers, etc.

G. The cooperative work not included in the Mechanical Division related to the general construction work is as follows:
   1. All formed concrete work.
   2. Framed openings in masonry and other Architectural and Structural elements.
   3. Wood grounds and nailing strips in masonry and concrete.

H. Inspect all material, equipment, and apparatus upon delivery and do not install any that may be subject to rejection as a result of damage or other defects. Provide covers to protect equipment and piping delivered to and stored at the site.

I. Install equipment to allow maximum possible headroom unless specific mounting heights are not indicated.

J. Install mechanical equipment to facilitate service, maintenance, and repair or replacement of components. Connect equipment for ease of disconnecting, with minimum interference to other installations. Extend grease fittings to accessible locations.

K. Erection: Piping shall be properly supported and adequate provisions shall be made for expansion, contraction, slope and anchorage. All piping shall be cut accurately for fabrication to measurements established at the construction site. Pipe shall be worked in place without springing or forcing. Cutting or other weakening of the building structure to facilitate installation will not be permitted. All pipes shall have burr and cutting slag removed by reaming or other approved cleaning methods. All changes in direction and branch connections shall be made with fittings.

L. Concealed and Exposed Piping: All piping in finished areas shall be concealed, unless otherwise noted. Piping exposed in mechanical rooms and other locations as noted shall be installed in an orderly manner and parallel with or perpendicular to building lines. Diagonal runs are prohibited unless specifically indicated otherwise. Exposed piping in occupied areas shall be routed tight to the structure or as high as is possible.
Section 23 05 00 | Common Work Results for HVAC

M. Grading: All piping shall be carefully installed so as to eliminate traps and pockets in pressurized lines and to maintain flow in gravity flow lines. Where air pockets and traps cannot be avoided, provide valved hose connections for water traps and valved automatic air vents for air traps. The Contractor shall consider pipe grading requirements when coordinating pipe routing for the project. Pipe slope shall be maintained throughout the project. Waste and vent piping shall be sloped in accordance with the applicable codes.

1. Slope piping as indicated, true to line and grade, and free of traps and air pockets. Unless indicated otherwise, slope piping in direction of flow as follows:

<table>
<thead>
<tr>
<th>Service</th>
<th>Inclination</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Water</td>
<td>Level</td>
<td>---</td>
</tr>
<tr>
<td>Heating Water</td>
<td>Up</td>
<td>1&quot; per 40'</td>
</tr>
<tr>
<td>Chilled Water</td>
<td>Up</td>
<td>1&quot; per 40'</td>
</tr>
<tr>
<td>High Temperature Heating Water</td>
<td>Up</td>
<td>1&quot; per 40'</td>
</tr>
<tr>
<td>Waste</td>
<td>Down</td>
<td>1/8&quot; min. per foot</td>
</tr>
<tr>
<td>Storm Water</td>
<td>Down</td>
<td>1/8&quot; min. per foot</td>
</tr>
<tr>
<td>Vent</td>
<td>Up</td>
<td>1&quot; per 40'</td>
</tr>
<tr>
<td>Engine Exhaust</td>
<td>Up</td>
<td>1&quot; per 10'</td>
</tr>
</tbody>
</table>

N. Slope fuel oil piping down toward tank 1" per 10'.

O. Install equipment to allow right of way for piping installed at required slope.

P. Connect branch piping to top mains, unless otherwise indicated.

Q. Provide drain valves and hose adapters at low points in piping and at bottom of each pipe riser. Provide drain valves for float type controllers.

R. Provide automatic air vents at high points in chilled water and heating water piping. Provide manual air vents at such points for heating water piping, when concealed.

S. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

T. Install piping to permit valve servicing.

U. Install piping at indicated slopes.

V. Install piping free of sags and bends.

W. Install piping to allow application of insulation.

X. Arrangement: Flanges or unions, as applicable for the type of piping specified, shall be provided in the piping at connections to all items of equipment. All valves and specialties shall be placed to permit easy and proper operation and access, and all valves shall be regulated, packed and glands adjusted at the completion of the work before final acceptance. Tapered reducers shall be used wherever changes in pipe sizes occur in mains. Bushings will not be permitted. The use of bull head tees or other high pressure drop configurations will not be permitted.

Y. Install fittings for changes in direction and branch connections.
Z. Expansion and Contraction: Provisions for expansion and contraction of piping shall be provided by expansion loops, bends or expansion joints to prevent injury to connections, piping, equipment or the elements of the building, whether shown or not.

AA. Anchors: Pipe anchors shall be provided and installed at each end of piping runs which require expansion loops or joints, and where indicated on Drawings. Anchors shall be fabricated of rigid structured steel members firmly secured to the building structure.

BB. Guides: Pipe guides shall be provided and installed on piping as shown on Drawings and as necessary to properly fulfill function of expansion loops and joints.

CC. Unions: Shall be provided on all bypasses, at control valves and at all connections to equipment where there are no flanged ends and where shown on the Drawings or where required to facilitate removal of equipment.

DD. Protection: All open ends of pipes and equipment shall be properly capped or plugged during construction to keep dirt and other foreign materials out of the system. Plugs of rags, wool, cotton, waste or similar materials are not acceptable.

EE. Pipe Sizes: If the size of the piping is not clearly evident in the Drawings, the Contractor shall request instruction as to the proper sizing. All valves shall be the same size as pipes.

FF. Domestic Water: Connect copper tubing to fixtures with copper fittings; chrome plate where exposed. Prevent damage to finished surfaces.

GG. Natural Gas: Make equipment connections with ground joint unions and gas cocks. Provide accessible main shut-off cock and seismic shut-off valve at entrance to building.

HH. Copper: Crimping of copper tubing is prohibited. Isolate copper pipe and tubing from contact with steel. For branch drops and rises to plumbing fixtures, anchor branch to waste and vent piping.

II. Coatings: Reapply coal-tar coating on buried piping, after installation, to surfaces from which coating has been removed or scraped.

JJ. Valves:
   1. Ensure valves are field checked for packing and lubricant and that disc is for service intended. Replace leaking packing. Service valves which do not operate smoothly and properly with suitable lubricant before placing in operation.
   2. Wherever possible, install valves accessible from floor level. Provide guided chain operators on valves over 7' above floor in equipment areas. Do not install valves with stem pointing downward. Provide operating handles for valves and cocks without integral operators.
   3. Provide valves same size as line size, unless indicated otherwise.
   4. Install swing checks and gravity closing lift checks in horizontal position.
   5. Provide gate blow-down valves and hose adapters at strainers; same size as strainer blow-off connection, unless otherwise indicated.
   6. Provide discharge pipe to atmosphere from all relief and safety valves, sized with area equal to sum of outlet areas of all valves connected thereto, unless indicated larger.
   7. Install globe valves to close against pressure.
8. Install automatic control valves, as per special systems requirements, in piping systems as indicated on the drawings. Provide all fittings, transitions, unions and other components necessary to result in installation in accordance with manufacturer's instructions. Verify flow direction, space clearances for actuator, etc. before installation.

KK. Leveling: Adjust hangers and supports and place grout as required under supports to bring piping to proper levels and elevations.

LL. Tunnel Pipe Racks: All piping in utility tunnels and all stacked piping in pump rooms shall be supported using floor-supported galvanized steel pipe racks. Anchor pads for attaching racks to the tunnel wall, floor and ceiling structure shall be cast in concrete and shall be adequate to properly distribute the rack load. Racks shall be constructed of galvanized channel or hot-dip galvanized steel shapes and shall be adjustable for grading of piping.

3.3 PIPING SPECIALTIES

A. Locate thermometers and gauges to permit observation by personnel standing on floor.

B. Provide instrument cocks at pressure gauges.

C. Provide straight runs of piping upstream and downstream from flow elements, as recommended by manufacturer.

D. Provide piping expansion joints as required where expansion loops are not possible.

E. Install Y-type strainers in horizontal piping with strainer basket on bottom.

F. Pipe all drain valves to floor drains, floor sinks or approved receptors unless otherwise indicated.

G. Escutcheons: Spring clamp plates (escutcheons) shall be provided where pipes are exposed in finish locations of the building and run through walls, floors, or ceilings. Plates shall be chrome-plated spun brass of plain or approved pattern and shall be set tight on the pipe and the building surface. Install pipe escutcheons on each pipe penetration through floors, wall, partitions, and ceilings where penetration is exposed to view; and on exterior of building. Secure escutcheon to pipe or insulation so escutcheon covers penetration hole, and is flush with adjoining surface.

1. New Piping:
   a. Piping with Fitting or Sleeve Protruding from Wall: One-piece, deep-pattern type.
   b. Chrome-Plated Piping: One-piece, cast-brass type with polished chrome-plated finish.
   c. Insulated Piping: One-piece, stamped-steel type with spring clips.
   d. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, cast-brass type with polished chrome-plated finish.
   e. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-Piece, stamped-steel type.
   f. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece, stamped-steel type.
   g. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece, cast-brass type with polished chrome-plated finish.
   h. Bare Piping at Floor Penetrations in Equipment Rooms: One-Piece, cast-brass type.
   i. Bare Piping at Floor Penetrations in Equipment rooms: One-Piece, floor-plate type.
H. **Drip Pans**: Locate drip pans under piping as indicated. Hang from structure with rods and building attachments, weld rods to sides of drip pan. Brace to prevent sagging or swaying. Connect 1” drain line to drain connection, and run to nearest plumbing drain or elsewhere as indicated.

I. **Fire Barrier Penetration Seals**: Fill entire opening with sealing compound in compliance approved and listed UL system number. Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Adhere to manufacturer’s installation instructions. Refer to “Through-Penetration Firestop Systems” for materials.

### 3.4 PIPE SLEEVES

A. Install pipe sleeves of types indicated where exposed in finished spaces in piping passes through concrete and masonry walls, floors, ceilings, roofs, gypsum-board partitions. Do not install sleeves through structural members of work, except as detailed on drawings, or as reviewed by Owner’s Representative. Install sleeves accurately centered on pipe runs.

B. Size sleeves so that piping and insulation (if any) will have free movement in sleeve, including allowance for thermal expansion; but not less than 2 pipe sizes larger than piping run. Sleeves shall be large enough to provide ¼” annular clear space between sleeve and pipe or pipe insulation. Use the following materials:
   2. Steel Sheet Sleeves: For pipes NPS 6 and larger, penetrating gypsum-board partitions.

C. Where insulation includes vapor-barrier jacket, provide sleeve with sufficient clearance for installation. Install length of sleeve equal to thickness of construction penetrated, and finish flush to surface; except floor sleeves.

D. Extend floor sleeves 0.25” above level floor finish, and 0.75” above floor finish sloped to drain.

E. Cut sleeves to length for mounting flush with both surfaces.
   1. Exception: Extend sleeves installed in floors of mechanical equipment areas, other wet areas, and for pipes with membrane waterproofing 2” above finished floor level. Extend cast-iron sleeve fittings below floor slab as required to secure clamping ring if ring is specified. Refer to flashing requirements.
   2. Seal space outside of sleeve fittings with grout.

F. Except for underground wall penetrations, seal annual space between sleeve and pipe or pipe insulation, using joint sealants appropriate for size, depth, and location of joint. Refer to “Joint Sealants” for materials and installation.

G. Install sleeves in new walls and slabs as new walls and slabs are constructed.

H. Provide temporary support of sleeves during placement of concrete and other work around sleeves, and provide temporary closure to prevent concrete and other materials from entering sleeves.

I. Install sheet metal sleeves at interior partitions and ceilings other than suspended ceilings.

J. Install iron pipe sleeves at exterior penetrations, both above and below grade.

K. Install steel pipe or plastic pipe sleeves except as otherwise indicated.
L. Sleeves are not required for core-drilled holes.

M. Permanent sleeves are not required for holes formed by removable PE sleeves.

N. Aboveground, Exterior-Wall Pipe Penetrations: Seal penetrations using sleeves and mechanical sleeve seals. Select sleeve size to allow 1” annular clear space between pipe and sleeve for installing mechanical sleeve seals.
   1. Install steel pipe for sleeves smaller than 6” in diameter.
   2. Install cast-iron “wall pipes” for sleeves 6” and larger in diameter.
   3. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

O. Underground, Exterior-Wall Pipe Penetrations: Install cast-iron “wall pipes” for sleeves. Seal pipe penetrations using mechanical sleeve seals. Select sleeve size to allow for 1” annular clear space between pipe and sleeve for installing mechanical sleeve seals.
   1. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

P. Mechanic Sleeve Seals: Loosely assemble rubber links around pipe with bolts and pressure plates located under each bolt head and nut. Push into sleeve and center. Tighten bolts until links have expanded to form a watertight seal.

3.5 PIPING JOINT CONSTRUCTION

A. Join pipe and fittings according to the following requirements and Division 23 Sections specifying piping systems.

B. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

C. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

D. Soldered and Brazed Joints:
   1. Clean surfaces to be jointed, of oil, grease, rust and oxides. Remove grease from fittings by applying carbon tetrachloride with brush. Clean socket of fitting and end of pipe thoroughly with emery cloth to remove rust and oxides. After cleaning and before assembly or heating, apply ASTM B 813, water-flushable flux to joint surface and spread evenly to tube end, unless otherwise indicated.
   2. Soldered Joints: Construct joints according to ASTM B 828 or CDA’s “Copper Tube Handbook,” using lead-free solder alloy complying with ASTM B 32.
E. Cast Iron Bell and Spigot Joints:
   1. Make joints with neoprene elastomeric gaskets installed using approved gasket lubricant.
   2. Make joints between cast iron pipe and steel with fittings made specially for that purpose, such as tapped spigots, Tucker connections, etc.

F. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
   1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
   2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

G. Welded Joints: Welding: Construct joints according to AWS D10.12, using qualified processed and welding operators according to Part 1 “Quality Assurance” Article. All welded joints in piping shall be continuous metallic arc or gas fusion welds connecting pipe ends which are beveled to 37-1/2 degrees before welding. The use of backing rings will not be acceptable. All taps shall be made using proper weld fittings. No “burn-ins” will be allowed. Gas torch cuts shall be true and free from burned metal. Clean pipe surfaces to be welded immediately prior to welding. Welded pipe joints shall be properly aligned with no weld material or bead projects into the pipe. All weld procedures shall be in accordance with requirements of the American Welding Society and shall be performed by certified welders. Documentation of welder certification shall be available if requested. All welding operations shall conform to the latest recommendations of the American Welding Society and to Section Six of Power Piping, ANSI B31.1, 1973; B31.3 for steam piping. All qualifying tests, welding and stress relieving procedures, shall, moreover, be in accord with Standard Qualification for welding procedures, welders and welding operators of the Code, current edition. In no cases shall Schedule 40 pipe be welded with less than three passes including one tack, one filler, and one lacer. Schedule 80 pipe shall be welded with not less than four passes including one tack, two fillers and one lacer.

3.6 Welds lacking penetration shall be removed. Internal and external cracks shall be ground down and removed.

   1. All weld fittings shall be USA factory made wrought carbon steel butt-welding fittings conforming to ASTM A123 and ASME/ANSI B16.9 latest edition, as made by Grinnell, Tube Turn, Hackney, Taylor Forge, or Ladish Company. Long radius fittings shall be provided for all 90° and 45° elbows. Each fitting shall be stamped as specified by ASME/ANSI B16.9 and, in addition, shall have the laboratory control number metal stenciled on each fitting for ready reference as to physical properties required for any fitting selected at random. Complete test reports may be required for any fittings selected at random. Only one manufacturer of weld fittings will be allowed on the project. Fittings which have been machined, remarked, printed or otherwise produced domestically from imported forgings or materials will not be acceptable. Each fitting shall have the manufacturer’s trademark permanently identified in accordance with MSS SP-25. Markings shall be placed on the fittings at the farther point from the edge to be welded to prevent disfiguring from the welding process. Submittal data for these fittings shall include a letter signed by an official of the manufacturing firm certifying compliance with these Specifications.

   2. Piping and fittings shall be welded and fabricated in accordance with ASME/ANSI and the latest edition of Standard B31.1 from the Code for Pressure Piping for all systems. Machine beveling in shop is preferred. Field beveling may be done by flame cutting to recognized standards.
3. Ensure complete penetration of deposited metal with base metal. Contractor shall provide filler metal suitable for use with base metal. Keep inside of fittings free from globules of weld metal.

4. Align piping and equipment so that no part is offset more than 1/16". Set all fittings and joints square and true, and preserve alignment during welding operation. Use of alignment rods inside pipe is prohibited.

5. Do not permit any weld to project within the pipe so as to restrict it. Tack welds, if used, must be of the same material and made by the same procedure as the completed weld. Otherwise, remove tack welds during welding operation.

6. Contractor shall not split, bend, flatten or otherwise damage piping before, during or after installation. Remove dirt, scale, and other foreign matter from inside piping before tying in sections, fittings, valves or equipment.

7. Welds lacking penetration, containing excessive porosity or cracks, or are found to be unacceptable for any reason, must be removed and replaced with an original quality weld as specified herein. All qualifying tests, welding, and stress relieving procedures shall, moreover, be in accord with Standard Qualification for Welding Procedures, Welders and Welding Operators of the Code, current edition.

B. Screw Pipe Fitting: All screw joints shall be made with taper threads, properly cut. Joints shall be made tight with Teflon applied to the pipe threads only and not to fittings. When threads are cut on pipes, the ends shall be carefully reamed to remove any burrs. Before installing pipe that has been cut and threaded, the lengths of pipe shall be upended and hammered to remove all shavings and foreign material. Apply Teflon tape to male threads.

C. Flange Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positions. Use suitable lubricant on bolt threads.

D. Plastic Piping Solvent-Cement Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:

1. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.
2. ABS Piping: Join according to ASTM D 2235 and ASTM D 2661 Appendixes.
3. CPVC Piping: Join according to ASTM D 2846/D 2846M Appendix.
4. PVC Pressure Piping: Join schedule number ASTM D 1785, PVC pipe and PVC socket fittings according to ASTM D 2672. Join other-than-schedule-number PVC pipe and socket fittings according to ASTM D 2855.
5. PVC Non-Pressure Piping: Join according to ASTM D 2855.
6. PVC to ABS Non-Pressure Transition Fittings: Join according to ASTM D 3138 Appendix.
   a. Plastic Pressure Pipe Gasketed Joints: Joint according to ASTM D 3139.
   b. Plastic Non-Pressure Pipe Gasketed Joints: Join according to ASTM D 3212.
   c. PE Pipe Heat-fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657.
      1) Plain-End Pipe and fittings: Use butt fusion.
      2) Plain-End Pipe and Socket Fittings: Use socket fusion.
   d. Fiberglass Bonded Joints: Prepare pipe endings and fittings, apply adhesive, and join according to pipe manufacturer’s written instructions.
3.7 PIPING CONNECTIONS

A. Make connections according to the following, unless otherwise indicated:

1. Install unions, in piping NPS 2 and smaller, adjacent to each valve and at final connection to each piece of equipment.

2. Install flanges, in piping NPS 2.5 and larger, adjacent to flanged valves and at final connection to each piece of equipment.

3. Dry Piping Systems: Install dielectric unions and flanges to connect piping materials of dissimilar metals.

4. Wet Piping Systems: Install dielectric unions and nipple fittings to connect piping materials of dissimilar metals.

B. Connections Between Copper and Steel Pipes: Connections shall be made with dielectric couplings, flanged dielectric unions, or nylon bushings temperature and pressure rated for the service at the point of installation.

3.8 SUPPORTS AND HANGERS

A. Proceed with installation of hangers, supports, and anchors only after required building structural work has been completed in areas where the work is to be installed. Correct inadequacies including, but not limited to, proper placement of inserts, anchors, and other building structural attachments.

B. Prior to installation of hangers, supports, anchors, and associated work, installer shall meet at project site with Contractor, installer of each component of associated work, inspection and testing agency representatives, (if any), installers of other work with requirements specified.

C. Installation of Building Attachments: Install building attachments at required locations within concrete or on structural steel for proper piping support. Install additional building attachments where support is required for additional concentrated loads, including valves, flanges, guides, strainers, expansion joints, and at changes in direction of piping. Install concrete inserts before concrete is placed. Fasten insert securely to forms. Where concrete with compressive strength less than 2500 psi is indicated, install reinforcing bars through opening at top of inserts.

D. Install hangers, supports, clamps, and attachments to support piping properly from building structure. Hangers shall be located within 1'-0" of every change in piping direction, end of pipe run or concentrated load, and within 3'-0" of every major piece of equipment. Hangers shall be installed on both sides of flexible connections. Where flexible connection connects directly to a piece of equipment only one hanger is required. Arrange for grouping of parallel runs of horizontal piping to be supported together on trapeze type hangers where possible. Where piping of various sizes is to be supported together by trapeze hangers, space hangers for smallest pipe size or install intermediate supports for smaller diameter pipe. Do not use wire or perforated metal to support piping, and do not support piping from other piping.

E. Install hangers and supports complete with necessary inserts, bolts, rods, nuts, washers, and other accessories. Except as otherwise indicated for exposed continuous pipe runs, install hangers and supports of same type and style as installed for adjacent similar piping.

F. Riser Supports: Vertical piping shall be secured at sufficiently close intervals to keep the pipe in alignment and carry the weight of the pipe and contents.
1. Cast iron soil pipe shall be supported at the base and at each story level, but in no case at intervals greater than 25'.

2. Steel pipe shall be supported at the base and at not less than every other story level, but in no case at intervals greater than 30', except that grooved-piping systems shall be supported at each pipe section.

3. Copper tube shall be supported at each story level, but in no case at intervals greater than 25'.

G. Prevent electrolysis in support of copper tubing by use of hangers and supports which are copper plated or felt lined steel hangers. Other recognized industry support methods may be used with prior approval.

H. Hanger spacing in accordance with following minimum schedules (other spacings and rod sizes may be used in accordance with the SMACNA Seismic Restraint Manual using a safety factor of five):

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Max. Hanger Spacing</th>
<th>Rod Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5” – 2”</td>
<td>6 feet</td>
<td>3/8”</td>
</tr>
<tr>
<td>2.5” and larger</td>
<td>8 feet</td>
<td>0.5”</td>
</tr>
</tbody>
</table>

I. Seismic restraints shall be located on each piping section per the SMACNA Seismic Restraint Manual. Where required, and as a minimum, provide at least one lateral and longitudinal support on each piping section. Connections to mechanical equipment shall not be considered as a permanent point of attachment in determining seismic restraints.

J. Sloping, Air Venting, and draining:

1. Slope all piping as specified and as indicated, true to line and grade, and free of traps and air pockets. Unless indicated otherwise, slope piping in the direction of flow.

K. Provisions for Movement:

1. Install hangers and supports to allow controlled movement of piping systems and to permit freedom of movement between pipe anchors, and to facilitate action of expansion joints, expansion loops, expansion bends, and similar units.

2. Load Distribution: Install hangers and supports so that piping live and dead loading and stresses from movement will not be transmitted to connecting equipment.

3. Insulated Piping: Comply with the following installation requirements:
   a. Clamps: Attach clamps, including spacers, (if any), to piping with clamps projecting through insulation.
   b. Shields: Where low compressive strength insulation or vapor barriers are indicated on cold or chilled water piping, install shields or inserts.
   c. Saddles: Where insulation without vapor barrier is indicated install protection saddles.

L. Installation of Anchors:

1. Install anchors at proper locations to prevent excessive stresses and to prevent transfer of loading and stresses to connected equipment.

2. Fabricate and install anchor by welding steel shapes, plates and bars to piping and to
structure.

3. Where expansion compensators are indicated, install anchors in accordance with expansion unit manufacturer’s written instructions, to limit movement of piping and forces to maximums recommended by manufacturer for each unit.

4. Anchor Spacings: Where not otherwise indicated, install anchors at ends of principal pipe runs, at intermediate points in pipe runs between expansion loops and bends. Make provisions for preset of anchors as required to accommodate both expansion and contraction of piping.

M. Equipment Supports:

1. Provide all concrete bases for all floor mounted equipment, unless otherwise specified. Furnish scaled layouts of all required bases, with dimensions of bases, and location to column center lines. Furnish templates, anchor bolts, and accessories necessary for base construction. Provide dowels between new concrete pads and existing support base. Provide rebar or mesh for pads larger than sixteen square feet in size.

2. Provide structural steel stands to support equipment not floor mounted or hung from structure. Construct of structural steel members or steel pipe and fittings. Provide factory-fabricated tank saddles for tanks.

3. Furnish roof equipment supports to specified sections, not work of this section.

N. Adjusting

1. Hanger Adjustment: Adjust hangers so as to distribute loads equally on attachments.

2. Support Adjustment: Provide grout under supports so as to bring piping and equipment to proper level and elevations.

3. Clean factory-finished surfaces. Repair any marred or scratched surfaces with manufacturer’s touch-up paint.

O. Erection of Metal Supports and Anchorages:

1. Refer to Section pertaining to “Metal Fabrications: for structural steel.

2. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor mechanical materials and equipment.

3. Field Welding: Comply with AWS D1.1.

3.9 PIPE CLEANING AND STERILIZATION

A. HVAC Piping: All piping shall be cleaned following successful pressure testing of pipe. Piping shall be completely drained following pressure testing and then filled with clear water and pipe cleaning treatment (Mogul C-641 or approved equal) to the suppliers recommended concentration required to rid the system of rust, dirt, piping compound, mill scale, oil, grease, and any other foreign material. The system shall then be circulated per the supplier’s recommendations. Following cleaning, each system shall be drained, refilled and then continuously filtered or flushed until clean water is obtained. Strainers shall be removed and cleaned after each flushing. After the system has been pressure tested, treated with pipe cleaning treatment and rinsed with clear water to remove the cleaning treatment, a 5 micron in-line filter may be installed in the system, in lieu of continuous water flushing, to clear the piping of construction debris. Each system being filtered shall be pumped continuously and the filter shall be cleaned once every 24 hours until no visible filtered matter is
present in the filter after 24 hours of circulation. After the cleaning process is complete, the filters shall be removed from the system and all strainers shall be cleaned prior to putting the piping system into operation. Provide temporary loop piping and fill/drain valves as required to allow building piping to be flushed and circulated until the system is clean, prior to making connections to the complex utility piping system. Piping mains shall be cleaned and flushed (or circulated and filtered) with coil and equipment isolation valves closed, until fully clean. When the mains are fully cleaned, then coil and equipment isolating and control valves shall be opened, air shall be removed from coils via air vents, and the system shall be cleaned and flushed (or circulated and filtered), until fully clean. Temporary loop connections shall be provided as required to circulate all main piping with coil and equipment isolation valves closed.

1. At the point of connection to each of the Contracts, provide isolation valves. Provide 2” by-pass between supply and return piping with a globe valve for flushing and cleaning. When piping is tested, flushed and cleaned and approved by the Airport Commission, the isolation valves shall be opened and the bypass valves closed and locked in those positions.

B. Domestic Water Piping: All potable water piping and tanks shall, after successful pressure testing, be thoroughly flushed with clear water and then sterilized. Sterilization shall be with either liquid chlorine or chlorine gas of adequate volume to give a concentration of 50 ppm based upon the volume of the system being treated. A minimum residual chlorine level of 5 ppm shall remain in each system for a minimum of 24 hours. After sterilization, all piping shall be thoroughly flushed. The above are minimum requirements and all sterilization procedures shall be in strict accordance with all local codes and authorities having jurisdiction.

3.10 EXCAVATION, TRENCHING AND BACKFILL

A. General: The work hereunder includes whatever excavating and backfilling is necessary to install the mechanical work. Coordinate the mechanical work with other work in the same area, including excavating and backfilling, dewatering, floor protection provisions, other temporary facilities, other underground services (existing and new), landscape development, paving, structural foundations, and floor slabs on grade. Coordinate with weather conditions and provide temporary facilities needed for protection and proper performance of excavating and backfilling.

B. Standards: Except as otherwise indicated, comply with the applicable provisions for mechanical and plumbing work excavating and backfilling. Refer instances of uncertain applicability to the Architect for resolution before proceeding with the work.

C. The bottoms of trenches shall be excavated to required depths, slope and grade. The bottom of the trench shall be accurately excavated to provide firm, uniform bearing for the bottom of the pipe. Where mud or unstable soil is encountered in bottom of trench, it shall be removed to firm bearing and the trench shall be backfilled with bedding sand to proper grade and tamped to provide uniform firm support.

D. The bottom of trenches shall be accurately graded to provide proper fall and uniform bearing and support for each section of the pipe on undisturbed soil or 2” of sand fill at every point along its entire length.

E. Exercise care not to excavate below required depth, leaving a flat bed of undisturbed earth, firm and secure, before laying pipe.

F. All grading in the vicinity of excavation shall be controlled to prevent surface ground water from flowing into the excavations. Any water accumulated in the excavations shall be removed by pumping or other acceptable method. During excavation, material suitable for backfilling shall be stacked in an
orderly manner a sufficient distance back from edges of trenches to avoid overloading and prevent slides or cave-ins. Material unsuitable for backfilling shall be wasted and removed from the site and properly disposed of.

G. The Contractor shall be fully responsible for the safety of persons, materials and equipment in or near trenches or other excavations and provide all required sloping, shoring, railings and other protective provisions. The Contractor shall provide a trench shoring plan and design which is sealed by a registered professional engineer.

H. If any unknown and/or uncharted utilities are encountered during excavation, promptly notify Architect and wait for his instructions before proceeding.

I. If such unknown utilities are encountered and work is continued without contacting the Architect or Engineer for instructions, and damage is caused to said utilities, the Contractor shall repair at his own expense, such damage to the satisfaction of the Owner or utility company concerned.

J. Trenches shall not be backfilled until all required tests have been made by the Contractor and approved by the Architect or Engineer, and any local authorities having jurisdiction.

K. Backfill shall be compacted or cement stabilized sand up to 6’ above the top of piping. Backfill up to grade shall be in maximum 6” lifts with minimum 95% compaction of lifts. Refer elsewhere in Contract Documents for additional trenching and backfill requirements.

3.11 FIRESTOPPING

A. General: Fire stopping material application is specified under relevant sections.

B. Provide all sleeves and insulation protection shields at each penetration such that they do not delay fire stopping application.

C. Provide fire stopping installer with penetration details, insulation thicknesses and other relevant information so that proper fire stopping system may be chosen.

D. Adjust sleeves and pipes through penetrations to create proper annular space where directed by fire stopping installer to achieve fireproof seals.

3.12 EQUIPMENT INSTALLATION

A. Pumps: Align pump and motor per manufacturer’s recommendations.

B. Equipment Requirements: Where not otherwise indicated, basis for installation is published recommendations of manufacturer. This requirement includes installation details, clearances, and accessories.

C. Head Clearance: Install elevated equipment to maintain not less than 7’-6” head clearance below, unless otherwise indicated.

3.13 EQUIPMENT CONNECTIONS

A. Alignment: All piping connecting to pumps and other equipment shall be installed without strain at the piping connection. The Contractor may be required as directed to remove the bolts in these flanged connections or disconnect piping to demonstrate that piping has been so connected.
B. Connections Different from Those Shown: Where equipment requiring different arrangement or connections from those shown is approved, it shall be the responsibility of the Contractor to install the equipment to operate properly and in harmony with the intent of the Drawings and Specifications. When directed by the Architect or Engineer, the Contractor shall submit drawings showing the proposed installation.

C. Equipment Guards: Provide easily removable expanded metal guards for all belts, couplings, exposed fan inlets and outlets and other moving parts of machinery. Provide access holes to motor and fan shafts on all belt drive and variable speed equipment.

D. Supports: The Contractor shall support plumb, rigid and true to lien all work and equipment furnished under his division. The Contractor shall study thoroughly all Architectural, Structural, Mechanical and Electrical drawings, shop drawings and catalog data to determine how equipment is to be supported, mounted or suspended, and shall provide all bolts, inserts, pipe stands, brackets and accessories for proper support.

3.14 EQUIPMENT HOUSEKEEPING PADS AND ANCHOR BOLTS

A. Concrete pads for equipment (housekeeping pads) will be furnished under another Division. Pads shall be provided in the central plant and in other locations where floor mounted equipment is to be installed.

B. Pads shall be nominal 6” high in the pump and fan rooms and nominal 4” high in all other locations and shall extend a minimum of 3” beyond all equipment and supports while generally conforming to the shape of the equipment.

C. Pad tops and sides shall be hard troweled smooth with a 0.75” bull nose on all external corners. Refer to Division 3 for additional requirements.

D. Furnish galvanized anchor bolts with layout templates for installation in equipment pads. Bolts shall be of the size and quantity recommended by the manufacturer or seismic calculations and where vibration isolators are used, they shall be anchor bolted to the equipment pad.

3.15 SEISMIC RESTRAINT AND EQUIPMENT VIBRATION ISOLATION REQUIREMENTS

A. All ductwork, regardless of size, equipment and piping shall be seismically supported and braced per the “Seismic Restraint Manual Guidelines for Mechanical Systems” as published by Sheet Metal and Air Conditioning Contractors National Association (SMACNA). Additional design guides required for installation include the “Superstrut: Seismic Restraint System” for pipes and conduits, and the “Kin-line: Seismic Restraint System” for pipes and conduits. Installed seismic restraints shall limit movement to 2” in any direction without damaging piping and/or ductwork systems.

B. Seismic bracing shall be per the California Building Code for maximum restraint for Seismic Zone 4.

C. Mechanical Balance: Fans, pumps, motors, and drives, when equipment is installed and in normal operation, shall be within following maximum limits:

1. 600 RPM and Less: Three mils displacement, peak-to-peak.
2. Over 600 RPM: 0.10” per second velocity.
3. See respective sections for additional requirements.
D. Pulley Run-Out: When equipment is installed and in normal operation, pulley run-out in radial and axial directions not to exceed 0.001”.

E. Field Tests: If requested, test equipment to determine compliance with specified requirements. Measure vibration displacement and velocity in vertical direction relative to floor. Make measurements on bearing housings (not end caps), or other heavy structural element directly connected to bearing housing, at each end of equipment.

F. Field Balancing: Balance and retest equipment as required for compliance with specified requirements.

G. Vibration Isolation: Refer to relevant sections for additional information and support requirements. Pipe hangers made of wood, wire, or sheet iron shall not be permitted.

H. Vibration Control Isolators

1. Comply with minimum static deflections recommended by ASHRAE, for selection and application of vibration isolation materials and units as indicated.

2. Manufacturer’s Recommendations: Except as otherwise indicated, comply with manufacturer’s recommendations for selection and application of vibration isolation materials and units.

3. Except as otherwise indicated, comply with manufacturer’s instructions for installation and load application to vibration control materials and units. Adjust to ensure that units have equal deflection, do not bottom out under loading, and are not short-circuited by other contacts or bearing points. Remove space blocks and similar devices intended for temporary support during isolation.

4. Spring type isolators shall be freestanding and laterally stable and complete with ¼” neoprene acoustical friction pads or neoprene cup between the spring and the base plate. All mountings shall have leveling bolts. Springs shall have a minimum additional travel to solid equal to 50% of the rated deflection. Submittals shall include spring diameters, deflections, compressed spring height and solid spring height. A steel housing shall be included to resist motion due to earthquake loads. A minimum clearance of ¼” shall be maintained around restraining bolts and between the housing and the spring so as not to interfere with the spring action. The housing shall be out of contact during normal operations. Mountings used out of doors shall be hot dipped galvanized.

   a. Manufacturer:
   1) Mason Industries #SLR.
   2) Or approved equal.

5. Install units between substrate and equipment as required for secure operation and to prevent displacement by normal forces, as indicated.

6. Adjust leveling devices as required to distribute loading uniformly onto isolators. Shim units as required where substrate is not level.

7. All-Directional seismic snubber restraints, with 1G load rating, shall consist of interlocking steel members restrained by a one-piece molded bushing or bridge bearing neoprene. A minimum air gap of 1/8” shall be incorporated in the snubber design in all directions before contact is made between the rigid and resilient surfaces. Snubber end shall be removable to allow inspection of internal clearances.

   a. Manufacturer:
1) Mason Industries #Z-1225.

8. Suspended isolated equipment and vessels shall be protected with cable restraints. Cables shall be installed to prevent excessive seismic motion and so arranged that they do not engage during normal operation, starting, or stopping.


10. Upon completion of vibration control work, prepare report showing measured equipment deflections for each major item of equipment as indicated.

11. Clean each vibration control unit, and verify that each is working freely, and that there is no dirt or debris in immediate vicinity of unit that could possibly short-circuit unit isolation.

I. Seismic restraints may be omitted from the following installations with prior approval from the Airport:

1. All piping suspended by individual hangers 12” or less in length from the top of pipe to the bottom of the support for the hanger.

2. All ducts suspended by hangers 12” or less in length from the top of the duct to the bottom of the support for the hanger. Ducts must be positively attached to the hangers within 2” of the top of the duct with a minimum of two #10 sheet metal screws.

3.16 WARNING SIGNS AND OPERATIONAL TAGS

A. Warning Signs: Provide warning signs where there is hazardous exposure associated with access to or operation of mechanical facilities. Provide text of sufficient clarity and lettering of sufficient size to convey adequate information at each location; mount permanently in an appropriate and effective location. Comply with recognized industry standards for color and design.

B. Operational Tags: Where needed for proper and adequate information on operation and maintenance of mechanical systems, provide tags of plasticized card stock, either preprinted or hand printed. Tags shall convey the message, example: “DO NOT OPEN THIS SWITCH WHEN BURNER IS OPERATING”.

3.17 IDENTIFICATION MARKERS

A. General: Where identification is to be applied to surfaces which require insulation, painting, or other covering or finish, including valve tags in finished mechanical spaces, install identification after completion of covering and painting. Install identification prior to installation of acoustical ceilings and similar removable concealment. Identification schemes shall comply with ANSI A13.1. Coordinate markers with Division 9 for piping to be painted.

B. Piping System Identification:

1. Install pipe markers on each system indicated to receive identification, and include arrows to show normal direction of flow.

2. Install valve tags on all valves. Where valve handles are located on top of pipe the tags shall hang sufficiently to be visible while standing on floor below.

3. Locate pipe markers as follows:
   a. Near each valve and control device.
   b. Near each branch, excluding short take-offs for fixtures and terminal units; mark each pipe at branch, where there could be question of flow pattern.
   c. Near locations where pipes pass through walls or floors/ceilings, or enter non-accessible
enclosures.

d. At access doors, manholes, and similar access points which permit view of concealed piping.

e. Near major equipment items and other points of origination and termination.

f. Spaced horizontally at maximum spacing of 20' along each piping run, with minimum of one in each room. Vertically spaced at each story traversed.

C. Mechanical Equipment Identification: Locate engraved plastic laminate signs on or near each major item of mechanical equipment and each operational device. Provide signs for the following:

1. Main control and operating valves, including safety devices.

2. Fans, blowers, primary balancing dampers, and VAV/mixing boxes.

D. Text of Signs: In addition to name of identified unit, provide lettering to distinguish between multiple units, inform operator of operational requirements, indicate safety and emergency precautions, and warn of hazards and improper operations.

3.18 CONNECTIONS TO EXISTING AIRPORT PIPING SYSTEMS

A. General: Connections to all existing piping shall be made in strict accordance with the Airport procedures and under guidance from the Owner's Engineering personnel.

B. All new piping shall be completely cleaned, charged with chemically treated water before any interconnecting valves between existing pipes and new pipes shall be allowed to be opened. Schedule all such operations with Owner's Engineering personnel, well in advance, so that their supervision of the process could be scheduled.

3.19 PROHIBITED MARKINGS

A. Prohibited Markings: Markings which are intended to identify the manufacturer, vendor, or other source from which the material has been obtained are prohibited for installation within public, tenant, or common areas within the project. Also prohibited are materials or devices which bear evidence that markings or insignias have been removed. Certification, testing (example, Underwriters' Laboratories, Inc.), and approved labels are exceptions to this requirement.

3.20 TAMPER RESISTANT FASTENERS

A. All exposed fasteners utilized shall be of a tamper resistant design. All fasteners shall be of the same type whenever possible. Coordinate fastener selection with other trades to provide similar fastener types whenever possible. A minimum of three tools for use with each type of tamper resistant fastener shall be furnished to the Owner at the time of substantial completion.

3.21 PIPE INSPECTIONS

A. Inspection – Above Grade: All piping installed above grade shall be inspected prior to finish of walls and ceilings by the Airport’s Inspector of Record. Contractor shall follow the Airport’s procedures for inspection requests with no less than 48 working hours’ notice prior to inspection time. Should the piping be hidden within the structure prior to inspection the Contractor may be requested to uncover the piping at no delay to the project and at no additional cost to SFO.

3.22 ELECTRICAL REQUIREMENTS
A. Mechanical Contractor shall coordinate with electrical work to provide complete systems as required to operate all mechanical devices installed under this Division of work.

B. Mechanical Contractor to provide the following:
   1. Motors.
   2. Starter and disconnects if part of a packaged piece of equipment. See equipment specifications and schedules for requirements.
   3. Low voltage and electronic control devices.
   4. Low voltage transformers.
   5. Low voltage conduit and wire as well as connecting devices.
   6. All electrical work listed above, shall be performed by an electrical installer or by the Controls Contractor, but to be provided for and coordinated under this work. In addition, all the controls to be supervised and subsequent installation and start-up approved in writing by the Control Manufacturer.

C. Mechanical Contractor to furnish the following to the Electrical Contractor for installation by the Electrical Contractor where applicable:
   1. Line voltage control equipment, including starters, switches (except disconnects), time switches, transformers, relays, etc. (except those part of motor control center).

D. Under Division 26 the following to be provided:
   1. Furnish and install line voltage wire and conduit system.
   2. Starters and disconnects not provided with equipment.
   3. Install equipment furnished under Division 23.

E. Motors and Motor Control Equipment: Conform to the standards of the NEMA. Equip motors with magnetic or manual line starters with overload protection. Motor starters and line voltage controls shall be installed under Electrical Section but located and coordinated as required under this Section of the work.Starters shall be combination type with non-fusible disconnect switches. All single phase fractional horsepower motors shall have built-in overload protection.

3.23 PAINTING

A. All painting shall be provided under this as Finishes requirements. Painting schemes shall comply with ANSI A13.1.
   1. Paint all exposed materials such as piping, ductwork, equipment, insulation, steel supports, etc.
   2. Exposed gas piping inside and outside the building shall be painted with two coats of “Rust-O-Ileum” Medium Gray, or color as directed by Owner’s Representative. All piping and fittings shall be thoroughly cleaned of dirt and rust BEFORE painting. All piping outside the building shall be painted immediately after installation to limit rusting.
   3. The inside surface of visible ductwork above diffusers/grilles shall be painted flat black.

B. All exposed work under Division 23 shall receive either a factory finish or a field prime coat finish,
except:

1. Exposed copper piping.
2. Aluminum jacketed piping.

C. Damage and Touchup: Repair marred and damaged factory-painted finishes with materials and procedures to match original factory finish.

3.24 CONCRETE BASES

A. Concrete Bases: Anchor equipment to concrete base according to equipment manufacturer’s written instructions and according to seismic codes at Project.

END OF SECTION 23 05 00
SECTION 23 05 02 – MECHANICAL DESIGN REQUIREMENTS FOR LEED® PROJECTS

PART 1 – GENERAL

1.1 PROJECT REQUIREMENTS

A. The Airport Commission is pursuing a LEED® Gold certification for the project. The purpose of this Section is to define the LEED® documentation and submittal requirements the Mechanical Subcontractor is responsible for and must include in his work. Reduction in scope of work or reduction in specified equipment efficiencies will not be allowed for this project.

B. LEED® documentation and calculations will be required for the prerequisites and credits as listed in the project score card. The Subcontractors involved in performing work for this Section shall provide information, documentation, calculations, etc., as necessary for completing the documentation required to obtain LEED® certification. Subcontractor may obtain further program documentation by visiting www.usgbc.com.

C. Subcontractor(s) shall provide systems and functions that meet or exceed the requirements of the LEED® certification process listed herein and in all other Division 23 Mechanical sections and the Contract Drawings.

1.2 APPLICABLE REQUIREMENTS

A. All work under this Section shall comply with the requirements of General Conditions, Supplemental Conditions, Special Conditions and Division 1, General Requirements and shall include all Mechanical Sections specified herein.

1.3 RELATED WORK SPECIFIED ELSEWHERE

A. All Division 23 Mechanical sections included herein.

1.4 APPLICABLE STANDARDS OR GUIDELINES

A. Provide in accordance with requirements of the United States Green Building Council (USGBC) requirements for the following:

1. LEED® Green Building Rating System as published by the USGBC.

2. LEED® Reference Guide as published by the USGBC.

1.5 SUBMITTALS

A. As a member of the project team, the Subcontractor shall submit LEED® documentation and calculations required for their credits and/or as necessary for construction procedures, materials, equipment efficiencies, etc., for compliance with the project LEED® requirements. At the Owner Representative’s direction, submittals will be to LEED® Online and/or in hardcopy format demonstrating compliance with the LEED® project criteria.

1.6 LEED® DOCUMENTATION
A. General:

1. Documentation shall be provided as required for the LEED® prerequisites or credits listed in the project scorecard. Some credits may be modified, removed or added as necessary during the course of construction as required to obtain the required LEED® rating.

END OF SECTION 23 05 02
PART 1 – GENERAL

1.1 DEFINITIONS

A. “Above Grade”: Not buried in the ground and not embedded in concrete slab on ground.

B. “Actuating” or “Control” devices: Automatic sensing and switching devices such as thermostats, pressure, float, electro-pneumatic switches and electrodes controlling operation of equipment.

C. “Below Grade”: Buried in the ground or embedded in concrete slab on ground.

D. “Concealed”: Embedded in masonry or other construction, installed in furred spaces, within double partitions or hung ceilings, in trenches, in crawl spaces, or in enclosures. In general, any item not visible or directly accessible.

E. “Connect”: Complete hook-up of item with required service.

F. “Exposed”: Not installed underground or “concealed”.

G. “Furnish”: To supply equipment and products as specified.

H. “Indicated,” “Shown” or “Noted”: As indicated, shown or noted on drawings or specifications.

I. “Install”: To erect, mount and connect complete with related accessories.

J. “Motor Controllers”: Manual or magnetic starters (with or without switches), individual push buttons or hand-off-automatic (HOA) switches controlling the operation of motors.

K. “Piping”: Pipe, tube, fittings, flanges, valves, controls, strainers, hangers, supports, unions, traps, drains, insulation, and related items.

L. “Provide”: To supply, install and connect as specified for a complete, safe and operationally ready system.

M. “Reviewed”, “Satisfactory,” or “Directed”: As reviewed, satisfactory, or directed by or to Architect/Engineer/Owner.

N. “Rough-In”: Provide all indicated services in the necessary arrangement suitable for making final connections to fixture or equipment.

O. “Shall”: An exhortation or command to complete the specified task.

P. “Similar” or “equal”: Of base bid manufacture, equal in materials, weight, size, design, and efficiency of specified products.

Q. “Supply”: To purchase, procure, acquire and deliver complete with related accessories.

R. “Will”: A desire to complete the specified task. Allows some flexibility in application as opposed to “shall”.

S. “Wiring”: Raceway, fittings, wire, boxes and related items.

T. “Work”: Labor, materials, equipment, apparatus, controls, accessories, and other items required for proper and complete installation.

1.2 RELATED WORK SPECIFIED ELSEWHERE

A. Division 3 - Concrete is related to provisions for:
   1. Concrete Curbs, housekeeping pads for the mechanical equipment.
   2. Thrust blocks, pads, and boxes for mechanical equipment.
   3. All concrete work for mechanical section shall be included in this section.

B. Division 7 – Thermal & Moisture Protection
   1. Flashing and Sheet Metal.
   2. Sealants and Caulking.

C. Division 9 - Finishes:
   1. Painting of all exposed steel, piping, ductwork, insulation, equipment and materials.
   2. Paint all exposed gas piping, interior and exterior to the building.
   3. All painting by Division 9.

D. Division 10 - Miscellaneous Metals:
   1. Exterior louvers and grilles shall be included in this section, unless specifically indicated otherwise on the drawings.

E. Division 26 - Electrical is related to work of:
   1. Power connections to all mechanical equipment.

F. Fire Life Safety Systems is related to work of:
   1. Fire Protection alarms and relays.
   2. Smoke detectors monitoring.
   3. Life safety provisions.

1.3 CODES AND STANDARDS

A. All work shall be in full accordance with all codes, ordinances and code rulings.

B. The Subcontractor shall furnish without any extra charge the labor and material required for the compliance of codes.

C. Perform all tests required by governing authorities and required under all Division 23 Sections. Provide written reports on all tests.

D. Electrical devices and wiring shall conform to the standards of the California Electrical Code; all devices shall be UL listed and so identified.
E. All plumbing and mechanical work shall comply with the Americans with Disabilities Act (ADA), local and state accessibility requirement.

F. All excavation work must comply with all provisions of state laws including notification to all owners of underground utilities at least 48 business day hours, but not more than 10 business days, before commencing an excavation.

G. Provide in accordance with latest edition of the rules and regulations of the following:
   1. SFO Airport Building Regulations
   2. California Building Code
   3. California Mechanical Code
   4. California Plumbing Code
   5. California Electric Code
   6. NFPA - State Fire Protection Association
   7. California Code of Requirements (CCR)

H. Provide in accordance with appropriate referenced standards of the following:
   1. AABC - Associated Air Balance Council
   2. AGA - American Gas Association
   3. ADC - Air Diffuser Council
   4. AMCA - Air Moving and Conditioning Association
   5. ANSI - American National Standards Institute
   6. ARI - Air Conditioning and Refrigeration Institute
   7. ASHRAE - American Society of Heating, Refrigerating & Air Conditioning Engineers
   8. ASME - American Society of Mechanical Engineers
   9. ASTM - American Society for Testing Materials
   10. AWS - American Welding Society
   11. AWWA - American Water Works Association
   12. FM - Factory Mutual
   14. MSS - Manufacturer’s Standardization Society
   15. NEMA - National Electrical Manufacturer’s Association
   16. SMACNA - Sheet Metal and Air Conditioning Contractors National Association
   17. UL - Underwriter’s Laboratories

1.4 QUALITY ASSURANCE

A. Labels and Listings: Refer to Division 1 for requirements that materials, appliances and equipment provided meet the requirements of the Underwriter’s Laboratories, Inc., (UL) and other standards organizations. Lettering size and style shall comply with American National Standards Institute, Inc., (ANSI) A13.1 “Scheme for the Identification of Piping Systems.”

B. Manufacturer’s Nameplates: Nameplates on manufactured items shall be aluminum or Type 304 stainless
steel sheet, not less than 20 USG, riveted or bolted to the manufactured item, with nameplate data engraved or punched to form a non-erasable record of equipment data.

C. Field Installation: Field-installed nameplates shall be engraved melamine plastic laminate, 1/8” thick, engraved in block capital lettering to expose white lettering on black face. Screw or bolt to equipment. Adhesive attachment will not be permitted.

D. National Fire Protection Association (NFPA): All work provided under this contract shall meet the requirements of the NFPA. Refer to individual NFPA code sections as referenced in other Division 23 sections.

E. Current Models. All work shall be as follows:
   1. Manufactured items furnished shall be the current, cataloged product of the manufacturer.
   2. Replacement parts shall be readily available and stocked in the USA.

F. Experience: Unless more stringent requirements are specified in other sections of Division 23, manufactured items shall have been installed and used, without modification, renovation or repair, on other projects for not less than one year prior to the date of bidding for this project.

1.5 GENERAL REQUIREMENTS

A. Examine all existing conditions at building site.

B. Review contract documents and technical specifications for extent of new work to be provided.

C. Provide and pay for all permits, licenses, fees and inspections.

D. Install equipment and materials to provide required access for servicing and maintenance. Coordinate the final location of concealed equipment and devices requiring access with final location of required access panels and doors. Allow ample space for removal of all parts that require replacement or servicing. This work shall include furnishing and installing all access doors required for mechanical access.

E. Verify final locations for rough-ins with field measurements and with the requirements of the actual equipment to be connected. Refer to equipment specifications in Divisions 2 through 26 for rough-in requirements.

F. Coordinate mechanical equipment and materials installation with other building components.

G. Verify all dimensions by field measurements.

H. Arrange for chases, slots, and openings in other building components to allow for mechanical installations.

I. Coordinate the installation of required supporting devices and sleeves to be set in poured-in-place concrete and other structural components, as they are constructed.

J. Sequence, coordinate, and integrate installations of mechanical materials and equipment for efficient flow of the work. Give particular attention to large equipment requiring positioning prior to closing-in the building.
K. Coordinate the cutting and patching of building components to accommodate the installation of mechanical equipment and materials. Conform to the requirements of Division 1, 2, 3 and 4. Subcontractor to provide for all cutting and patching required for installation of his work unless otherwise noted in Division 1.

L. Where mounting heights are not detailed or dimensioned, install mechanical services and overhead equipment to provide the maximum headroom possible.

M. Install mechanical equipment to facilitate maintenance and repair or replacement of equipment components. As much as practical, connect equipment for ease of disconnecting, with minimum of interference with other installations.

N. Coordinate the installation of mechanical materials and equipment above ceilings with ductwork, piping, conduits, suspension system, light fixtures, cable trays, sprinkler piping and heads, and other installations.

O. Coordinate connection of mechanical systems with exterior underground and overhead utilities and services. Comply with requirements of governing regulations, franchised service companies, and controlling agencies. Provide required connection for each service.

P. Coordinate with the Owner’s Representative in advance to schedule shutdown of existing systems to make new connections. Provide valves in new piping to allow existing system to be put back in service with minimum down time.

Q. All materials (such as insulation, ductwork, piping, wiring, controls, etc.) located within air plenum spaces, air shafts, and occupied spaces shall have a flame-spread index of 25 or less, and smoke-developed index of 50 or less, as tested by ASTM E84 (NFPA 255) method. In addition, the products, when tested, shall not drip flame particles, and flame shall not be progressive. Provide Underwriters Laboratories, Inc., label or listing, or satisfactory certified test report from an approved testing laboratory to prove the fire hazard ratings for materials proposed for use do not exceed those specified.

1.6 DESCRIPTION OF BID DOCUMENTS

A. Specifications:
   1. Specifications, in general, describe quality and character of materials and equipment.
   2. Specifications are of simplified form and include incomplete sentences.
   3. Words or phrases such as “The Subcontractor shall,” “shall be,” “furnish,” “provide,” “a,” “an,” “the,” and “all” may have been omitted for brevity.

B. Drawings:
   1. Drawings in general are diagrammatic and indicate locations and connections to equipment.
   2. Scaled and figured dimensions are approximate and are for estimating purposes only.
   3. Before proceeding with work check and verify all dimensions.
   4. Assume all responsibility for fitting of materials and equipment to other parts of equipment and structure.
   5. Make adjustments that may be necessary or requested in order to resolve space problems, preserve headroom, and avoid architectural openings, structural members and work of other
trades.

6. Where existing pipes, conduits and/or ducts prevent installation of new work as indicated, relocate, or arrange for relocation, of existing pipes, conduits and/or ducts.

7. If any part of Specifications or Drawings appears unclear or contradictory, apply to the Owner’s Representative for interpretation and decision as early as possible, including during bidding period.

1.7 MINOR DEVIATIONS

A. The Drawings are diagrammatic and show the general arrangements of all mechanical work and requirements to be performed. It is not intended to show or indicate all offsets, fittings, and accessories which will be required as a part of the work of this section.

1.8 CONSTRUCTION AND SHOP DRAWINGS

A. Refer to Division 1 for General Requirements.

1.9 COORDINATION DOCUMENTS

A. The Subcontractor shall prepare coordinated layout drawings, to coordinate the installation and location of all HVAC equipment, ductwork, grilles, diffusers, piping, fire sprinklers, lights, and electrical services. The Drawings shall be keyed to the structural column identification system, and shall be progressively numbered. Prior to completion of the Drawings, the Subcontractor shall coordinate the proposed installation with the architectural and structural requirements, and all other trades (including HVAC, Plumbing, Fire Protection, Electrical, Ceiling Suspension, and Tile Systems), and provide reasonable maintenance access requirements.

B. The drawings shall be prepared as follows:
   1. Piping that must be graded shall have right-of-way over more flexible items.
   2. Plans are to incorporate all addenda items and change orders.
   3. Distribute plans to all trades and provide additional coordination as needed.

C. Provide means of access to all valves, dampers, controllers, operable devices, and other apparatus which may require adjustment or servicing.

D. Verify in field exact size, location, invert, and clearances regarding all existing piping, equipment and apparatus.

E. Final coordination drawings with all appropriate information added are to be submitted as record drawings at completion of project.

1.10 DELIVERY, STORAGE AND HANDLING

A. Deliver products to project properly identified with names, model numbers, types, grades, compliance labels, and similar information needed for distinct identifications; adequately packaged and protected to prevent damage during shipment, storage, and handling.

B. Store equipment and materials in an environmentally controlled area at the site, unless off-site storage is authorized in writing. Protect stored equipment and materials from damage. Piping shall be stored in bundles and covered. Piping showing signs of rust shall be removed from site and replaced.
1.11 TESTING

A. Refer to other Division 23 Mechanical sections and Division 1 for specific requirements.

1.12 CLEANING AND CLOSING

A. All work shall be inspected, tested, and approved before being concealed or placed in operation.

B. Upon completion of the work, all equipment installed as specified in this section, and all areas where work was performed, shall be cleaned to provide operating conditions satisfactory to the Airport.

C. Refer to Division 1 for additional requirements.

1.13 START-UP SERVICE AND BUILDING COMMISSIONING

A. Prior to start-up, assure that systems are ready, including checking the following: Proper equipment rotation, proper wiring, auxiliary connections, lubrication, venting, controls, and installed and properly set relief and safety valves.

B. Provide services of factory trained technicians for start-up of air conditioning units, temperature controls, and other major pieces of equipment.

C. Refer to other Division 23 Sections for additional requirements.

1.14 INSTRUCTION, MAINTENANCE, AND O&M MANUALS

A. O&M Manuals: Upon completion of the work, the Subcontractor shall provide operating instructions, maintenance instructions, part lists, and all other bulletins and brochures pertinent to the operation and maintenance of any equipment furnished and installed as specified in this section. Refer to Division 1.

B. The Contractor shall be responsible for proper instruction of SFO personnel for operation and maintenance of equipment, and apparatus installed as specified in Division 23 to be no less than 2 hours for each piece of equipment.

C. The Subcontractors for “Air Distribution”, “Controls” and “Testing, Adjusting and Balancing” shall participate in a building system commissioning. The commissioning will include testing of all new, refurbished, and/or relocated mechanical systems and control systems in the presence of the Airport Commission’s Representative. The Subcontractor shall include commissioning in the bid.

1.15 POSTED OPERATING INSTRUCTIONS

A. General: Furnish approved operating instructions for systems and equipment indicated in the technical sections for use by operation personnel. The operating instructions shall include wiring diagrams, control diagrams, and control sequence for each principal system and equipment.

1.16 WARRANTIES

A. Refer to the General Conditions and Division 1 for procedures and submittal requirements for warranties. All equipment shall be provided with a minimum one (1) year warranty to include parts and labor. Refer to individual equipment specifications for extended or longer term warranty
requirements.

B. Provide complete warranty information for each item, to include product or equipment, and date of beginning of warranty or bond; duration of warranty or bond; and names, addresses, and telephone numbers and procedures for filing a claim and obtaining warranty services.

1.17 GUARANTEE

A. The Subcontractor shall guarantee and service all workmanship and materials to be as represented by him and shall repair or replace, at no additional cost to the Airport, any part thereof which may become defective within the period of one (1) year after the Date of Final Acceptance, ordinary wear and tear excepted.

B. Subcontractor shall be responsible for and pay for any damages caused by or resulting from defects in their work.

END OF SECTION 23 05 10
SECTION 23 05 13 – COMMON MOTOR REQUIREMENTS FOR HVAC

PART 1 – GENERAL

1.1 DESCRIPTION

A. Provide Motors, Starters and Variable Frequency Drives in accordance with the contract documents.

B. Related Work Specified Elsewhere:
   1. Drawings and general provisions of the Contract, apply to this Section.
   2. Installation of VFD shall require installation of shaft grounding system on the motor shaft of the equipment controlled. Coordinate with manufacturers of air handlers, pumps, etc. as necessary.

1.2 REFERENCES

A. National Fire Protection Association (NFPA)
B. National Electrical Manufacturers Association (NEMA)
C. American National Standards Institute (ANSI)
D. Energy Information Administration (EIA)
E. Institute of Electrical and Electronic Engineers (IEEE)
F. National Electrical Code (NEC)
G. Underwriters Laboratories (UL) ratings

1.3 SCOPE

A. Factory installed motors.

B. Furnish variable frequency drives as indicated on the plans, including, but not necessarily limited to, the following:
   1. Variable Frequency Drives (VFD)
   2. Shaft Grounding System
   3. Controls

1.4 DEFINITIONS

A. Factory-Installed Motor: A motor installed by motorized-equipment manufacturer as a component of equipment.

1.5 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article
100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. Comply with NFPA 70.

C. Products shall be designed, manufactured, tested, and installed in compliance with the following standards, as applicable:
   1. NEMA ICS 2 – Industrial Controls Devices, Controllers and Assemblies.
   2. NEMA KS 1 – Enclosed Switches

D. Codes and Standards: Provide VFDs conforming to the requirements of the latest addition of the following:
   1. American National Standards Institute:
      a. ANSI/EIA 508 – Electrical Performance Standards for Television Broadcast Transmitters.

E. Each VFD shall comply with the applicable requirements for the latest standards of ANSI and IEEE-519-1981 5% voltage distortion and line notching category. Computations or computer simulations shall be provided with the submittals to confirm compliance. The VFD manufacturer shall supply all necessary items to comply.

F. VFD design and construction shall comply with all applicable provisions of the National Electric Code and the entire assembly shall be UL listed.

G. Each VFD shall comply with Part 15, Subpart J of FCC rules for Class A computing devices in the range of 7 to 30 MHz for conduction. FCC label of compliance shall be displayed on the VFD.

H. The Variable Frequency Drive (VFD) manufacturer shall be responsible for the type of construction of motors and shall guarantee compatibility and safe operation of all motors driven by VFD at all speeds and that VFD’s will not cause any damage to the connected motors. Any remedial costs for replacing and rewiring of non-compatible motors shall be borne by VFD supplier. The VFD manufacturer shall also be responsible to remedy any motor bearing failure due to pitting, at no cost to the Owner.

I. Manufacturer shall have a minimum of 10 years’ experience building similar equipment for controlling the speed for induction motors and at least one hundred successful installations with a variety of VFD sizes and applications.

J. Each VFD shall be factory tested over the entire range of its operation.

K. Two (2) year on-site warranty including parts, labor and travel costs.

1.6 SUBMITTALS

A. Prior to construction, submit for approval the following materials:
   1. Manufacturer’s data, installation instructions, and maintenance and operational instructions for variable frequency drives and shaft grounding systems. Indicate electrical service and special
requirements. Include manufacturer’s descriptive literature, repair data, and parts listing.

B. Shop drawing submittals for motorized equipment shall include, but not be limited to, the following information on motors provided with equipment.

1. Manufacturer’s name and cut sheets.
2. Motor type.
3. Horsepower and “air over” ratings.
4. Voltage/Phase/Hertz.
5. RPM.
7. Insulation class.
8. NEC code number.
9. Motor efficiency and testing method and results.

C. Shop drawing submittals for VFD shall include, but not be limited to, the following:

1. Cut sheets of individual speed controllers with construction, dimensions, weights, ratings, voltage, poles, options, and all associated accessories clearly indicated.
2. Wiring diagrams for the drive power, bypass, and control sections.
3. A detailed description of drive operation and adjustable parameters.
4. A detailed description of factory testing.

D. Manufacturer Seismic Qualification Certification: Submit certification that motors, accessories, and components will withstand seismic forces defined in Division 23 Section “Vibration and Seismic Controls. Include the following:

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   a. The term “withstand” means “the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified.”
   b. The term “withstand” means “the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event.”
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

E. Qualification Data: For testing agency.

F. Source quality-control test reports.

G. Operation and Maintenance Data: For motors to include in emergency, operation, and maintenance manuals.
1.7 COORDINATION

A. Coordinate features of motors, installed units, and accessory devices and features that comply with the following:
   1. Compatible with the following:
      a. Magnetic controllers.
      b. Multispeed controllers.
      c. Reduced-voltage controllers.
      d. Variable speed drive.
   2. Designed and labeled for use with variable frequency controllers, and suitable for use throughout speed range without overheating.
   3. Matched to torque and horsepower requirements of the load.
   4. Matched to ratings and characteristics of supply circuit and required control sequence.

1.8 DELIVERY, STORAGE AND HANDLING

A. Deliver units to the site in containers with manufacturer’s stamp or label affixed.
B. Store equipment in clean, dry space protected against dirt, water, chemical, and mechanical damage. Maintain factory-wrapping or provide additional heavy canvas or plastic cover to protect units from dirt, water, construction debris and traffic.
C. Handle equipment carefully to avoid any damage.
D. Protect motors stored on site from weather and moisture by maintaining factory covers and suitable weatherproof covering. For extended outdoor storage, remove motors from equipment and store separately.
E. Do not install damaged units. Remove from project site.

1.9 WARRANTY

A. Provide three-year (36 months) warranty. This warranty shall include VFD induced damage to motors, bearings, shafts, impellers, etc. The warranty shall include parts, labor, travel costs, and living expenses incurred by the manufacturer to provide factory authorized service.

PART 2 – PRODUCTS

2.1 MOTORS

A. General:
   1. Provide motors for equipment of this Division. Motors shall be minimum size as indicated but shall have sufficient starting torque to start equipment.
   2. Motors shall be open drip-proof for general use, totally enclosed for wet or exterior use and explosion proof for hazardous duty where specified. Motors for in-line fans shall be of special frame to suit the fan construction requirements.
3. Motors 1/2 hp or larger shall be 460 volts, 3 phase, and smaller than 1/2 hp shall be 120 volts, single phase unless otherwise noted.

4. Motors connected to VFD’s shall be furnished by the variable frequency drive manufacturer, or under his responsibility.

5. Electric motors shall be selected for quiet operation. All motors shall be rated for continuous operation at 115% of nameplate amperage.

B. Bearings: Motors shall have either sealed or field-lubricated type roller or ball-bearings. Field lubricated ball bearings shall be drilled for grease fittings and have fittings installed. Where motors are installed inside equipment, extended grease fittings shall be provided. All bearings shall be designed for L-10, 100,000-hour minimum life hours of continuous service unless otherwise indicated. For motors driven by VFD’s, provide appropriate shaft insulation or shaft grounding devices to prevent possible pitting of bearings.

C. Balancing: Motors shall be statically and dynamically balanced and tested at the factory prior to shipment and shall be selected for quiet operation.

D. Windings: All motors shall have copper windings.

E. Insulation: Open single phase motors shall have Class A or Class B insulation, open 3-phase motors shall have Class B insulation and all enclosed motors shall have Class F insulation. Motors driven by VFD’s shall have minimum Class F insulation.

F. Single Phase Motors: All single phase motors shall be capacitor start or permanent split capacitor type selected to suit the load served. Single phase motors 1/4 hp and smaller shall have internal thermal protection.

G. Housing: All open motors 10 hp and smaller shall have cast aluminum end bells with steel frames. All open motors 15 hp and larger, all enclosed motors and all motors used with VFD’s shall have cast iron housings.

H. Rotation: The contractor shall be responsible to verify that the rotation of all 120 volts, single phase motors for mechanical equipment is in the correct direction prior to installation. Coordinate with electrical for correct rotation of all 3-phase motors.

I. Nameplates: A motor nameplate shall be securely affixed to each motor and shall clearly indicate the electrical data, horsepower, rpm, frequency, NEC code number, and motor efficiency, class of insulation, winding material, and service factor.

J. Premium Efficiency Motors: “Premium” efficiency motors shall be provided for all 3-phase motors unless noted otherwise. Motor efficiency shall be based upon dynamometer testing per IEEE 112-E Test Standard, Method B, as set forth by NEMA MG 1-12.53a standard for efficiency testing and motor shall be labeled in accordance with NEMA MG1-12.53b. Motors shall be Baldor Super-E motors or an approved equal by General Electric, Reliance, Westinghouse, U. S. Motors or Lincoln. Motors shall have a minimum efficiency as follows:

1) ODP
2) Minimum Horsepower Efficiency
3) Efficiency Power Factor
Less than 1 hp | 80.0% | -- | 0.75  
1 to 1.5 hp | 82.0% | -- | 0.77  
1.5 to 2 hp | 84.0% | -- | 0.80  
3 to 5 hp | 86.0% | 89.0% | 0.81  
7.5 to 15 hp | 88.0% | 91.0% | 0.87  
20 to 40 hp | 92.0% | 93.0% | 0.85  
50 hp and up | 93.5% | 95.0% | 0.87

K. Additional Requirements: Refer to the various equipment Sections of this Division for additional motor requirements.

L. Motor requirements below apply to factory installed motors, except as follows:

1. Different ratings, performance, or characteristics for motor are specified in another Section.
2. Motorized-equipment manufacturer requires ratings, performance, or characteristics, other than those specified in this Section, to meet performance specified.
3. Motor Characteristics:
   a. Motors ¾ HP and Larger: Three phase.
   b. Motors Smaller than 0.75 HP: Single phase.
   c. Frequency Rating: 60 Hz.
   d. Voltage Rating: NEMA standard voltage selected to operate on nominal circuit voltage to which motor is connected.
   e. Service Factor: 1.15 for open drip-proof and totally enclosed motors.
   f. Duty: Continuous duty at ambient temperature of 105 °F and at an altitude of 3300 feet above sea level.
   g. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.

4. Enclosure:
   a. Open drip-proof (ODP) for indoor applications.
   b. Totally enclosed fan cooled (TEFC) for outdoor applications.

M. Polyphase Motors:

1. Description: NEMA MG 1, Design B, medium induction motor.
2. Efficiency: Premium, as defined in NEMA MG 1.
3. Stator: Copper windings, unless otherwise indicated.
   a. Multi-speed motors shall have separate winding for each speed.
4. Rotor: Squirrel cage, unless otherwise indicated.
5. Bearings: Double-shielded, pre-lubricated ball bearings suitable for radial and thrust loading.
6. Temperature Rise: Match insulation rating, unless otherwise indicated.
7. Insulation: Class F, unless otherwise indicated.
8. **Code Letter Designation:**
   a. Motors 15 HP and Larger: NEMA starting Code F or Code G.
   b. Motors Smaller than 15 HP: Manufacturer’s standard starting characteristic.

9. **Enclosure:** Cast iron for motors 7.5 hp and larger; rolled steel for motors smaller than 7.5 hp.
   a. Finish: Gray enamel.

N. **Polyphase Motors with Additional Requirements:**

1. Motors Used with Reduced-Inrush Controllers: Match wiring connection requirements for controller with required motor loads. Provide terminals in motor terminal box, suited to control method.

2. Motors Used with Variable Frequency Controllers: Ratings, characteristics, and features coordinated with and approved by controller manufacturer.
   a. Designed with critical vibration frequencies outside operating range of controller output.
   b. Temperature Rise: Matched to rating for Class B insulation.
   c. Insulation: Class H.
   d. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.

O. **Single-Phase Motors:**

1. Type: One of the following to suite starting torque and requirements of specific motor application:
   a. Permanent-split capacitor.
   b. Split-phase start, capacitor run.
   c. Capacitor start, capacitor run.

2. **Shaded-Pole Motors:** For motors 1/20 hp and smaller only.

3. **Thermal Protection:** Internal protection to automatically open power supply circuit to motor when winding temperature exceeds a safe value calibrated to temperature rating of motor insulation. Thermal-protection device shall automatically reset when motor temperature returns to normal range.

4. **Bearings:** Ball type for belt-connected motors and other motors with high radial forces on motor shaft; sealed, pre-lubricated-sleeve type for other single-phase motors.

5. **Efficiency:** Premium, as defined in NEMA MG 1.

2.2 **VARIABLE FREQUENCY DRIVES (VFD)**

A. **Acceptable Manufacturers:**

1. Asea-Brown-Bowery (ABB) Model ACH 501, ACH 502 or approved equal by:
   a. Toshiba.
   b. Graham.
   c. Allen-Bradley.
   d. Reliance.
   e. Safetronics.
B. Connected motors should be by the same manufacturer, where possible.

C. It is the responsibility of the drive supplier to assure that the drive is compatible with the controlled motor.

D. Furnish complete VFDs as scheduled on the plans. Refer to plans for location of variable speed controllers. Each fan motor shall have a dedicated VFD unit, with all standard and optional features included within the VFD enclosure, unless otherwise specified or indicated on the plans.

E. Operation: Each VFD shall convert available utility power to adjustable voltage/frequency, 3-phase, ac power for step less motor control from 10 to 110% of motor speed, where 110% of the motor nameplate full load current is the maximum output. VFD shall be able to start in a rotating load in either direction without trip.

   1. The VFD shall produce an adjustable ac voltage/frequency output for complete motor speed control. Speed control shall be step less throughout the range under a variable torque load on a continuous basis. The VFD shall be automatically controlled by an external control signal.

   2. The VFD maximum output current rating shall be greater than or equal to the motor nameplate full load. The input factor of the controller shall be 0.95 or greater under all speed and load conditions and the unit shall be rated for 100% operation at full rated current, voltage and frequency.

   3. The VFD shall contain a fused input power disconnect or circuit breaker with door interlock.

   4. A dedicated line filter shall be provided at the input of the VFD to limit EMI from interference with vital electrical equipment. The VFD’s shall not interfere with any airport communication and air traffic control systems, and shall meet all FAA and FCC regulations for radio frequency interference standards. VFD manufacturer shall be responsible for any damage caused by not meeting this requirement and must provide all necessary shielding, protection, etc. to correct the problem.

F. Components: Each controller shall include, but not be limited to an input rectifier, constant voltage dc link, filter, sine-weighted pulse width modulation inverter and accessory sections with each section modularized for ease of troubleshooting. Controller shall be protected with I2T fuses or circuit breakers per the manufacturer’s design and specification. All components shall be factory mounted and wired on a dead-front, grounded, naturally vented, free-standing or wall-mounted NEMA 12 enclosure arranged for top or bottom conduit entry. The free-standing enclosure shall be suitable for mounting on a steel platform or on a concrete housekeeping pad.

   1. The controller enclosure shall be provided with the manufacturer's illustrated operating instructions and parts list mounted inside the enclosure door, manual speed control potentiometer, three position mode selector switch (manual-off-auto), “power on” light, diagnostic/frequency display, auxiliary relays, and contracts for interlock and control wiring.

   2. The adjustable frequency controller shall convert three-phase, 60 Hz utility power to adjustable voltage and frequency, three-phase, AC power for step less motor speed control from 10% to 100% of the motor’s 60 Hz speed.

G. Construction: 100% solid state, power width modulated (PWM) wave form utilizing insulated gate bipolar transistors (IGBT). Provide with three adjustable critical frequency avoidance bands. Carrier frequency shall be adjustable to 12 KHZ or provide noise reduction filters at drive output to reduce motor acoustical noise.
H. Features: VFD features shall include, but not be limited to, the following:

1. **Input Power:** 480 volts ac +10%, 60 Hz, +1.8 Hz. Input power factor shall be 0.95 or greater from full motor speed to zero speed for any motor load.

2. **Output Power:** Three phase, 0-480, 2-66 Hz.

3. **Ambient Temperatures:** Operating: 32°F to 104°F (0°C to 40°C). Storage: --4°F to 140°F (20°C to 60°C).

4. **Frequency Stability:** Output frequency will be held to +0.1% of maximum frequency regardless of load, +10% input voltage change or temperature changes within the ambient specification.

5. **Disconnect:** Locking type input disconnect switch with external operating handle.

6. **Bypass:** Manual bypass which isolates the drive from the circuit and allows motor operation at full across-the-line speed. Bypass shall include motor contactor, drive isolation contactors, motor overload protection, fused control power transformer and front panel mounted bypass controls. VFD to be fully serviceable under bypass mode.

7. **Input Filter:** Input line filter capable of protecting the electronics against transient voltage spikes or notches.

8. **Current Limit:** To limit output current to 110% of that of the drive rating. The current limit shall be designed to function automatically to prevent overcurrent trip due to momentary overload conditions, allowing the drive to continue operation.

9. **Instantaneous Overcurrent Trip:** To safely limit the output current in under 50 microseconds due to short circuit or severe overload conditions.

10. **Under voltage Trip:** To protect the drive due to voltage levels in excess of its rating. The overvoltage trip will activate automatically when the inverter bus in the controller exceeds 950 volts dc.

11. **Overvoltage Trip:** To protect the drive due to voltage levels in excess of its rating. The overvoltage trip will activate automatically when the inverter bus in the controller exceeds 950 volts dc.

12. **Ground Fault Protection:** Fuse less electronic power protection for ground fault protection. Isolation transformers for ground fault protection are not acceptable. Ground fault shall not cause fuses to open.

13. **Overload Protection:** Electronic output overload protection shall be provided to eliminate the use of bimetallic overloads. The drive shall not be phase sequence sensitive. The overload protection shall also protect the motor when it is operated at full speed in the bypass mode.

14. **Over temperature Trip:** To protect the drive from elevated temperatures in excess of its rating. An indicating light which begins flashing with 10°C of the trip point will be provided to alert the operator to the increasing temperature condition. When the over temperature trip point is reached, this light will be continuously illuminated.

15. **Automatic Reset/Restart:** The drive shall be equipped such that a trip condition resulting from overcurrent, under voltage, overvoltage or over-temperature shall be automatically reset, and the drive shall automatically restart upon removal, or correction of the causative condition. The number of reset/restart attempts for under voltage, overvoltage, over-temperature and overcurrent shall be limited to five. If, in the five attempts, a reset/restart is not successful, the
drive shall shut down safely, requiring a manual restart. If, within five attempts, a successful reset/restart occurs, the Auto Reset/Restart circuit will reset the attempts counted to zero after approximately 10 minutes of continuous operation.

16. Power Interruption: In the event that an input or output power contactor is opened or closed while the drive is activated, no damage to the drive shall result.

17. Short Circuit Protection: In the event of a phase-to-phase short circuit the drive shall be designed to shut down safely without component failure.

18. Sustained Power Loss: In the event of a sustained power loss, the drive shall be designed to shut down safely without component failure. Upon return of power, the system shall be designed to automatically return to normal operation.

19. Momentary Power Loss: In the event of a momentary power loss, the drive shall be designed to ride-through a power interruption up to five cycles and shut down safely without component failure. Upon a more extended momentary power loss, the system shall be designed to automatically return to normal operation upon return of power.

20. Stand Alone Operation: To facilitate start-up troubleshooting, the drive shall be designed to operate without a motor or any other equipment connected to the drive output.

21. Start/Stop Control: The drive may be started or stopped by any one of the following:
   a. A contact closure rated 50 ma, 115 volt ac minimum.
   b. Use of a motor starter or contactor in the input power line.
   c. The speed control signal dropping below or rising above minimum.
   d. An external 115 volt ac signal.
   e. Operation of momentary start/stop switch or pushbuttons. The drive shall include built-in holding contracts for this purpose.

22. Speed Control: The drive will adjust the output frequency in proportion to a 4-20 ma Analog input, 0-10V dc, 3-15 psi signal or RS-232 direct digital input.

23. Minimum and Maximum Speed Control: Adjustable minimum and maximum speed potentiometers for all speed signals. Minimum range shall be 0-80%, field set at 40%. Maximum range shall be 110-0%, field set at 100%.

24. Signal Gain and Offset: Adjustable signal gain (1:1 to 10:1 range) and offset (0-50% of input signal for all speed signals.

25. Inverted Signal: Inverted speed signal selector switch to invert the response to input speed signal.

26. Automatic Reversing: Reversing terminals to automatically reverse the rotation of the motor(s) shall be available for customer use if so desired. When a contact closure is made across these terminals, the motor shall decelerate from its operating speed to zero at the preset deceleration rate. Upon reaching zero, it shall reverse direction and accelerate to the set speed at the present acceleration rate.

27. Adjustable Acceleration/Deceleration: Independently adjustable acceleration and deceleration time potentiometers from 30-300 seconds, field set at 90 seconds.

28. Control Isolation: Low voltage logic and 115 volt control circuits shall be electrically isolated from the power circuits. Signal circuit common shall be grounded.
29. Control Adjustments: All control adjustments shall be made without the necessity of an extender board or specialized meters, and from front accessible controls.

30. Diagnostics: A diagnostic fault detection center shall be integral to each VFD, providing an indication of the following fault conditions:
   a. External fault.
   b. Processor line fault.
   c. Low ac line voltage.
   d. High ac line voltage.
   e. Current overload.
   f. High dc bus voltage.
   g. VFD output fault.

31. Status Lights: Status lights for indications of conditions described in Items 1 through 5 shall be provided. An SPDT for remote indication of Items 2 through 5 shall be provided. Additionally, status lights to show “Power On”, “Zero Speed”, and “Drive Enabled” shall be provided. All status lights shall be self-contained in the front panel of the unit and shall be duplicated for ease of troubleshooting on the inside of the unit. Status lights shall be red, light-emitting diode type for high visibility and reliability.

32. Indicating Lights:
   a. Power On: Lights any time input power is applied to the drive.
   b. Zero Speed: Illuminates whenever the drive is at zero frequency.
   c. Enabled: Lights to indicate that the drive has a start command.
   d. Over Temperature: Begins flashing when the internal temperature of the drive is within 10°C of overheating. Upon reaching the over temperature trip point, the light is continuously illuminated.
   e. Current Limit: Indicates that the Acceleration, Deceleration or Run Limit circuit is in operation.
   f. Under Voltage: Indicates that an under voltage trip has occurred.
   g. Over Voltage: Indicates that an overvoltage trip has occurred.
   h. Overcurrent: Indicates that the current rating of the drive has been exceeded and the overcurrent trip circuit has been activated.

33. External Alarm Contacts: A single pole, double throw contact rated 115-volt ac, 28-volt dc, 1 amp resistive, shall be available for external monitoring. Contact will change state when any trip condition has occurred.

34. Speed Reference Signal: A 0 to 5-volt dc signal shall be provided for customer use. This 0 to 5-volt dc signal shall vary in direct proportion to the drive speed.

35. User Interface: The VFD shall have the following door mounted user interface devices.
   b. Hand/Off/Auto (or equivalent) selector switch.
   d. Digital Readout Frequency Meter/Diagnostic Display.

36. Cooling: The VFD shall be convection-cooled in the ambient condition where they are located.
Units requiring fan cooling are not acceptable. The unit shall have high temperature protection.

37. Control Power: A 115-volt ac, control power shall be available for customer use whenever drive input power is applied.


39. Motor Noise: Radiated noise from motor as a result of the VFD system at any drive speed shall be limited to 3 dBA above across-the-line operation noise when operated over the full speed range, as measured at 3 ft. from the motor centerline.
   a. Power line noise shall be limited to a voltage distortion factor and line notch depth as defined in ANSI/IEEE Standard 519.

40. Remote indication/control points interface for Automation System:
   a. On/off commands and status (including hand/off/auto switch position).
   b. Trouble/alarms.
   c. PID speed controls.
   d. Wattmeter
   e. Contact to reset predetermined set-speed for fire mode operation.

41. The VFD shall include a converter and an inverter section. The converter section shall convert fixed frequency and voltage AC utility power to a DC voltage. Drive shall utilize a single surface mount-micro-processor.

42. VFDs shall be provided with an advanced flux vector frequency control to limit noise at drive and motor.

43. The VFD shall not emit either conducted or radiated radio frequency interference in excess of the limitations set forth in the FCC Rules and Regulations, Part 15, Subpart J, class A.

44. The drive efficiency shall be 97% (minimum) and have a fundamental power factor of 0.98 at all speeds.

45. The VFD shall be housed in a NEMA-1 enclosure. The enclosure shall be louvered, vented through cabinet and arranged so that units can be mounted back to back on a frame and/or side to side on a wall. Venting fans shall be supplied in enclosure if required. Enclosure shall be complete with no requirements for low voltage wiring. Factory mounted main disconnected shall be included.
   a. The following operator controls shall be located on the front of the enclosure:
      1) Door mounted operator digital controls consisting of auto/manual switch, start/stop switch with reset and manual speed control. In the auto position, the drive will start/stop from a remote contact closure and motor speed is determined by the follower signal. In the manual position, motor speed is determined by manual speed selection. Manual potentiometers are not acceptable.
      2) Power on pilot light to indicate that the VFD is being supplied by the power line.
      3) Fault digital display to indicate that the VFD has tripped on a fault condition. The drive shall retain in memory the last three (3) fault conditions that caused the drive to trip. Indication should include but not be limited to the following: Under voltage, over voltage, over current, over temperature, phase loss, phase imbalance and external trip.
      4) Digital display to indicate voltage, current, frequency or RPM. Selectable by the operator while the VFD is running.
46. VFD shall be provided with two (2) each form C dry contacts for indications of run and fault starters. In addition, each drive shall have an analog output signal 0 to 10 VAC (or 4-20MA) to indicate drive speed (percent of full load).

47. While in the remote mode, the VFD will attempt at least five (5) restarts after a power outage, drive fault or external fault before requiring manual reset. After ten minutes of runtime, the restart attempts return to zero. The VFD shall display a countdown timer when auto restart is being attempted, or incorporate programming to select number of restarts, number of faults per time period, and time between restarts.

I. Shaft Grounding System:
   1. General: A shaft grounding system shall be installed on each motor, connected to the VFD, to prevent shaft-to-frame voltage above 2.8 volts. The shaft grounding system shall prevent current flow across the bearings, thereby eliminating bearing damage ("fluting") caused by shaft voltage potential.
   2. Shaft grounding system shall have a solid housing constructed of bronze, brass, aluminum or stainless steel. Brush material shall be a carbon compound with a wear life expectancy of 5 years. In clean environments areas served by air handlers, such as clean rooms and electronic equipment rooms, a fully enclosed housing shall be provided to contain brush wear products.
   3. Acceptable Manufacturers:
      a. Albany.
      b. Oregon.
      c. Or approved equal.

J. Protective VFD Features
   1. Protection against input transient voltage spikes.
   2. Overload protection for the motor. If power input or output is interrupted while the control is in operation, no damage shall result. The unit shall be able to operate without any equipment connected to the inverter output. The drive must protect itself against all phase-to-phase short circuits and ground faults.
   3. Protection against input power under voltage, over voltage and phase loss.
   4. Protection against output current overload and over current.
   5. Protection against over-temperature within the VFD enclosure.
   6. Protection against over voltage on the DC bus.
   7. Drive shall have an auxiliary contact to permit a remote trip.
   8. DC bus discharge circuit and warning light for protection of service personnel or meet UL requirements for DC bus discharge.
   9. Drive shall be capable of operating and insensitive to imbalance or out-of-rotation incoming power phase.
   10. Lockable main fused input disconnect shall be factory mounted as specified on the drawings or as required by the application.
1. Selector switch in the “off” position - the controller run circuit will be open and the system will not operate.

2. Selector switch in the “manual” position - the speeds of the motor will be controlled by the manual speed potentiometer.

3. Selector switch in the “auto” position - operation will be via the external control input signal with the output speed proportional to the input signal.

L. The VFD and options shall be tested to ANSI/EIA Standard 508 and listed by a nationally recognized testing agency such as UL or ETL.

M. Adjustments:
   1. Maximum speed, adjustable to 100% base speed.
   2. Minimum speed, adjustable to 10% base speed.
   3. Acceleration time, adjustable .1 to 360 seconds (minimum) factory set at 20 seconds.
   4. Deceleration time, adjustable .1 to 360 seconds (minimum) factory set at 20 seconds.
   5. Current limit, adjustable 50 to 110%.
   6. Adjustable speed lock-outs for three (3) operating ranges.
   7. Capable of following 0-5 MA, 4-20 MA, 10-50 MA, 0-4 VDC, 0-8 VDC, 0-10 VDC grounded or ungrounded signal as required to interface with the building control system.

N. Special VFD Features:
   1. All control wiring, and accessories shall be factory installed in the drive casing that only the connection of the remote auxiliary start/stop and override contacts is required to provide override control as described above.
   2. All drives shall be equipped with fail safety speed control (adjustable 20-100%), factory installed and wired, that operates as follows: If the drive is on (in either normal or override mode) and no signal is detected from the building control system, the drive shall operate at a preset adjustable speed. On resumption of the building control system signal, the drive shall operate as normal. Fail safe speed shall be adjustable through digital keyboard mounted on the outside drive cabinet.
   3. Drives shall be protected with input line reactors factory mounted.

PART 3 – EXECUTION

3.1 INSTALLATION OF MOTORS

A. Examination:
   1. Examine areas to receive motors for compliance with requirements, installation tolerances, and other conditions affecting performance.
   2. Examine roughing-in for conduit systems to verify actual locations of conduit connections before motor installation.
   3. Proceed with installation only after unsatisfactory conditions have been corrected.
B. Install in accordance with manufacturer's instructions.

C. Install securely on firm foundation. Mount ball bearing motors with shaft in any position.

D. Check line voltage and phase and ensure agreement with nameplate.

E. Motors shall be leveled, set in true angular and concentric alignment with driven equipment, and bolted firmly to motor base, if not mounted on equipment. Motors factory-mounted on equipment shall be checked for alignment to driven equipment and mounting bolts shall be checked to ensure bolts are tightly fastened.

3.2 INSTALLATION OF VARIABLE FREQUENCY DRIVES (VFD)

A. General: Install VFD's where shown, in accordance with the manufacturer's written instructions, the applicable requirements of the NEC and the NECA's “Standard of Installation,” and recognized industry practices to ensure that products serve the intended function.

B. Supports: Provide all electronic VFD's with galvanized angle or other suitable supports with neoprene isolators for mounting on wall or floor. Drives shall not be supported by conduit alone. Conduit connections to be not less than 18” length of flexible liquid tight conduit between drive and first conduit anchor to wall or building structure. Where drives are mounted on equipment served, the drive shall not inhibit removal of any service panels or interfere with any required access areas. All drives shall be installed plumb and aligned in the plane of the wall in/on which they are installed.

C. Coordination: The contractor shall coordinate electronic VFD selection and installation including, but not limited to, the following:

1. Coordinate power wiring to VFD's and served motors with the Electrical work
2. Coordinate selection of VFD's and served motors to insure compatibility.
3. Coordinate VFD control interface with controls and sequence of operation.

D. Where not factory installed on equipment, verify that mounting surface for VFD(s) is ready to receive work. Mount the VFD(s) on the wall or at supports in locations identified on the drawings. Provide a layout drawing of VFD locations to electrical installer.

E. Install shaft grounding system on each motor per manufacturer's recommendations.

F. Control Contractor shall install all wiring associated with control signals into the VFD and for interlock control wiring between disconnects and VFDs.

G. Electrical Contractor shall install all line voltage power wiring and conduit from electrical switchgear and from the VFD to the disconnect at the controlled motor.

3.3 MANUFACTURER'S START-UP SERVICES FOR VFDs

A. The manufacturer shall provide start-up service in the form of a factory trained service technician. The service technician shall verify correct installation, verify control wiring, verify power wiring, start-up the drive, and check for proper operation. The service technician shall provide final adjustments to meet the specified performance requirements. Harmonic test with scope shall be also performed at the job site and results submitted. Fully staffed parts and service personnel shall be within four hours travel from the jobsite.
3.4 START-UP TESTING

A. Pre-energization Check: The contractor shall check electronic VFD power wiring for continuity of circuits and for short circuits.

B. Start-up Services: A factory representative of the VFD manufacturer shall provide start-up services for each drive including, but not limited to, the following:
   1. Check out of drive control and power wiring.
   2. Start-up drive and demonstrate proper manual, automatic, and bypass operation.
   3. Adjust VFD overload protection and other adjustable parameters to suit project requirements.

C. Motor/Controller Coordination Documentation: Provide motor/controller coordination documents including, but not limited to, the following information in the operation and maintenance manuals.
   1. Motor size in horsepower.
   5. Size and manufacturer's catalog number of electronic VFD's.
   7. Certification that compatibility of motor/VFD has been ascertained.

D. Motor Rotation: Verify that motor rotation is correct as connected.

3.5 TRAINING

A. General: An authorized representative of the VFD’s manufacturer shall provide for and present to the Owner, at no cost, a training and troubleshooting course at the owner’s location. This course is not to be construed as a sales meeting, but rather as a school to familiarize the owner with the care, troubleshooting, and servicing of the VFD's. The manufacturer's representative shall provide a list of recommended spare parts.

3.6 IDENTIFICATION

A. Refer to Section pertaining to painting for painting and nameplate requirements for all electronic VFD's.

B. Each electronic VFD shall have an internal wiring diagram on the inside of the drive cover and shall be labeled inside the cover to indicate the type, ampacity and horsepower rating of the unit.

END OF SECTION 23 05 13
SECTION 23 05 19 – METERS AND GAUGES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:
   1. Thermometers.
   2. Gages.
   3. Test plugs.

1.3 DEFINITIONS

A. CR: Chlorosulfonated polyethylene synthetic rubber.

B. EPDM: Ethylene-propylene-diene monomer rubber.

1.4 REFERENCES

A. The latest editions of the standards listed, as well as all other applicable codes, standards, and good engineering practices shall be used as “minimum” design standards.

   1. American Society of Mechanical Engineers (ASME)

1.5 SUBMITTALS

A. Product Data: For each type of product indicated; include performance curves.

B. Product Certificates: For each type of thermometer gauge flow meter and thermal-energy meter, signed by product manufacturer.

C. Operation and Maintenance Data: For flow meters and thermal-energy meters to include in emergency, operation, and maintenance manuals.

PART 2 - PRODUCTS

2.1 METAL-CASE, LIQUID-IN-GLASS THERMOMETERS

A. Acceptable Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

   1. Palmer - Wahl Instruments Inc.
   2. Trerice, H. O. Co.
   3. Weiss Instruments, Inc.
   4. Weksler Instruments Operating Unit; Dresser Industries; Instrument Div.
   5. Or approved equal.
B. Case: Die-cast aluminum or brass, 9” long.

C. Tube: Blue reading, organic-liquid filled, with magnifying lens.

D. Tube Background: Satin-faced, non-reflective aluminum with permanently etched scale markings.

E. Window: Glass.

F. Connector: Adjustable type, 180° in vertical plane, 360° in horizontal plane, with locking device.

G. Stem: Copper-plated steel, aluminum, or brass for thermowell installation and of length to suit installation.

H. Accuracy: Plus or minus 1% of range or plus or minus 1 scale division to maximum of 1.5% of range.

2.2 DUCT-TYPE, LIQUID-IN-GLASS THERMOMETERS

A. Acceptable Manufacturers: Subject to compliance with requirements, acceptable manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   1. Miljoco Corp.
   2. Palmer - Wahl Instruments Inc.
   3. Trerice, H. O. Co.
   4. Weiss Instruments, Inc.
   5. Or approved equal.

B. Case: Die-cast aluminum, 7” long.

C. Tube: Red or blue reading, mercury or organic filled, with magnifying lens.

D. Tube Background: Satin-faced, nonreflective aluminum with permanently etched scale markings.

E. Window: Glass or plastic.

F. Connector: Adjustable type, 180° in vertical plane, 360° in horizontal plane, with locking device.

G. Stem: Metal, for installation in mounting bracket and of length to suit installation.

H. Mounting Bracket: Flanged fitting for attachment to duct and made to hold thermometer stem.

I. Accuracy: Plus or minus 1% of range or plus or minus 1 scale division to maximum of 1.5% of range.

2.3 THERMOWELLS

A. Acceptable Manufacturers: Subject to compliance with requirements, acceptable manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   1. AMETEK, Inc.; U.S. Gauge Div.
   3. Ernst Gage Co.
5. Miljoco Corp.
6. NANMAC Corporation.
7. Noshok, Inc.
8. Palmer - Wahl Instruments Inc.
9. REO TEMP Instrument Corporation.
10. Tel-Tru Manufacturing Company.
11. Terglo, H. O. Co.
12. Weiss Instruments, Inc.
13. Weksler Instruments Operating Unit; Dresser Industries; Instrument Div.
15. Winters Instruments.
16. Or approved equal.

B. Manufacturers: Same as manufacturer of thermometer being used.

C. Description: Pressure-tight, socket-type metal fitting made for insertion into piping and of type, diameter, and length required to hold thermometer.

2.4 PRESSURE GAGES

A. Acceptable Manufacturers: Subject to compliance with requirements, acceptable manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. AMETEK, Inc.; U.S. Gauge Div.
3. Ernst Gage Co.
4. Eugene Ernst Products Co.
5. KOBOLD Instruments, Inc.
7. Miljoco Corp.
8. Noshok, Inc.
10. REO TEMP Instrument Corporation.
11. Terglo, H. O. Co.
12. Weiss Instruments, Inc.
13. Weksler Instruments Operating Unit; Dresser Industries; Instrument Div.
15. Winters Instruments.
16. Or approved equal.

B. Direct-Mounting, Dial-Type Pressure Gages: Indicating-dial type complying with ASME B40.100.

1. Case: Dry type, drawn steel or cast aluminum, 4-1/2" diameter.
2. Pressure-Element Assembly: Bourdon tube, unless otherwise indicated.
3. Pressure Connection: Brass, NPS 1/4, bottom-outlet type unless back-outlet type is indicated.
4. Movement: Mechanical, with link to pressure element and connection to pointer.
5. Dial: Satin-faced, non-reflective aluminum with permanently etched scale markings.
7. Window: Glass.
8. Ring: Brass.
9. Accuracy: Grade A, plus or minus 1% of middle half B, plus or minus 2% of middle half scale.
10. Vacuum-Pressure Range: 30-in. Hg of vacuum to 15 psig of pressure.
11. Range for Fluids under Pressure: Two times operating pressure.

C. Remote-Mounting, Dial-Type Pressure Gages: ASME B40.100, indicating-dial type.
   1. Case: Dry type, drawn steel or cast aluminum, 4.5” diameter with holes for panel mounting.
   2. Pressure-Element Assembly: Bourdon tube, unless otherwise indicated.
   3. Pressure Connection: Brass, NPS 1/4, bottom-outlet type unless back-outlet type is indicated.
   4. Movement: Mechanical, with link to pressure element and connection to pointer.
   5. Dial: Satin-faced, non-reflective aluminum with permanently etched scale markings.
   7. Window: Glass.
   8. Ring: Brass.
   9. Accuracy: Grade A, plus or minus 1% of middle half scale.
   10. Vacuum-Pressure Range: 30-in. Hg of vacuum to 15 psig of pressure.
   11. Range for Fluids under Pressure: Two times operating pressure.

D. Pressure-Gage Fittings:
   1. Valves: NPS 1/4 brass or stainless-steel needle type.
   2. Syphons: NPS 1/4 coil of brass tubing with threaded ends.
   3. Snubbers: ASME B40.5, NPS 1/4 brass bushing with corrosion-resistant, porous-metal disc of material suitable for system fluid and working pressure.

2.5 TEST PLUGS

A. Acceptable Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   1. Flow Design, Inc.
   2. MG Piping Products Co.
   4. Peterson Equipment Co., Inc.
   5. Sisco Manufacturing Co.
   6. Trerice, H. O. Co.

B. Description: Corrosion-resistant brass or stainless-steel body with core inserts and gasketed and threaded cap, with extended stem for units to be installed in insulated piping.

C. Minimum Pressure and Temperature Rating: 500 psig at 200 °F.

D. Core Inserts: One or two self-sealing rubber valves.
   1. Insert material for air, water, oil, or gas service at 20 to 200 °F shall be CR.
   2. Insert material for air or water service at minus 30 to plus 275 °F shall be EPDM.

E. Test Kit: Furnish one test kit containing one pressure gauge and adaptor, one two thermometer(s), and carrying case. Pressure gauge, adapter probes, and thermometer sensing elements shall be of diameter to fit test plugs and of length to project into piping.
   1. Pressure Gage: Small bourdon-tube insertion type with 2- to 3”-diameter dial and probe. Dial range shall be 0 to 200 psig.
   2. Low-Range Thermometer: Small bimetallic insertion type with 1- to 2”-diameter dial and tapered-end sensing element. Dial ranges shall be 25 to 125 °F.
3. Carrying case shall have formed instrument padding.

PART 3 – EXECUTION

3.1 THERMOMETER APPLICATIONS

A. Install liquid-in-glass thermometers in the following locations:
   1. Inlet and outlet of each hydronic zone excluding reheat coil at VAV boxes.
   2. Inlet and outlet of each hydronic boiler and chiller.
   3. Inlet and outlet of each hydronic coil in air-handling units, water-cooled units and built-up central systems.

B. Provide the following temperature ranges for thermometers:
   1. Heating Hot Water: 30 to 240 °F, with 2-degree scale divisions.
   2. Condenser Water: 0 to 160 °F, with 2-degree scale divisions.
   3. Chilled Water: 0 to 100 °F, with 2-degree scale divisions.
   4. Air Ducts: Minus 40 to plus 110 °F, with 2-degree scale divisions.

3.2 GAGE APPLICATIONS

A. Install dry-case-type pressure gauges for discharge of each pressure-reducing valve.

B. Install dry-case-type pressure gauges at chilled- and condenser-water inlets and outlets of chillers.

C. Install dry-case-type pressure gauges at suction and discharge of each pump.

3.3 INSTALLATIONS

A. Install direct-mounting thermometers and adjust vertical and tilted positions.

B. Install remote-mounting dial thermometers on panel, with tubing connecting panel and thermometer bulb supported to prevent kinks. Use minimum tubing length.

C. Install thermowells with socket extending to center of pipe and in vertical position in piping tees where thermometers are indicated.

D. Duct Thermometer Support Flanges: Install in wall of duct where duct thermometers are indicated. Attach to duct with screws.

E. Install direct-mounting pressure gauges in piping tees with pressure gauge located on pipe at most readable position.

F. Install remote-mounting pressure gauges on panel.

G. Install needle-valve and snubber fitting in piping for each pressure gauge for fluids (except steam).

H. Install needle-valve and syphon fitting in piping for each pressure gauge for steam.

I. Install test plugs in tees in piping.

J. Install flow indicators, in accessible positions for easy viewing, in piping systems.
K. Assemble and install connections, tubing, and accessories between flow-measuring elements and flow meters as prescribed by manufacturer’s written instructions.

L. Install flow meter elements in accessible positions in piping systems.

M. Install differential-pressure-type flow meter elements with at least minimum straight lengths of pipe upstream and downstream from element as prescribed by manufacturer’s written instructions.

N. Install wafer-orifice flow meter elements between pipe flanges.

O. Install permanent indicators on walls or brackets in accessible and readable positions.

P. Install connection fittings for attachment to portable indicators in accessible locations.

Q. Install flow meters at discharge of hydronic system pumps and at inlet of hydronic air coils.

R. Assemble components and install thermal-energy meters.

S. Mount meters on wall if accessible; if not, provide brackets to support meters.

3.4 CONNECTIONS

A. Install meters and gauges adjacent to machines and equipment to allow service and maintenance for meters, gauges, machines, and equipment.

B. Connect flow meter-system elements to meters.

C. Connect flow meter transmitters to meters.

D. Connect thermal-energy-meter transmitters to meters.

3.5 ADJUSTING

A. Calibrate meters according to manufacturer’s written instructions, after installation.

B. Adjust faces of meters and gauges to proper angle for best visibility.

END OF SECTION 23 05 19
SECTION 23 05 48 – VIBRATION AND SEISMIC CONTROLS FOR HVAC

PART 1 – GENERAL

1.1 DESCRIPTION

A. General: Provide Vibration Isolators and Seismic Restraints in accordance with the contract documents.

B. The requirements of this Section are governing.

1.2 SUMMARY

A. This section includes the following:
   1. Elastomeric isolation pads and mounts.
   2. Restrained elastomeric isolation mounts.
   3. Freestanding and restrained spring isolators.
   4. Housed spring mounts.
   5. Elastomeric hangers.
   7. Spring hangers with vertical-limit stops.
   8. Thrust limits.
   9. Pipe riser resilient supports.
  10. Resilient pipe guides.
  11. Seismic snubbers.
  12. Restraining cables.

1.3 REFERENCES

A. The latest editions of the standards listed, as well as all other applicable codes, standards, and good engineering practices shall be used as “minimum” design standards.
   1. California Building Code (CBC)
   2. American Welding Society (AWS)
   3. Sheet Metal and Air Conditioning Contractors’ National Association (SMACNA)
   4. California Code of Regulations (CCR)

1.4 DEFINITIONS

A. Av: Effective peak velocity related acceleration coefficient.

B. OSHPD: Office of Statewide Health Planning & Development for the State of California. OSHPD assigns a unique anchorage preapproval “R” number to each seismic restraint it tests. The number describes a specific device applied as test.

1.5 QUALITY ASSURANCE

A. General: Obtain all vibration isolation materials from a single manufacturer, as much as possible.
B. Supervision: Vibration Isolation and Seismic Restraint manufacturer and the engineer certifying the calculations shall provide technical supervision of the installation, and provide a written certificate to verify compliance of the field installation.

C. Seismic-Restraint Devices shall have horizontal and vertical load testing and analysis and shall bear anchorage preapproval "R" number, from an agency acceptable to authorities having jurisdiction, showing maximum seismic-restraint ratings. If preapproved ratings are not available, submittals based on calculations (including combining shear and tensile loads) to support seismic-restraint designs must be prepared and signed and sealed by a qualified professional engineer. Testing and calculations must include both shear and tensile loads and 1 test or analysis at 45° to the weakest mode.

D. Welding: Qualify procedures and personnel according to AWS D1.1, “Structural Welding Code – Steel.”

E. Acceptable Manufacturers:
   1. Mason.
   2. Amber/Booth.
   4. Or approved equal.

1.6 SUBMITTALS

A. Product Data: Include load deflection curves for each vibration isolation device.

B. Shop drawing shall be signed and sealed by a qualified professional engineer. Submittals shall include, but not be limited to, the following:
   1. A complete listing of the proposed type of isolators and seismic restraints for each specified application, including size and deflection information.
   2. Design Calculations: Selection calculations for all isolators, restraints, and vibration isolation bases with weight, size and deflection noted at each support point. Seismic loads shall be determined in accordance with the California Building Code.
   3. Riser Supports: Include riser diagrams and calculations showing anticipated expansion and contraction at each support point, initial and final loads on building structure, spring deflection changes, and seismic loads. Include certification that riser system has been examined for excessive stress and that none will exist.
   4. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, base weights, equipment static loads, power transmission, component misalignment, and cantilever loads.
   5. Seismic-Restraint Details: Detail fabrication and attachment of seismic restraints and snubbers. Show anchorage details and indicate quantity, diameter, and depth of penetration of anchors.
   6. Submittals for Interlocking Snubbers: Include load deflection curves up to ½” deflection in x, y, and z planes.
   7. Cut sheets for all bases, isolators and seismic restraints.
   8. A clearly outlined procedure for installing and adjusting vibration isolators and seismic restraints.

C. Welding Certificates
D. Air-Mounting System Performance Certification: Include natural frequency, load, and damping tests performed by an independent laboratory or acoustician.

E. Manufacturer Seismic Qualification Certification: Submit certification that all specified equipment will withstand seismic forces identified in “Performance Requirements” Article above. Include the following:

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculations.
   a. The term “withstand” means “the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified.”
   b. The term “withstand” means “the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event.”

2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

1.7 COORDINATION

A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into base. Concrete, reinforcement, and formwork requirements are specified in Division 3.

B. Coordinate installation of roof curbs, equipment supports, and roof penetrations.

1.8 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver vibration isolators and seismic restraints in factory-fabricated water-resistant wrapping.

B. Handle all material carefully to avoid damage to components, enclosures and finishes.

C. Store all material in clean, dry space and protect from the weather.

PART 2 – PRODUCTS

2.1 MANUFACTURERS

A. In other Part 2 articles where subparagraph titles below introduce lists, the following requirements apply for product selection:

1. Basis of Design Product: The design for each product is based on manufacturer named on the drawings Subject to compliance with requirements, provide either named product or a comparable equivalent product by one of the other manufacturers specified.

2. Manufacturers: Subject to compliance with requirements, provide products by the manufacturers specified.

2.2 VIBRATION ISOLATORS
A. Acceptable Manufacturers:
   2. Mason Industries, Inc.
   3. Amber/Booth Company, Inc.
   4. Ace Mounting Co., Inc.
   5. Or approved equal.

B. Spring type vibration isolators shall be used for all equipment driven by motors of 3 hp and larger, unless otherwise noted. Equipment driven by motors 2 hp and smaller shall be isolated by means of elastomeric mounts or hangers properly sized for 0.30” minimum deflection, unless noted otherwise.

C. All spring isolators shall be completely stable in operation and shall be designed for not less than 50% reserve deflection beyond actual operating conditions. Spring isolators shall be horizontally stable with spring diameter not less than 0.8 times the operating height and horizontal to vertical spring constant ratio between 0.90 and 1.10. Dual spring models with inner and outer springs and multiple spring models shall not be acceptable.

D. All elastomeric isolators and isolator components shall be of neoprene or high quality synthetic rubber with antioxidant additives and shall be sized for a maximum load of 60 psi and a rating of 40 durometer.

E. All vibration isolators and bases furnished by the Contractor shall be designed for and treated for resistance to corrosion. Steel components shall be cleaned and painted with industrial grade enamel. All nuts, bolts, and washers shall be zinc-electroplated. Structural steel bases shall be thoroughly cleaned of welding slag and primed with zinc-chromate or metal etching primer. A finish coat of industrial grade enamel shall be applied over the primer.

F. All isolators exposed to the weather shall have cadmium coated springs dipped in neoprene, cadmium plated hardware and hot-dipped galvanized holders.

G. Isolators for equipment installed outdoors shall be designed to provide adequate restraint due to normal wind conditions and to withstand wind loads of 50 pounds/square foot applied to any exposed surface of the isolated equipment. Where isolators do not meet this requirement, stainless steel tie down cables with 0.25” slack shall be provided.

H. Fans and equipment subjected to excessive horizontal air thrust shall be furnished with isolated thrust resisters to limit displacement to 0.25”.

I. Where height-saving brackets for side mounting of isolators are required, the height-saving brackets shall be designed to provide for an operating clearance of 2” under the isolated structure, and designed so that the isolators can be installed and removed when the operating clearance is 2” or less. When used with spring isolators having a deflection of 2.5” or more, the height-saving brackets shall be of the pre-compression type to limit exposed bolt length between the top of the isolator and the underneath side of the bracket.

J. All isolators supporting a given piece of equipment shall be selected for approximately equal spring deflection, ±10%.

K. Provide levelling devices and install springs such that ends of springs remain parallel.

L. For Seismic Restraint criteria of the vibration isolators, see Paragraph “SEISMIC RESTRAINTS.”
2.3 VIBRATION ISOLATION EQUIPMENT

A. Provide vibration isolation equipment for all mechanical equipment and piping as specified herein and indicated on the drawings. The vibration isolation system shall be installed in a manner to prevent the transmission of vibration to the structure. No rigid connections between rotating or oscillating equipment or piping and the building will be permitted.

B. Acceptable Manufacturers:
   2. Mason Industries.
   3. Amber Booth.
   4. Or approved equal.

C. General Requirements:
   1. Vibration isolation manufacturer shall furnish written instructions covering the installation and adjustment of all isolators. The manufacturer shall replace any isolation that has been improperly sized. Piping supports in the penthouse equipment areas shall be designed by the vibration isolation manufacturer.
   
   2. Contractor shall coordinate his work with the other trades. Contractor following him, such as plastering or electrical, shall be notified and instructed to avoid any contact with his installation that would reduce the effectiveness of the system.
   
   3. Inspections: Vibration isolation manufacturer shall make an inspection of the vibration installation, and inform the Contracting Officer in writing of any necessary corrections and/or adjustments.
   
   4. All isolators shall be selected to perform their function without undue stress or overloading. All isolators shall have a method for leveling and have a 0.25” thick ribbed neoprene acoustical pad under the spring baseplate.
   
   5. All isolators shall be designed to operate in the linear portion of their load versus deflection curve. Load versus deflection curves shall be furnished by the manufacturer, and must be linear over a deflection range of not less than 50% above the design deflection. The ratio of lateral to vertical stiffness shall be not less than 0.8 nor greater than 1.5. Isolators shall be designed to be non-resonant with equipment forcing frequencies or support structure natural frequencies. Design isolators for positive anchorage against uplift and overturning.
   
   6. Unless otherwise indicated, all equipment on vibration bases shall have a minimum operating clearance of 1” between structural steel base and floor or support base beneath. The minimum operating clearance between concrete inertia bases and housekeeping pads shall be 2”. Check clearance space after installation to ensure that no debris has been left to possibly short circuit isolation bases.
   
   7. Vibration isolation shall be manufactured by a single manufacturer. All isolation shall be in strict accordance with the following specifications. The isolation manufacturer shall include in the submittal the following information:
      a. Specific vibrator isolators and seismic restraints to be utilized showing compliance with the specifications, including deflection, free height, and physical characteristics.
      b. Isolation frame construction for each machine including dimensions, structural member sizes, support points and restraint locations and details.
      c. Methods for isolation and restraint of suspended piping, ductwork, and equipment.
d. Methods for guides and isolation of piping risers.

D. Technical Requirements:

1. Isolators shall be designed or treated for resistance to corrosion. Structural steel bases shall be cleaned of welding slag and painted with a coat of red lead primer-finish composed of basic lead silicon chromate. All nuts, bolts and washers shall be zinc-electroplated.

2. All equipment shall be equipped with seismic restraints in accordance with the requirements of all governing agencies. These restraints shall be designed and supplied by the vibration isolation manufacturer. Suspended equipment and piping shall be restrained by steel cable. This cable and the method of installation shall be the responsibility of the contractor. The cable restraints shall be installed in such a manner as to not short circuit the vibration isolation. The contractor shall submit details for approval:
   a. Seismic restraints for pipes and ducts shall be as per the 4 SMACNA GUIDELINES FOR SEISMIC Restraints of Mechanical Systems.
   b. Seismic restraints for equipment shall be designed to meet the criteria established in the California Code of Regulations latest edition.
   c. The manufacturer of Vibration isolation and Seismic Control Equipment shall have the following responsibilities:
      1) Determine adequate vibration isolation and seismic restraint sizes and locations.
      2) Provide piping and equipment isolation systems and seismic restraints as scheduled and/or specified.
      3) Provide installation instructions and drawings to assure proper installation and performance.
   d. Seismic restraint calculations signed and stamped by an engineer licensed in the State of California and experienced in the design of isolation and seismic restraint for flexibly mounted equipment.

2.4 ISOLATOR TYPES

A. General: Isolator types shall be one or more of the following types as listed below and as scheduled on the drawings. Model numbers of Mason products are included for identification. Products of other specified manufacturers are acceptable provided they comply with all of the requirements of the specifications.

B. Type A: Air Spring: A complete vibration isolation system consisting of a minimum of three air springs, a total of three height-sensing valves and associated interconnecting air tubing. Air tubing and connection shall also be provided to a source of compressed air providing a minimum 100 psi. If the building uses a pneumatic control system, the air compressor for that system may be used for this system if it is sized properly. Otherwise, an adequately-sized air compressor is a part of this work. One height control valve shall be provided at each isolator mounting location. If there are two or more air springs per location, they shall be connected to the outlet of the height control valve in parallel. The air spring shall operate at its normal operating height and the maximum pressure shall not exceed the manufacturer’s recommendations. The air system shall maintain an elevation of + 1/8”, once adjusted. Height limit stops shall be provided to preclude more than ¼” rise in the event of failure. The vertical natural frequency of the air spring system shall not exceed 1.5 Hertz. The ratio of lateral to vertical stiffness shall meet the general types.

C. Type B: Unhoused Spring: Springs shall be designed and installed so their ends are parallel before
and after installation and during equipment operation. All mounts shall have equipment leveling bolts. Each isolator shall have a steel base plate with mounting bolt holes and a ribbed or waffled neoprene friction pad permanently adhered to the bottom. The pad shall be 5/16 to 1/2” thick, 40 durometer hardness, and sized for a load of 60 psi.

D. Type C: Spring with Seismic Restraint and Vertical Travel Limit: Same as Mount B with the addition of steel columns on either side of the spring to provide seismic restraint and accommodate vertical travel limit stops. Mount shall resist a seismic acceleration in any direction of at least 0.5 G or as required by the relevant codes. Travel limit stops shall be capable of serving as blocking during erection of the equipment. A minimum clearance of 0.25” shall be maintained around restraining bolts and between the limit stops and the spring so as not to interfere with the spring action. Each isolator assembly shall have a friction pad of ribbed or waffled neoprene permanently adhered to the bottom. The pad shall be 5/16 to 1/2” thick, 40 durometer hardness, and sized for a load of 60 psi.

E. Type D: Isolator shall be an individual semi-housed steel spring isolator complete with vertical motion limit stops incorporating seismic restraints, leveling, and ribbed neoprene pad bonded to the baseplate.

F. Type E: Neoprene Pad(s) and Bearing Plate(s): Neoprene pad shall be ribbed or waffled, 5/16 to 1/2” thick, 40 durometers, with a minimum 1/16”-thick steel bearing plate on top. Size pad and bearing plate to receive 60 psi load. Provide single or multiple pads and plates in series as specified, with 1/16”-thick steel shim between layers.

G. Type F: Spring Hanger: Vibration isolation hangers shall contain a laterally-stable steel spring set in a neoprene cup manufactured with a bushing to prevent short circuiting of the hanger rod as it passes through the hanger housing. The cup shall contain a steel washer designed to properly distribute the spring load on the neoprene and prevent its crushing. Spring diameters and hanger housing lower hole sizes shall be large enough to permit the hanger rod to swing through a 30° arc before contacting the housing. Neoprene cup shall be minimum 0.25” thick and maximum 50 durometer.

H. Type G: Same as “Type F” with the addition of a neoprene element in series to isolate the upper connection.

I. Type P3: Neoprene Bushing for Bolt Holes in Pads: Bushings shall be minimum 3/16” thick in all places and maximum 40 durometer. Provide steel washer to distribute bolt head loads to bushing.

J. Mount BEQ: Neoprene Mount with Integral Seismic Restraint: A neoprene isolator with concentric steel elements separated by neoprene no harder than 50 durometers. Mount capable of acting in tension, compression or shear.

K. Type C2: Vibration Isolation Curb: Vibration isolation curbs shall be a prefabricated assembly consisting of a lower frame of steel tubes topped by steel springs resting on neoprene pads in turn topped with an upper frame which provides continuous equipment support. Upper frame and spring connections to be adjustable and to include resilient snubbing to resist wind and seismic forces. Springs to be galvanized, accessible and stable. Springs shall be placed no less than 7’ apart along the 2 long sides of the curb. The static deflection of any individual spring shall differ from the others by no more than 10%. It shall be possible to replace individual springs while the isolated equipment is operating normally, without affecting its performance. Provide “RSC” by Mason or approved equal.

L. Type H3: Felt-lined Clevis Hanger: Clevis hanger to be lined with minimum 0.25” thick felt to prevent the contact between piping and metal parts of hanger. Hangers to be spaced to prevent crushing of
the felt liner by more than 1/8”.

M. Floor Mounts:

1. Code “S-1”: Single, freestanding, unhoused spring Model SLF, Series 100 with upper and lower ferrous cup, non-skid neoprene acoustical pad, 1/2” thick, adjustment bolt and locking cap screw. Provide with height-saving brackets unless otherwise indicated.

2. Code “S-2”: Housed spring Model SLR with built-in resilient limit stops, tapped holes in top plate for bolting to equipment, adjustment bolt, inner and outer neoprene acoustical pad, outer pad 1/2” minimum thickness, neoprene grommets at anchor bolts. Integral seismic restraints with OSHPD pre-approval.

3. Code “S-3”: Housed spring Model SSLFH with ductile iron housing, spring inspection ports, upward rebound plate with adjustment ports, neoprene acoustical cup for spring, all directional neoprene cushion, down stop and adjusting bolt. Integral seismic restraints with OSHPD pre-approval.

4. Code “N-1”: Elastomer in-shear mount Model BR with bolt holes for bolting to equipment base, bottom steel plate, ductile iron housing a bridge bearing quality neoprene. OSHPD pre-approval for seismic restraints.

5. Code “N-2”: Elastomer pad mountings, Model W. Waffled design, 5/16” minimum thickness, 1/16” deflection per pad. Provide 1/16” galvanized steel plate between multiple pads, suitable top bearing plate to distribute load, and neoprene grommets at bolts.

N. Hangers:

1. Code “H-1”: Spring hanger rod isolators, Model 30N with double deflection neoprene or EPDM element, neoprene cup, 30° swing capability, and projecting bushing to prevent steel to steel contacts, and reinforced housing. Provide with pre-compression washer or wire attachment eye bolt, as scheduled.

2. Code “H-2”: Elastomer hanger rod isolators Model HD with double deflection neoprene or EPDM element with projecting bushing to prevent steel to steel contact.

O. Equipment Rails and Bases:

1. Where called for in the specifications and on the drawings, all structural steel bases, including concrete pouring form bases, shall be designed and fabricated by the vibration isolation manufacturer. The concrete for the pouring form bases shall be by others.

2. Type 1: Steel Frame for Floor Mounting: Steel frames for floor-mounted equipment shall consist of structural steel sections sized, spaced, and connected to form a rigid base that will not twist, rack, deform, or deflect in any manner that will negatively affect the equipment or isolation mounts. Frames shall be adequately sized to support basic equipment units and motors plus any associated pipe elbow supports, duct elbow supports, electrical control elements, or other components closely related and requiring resilient support in order to prevent vibration transfer to the building structure. Frames may be rectangular or tee-shaped in plan. The depth of steel frame base members shall be minimum one-tenth he isolator spacing. Frame bases shall include side-mounting height-saving brackets for attachment to vibration isolators. A four” layer of 1.5 density fiberglass shall cover the entire solid roof surface under the unit. Ductwork shall be lined with sound absorbent material.

3. Type 2: Steel Frame for Suspended Equipment: Steel base frames for ceiling-suspended equipment shall consist of structural steel sections sized, spaced, and connected to form a rigid
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base that will not twist, rack, deform, or deflect in any manner that will negatively affect the operation of the supported equipment or vibration isolators. Frames shall be adequately sized to support basic equipment units and motors plus any associated ducts or pipes or electrical elements closely related and requiring resilient support in order to prevent vibration transfer to the building. The depth of the steel frame base members shall be no less than one-twentieth the longest dimension of the base. Equipment shall be rigidly attached to top of frames.

4. Code “B-1”: Integral structural steel base, Model WF, or WF vent set bases, as required.
   a. Reinforced as required to prevent base flexure at startup and misalignment of drive and driven units.
   b. Fan bases with motor slide rails.
   c. Perimeter member minimum depth 1/10 of longest base dimension.
   d. Height saving brackets.

5. Code “B-2”: Concrete inertia base, Model K.
   a. Concrete formed in structural perimeter base.
   b. Welded channel frame and prelocated equipment anchor bolts; welded-in 1/2” reinforcing bars on minimum of 6” centers each way; and isolator brackets to reduce mounting height of equipment.
   c. Minimum thickness per following schedule:

<table>
<thead>
<tr>
<th>Motor Sizes (HP)</th>
<th>Thickness, Inches</th>
</tr>
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<tbody>
<tr>
<td>5 - 15</td>
<td>6</td>
</tr>
<tr>
<td>25 - 50</td>
<td>8</td>
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<tr>
<td>60 - 100</td>
<td>10</td>
</tr>
<tr>
<td>greater than 100</td>
<td>12</td>
</tr>
</tbody>
</table>

   d. Fan bases with motor slide rails.
   e. Pump bases with base elbow supports.
   f. Height saving brackets.

P. Thrust Restraints: Model WBI or WBD. Single spring with steel and neoprene cup with adjustment and retainer bolts to limit movement to 0.25”.

Q. Risers and Anchors:
   1. Acoustical Anchors and Vertical Slide Guide: Model ADA all directional anchor and VSG vertical sliding guides. Install where shown, in accordance with manufacturer’s recommendations.
   2. Vertical riser piping support/suspension. Pipe clamps supported on each side from structure through appropriate isolator and static deflection. Single point of support desired. Multiple points of support acceptable, but must be engineered, complete with detailed installation and adjustment instruction by supplier.
   3. Vertical riser guides. Double deflection neoprene guides at mid or multiple locations along riser to preclude swing motion. Points to comply with local codes regarding normal attachment points.
   4. Pipe anchors, vertical, or horizontal. Resilient anchor points in piping to preclude direct contact of piping with structure, yet provide a neutral point for expansion/contraction of piping.
5. Trisolators. Sheet metal sleeve with felt insert to be installed at attachment points of hangers or piping. Semco, Elcen, or equal shop fabricated device.

6. Type RPAG: Resilient Pipe Anchor or Guide: These units shall be the standard product of the vibration isolation mounting manufacturer, incorporating neoprene isolation elements that are specifically designed for providing resilient vertical and/or horizontal support when serving as a pipe anchor or guide. Minimum neoprene thickness ¼”. Maximum neoprene durometer 50.

7. Type RPS1: Resilient Pipe Sleeve at Support or Construction Penetration: Sleeve shall consist of a formed and stiffened galvanized steel sleeve lined on the inside with moisture and vermin resistant felt bonded to the metal sleeve and ¼” thick for pipe diameters up to 2” and ½” for larger pipe diameters. Sleeve inside diameter shall equal pipe outside diameter in each application. Sleeve shall be split longitudinally so it can be snapped over pipes and re-closed without damage. Sleeve lengths shall be as recommended by the manufacturer for the given diameters, but shall not be less than 3”.

8. Type RPS 2: Resilient Pipe Sleeve at Construction Penetration: This unit shall consist of two bolted pipe halves with 0.75” or thicker neoprene sponge bonded to the inner faces. The seal shall be tightenable around the pipe to eliminate clearance between the inner sponge face and the piping. Sleeve shall be 2” longer than the thickness of the construction it penetrates. Where pipe temperatures exceed 240 °F, use 10-pcf-density glass fiber glass insulation in lieu of sponge neoprene.

R. Snubbers: All directional seismic snubber Model Z-1225 with steel and all directional neoprene bushing, snubber bolt and washer. OSHPD approved. Provide restraining angle after equipment installation to assure design clearances.

S. Slack Cable: Seismic cable and brace anchor assembly Model SCB. OSHPD approved. Galvanized aircraft cable 7 x 19 strand core, formed steel cable base anchors. Select as required for loads and install per manufacturer’s recommendations.

2.5 SEISMIC RESTRAINTS

A. Provide seismic restraints, supports and anchorage for all piping, ductwork and equipment either hung or mounted otherwise, per the requirements of CBC Title-24, using the Hospital and Essential Buildings Seismic Design Criteria with an importance factor of 1.5. The criteria shall be applied appropriately to both rigidly and flexibly supported equipment, ducts and piping. OSHPD seismic restraints or qualified to be approved by OSHPD shall be acceptable.

B. Restraints shall be capable of safely accepting external forces as specified in the applicable codes without failure. Restraints shall maintain equipment, duct, and piping in a captive position during an earthquake. Restraints shall not short circuit vibration isolation systems or transmit objectionable vibration or noise under normal operating conditions. Seismic restraints shall be provided on all equipment as scheduled on the drawings. Submit calculations by a California registered structural engineer to verify.

C. Provide calculations and details by a California registered structural engineering to verify the support and bracing of capacities of equipment, pipes, ducts, and conduits per CBC minimum requirements and the latest SMACNA “Guidelines for Seismic Restraints of Mechanical Systems and Plumbing Piping Systems” or per the latest NUSIG “National Uniform Seismic Installation Guidelines” which are OSHPD pre-approved systems. The following types of calculations and drawings shall be prepared and submitted to the architect of record for review. Both drawings and calculations shall be prepared, stamped and signed by a structural engineer registered in the State of California.
1. Provide details on the plans substantiating calculations for the support and anchorage of all piping, ductwork and equipment.
   a. General Contractor shall coordinate installation and location of seismic restraints for anchorage of all piping, ductwork and equipment including related contract work, such as baggage handling system supports.
   b. Where coordination conflicts do not allow the use of pre-approved seismic restraint details, provide additional details and calculations as necessary to meet CBC design criteria.
   c. Modifications to pre-approved details are not acceptable. Contractor shall be responsible for any additional costs for the review of all detail substitutions.

2. Provide calculations, details, and/or test data for all vibration isolators, restraints and their anchorages, to substantiate their capacity for vertical and lateral loads or use OSHPD pre-approved isolators and restraints. Submit calculations (whether preapproved or not) to substantiate the size, quantity, location and connection of isolator to structure. The submitted drawings and calculations shall be closely coordinated and clearly specify the manufacturer, model type, model number, base plate size, quantity used and location of each piece of equipment, and how it is attached to the structure. Submit calculations for isolators which support equipment (such as fans inside air handling units) along with the calculations for anchoring of the parent equipment (such as air handling unit).

3. In no case shall the forces transmitted to the building structure exceed the allowable capacities of the building structure. Contractor shall provide slab inserts, deck inserts and supplementary steel members to distribute the loads safely to the structure. Supplementary steel shall be provided where required, whether shown on drawings or not, to support equipment, pipes and ducts. Supplementary steel where required shall be detailed with sizes, locations and methods of attachments shown.

D. Contractor shall provide flexible devices for all pipes, ducts, and conduits which cross building separation spaces (building seismic joints) whether shown on plan or not. Such devices shall be designed and detailed to accommodate displacements calculated on the basis noted in Title 24, CBC Section 2336 or as indicated on the structural drawings and calculations. The flexible devices shall be designed for the temperature and pressure of the media transported. Contractor shall submit the required details on the plans along with the substantiating calculations.

E. For heating, high temperature heating and chilled water insulated piping system, provide pre-engineered and pre-insulated pipe supports, guides and anchors to prevent heat transmission between the pipe and support steel and maintain continuous vapor barrier throughout the entire pipe run.

F. Building structural steel shall not be cut or modified without the written approval of the structural engineer of record. Patch and repair fireproofing at the point of connection to the structure.

G. Type S1: Seismic restraint shall be constructed of steel plate, concentric steel pipes, and structural members in an all welded assembly. All contact points shall be cushioned with minimum ¼" thick resilient pad. Restraints shall be O.S.H.P.D. pre-approved type R-0029.

H. Type S2: Seismic restraints shall be constructed of 7x19 strand galvanized aircraft cable. Cable assembly shall come complete with minimum (2) “U” bolt clamps per end and thimbles to protect cable from chafing. Allowed loads shall be the cable breaking strength with a safety factory of three. Actual loads shall be calculated with the worst case of all load applied to one cable and anchor pattern. Cable shall be installed with ¼” slack to prevent the transmission of vibration to the structure.
PART 3 – EXECUTION

3.1 VIBRATION ISOLATOR INSTALLATION

A. General: Except as otherwise indicated, comply with manufacturer’s instructions for the installation and load application of vibration isolation materials and units. Adjust to ensure that units do not exceed rated operating deflections, do not bottom out under loading, and are not short circuited by seismic restraints, other contacts or bearing points. Remove space blocks and similar devices (if any) intended for temporary protection against overloading during installation.

B. Secure Attachment: Anchor and attach units to substrate and equipment for secure operation, to prevent displacement by normal forces. Submit calculations for anchor and attachments for approval.

C. Adjustment: Adjust leveling devices to distribute loading uniformly onto isolators. Shim units where leveling devices cannot be used to distribute loading properly.

D. Base Frames: Install inertia base frames on isolator units so a 2” (minimum) clearance below base will result when frame is filled with concrete and supported equipment has been installed and loaded for operation.

E. Isolation Hangers: Locate isolation hangers as near the overhead support structure as possible.

F. Welding: Weld riser isolator units in place to prevent displacement from loading and operations.

3.2 EXAMINATION

A. Examine areas and equipment to receive vibration isolation and seismic-control devices for compliant with requirements, installation tolerance, and other conditions affecting performance.

B. Examine roughing-in of reinforcement and cast-in-place anchors to verify actual locations before installation.

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

3.3 EXAMINATION OF RELATED WORK

A. Examination and Reporting: The Contractor shall observe the installation of other work related to and connected to vibration isolation work. After completion of other related work (but before equipment start up), he shall furnish a written report to the Architect, listing observed inadequacies, if any, for proper operation and performance of vibration isolation work, caused by other trades.

B. Correction and Start-up: Do not start up equipment until inadequacies have been corrected in a manner acceptable to the vibration isolation manufacturer’s representatives.

3.4 FIELD SERVICES

A. Representative: The isolation materials manufacturer shall provide the services of an authorized representative to supervise and ensure correct installation of isolators and sound attenuation materials, and proper adjustment of the isolators after installation. Upon completion of the installation and after the system is put into operation and before acceptance by the Owner, the
authorized manufacturer's representative shall make a final inspection and submit his report to the Architect in writing, certifying the correctness of the vibration isolation installation and compliance with approved submittal data. Any discrepancies or maladjustments found shall be so noted in the report and shall be corrected by the Contractor and accepted in writing by the authorized manufacturer's representative. Should any noise or vibration be objectionable to the Owner or Architect, the Contractor shall provide the services of a qualified Vibration/Noise Consultant who shall provide a field instrumentation test at no cost to the Owner or Architect. Any variation or noncompliance with these specification requirements is to be corrected by the installing contractor in an approved manner.

3.5 EQUAL LOADING

A. General: All equipment installed on vibration isolation mountings shall be level after load is applied. Further, vibration isolation mountings shall be selected and installed to compensate for unequal loading. Spring isolators with coils touching during equipment start up or operation will not be acceptable.

3.6 INSTALLATION – GENERAL

A. Install roof curbs, equipment supports, and roof penetrations as specified.

B. Install thrust limits at centerline of thrust, symmetrical on either side of equipment.

C. Install seismic snubbers on isolated equipment. Locate snubbers as close as possible to vibration isolators and bolt to equipment base and supporting structure.

D. Install restraining cables at each trapeze and individual pipe hanger. At trapeze anchor locations, shackle piping to trapeze. Install cables so they do not bend across sharp edges of adjacent equipment or building structure.

E. Install steel angles or channel, sized to prevent buckling, clamped with ductile-iron clamps to hanger rods for trapeze and individual pipe hangers. At trapeze anchor locations, shackle piping to trapeze. Requirements apply equally to hanging equipment. Do not weld angles to rods.

F. Install resilient bolt isolation washers on equipment anchor bolts.

3.7 SEISMIC RESTRAINTS INSTALLATION

A. General: Seismic Restraints shall be installed in accordance with the manufacturer's instructions and Title 24, CBC criteria. (See Seismic Restraint Criteria.)

B. Design and provide restraints to prevent permanent displacement in any direction caused by lateral motion, overturning or uplift.

C. Provide calculations, details and drawings for all piping equipment and ductwork showing location of supports, anchorage, guides, expansion joints/loops, flexible connections at seismic joints. The calculations shall clearly indicate the location, direction and load forces transferred to the structure. The calculations shall take into account the operating weight, thermal expansion/contraction forces and seismic forces. The calculations shall indicate method of attachment to the structure, size of anchor bolts, depth of embedment, welding size, etc.

D. The anchorage details and calculations must be submitted sufficiently in advance of the desired date.
of approval to provide time for the initial review by the architects, structural engineer of record and mechanical engineer of record, and at least one cycle of response and back check.

E. Seismic restraints must be installed and adjusted so that equipment, piping and ductwork vibration isolation is not degraded by utilization of restraints.

F. Contractor shall install supports, bracing and anchoring per the approved shop drawings. After the completion of the installation and adjustments, the contractor shall certify that seismic restraints have been installed to meet the requirements of Code, specifications, the seismic restraints criteria and approved shop drawings, signed by a structural/civil engineer registered in the State of California.

G. Criteria:
   1. Seismic Force Criteria: Per CBC with both lateral and uplift occurring simultaneously.
      a. Rigidly mounted piping, ductwork and equipment - 0.5 g.
      b. Flexibly mounted piping, ductwork and equipment - 1.0 g (minimum).
   2. Restraint: Required for the following:
      a. Major equipment including air handling units, coils, fan coil units, water heaters, tanks, heat exchangers, pumps, fans, variable frequency drives, pump controllers, fuel storage tanks and other such items.
      b. Flues, and engine exhaust pipes.
      c. Piping and Ducts: For pipe and duct sizes covered by OSHPD (CBC) requirements.

H. Equipment: The restrained equipment itself must be designed to withstand the required seismic force criteria, including its internal design, components and frame, and must have suitable structural elements to which restraining attachments may be fastened.

I. Attachments to Structure: As specified.

J. Flexibly Supported Equipment, Piping and Ducts:
   1. General: Restrain as indicated or as required. Provide and locate restraints to allow normal operation of systems without transmitting vibrations to building structure. Normal operation includes static condition, start-up, normal running and shut-down. Allow maximum of 0.25” between restraint and restrained device.
   2. Base Mounted Equipment: Restraints to be separate from vibration isolator unless otherwise indicated. Minimum four restraints for each piece of equipment.
   3. Piping, Ducts and Suspended Equipment:
      a. Locations of Restraints: Per OSHPD (CBC) requirements.
      b. Construction of Restraints: As indicated and as required. Steel cables, installed slack, may be used.

3.8 FIELD QUALITY CONTROL

A. Testing: Owner will engage a qualified testing agency to perform the following field quality control testing.
B. Testing: Engage a qualified testing agency to perform the following field quality-control testing.

C. Testing: Perform the following field quality-control testing:
   1. Isolator seismic-restrain clearance.
   2. Isolator deflection.
   3. Snubber minimum clearances.

3.9 ADJUSTING

A. Adjust isolators after piping system have been filled and equipment is at operating weight.

B. Adjust limit stops on restrained spring isolators to mount equipment at normal operating height. After equipment installation is complete, adjust limit stops so they are out of contact during normal operation.

C. Attach thrust limits at centerline of thrust and adjust to a maximum of \( \frac{1}{4} \)" movement during start and stop.

D. Adjust spring leveling mechanism.

E. Adjust active height of spring isolators.

F. Adjust snubbers according to manufacturer’s written recommendations.

G. Adjust seismic restraints to permit free movement of equipment with normal mode of operation.

H. Torque anchor bolts according to equipment manufacturer’s written recommendations to resist seismic forces.

3.10 CLEANING

A. After completing equipment installation, inspect vibration isolation and seismic-control devices. Remove paint splatters and other spots, dirt, and debris.
SECTION 23 05 53 – IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

   A. Drawings and general provisions of the Contract, including General and Supplementary Conditions apply to this Section.

1.2 SUMMARY

   A. This Section includes the following mechanical identification materials and their installation:

      1. Equipment nameplates.
      2. Equipment markers.
      3. Equipment signs.
      4. Access panel and door markers.
      5. Pipe markers.
      6. Duct markers.
      7. Stencils.
      8. Valve tags.
     10. Warning tags.

1.3 SUBMITTALS

   A. Product Data: For each type of product indicated.

   B. Valve numbering scheme.

   C. Valve Schedules: For each piping system. Furnish extra copies (in addition to mounted copies) to include in maintenance manuals.

1.4 REFERENCES


   B. American Society for Testing and Materials (ASTM) requirements

1.5 COORDINATION

   A. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.
B. Coordinate installation of identifying devices with location of access panels and doors.

C. Install identifying devices before installing acoustical ceilings and similar concealment.

PART 2 – PRODUCTS

2.1 EQUIPMENT IDENTIFICATION DEVICES

A. Equipment Nameplates: Metal, with data engraved or stamped, for permanent attachment on equipment.
   1. Data:
      a. Manufacturer, product name, model number, and serial number.
      b. Capacity, operating and power characteristics, and essential data.
      c. Labels of tested compliances.
   2. Location: Accessible and visible.
   3. Fasteners: As required to mount on equipment.

B. Equipment Markers: Engraved, color-coded laminated plastic. Include contact-type, permanent adhesive.
   1. Terminology: Match schedules as closely as possible.
   2. Data:
      a. Name and plan number.
      b. Equipment service.
      c. Design capacity.
      d. Other design parameters such as pressure drop, entering and leaving conditions, and speed.
   3. Size: 2.5 by 4" for control devices, dampers, and valves; 4-1/2 by 6" for equipment, exhaust fans and sound traps.

C. Equipment Signs: ASTM D 709, Type I, cellulose, paper-base, phenolic-resin-laminate engraving stock; Grade ES-2, black surface, black phenolic core, with white melamine sub core, unless otherwise indicated. Fabricate in sizes required for message. Provide holes for mechanical fastening.
   1. Data: Instructions for operation of equipment and for safety procedures.
   2. Engraving: Manufacturer's standard letter style, of sizes and with terms to match equipment identification.
   3. Thickness: 1/16" for units up to 20 sq. in. or 8" in length, and 1/8" for larger units.
   4. Fasteners: Self-tapping, stainless-steel screws or contact-type, permanent adhesive.

D. Access Panel and Door Markers: 1/16"- thick, engraved laminated plastic, with abbreviated terms and numbers corresponding to identification. Provide 1/8" center hole for attachment.
   1. Fasteners: Self-tapping, stainless-steel screws or contact-type, permanent adhesive.

2.2 PIPING IDENTIFICATION DEVICES
A. Manufactured Pipe Markers, General: Preprinted, color-coded, with lettering indicating service, and showing direction of flow.
   1. Colors: Comply with ASME A13.1, unless otherwise indicated.
   2. Lettering: Use piping system terms indicated and abbreviate only as necessary for each application length.
   3. Pipes with OD, Including Insulation, Less Than 6 Inches: Full-band pipe markers extending 360° around pipe at each location.
   4. Pipes with OD, Including Insulation, 6 Inches and Larger: Either full-band or strip-type pipe markers at least three times letter height and of length required for label.
   5. Arrows: Integral with piping system service lettering to accommodate both directions; or as separate unit on each pipe marker to indicate direction of flow.

B. Pre-tensioned Pipe Markers: Pre-coiled semi rigid plastic formed to cover full circumference of pipe and to attach to pipe without adhesive.

C. Shaped Pipe Markers: Preformed semi rigid plastic formed to partially cover circumference of pipe and to attach to pipe with mechanical fasteners that do not penetrate insulation vapor barrier.


E. Plastic Tape: Continuously printed, vinyl tape at least 3 mils thick with pressure-sensitive, permanent-type, self-adhesive back.
   1. Width for Markers on Pipes with OD, Including Insulation, Less Than 6 Inches: 0.75” minimum.
   2. Width for Markers on Pipes with OD, Including Insulation, 6 Inches or Larger: 1.5” minimum.

2.3 DUCT IDENTIFICATION DEVICES

A. Duct Markers: Engraved, color-coded laminated plastic. Include direction and quantity of airflow and duct service (such as supply, return, and exhaust). Include contact-type, permanent adhesive.

2.4 STENCILS

A. Stencils: Prepared with letter sizes according to ASME A13.1 for piping; minimum letter height of 1-0.25” for ducts; and minimum letter height of 0.75” for access panel and door markers, equipment markers, equipment signs, and similar operational instructions.
   1. Stencil Material: Metal or fiberboard.
   2. Stencil Paint: Exterior, gloss, black, unless otherwise indicated. Paint may be in pressurized spray-can form.
   3. Identification Paint: Exterior, in colors according to ASME A13.1, unless otherwise indicated.

2.5 VALVE TAGS

A. Valve Tags: Stamped or engraved with 0.25” letters for piping system abbreviation and 1/2-” numbers, with numbering scheme approved by Architect or Engineer. Provide 5/32” hole for fastener.
1. Material: 0.032”- thick brass.
2. Valve-Tag Fasteners: Brass wire-link or beaded chain; or S-hook.

2.6 VALVE SCHEDULES

A. Valve Schedules: For each piping system, on standard-size bond paper. Tabulate valve number, piping system, system abbreviation (as shown on valve tag), location of valve (room or space), normal-operating position (open, closed, or modulating), and variations for identification. Mark valves for emergency shutoff and similar special uses.
   1. Valve-Schedule Frames: Glazed display frame for removable mounting on masonry walls for each page of valve schedule. Include mounting screws.
   2. Frame: Extruded aluminum.
   3. Glazing: ASTM C 1036, Type I, Class 1, Glazing Quality B, 2.5-mm, single-thickness glass.

2.7 WARNING TAGS

A. Warning Tags: Preprinted or partially preprinted, accident-prevention tags; of plasticized card stock with matte finish suitable for writing.
   1. Size: 3 by 5-0.25” minimum.
   2. Fasteners: Brass grommet and wire.
   3. Nomenclature: Large-size primary caption such as DANGER, CAUTION, or DO NOT OPERATE.

PART 3 – EXECUTION

3.1 APPLICATIONS, GENERAL

A. Products specified are for applications referenced in other section. If more than single-type material, device, or label is specified for listed applications, selection is Installer's option.

3.2 EQUIPMENT IDENTIFICATION

A. Install and permanently fasten equipment nameplates on each major item of mechanical equipment that does not have nameplate or has nameplate that is damaged or located where not easily visible. Locate nameplates where accessible and visible. Include nameplates for the following general categories of equipment:
   1. Fuel-burning units, including boilers, furnaces, heaters, stills, and absorption units.
   2. Pumps, compressors, chillers, condensers, and similar motor-driven units.
   3. Heat exchangers, coils, evaporators, cooling towers, heat recovery units, and similar equipment.
   4. Fans, blowers, primary balancing dampers, and mixing boxes.
   5. Packaged HVAC central-station and zone-type units.

B. Install equipment markers with permanent adhesive on or near each major item of mechanical equipment. Data required for markers may be included on signs, and markers may be omitted if both
are indicated.

1. **Letter Size:** Minimum 0.25” for name of units if viewing distance is less than 24”, 1/2” for viewing distances up to 72”, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

2. **Data:** Distinguish among multiple units, indicate operational requirements, indicate safety and emergency precautions, warn of hazards and improper operations, and identify units.

3. Locate markers where accessible and visible. Include markers for the following general categories of equipment:
   a. Main control and operating valves, including safety devices and hazardous units such as gas outlets.
   b. Fire department hose valves and hose stations.
   c. Meters, gauges, thermometers, and similar units.
   d. Fuel-burning units, including boilers, furnaces, heaters, stills, and absorption units.
   e. Pumps, compressors, chillers, condensers, and similar motor-driven units.
   f. Heat exchangers, coils, evaporators, cooling towers, heat recovery units, and similar equipment.
   g. Fans, blowers, primary balancing dampers, and mixing boxes.
   h. Packaged HVAC central-station and zone-type units.
   i. Tanks and pressure vessels.
   j. Strainers, filters, humidifiers, water-treatment systems, and similar equipment.

C. **Stenciled Equipment Marker Option:** Stenciled markers may be provided instead of laminated-plastic equipment markers, at Installer’s option, if lettering larger than 1” high is needed for proper identification because of distance from normal location of required identification.

D. Install equipment signs with screws or permanent adhesive on or near each major item of mechanical equipment. Locate signs where accessible and visible.

1. Identify mechanical equipment with equipment markers in the following color codes:
   a. Green: For cooling equipment and components.
   b. Yellow: For heating equipment and components.
   c. Green and Yellow: For combination cooling and heating equipment and components.
   d. Brown: For energy-reclamation equipment and components.

2. **Letter Size:** Minimum 0.25” for name of units if viewing distance is less than 24”, 1/2” for viewing distances up to 72”, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

3. **Data:** Distinguish among multiple units, indicate operational requirements, indicate safety and emergency precautions, warn of hazards and improper operations, and identify units.

4. Include signs for the following general categories of equipment:
   a. Main control and operating valves, including safety devices and hazardous units such as gas outlets.
   b. Fuel-burning units, including boilers, furnaces, heaters, stills, and absorption units.
c. Pumps, compressors, chillers, condensers, and similar motor-driven units.
d. Heat exchangers, coils, evaporators, cooling towers, heat recovery units, and similar equipment.
e. Fans, blowers, primary balancing dampers, and mixing boxes.
f. Packaged HVAC central-station and zone-type units.
g. Tanks and pressure vessels.
h. Strainers, filters, humidifiers, water-treatment systems, and similar equipment.

E. Stenciled Equipment Sign Option: Stenciled signs may be provided instead of laminated-plastic equipment signs, at Installer’s option, if lettering larger than 1” high is needed for proper identification because of distance from normal location of required identification.

F. Install access panel markers with screws on equipment access panels.

3.3 PIPING IDENTIFICATION

A. Install manufactured pipe markers indicating service on each piping system. Install with flow indication arrows showing direction of flow.
   1. Pipes with OD, Including Insulation, Less Than 6 Inches: Pre-tensioned pipe markers. Use size to ensure a tight fit.
   2. Pipes with OD, Including Insulation, 6 Inches and Larger: Shaped pipe markers. Use size to match pipe and secure with fasteners.

B. Stenciled Pipe Marker Option: Stenciled markers may be provided instead of manufactured pipe markers, at Installer’s option. Install stenciled pipe markers with painted, color-coded bands or rectangles on each piping system.
   1. Identification Paint: Use for contrasting background.

C. Locate pipe markers and color bands where piping is exposed in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior nonconcealed locations as follows:
   1. Near each valve and control device.
   2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
   3. Near penetrations through walls, floors, ceilings, and nonaccessible enclosures.
   4. At access doors, manholes, and similar access points that permit view of concealed piping.
   5. Near major equipment items and other points of origination and termination.
   6. Spaced at maximum intervals of 50 feet along each run. Reduce intervals to 25 feet in areas of congested piping and equipment.
3.4 DUCT IDENTIFICATION

A. Install duct markers with permanent adhesive on air ducts in the following color codes:
   1. Green: For cold-air supply ducts.
   2. Yellow: For hot-air supply ducts.
   3. Blue: For exhaust-, outside-, relief-, return-, and mixed-air ducts.
   4. ASME A13.1 Colors and Designs: For hazardous material exhaust.
   5. Letter Size: Minimum 0.25" for name of units if viewing distance is less than 24", 1/2" for viewing distances up to 72", and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

B. Stenciled Duct Marker Option: Stenciled markers, showing service and direction of flow, may be provided instead of laminated-plastic duct markers, at Installer’s option, if lettering larger than 1” high is needed for proper identification because of distance from normal location of required identification.

C. Locate markers near points where ducts enter into concealed spaces and at maximum intervals of 50 feet in each space where ducts are exposed or concealed by removable ceiling system.

3.5 VALVE-TAG INSTALLATION

A. Install tags on valves and control devices in piping systems, except check valves; valves within factory-fabricated equipment units; plumbing fixture supply stops; shutoff valves; faucets; convenience and lawn-watering hose connections; and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units. List tagged valves in a valve schedule.

B. Valve-Tag Application Schedule: Tag valves according to size, shape, and color scheme and with captions similar to those indicated in the following:

   1. Valve-Tag Size and Shape:
      a. Cold Water: 1.5”, round.
      b. Hot Water: 1.5”, round.
      c. Fire Protection: 1.5”, round.
      d. Gas: 1.5”, round.
      e. Steam: 1.5”, round.

   2. Valve-Tag Color:
      b. Hot Water: Red.
      c. Fire Protection: Black.
      d. Gas: Green.
      e. Chilled Water: Blue.
      g. Heating Hot Water: Red.

   3. Letter Color:
      d. Gas: White.
e. Chilled Water: White.
g. Heating Hot Water: White.

3.6 VALVE-SCHEDULE INSTALLATION

A. Mount valve schedule on wall in accessible location in each major equipment room.

3.7 WARNING-TAG INSTALLATION

A. Write required message on, and attach warning tags to, equipment and other items where required.

3.8 ADJUSTING

A. Relocate mechanical identification materials and devices that have become visually blocked by other work.

3.9 CLEANING

A. Clean faces of mechanical identification devices and glass frames of valve schedules.

END OF SECTION 23 05 53
SECTION 23 05 93 – TESTING, ADJUSTING AND BALANCING FOR HVAC

PART 1 – GENERAL

1.1 DESCRIPTION

A. General: Perform testing, adjusting and balancing in accordance with the contract documents.

1.2 SUMMARY

A. Scope: Extent of testing, adjusting, and balancing work required by this Section is indicated on the drawings, in schedules, and by the requirements of this Section, and Standards & Criteria for HVAC, Testing, adjusting and balancing for HVAC consist of furnishing transportation, labor, materials, and equipment to test, adjust, and balance heating, ventilating, and air conditioning (HVAC) system.

B. Systems: Testing, adjusting, and balancing specified in this Section shall include, but not be limited to, the following systems:

1. Air handling systems including supply, return, and exhaust.
   a. Constant-volume air systems.
   b. Variable-air-volume systems.

2. HVAC equipment quantitative-performance settings.

3. Space pressurization testing and adjusting.

4. Verifying that automatic control devices are functioning properly.
   a. Automatic temperature control system.

5. Hydronic systems including heating and chilled water.

6. Air distribution ductwork including supply return, and exhaust.

7. Reporting results of activities and procedures specified in this Section.

1.3 REFERENCES

A. Comply with applicable requirements and recommendations of the following standards. Where the requirements conflict or are different, comply with more stringent.

1. National Environmental Balancing Bureau (NEBB) or Associated Air Balance Council (AABC):


4. American National Standards Institute (ANSI)
   a. S1.4 – Specifications for Sound Level Meters.
   b. S1.11 – Specifications for Octave-Band and Fractional-Octave Band Analog and Digital Filters.

5. American Society of Mechanical Engineers (ASME)

6. California Energy commission (CEC)

7. American National Standards Institute (ANSI)

1.4 DEFINITIONS

A. Adjust: to regulate fluid flow rate and air patterns at the terminal equipment, such as to reduce fan speed or adjust a damper.

B. Balance: to proportion flows within the distribution system, including submains, branches, and terminals, according to indicated quantities.

C. Barrier or Boundary: Construction, either vertical or horizontal, such as walls, floors, and ceilings that are designed and constructed to restrict the movement of airflow, smoke, odors, and other pollutants.

D. Draft: A current of air, when referring to localized effect caused by one or more factors of high air velocity, low ambient temperature, or direction of airflow, whereby more heat is withdrawn from a person’s skin than is normally dissipated.

E. NC: noise criteria.

F. Procedure: An approach to and execution of a sequence of work operations to yield repeatable results.

G. RC: Room criteria.

H. Report Forms: Test data sheets for recording test data in logical order.

I. Smoke-Control System: An engineered system that uses fans to produce airflow and pressure differences across barriers to limit smoke movement.

J. Smoke-Control Zone: A space within a building that is enclosed by smoke barriers and is part of a zoned smoke-control system.

K. Stair Pressurization System: A type of smoke-control system that is intended to positively pressurize stair towers with outdoor air by using fans to keep smoke from contaminating the stair towers during an alarm condition.

L. Static Head: The pressure due to the weight of the fluid above the point of measurement. In a closed system, static head is equal on both sides of the pump.

M. Suction Head: The height of fluid surface above the centerline of the pump on the suction side.

N. System Effect: A phenomenon that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
O. System Effect Factors: Allowances used to calculate a reduction of the performance ratings of a fan when installed under conditions different from those presented when the fan was performance tested.

P. TAB: Testing, adjusting, and balancing.

Q. Terminal: A point where the controlled medium, such as fluid or energy, enters or leaves the distribution system.

R. Test: A procedure to determine quantitative performance of systems or equipment.

S. Testing, Adjusting, and Balancing (TAB) Firm: The entity responsible for performing and reporting TAB procedures.

1.5 REQUIREMENTS:

A. All HVAC, plumbing and fire protection systems and equipment on this project shall be successfully proof, acceptance and operationally tested and balanced, as applicable prior to acceptance of the project by the Owner.

B. All work to be furnished and installed under this Section shall comply with all the requirements of Standards and Criteria for HVAC, and other Sections in Division 23 specified herein.

C. Proof and Acceptance Testing: The Contractor shall provide proof and acceptance testing of HVAC, plumbing and fire protection systems and equipment during the construction process to verify that systems are installed and function as specified. Piping systems shall not be insulated, covered up, or placed in service until piping has been successfully leak tested, flushed, cleaned and water-treated, as applicable. Ductwork shall not be externally insulated, covered up or placed in service until it has been successfully leak tested. Equipment shall not be placed in service until it has been checked out, tested and adjusted, as applicable. The Contractor shall provide all required proof and acceptance testing, as specified.

D. System Adjustments/Operational Certification: The Contractor shall provide required system adjustments and certify that each HVAC, plumbing and fire protection system is operational, as specified.

E. Balancing: The Contractor shall provide balancing of all air and water systems to the design quantities.

1.6 QUALITY ASSURANCE:

A. Tester’s Qualifications: A specialist certified by NEBB or AABC with at least 3 years of experience in those testing, adjusting, and balancing requirements similar to those required for this project, who is not the installer of the system to be tested and is otherwise independent of the project.

B. TAB Conference: Meet with Engineer on approval of TAB strategies and procedures plan to develop a mutual understanding of the details. Ensure the participation of TAB team members, equipment manufacturers’ authorized service representatives, HVAC controls installers, and other support personnel. Provide seven days’ advance notice of scheduled meeting time and location.

1. Agenda items: Include at least the following
   a. Submittal distribution requirements.
c. TAB plan.
d. Work schedule and Project-site access requirements.
e. Coordination and cooperation of trades and Contractors.
f. Coordination of documentation and communication flow.

C. Penalty: The Contractor shall submit the name of the TAB organization he proposes to employ, as well as four copies of evidence that the firm and Project’s TAB team members meet the qualifications specified in Quality Assurance Article of this Section, for approval by the Architect within 30 days after contract award. If the Contractor fails to submit the name of an acceptable agency within the specified time, a firm may be selected to accomplish the work, and this selection shall be binding upon the Contractor at no additional cost.

D. For a period of 60 days following the acceptance of the project the Contractor shall investigate and correct any reported deficiencies unless such deficiencies are a result of unauthorized tampering by building occupants.

E. Testing and balancing agency, as part of its contract, shall act as authorized inspection agency responsible to the Airport, and shall list all items that are installed correctly, require correction, or have not been installed in accordance with contract Drawings and Specifications, pertaining to air distribution, cooling, and heating systems. The testing and balancing agency is required to provide written reports of all deficiencies and proposed recommendations to the Airport.

F. Certification of TAB Reports: Certify TAB field data reports. This certification includes the following:
   1. Review field data reports to validate accuracy of data and to prepare certified TAB reports.
   2. Certify that TAB team complied with approved TAB plan and the procedures specified and referenced in this Specification.


I. Instrumentation Type, Quantity, and Accuracy: As described in AABC’s “National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems” or NEBB’s “Procedural Standards for Testing, Adjusting, Balancing of Environmental Systems.”

J. Instrumentation Calibration: Calibrate instruments at least every six months or more frequently if required by instrument manufacturer.
   1. Keep an updated record of instrument calibration that indicates date of calibration and the name of party performing instrument calibration.

K. The testing and balancing agency shall provide with his bid a performance guarantee covering all phases of the work as herein specified.

L. The HVAC Contractors shall cooperate with the selected testing and balancing agency in the following manner:
1. Provide sufficient time before final completion dates so that tests and balancing can be accomplished.

2. The various system installers, suppliers, and Contractors shall provide all required materials, labor and tools to make corrections when required without undue delay. Install balancing dampers as required by testing and balancing agency.

3. The HVAC Contractors shall put all heating, ventilating and air conditioning systems and equipment and controls into full operation and shall continue the operation of the same during each working day of testing and balancing.

4. Testing and balancing agency shall be kept informed of any major changes made to the system during construction, and shall be provided with a complete set of Record Drawings.

5. Other facilities shall be available to the testing and balancing agency to enable their work to progress. The TAB work shall be scheduled to avoid conflicts with other trades work.

1.7 SUBMITTALS:

A. Testing Procedures: Submit six copies of all proposed proof and acceptance testing and operational certification procedures to the Architect for review at least 30 days prior to conducting any testing or certification.

B. Reporting Forms: Submit four copies of proposed TAB approved forms to be used in recording test and certification data and results to the Architect for review at least 30 days prior to conducting any testing on the project. Data forms shall be either from AABC or NEBB. These forms shall serve as specific guidelines for producing final test reports.
   1. Hybrid or non-standards forms are not acceptable.

C. Test and Certification Data and Results: Submit six copies, signed by the test and balance supervisor who performed the work, of complete data and certified test results for each test performed (covering air and water system performance, air motion (fpm), and sound pressure levels) shall be submitted prior to final tests and inspection. TAB report forms should be used. Reports should include, but are not limited to:

   1. Title Page: Provide the following information on a title page:
      a. Title, with building information.
      b. System(s) tested
      c. Testing Company Name
      d. Testing Company Address
      e. Testing Company Telephone Number
      f. Testing Company Contact Person
      g. Project Name
      h. Project Location
      i. Project Architect
      j. Project Engineer
      k. Project General Contractor
      l. Other pertinent information

   2. Instrument List: Provide the following information on an instrument listing page:
      a. Instruments
      b. Manufacturers
      c. Models
d. Serial Numbers  
e. Ranges  
f. Calibration Dates

3. Test/Certification Data and Results: Provide pages with applicable test and certification data and results including, but not limited to the following:

   a. Test/certification performed  
   b. Test/certification procedure  
   c. System and area tested  
   d. Date(s) and time(s) of test  
   e. Weather conditions  
   f. Test/certification criteria  
   g. Test/certification results  
   h. Additional pertinent information

4. Report Content:

   a. General: Certification shall include checking of adherence to agenda, of calculations, of procedures and evaluation of final summaries. Reports shall conspicuously identify items not conforming to contract requirements, or obvious maloperation and design deficiencies.

   b. Air Balance:

      1) Air flow.

      2) Fans:

         a) Number, service, model, and size.
         b) Delivery in CFM with system both in 100% O.A. and exhaust and with minimum O.A.
         c) Minimum outside air CFM.
         d) Static Pressure: Suction, discharge, and total.
         e) Voltage: Rated and actual.
         f) Motor Amperage: Rated and actual. Motor operating bhp
         g) Motor Sheave Diameter: Adjustable or solid.
         h) Fan sheave diameter.
         i) Motor RPM.
         j) Fan RPM.

      3) Fans Graphic Plot: For each fan, on its actual fan curve, plot intersections of the following lines:

         a) CFM from transverse.
         b) Static pressure (or total pressure for fans so rated).
         c) Brake horsepower from amperes.
         d) RPM.
         e) Position of fans variable adjustment.

      4) Outside air, return air, and exhaust air CFMs.

      5) Pressure drops for coil, filters, sound traps, etc.

      6) All supply, exhaust, and return air diffusers and grilles; arrange in following columns:

         a) Outlet location by room number, or other suitable means. Include key plans, if necessary, to identify location.
         b) Supply/make-up outlet size and type. Supply outlet design CFM.
         c) Supply outlet actual CFM.
d) Return or exhaust outlet size and type.
e) Return or exhaust outlet design CFM.
f) Return or exhaust outlet actual CFM.

c. Water Balance:
1) Water flows.

2) Pumps:
a) Manufacturer.
b) Number, service, model, and size.
c) GPM.
d) Pressures: Suction, discharge, and total.
e) Voltage: Rated and actual.
f) Amperage: Rated and actual.
g) BMP, calculated from Amperes and Volts

3) Heat Exchangers:
a) Manufacturer.
b) Number, service, model, and size.
c) GPM of shell side and tube side temperatures of entering and leaving each side.
d) Pressures: entering and leaving, each side

4) Each flow measuring device (circuit setter, venturi, etc.)
a) Manufacturer
b) Device type, model, and size.
c) Pressure differential.
d) GPM.

5) Each cooling coil & heating coils (except in VAV boxes): Number, service, models, and size.
a) GPM.
b) CFM Air flow (maximum)
c) Entering air DB and WB and water temperature.
d) Leaving air DB and WB and water temperature.
e) Pressures: Inlet and outlet (for air and water).

d. Duct Systems:
1) Duct air quantities (maximum and minimum) – main, submains, branches, outdoor (outside) air, total air, and exhaust
2) Duct size
3) Number of pitot tube (pressure measurements)
4) Sum of velocity measurements (Note: do not add pressure measurements)
5) Average velocity
6) Recorded (test) cfm Design cfm
7) Individual air terminals
8) Terminal identification supply or exhaust, location and number designation
9) Type size, manufacturer, and catalog identification applicable factor for application, velocity, area, etc., and designated area
10) Design and recorded velocities – fpm (state “core,” inlet,” etc., as applicable)
11) Design and recorded quantities – cfm (deflector vane or diffusion cone settings)

e. Miscellaneous
1) Sound levels
2) Capacities
3) Nameplate data

D. Qualifications: The Contractor shall submit the certified individual qualifications of all persons responsible for supervising and performing the actual work and the name of the certifying engineer. Provide a reference list of five (5) similar size projects with contact person and telephone number.

E. Contract Examination Report: Within 45 days from Contractor’s Notice to Proceed, submit 4 copies of the Contract Documents review report as specified in this Section.

F. Strategies and Procedures Plan: Within 60 days from Contractor’s Notice to Proceed, submit 4 copies of TAB strategies and step-by-step procedures as specified in Preparation Article of this Section. Include a complete set of report forms intended for use on this Project.

G. Operational Certification: Submit six certified copies of an operational certification which documents that all equipment and systems have been fully tested to verify proper operation in accordance with the design shown in the Construction Documents and manufacturer’s recommendations.

H. Certification of System Preparations: The Contractor shall certify in writing to the Owner by system and area, when coordination is completed and systems have been fully proof/acceptance tested and are operational and prepared for balancing.

I. Certification: Certifications stating that submitted data is true and correct shall be provided for all submittals under this Section. Certification shall be executed by an authorized officer if the Contractor is a corporation, by a partner if the Contractor is a partnership, by the Owner if the Contractor is a sole proprietorship or by the authorized representative if the Contractor is a joint venture.

J. Calibration List: Submit four copies of a listing of testing devices to be used for the project to the Engineer for approval. Listing shall include documentation that devices are properly calibrated.

K. Test/Certification Log: The Contractor shall maintain a test/certification as it is performed. This log shall be available for review by the Owner and a copy of the log shall be submitted to the Owner prior to the Substantial Completion inspection. A space shall be provided on the test/certification log for signoff by the Owner.

L. Operating and Maintenance Manuals: Approved copies of Testing Procedures, Test and Certification Data and Results, Operational Certification and Test/Certification Log shall be included in the Operating and Maintenance Manuals specified.

M. Warranties, as specified in this section.

1.8 AGENDA

A. Agenda: A preliminary report and agenda shall be submitted and approved prior to the start of testing and balancing work.

1. Review plans and specifications prior to installation of any of the affected systems, and submit a report indicating any deficiencies in the systems that would preclude the proper adjusting, balancing, and testing of the systems.

2. The agenda shall include a general description of each air and water system with its associated equipment and operation cycles for heating and cooling.
3. The agenda shall include a list of all air and water flows to be performed at all mechanical equipment.

4. The agenda shall incorporate the proposed selection points for sound measurements, including typical spaces as well as sound sensitive areas such as conference rooms.

5. The agenda shall include specific test procedures and parameters for determining specified quantities (e.g. flow, drafts, sound levels) from the actual field measurements to procedures and calculations to typical systems shall be submitted.

6. Specific test procedures for measuring air quantities at terminals shall specific type of instrument to be used, method of instrument application (by sketch) and factors for:
   a. Air terminal configuration.
   b. Flow direction (supply or exhaust).
   c. Velocity corrections.
   d. Effective area applicable to each size and type of air terminal.
   e. Density corrections.

7. The agenda shall include identification and types of measurement instruments to be used, and their most recent calibration date.

1.9 JOB CONDITIONS

A. General: Do not proceed with testing, adjusting and balancing work until the following conditions have been met:

1. Work has been completed and is operable. Ensure that there is no latent residual work yet to be completed on the tested equipment.

2. Work scheduled for testing, adjusting and balancing is clean and free from debris, dirt, and discarded building materials.

3. All architectural openings (doors, windows, and other openings) which may affect the operation of the system to be tested, adjusted, and balanced shall at their normal states.

4. All related mechanical systems which may affect the operation of the system to be tested, adjusted, and balanced shall be at their normal operating conditions.

B. Partial Occupancy: the Department may occupy completed areas of building before Substantial Completion. Cooperate with Department during TAB operations to minimize conflicts with Department operations.

1.10 COORDINATION

A. Coordinate the efforts of factory-authorized service representatives for systems and equipment, HVAC controls installers, and other mechanics to operate HVAC systems and equipment to support and assist TAB activities.

B. Notice: Provide seven days’ advance notice for each test. Include scheduled test dates and times.

C. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.
1.11 WARRANTY

A. National Project Performance Guarantee: Provide a guarantee on AABC’s “National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems” or NEBB’s “Procedural Standards for Testing, Adjusting, Balancing of Environmental Systems” forms stating that AABC or NEBB will assist in completing requirements of the Contract Documents if TAB firm fails to comply with the Contract Documents.

1.12 NOTICE:

A. General: Notify the Project Manager in writing 2 weeks prior to all scheduled testing and certification to allow time for the Project Manager to schedule witnessing of testing and certification, where elected by the Project Manager.

PART 2 – PRODUCTS

2.1 TESTING MATERIALS:

A. General: Provide all materials, equipment and personnel for all required proof and acceptance testing and preparation for operational testing and balancing, including all required retesting and re-preparation.

B. Products: Tested products which fail to provide acceptable test results shall be repaired or replaced with suitable materials and then retested until acceptable test results are obtained.

2.2 TEST HOLES

A. Test holes shall be provided in ducts, housing, and pipes as necessary for the proper air and water measurements and to balance systems. At each location where ducts or plenums are insulated, test holes shall be provided with an approved extension plug fitting.

2.3 PATCHING MATERIALS

A. Material: Seal, patch, and repair ductwork, piping and equipment drilled or cut for testing purposes.
   1. Plastic plugs with retainers may be used to patch drilled holes in ductwork and housings.
   2. Piping shall be capped with materials the same as the piping system.
   3. Insulation shall be neatly hemmed with metal or plastic edging, leaving test points visible for future testing.

2.4 TEST INSTRUMENTS

A. Standards: Utilize instruments and equipment of type, precision, and capacity as recommended in the NEBB “Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems” and AABC manual MN-1.

B. Test Instruments: all instruments used for measurements shall be accurate and calibration histories for each instrument shall be available for examination. Each test instrument shall be calibrated by an approved laboratory or by the manufacturer. A representative has the right to require instrument recalibration, or the use of other instruments and test methodology, where accuracy of reading is
C. Additional Instruments: Permanently installed measuring instruments, such as temperature and pressure gauges, shall be checked against transfer standard instruments. Any instrument which does not meet specification requirement shall be replaced or recalibrated.

D. Cone Instruments: The Contractor shall employ manufactured enclosure type cones, capable of air volume direct readings, for all diffuser/grille/register air flow measurements. The readout meters shall meet calibration requirements.

PART 3 – EXECUTION

PART 4 Note: LEED® Requirements may be found in Standards and Criteria for HVAC.

4.1 PROCEDURES AND INSTRUMENTS, GENERAL

A. Requirements: All systems and components thereof shall be adjusted to perform as required by drawings and specifications. Tests shall be made to demonstrate that capacities and performance of air and water systems comply with contract requirements.

B. Test Duration: Operating tests of heating and cooling coils, fans, and other equipment shall be of not less than 4 hours’ duration after stabilized operating conditions have been established. Capacities shall be based on temperatures and air and water quantities measured during each test.

C. Instrumentation: Method of application of instrumentation shall be in accordance with approved agenda.

   1. All instruments shall be applied in accordance with the manufacturer’s certified instructions.

   2. All labor, instruments, and appliances required shall be furnished by the Contractor. Permanently installed instruments used for the tests (e.g., flow meters and Btu meters) shall not be installed until the entire system has been cleaned and ready for operation.

D. Calibration of Testing Instruments: All measurement instruments used for testing, adjusting, balancing, and commissioning shall be calibrated. The time between the most recent calibration data and the final test report date shall not be over 3 years.

4.2 EXAMINATION

A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems' designs that may preclude proper TAB of systems and equipment.

   1. Contract Documents are defined in the General and Supplementary Conditions of Contract.

   2. Verify that balancing devices, such as test ports, gauge cocks, thermometer wells, flow control devices, balancing valves and fittings, and manual volume dampers, are required by the Contract Documents. Verify that quantities and locations of these balancing devices are accessible and appropriate for effective balancing and for efficient system and equipment operation.

B. Examine approved submittal data of HVAC systems and equipment.

C. Examine design data, including HVAC system descriptions, statements of design assumptions for environmental conditions and systems' output, and statements of philosophies and assumptions.
about HVAC system and equipment controls.

D. Examine equipment performance data including fan and pump curves. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system. Calculate system effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from those presented when the equipment was performance tested at the factory. To calculate system effects for air systems, use tables and charts found in AMCA 201, “Fans and Systems,” Sections 7 through 10; or in SMACNA’s “HVAC Systems–Duct Design”. Compare this data with the design data and installed conditions.

E. Examine system and equipment installations to verify that they are complete and that testing, cleaning, adjusting, and commissioning specified in individual Sections have been performed.

F. Examine system and equipment test reports.

G. Examine HVAC system and equipment installations to verify that indicated balancing devices, such as test ports, gauge cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers, are properly installed, and that their locations are accessible and appropriate for effective balancing and for efficient system and equipment operation.

H. Examine systems for functional deficiencies that cannot be corrected by adjusting and balancing.

I. Examine HVAC equipment to ensure that clean filters have been installed, bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.

J. Examine terminal units, such as variable-air-volume boxes, to verify that they are accessible and their controls are connected and functioning.

K. Examine plenum ceilings used for supply air to verify that they are airtight. Verify that pipe penetrations and other holes are sealed.

L. Examine strainers for clean screens and proper perforations.

M. Examine three-way valves for proper installation for their intended function of diverting or mixing fluid flows.

N. Examine heat-transfer coils for correct piping connections and for clean and straight fins.

O. Examine system pumps to ensure absence of entrained air in the suction piping.

P. Examine equipment for installation and for properly operating safety interlocks and controls.

Q. Examine automatic temperature system components to verify the following:
   1. Dampers, valves, and other controlled devices are operated by the intended controller.
   2. Dampers and valves are in the position indicated by the controller.
   3. Integrity of valves and dampers for free and full operation and for tightness of fully closed and fully open positions. This includes dampers in multi-zone units, mixing boxes, and variable-air-volume terminals.
   4. Automatic modulating and shutoff valves, including two-way valves and three-way mixing and
diverting valves, are properly connected.

5. Thermostats and humidistats are located to avoid adverse effects of sunlight, drafts, and cold walls.

6. Sensors are located to sense only the intended conditions.

7. Sequence of operation for control modes is according to the Contract Documents.

8. Controller set points are set at indicated values.

9. Interlocked systems are operating.

10. Changeover from heating to cooling mode occurs according to indicated values.

R. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

4.3 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in AABC’s "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems" or NEBB’s "Procedural Standards for Testing, Adjusting, Balancing of Environmental Systems" and this Section.

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary to allow adequate performance of procedures. After testing and balancing, close probe holes and patch insulation with new materials identical to those removed. Restore vapor barrier and finish according to insulation Specifications for this Project.

C. Mark equipment and balancing device settings with paint or other suitable, permanent identification material, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, to show final settings.

D. Take and report testing and balancing measurements in inches-pound (IP) units.

4.4 PROOF AND ACCEPTANCE OF TESTING

A. General: Proof and acceptance tests shall be made during the course of construction as specified herein below and in other Sections of this Division and as required by Authorities having jurisdiction. Such tests shall be conducted by this Division as a part of the Work and shall include all provisions, personnel, material and equipment required to perform tests until satisfactory results are obtained. Any defects detected during testing shall be satisfactorily repaired or the equipment involved shall be replaced and the tests re-executed.

B. Tests: Testing shall include, but not be limited to, all items listed in other Sections of this Division, and the following:

1. Hydrostatic Testing: All pressurized piping except diesel fuel and natural gas piping shall be hydrostatically leak-tested prior to enclosure or cover-up. Piping shall be leak tested for 24 hours under a hydrostatic pressure of 150% of the system design working pressure, but not less than 200 psi. The Architect shall be notified prior to all hydrostatic tests and may elect to witness any of the tests. Water shall not be drawn off of the piping and the piping shall not be covered up until it has been approved by the Architect. Care shall be taken to protect any equipment which
may be damaged by hydrostatic testing. Following successful testing, domestic water piping shall be sterilized as specified and chilled, high temperature and heating hot water piping shall be flushed and chemical treated as specified. Successful testing means no loss of pressure over 24-hour period except due to temperature change.

C. The test schedules for pipes shall be as follows:

<table>
<thead>
<tr>
<th>System</th>
<th>Test Medium</th>
<th>Minimum Test Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Temp (primary)</td>
<td>Water</td>
<td>600 PSIG</td>
</tr>
<tr>
<td>Heating Hot Water</td>
<td>Water</td>
<td>200 PSIG</td>
</tr>
<tr>
<td>Primary Chilled Water</td>
<td>Water</td>
<td>200 PSIG</td>
</tr>
<tr>
<td>Chilled Water</td>
<td>Water</td>
<td>200 PSIG</td>
</tr>
<tr>
<td>Make-Up Water</td>
<td>Water</td>
<td>200 PSIG</td>
</tr>
<tr>
<td>Domestic Water</td>
<td>Water</td>
<td>200 PSIG</td>
</tr>
<tr>
<td>Fire Protection Water Supply</td>
<td>Water</td>
<td>As required</td>
</tr>
</tbody>
</table>

1. Pneumatic Testing: All diesel fuel and natural gas piping shall be leak tested prior to enclosure or cover-up. Diesel piping shall be leak tested for 24 hours under a pneumatic pressure of 150 psi. Natural gas piping shall be leak tested for 24 hours under a pneumatic pressure of five times the service pressure but not less than 100 psi or a higher pressure if required by the natural gas utility. At the contractor's option, soil, waste, storm and vent piping may be tested by the use of air pressure as described in the Uniform Plumbing Code, in lieu of the leak testing method described in paragraph 3.01.B.3. Test pressure shall be 5 psi, and shall be maintained without the introduction of additional air for a period of at least 45 minutes. The Owner shall be notified prior to pneumatic tests and may elect to witness any of the tests. Air shall not be drawn off of piping until it has been approved by the Owner's representative. Care shall be taken to protect any equipment which may be damaged by pneumatic testing. Pneumatic testing is potentially explosive and Contractor shall take precautions to protect people and installation.

2. Leak Testing: All soil, waste, storm and vent piping shall be leak tested by temporarily plugging piping stacks and filling the system to be tested with standing water at 10 ft. head for 45 minutes. Water shall not be drawn off of piping and the piping shall not be covered up until it has been approved by the Owner. Additional testing shall also be provided as required by the Airport Plumbing Inspection Department. Submit the proposed test procedure and grouping to the Owner for review.

3. Fire Protection System Hydrostatic Testing: All fire protection piping (standpipes, fire sprinkler mains and branches, pumper connection piping) shall be hydrostatically tested in accordance with NFPA and local Fire Marshal requirements and additional tests shall be performed as specified.

4. Fire Pump Testing: Provide testing and certification of fire pump operation and capacity as specified.

5. Sump Pump and Sewage Ejector Testing: Provide testing and certification as specified.

6. Fuel Oil System Testing: Provide fuel system testing as specified.

7. Air Handling Unit Acoustical Performance Testing: Provide factory acoustical performance and leakage testing for air handling units as specified.

8. Stair Pressurization System Testing: The operation of the pressurization system in each pressurized stair shall be tested as follows:
   a. Verify fan stop/start control from the fire alarm system, including firefighters' override.
b. Verify proper operation of the fan inlet damper and that the stair relief damper is closed with the fan off.

c. Adjust fan speed, barometric relief dampers, discharge dampers or other volume control devices, as required, to result into stair pressurization system to comply with the pressure requirements. Coordinate work with Division 9.

d. Certify the results of all tests and verification hereinabove, for each pressurized stair.

9. Smoke Exhaust System Testing: The operation of the smoke exhaust system shall be tested as follows:

a. Verify smoke management activation/deactivation from the fire alarm system, including firefighters’ override.

b. Verify fan start/stop control from the fire alarm system, including proper speed selection and firefighters’ override and speed selection.

c. Verify air flow quantities at each floor.

d. For each floor, verify that smoke and fire dampers and makeup dampers, as applicable, open and close properly upon signal from the fire alarm system, including firefighters’ override.

e. Certify the results of all tests and verification hereinabove, for each smoke compartment and the atrium.

10. Fire Alarm System Interface: Provide testing, in conjunction with the Fire Alarm System functional testing specified, to verify that all fire alarm related HVAC control functions and shutdowns operate as specified and as shown on the Drawings.

11. Duct Leakage Testing: Provide duct integrity and leakage testing as specified.

12. Operational Testing: The Contractor shall test all systems and components installed in the building to verify proper operation is provided as described in the specifications and manufacturer’s recommendations.

13. Vibration Isolation Certification: Provide certification of the installation of vibration isolation as specified in section pertaining to Vibration Isolators and Seismic Restraints.

14. Emergency Power Operation Testing: Testing of HVAC, plumbing and fire protection system operation under emergency power shall be coordinated with electrical work such that the testing is conducted along with the emergency power system testing and certification.

15. Sewer Rodding: All sanitary and storm sewer piping shall be free of obstructions both inside the building and to the points of connection to site utilities. If blockage develops in any sanitary or storm piping within the warranty period and the blockage is due to construction related debris or defects, the Contractor shall be responsible for the cost of rodding out the piping to remove the blockage or obstruction. The rodding shall be done at no additional cost to the Owner. Notify the Owner prior to proceeding with rodding of any piping.

16. Duct Smoke Detectors: The testing and balancing agency shall direct the placement of all smoke detectors. Obtain information from the HVAC Contractor, who is to furnish the smoke detectors, on the proper differential pressure across the sampling tubes of the duct detectors. By pitot tube find the location in the ductwork where sufficient differential pressure exists. Provide this information to the HVAC Contractor. After the installation of all smoke detectors test them again in the final installation position and report differential pressures.

D. Authorities Having Jurisdiction: The Contractor shall also perform any additional proof and acceptance testing required by all applicable Authorities having jurisdiction over the project.
4.5 OPERATIONAL TESTS AND ADJUSTMENTS:

A. General: Submit HVAC, plumbing and fire protection systems to operational tests to demonstrate satisfactory system operation.

B. HVAC Systems: Operationally test and adjust project HVAC systems and their components to demonstrate satisfactory and safe operation. The test shall include verification of all valves, expansion/ball joints, dampers, safety features, etc. Operation tests shall include, but not be limited to:

1. Primary and secondary chilled water system operation.
2. High temperature heating water and heat exchangers.
3. Heating water system operation.
4. Operation of heating and cooling coils.
5. Water treatment system.
6. Air handling unit and air distribution components, such as smoke dampers, balancing dampers (including concealed damper regulators), and backdraft dampers.
7. All fans and air terminal units.
8. Humidifiers
9. Time, date and duration of each test.

C. Plumbing Systems: Operationally test and adjust project plumbing systems to demonstrate safe and satisfactory operation. Operational testing shall include, but not be limited to:

1. Water pressure at inlet and discharge of each PRV.
2. Water pressure at most remote and highest fixtures.
3. Operation of each fixture and fixture trim.
4. Operation of each valve, hydrant and faucet.
5. Operation of each backflow preventer and vacuum breaker.
6. Operation of each floor and hub drain by flooding with water.
7. Operation of each trap primer.
8. Operation of all pumps and related controls and alarms.
9. Operation of domestic water heaters and supply/return water temperature at each heater.
10. Operation of sump pumps and sewage ejectors including lead/lag and level controls and alarms.
11. Fuel oil system controls, monitoring and alarms. Proper operation of fuel oil supply and return system.
12. Test results for disinfection of domestic water system.
13. Time, date and duration of each test.
D. Fire Protection Systems: Clean storage tank and operationally test and adjust fire protection systems per NFPA to demonstrate satisfactory and safe operation. Operational testing shall include, but not be limited to:

1. Fire Service water pressure.
2. Operation of fire and jockey pumps.
3. Operation of fire protection/suppression systems.
4. Suction and discharge pressure at each pump.
5. Results of fire pump flow test.
6. Results of other required fire protection system tests.
7. Test results for all piping system leakage tests.
8. Time, date and duration of each test.

4.6 PREPARATION FOR FINAL TESTING AND BALANCING:

A. General: All air and water systems installed on the project shall be balanced and/or adjusted to provide proper operation or function in accordance with the drawings, specifications and manufacturer’s recommendations. System startup and preparation for operational testing and balancing shall be provided under this Section.

B. Prepare a TAB plan that includes strategies and step-by-step procedures.

1. Complete system readiness checks and prepare system readiness reports. Verify the following:
   a. Permanent electrical power wiring is complete.
   b. Hydronic systems are filled, clean, and free of air.
   c. Automatic temperature-control systems are operational.
   d. Equipment and duct access doors are securely closed.
   e. Balance, smoke, and fire dampers are open.
   f. Isolating and balancing valves are open and control valves are operational.
   g. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.
   h. Windows and doors can be closed so indicated conditions for system operations can be met.

C. Provisions for Operational Testing and Balancing: The Contractor shall install all provisions for operational testing and balancing as shown on the drawings, specified and required for the balancing of systems. These provisions shall include, but not be limited to all control, regulating and readout devices necessary to operationally test and balance all air and water systems including, but not limited to: thermometers; pressure gauges; air monitoring stations; flow meters; flow venturis; balancing valves; air volume, splitter and extractor dampers; pressure taps; temperature taps and wells; pitot tube ports; and other necessary provisions.

D. Coordination and Scheduling: The Contractor shall coordinate and schedule preparations for
operational testing and balancing.

E. Noted Deficiencies: The Contractor shall correct any deficiencies noted during the operational testing and balancing process. Corrections shall be made in a timely manner so as not to impede the balancing work. These corrections shall include, but not be limited to:

1. Relocating test points and sensors/controllers which are installed or positioned in a manner which prevents correct measurement or sensing of temperatures, pressure, humidity, etc. and to provide sufficient access to these devices.

2. Corrections to control functions which do not operate in accordance with the sequence of operation.

3. Recalibration of control devices.

4. Relocation of air and water taps which are installed or positioned in a manner which does not allow design flows to be obtained in the tap.

5. Relocation of balancing and control devices to provide sufficient access to these devices.

6. Addition of required balancing dampers and valves.

F. Preparation for Air Balancing: All air systems shall be completely installed, operational and prepared prior to commencing with air balancing. The minimum steps required for preparation for air balancing shall include, but not be limited to:

1. Inspection: Inspect and certify in writing that the complete air system including, not limited to: air handling equipment, fans, terminal units, coils, ductwork, air devices, dampers, controls, balancing devices, access doors, test ports and return air paths are installed and operational, as applicable.

2. Operation: Certify that the complete air system is operable and operates in a safe and normal manner.

3. Dampers: Inspect and certify in writing, that all required volume, splitter, extractor, fire, smoke and fire/smoke dampers are installed, that all balancing dampers are in the wide open and locked position, that all fire dampers are open, that all fire/smoke, smoke and control dampers open and close properly in response to control sequences and that all doors are closed and sealed.

4. Fans: Adjust and verify in writing that all fans are operating properly, are rotating at design fan RPM in the proper direction, are free from vibration, have proper belt tension and that properly sized overload elements are installed in motor starters, where motors are not self-protected. Record motor nameplate data and measured voltage and amperage on each phase at initial motor startup.

5. Variable Frequency Drives (VFD's): Verify in writing that all VFD's have been factory pre-tested prior to shipment and field tested for proper operation and controls interface.

6. Controls: Verify in writing that all required air system controls, interlocks and safety devices are fully operational and that all controlling devices are calibrated and set for designed conditions.

7. Testing: Verify in writing that all specified duct leakage and fire, smoke and fire/smoke damper testing has been successfully completed and that duct systems are clean and free of any dirt or debris.

8. Cleaning: Install clean air filters in all equipment and, where equipment has been operated, clean
coils and vacuum equipment interior in preparation for balancing. Comb out any coiled fins damaged by construction or cleaning. The Owner shall be the final decision makers on whether coils and equipment must be cleaned prior to balancing.

9. Notification: Notify the Owner in writing when all items required in paragraphs above have been completed for a specific air system and certify that the system is operational prepared for operations testing and balancing.

G. Preparation for Chilled, High Temperature Heating and Heating Water Balancing: All chilled, high temperature heating water, and heating water systems shall be completely installed, operational and prepared prior to commencing with water balancing. The minimum steps required for preparation for water balancing shall include, but are not limited to:

1. Inspection: Inspect and certify in writing that the complete water system including, but not limited to pumps, heat exchangers, coils, piping, valves, meters, venturis, gauges, thermometers, test ports and controls are installed and operational, as applicable.

2. Operation: Certify that the complete HVAC water system is operable and operates in a safe and normal manner.

3. System Filling: Verify and certify in writing that water systems are full of water and free of air, that water treatment has been installed, that properly operating air vents are installed at all system high points, that drain valves are installed at all system low points and that expansion/compression tanks are properly charged and are not water logged.

4. Valves: Inspect and certify in writing that all stop, isolation, balancing and control valves are wide open and that all bypass valves are closed. Mixing valves shall be open to system components.

5. Pumps: check and certify in writing that pumps are properly aligned, that pump bases have been grouted, that pumps are rotating in the correct direction that pumps are free from vibration and that properly sized overload elements are installed in motor starters. Record motor nameplate data measured and voltage and amperage on each phase at initial motor startup.

6. Variable Frequency Drives (VFD's): Verify in writing that all VFD's have been factory pre-tested prior to shipment and field tested for proper operation and controls interface.

7. Controls: Verify in writing that all required water system controls, interlocks and safety devices are fully operational and that all controlling devices are calibrated and set for design condition.

8. Testing: Verify in writing that all specified piping system leakage testing has been successfully completed.

9. Cleaning: Verify in writing that all specified system flushing and cleaning has been completed and that all system strainers have been removed, cleaned and reinstalled.

10. Notification: Notify the Architect in writing when all items required in paragraphs above have been completed for a specific HVAC water system and certify that the system is operational and prepared for operational testing and balancing.

4.7 AIR SYSTEM PROCEDURES

A. General:

1. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.
2. Prepare schematic diagrams of systems’ “as-built” duct layouts.
3. For variable-air-volume systems, develop a plan to simulate diversity.
4. Determine the best locations in main and branch ducts for accurate duct airflow measurements.
5. Check airflow patterns from the outside-air louvers and dampers and the return- and exhaust-air dampers, through the supply-fan discharge and mixing dampers.
6. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.
7. Verify that motor starters are equipped with properly sized thermal protection.
8. Check dampers for proper position to achieve desired airflow path.
9. Check for airflow blockages.
10. Check condensate drains for proper connections and functioning.
11. Check for proper sealing of air-handling unit components.
12. Check for proper sealing of air duct system.

B. Adjustments: Adjust all air handling systems to provide approximate design air quantity to or through, each component, and to maintain stable and comfortable interior temperatures, free of drafts or stagnant conditions. Adjusting and balancing of all systems shall be adjusted to within ten% of listed quantities shown on plans.

C. Equalizers: Equalizing devices shall be adjusted to provide uniform velocity across the inlets (duct size for supply) of terminals prior to measuring flow rates.

D. Balance: Flow adjusting (volume control) devices shall be used to balance air quantities (i.e., proportion flow between various terminals comprising system) to the extent that their adjustments do not create objectionable air motion or sound (i.e., in excess of specified limits).

1. Balancing between runs (submains, branch mains, and branches) generally shall be accomplished by flow regulating devices at, or in, the divided-flow fitting.
2. Restriction imposed by flow regulating devices in or at terminals shall be minimal.
3. Final measurements of air quality shall be made after the air terminal has been adjusted to provide the optimum air patterns of diffusion.

E. Fan Adjustment: Total air system quantities, generally, shall be varied by adjustment of fan speeds or axial-flow fan wheel blade pitch. Damper restriction of a system’s total flow may be used for systems with direct-connected fans (without adjustable pitch blades), provided system pressure is less than ½” W.G. and sound level criteria is met.

F. Air Measurement: Where air quantity measuring devices are specified in other sections such systems shall be used as a cross-check of portable measuring equipment.

1. Except as specifically indicated herein, Pitot tube traverses shall be made of each duct to measure air flow therein. Pitot tubes, associated instruments, traverses, and techniques shall conform to the ASHRAE Fundamentals Handbook “Inch Pound Edition.”
2. Where duct’s design velocity and air quantity are both less than 1000 (fpm/cfm), air quantity may be determined by measurements at terminals served.
G. Test Holes: Test holes shall be in a straight duct, as far as possible downstream from elbows, bends, take-offs, and other turbulence generating devices, to optimize reliability of flow measurements.

H. Air Terminal Balancing: Generally, measurement of flow rates by means of velocity meters applied to individual terminals, with or without cones or other adapters, shall be used only for balancing. Measurement of air quantities at each type of terminal (inlet and outlet) shall be determined by the method approved for the balancing agenda. Laboratory tests shall be conducted to prove of methodology when so directed. Such tests shall be conducted in conformance with applicable ASHRAE or American Society of Mechanical Engineers (ASME) codes and shall be made at no cost.

I. Air Motion: Air motion and distribution shall be as specified and indicated on drawings. The Contractor at no additional cost shall, in addition to air motion measurements, make smoke tests wherever requested to demonstrate the air distribution from air terminals.

4.8 AIR SYSTEM FINAL TESTING AND BALANCING:

A. Test, adjust, and balance the systems in accordance with the following requirements:

1. Test and adjust blower RPM to design requirements.
2. Test and record motor full load amperages and volts.
3. Make pilot-tube transverse of main supply, return, and outside air ducts and obtain design CFM at the air handlers, return air, and exhaust air fans.
4. Test and record system static pressure, suction, and discharge and at coils, filters and sound traps.
5. Test and adjust system for design recirculated air, supply and return CFM.
6. Test and adjust system for design minimum outside air CFM.
7. Test and adjust system for design exhaust air CFM.
8. Test and record entering air temperature (dry bulb, heating and cooling coils).
9. Test and record entering air temperatures (wet bulb, cooling coils).
10. Test and record leaving air temperatures (dry bulb, heating and cooling coils).
11. Test and record leaving air temperatures (wet bulb, cooling coils).
12. Adjust all main supply and return air ducts to proper peak design CFM.
13. Adjust all zones to proper design CFM, supply, return, and exhaust.
14. Test and adjust each variable air volume box, diffuser, grilles, and register to within tolerance limits (10%) listed herein of design requirements.
15. Adjust all diffusers, grilles, and registers to minimize drafts in all areas.
16. Readings and test records of diffusers, grilles, and registers shall include required FPM velocity and test resultant velocity, required CFM after adjustments.
17. Record inlet static pressure of each variable air volume box.
18. Identify each variable air volume box, diffusers, grilles, and register as to location and area.
19. Identify and list the size, type, and manufacture of VAV boxes, diffusers, grilles, registers, and all
tested equipment. Use manufacturer's ratings on all equipment to make required calculations.

20. All mixing boxes, VAV air valves, control dampers, smoke dampers, and similar devices which operate at 100% shut off shall be tested for leakage.

21. Balance with outside, return, and exhaust air dampers fixed in 100% outside air and 100% exhaust positions. Then verify and make adjustments for air balance under 100% return and under minimum outside air conditions. Obtain value of minimum outside air from Drawings or Owner.

22. Verify proper automatic operation of automatic outside, return, and exhaust air dampers throughout entire range of operation.

23. Adjust overall system balances to allow all self-closing exterior doors to close from any open position. Maximum interior air pressure in a 100% outside air intake mode shall not exceed 0.05% static pressure relative to the outside air pressure.

24. In cooperation with the control manufacturer’s representative, setting adjustments of automatically operated dampers to operate as specified, indicated, and/or noted. Testing agency shall check all controls requiring adjustment by control installers. Room thermostats shall be checked for cooling and heating responses.

25. As part of the work of this contract, the HVAC Contractor shall make any changes in the pulleys, belts, and dampers or the addition of dampers required for correct balance as recommended by air balance agency, at no additional cost to the Airport.

26. After air balancing is completed and RPM determined, HVAC Contractor shall provide fixed pitch pulleys.

27. Balance with filter pressure drop at midpoint between clean and dirty filters. Artificially create required pressure drop, if necessary, by blanking off coils.

28. Balance with doors and windows in their normal, closed position.

29. Balance maximum air to the following tolerances:
   a. Each Outlet: +/-10%.
   b. Each Room with Multiple Outlets: 0% to +10%.
   c. Each System: 0% to +10% of system CFM.

30. Balance main exhaust systems to maintain interior building pressure at 0.05” water greater than outdoor pressure. This may require adjustments to exhaust or return air quantities scheduled.

31. Adjust throw patterns of supply air outlets to result in uniform, draft-free room air distribution. Verify throws at maximum and minimum airflows for VAV systems at or near the design supply temperatures.

32. System design static pressures are approximations. Make changes in sheaves and belts as required for specific air balance. Final adjustment of sheaves to result in sheave with additional possible adjustment in both directions.

33. Inspect all rooms for room temperatures, drafts, and noise. Make adjustments to correct any problems.

34. Operate each room thermostat to verify correct system response to raising and lowering thermostat set points.

B. Variable Air Volume Systems:

1. Variable air Volume Fan Systems: The primary balancing mode is 100% outside air with all terminal
boxes on full cooling. Also check and record performance at minimum outside air with all terminal boxes on call for full cooling and at minimum outside air with all terminal boxes on call for full heating. Verify that the systems are operating on a stable part of the fan curves in each mode. Record final duct static controller settings.

2. General:
   a. Comply with requirements of Paragraph 3.5 article A.
   b. Follow step-by-step procedure specified; if alternate procedure is proposed, submit for review.

3. Verify proper operation of fan variable adjustment (variable frequency drives) throughout full range of operation by varying signal from duct static pressure controller.

4. Set duct static pressure controller to maintain proper duct pressure at inlet of terminal units located greatest distance from fan. Proper pressure is approximately 0.25” water greater than minimum required terminal inlet pressure during each mode of operation.

5. Operate Fans and Record the Following:
   a. Total supply CFM, by traverse of main duct.
   b. Total supply CFM, by traverse of filters or coils.
   c. Total supply CFM by totaling Terminal Unit airflows, where possible.
   d. Repeat above until equal valves are obtained or differences explained.
   e. Minimum outside air CFM.
   f. Return air CFM.
   g. Exhaust air CFM.
   h. For Supply and Exhaust Fans:
      1) Suction static pressure.
      2) Discharge static pressure.
      3) Total static pressure.
      4) Motor brake horsepower derived from motor amperes and volts.
      5) RPM.
      6) Position of fan variable adjustment (variable frequency inlet, etc.).
   i. Pressure at static pressure controllers.

C. Any changes in pulleys, belts, and dampers or the addition of dampers, etc., required to correct the air balance shall be presented to the Owner. The Contractor shall make all such changes to the system.

D. CEC Title-24 Certification: The Contractor in cooperation with the balancing contractor shall certify after completion of testing and balancing that each of the occupied areas meet the minimum ventilation requirements as set forth in CEC Standards.

4.9 HYDRONIC SYSTEMS FINAL TESTING AND BALANCING:

A. The air balance must have been accomplished before actual hydronic balance begins.

B. Test and Balance Procedure – Phase 1:
   1. Open all valves to full open position. Set temperature control valves to full coil flow.
   2. Remove all strainers and clean same, reinstall.
3. Examine water in system and determine if water has been treated and cleaned.

4. Check pump rotation.

5. Check expansion tanks to determine that they are not waterlogged and each system is completely full of water.

6. Check all air vents at high points of water systems and determine that all are installed and operating freely.

7. Coordinate this work with the mechanical work contract for the setting of all temperature controls so all coils are calling for full cooling. Use same procedure when balancing the heating coils, set on call for full heating.

8. Check operation of automatic temperature control valves.

9. Check and set operating temperatures of heating water heat exchanger to meet the design requirements.

C. Adjustment: All heating, and cooling water systems shall be adjusted to provide required quantity through each component. Flows shall be adjusted to within ten% of flows shown on plans.

D. Test and Balance Procedure - Phase 2:
   1. Set flow control devices so that heating water pumps provide proper GPM delivery.
   2. Adjust heating water flow through heat exchanger.
   3. Adjust chilled water flow through coils.
   4. Check and record leaving water temperatures and return water temperatures through heat exchanger. Reset to correct design temperatures.
   5. Check water temperatures at inlet side of cooling and heating coils. Note and report the rise or fall of temperature from source.
   6. Proceed to balance each chilled water and heating water coil (terminal unit).
   7. Upon completion of readings and adjustments at coils, mark all settings and record data. Mark all balancing valves to locate final balanced position.

E. Test and Balance Procedure - Phase 3:
   1. After adjustments to coils are made, recheck settings at the pumps and heat exchanger, and readjust if required.
   2. Install pressure gauges on coils, read pressure drop through coils at set flow rate on call for full cooling and for full heating.
   3. Record and check the following items at each cooling and heating element:
      a. Inlet water temperature.
      b. Leaving water temperature.
      c. Pressure drop of each coil.
      d. Pressure drop across heat exchanger.
      e. Pumps operating suction and discharge pressure and final T.D.H.
      f. List all mechanical specifications of the pumps.
g. Rating and actual running amperage of pump motors and brake horsepower.

4. Air Heating and Cooling Equipment:
   a. Design data
      1) Load in Btu or Mbh (thousands of Btu)
      2) GPM
      3) Entering and leaving water temperature
      4) Entering and leaving air conditions (DB and WB)
      5) CFM
      6) Water pressure drop
   b. Recorded data
      1) Type of equipment and identification (location or number designation)
      2) Entering and leaving air conditions (DB and WB)
      3) Entering and leaving water temperatures
      4) GPM (if metered) Temperature rise or drop

F. Metering: Water quantities and pressures shall be measured with calibrated meters.
   1. Venturi tubes, orifices, or other metering fittings and pressure gauges shall be used to measure water flow rates and balance systems. Systems shall be adjusted to provide the approved pressure drops through the heat transfer equipment (coils except room units, converters, etc.) prior to the capacity testing.
   2. Where flow metering fittings are not installed, in air/water type heat transfer equipment, flow balance shall be determined by measuring the air side energy differential across the heat transfer equipment. Measurement of water temperature differential shall be performed with the air system, adjusted as described herein, in operation.

G. Automatic Controls: Automatic control valves shall be positioned for full flow through the heat transfer equipment of the system during tests.

H. Flow: Flow through bypass circuits at three-way valves shall be adjusted to equal that through the supply circuit, when the valve is in the bypass position.

I. Distribution: Adjustment of distribution shall be effected by means of balancing devices ( cocks, valves, and fittings) and automatic flow control valves as provided; service valves shall not be used.
   1. Where automatic flow control valves are utilized in lieu of Venturi tubes, only pressure differential need be recorded, provided that the pressure is at least the minimum applicable tag rating.

4.10 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.
   1. Measure fan static pressures to determine actual static pressure as follows:
      a. Measure outlet static pressure as far downstream from the fan as practicable and upstream from restrictions in ducts such as elbows and transitions.
b. Measure static pressure directly at the fan outlet or through the flexible connection.
c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from flexible connection and downstream from duct restrictions.
d. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.

2. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and-treating equipment.
   a. Simulate dirty filter operation and record the point at which maintenance personnel must change filters.

3. Measure static pressures entering and leaving other devices such as sound traps, heat recovery equipment, and air washers, under final balanced conditions.

4. Compare design data with installed conditions to determine variations in design static pressures versus actual static pressures. Compare actual system effect factors with calculated system effect factors to identify where variations occur. Recommend corrective action to align design and actual conditions.

5. Obtain approval from Engineer for adjustment of fan speed higher or lower than indicated speed. Make required adjustments to pulley sizes, motor sizes, and electrical connections to accommodate fan-speed changes.

6. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full cooling, full heating, economizer, and any other operating modes to determine the maximum required brake horsepower.

B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows within specified tolerances.

1. Measure static pressure at a point downstream from the balancing damper and adjust volume dampers until the proper static pressure is achieved.
   a. Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.

2. Re-measure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.

C. Measure terminal outlets and inlets without making adjustments.

1. Measure terminal outlets using a direct-reading hood or outlet manufacturer’s written instructions and calculating factors.

D. Adjust terminal outlets and inlets for each space to indicated airflows within specified tolerances of indicated values. Make adjustments using volume dampers rather than extractors and the dampers at air terminals.

1. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.
2. Adjust patterns of adjustable outlets for proper distribution without drafts.

4.11 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

A. Compensating for Diversity: When the total airflow of all terminal units is more than the indicated airflow of the fan, place a selected number of terminal units at a maximum set-point airflow condition until the total airflow of the terminal units equals the indicated airflow of the fan. Select the reduced airflow terminal units so they are distributed evenly among the branch ducts.

B. Pressure-Dependent, Variable-Air-Volume Systems without Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Balance systems similar to constant-volume air systems.
2. Set terminal units and supply fan at full-airflow condition.
3. Adjust inlet dampers of each terminal unit to indicated airflow and verify operation of the static-pressure controller. When total airflow is correct, balance the air outlets downstream from terminal units as described for constant-volume air systems.
4. Readjust fan airflow for final maximum readings.
5. Measure operating static pressure at the sensor that controls the supply fan, if one is installed, and verify operation of the static-pressure controller.
6. Set supply fan at minimum airflow if minimum airflow is indicated. Measure static pressure to verify that it is being maintained by the controller.
7. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow as described for constant-volume air systems.
   a. If air outlets are out of balance at minimum airflow, report the condition but leave the outlets balanced for maximum airflow.
8. Measure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets as described for constant-volume air systems.

C. Pressure-Dependent, Variable-Air-Volume Systems with Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Set system at maximum indicated airflow by setting the required number of terminal units at minimum airflow. Select the reduced airflow terminal units so they are distributed evenly among the branch ducts.
2. Adjust supply fan to maximum indicated airflow with the variable-airflow controller set at maximum airflow.
3. Set terminal units at full-airflow condition.
4. Adjust terminal units starting at the supply-fan end of the system and continuing progressively to the end of the system. Adjust inlet dampers of each terminal unit to indicated airflow. When total airflow is correct, balance the air outlets downstream from terminal units as described for constant-volume air systems.
5. Adjust terminal units for minimum airflow.
6. Measure static pressure at the sensor.

7. Measure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets as described for constant-volume air systems.

### 4.12 PROCEDURE FOR MOTORS

**A. Motors, ½ HP and Larger:** test at final balanced conditions and record the following data:

1. Manufacturer, model, and serial numbers.
4. Efficiency rating.
5. Nameplate and measured voltage, each phase.
6. Nameplate and measured amperage, each phase.
7. Starter thermal-protection-element rating.

**B. Motors Driven by Variable-Frequency Controllers:** Test for proper operation at speeds varying from minimum to maximum. Test the manual bypass for the controller to prove proper operation. Record observations, including controller manufacturer, model and serial numbers, and nameplate data.

### 4.13 PROCEDURES FOR CONDENSING UNITS

**A.** Verify proper rotation of fans.

**B.** Measure entering and leaving-air temperatures.

**C.** Record compressor data.

### 4.14 PROCEDURES FOR HEAT-TRANSFER COILS

**A. Water Coils:** Measuring the following data for each coil:

1. Entering- and leaving-water temperature.
2. Water flow rate.
3. Water pressure drop.
4. Dry-bulb temperature of entering and leaving air.
5. Wet-bulb temperature of entering and leaving air for cooling coils.
6. Airflow.
7. Air pressure drop.

**B. Refrigerant Coils:** Measure the following data for each coil:

1. Dry-bulb temperature of entering and leaving air.
2. Wet-bulb temperature of entering and leaving air.
3. Airflow.
4. Air pressure drop.
5. Refrigerant suction pressure and temperature.

C. Coil Capacity Verification

1. Air coil capacities shall be verified from air side measurement data. Capacities of coils shall be the difference of the energy carried by the air between the upstream and downstream of the coils.
2. The measured air flow rate for the fan may be used for air coil capacity calculations providing no ducted bypassing of coil is occurring.
3. Capacity verification shall be performed after air and water systems have been balanced.
4. False load shall be applied if the upstream air or water does not meet the specified conditions at the time of test.

4.15 PROCEDURES FOR TEMPERATURE MEASUREMENTS

A. During TAB, report the need for adjustment in temperature regulation within the automatic temperature-control system.

B. Measure indoor wet- and dry-bulb temperatures every other hour for a period of two successive eight-hour days, in each separately controlled zone, to prove correctness of final temperature settings. Measure when the building or zone is occupied.

C. Measure outside-air, wet- and dry-bulb temperatures.

4.16 PROCEDURES FOR SPACE PRESSURIZATION MEASUREMENTS AND ADJUSTMENTS

A. Before testing for space pressurization, observe the space to verify the integrity of the space boundaries. Verify that windows and doors are closed and applicable safing, gaskets, and sealants are installed. Report deficiencies and postpone testing until after the reported deficiencies are corrected.

B. Measure, adjust, and record the pressurization of each room, each zone, and each building by adjusting the supply, return, and exhaust airflows to achieve the indicated conditions.

C. Measure space pressure differential where pressure is used as the design criteria, and measure airflow differential where differential airflow is used as the design criteria for space pressurization.

1. For pressure measurements, measure and record the pressure difference between the intended spaces at the door with all doors in the space closed. Record the high-pressure side, low-pressure side, and pressure difference between each adjacent space.
2. For applications with cascading levels of space pressurization, begin in the most critical space and work to the least critical space.
3. Test room pressurization first, then zones, and finish with building pressurization.

D. To achieve indicated pressurization, set the supply airflow to the indicated conditions and adjust the exhaust and return airflow to achieve the indicated pressure or airflow difference.

E. For spaces with pressurization being monitored and controlled automatically, observe and adjust the controls to achieve the desired set point.
1. Compare the values of the measurements taken to the measured values of the control system instruments and report findings.

2. Check the repeatability of the controls by successive tests designed to temporarily alter the ability to achieve space pressurization. Test overpressurization and underpressurization, and observe and report on the system’s ability to revert to the set point.

3. For spaces served by variable-air-volume supply and exhaust systems, measure space pressurization at indicated airflow and minimum airflow conditions.

F. In spaces that employ multiple modes of operation, such as normal mode and emergency mode or occupied mode and unoccupied mode, measure, adjust, and record data for each operating mode.

G. Record indicated conditions and corresponding initial and final measurements. Report deficiencies.

4.17 TEMPERATURE-CONTROL VERIFICATION

A. Verify that controllers are calibrated and commissioned.

B. Check transmitter and controller locations and note conditions that would adversely affect control functions.

C. Record controller settings and note variances between set points and actual measurements.

D. Check the operation of limiting controllers (i.e., high- and low-temperature controllers).

E. Check free travel and proper operation of control devices such as damper and valve operators.

F. Check the sequence of operation of control devices. Note air pressures and device positions and correlate with airflow and water flow measurements. Note the speed of response to input changes.

G. Check the interaction of electrically operated switch transducers.

H. Check the interaction of interlock and lockout systems.

I. Check main control supply-air pressure and observe compressor and dryer operations.

J. Record voltages of power supply and controller output. Determine whether the system operates on a grounded or non-grounded power supply.

K. Note operation of electric actuators using spring return for proper fail-safe operations.

4.18 SOUND TEST PROCEDURES

A. Scope: Tests of sound levels shall be made at each selection point included in the agenda.

B. Timing: sound level measurements shall be taken at times when the building is unoccupied, or when activity in surrounding areas and background noise levels in areas tested are at a minimum and relatively free from sudden changes in noise levels.

1. Measurements shall be taken with all equipment turned off, except that being tested.

2. The required sound levels shall be measured at any point within a room not less than 6 feet from
an air terminal unit or room unit, and not closer than 3 feet from any floor, wall, or ceiling surface.

C. Meters: Sound levels shall be measured with a sound meter complying with ANSI S1.4. The “A” scale shall be used to measure over all sound levels. To determine the specified octave band levels, the above sound level meter, set on “C” scale, shall be supplemented by an octave band analyzer complying with ANSI S1.11.

D. Equipment Components: The “Equipment Component” of room sound equals L_Pt-C. The “Equipment Component” of room sound (noise) levels shall be determined for each of eight octave bands as follows:

1. Measure room sound pressure level “L_Pb” with equipment to be tested shut off.
2. Measure room sound pressure level “L_Pt” with equipment to be tested turned on.
3. Calculate L_Pt-L_Pb; if this value is less than 1, applicable test must be rerun with lower background level (L_Pb) unless L_Pt is within sound pressure level specified for equipment.
4. Determine “c” from the table below

<table>
<thead>
<tr>
<th>L_Pt-L_Pb (db)</th>
<th>c(db)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4 to 4-1/2</td>
<td>2</td>
</tr>
<tr>
<td>5 to 5-1/2</td>
<td>1.5</td>
</tr>
<tr>
<td>6 to 7-1/2</td>
<td>1</td>
</tr>
<tr>
<td>8 to 12</td>
<td>0</td>
</tr>
<tr>
<td>Over 12</td>
<td>0</td>
</tr>
</tbody>
</table>

4.19 SOUND LEVEL DATA

A. Report: certified report shall record data on sound levels, taken at each selected location, as follows:

1. Source of sound and location.
2. Diagram or description of relationship of sound source to measuring instrument.
3. “A” scale readings equipment being tested turned off (ambient) equipment being tested turned on (operating conditions).
4. Readings at each specified octave band frequency equipment being tested turned off (ambient) equipment being tested turned on (operating conditions).
5. “Equipment Components” of sound (noise) levels with applicable calculations per “Sound Test Procedures”.
6. Graph showing relationship between pressure levels specified and recorded readings.

B. Retest: Subsequent to any correctional construction work, such as acoustic corrections, measurement shall be made to verify that associated air and water quantities, as previously measured, have not been disrupted.

1. Certified report shall record all sound data, and their locations, after final adjustments of air and
4.20 TOLERANCE

A. Set HVAC system airflow and water flow rates within the following tolerances:
   1. Supply, Return, and Exhaust Fans and Equipment with Fans: Plus 5 to plus 10%.
   2. Air Outlets and Inlets: 0 to minus 10%.
   3. Heating-Water Flow Rate: 0 to minus 10%.
   4. Cooling-Water Flow Rate: 0 to minus 5%.

4.21 REPORTING

A. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in Examination Article of this Section, prepare a report on the adequacy of design for systems' balancing devices. Recommend changes and additions to systems' balancing devices to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.

B. Status Reports: As Work progresses, prepare reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

C. Final Report: Final report shall be provided to the building official for review and approval.

4.22 FINAL REPORT

A. General: Typewritten, or computer printout in letter-quality font, on standard bond paper, in three-ring binder, tabulated and divided into sections by tested and balanced systems.

B. Include a certification sheet in front of binder signed and sealed by the certified testing and balancing engineer.
   1. Include a list of instruments used for procedures, along with proof of calibration.

C. Final Report Contents: In addition to certified field report data, include the following:
   1. Pump curves.
   2. Fan curves.
   3. Manufacturers' test data.
   4. Field test reports prepared by system and equipment installers.
   5. Other information relative to equipment performance, but do not include shop drawings and product data.

D. General Report Data: In addition to form titles and entries, include the following data in the final report, as applicable:
   1. Title page.
   2. Name and address of TAB firm.
3. Project name.
4. Project location.
5. Architect’s name and address.
6. Engineer’s name and address.
7. Contractor’s name and address.
9. Signature of TAB firm who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
11. Summary of contents including the following:
   a. Indicated versus final performance.
   b. Notable characteristics of systems.
   c. Description of system operation sequence if it varies from the Contract Documents.
12. Nomenclature sheets for each item of equipment.
13. Data for terminal units, including manufacturer, type size, and fittings.
14. Notes to explain why certain final data in the body of reports varies from indicated values.
15. Test conditions for fans and pump performance forms including the following:
   a. Settings for outside-, return-, and exhaust-air dampers.
   b. Conditions of filters.
   c. Cooling coil, wet- and dry-bulb conditions.
   d. Face and bypass damper settings at coils.
   e. Fan drive settings including settings and percentage of maximum pitch diameter.
   f. Inlet vane settings for variable-air-volume systems.
   g. Settings for supply-air, static-pressure controller.
   h. Other system operating conditions that affect performance.

E. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:
1. Quantities of outside, supply, return, and exhaust airflows.
2. Water and steam flow rates.
3. Duct, outlet, and inlet sizes.
4. Pipe and valve sizes and locations.
5. Terminal units.

F. Air-Handling Unit Test Reports: For air-handling units with coils, include the following:
1. Unit Data: Include the following:
   a. Unit identification.
   b. Location.
   c. Make and type.
   d. Model number and unit size.
   e. Manufacturer’s serial number.
   f. Unit arrangement and class.
   g. Discharge arrangement.
h. Sheave make, size in inches, and bore.
i. Sheave dimensions, center-to-center, and amount of adjustments in inches.
j. Number of belts, make, and size.
k. Number of filters, type, and size.

2. Motor Data:
a. Make and frame type and size.
b. Horsepower and rpm.
c. Volts, phase, and hertz.
d. Full-load amperage and service factor.
e. Sheave make, size in inches, and bore.
f. Sheave dimensions, center-to-center, and amount of adjustments in inches.

3. Test Data (Indicated and Actual Values):
a. Total airflow rate in cfm.
b. Total system static pressure in inches wg.
c. Fan rpm.
d. Discharge static pressure in inches wg.
e. Filter static-pressure differential in inches wg.
f. Preheat coil static-pressure differential in inches wg.
g. Cooling coil static-pressure differential in inches wg.
h. Heating coil static-pressure differential in inches wg.
i. Outside airflow in cfm.
j. Return airflow in cfm.
k. Outside-air damper position.
l. Return-air damper position.
m. Vortex damper position.

G. Apparatus-Coil Test Reports:

1. Coil Data:
a. System identification.
b. Location.
c. Coil type.
d. Number of rows.
e. Fin spacing in fins per” o.c.
f. Make and model number.
g. Face area in square feet.
h. Tube size in NPS.
i. Tube and fin materials.
j. Circuiting arrangement.

2. Test Data (Indicated and Actual Values):
a. Airflow rate in cfm.
b. Average face velocity in fpm.
c. Air pressure drop in inches wg.
d. Outside-air, wet- and dry-bulb temperatures in °F.
e. Return-air, wet- and dry-bulb temperatures in °F.
f. Entering-air, wet- and dry-bulb temperatures in °F.
g. Leaving-air, wet- and dry-bulb temperatures in °F.
h. Water flow rate in gpm.
i. Water pressure differential in feet of head or psig.
j. Entering-water temperature in °F.
k. Leaving-water temperature in °F.
l. Refrigerant expansion valve and refrigerant types.
m. Refrigerant suction pressure in psig.
n. Refrigerant suction temperature in °F.
o. Inlet steam pressure in psig.

H. Gas- and Oil-Fired Heat Apparatus Test Reports: In addition to manufacturer's factory startup equipment reports, include the following:

1. Unit Data:
   a. System identification.
   b. Location.
   c. Make and type.
   d. Model number and unit size.
   e. Manufacturer’s serial number.
   f. Fuel type in input data.
   g. Output capacity in Btuh.
   h. Ignition type.
   i. Burner-control types.
   j. Motor horsepower and rpm.
   k. Motor volts, phase, and hertz.
   l. Motor full-load amperage and service factor.
   m. Sheave make, size in inches, and bore.
   n. Sheave dimensions, center-to-center, and amount of adjustments in inches.

2. Test Data (Indicated and Actual Values):
   a. Total airflow rate in cfm.
   b. Entering-air temperature in °F.
   c. Leaving-air temperature in °F.
   d. Air temperature differential in °F.
   e. Entering-air static pressure in inches wg.
   f. Leaving-air static pressure in inches wg.
   g. Air static-pressure differential in inches wg.
   h. Low-fire fuel input in Btuh.
   i. High-fire fuel input in Btuh.
   j. Manifold pressure in psig.
   k. High-temperature-limit setting in °F.
   l. Operating set point in Btuh.
   m. Motor amperage for each phase.
   n. Heating value of fuel in Btuh.

I. Fan Test Reports: For supply, return, and exhaust fans, include the following:

1. Fan Data:
   a. System identification.
   b. Location.
   c. Make and type.
   d. Model number and size.
   e. Manufacturer’s serial number.
   f. Arrangement and class.
2. Motor Data:
   a. Make and frame type and size.
   b. Horsepower and rpm.
   c. Volts, phase, and hertz.
   d. Full-load amperage and service factor.
   e. Sheave make, size in inches, and bore.
   f. Sheave dimensions, center-to-center, and amount of adjustments in inches.
   g. Number of belts, make, and size.

3. Test Data (Indicated and Actual Values):
   a. Total airflow rate in cfm.
   b. Total system static pressure in inches wg.
   c. Fan rpm.
   d. Discharge static pressure in inches wg.
   e. Suction static pressure in inches wg.

J. Round, Flat-Oval, and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:

1. Report Data:
   a. System and air-handling unit number.
   b. Location and zone.
   c. Traverse air temperature in °F.
   d. Duct static pressure in inches wg.
   e. Duct size in inches.
   f. Duct area in square feet.
   g. Indicated airflow rate in cfm.
   h. Indicated velocity in fpm.
   i. Actual airflow rate in cfm.
   j. Actual average velocity in fpm.
   k. Barometric pressure in psig.

K. Air-Terminal-Device Reports:

1. Unit Data:
   a. System and air-handling unit identification.
   b. Location and zone.
   c. Test apparatus used.
   d. Area served.
   e. Air-terminal-device make.
   f. Air-terminal-device number from system diagram.
   g. Air-terminal-device type and model number.
   h. Air-terminal-device size.
   i. Air-terminal-device effective area in square feet

2. Test Data (Indicated and Actual Values):
   a. Airflow rate in cfm.
   b. Air velocity in fpm.
c. Preliminary airflow rate as needed in cfm.
d. Preliminary velocity as needed in fpm.
e. Final airflow rate in cfm.
f. Final velocity in fpm.
g. Space temperature in °F.

L. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:

1. Unit Data:
   a. System and air-handling unit identification.
   b. Location and zone.
   c. Room or riser served.
   d. Coil make and size.
   e. Flowmeter type.

2. Test Data (Indicated and Actual Values):
   a. Airflow rate in cfm.
   b. Entering-water temperature in °F.
   c. Leaving-water temperature in °F.
   d. Water pressure drop in feet of head or psig.
   e. Entering-air temperature in °F.
   f. Leaving-air temperature in °F.

M. Compressor and Condenser Reports: For refrigerant side of unitary systems, stand-alone refrigerant compressors, air-cooled condensing units, or water-cooled condensing units, include the following:

1. Unit Data:
   a. Unit identification.
   b. Location.
   c. Unit make and model number.
   d. Compressor make.
   e. Compressor model and serial numbers.
   f. Refrigerant weight in lb.
   g. Low ambient temperature cutoff in °F.

2. Test Data (Indicated and Actual Values):
   a. Inlet-duct static pressure in inches wg.
   b. Outlet-duct static pressure in inches wg.
   c. Entering-air, dry-bulb temperature in °F.
   d. Leaving-air, dry-bulb temperature in °F.
   e. Condenser entering-water temperature in °F.
   f. Condenser leaving-water temperature in °F.
   g. Condenser-water temperature differential in °F.
   h. Condenser entering-water pressure in feet of head or psig.
   i. Condenser leaving-water pressure in feet of head or psig.
   j. Condenser-water pressure differential in feet of head or psig.
   k. Control settings.
   l. Unloader set points.
   m. Low-pressure-cutout set point in psig.
   n. High-pressure-cutout set point in psig.
   o. Suction pressure in psig.
p. Suction temperature in °F.
q. Condenser refrigerant pressure in psig.
r. Condenser refrigerant temperature in °F.
s. Oil pressure in psig.
t. Oil temperature in °F.
u. Voltage at each connection.
v. Amperage for each phase.
w. Kilowatt input.
x. Crankcase heater kilowatt.
y. Number of fans.
z. Condenser fan rpm.
aa. Condenser fan airflow rate in cfm.
bb. Condenser fan motor make, frame size, rpm, and horsepower. cc. Condenser fan motor voltage at each connection.
cc. Condenser fan motor amperage for each phase.

N. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves and include the following:

1. Unit Data:
   a. Unit identification.
   b. Location.
   c. Service.
   d. Make and size.
   e. Model and serial numbers.
   f. Water flow rate in gpm.
   g. Water pressure differential in feet of head or psig.
   h. Required net positive suction head in feet of head or psig.
   i. Pump rpm.
   j. Impeller diameter in inches.
   k. Motor make and frame size.
   l. Motor horsepower and rpm.
   m. Voltage at each connection.
   n. Amperage for each phase.
   o. Full-load amperage and service factor.
   p. Seal type.

2. Test Data (Indicated and Actual Values):
   a. Static head in feet of head or psig.
   b. Pump shutoff pressure in feet of head or psig.
   c. Actual impeller size in inches.
   d. Full-open flow rate in gpm.
   e. Full-open pressure in feet of head or psig.
   f. Final discharge pressure in feet of head or psig.
   g. Final suction pressure in feet of head or psig.
   h. Final total pressure in feet of head or psig.
   i. Final water flow rate in gpm.
   j. Voltage at each connection.
   k. Amperage for each phase.

O. Boiler Test Reports:

1. Unit Data:
Section 23 05 93 | Testing, Adjusting and Balancing for HVAC

a. Unit identification.
b. Location.
c. Service.
d. Make and type.
e. Model and serial numbers.
f. Fuel type and input in Btuh.
g. Number of passes.
h. Ignition type.
i. Burner-control types.
j. Voltage at each connection.
k. Amperage for each phase.

2. Test Data (Indicated and Actual Values):
   a. Operating pressure in psig.
   b. Operating temperature in °F.
   c. Entering-water temperature in °F.
   d. Leaving-water temperature in °F.
   e. Number of safety valves and sizes in NPS.
   f. Safety valve settings in psig.
   g. High-limit setting in psig.
   h. Operating-control setting.
   i. High-fire set point.
   j. Low-fire set point.
   k. Voltage at each connection.
   l. Amperage for each phase.
   m. Draft fan voltage at each connection.
   n. Draft fan amperage for each phase.
   o. Manifold pressure in psig.

P. Indoor-Air Quality Measurement Reports for Each HVAC System:
   1. HVAC system designation.
   2. Date and time of test.
   3. Outdoor temperature, relative humidity, wind speed, and wind direction at start of test.
   4. Room number or similar description for each location.
   5. Measurements at each location.
   6. Observed deficiencies.

Q. Instrument Calibration Reports:
   1. Report Data:
      a. Instrument type and make.
      b. Serial number.
      c. Application.
      d. Dates of use.
      e. Dates of calibration.

4.23 ACCEPTANCE OF FINAL BALANCING:

A. After the balance report has been reviewed by the Airport’s representative will perform random testing of air outlets, with the Contractor present, who shall also furnish the calibrated air flow meter and other measuring instruments. The Contractor shall recheck random selection of data (water and air.
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quantities, air motion, and sound levels) recorded in the certified report.

B. Randomly check the following for each system:
   1. Measure airflow of at least 10% of air outlets.
   2. Measure water flow of at least 5% of terminals.
   3. Measure room temperature at each thermostat/temperature sensor. Compare the reading to the set point.
   4. Measure sound levels at two locations.
   5. Measure space pressure of at least 10% of locations.
   6. Verify that balancing devices are marked with final balance position.

C. Points and areas for recheck shall be selected by the Airport representative.

D. Measurement and test procedures shall be the same as approved for work forming basis of certified report.

E. Selections for recheck (specific plus random), in general, will not exceed 25% of the total number tabulated in the report, except that special air systems may require a complete recheck for safety reasons.

F. Retests: If random tests elicit a measured flow deviation of 10% or more from, or a sound level of 2 db or more that recorded in the certified report listings, as 10% or more of the rechecked selections, the report shall be automatically rejected. In the event the report is rejected, all systems shall be readjusted and tested, new data recorded, new certified reports submitted, and new inspection tests made, all at no additional cost.

G. Marking of Settings: Following final acceptance of certified reports, the settings of all valves, splitters, dampers, and other adjustment devices shall be permanently marked by the Contractor so that adjustment can be restored if disturbed at any time. Devices shall not be marked until after final acceptance.

4.24 The Owner shall also have the option of using a separate independent contractor to rebalance the system with all such costs borne by the Mechanical Contractor. The process will be repeated for all air handling systems, outside air systems and exhaust systems with total airflows exceeding 2000 CFM.

4.25 FINAL INSPECTION

A. After initial inspection is complete and evidence by random checks verifies that testing and balancing are complete and accurately documented in the final report, request that a final inspection be made by the Engineer.

B. TAB firm test and balance engineer shall conduct the inspection in the presence of the Engineer.

C. Owner shall randomly select measurements documented in the final report to be rechecked. The rechecking shall be limited to either 10% of the total measurements recorded, or the extent of measurements that can be accomplished in a normal 8-hour business day.

D. If the rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as “FAILED.”
E. If the number of “FAILED” measurements is greater than 10% of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.

F. TAB firm shall recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes and resubmit the final report.

G. Request a second final inspection. If the second final inspection also fails, Engineer shall contract the services of another TAB firm to complete the testing and balancing in accordance with the Contract Documents and deduct the cost of the services from the final payment.

4.26 ADDITIONAL TESTS

A. Within 90 days of completing TAB, perform additional testing and balancing to verify that balanced conditions are being maintained throughout and to correct unusual conditions.

B. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional testing, inspecting, and adjusting during near-peak summer and winter conditions.

END OF SECTION 23 05 93
SECTION 23 07 00 – HVAC INSULATION

PART 1 – GENERAL

1.1 DESCRIPTION

A. General: Provide mechanical insulation in accordance with the contract documents.

1.2 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this Section shall comply with all the requirements of Standards & Criteria for HVAC.

1.3 SCOPE

A. Work to be furnished and installed under this Section shall include, but not necessarily be limited to, providing insulation for the following:

1. All supply air and return air ductwork.
2. Acoustical duct lining in supply and return ducts and as indicated on Drawings.
3. Condensate drains inside the building from cooling coil drip pans to discharge point.
4. Heating hot water supply and return piping.
5. Chilled water supply and return piping.
6. Valves and fittings in insulated piping systems.
7. Repair or replacement of existing duct and pipe insulation and/or duct lining removed or damaged for installation of new work.

B. Types of mechanical insulation specified in this Section include the following:

1. Fiberglass pipe insulation.
2. Cellular glass pipe insulation.
3. Calcium silicate pipe insulation.
4. Flexible unicellular pipe insulation.
5. Fiberglass duct insulation.
6. Cellular glass duct insulation.
7. Flexible unicellular duct installation.
8. Fiberglass equipment insulation.
9. Calcium silicate equipment insulation.
10. Cellular glass equipment insulation.
11. Flexible unicellular equipment insulation.
12. Insulation jackets.
13. Insulation accessories.

1.4 Note: More durable insulation protection shall be added at areas more susceptible to damage.
1.5 REFERENCES

A. Codes and Standards: Provide products conforming to the requirements of the following:

1. American Society for Testing and Materials (ASTM): Manufacture and test insulation in accordance with the ASTM standards, including:
   a. B209 – Specification for Aluminum and Aluminum-Alloy Sheet and Plate
   b. C165 – Recommended Practice for Measuring Compressive Properties of Thermal Insulation

B. Insulation

   a. C167 – Test Methods for Thickness and Density of Blanket or Batt Thermal Insulations
   d. C196 – Specification for Expanded or Exfoliated Vermiculite Thermal Insulating Cement
   e. C302 – Test Method for Density of Preformed Pipe-Covering-Type Thermal Insulation
   f. C303 – Test Method for Density of Preformed Block-Type Thermal Insulation
   g. C305 – Test for Thermal Conductivity of Pipe Insulation
   h. C356 – Test for Linear Shrinkage of Preformed High-Temperature Thermal Insulation
   i. C411 – Test for Hot-Surface Performance of High Temperature Thermal Insulation
   k. C533 – Specification for Calcium Silicate Block and Pipe Thermal Insulation
   l. C534 – Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form
   m. C547 – Specification for Mineral Fiber Preformed Pipe Insulation
   n. C552 – Specification for Cellular Glass Black and Pipe Thermal Insulation
   o. C553 – Specification for Mineral Fiber Blanket-Type Pipe Insulation (Industrial Type)
   p. C592 – Mineral Fiber Blanket Insulation and Blanket-Type Pipe Insulation (Metal-Mesh Covered)
   q. C612 – Specification for Mineral Fiber Block and Board Thermal Insulation
   r. C916 – Standard Specification for Adhesives for Duct Thermal Insulation
   s. C921 – Practice for Determining Properties of Jacketing Materials for Thermal Insulation

2. American Society of Heating, Refrigerating, and Air-Conditioning (ASHRAE): Provide and install pipe and duct insulation in accordance with the following ASHRAE standard:
   a. 90 – Energy Conservation in New Building Design

3. National Fire Protection Association (NFPA): Manufacture insulation in accordance with the following NFPA standards:
   a. 225 – Test Methods, Surface Burning Characteristics of Building Materials

4. Sheet Metal and Air Conditioning Contractors’ National Association (SMACNA)
5. Underwriters Laboratories (UL)

1.6 QUALITY ASSURANCE

A. Flame/Smoke Rating: Provide composite mechanical insulation (insulation, jackets, coverings, sealers, mastics and adhesives) with flame-spread index 25 or less, and smoke-developed index of 50 or less, as tested by ASTM E84 (NFPA 255) method. In addition, the products, when tested, shall not drip flame particles, and flame shall not be progressive. Provide Underwriters Laboratories (UL), Inc., label or listing, or satisfactory certified test report from an approved testing laboratory to prove the fire hazard ratings for materials proposed for use do not exceed those specified.

B. Corrosiveness: Provide insulation such that when tested in accordance with the following test, the steel plate in contact with the insulation shows no greater corrosion than sterile cotton in contact with a steel plate for comparison.

1. Test Specimen: Two specimens shall be used, each measuring 1” by 4” by approximately ½” thick.

2. Apparatus: Provide a humidity test chamber in which two polished-steel test plates 1” wide, 4” long and 0.020” thick shall be placed. Plates shall be clear finish, cold-rolled strip steel, American quality, quarter hard, temper No. 3, weighing 0.85 lb/sq.ft.

3. Procedure; The steel test plates shall be rinsed with cp benzol until their surfaces are free from oil and grease and allowed to dry. One piece of cold-rolled steel shall be placed between the two insulation specimens and secured with tape or twine. The test specimen and uncovered plate shall be suspended vertically in an atmosphere having a relative humidity of 95% plus or minus 3%, and a temperature of 120° plus or minus 3 °F, for 96 hours, and then be examined for corrosion.

C. Products Containing Prohibited Chemicals:

1. Products containing the following prohibited chemicals for use as flame retardants or for other purposes will not be acceptable when present in quantities greater than 0.1% by mass:
   a. Pentabrominated diphenyl ether (CAS#32534-81-9)
   b. Octabrominated diphenyl ether (CAS#32536-52-0)
   c. Decabrominated diphenyl ether (CAS#1163-19-50)

D. Insulation thickness shall be the greater of that specified here or the State energy conservation requirements.

1.7 SUBMITTALS

A. Shop Drawings submittals shall include, but not be limited to, the following:

1. Cut sheets on all insulation products to be used.

2. Cut sheets on all mastics and other products to be used with insulation products.

3. Cut sheets on PVC and aluminum jacketing materials.

4. Manufacturer’s printed installation instructions for all of the above products.

5. Additional information as required by General Requirements.

B. Product Data: Submit manufacturer’s technical product data and installation instructions for each type of mechanical insulation. Submit schedule showing manufacturer’s product number, K- value,
Section 23 07 00 | HVAC Insulation

thickness, and furnished accessories for each mechanical system requiring insulation. Also furnish necessary test data certified by an independent testing laboratory.

C. Maintenance Data: Submit maintenance data and replacement material lists for each type of mechanical insulation. Include this data and product maintenance manual.

1.8 DELIVERY, STORAGE AND HANDLING

A. Deliver products to site under provisions of division 1. Deliver insulation, coverings, cements, adhesives, and coating to the site in containers with manufacturer’s stamp or label affixed showing fire hazard indexes of products.

B. Store insulation products in their factory-furnished coverings, and in a clean, dry indoor space which provides protection against the weather, dirt, water, chemical, and mechanical damage.

C. Do not install damaged or wet insulation; remove from project site.

PART 2 – PRODUCTS

2.1 GENERAL

A. Quality: The type of insulation and its installation in accordance with this Section of the Specifications for each service and the application technique shall be as recommended by the manufacturer.

B. Fire Rating: All insulation shall have a composite (insulation, jacket or facing and adhesive used to adhere facing or jacket to insulation) fire and smoke hazard, as tested by ASTM E84, NFPA 255, and UL 723, not to exceed:
   1. Flame Spread - 25.
   2. Smoke Developed - 50.

C. Accessories: Accessories such as adhesives, mastics, tapes, and cements shall have the same component ratings as listed.

D. Labels: Label products and their shipping cartons indicating that flame spread and smoke developed ratings do not exceed the above requirements.

E. Piping insulation means insulation of all components of the piping system including, but not limited to, fittings, joints, flanges, equipment, valves, pump volutes, tanks and all exposed surfaces subject to temperatures above 100°F or below 60°F.

F. Acceptable Manufacturers:
   1. Schuller (formerly Manville).
   2. Owens-Corning.
   5. Pittsburgh-corning.
   7. Halstead.
   8. Rubatex.
   9. Or approved equal.
G. Manufacturer and insulation types listed indicate a minimum acceptable level of quality required for each classification.

2.2 PIPING INSULATION:

A. Fiberglass Pipe Insulation:

1. Insulation: Molded fiberglass pipe covering, Owens Corning Fiberglas SSLII, Schuller Micro-Lok meeting ASTM C547, or equal. Minimum density 3.5 PCF, maximum thermal conductivity of 0.25 BTUH/sq. ft. °F./in. at 75°F.
   a. ‘K’ Value: 0.23 at 75°F.
   b. Maximum Service Temperature: 850°F.

2. Jacket: Factory applied, paintable, white kraft outer surface bonded to aluminum foil and reinforced with fiber glass yarn with self-sealing longitudinal laps and butt strips or AP jack with outward clinch expanding staples or vapor barrier mastic as needed. Maximum vapor permeance of 0.02 perms and minimum beach puncture of 50 units. Seal end joints with sealing strip or tape to provide vapor tight installation.

3. Fittings and Valves: Pre-molded PVC fitting covers over precut insulation of same thickness as adjacent piping. In addition, on cold and chilled water pipes, apply vapor-barrier adhesive mastic on PVC cover seams and on circumferential edges wrap with vapor-barrier pressure-sensitive tape. The tape shall overlap 2" over the adjacent pipe insulation.

4. Ball Joints: On ball joints in insulated piping, provide ball joint manufacturer made insulation covers specifically made for the purpose. The covers shall be pre-shaped, shall cover entire joints including flanges and shall allow the anticipated movement of the joints without breaking the insulation or jacket. The covers shall also be removable to facilitate inspection of joints by maintenance personnel. Insulation for chilled water and cold piping shall allow for continuous vapor barrier across the joints.

B. Hydrous Calcium Silicate: Schuller Thermo-12/blue ASTM C533; rigid molded pipe; asbestos-free coded throughout material thickness and maintained throughout temperature range or equal.

1. ‘K’ Value: 0.40 at 300°F.
2. Maximum Service Temperature: 1200°F.
3. Compressive Strength (block): Minimum of 160 psi to produce 5% compression at 1.5" thickness.
4. Tie Wire: 16-gauge stainless steel with twisted ends on maximum 12" centers.

C. Elastomeric Foam: Rubatex R-180-FS/R-1800-FS meeting ASTM C534; flexible, cellular elastomeric, molded or sheet or equal.

1. ‘K’ Value: 0.28 at 75°F.
2. Maximum Service Temperature of 220 °F.
4. Maximum Smoke Developed: 50 (0.75" thick and below) or 100 (above ¾" thick).
5. Connection: Waterproof vapor retarder adhesive as needed; Rubatex R-373 Adhesive.
6. UV Protection: Outdoor protective coating; Rubatex 374 Coating.

D. Cellular Glass: Pittsburgh-Corning Foamglas meeting ASTM C522: cellular glass thermal insulation or
equal.

1. ‘K’ Value of 0.35 at 75°F.
2. 8.0 lb/cu ft density.
3. Maximum service temperature of 900°F.

E. Field Applied Jackets:

1. All longitudinal seams shall be located on bottom of pipes.
4. Aluminum Jacket: 0.016” thick sheet, (smooth/embossed) finish, with longitudinal slip joints and 2” laps, die shaped fitting covers with factory attached protective liner.
5. Stainless Steel Jacket: Type 304 stainless steel, 0.010”, (smooth/corrugated) finish.

F. Removable Covers:

1. Provide removable covers on valves, fittings, flanges, strainers, traps, etc. where periodic maintenance or removal is required.
2. Use of pre-molded fittings with PVC covers is acceptable.
3. Use of lace-on type insulating blankets is acceptable.

G. System Codes and Insulation Types: Provide fiberglass insulation, unless indicated otherwise.

1. CODE I - High temperature heating water
2. CODE II - Heating water, domestic hot water, tempered water
3. CODE III - Primary chilled water
4. CODE IV - Chilled water, chilled drinking water
5. CODE V - Rainwater Leaders, Storm and overflow drains (where indicated)
6. CODE VI - Condensate drains, domestic cold water (where indicated)
7. CODE VII - Lavatory drain traps and tail pieces

H. Piping Insulation Schedule:

<table>
<thead>
<tr>
<th>System Code</th>
<th>Pipe Sizes: 2” and Smaller</th>
<th>Pipe Sizes: 2.5” and Larger</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2.5”</td>
<td>3.5”</td>
</tr>
<tr>
<td>II</td>
<td>1.5”</td>
<td>1.5”</td>
</tr>
<tr>
<td>III</td>
<td>1.5”</td>
<td>1.5”</td>
</tr>
<tr>
<td>IV</td>
<td>1”</td>
<td>1”</td>
</tr>
<tr>
<td>V</td>
<td>1”</td>
<td>1”</td>
</tr>
<tr>
<td>VI</td>
<td>1”</td>
<td>1”</td>
</tr>
<tr>
<td>VII</td>
<td>0.5”</td>
<td>---</td>
</tr>
</tbody>
</table>

I. Where piping systems are scheduled, insulate all supply and return piping.
2.3 EQUIPMENT INSULATION

A. Rigid Board without Vapor Barrier Equipment Insulation:
   1. Insulation: Fiberglass board, Owens Corning Fiberglas Type 705 or equal. Minimum density 6 PCF, maximum thermal conductivity 0.25 BTUH/sq. ft. °F./in. at 75 °F.
   2. Application: Impale insulation on weld pins on flat surfaces, or band in place on irregular surfaces with 16 gauge annealed steel wire on maximum 9” centers. Apply 0.25” coat of insulating and finishing cement filling all voids. Secure lightweight glass cloth with Foster 30-36 adhesive over cement.

B. Calcium Silicate Equipment Insulation:
   1. Insulation: Preformed calcium silicate block insulation. Minimum density 12.5 PCF, maximum thermal conductivity 0.40 BTUH/sq. ft. °F./in. at 200 °F.
   2. Application: Securely band blocks, tightly butted, and joints evenly staggered with 16 gauge galvanized annealed steel wire on maximum 12” centers. Provide weld pins, clips, and angles for anchors. Stretch 2” hexagonal meshwire on anchors. Apply 0.25” coat insulating and finishing cement. Apply heavy weight glass cloth with Foster 30-36 adhesive. Apply finish coat of adhesive.

C. Plastic Foam Equipment Insulation:
   1. Insulation: Plastic foam with minimum density 5.0 PCF, maximum thermal conductivity 0.28 BTUH/sq. ft. °F./in. at 75°F., and maximum flame spread rating of 25.
   3. Finishes: Apply flexible waterproof finish from manufacturer over all insulation outdoors.

D. Equipment Insulation Schedule:

<table>
<thead>
<tr>
<th>Service</th>
<th>Temperature Range</th>
<th>Insulation Type</th>
<th>Insulation Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chilled Water Pump Volutes, Air Separator</td>
<td>All</td>
<td>Plastic foam</td>
<td>1”</td>
</tr>
<tr>
<td>Expansion Tanks, and all other cold surfaces.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engine Muffler and Exhaust Pipe</td>
<td>Up to 1200°F.</td>
<td>Calcium Silicate</td>
<td>3”</td>
</tr>
<tr>
<td>Heating Water Pump Volutes, Water Heaters,</td>
<td>All</td>
<td>Rigid Board</td>
<td>1.5”</td>
</tr>
<tr>
<td>Hot Water Storage Tanks, Expansion Tanks,</td>
<td></td>
<td>without Vapor</td>
<td></td>
</tr>
<tr>
<td>Air Separators, and other hot surfaces.</td>
<td></td>
<td>Barrier</td>
<td></td>
</tr>
<tr>
<td>Heat Exchangers</td>
<td>Above 250°F.</td>
<td>Calcium Silicate</td>
<td>4”</td>
</tr>
</tbody>
</table>

2.4 DUCT AND PLENUM INSULATION

A. Linings:
   1. Duct Lining: Flexible, coated, fiberglass duct liner, 1” thick, minimum density of 1.5 PCF,
maximum thermal conductivity 0.26 BTUH/sq. ft. °F./in. at 75 °F., and minimum noise reduction coefficient of 0.60 for 1” thickness, No. 6 mountings. Owens Corning Aeroflex Plus or equal.

a. Schuller Linacoustic Mat Faced or Permacote meeting ASTM C1071; flexible blanket or equal.
   1) ‘K’ Value: ASTM C518, 0.25, at 75 °F.
   2) Noise Reduction Coefficient: 0.65 or higher based on “Type A Mounting”
   3) Maximum Velocity on Mat or Coated Air Side: 5,000 ft/min.
   4) Adhesive: UL listed waterproof type.
   5) Fasteners: Duct liner galvanized steel pins welded or mechanically fastened.

b. Round Duct Liner: Schuller spiracoustic, meeting ASTM C427; rigid.
   1) ‘K’ Value: ASTM C518, 0.23 at 75 °F.
   2) Noise Reduction Coefficient of 0.70 as per ASTM C427. (Type A mounting).
   3) Maximum Velocity: 4,000 ft/min.

2. Plenum Lining: Rigid, neoprene coated fiberglass board, 2” thick, minimum density of 3.0 PCF, maximum thermal conductivity 0.23 BTUH/sq. ft. °F./in. at 75 °F., and minimum noise reduction coefficient of 0.90 for 2” thickness, No. 6 mounting.

3. Application: Comply with SMACNA Duct Liner Application Standard, published recommendations of manufacturer, and the following:
   a. Surface adjacent to air flow, including at joints, to be uniformly flat.
   b. Seal butt joint edges of liner to prevent erosion. Provide sheetmetal end caps to cover liner edges at entering and leaving edges of lined duct sections.

B. Flexible Fiberglass Blanket: Schuller Microlite Type 75 meeting ASTM C553, Type 1, Class B- 2; flexible blanket or equal.
   1. ‘K’ Value; 0.27 at 75 °F installed.
   2. Density: 0.75 lb/cu ft.
   3. Vapor Barrier Jacket: AP, bleached kraft paper bonded to aluminum foil, reinforced with fiberglass yarn; or FSK, aluminum foil reinforced with fiberglass yarn and laminated to fire-resistant kraft, secured with UL listed pressure sensitive tape and/or outward clinched expanded stables and vapor barrier mastic needed.

C. Canvas Jacket: UL listed fabric, 6 oz./sq. yd. plain wave cotton treated with undiluted fire retardant lagging adhesive.

D. Duct Wrap with Vapor Barrier:
   1. Insulation: Flexible fiberglass wrap with minimum density of 1.0 PCF, maximum thermal conductivity of 0.27 BTUH/sq. ft. °F./in. at 75 °F., 1.5” thick. Owens Corning All Service Faced Duct Wrap or equal, consisting of glass fiber blanket factory laminated to a reinforced foil/kraft (FRK) vapor barrier facing with 2” stapling and taping flange on one edge. Vapor permeance of 0.02 perm.
   2. Application: Comply with published recommendations of manufacturer and with the following:
      a. Secure with 4” strips of adhesive, 8” on center.
b. Staple edges at 6” on center.
c. For rectangular ducts 24” and wider, secure to bottom of duct with mechanical fasteners 18” on center.
d. Seal vapor tight at punctures made by staples and fasteners.
e. Adhesive and sealant requirements same as for duct liner.

E. Rigid Board with Vapor Barrier:
   1. Insulation: Fiberglass board minimum density of 6.0 PCF, maximum thermal conductivity of 0.23 BTUH/sq. ft. °F./in. at 75°F., 1” thick.
   2. Jacket: Factory applied, paintable, white kraft outer surface bonded to aluminum foil and reinforced with fiberglass yarn with maximum vapor permeance of 0.02 perms and maximum beach puncture of 50 units.
   3. Application: Apply to exterior of duct impaled on weld pins or Tuff-Weld nylon pins on maximum 12” centers with minimum of two rows per side of duct.
   4. Exposed supply and return ducts and plenums that are not lined. This includes, but is not limited to:
      a. Supply and return ducts for the exhibit boxes after the humidifier in the Fan Rooms.

F. Outdoor Ducts:
   1. All longitudinal seams shall be located on bottom of pipes.
   2. Aluminum Jacket: 0.016” thick sheet, smooth/embossed finish, with longitudinal slip joints and 2” laps.
   3. Schuller Insulkote ET, a non-water-vapor retarder, non-burning, weatherproof coating for use over insulation where ‘breathing’ is required.
   4. Schuller Zeston 2000 jacketing, UV resistant polyvinyl chloride covering with joints secured and sealed with Schuller Perma-Weld Adhesive.

G. Apply insulation, by type and location as follows:
   1. Lining:
      a. Supply and return ducts at the following locations:
         1) In Mechanical Rooms and in Fan Rooms.
         2) Exposed supply ducts (ducts above airline ticket offices, etc.).
         3) Out-of-doors.
         4) At ducts and plenums as indicated.
         5) Air terminal unit discharge plenums, thickness 1”, unless otherwise noted.
         6) All air transfer boots, thickness 1”, unless otherwise noted.
         7) Supply and return ducts exposed in unconditioned areas.
      b. At Supply, Outside Air, Return and Exhaust Fans:

<table>
<thead>
<tr>
<th>Upstream</th>
<th>Downstream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply/Outside Air Fans</td>
<td>20 ft.</td>
</tr>
</tbody>
</table>
c. In ducts interconnecting air outlets in different rooms where such outlets are separated by less than 10 LF.

d. Supply and return plenums at linear diffusers and return grilles, 1/2” thick, minimum.

e. Outside air ducts and plenums, where indicated.

f. Do not line ducts prohibited by Code.

2. Duct Wrap with Vapor Barrier:

   a. Concealed supply and return ducts and plenums, except that lined ducts need not be wrapped.

2.5 PIPE INSULATION METAL JACKETING:

   A. Provide 0.016” thick factory made pipe insulation waterproof aluminum jacket for all insulated piping in tunnel, out of doors, and additionally where shown on the drawings. Metal jacketing to be with Z-joints at longitudinal seams arranged to prevent water from entering, and use factory supplied stainless steel butt straps at transverse joints. Field-made jacketing with aluminum sheets will not be acceptable.

PART 3 – EXECUTION

3.1 INSTALLATION

   A. General: Install insulation products in accordance with the manufacturer’s written instructions, Commercial and Industrial Standards, and recognized industry practices to ensure that the insulation serves the intended purpose.

   B. Drawings: In addition to that specified, provide insulation by type and locations as indicated on the Drawings.

3.2 EXAMINATION AND PREPARATION

   A. Verify that piping and ductwork has been tested for leakage in accordance with specifications before applying insulation materials. All piping and ductwork shall be inspected by SFO Representative prior to installation of insulation. Any insulation applied prior to inspection shall be removed and new insulation applied at no additional cost to SFO. Notify SFO Representative five (5) working days prior to insulation installation.

   B. Surfaces to be insulated shall be thoroughly cleaned with all testing successfully completed prior to insulation. Verify that all surfaces are clean, dry, and free of foreign material.

3.3 EQUIPMENT APPLICATION:

   A. Chilled and Heating Hot Water Pumps: Apply insulation to the surface to be insulated with adhesive over the entire surface. The entire insulation installation shall be in accordance with application
recommendation described in the latest published manufacturers’ pamphlets. All lap and butt joints shall be sealed vapor tight. The insulation shall be finished with two coats of manufacturer’s finish coating, vinyl-lacquer coating, or approved equal. Application shall be such that removal of the pump casing or a pump casing section will not destroy the installation.

B. Chilled Water Air Separators, Expansion Tank and Cold Surfaces: Apply insulation to air separators and non-factory insulated cold surfaces with adhesive over the entire surface being insulated. The entire insulation installation shall be in accordance with application recommendations described in the latest published manufacturers’ pamphlets. All lap and butt joints shall be sealed, vapor tight on cold surfaces, using the manufacturer’s recommended adhesive. The insulation shall be finished using two coats of the manufacturer’s finish coating, vinyl-lacquer coating, or approved equal. Insulation installation shall have removable sections to allow maintenance access.

C. Heating Water Air Separators, Expansion Tanks and Other Hot Surfaces: Apply insulation to the entire surface with recommended adhesive. Apply adhesive over the entire clean, dry, bare metal surface, and all butt and lap joints shall be sealed vapor tight. The entire insulation installation shall be in accordance with application recommendations described in the latest manufacturers’ pamphlets. The insulation shall be finished with two coats of manufacturer’s finish coating, vinyl-lacquer coating, or approved equal.

D. Diesel Engine Exhaust Pipes and Muffler, and High Temperature Heat Exchangers and Converters: After all pressure tests have been completed, apply insulation, with joints staggered, to clean, dry metal surfaces which have not been factory insulated, and hold in place with one” (1”) galvanized hexagonal wire mesh with edges laced together. Where necessary to achieve snug fit of insulation on large surfaces, install weld clips 18” on center to surfaces before installation of insulation and tie to wire mesh with 20 gauge galvanized wire. Apply 0.25” coat insulating and finishing cement. Apply heavy weight glass cloth with Foster 30-36 adhesive. Apply finish coat of adhesive.

E. Condensate Drain Pans: Insulate all non-factory-insulated drain pans in Fan Coil Units and packaged Air Handling Units as specified for cold surfaces.

F. Heating and Cooling Coils: Insulate all coil perimeter surfaces that are not factory-insulated with rigid fiberglass insulation with vapor barrier.

3.4 PIPING APPLICATION

A. General: Apply insulation to clean dry pipes after all pressure tests have been completed. Firmly butt all joints of insulation and seal all joints per manufacturer’s recommendations. Install insulation in strict accordance with these Specifications and the manufacturer’s printed instructions.

B. Locate insulation and cover seams in least visible locations.

C. Neatly finish insulation at supports, protrusions, and interruptions.

D. Provide insulated dual temperature pipes or cold pipes conveying fluids below ambient temperature with vapor retardant jackets with self-sealing laps. Insulate complete system.

E. For insulated pipes conveying fluids above ambient temperature, secure jackets with self-sealing lap or outward clinched, expanded staples. Bevel and seal ends of insulation at equipment, flanges, and unions.

F. Provide insert between support shield and piping on piping 1.5” diameter or larger. Fabricate of
Schuller Thermo-12 or other heavy density insulating material suitable for temperature.

G. Flanges, Strainers and Unions: Insulate flanges, strainers, and unions with pre-molded or shop-fabricated rigid insulation of same material and thickness as specified for adjacent piping. Cover fiberglass insulation with pre-molded PVC covers, held in place with Zeston “Z-tape” or an approved equal. Covers and finish for foam glass and calcium silicate insulation shall be as specified for the adjacent pipe insulation. Ensure that insulation and covers for flanges, unions, and access plates shall be removable without damage to insulation or jackets.

H. Valves and Fittings: Insulate and cover valves, tees, elbows, test parts, and other fittings the same as flanges and unions

1. Where valves, strainers, etc., with insulation require periodic opening for maintenance, repair or cleaning, install insulation in such a manner that it can be easily removed and replaced without damage. Use of pre-molded covers or lace-on type insulation blanket is acceptable.

I. Lavatories: For all handicap accessible lavatories, insulate exposed tailpieces, traps, and hot and cold water supplies with fully molded, flexible vinyl insulation installed per the manufacturer’s recommendations and per Code.

J. Primary Chilled Water, Chilled Water, Domestic Refrigerated Water, Pumped AHU Condensate, Condensate Drains, Drains Receiving Condensate and Cold Water, Drinking Fountains throughout, and Horizontal Roof, Areatray, and Overflow Roof Drain Leader Piping: Install specified fiberglass insulation to provide a continuous external vapor barrier on all pipe insulation. Seal insulation lap joints using the manufacturer’s standard pressure-sensitive self-sealing lap joint system. Seal butt joints using the manufacturer’s standard pressure-sensitive closure strip system. Butt strips shall be a minimum of 3” wide. Where insulation is interrupted at fittings, unions, flanges, or valves and at intervals not exceeding 50’ on straight runs of pipe, form an isolating seal between the insulation vapor barrier and the bare pipe by liberal application of Insul-Coustic No. 215 or equal vapor barrier adhesive. Extend the adhesive 2” along the insulation jacket, across the face of the insulation and 4” along the pipe.

K. Domestic Hot and Cold Water Piping, High Temperature Heating Water, Heating Water Piping, and Other Hot Piping which is Insulated: Install preformed fiberglass insulation on all pipe insulation. Seal insulation lap joints using the manufacturer’s standard pressure-sensitive self-sealing lap joint system. Seal butt joints using the manufacturer’s standard pressure-sensitive closure strip system. Butt strips shall be a minimum of 3” wide. At the Contractor’s option, staples may be used in lieu of self-sealing closures for hot piping.

L. Use of metal saddles is acceptable as specified. Fill interior voids with segments of insulation matching adjoining pipe insulation.

M. Hangers and Supports: Blocking shall be provided at all hanger and support locations. Install insulation inside all pipe saddles. Extend vapor barrier across all pipe blocking.

N. Pipe Anchors: Insulate pipe anchors as specified for piping. Provide an isolating seal at anchors on piping with a vapor barrier.

O. Pipe Accessories: Valve operators, pressure/temperatures plugs, meters and gauge fittings and all other items which extend through required insulation shall be suitably insulated with removable caps to allow use without disturbing the insulation.

P. Heat Tracing: Where pipe is heat-traced, the insulation size (inside dimensions) shall be increased.
Q. Pump Rooms, Fan Rooms, Mechanical Rooms and Tunnel Protective Covering: Protect the insulation jacket on all fiberglass insulation and accessories in the rooms and tunnels within 6'-0" of finished floor with a field-installed covering using vapor barrier mastic and reinforcing mesh installed per the manufacturer's recommendations, except where metal jacket is specified. The insulation surface, covering or jacket on all piping in the rooms and tunnels shall be sized, coated and prepared as required for finish color-coded painting.

R. Metal Protective Jacket: Protect outer covering of insulation with a metal jacket system over both pipe and fitting insulation where exposed to weather, in the tunnel or where specified. Metal jacket shall extend over PVC jacketing or vapor barrier, down to grade at riser locations. Longitudinal seals shall provide a 3" overlap installed at the 9 o'clock or 3 o'clock position to shed water. Butt joints shall be overlapped a minimum of 3" in a manner to prevent the entry of water. Seal metal jacketing with 0.75" stainless steel sealing bands to be installed on 12" centers along the metal jacket. Locate strap joints so as to prevent personnel contact. Metal jacket on valves and flanges shall be removable without disturbing the adjacent jacket. Insulated pipe fittings joints, and valves shall be covered with Schuller Zeston 2000 PPVC or aluminum jacket. Jacket seams shall be located on bottom side of horizontal piping.

S. Vapor Barrier: Maintain integrity of vapor barrier on chilled water and all other cold pipe insulation and protect barrier to prevent puncture and other damage.

T. Penetrations: Extend piping insulation without interruption through walls, floors, and similar penetrations.

1. Continue insulation vapor barrier through penetrations except where prohibited by code.

U. Ventilation: Provide adequate ventilation during initial start-up of piping systems to remove smoke and odor given off when the organic binders in the insulation are initially heated.

V. For pipe exposed in mechanical equipment rooms or in finished spaces below 10 feet above finished floor, finish with Schuller Zeston 2000 PVC jacket and fitting covers or aluminum jacket.

W. Piping Insulation Schedule

1. All insulation thicknesses shall meet or exceed state energy code requirements as noted below. Increase thickness ½’ if exposed to ambient air. Minimum thermal resistance in range of 4.0 to 4.6 per” of thickness.

2. Fiberglass Insulation:

<table>
<thead>
<tr>
<th>Pipe Size (inches)</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating water supply &amp; return &lt;200 °F</td>
<td>Up to 2</td>
</tr>
<tr>
<td></td>
<td>2.5 and over</td>
</tr>
<tr>
<td>Heating water supply &amp; return &gt;200 °F</td>
<td>Up to 2</td>
</tr>
<tr>
<td></td>
<td>2.5 to 4</td>
</tr>
<tr>
<td>Chilled water supply and (above ground) return</td>
<td>Up to 2</td>
</tr>
<tr>
<td></td>
<td>2.5 and over</td>
</tr>
</tbody>
</table>

3. Elastomeric Foam
4. Cellular Glass: may be used on application listed above.

3.5 DUCTWORK APPLICATION

A. Exterior Duct wrap Insulation on Supply and Return Ductwork: After ductwork testing has been completed, insulate ductwork as specified. On ducts over 18” wide, apply weld clips or stick clips to bottom of duct, spaced 18” on center each way, maximum. Seal all longitudinal and transverse seams and all punctures caused by weld clips or stick clips with 2” wide SMACNA-labeled duct tape and mastic.

B. Duct Lining for Supply, Return and General Exhaust Ductwork: Install per manufacturer’s recommendations and UL listing.

1. Adhere insulation to sheet metal with full coverage of a UL listed adhesive. Adhesive shall be applied to the sheet metal with a minimum coverage of 90%. Unless factory coated, all transverse edges and longitudinal joints of the duct liner shall be coated.

2. Secure insulation with mechanical liner fasteners as indicated by SMACNA or manufacturer. Pin length should be as recommended by the liner manufacturer.

3. All exposed edges of the liner must be factory or field coated.

4. For systems operating at 4000 fpm or higher, a metal nosing must be installed at all liner leading edges.

5. A metal nosing must be installed at the liner leading edges of liner immediately downstream of the any fan or air handler connections.

6. Repair liner surface penetrations with UL listed adhesive.

7. Duct dimensions indicated are net inside dimensions required for air flow. Increase duct size to allow for insulation thickness.

C. Ductwork Insulation Accessories: Provide staples, bands, wires, tape, anchors, corner angles, cements, adhesives, coatings, sealers, protective finishes, and similar compounds as recommended by the insulation manufacturer for the applications indicated.

D. Air Outlets: Insulate all air outlets not factory-insulated with fiberglass duct wrap where diffusers are located in ceilings that are not used as return air plenums.

E. Special Applications: Horizontal roof drains and required floor drains may be insulated with duct wrap, where indicated, if the Contractor submits and receives approval on his recommended means of maintaining a vapor seal.

F. Surfaces: Install insulation materials with smooth, even surfaces.

G. Butt Joints: Clean and dry ductwork prior to insulating. Butt insulation joints firmly together to ensure complete and tight fit over surfaces to be covered.

H. Vapor Barrier: Maintain integrity of vapor barrier on duct wrap insulation and protect barrier to prevent punctures and other damage.

I. Penetrations: Extend duct wrap insulation without interruption through walls, floors, and similar
ductwork penetrations, except where otherwise indicated.

J. External Ductwork Insulation:

1. Provide insulated ductwork conveying air below ambient temperature with vapor retardant jacket. Seal all vapor retardant jacket seams and penetrations with UL listed tapes or vapor retardant adhesive.

2. Provide insulated ductwork conveying air above ambient temperature with or without vapor retardant jacket. Where service access is required, bevel and seal ends of insulation.

3. The underside of duct work 24" or greater shall be secured with mechanical fasteners and speed clips spaced approximately 18" on center. The protruding ends of the fasteners should be cut off flush after the speed clips are installed, and then, when required, sealed with the same tape as specified above.

4. For ductwork exposed to physical abuse in mechanical equipment rooms or in finished spaces, finish with Schuller Zeston 2000 PVC jacket or aluminum jacket.

5. For exterior applications, provide insulation with a weather protection jacket.

K. Ductwork Insulation Schedule:

<table>
<thead>
<tr>
<th>Flexible Fiberglass:</th>
<th>Thickness (inches)</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Ducts:</td>
<td>1.5</td>
<td>FSK</td>
</tr>
<tr>
<td>Return Ducts:</td>
<td>1.5</td>
<td>FSK</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rigid Fiberglass:</th>
<th>Thickness (inches)</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plenums</td>
<td>2</td>
<td>FSK</td>
</tr>
<tr>
<td>Supply &amp; return ducts in mechanical rooms</td>
<td>1.5</td>
<td>FSK</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Duct Liner (Rectangular):</th>
<th>Thickness (inches)</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where indicated unless otherwise noted on plans</td>
<td>1</td>
<td>Linacoustic permacote or MatFace</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Duct Liner (Round)</th>
<th>Thickness (inches)</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where indicated</td>
<td>1&quot;</td>
<td>Spiracoustic</td>
</tr>
</tbody>
</table>

3.6 INSPECTION

A. General: Visually inspect the complete insulation installation and repair or replace any improperly sealed joints.

B. Wet Insulation: Where there is evidence of vapor barrier failure or “wet” insulation after installation, the damaged insulation shall be removed, the pipe or duct surface shall be cleaned and dried, and new insulation shall be installed.

END OF SECTION 23 07 00
SECTION 23 08 00 – COMMISSIONING OF HVAC

PART 1 – GENERAL

1.1 SUMMARY

A. Section Includes:
   1. System specific commissioning for the HVAC Systems
   2. System specific commissioning for the Building Automation System. This includes commissioning of all controls that relate to the HVAC equipment at the building.

1.2 ACRONYMS

A. Commissioning Authority (CxA)
B. Functional Performance Test (FPT)
C. Building Automation System (BAS)
D. Testing, Adjusting and Balancing (TAB)

PART 2 – EXECUTION

2.1 SYSTEMS READINESS CHECKLISTS

A. Review and complete Systems Readiness Checklists.
B. Contractor’s Commissioning Coordinator shall verify completion of all items, sign and return the checklist to the Commissioning Authority as an indication of final completion with all installation criteria as specified in the Project Contract Documents
C. To demonstrate the level of rigor required during this process, a sample System Readiness Checklist is provided later in Appendix C. Initial checklists will be developed and delivered to the Contractor by the Commissioning Authority after equipment submittals have been accepted. The Contractor shall review the initial Systems Readiness Checklists for completeness and add items as necessary. After approval by the Commissioning Authority, the final Systems Readiness Checklists shall be inserted into the Contractor’s Systems Readiness Plan during the Pre-Functional Testing phase.
D. A separate completed checklist shall be submitted for each system and item of equipment within the commissioning scope of work, along with associated start-up forms.
E. The Systems Readiness Checklists do not represent all the contract documents for the associated equipment. Completion of the items on this checklist does not release the contractor from requirements specified elsewhere.

2.2 SYSTEMS READINESS PLAN

A. The Contractor shall provide a Systems Readiness Plan and Manual.

2.3 TAB REVIEW
A. Testing, Adjusting and Balancing (TAB): TAB shall be provided by the Contractor in accordance with the project specifications. The TAB contractor shall support commissioning by submitting the preliminary TAB data for CxA review and participating on the Commissioning TAB Field Review, in which the TAB Contractor demonstrates specified results to the CxA after completion of final TAB.

B. Equipment tested: All HVAC systems & equipment

C. Demonstrate:
   1. Determination of the final set points for pump speed and fan speed control per the project specification 23 05 93. Demonstrate for all set points.
   2. Airflow rates are balanced and adjusted per the project specification 23 05 93.
      a. Demonstrate minimum outside airflow rates for all air handling equipment.
      b. Demonstrate a 10% sample for all other measurements; this includes testing and balancing of all air distribution equipment that is served by the chilled water loop and / or hot water loop.
   3. Hydronic system flow rates are balanced and adjusted per the project specification 23 05 93.
      a. Demonstrate for all boilers, chillers, cooling towers and distribution pumps.
      b. Demonstrate a 10% sample for all other measurements; this includes all equipment in the chilled water and hot water loop.

2.4 FUNCTIONAL PERFORMANCE TESTING

A. The Functional Performance Test (FPT) Procedures shall be developed, performed and demonstrated.

B. At a minimum, the contractors and equipment suppliers listed in the FPTs Minimum Participants Table in this section of the specifications are required to participate in developing, performing and demonstrating the indicated FPTs.

C. The initial FPT procedures shall be provided after review of the controls submittal. The final FPT procedures may be modifications of the initial FPT procedures, and FPT procedures may be added; modifications and additions to be made by the Commissioning Authority after equipment submittals have been accepted.

D. The General Contractor’s Commissioning shall coordinate with the Contractors, with the Commissioning Authority's input, in developing, performing and demonstrating the Working FPT.

E. Functional testing shall consist of the following phases:
   1. Component testing:
      a. Component testing applies to all control input and output devices, including those provided by the equipment suppliers and those provided with the Building Automation System (BAS). Examples include but are not limited to: sensor assemblies, detectors, relays and switches, valves, dampers, and actuators.
      b. Component testing applies to thermometers and gauges.
      c. Component testing consists of demonstrating field I/O calibration and operation including but not limited to:
         1) Accuracy of sensors is within design range as specified.
2) Alarmed points report correctly to operator workstation.
3) Accuracy and settings of binary switches and alarms is as specified, within design temperature range.
4) Actuators operate smoothly in a relation to the signal they receive over the full range of operation.
5) Fail-safe operation of components and controllers is as specified for loss of control signal, electric power, and network communications.
6) All components, values and alarms are correctly mapped to operator interface station

2. Systems Testing

a. Operational Verification: After functional testing of the system components has been successfully completed, each sequence of operation and control system function shall be functionally tested, including those provided by the equipment suppliers and those provided with the Building Automation System (BAS). Each control loop shall be tested to verify stable control with the specified and appropriate responses.

b. Integrated System Verification: After operational testing has successfully demonstrated that each system functions in accordance with the project documents, functional testing shall occur to verify that the interaction between the systems is as required. Each interactive function shall be functionally tested, including those provided by the equipment suppliers and those provided with the BAS.

c. Real Time Performance Analysis (trend logging):
   1) After operational testing has been successfully completed real time performance testing shall be performed. Data shall be logged for the intervals and periods specified in the FPT procedures. Unless otherwise specified in the FPTs, test periods shall include occupied, unoccupied, weekend, and holiday schedules.
   2) Analysis of the data shall demonstrate that the systems operate in accordance with the acceptance criteria specified in the FPT procedures. Verify that data demonstrates acceptable results before submitting for CxA review. If acceptable results are not demonstrated, perform testing and trouble shooting and corrective action to provide resolution. Provisions for retesting shall apply to trend log analysis.
   3) In addition to the initial test period, data shall be logged during a peak heating period, a peak cooling period, and a transitional season period if so specified under FUNCTIONAL PERFORMANCE TEST (FPT) SEASONAL TESTING.

2.5 FUNCTIONAL PERFORMANCE TEST (FPT) SEASONAL TESTING

A. Perform seasonal testing in accordance with the specification for Real Time Performance Analysis, which is specified elsewhere in this section.

B. The following table indicates which FPTs include Seasonal Testing.

C. The key to the codes used in Seasons column of the table is as follows: W = winter/peak heating; SU = summer/peak cooling; SP = spring/heating to cooling transitional season; F = fall/cooling to heating transitional season

<table>
<thead>
<tr>
<th>FPT PROCEDURE</th>
<th>SEASONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating System</td>
<td>W</td>
</tr>
<tr>
<td>Cooling System</td>
<td>SU</td>
</tr>
</tbody>
</table>
2.6 FUNCTIONAL PERFORMANCE TEST (FPT) DEMONSTRATION SAMPLING

A. When a FPT applies to many similar components or systems that are not a part of a life-safety system, the contractor may demonstrate the functional performance tests (FPTs) to the Commissioning Authority (CxA). Demonstration Sampling will apply only for the components and systems listed in the accompanying Functional Performance Test (FPT) Demonstration Sampling Table.

<table>
<thead>
<tr>
<th>FPT PROCEDURE</th>
<th>SAMPLE SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>All major HVAC equipment (Air Handlers, Pumps etc.)</td>
<td>All Units</td>
</tr>
<tr>
<td>Terminal Units (VAV boxes, Fan Coil Units)</td>
<td>30% of units</td>
</tr>
</tbody>
</table>

2.7 FPT MINIMUM PARTICIPANTS TABLE

A. At a minimum, the Contractors or coordinators for the mechanical systems and the BAS shall participate, demonstrating successful FPTs to the Commissioning Authority.

END OF SECTION 23 08 00
SECTION 23 21 13 – HYDRONIC PIPING

PART 1 – GENERAL

1.1 DESCRIPTION

A. General: Provide HVAC piping systems in accordance with the contract documents.

1.2 REFERENCES

A. The latest editions of the standards listed, as well as all other applicable codes, standards, and good engineering practices shall be used as “minimum” design standards.
   1. National Fire Protection Association (NFPA) Standard
   2. American National Standards Institute (ANSI)
   3. American Society for Testing and Materials (ASTM)
   4. Electrical devices and wiring shall conform to the latest standards of National Electrical Code (NEC)
   5. All devices shall be Underwriters Laboratories (UL) listed and so identified.
   6. American Society of Mechanical Engineers (ASME)
   7. American Society for Metals (ASM)
   8. National Electrical Manufacturers Association (NEMA)
   9. American Society of Safety Engineers (ASSE)

1.3 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this section shall comply with all the requirements of General Conditions, Supplemental Conditions, General Requirements, Section pertaining to Basic Materials and Methods, and other Sections in Division 23 specified herein.

1.4 SCOPE

A. All work to be furnished and installed under this section shall include, but not necessarily be limited, to the following:

   1. Pipe and fittings
      a. Chilled water above grade.
      b. Cold condensate drainage piping.
      c. Refrigerant piping.
      d. Heating water above grade (<210 °F)
      e. High temperature heating water above grade (>210 °F)
      f. Temperature and pressure relief.

   2. Valves
      a. HVAC Service Valves (125 psig max. working pressure)
      b. HVAC Series Valves (250 psig max. working pressure)
      c. Balancing Valves (125 psig working pressure)
      d. Combination HVAC terminal unit valve line sets
e. Hydronic Service Pressure Reducing Valves
f. Hydronic Service Pressure Relief Valves

3. Thermometers, gauges, and accessories

4. Piping specialties
   a. Pipe escutcheons
   b. Strainers
   c. Drip pans
   d. Air vent
   e. Unions
   f. Flanges
   g. Pipe sleeves
   h. Pipe coating
   i. Expansion compensators

B. In addition, provide the following:
   1. Furnish accessories and labor for flushing and cleaning HVAC piping.
   2. Install water treatment systems.

1.5 QUALITY ASSURANCE

A. Manufacturers Qualifications;
   1. Manufactured items furnished shall be the current, cataloged product of the manufacturer.
   2. Replacement parts shall be readily available and stocked in the USA.

B. Pumps: Provide pumps whose performance is certified by the manufacturer.

1.6 SUBMITTALS

A. Shop drawings submittals shall include, but not be limited to, the following:
   1. Cut sheets marked to clearly indicate all HVAC piping system materials.
   2. Piping fabrication drawings for all piping runs including connections to existing piping and piping provided under other contracts. Fabrication drawings shall include plan views and suitable elevations and shall include all accessories and equipment.
   3. Drawings indicating underground piping installation showing all fittings with inverts. Indicate all footings and grade beams.
   4. Pipe fabrication drawings for all piping showing location and sizes of all expansion/contraction loops, supports, supplementary steel, expansion joints, anchors and guides.
   5. Pump cut sheets with all pump capacities, characteristics, features accessories and options clearly indicated.
   6. Pump curves with selection point clearly indicated.
   7. Motor and VFD data as required

B. Product Data: Submit manufacturer’s technical product data for all piping, valves, and specialties
indicating dimensions, valve CV, flow capacity, pressure setting, tolerances, etc.

C. Maintenance Data: Submit maintenance instructions, including instructions for lubrication, valve replacement, and spare parts lists. Include this data, product data, and shop drawings in operating and maintenance manuals.

1.7 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver pumps and other components in factory-fabricated water-resistant wrapping.

B. Handle carefully to avoid damage to material components, enclosure and finish.

C. Store pumps and other materials in a clean, dry space and protect from the weather.

1.8 SYSTEM PARAMETERS

A. All piping system components, accessories, seals, gaskets, and other construction materials shall be selected to satisfactorily and safely perform under normal working conditions as follows:

<table>
<thead>
<tr>
<th>Piping System</th>
<th>Working Pressure</th>
<th>Operating Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Chilled Water</td>
<td>150 psig</td>
<td>40° to 60 °F</td>
</tr>
<tr>
<td>2. High Temperature Heating Water</td>
<td>500 psig</td>
<td>275° to 400 °F</td>
</tr>
<tr>
<td>3. (Before Heat Exchangers) Heating Water</td>
<td>150 psig</td>
<td>120 °F to 200 °F</td>
</tr>
<tr>
<td>4. Condensate Drain</td>
<td>------------------</td>
<td>40 °F to 60 °F</td>
</tr>
</tbody>
</table>

PART 2 – PRODUCTS

2.1 GENERAL

A. Furnish and install all new material, equipment, and apparatus hereinafter specified unless specifically noted otherwise. All material, equipment, and apparatus shall be identified by the manufacturer’s name, nameplate, and pertinent data.

B. Type M copper piping is not acceptable for any pressure water piping unless specifically noted otherwise.

C. All materials, equipment, and apparatus are mentioned as standards unless noted otherwise. The words “or approved equal” shall be considered to be subsequent to all manufacturer’s’ names used herein, unless specifically noted that substitutes are not allowed.

2.2 PIPES AND FITTINGS: Refer to Basic Materials and Methods Section for pipe specifications.

A. Chilled Water (Including Primary Chilled Water):

1. Steel Pipe:
1) 2” and Smaller: Black steel, threaded malleable iron.
2) 2.5” and larger: Black steel, butt weld. Mechanical Joints may be used in lieu of butt weld, in pump rooms, fan rooms, pipe trench and Level-1 open areas only. If Mechanical joints are used, provide factory moulded insulation with vapor barrier, proper supports and seismic bracing, and the joint components individually and as an assembly shall be rated for the system temperature and pressure ratings specified.

b. Fittings:
1) Steel normal pressure application: 150 lb. rating. ANSI B16.3, malleable iron threaded for pipe 2” and under; ANSI B16.5, flanged; ANSI B16.9, steel bevel welding; grooved couplings by Victaulic.
2) Steel high pressure application: 300 lb. rating. ANSI B16.3, malleable iron threaded; ANSI B16.5 flanges; ANSI B16.9, steel bevel welding.
3) Joints: 2” and smaller, threaded (except in the case of piping located in shafts which must be welded); 2.5” and larger, ANSI B16.25 bevel weld, ANSI B16.5 flanges, ANSI B16.11 socket weld.

2. Copper Tubing:
   a. Pipe Material: ASTM B88, Type L hard drawn copper water tube for normal pressure above grade.
   b. Fittings: Copper system: ASME B16.23 cast brass or ANSI/ASME B16.22 wrought copper with the following connection methods.
      1) Soldered or brazed. ASTM B32, solder, Grade 95TA.
         a) 2” and smaller: Make connections using 95%-5% tin-antimony solder joints above grade and sil-fos brazing below grade.
         b) 2.5” and larger: Sil-fos brazing or brazed and flanged.

B. Cold Condensate Drain Piping from Cooling Coils
   1. Pipe: ASTM B88, Type M, hard drawn copper water tube.
   4. Insulate condensate drain pipes with minimum ½” insulation to prevent moisture dripping from pipe.

C. Refrigerant Piping
   1. Pipe: Acceptable alternatives are:
      a. ASTM B88, Type K or L copper tubing
      b. AC/R pipe.
   2. Fittings: No joints below ground. For pipes below grade wrap with Scotch Wrap #51, ¼ thick, with 20% overlap.

D. High Temperature Heating Water: Black steel, butt weld, except as follows:
1. All components of the high temperature piping system, shall be rated for continuous operating temperature of 400 °F at 500 PSIG pressure. Accordingly, provide schedule 80, black steel, buttweld for pipes and fittings 4” and smaller; flanges shall be ANSI B16.5, weld neck pattern, 300 PSIG Class for all pipe sizes; and for pipes 0.75” and smaller provide threaded joints with seal weld.

E. Heating Water:

1. 2” and smaller: Black steel, threaded malleable iron or copper pressure Type 'L', joints 95/5 solder.

2. 2.5” and larger: Black steel, buttweld. Mechanical Joints may be used in-lieu of buttweld, in pump rooms, fan rooms, pipe trench and Level-1 open areas only. If Mechanical joints are used, provide factory moulded insulation with vapor barrier, proper supports and seismic bracing, and the joint components individually and as an assembly shall be rated for the system temperature and pressure ratings specified.

3. Above Grade (<210 °F):
      2) Joints:
         a) 2” and smaller, threaded except in the case of piping located in shafts which must be welded.
         b) 2.5” and larger, ANSI B16.25 bevel weld, ANSI B16.5 flanges, ANSI B16.11 socket weld.
   b. Copper: ASTM B88, Type K or L hard drawn copper water tube for normal pressure above grade.
      1) Fittings:
         a) Copper System: ANSI B16.22, wrought copper with the following connection methods.
            (1) Soldered or brazed:
            (2) 2” and smaller: Make connections using 95%-5% tin-antimony solder joints above grade and sil-fos brazing below grade.
            (3) 2.5” and larger: Sil-fos brazing or brazed and flanged

4. Above Grade (>210 °F):
   a. Steel Pipe: ASTM A53 Schedule 80 Black Steel for 2” and smaller; Std. Wt. Black steel for 201/2” and larger.
      1) Fittings:
         a) Steel high-pressure application: 600 lb. rating. ANSI B16.3, malleable iron threaded; ANSI B16.5, flanges; ANSI B16.9, steel bevel welding.
      2) Joints:
         a) 2” and smaller: threaded or socket welded (except in the case of piping located in shafts which must be welded)
         b) 2.5” and larger: ANSI B16.25 bevel weld, ANSI B16.5 flanges, ANSI B16.11 socket weld.
F. Condensate Drain: Copper drainage, Type ‘M’.

G. Make-up Water: Copper pressure, Type ‘L’, joints 95/5 solder.

2.3 VALVES: Refer to Basic Materials and Methods Section for Valves Specifications.

A. Valve ratings shall exceed respective system operating pressures by 50% (minimum). All valves shall be line size unless otherwise noted.

B. Chilled Water (including primary chilled water) - Group 1A, 2A, 4A.

C. High Temperature Heating Water - Group 3A, 6A.

D. Heating Water - Group 1A, 2A, 4A.

E. Make-up Water - Group 1A, 1B, 2A, 2B.

F. Product Data: Submit manufacturer’s technical product data, including installation instructions for each type of valve. Include pressure drop curve or chart for each type and size of balancing valve or circuit setter. Submit valve schedule showing manufacturer’s figure number, size, location, and valve features for each required valve.

G. Shop Drawings: Submit manufacturer’s assembly-type (exploded view) shop drawings for each type of valve, indicating dimensions, weights, materials and methods of assembly of components.

H. Acceptable Manufacturers (manufacturer and model number listed for individual valves indicated minimum acceptable by all manufacturers):
   1. Gate, Globe, Check or Butterfly: Crane, Delta Control Products, Hammond, Gruvlok, Milwaukee, Nibco.
   2. Ball and Drain Valves: Apollo, Hammond, Milwaukee, Nibco, or Watts.
   3. Lubricated Natural Gas Service Plug Valves: Homestead, Resun, or Rockwell.
   4. Hydronic System Pressure Reducing Valves: Cash-Acme, Cla-Val, Watt, or Wilkins
   6. Hydronic Pressure Relief Valves: Cash-Acme, Cla-Val, Watts, or Wilkins.
   7. Steam System Pressure Relief Valves: Sarco, Fischer, Spence, or Lonergan-Kunkle.
   9. Hydronic Balancing valves and circuit setters: Griswold (Venturi with characterized ball valve only), Wheatley (Y-globe type only), Armstrong, Nibco (globe style) or Bell & Gossett Circuit Setter.

I. Valve Identification: Provide valves with manufacturer’s name (or trademark) and pressure rating clearly marked on the valve body.

J. Operators:
   1. Provide standard handwheel for gate, globe valves.
   2. Provide 90° lever operator for ball valves.
   3. Provide 90° lever operator for lubricated natural gas plug valves Exterior located natural gas plug valves shall be provided with removable manual wrench handle, one wrench for each
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10 valves.

4. Provide 90 degree locking lever operator for butterfly valves 6” size. For 8” size and greater, provide gear operator and handwheel.

5. Provide valve stem extensions for lever-operated valves on insulated piping, so handle will clear insulation.

6. Provide valves size 2.5” and larger located more than 10 feet from floor in equipment room areas with chain operated sheaves. Provide chain and extend down to 5ft above floor and hook clips on chain arranged to clear walking aisles.

K. Valve Features:

1. Provide valves with features indicated and, where not otherwise indicated, provide proper valve features. Comply with ASME B31.9 for building services piping and ASME B31.1 for power piping.

2. Bypass: on valves 6” and larger, comply with MSS SP-45, and except as otherwise indicated, provide manufacturer's standard bypass piping and valving. Provide a 3-valve bypass, minimum 1” size, to consist of two threaded shut-off valves and a plugged drain valve.

3. Drain: Comply with MSS SP-45, and provide ¼” threaded pip end with cap on chain.


7. Flangeless: Valve bodies manufactured to fit between flanges complying with ANSI B16.1 (cast iron), ANSI B16.5 (steel), or ANSI B16.24 (bronze)

2.4 HVAC SERVICE VALVES: MAXIMUM 125 PSIG SYSTEM WORKING WATER PRESSURE

A. Gate Valves:

1. 2” and Smaller: class 150, MSS SP-80, ASTM B62 cast bronze body, bronze union bonnet, bronze wedge, rising stem, brass packing gland, non-asbestos packing and aluminum or malleable iron hand-wheel. Threaded steel pipe: Milwaukee #1151. Soldered copper pipe: Milwaukee #1169.

2. 2.5” and Larger: Class 125, MSS SP-70, ASTM A126 Grade B cast iron body, flanged ends, bolted bonnet and disc, bronze trim, OS&Y, brass packing gland, non-asbestos packing and cast iron hand-wheel. Milwaukee #F-2885-M.

B. Globe Valves:

1. 2” and Smaller: Class 150, MSS SP-80, ASTM B62 cast bronze body, bronze union bonnet, bronze wedge, rising stem, brass packing gland, non-asbestos packing and aluminum or malleable iron hand-wheel. Threaded steel pipe: Milwaukee #590T. Soldered copper pipe: Milwaukee #1590T.

2. 2.5” and Larger: Class 125, MSS SP-70, ASTM A126 Grade B cast iron body, flanged ends, bolted bonnet and disc, bronze trim, OS&Y, brass packing gland, non-asbestos packing and cast iron hand-wheel. Milwaukee #F-2981-M.
C. Butterfly Valves:

1. 2.5” and Larger:
   a. MSS SP-67, lug type. Ductile iron body, stainless steel disc, stainless steel stem, EPDM seat, memory stop control, lever handle thru 5” size and worm gear operator for 6” and larger. Mount stem in horizontal position. Milwaukee #ML32E.
   b. 2-12” through 12” grooved end type, Black enamel-coated ASTM A395 and A536 ductile iron body, elastomer encapsulated or nickel-plated ductile iron disc offset to provide continuous 360 degree seating, with integrally cast or Type 416 stainless steel stem, memory stop control, lever handle thru 5” size and worm gear operator for 6” and larger. Mount stem in horizontal position.

D. Ball Valves:

1. 2” and smaller:
   a. 600 psi, 2-piece brass body, stainless steel ball, Teflon seat, brass stem, steel handle, full port. Threaded steel ends for iron pipe and soldered ends for copper pipe.
   b. 300 psi maximum operating pressure, 2-piece brass body, chrome plated brass ball and stem, TFE seats, steel handle, standard port.

E. Check Valves:

1. 2” and Smaller: Class 125, MSS SP-80, ASTM B62 and ASTM B16, cast bronze body, screwed cap, swing type, Teflon bronze disc. Threaded steel ends for iron pipe and soldered ends for copper pipe. Threaded steel pipe: Milwaukee #1509T. Soldered copper pipe: Milwaukee #1509.
2. 2.5” and Larger:
   a. Class 125, MSS SP-71, ASTM A126 class B cast iron body, bolted bonnet flanged ends, bolted cap, swing type, cast iron disc with bronze face rings. Milwaukee #F-2974M.
   b. 300 psi maximum operating pressure, ASTM A395 and A536 ductile iron body and closure, coupled cap, swing type, stainless steel disc with elastomer seat.
3. Silent Check 2.5” and Larger:
   a. Class 125, ASTM A126 class B cast iron body, flanged globe style, silent non-slam design, spring loaded, center guided, bronze trim, stainless steel spring and screws. Milwaukee #1800.
   b. 365 psi maximum operating pressure, ASTM A395 and A536 ductile iron body, stainless steel spring and shaft.
      1) 2.5” and 3”: Black enamel coated, stainless steel aluminum bronze disc with mounted elastomer seal and machined seat.
      2) 4”-12”: Black enamel coated body, elastomer encapsulated ductile iron disc with welded-in nickel seat. 300 psi maximum operating pressure.
      3) 14”-24”: Black enamel coated body, stainless steel disc, with EPDM seat bonded to the valve body, 230 psi maximum operating pressure.

F. Drain Valves:

1. Threaded or soldered ends, Class 125, ASSE 1005, bronze body, screw-in bonnet, rising stem, composition disc, ¾” hose outlet.
2. Threaded or soldered ends, class 600, bronze body, 2-piece ball valve, \(\frac{3}{8}\)" hose outlet with cap and chain. Milwaukee #BA-100-150H.

G. Lubricated Plug Valve:
1. \(\frac{1}{2}-6\)”, Class 125, MSS SP-78, 200 psi, lubricated plug type, iron or semi-steel body, loose, wrench operated, straight way pattern round port, combination button head fitting and lubricant screw, Teflon seal and discs. Rockwell model “Super Nordstrom.”

H. Combination Valve Sets: In lieu of separate flow balancing, shutoffs, and control valves, where line size is under 1 ½” and flows are under 57 gpm, the contractor may submit a combination valve and line set for air handler or terminal unit control. Control valve actuator to be provided by the temperature control contractor or in coordination with temperature control contractor, Division 23 sections pertaining to Instrumentations and Control.
1. Acceptable product shall be Griswold “Automizer”, Delta control Products AutoTouch2, or equal.

2.5 HVAC SERVICE VALVES: MAXIMUM 250 PSIG SYSTEM WORKING WATER PRESSURE

A. Gate Valves:
1. 2" and Smaller: Class 200, MSS SP-80, ASTM B61, threaded ends, cast bronze body, cast iron union bonnet, cast iron wedge, rising stem, brass packing gland, non-asbestos packing and aluminum or malleable iron hand-wheel. Milwaukee #1153.
2. 2.5” and Larger: Class 200, MSS SP-70, ASTM A126 Grade B cast iron body, flanged ends, OS&Y cast iron bonnet, cast iron wedge, bronze trim, rising stem, brass packing gland, non-asbestos packing and cast iron hand-wheel. Milwaukee #F-2984.

B. Globe Valves:
1. 2" and Smaller: Class 200, MSS SP-80, ASTM B62 cast bronze body, bronze union bonnet, bronze wedge, rising stem, brass packing gland, non-asbestos packing and aluminum or malleable iron hand-wheel. Threaded steel pipe: Milwaukee #570.
2. 2.5" and Larger: Class 200, MSS SP-70, ASTM A126 Grad B cast iron body, flanged ends, bolted bonnet and disc, bronze trim, OS&Y, brass packing gland, non-asbestos packing and cast iron hand-wheel. Milwaukee #F-2983M.

C. Ball Valves:
1. 2" and Smaller:
   a. MSS SP-110, 1000 psig WOG rating up to 300 °F, Carbon steel 3-piece body, threaded ends, stainless steel ball, reinforced Teflon with 15% glass fiber seat, stainless steel stem, stainless steel lever handle, convention port. Milwaukee #30CSOF.
   b. 300 psi maximum operating pressure, 2-piece brass body, chrome plated brass ball and stem, TFE seats, steel handle, standard port.

D. Check Valves:
1. 2" and smaller: Class 200, MSS SP-80, ASTM B61 and ASTM B16, cast bronze body, threaded ends, screwed cap, swing Y-pattern type, bronze disc. Milwaukee #508.
2. 2-12” and Larger:
a. 200 lb. WOG, MSS SP-71, ASTM A126 Class B cast iron body, bolted cap, swing type, bronze disc with bronze face rings, Milwaukee #2970.

b. 300 psi maximum operating pressure, ASTM A395 and A536 ductile iron body and closure, coupled cap, swing type, stainless steel disc with elastomer seat.

c. 365 psi maximum operating pressure, ASTM A395 and A536 ductile iron body, stainless steel spring and shaft.

1) 2.5’ and 3”: Black enamel coated, stainless steel aluminum bronze disc with mounted elastomer seal and machined seat.

2) 4”-12”: Black enamel coated body, elastomer encapsulated ductile iron disc with welded-in nickel seat, 300 psi maximum operating pressure.

3) 14”-24”: Black enamel coated boy, stainless steel disc, with EPDM seat bonded to the valve body, 230 psi maximum operating pressure.

2.6 HIGH TEMPERATURE HOT WATER VALVES

A. General: Valves shall have a minimum service pressure temperature rating of 665 psig at 400°F and shall have a primary service pressure class designation of not less than 600 psig. Valves shall have flanged ends except where welding ends are specified or indicated on Drawings. Welding ends shall be socket-weld or weld type on 1.5” valves and smaller, either socket-weld or butt weld on 2” valves, and butt-weld on 2.5” valves and larger. Flanged ends shall be of the raised face type.

B. Stem packing shall be of ring type Teflon impregnated acrylic and novoloid fibers (non-asbestos) material suitable for high temperature water service. Spiral or continuous packing or packing having an outer jacket over an inner core will not be acceptable. Valves 1.5” and smaller shall have 4 or 5 packing rings and valves 2” and larger shall have at least 6 rings. Valves shall be outside screw and yoke type with bolted packing glands. Valves trim shall be stainless steel. Stems shall be provided with bevel above the disc for cutoff and repacking valve under pressure when fully open. Globe valves shall have plug type discs and gate valves shall have wedge type discs. Gate valve bodies shall have straight-through ports without recesses except between seats to assure minimum turbulence, erosion, and resistance to flow. Gate valves 4” size and larger shall be provided with a bypass valve for pressure equalization during valve operation. Valves shall be installed with the stems horizontal or above.

C. Balancing valves shall be globe or angle valves as herein specified except that discs shall be of the 2 or 4 V-port type. Valves shall be equipped with position indicating dial. Contractor shall submit valve size and flow characteristic curves of valves selected.

D. Gate Valves:

1. 2” and smaller: Fig. 8800W, socket weld.

2. 2.5” and larger: Fig 1010B8F, flanged end; Fig. 2010B8F, butt weld end.

E. Globe Valves:

1. 2” and smaller; Fig. 8G80W, socket weld.

2. 201/2” and larger: Fig. 1042B2, flanged end; Fig. 2042B2, butt weld end.

F. Check Values: Muessco Fig. 109 DT, shall be non-slam vertical lift type. Valves shall be cast steel or forged steel bodies with bolted caps and stainless steel trim, flanged ends.
G. Pet Cock: High temperature water “Pet Cock” shall consist of double valve assembly as follows: safety shutoff valve net to HTW header or line shall be forged steel body, plug-type seal globe valve, with stainless steel trim, socket-weld ends. Gage service valves to be “bar stock” plug type seal needle valves, with carbon steel bodies and stainless steel trim, thread ends. Bodies shall be protected against corrosion by “Parkerizing” or similar process. Rating shall be 600 psig at 750-psig °F.

H. Pressure relief valves shall be Kunkle 5000 Series, size as scheduled, constructed and stamped in accordance with ASME, size as applicable.

2.7 BALANCING VALVES: MAXIMUM 125 PSIG SYSTEM WORKING WATER PRESSURE

A. Pressure dependent water flow in constant flow systems:
   1. ½” and Larger: Construction and attachment style as required by piping system. Characterized ball valve or Y-type globe valve design with memory stop. Valves shall be field adjustable. Quick disconnect valves shall be extended to outside of insulation. Install in pipe with minimum length of unrestricted straight pipe equivalent to five pipe diameters upstream and two pipe diameters downstream.

2.8 HYDRONIC SYSTEM PRESSURE REDUCING VALVES

A. Single seated, direct operated type; high-capacity, having bronze body with strainer, by-pass feature, pressure gauge tappings and complying with requirements of ASSE Standard 1003. Select proper size for maximum flow rate and fall-off at inlet and outlet pressure indicated.
   1. 25-75 psig range: Watts #US series.
   2. 10-25 psig range: Watts #N256.

2.9 HYDRONIC SYSTEM PRESSURE RELIEF VALVES

A. Pressure Relief Valves: Constructed in accordance with ASME, 125-pound setting, and so stamped. Size as required. Watts #740 Series.

B. Temperature and Pressure Relief Valve: Constructed in accordance with ASME, 125-pound setting (or pressure setting as indicated on construction documents), and so stamped. Size as required. Watts #100XL, 40XL, 140, N240, or 340 Series.

2.10 THERMOMETERS AND GAUGES

A. General:
   1. Certification: Provide meters and gauges whose accuracies, under specified operating conditions, are certified by manufacturer.
   2. No mercury shall be used in thermometers due to hazardous material classification.
   3. Acceptable Manufacturers:
      a. Weksler.
      b. Ashcroft.
      c. Trerice.
      d. Marshalltown.
      e. WIKA.
f. US Gauge.
g. Or approved equal.

B. Thermometers:

1. Bi-Metal Type: Provide bi-metal glass thermometers of materials, capacities, and ranges indicated, designed and constructed in service indicated. Accuracy shall be 1% ± full scale with adjustable recalibration.
   a. Case: Type 300 series stainless steel, hermetically sealed, glass window, 3” diameter dial, with adjustable angle.
   b. Adjustable Joint: die cast aluminum, finished to match case, 180° adjustment in vertical plane, 360° adjustment in horizontal plane, with locking device.
   c. Scale: Stain faced, non-reflective aluminum, permanently etched markings.
   d. Stem: Stainless steel, adjustable angle socket, length to suit installation.

2. Glass Thermometer: Provide adjustable angle 9” thermometer of materials, capacities and ranges as appropriate to medium being measured and designed and constructed for service indicated. Accuracy to be 1% ± of full scale.
   a. Case: Aluminum or Valox.
   c. Scale: Aluminum painted white with black markings.
   d. Connection: 0.5” NPT with thermowell, 1.25” UNF swivel nut without thermowell.

3. Photovoltaic Cell Powered LCD Thermometer
   a. Case: ABS Plastic
   b. Accuracy: 1% of full scale.
   c. Display: 16 LUX rating LCD display. Switchable Fahrenheit and Celsius.
   d. Connection: ¾ NPT with thermowell 1.25” UNF swivel nut without thermowell.

4. Range: Conform to the following:

C. Thermometer Test Wells:

1. Provide thermometer test wells system design pressure. Provide 2” extensions for insulated piping. Provide cap nut wit chain fastened permanently to thermometer well.

D. Temperature/Pressure Gauge Connector Test Plugs (Pete’s Plugs):

1. Provide temperature gauge connector as indicated, constructed of brass or stainless steel, pressure rated to match piping plugs pressure rated for 500 psi and 200°F (93°C). Construct of brass or stainless steel, equip with ½” NPT fitting, with self-sealing valve core type neoprene gasketed orifice suitable for inserting 1/8” O.D. probe assembly from dial type insertion thermometer or pressure gauge. Equip orifice with gasketed screw cap and chain. Provide extension, length equal to insulation thickness, for insulated piping.
E. Pressure Gauges:

1. General: Provide pressure gauges of materials, capacities, and ranges indicated, designed, and constructed for use in service indicated.
2. Type: General use, 1% accuracy ANSI B40.1 grade A, phosphor bronze bourbon type, bottom connection.
3. Case: Drawn steel or brass, glass lens, 4.5” diameter.
4. Connector: Brass with 0.25 male NPT.
5. Scale: White coated aluminum, with permanently etched markings.
6. Pressure differential range shall be 100 psig minimum for the appropriate application with maximum 1 psig divisions.

F. Pressure Gauge Cocks:

1. General: Provide pressure gauge cocks between pressure gauges and gauge tees on piping systems. Gauge cock shall be 0.25” - 1.5” threaded end, 2-piece bronze body ball valve. Milwaukee #BA-100.
2. Syphon: 0.25” straight coil constructed of brass tubing with 0.25” male NPT on each end.
3. Snubber: 0.25” brass bushing with corrosion resistant porous metal disc, through which pressure fluid is filtered. Select disc material for fluid served and pressure rating.

2.11 HORIZONTAL SPLIT CASE PUMPS

A. General: Provide double suction, split case, flexible coupled, cast iron casing, bronze fitted centrifugal type, mechanical seal pumps of the size, capacity and head scheduled on the drawings. Pump selections and submittals shall be made using pressure versus flow curves. The selected pump operation point shall have a minimum efficiency as scheduled and impeller diameter shall not exceed 85% the scheduled percentage of the cutwater diameter for the selected pump casing size. All pump shall have dynamically balanced impellers and the critical speed of all pumps shall be at least 115% of the design speed. Pumps shall be free from flashing and cavitation at all flow rates from 25% to 125% of design flow under suction conditions of the pump installation.

B. Features: Pumps, casings, flanges and seals shall be suitable for operation as scheduled and shall be suitable for use within the normal temperature operating ranges of the system in which they are installed. Pump suction and discharge flanges shall be minimum Class 125 or 250 ANSI-rated and shall correspond to the pump casing pressure rating. Pumps shall have carbon steel shafts, stainless steel shaft sleeves, field-replaceable cast iron or bronze casing wear rings, bronze impeller with replaceable bronze wear rings, external seal water piping, cast iron deflectors, stainless steel impeller keys, coated fiber parting gaskets and steel casing studs and bolts.

C. Pump Casing: The pump casings shall be cast iron members. They shall be split at the horizontal center line of the shaft in each case. The flanges of the upper and lower sections of the casing shall be arranged so that they may be held together rigidly with the use of appropriate bolts. The pump section and discharge nozzles shall be located in the lower section of the casings. The design shall be such that the rotors of the pumps may be exposed for inspection or for removal by resorting to the expediency of removing the top section of the casing, but without disconnecting any part of the main interconnecting pipe systems. Casing tapped for pressure gauge installations.
D. Seals: Seals for all pumps shall be mechanical seals suitable for the working pressure and temperature of the pump and application. All metal seal parts shall be 316 stainless steel. Mechanical seals shall be as manufactured by the John Crane Company and shall be suitable for the service specified. Provide one set of spare seals for each type of pump.

E. Bearings: The pump rotors shall be supported in the case of each pump upon two ball type bearings. One ball bearing shall be located on each side of the pump impeller and each shall be in split bearing housings. The design of the split bearing housings shall be such as to make them dust-tight, grease-tight, watertight with integral bearing arms cast to the main pump frame. All pumps shall have grease-lubricated ball bearings with grease fittings and relief plugs. Bearings shall have 40,000 hours minimum life. Bearings shall limit impeller and mechanical seal face deflection to a maximum of 0.002".

F. Couplings: Pump couplings shall be Thomas metallic couplings with stainless steel flexing members or an approved equal. Coupling alignment shall be field calibrated to a maximum of 2 mils vibration, peak-to-peak.

G. Pump Bases: All pumps shall have cast iron or fabricated steel drip lip bases with coupling guards, anchor bolts, provisions for grouting and shall have provisions for collection of all seal and condensation leakage. Motor and pump mounting surfaces shall be machined and the motor mounting shall include provisions for horizontal movement and alignment. Pump bases shall be provided with continuous drip canal around three sides, arranged for drainage to a 0.75” threaded drainage opening. All bases shall have sufficient strength to prevent vibration, warping and misalignment when installed without grouting.

H. Motors: Pump motors shall be premium efficiency, 1750 rpm, open drip proof and shall be selected to drive the pump through its characteristic curve without exceeding rated full load nameplate horsepower.

I. Testing: Pumps shall be individually factory pressure and capacity tested after final assembly using shop calibrated driver or turbine per Hydraulic Institute Standards and a complete set of test curves shall be obtained. Provide certified copies of test results showing capacity, head, horsepower and efficiency at flow rates from shutoff to 125% of design flow. The certification shall also indicate results of factory dynamic balance and pressure testing using Job specific motor, shaft coupling and mechanical seals.

J. Manufacturers: PACO, Bell and Gossett, Taco, Allis-Chalmers, Ingersoll-Rand, Peerless, Weinman or approved equal.

2.12 END SUCTION BASE-MOUNTED PUMPS:

A. General: Provide horizontal base mounted, flexible coupled, cast iron casing, bronze fitted, true rear pullout centrifugal type, mechanical seal pumps of the size, capacity and head scheduled on the Drawings. Pumps and motors shall be individually mounted on pump base so that bearing assembly and impeller can be removed without disconnecting piping, removing pump casing, or removing motor. Pump shaft shall be supported from removable bearing assembly bolted to pump casing and shall be connected to pump motors by flexible coupling. Pump selections and submittals shall be made using pressure verses flow curves. The selected pump operation point shall have a minimum efficiency as scheduled and impeller diameter shall not exceed the scheduled percentage of the cutwater diameter for the selected pump casing size. All pump shall have dynamically balanced impellers and the critical speed of all pumps shall be at least 115% of the design speed. Pumps shall be free from flashing and cavitation at all flow rates from 25% to 125% of design flow under the suction conditions of the pump installation.
B. Features: Pumps, casings, fittings, flanges and seals shall be suitable for operation as scheduled and shall be suitable for use within the normal temperature operating ranges of the system in which they are installed. Pump suction and discharge flanges shall be minimum Class 125 ANSI flanges and shall correspond to the pump casing pressure rating. Pumps shall have carbon steel shafts, stainless steel sleeves, field replaceable bronze front and rear casing wear rings, bronze impeller with replaceable bronze impeller wear rings, external seal water piping, stainless steel impeller keys and steel casing bolts.

C. Seals: Mechanical seals shall be suitable for the working pressure and temperature of the pump application. All metal seal parts shall be 316 stainless steel. Mechanical seals shall be as manufactured by the John Crane Company and shall be suitable for the service specified. Provide one set of spare seals for each type of pump.

D. Bearings: All pumps shall have grease-lubricated ball bearings with grease fittings and relief plugs. Bearings shall have 40,000 hours minimum life. Bearings shall limit impeller and mechanical seal face deflection to a maximum of 0.002”.

E. Couplings: Pump couplings shall be Thomas metallic couplings with stainless steel flexing members or an approved equal. Coupling alignment shall be field calibrated to a maximum of 2 mils vibration, peak-to-peak.

F. Pump Bases: All pumps shall have cast iron or fabricated steel drip lip bases with coupling guards, anchor bolts, provisions for grouting and shall have provisions for collection of all seal and condensation leakage. Motor and pump mounting surfaces shall be machined and the motor mounting shall include provisions for horizontal movement and alignment. Pump bases shall be provided with continuous drip canal around three sides, arranged for drainage to a 0.75” threaded drainage opening. All bases shall have sufficient strength to prevent vibration, warping and misalignment when installed without grouting. Bases on pumps shall be adequately stiffened to prevent flexing of panels.

G. Pump motors shall be premium efficiency, 1750 rpm unless otherwise indicated and shall be selected to drive the pump through its characteristics curve without exceeding rated full load nameplate horsepower. Refer to pertinent sections for additional motor and VFD requirements.

H. Testing: Pumps shall be individually factory pressure capacity tested after final assembly using shop Calibrated driver or turbine per Hydraulic Institute Standards and a complete set of test curves shall be obtained. Provide certified copies of test results showing capacity, head, horsepower and efficiency at flow rates from shut off to 125% of design flow. The certification shall also indicate results of factory dynamic balance and pressure testing using job specific motor, shaft coupling and mechanical seals.

I. Manufacturers: Paco, Bell and Gossett, Allis-Chalmers, Ingersoll-Rand, Peerless, Weinman, or approved equal.

2.13 IN-LINE CENTRIFUGAL PUMPS

A. General: Provide circulating pumps with all-bronze construction of the size, type, and capacity scheduled or shown on the Drawings. Pumps shall be fitted with a dynamically balanced brass enclosed type impeller with mechanical seal. Mechanical seal shall be Type 1 or Type 2 material, Code BP-1D1 as manufactured by John Crane Company or an approved equal, suitable for service specified. Motor shall not be overloading and have a maximum speed of 1750 rpm, unless otherwise noted. Pumps, casings, flanges, and seals shall be suitable for operation with the working pressures and temperatures indicated. The scheduled working pressure applies to the entire pump assembly.
B. Manufacturers: Paco, Bell and Gossett, Armstrong, Taco, Weinman or approved equal.

2.14 SHELL AND TUBE HEAT EXCHANGERS

A. General: Provide shell-and-tube heat exchanges, complete with steel supporting saddles. Erect on frame as indicated on Drawings.

B. Acceptable Manufacturers:
   1. Bell & Gossett
   2. Taco
   3. Patterson-Kelly
   4. Yula
   5. Adamson
   6. Or approved equal.

C. Construction: Per ASME Codes for system pressures in both shell and tubes, construct components of the following materials:

<table>
<thead>
<tr>
<th>Components</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell</td>
<td>Steel</td>
</tr>
<tr>
<td>Tube sheets/supports</td>
<td>90/10 Copper Nickel</td>
</tr>
<tr>
<td>Tubes</td>
<td>0.75” OD, 90/10 Copper Nickel</td>
</tr>
<tr>
<td>Heads (Removable)</td>
<td>Cast iron or fabricated steel</td>
</tr>
</tbody>
</table>

D. Type and Capacity: Provide units of types with capacities as scheduled on the Drawings. Pressure drops scheduled are maximum. Fouling factor of 0.001 shall be included. Water velocity shall not exceed 4 fps.

E. Connections: Provide flanged in and out water connections and drain and relief valve connections for shell side.

F. ASME Symbol: A manufacturer's data report for pressure vessels, Form No. U-1 as required by the provisions of the ASME Code, shall be furnished to the Engineer for the Owner. This form shall be signed by a qualified inspector holding a National Board commission certifying that construction conforms to the latest ASME Code for Pressure Vessels for design pressure and system temperatures as indicated on the Drawings and Specifications and as detailed on Form No. U-1. The ASME “U” symbol shall be stamped on the heat exchangers.

G. Mounting Saddles: Factory-made, heavy duty, minimum two per heat exchanger.

H. Painting: Remove rust, scale and dirt by sandblasting or wire brush. Heat exchangers and accessories shall be primed and finish-painted using the manufacturer's standard paint system.

2.15 HUMIDIFIERS

A. General: Provide factory packaged electric evaporative humidifiers complete with dispersion tubes, control panel and other accessories. Humidifiers shall be immersion heater type VPC as manufactured by Dri-steem or equal by Pure or Armstrong. Type, size, capacity and arrangement as shown and scheduled on the Drawings. Humidifiers shall be UL or ETL listed and shall be suitable for use with deionized (DI)/reverse osmosis (RO).
B. Construction:
   1. Vaporizing chamber, cover and fitting shall be constructed of stainless steel with all welded seams. Gasketed cover shall be readily removable.
   2. Heaters shall be “Incoloy” alloy sheathed resistance type design for maximum 90 watts per square”.
   3. Inverted U-tubes or direct connection dispersion tubes shall be provided so that humidifiers can be installed directly under the duct. Dispersion tubes shall be 1.5” OD stainless steel tubing with calibrated orifices for uniform dispersion. Humidifier cover shall be fitted with matching connection to the U-tubes. Include hose cuff, stainless steel clamps and escutcheon plate to result in an air-tight connection to the duct.

C. Provide float operated makeup valve constructed entirely of stainless steel, including float ball and valve body. Provide another float-operated low water cut-off with all portions exposed to water made of stainless steel.

D. Controls: Provide microprocessor based factory mounted controls for humidifiers within a control panel factory-attached to side of humidifier with all wiring between control cabinet and humidifier factory-installed. The control shall be fully automatic and shall include, but not be limited to, the following:
   1. Water make-up valve control and low water safety shutdown.
   2. End of season drain.
   4. Duct mounted humidistat to control humidifier.

E. Options: Provide the following options and optional features for the humidifiers:
   1. Add-on keypad/digital display mode to monitor and adjust all settings and set points.
   2. Time Proportioning (TP) Modulating Option with duct mounted humidistat controlling the humidifier operation.
   3. Vane Type sail switch.
   4. Duct high limit humidistat (two position).
   5. Factory insulation of humidifier casing (0.75” thick, rigid, foil faced fiberglass).
   6. Remote contact points for on/off commands, status, set points, and trouble monitoring from Building Automation System.

F. Start-up: Factory Authorized Representative shall provide initial start-up, calibration and operator training for the humidifiers.

2.16 CHEMICAL FEEDERS

A. Five (5) gallon bypass feeder, designed per ASME rating of 175 psig at 200 °F. Mogul “One Shot” feeder or approved equal.

B. Provide with funnel and 1” fill valve, 0.75” inlet and outlet connections, 3/8” air release valve, 0.75” drain and minimum 3 welded legs for floor mounting.
C. Provide one year’s supply of corrosion inhibitor chemicals.

2.17 PIPING SPECIALTIES

A. General:

1. Provide factory fabricated piping specialties recommended by manufacturer for use in service indicated. Provide piping specialties of types and pressure ratings indicated for each service, or provide proper selection to comply with installation requirements. Provide sizes as indicated, and connections, which properly mate with pipe, tube, and equipment connections. Where more than one type is indicated, selection is installer’s option.

B. Pipe Escutcheons:

1. Provide pipe escutcheons as specified herein with inside diameter closely fitting pipe outside diameter, or outside of pipe insulation where pipe is insulated. Select outside diameter of escutcheon to completely cover pipe penetration hole in floors, walls, or ceilings; and pipe sleeve extension, if any. Furnish pipe escutcheons with nickel or chrome finish for occupied areas, prime zinc base paint finish for unoccupied areas.

2. Pipe Escutcheons for moist Areas: For waterproof floors, and areas where water and condensation can be expected to accumulate, provide stainless steel, cast brass or sheet brass escutcheons, solid, or split hinged.

3. Pipe Escutcheons for Dry Areas: Provide stainless steel escutcheons, solid, or split hinged.

C. Low Pressure Y-Type Pipeline Strainers:

1. Provide strainers full line size of connecting piping, with ends matching piping system materials. Select strainers for 125% of the work pressure of piping system, with Type 304 stainless steel screens, with 3/64” perforations at approximately 233 perforations per square inch.

2. Threaded ends, 2” and Smaller: Cast-iron body, screwed screen retainer with centered blowdown fitted with hose bibb.

   a. Acceptable Manufacturers:

      1) Sarco.
      2) Keckley.
      3) Wheatley.
      4) Mueller.
      5) Or approved equal.

3. Flanged Ends, 2.5” and Larger: Cast-iron body, bolted screen retainer with off-center blowdown fitted with 0.75” drain valve.

   a. Acceptable Manufacturers:

      1) Sarco.
      2) Keckley.
      3) Wheatley.
      4) Mueller.
      5) Or approved equal.
D. Drip Pans:
   1. Provide drip pans fabricated from 16-gauge galvanized sheet metal with watertight joints, and
      with edges turned up 2.5”. Reinforced top by structural angles. Provide hole, gasket, and flange
      at low point for watertight joint and 1” copper drain line connection.

E. Air Vents with Valves:
   1. Install in all closed and open loop water systems at high points of systems and at any other point
      necessary to free system of air. A shut-off valve shall be provided in riser to each automatic
      vent valve to facilitate servicing. A minimum 3/8” type “L” copper tubing drain line shall be run
      to floor sink, floor drain, or other approved drain receptacle to carry away water that valve
      discharges. Manual type vent may be used in lieu of automatic type, where specifically shown on
      the Drawings.
   2. Provide Hoffman #79 or equal by:
      a. Amtrol.
      b. Watts.
      c. Dole.

F. Dielectric Waterways:
   1. Brass unions and nipples shall be provided to effectively isolate ferrous from non-ferrous piping
      (electrical conductance), prevent galvanic action, and stop corrosion in accordance with SFO
      standards.
   2. Connection: screwed, grooved, sweat, or flanged to match pipe.

G. Dielectric Flanges: Provide dielectric flanges and dielectric bolt sleeves for flanged transitions
   between dissimilar metal piping. Watts Series 3100 or approved equal.

H. Unions:
   1. Unions shall be of type specified in following schedule:
      a. Black Steel, 2” and smaller: 250 lb. screwed malleable iron, ground joint, brass to iron seat.
      b. Black Steel, 2.5” and larger: 150 lb. cast iron screwed flanged, flat faced, full faced gasket.
      c. Soldered Copper or Brass Pipe, 2” and smaller: 150 lb. cast bronze or copper, ground joint,
         non-ferrous seat with soldered ends.
      d. Screwed Copper or Brass pipe, 2” and smaller: 150 lb. cast brass, ground joint, brass to brass
         seat, with threaded ends.
      e. Flanged Copper or Brass Pipe, 2.5” and larger: two (2) 150 lb. cast bronze flanges.
      f. Acceptable Manufacturers:
         1) EPCO.
         2) Mueller.
         3) Stanley G. Flagg.
         4) Victaulic.
         5) Tyco-Grinnell.
         6) Watts.
         7) Or approved equal.
I. **Flanges:**

1. Provide flanges at flanged connections to equipment, tanks, and valves. Faces of flanges being connected shall be alike in all cases. Connection of raised-face flange to flat-faced flange not permitted.

2. Use ASTM A307, Grade B, bolts and nuts for cast iron flanges and ASTM A193 for steel flanges. Regular square head unfinished bolts with heavy semi-finished hex nuts ASTM A194. Cadmium plated where exposed to weather. Rating: 150 lb. or 300 lb. in high pressure portions.

3. Type of pipe and corresponding flanges follows:
   a. Screwed Black Steel Pipelines: 125 lb. black cast iron screwed flange, flat faces.
   b. Welded Steel Pipe, 150 lb. black forged steel welding flanges, 1/16” raised face ASTM A181 Grade I. Use flat face when connected to flat faced companion flange.

J. **Flange Gaskets:**

1. Type: full faced or flat ring to suite flange facings.

2. Shall conform to ASTM F-104.

3. Minimum thickness: 1/16”.

4. Flange gaskets for medium and high pressure steam service shall be provided with metallic rim.

5. Acceptable Manufacturers:
   a. Garlock style 3200.
   b. Or approved equal.

K. **Pipe Sleeves**

1. Provide fire proof sleeve assemblies utilizing UL rated sealant systems at all fire rated penetrations. For non-rated sleeve penetrations pack the annular space between the pipe and sleeve with fiberglass and/or mastic.

2. Sleeves shall provide a minimum ½” annular clearance around pipe.

3. Sheet metal: Fabricate from galvanized sheet metal; round tube closed with snaplock joint, welded spiral seams or welded longitudinal joint. Fabricate from the following gauges: 3” and smaller, 20 gauge; 4” to 6”, 16 gauge; over 6”, 14 gauge.

4. Steel pipe: Fabricate from Schedule 40 galvanized steel pipe; remove burrs.

5. Iron Pipe: Fabricate from cast iron or ductile-iron pipe; remove burrs.

6. Plastic and Copper Pipe: Fabricate from Schedule 80 PVC plastic pipe; remove burrs.

7. Sleeves through interior concrete walls and floors: Telescopic submerged, adjustable sleeves
   a. Acceptable Manufacturers:
      1) Adjust-to-Crete.
      2) AMI.
      3) Shamrock.
      4) Or approved equal.
   b. Floor sleeves to extend a minimum of 1” above finished floor.
8. Through exterior walls and floor on grade; 150-pound class cast-iron pipe sleeve. Where waterproof membranes are used, provide membrane clamps. For insulated piping, sleeve diameter shall not be less than diameter of insulated pipe.

L. Sleeve Seals:
1. All sleeves shall be sealed to prevent intrusion of moisture, dust, or insects.
2. Underground: For sleeves passing through exterior or foundation walls, provide mechanical link seal assembly.
3. Aboveground: For sleeves passing through walls or floors provide a non-toxic 3-hour rated fire resistant silicone foam sealant with a Flame Spread Rating of 20. Sealant to be tested and approved under UL 263, ASTM E119, and NFPA 251 Standards. All fire rated penetrations shall be sealed with approved UL system.
4. Local Approvals: All seals to be provided shall be in accordance with the regulations of all governing agencies of the city, county, and State Fire Marshall’s Office.

2.18 PIPE COATING

A. All above ground uninsulated steel and copper pipe and fittings in corrosive air environments shall be covered with one of the following methods:
1. Twice Wrap 20 Mill Scotch Wrap PVC No. 51, 50% overlap.
2. Prefabricated extruded plastic cover with joints sealed with two coats of 20 Mill Scotch Wrap No. 51.

2.19 EXPANSION COMPENSATORS AND FLEXIBLE PIPING CONNECTIONS

A. General: Pipe expansion, in general, is to be absorbed in bends, swing joints, expansion loops, and offsets. All piping mains, branches, and runouts shall be installed to allow for free expansion and contraction without developing leaks or undue stressing of pipe. Stresses shall be within allowable limits of ANSI B31.9. Expansion products to conform to the standards of the Expansion Joint Manufacturer’s Association. Expansion joints shall not require packing. Installer shall select materials and pressure/temperature ratings to suit intended service. Select packless expansion joints to provide 150% absorption capacity of calculated maximum piping expansion between anchors. All connections shall have ends to match piping system application.

B. Expansion Compensators (Pipe Compression and Extension): Multiple stainless steel bellows and stainless steel liner with shroud and end fittings.
1. Acceptable Manufacturers:
   a. Keflex #311.
   b. Or approved equal.

C. Flexible Expansions Joint/Seismic Connector for Steel Pipe: Stainless steel hose and braid, 180° return, CSA approved, and end fittings.
1. Acceptable Manufacturers:
   a. Metraflex #Metraloop.
   b. Unisource V-SF21 Style.
   c. Or approved equal.
D. Flexible Connection for Steel Pipe (Piping and Equipment Located Outside the Building): Stainless steel hose and braid, with threaded or flanged ends.

1. Acceptable Manufacturers:
   a. Metraflex #SST.
   b. Or approved equal.

E. Flexible Connection for Copper Pipe: Bronze hose and braid, copper tube ends. Provide steel supports to prevent sagging is required.

1. Acceptable Manufacturers:
   a. Metraflex #BBS.
   b. Unisource V-BF11 Style.
   c. Or approved equal.

F. Flexible Rubber Connectors (Pump Connections): Concentric spool type expansion joint, single or double arch. Chlorobutyl tube and cover, meeting ASTM specification D2000 Grade 2AA610AB, L13. The body shall be reinforced with rectangular body rings and a minimum of six bias plies of polyester fabric. A hypalon coating shall be applied completely and uniformly to the cover. All expansion joints shall be rated 190 PSI/26” vacuum at 250°F for sizes up to and including 12”.

1. For heating hot water service and critical pump connections. Furnish with fluorelastomer tube and cover to ASTM D2000 Grade 1HK710. The body shall be reinforced with rectangular body rings and six bias plies of fiberglass/Kevlar fabric rated 190#/26” vacuum at 400°F. Provide galvanized flat (not L shaped) back up rings and control rods to limit maximum axial extension. Manufacturer shall provide documentation utilizing oven aged and cold flexibility tests to verify elastomer capability. Each batch of compound manufactured shall be tested to verify it conforms to the ASTM specifications listed below.
   a. Manufacturer: Garlock #204HP. No known equals.

<table>
<thead>
<tr>
<th>CHLOROBUTYL</th>
<th>VITON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>ASTMD 792</td>
</tr>
<tr>
<td>Durometer Shore A</td>
<td>ASTMD 2240</td>
</tr>
<tr>
<td>Tensile</td>
<td>ASTMD 412</td>
</tr>
<tr>
<td>Elongation</td>
<td>ASTMD 412</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>POLYESTER</th>
<th>FIBERGLASS/KEVLAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thread Count</td>
<td>ASTMD 3775</td>
</tr>
<tr>
<td>Gauge</td>
<td>ASTMD 1777</td>
</tr>
<tr>
<td>Weight</td>
<td>ASTMD 3776</td>
</tr>
<tr>
<td>Breaking Strength</td>
<td>ASTMD 1682</td>
</tr>
</tbody>
</table>

2. For chilled water, and non-critical pump connections. Furnish with fluorelastomer tube and cover to ASTM D2000 Grade 1HK710. The body shall be reinforced with rectangular body rings and six bias plies of fiberglass/Kevlar fabric rated 190#/26” vacuum at 250°F. Provide galvanized flat (not L shaped) back up rings and control rods to limit maximum axial extension.

   a. Manufacturer:
      1) Garlock #206 EZ-FLO.
      2) Or approved equal.
G. Pipe Alignment Guides: Provide pipe alignment guides on both sides of expansion joints and elsewhere as indicated on drawings. Guide shall be of carbon steel construction with split guiding cylinder and integral anchor base and internal four finger two-place spider. Cylinder wall thickness shall be equal to schedule 40 wall thickness of pipe being guided. Spider shall be capable of clamping directly to pipe and moving only in an axial direction while inside cylinder. Anchoring directly to building substrate.

1. Acceptable Manufacturers:
   a. Metraflex #Style IV.
   b. Or approved equal.

H. Expansion Loops: Field fabricated pipe expansion loops may be provided in place of mechanical expansion joints.

PART 3 – EXECUTION

3.1 GENERAL

A. Workmanship shall be performed by licensed journeymen or master mechanics and shall result in an installation consistent with best practices of trades.

B. Install work uniform, level, and plumb, in relationship to lines of building Do not install any diagonal or otherwise irregular work unless so indicated on Drawings or approved by Architect.

3.2 INSTALLATION OF PUMPS

A. General: Install pumps where shown, in accordance with manufacturer's written instructions and recognized industry practices to ensure that pumps comply with requirements and serve intended purposes. Comply with NEMA standards and requirements of NEC.

B. Follow manufacturers’ directions and recommendations in all cases where the manufacturers of articles used on this Contract furnish directions covering points not shown on the Drawings or covered in these Specifications.

C. Install pipes and pipe fittings in accordance with recognized industry practices which will achieve permanently leak proof piping systems, capable of performing each indicated service without piping failure. Install each run with minimum joints or couplings, but with adequate and accessible unions for disassembly and maintenance/replacement of valves and equipment. Reduce sizes (where indicated) by use of reducing fittings. Align piping accurately at connections, within 1/16” misalignment tolerance. Comply with ASM B31.9.

D. Coordination: Coordinate the work between the various Mechanical Sections and with the work specified under other Divisions of the work or contracts toward rapid completion of the entire project. If any cooperative work must be altered due to lack of proper supervision or failure to make proper provisions in time, then the work hereunder shall include all expenses of such changes as are necessary in the work under other contracts, and such changes shall be directly supervised by and made to the satisfaction of the Engineer.

E. Base-Mounted Pumps: Pumps shall be leveled, bolted, and grouted to pump bases. Piping shall be arranged so pump cases are not subjected to any piping forces. Contractor shall check for proper angular and concentric alignment of pumps and motors before pumps are operated. Pump bases shall be filled with grout in place after pump alignment.
F. Alignment: Check alignment and, where necessary, realign shafts of motors and pumps within tolerances recommended by manufacturer.

G. Drain Lines: Provide a drain line (0.75" minimum) from each pump drip base to the nearest floor drain.

H. The cooperative work not included in the Mechanical Division related to the general construction work is as follows:
   1. All formed concrete work.
   2. Framed openings in masonry and other Architectural and Structural elements.
   3. Wood grounds and nailing strips in masonry and concrete.

I. Inspect all material, equipment, and apparatus upon delivery, and do not install any that may be subject to rejection as a result of damage or other defects. Provide tarps and visqueen cover to protect equipment and piping delivered to and stored at the site.

J. Locate piping runs, except as otherwise indicated, vertically and horizontally and avoid diagonal runs wherever possible. Orient horizontal runs parallel with walls and column lines. Locate runs as shown or described by diagrams, details, and notations or, if not otherwise indicated, run piping in shortest route which does not obstruct space or block access for servicing building and its equipment. Hold piping close to walls, overhead construction, and other structural and permanent-enclosure elements of building. Limit clearance to 0.5” where furring is shown for enclosure or concealment of piping, but allow for insulation thickness, if any. Where possible, locate insulated piping for 1” clearance outside insulation. Whenever possible in finished and occupied spaces, conceal piping from view, by locating in column enclosures, in hollow wall construction, or above suspended ceilings. Do not encase horizontal runs in solid partitions, except as indicated.

K. Elevator Machine Rooms, Switchgear, Generator, SSR/Telecommunications, and Electrical Equipment Spaces: Do not run piping through electrical or electronic equipment spaces and enclosures unless unavoidable. Install drip pan under piping that must be run through electrical spaces.

L. Cleaning: Clean exterior surfaces of installed piping systems of superfluous materials, and prepare for application of specified coatings as necessary.

3.3 ELECTRICAL CONNECTIONS

A. Power: Coordinate pump power connections.

B. Grounding: Provide positive electrical pump and motor grounding in accordance with applicable requirements of the NEC.

3.4 HEAT EXCHANGER INSTALLATION

A. General: Install in accordance with manufacturer’s instruction and ASME Code. Provide a safety relief valve on heated water side to prevent excessive buildup of pressure. Safety relief valve shall be selected to coordinate with the piping system pressure rating.

B. Testing: Test shell and tube heat exchangers concurrently with connected piping systems.
3.5 HUMIDIFIER INSTALLATION

A. Humidifier installation shall be in accordance with the manufacturer’s instructions. Obtain assembly instruction, piping diagrams, wiring diagrams and other directions from the factory before proceeding with the installation.

B. Install humidifiers to maintain access and clearances in front of control panels and other devices for proper adjustment and maintenance.

C. Install humidifier manufacturer provided devices for field installation and provide all wiring and conduits between them.

3.6 FIELD QUALITY CONTROL AND START-UP

A. Start-Up: The pump supplier shall provide pump checkout, start-up, testing and adjusting of system components.

B. Field Test: Upon completion of pump installation and after motor has been energized from normal power source, bleed air pump casing and test pump to demonstrate compliance with requirements. When possible, field-correct malfunctioning units then retest to demonstrate compliance. Replace units which cannot be satisfactorily corrected.

C. Seals: After pumps have been in operation for 90 days, the Contractor shall check all seals and replace any which are defective.

3.7 FLUSHING AND CLEANING PIPING SYSTEMS

A. Water Piping (chilled, heating): Clean systems following the method provided below or method recommended by the Airport’s water treatment supplier.

1. Initial flushing: Remove loose dirt, mill scale, metal chips, weld beads, rust, and similar deleterious substances without damage to any system component. Provide temporary piping or hoses to bypass coils, control valves, exchangers and other factory cleaned equipment unless acceptable means of protection are provided and subsequent inspection of hide-out areas takes place. Isolate or protect clean system components, including pumps and pressure vessels, and remove any components which may be damaged. Open all valves, drains, vents and strainers at all system levels. Remove plugs, caps, spool pieces, and components to facilitate early debris discharge from system. Sectionalize system to obtain debris-carrying velocity of 2.5 to 6 feet per second, if possible. Connect dead-end supply and return headers as necessary. Flush bottoms of risers. Install temporary strainers where necessary to protect down-stream equipment. Supply and remove flushing water and drainage by various type hose, temporary and permanent piping and contractor’s booster pumps. Flush until clean as approved by the Owner, Architect or Engineer.

2. Cleaning: Using products recommended by the Airport’s water treatment supplier, circulate systems at normal temperature to remove adhering organic soil, hydrocarbons, flux, pipe mill varnish, pipe joint compounds, iron oxide, and similar substances not removed by flushing, without chemical or mechanical damage to any system component. Removal of tightly adherent mill scale is not required. Before cleaning isolate equipment which is “clean” and where dead-end debris accumulation must not occur. Sectionalize system if possible, to circulate at velocities not less than 6 feet per second. Circulate each section for not less than four hours. Blow-down all strainers, or remove and clean as frequently as necessary. Drain and prepare for final flushing.
3. Final Flushing: Return systems to conditions required by initial flushing after all cleaning solution has been displaced by clean make-up. Flush all dead ends and isolated clean equipment. Gently operate all valves to dislodge any debris in valve body using the velocity of this throttling action. Flush for not less than one hour.

3.8 WATER TREATMENT EQUIPMENT AND SYSTEMS

A. Install water treatment equipment and provide water treatment for systems as required.

B. Close and fill systems as soon as possible after final flushing to minimize corrosion.

3.9 WELDING

A. Qualifications of Welders: Welders performing work under this Contract shall be certified and qualified in accordance with tests prescribed by the National Certified Welding Bureau (NCWB) or by other approved test procedures using methodology and procedures covered in the ASME Boiler and Pressure Vessel Code, Section IX, “Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators.” Installation shall conform to ANSI 31.9 “Building Piping.”

1. Submit for approval the names, identification, and welder’s assigned number, letter or symbol of welders assigned to this project.

2. The assigned identification symbol shall be used to identify the work of each welder and shall be indelibly stamped immediately upon completion of each weld.

3. Welders shall be tested and certified for all positions.

4. Submit identifying stenciled test coupons made by each operator.

5. Any or all welders may be required to retake welding certification tests without additional expense.

6. When so requested, a welder shall not be permitted to work as a welder on this project until he has been recertified in accordance with NCWB. Recertification of the welder shall be made after the welder has taken and passed the required tests.

7. Where piping 1.5” and smaller is butt or socket welded, submit 3 samples of test welds for approval.

3.10 PIPING SYSTEM JOINTS

A. All piping shall be cut squarely, free of rough edges and reamed to full bore. Piping shall be mechanically cleaned prior to make-up of joints and fully inserted into fittings.

B. Provide joints of type indicated in each piping system.

C. Thread pipe in accordance with ANSI B2.1. Cut threads full and clean using sharp dies. Ream threaded ends to remove burrs and restore full inside diameter. Remove excess cutting oil from piping prior to assembly. Apply pipe joint compound, or pipe joint tape (Teflon) where recommended by pipe/fitting manufacturer, on male threads at each joint and tighten joint to leave not more than 3 threads exposed.

D. Solder copper tube and fitting joints with lead free nickel/silver bearing solder meeting ASTM. B-32, in accordance with IAPMO IS 3-93, ASTM B-828 and Copper Development Association recommended
procedures. Joints shall be cleaned by other than chemical means prior to assembly. “Shock” cooling is prohibited. Fluxes shall be applied liberally to the outside of the pipe and the solder cup of the fitting. Fluxes shall be water soluble for copper and brass potable water applications, and shall meet CDA standard test method 1.0 and ASTM B813-91. Solder shall be applied until a full fillet is present around the joint. Solder and flux shall not be applied in such excessive quantities as to run down interior of pipe. Lead solder or corrosive flux shall not be present at the jobsite.

1. Acceptable Manufacturers:
   a. Solder:
      1) JW Harris “Bridgit”.
      2) Englehard “Silvabrite 100”.
      3) Or approved equal.
   b. Flux:
      1) Laco “Flux-Rite 90”.
      2) MW Dunton “Nokorode CDA Flux”.
      3) Hercules “Fluid Action Solder Flux”.
      4) Or approved equal.

E. Braze copper tube and fitting socket or extrude joints (T-drill) with BCUP series filler metal without flux. Listed brazing flux shall be used for joining copper tube to brass or bronze fittings and shall meet AWS FB3A or FB3C. “Shock” cooling is prohibited. A continuous fillet shall be visible around the completed joint. After cooling, flux residue shall be thoroughly removed with warm water and a brush prior to testing. Do not use BCUP filler on copper alloys containing over 10% nickel.

F. Piping shall be capped during construction to prevent entry of foreign material.

G. Weld pipe joints in accordance with recognized industry practice and as follows:
   1. Weld pipe joints only when ambient temperature is above 0 °F.
   2. Bevel pipe ends at a 37.5° angle where possible, smooth rough cuts, and clean to remove slag, metal particles, and dirt.
   3. Use pipe clamps or tack-weld joints with 1" long welds, 4 welds for pipe sizes to 10", 8 welds for pipe sizes 12" to 20".
   4. Build up welds with stringer-bead pass, followed by hot pass, followed by cover or filler pass. Eliminate valleys at center and at edges of each weld. Weld by procedures which will ensure elimination of unsound or un-fused metal, cracks, oxidation, blow-holes, and non-metallic inclusions.
   5. Do not weld out piping system imperfections by tack-welding procedures. Re-fabricate to comply with requirements.
   6. At Installer’s option, install forged branch-connection fittings whenever branch pipe is indicated, or install regular T-fitting.

H. Flanged Joints: Match flanges within piping system and at connections with valves and equipment. Clean flanges faces and install gaskets. Tighten bolts to provide uniform compression of gaskets.

3.11 VALVES

A. General: Except as otherwise indicated, comply with the following requirements.
1. Install valves where required for proper orientation of piping and equipment, including valves in branch lines where necessary to isolate sections of piping. Locate valves so as to be accessible and so that separate support can be provided as necessary.

2. Install valves, except butterfly valves, with stems pointed up, in vertical position where possible, but in no case with stems pointed downward from horizontal plane without prior written approval. Install valve drains with hose-end adapter for each valve that must be installed with stem below horizontal plane.

3. Install butterfly valves with stems mounted horizontally.

4. All valves mounted higher than 10 feet above floor in mechanical rooms and where indicated shall be installed with stem horizontal and equipped with chain wheels and chains extending to 5 feet above floor.

B. Insulation: Where insulation is indicated, install extended-stem valves, arranged in proper manner to receive insulation.

C. Selection of Valve Ends (Pipe Connections): Except as otherwise indicated, select and install valves with the following ends of types of pipe/tube connections:

   1. Copper Pipe, 2.5" and Smaller:
      a. Soldered-joint valves.

   2. Copper Pipe, 2.5" and Larger: Soldered joint or flanged.

   3. Steel Pipe, 2" and Smaller: Threaded joint valves.

   4. Steel Pipes, sizes 2.5" and larger: One of the following, at installer's option:
      a. Flanged valves.
      b. Lug valves.

D. Non-Metallic Disc: Limit selection and installation of valves with non-metallic discs to locations indicated and where foreign material in piping system can be expected to prevent tight shutoff of metal seated valves.

E. Renewable Seats: Select and install valves with renewable seats, except where otherwise indicated.

F. Fluid Control: Except as otherwise indicated, install gate, globe, ball, plug, circuit setter, glove, and butterfly valves to comply with ASME B31.9.

G. Swing Check Valves: Install in horizontal position with hinge pin horizontally perpendicular to center line of pipe. Install for proper direction of flow.

H. Wafer Check: Install between 2 flanges in horizontal or vertical position.

I. Ball Valve: Ball valve used on gas systems shall be UL listed, CSA approved for pressure of system, no exception.

J. Valve Adjustment: After piping systems have been tested and put into service, but before final testing, adjusting, and balancing, inspect each valve for possible leaks. Adjust or replace packing to stop leaks, replace valve if leak persists.
K. Valve Identification: Tag each valve in accordance with “Mechanical Identification” section.

L. Cleaning: Clean factory-finished surfaces. Repair marred or scratched surfaces with manufacturer’s touch-up paint.

M. Install so handles are readily available. Locate valves and valve handles for appropriate maintenance access.

N. Gasket and O Ring Material: Valve manufacturer is responsible for submittals. Provide gasket and O ring material best suited for the both piping systems.

3.12 TEMPERATURE GAUGES

A. General: Install temperature gauges in vertical upright position, and tilted so as to be easily read by observer standing on floor without supplemental illumination. All gauges to be installed with snubbers to absorb system shock.

B. Install in the following locations, and elsewhere as indicated:
   1. At inlet and outlet of heat exchangers.

3.13 MECHANICAL SLEEVE SEALS

A. Loosely assemble rubber links around pipe with bolts and pressure plates located under each bolt head and nut. Push into sleeve and center. Tighten bolts until links have expanded to form a watertight seal.

B. Fire Barrier Penetration Seals: Fill entire opening with sealing compound in compliance approved and listed UL system number. Adhere to manufacturer’s installation instructions.

3.14 EXPANSION LOOPS

A. Expansion Loops: Fabricate expansion loops as indicated, in locations indicated, and elsewhere as determined by installer for adequate expansion of installed piping system. Provide pipe anchors and pipe alignment guides as indicated, and elsewhere as determined by installer to properly anchor piping in relationship to expansion loops.

3.15 PIPE INSPECTIONS

A. It is the intent of the Contract Documents that systems be inspected at completion of each phase while under tests required for administrative authorities, and prior to concealment, i.e. “Rough-in” “Top-out” and final.

B. Inspection – Above Grade: All piping installed above grade shall be inspected upon completion and prior to finish of walls and ceilings by the Architect, the Airport’s representative. Contractor must notify Airport’s representative no less than 24 working hours prior to inspection time. Should the piping be hidden within the structure prior to inspection approval the contractor may be requested to uncover the piping at no delay to the project and at no additional cost to the owner.

3.16 WATER ANALYSIS AND TREATMENT

A. Upon completion of systems installation, cleaning and filling, engage a qualified water treatment firm, acceptable to the Airport. The water treatment firm shall perform a chemical analysis on each system.
listed hereinafter, and shall submit a report, including the following:

1. Analysis of heating water and chilled water systems.
2. Initial treatment of each system.
3. Recommendations regarding subsequent, periodic, or continuous treatment on each system.

B. Contractor is to furnish and install initial treatment as specified in paragraph A, item 2 above.

3.17 TESTING

A. General: Test and adjust all installed pumps and controllers to verify proper operation as specified herein and as recommended by the manufacturers. Where specified hereinafter, start-up, testing, and adjustment shall be provided by a representative of the equipment supplier.

B. Provide all tests specified hereinafter and as otherwise required. Provide all test equipment including test pumps, gauges, instruments, and other equipment required. Test all rotational equipment for proper direction of rotation. Upon completion of testing, certify to the Architect, in writing, that the specified tests have been performed and that the installation complies with the specified requirements and provide a report of the test observations signed by qualified inspector.

C. Piping: Remove from the system, during testing, all equipment which would be damaged by test pressure. Replace removed equipment when testing has been accomplished. The systems may be tested in sections as the work progresses; however, any previously tested portion shall become a part of any latter test of a composite system. Correct leaks by remaking joints with new material.

D. Test Time will be accrued only while full test pressure is on the system, unless indicated otherwise. “Tolerance” shall be no pressure drop, except that due to temperature change in a 24-hour period. Inspect and test all work prior to burying or concealing. Test pressure shall be one and one-half times the system operating pressure or the listed test pressure below, whichever is greater:

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>TEST MEDIUM</th>
<th>TEST PRESSURE</th>
<th>TOLERANCE – TEST PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chilled Water</td>
<td>Water</td>
<td>125 psig</td>
<td>None – 2 hours</td>
</tr>
<tr>
<td>Heating Water</td>
<td>Water</td>
<td>125 psig</td>
<td>None – 2 hours</td>
</tr>
<tr>
<td>Refrigerant Piping</td>
<td>Nitrogen</td>
<td>200 psig</td>
<td>None – 2 hours</td>
</tr>
</tbody>
</table>

E. Functional Tests: Test controllers and annunciators to verify that all control, alarm, and indicator functions operate properly and to verify that pump discharge pressures and flows are as specified.

F. Valves: Test all valve bonnets for tightness. Test operate all valves at least once from closed-to-open-to-closed position while valve is under test pressure.

G. Piping Specialties: Test all thermometers, pressure gauges, and water meters for accurate indication; and air vents for proper performance. Test all air vent points to ensure that all air has been vented.

3.18 IDENTIFICATION

A. As per requirements for applicable painting, nameplates, and labeling requirements.

END OF SECTION 23 21 13
SECTION 23 21 23 – HYDRONIC PUMPS

PART 1 – GENERAL

1.1 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this section shall comply with all the requirements of General Conditions and all Supplemental Conditions.

1.2 SCOPE

A. All work to be furnished and installed under this section shall include, but not necessarily be limited to, the following:
1. Flexible coupled end suction pumps.
2. Close coupled end suction pumps.
3. In-line flexible coupled pumps.
4. In-line close coupled pumps.
5. Vertical split cased double suction pumps.
6. Horizontal split cased pumps
7. In-line circulators
8. Expansion tanks - diaphragm type pre-pressurized.
10. Air elimination valve.
11. Suction diffusers.
12. Chemical pot feeders.

1.3 REFERENCES

A. Codes and Standards: Provide pumps which conform to the requirements of:
1. Hydraulic Institute (HI): Manufacturer pumps in accordance with “Standards for Centrifugal Rotary and Reciprocating Pumps.”
2. National Electrical Manufacturers Association (NEMA): Provide electrical components which comply with NEMA Standards.
   a. 70: National electrical Code
4. Underwriters Laboratories (UL):
   a. UL-778: Motor Operated Water Pumps
5. American Society of Mechanical Engineers (ASME)

1.4 QUALITY ASSURANCE

A. Manufacturer’s Qualifications: Provide systems that are the standard product of an equipment manufacturer regularly engaged in the production of such units who issues complete catalog information on such products.
1.5 SUBMITTALS

A. Product Data: Submit manufacturer’s technical product data for units showing dimensions, weights (shipping, installed, and operating), capacities, ratings, performance with operating point clearly indicated, motor electrical characteristics, finishes of materials, and installation instructions.

1. Parallel pump plots: For all parallel and series pump applications submit a combined pump curve showing parallel pump operation and single pump non-overloaded operation verifying that the pump selections operate non-overloading on curve in a single pump operation.

2. Submittal information to verify all scheduled characteristics are met including efficiency.

B. Shop Drawings: Submit manufacturer’s shop drawings indicating dimensions, weight (shipping, operating), required clearances, methods of assembly of components, and location and size of each field connection.

C. Maintenance Data: Submit maintenance instructions, including instructions for lubrication, tube replacement, motor and drive replacement, and spare parts lists. Include this data, product data, shop drawings, and wiring diagrams in operating and maintenance manuals.

D. Wiring Diagrams: Submit manufacturer’s ladder-type wiring diagrams for power and control wiring required. Differentiate between factory-installed and field-installed wiring.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver units to the site in containers with manufacturer’s stamp or label affixed.

B. Store and protect products and units against dirt, water, chemical, and mechanical damage. Do not install damaged units - remove from project site.

C. Rigging: Comply with the manufacturer’s rigging and installation instructions.

1.7 WARRANTY

A. Provide general one (1) year warranty. The warranty shall include parts, labor, travel costs, and living expenses incurred by the manufacturer to provide factory authorized service.

PART 2 – PRODUCTS

2.1 FLEXIBLE COUPLED END SUCTION PUMPS

A. Furnish and install pumps with capacities as shown on plans. Pumps shall be base mounted, single stage, end suction design with true back pull-out, capable of being serviced without disturbing piping connections.

B. Pump volute shall be Class 30 cast iron with integrally cast pedestal support. The impeller shall be cast bronze, enclosed type, dynamically balanced, keyed to the shaft and secured by a locking capscrew. Impeller trim shall be no greater than 85% of the maximum impeller size for the pump.

C. The liquid cavity shall be sealed off at the pump shaft by an internally flushed mechanical seal with ceramic seal seat of at least 98% alumina oxide content, and carbon seal ring, suitable for continuous operation at 225°F. A replaceable bronze shaft sleeve shall completely cover the wetted area under the seal.
D. Pumps shall be rated for minimum of 175 psi working pressure. Casings shall have gauge ports at nozzles and vent and drain ports at top and bottom of casing.

E. Pump bearing housing assembly shall have heavy duty re-greaseable ball bearings, replaceable without disturbing piping connections and have foot support at coupling end.

F. Base plate shall be of structural steel or fabricated steel channel configuration fully enclosed at sides and ends, with securely welded cross members and fully open grouting area. A flexible type coupler, capable of absorbing torsional vibration, shall be employed between the pump and motor, and shall be equipped with an OSHA approved coupling guard. Contractor to level and grout each unit according to manufacturer’s instructions.

G. The motor shall meet NEMA specifications and shall be the size, voltage and enclosure called for on the plans. Pump and motor shall be factory aligned, and shall be realigned by contractor after installation. Provide premium efficiency motors as specified.

H. Each pump shall be factory tested, it shall then be thoroughly cleaned and painted with at least one coat of high grade machinery enamel prior to shipment.

I. Each unit shall be checked by the contractor and regulated for proper differential pressure, voltage and amperage draw. This data shall be noted on a permanent tag or label and fastened to the pump for owner’s reference.

J. Manufacturer: Bell & Gossett series “1510” or approved equal by Taco, Paco, Peerless or Armstrong.

2.2 CLOSED COUPLED END SUCTION PUMPS

A. Furnish and install pumps with capacities as shown on plans. Pumps shall be close coupled, single stage, vertically split case design, capable of being serviced without disturbing piping connections.

B. Pump volute shall be Class 30 cast iron, and impeller shall be cast bronze enclosed type, dynamically balanced, keyed to the shaft and secured by a locking caps crew. Impeller trim shall be no greater than 85% of the maximum impeller size for the pump.

C. The liquid cavity shall be sealed off at the motor shaft by an internally flushed mechanical seal with ceramic seal seat of at least 98% alumina oxide content, and carbon seal ring, suitable for continuous operation at 225° F. A replaceable shaft sleeve of bronze alloy shall completely cover the wetted area under the seal.

D. Pumps shall be rated for minimum of 175 psi working pressure. Casings shall have gauge ports, and vent and drain ports at top and bottom of casing.

E. Motor shall meet NEMA specifications and shall be of the size, voltage and enclosure called for on the plans. It shall have heavy duty grease lubricated ball bearings, completely adequate for the maximum load for which the motor is designed.

F. Each pump shall be factory tested. It shall then be thoroughly cleaned and painted with at least one coat of high grade machinery enamel prior to shipment.

G. Each pump shall be checked by the contractor and regulated for proper differential pressure, voltage and amperage draw. This data shall be noted on a permanent tag or label and fastened to pump for
owner's reference.

H. Manufacturer: Bell & Gossett series “1531” or approved equal by Taco, Paco, Peerless or Armstrong.

2.3 IN-LINE FLEXIBLE COUPLED PUMPS

A. Furnish and install pumps with capacities as shown on plans. Pumps shall be in-line type for installation in vertical or horizontal piping. Pump must be capable of being serviced without disturbing piping connections.

B. Pump body shall be of Class 30 cast iron, rated 175 psi working pressure, with gauge ports at nozzles, and with vent and drain ports.

C. Impeller shall be non-ferrous material, enclosed type, dynamically balanced, keyed to the shaft and secured by a locking caps crew or nut. Impeller trim shall be no greater than 85% of the maximum impeller size for the pump.

D. The liquid cavity shall be sealed off at the motor shaft by an internally flushed mechanical seal with ceramic seal seat, and carbon seal ring, suitable for continuous operation at 225° F. A non-ferrous shaft sleeve shall completely cover the wetted area under the seal.

E. Pump bearing bracket shall have oil lubricated bronze journal and thrust bearings. Bracket shaft shall be alloy steel having ground and hardened thrust bearing faces. A flexible coupling to dampen starting torque and torsional vibrations shall be employed. Flexible coupling shall be equipped with an OSHA approved coupling guard.

F. Motor shall meet NEMA specifications and shall be the size, voltage and enclosure called for on the plans. Provide premium efficiency motors as specified.

G. Each pump shall be factory tested. It shall then be thoroughly cleaned and painted with at least one coat of high grade machinery enamel prior to shipment.

H. Manufacturer: Bell & Gossett series “60” or approved equal by Taco, Paco, Peerless or Armstrong.

2.4 IN-LINE CLOSE COUPLED PUMPS

A. Furnish and install pumps with capacities as shown on plans. Pumps shall be in-line type, close coupled, single stage design, for installation in vertical or horizontal position, and capable of being serviced without disturbing piping connections.

B. Pump casing shall be Class 30 cast iron, and impeller shall be of cast bronze enclosed type, dynamically balanced, keyed to the shaft and secured by a locking caps crew. Impeller trim shall be no greater than 85% of the maximum impeller size for the pump.

C. The liquid cavity shall be sealed off at the motor shaft by an internally flushed mechanical seal with ceramic seal seat and carbon seal ring, suitable for continuous operation at 225° F. A bronze shaft sleeve shall completely cover the wetted area under the seal.

D. Pumps shall be rated for minimum of 175 psi working pressure. The pump case shall have gauge tappings at the suction and discharge nozzles and will include vent and drain ports.

E. Motor shall meet NEMA specifications and shall be of the size, voltage and enclosure called for on
the plans. It shall have heavy duty grease lubricated ball bearings, completely adequate for the maximum load for which the motor is designed.

F. Each pump shall be factory tested. It shall then be thoroughly cleaned and painted with at least one coat of high grade machinery enamel prior to shipment.

G. Manufacturer: Bell & Gossett “80” or approved equal by Taco, Paco, Peerless or Armstrong.

2.5 IN LINE WATER LUBRICATED CIRCULATING PUMPS (SECONDARY PUMPING AND BOOSTER APPLICATIONS)

A. Furnish and install pumps with capacities as shown on plans. Pumps shall be in-line type for installation in vertical or horizontal piping. Pump must be capable of being serviced without disturbing piping connections.

B. Pump body shall be of all bronze construction, rated 175 psi working pressure, with gauge ports at nozzles, and with vent and drain ports.

C. Impeller shall be non-ferrous material, enclosed type, dynamically balanced, keyed to the shaft and secured by a locking cap screw or nut.

D. The liquid cavity shall be sealed off at the motor shaft by an internally-flushed mechanical seal with ceramic seal seat, and carbon seal ring, suitable for continuous operation at 225°F. A non-ferrous shaft sleeve shall completely cover the wetted area under the seal.

E. Motor shall meet NEMA specifications and shall be the size, voltage and enclosure called for on the plans.

F. Each pump shall be factory tested. It shall then be thoroughly cleaned and painted with at least one coat of high-grade machinery enamel prior to shipment.

G. Provide H-O-A switch with overload protection. Pump shall run continuously. Wiring between switch and pump provided under Division 23, as stated in Section 23 05 00.


2.6 EXPANSION TANKS

A. Diaphragm Type Pre-pressurized:
   1. The pressurization system shall include a diaphragm-type expansion tank which will accommodate the expanded water of the system generated within the normal operating temperature range, limiting this pressure increase at all components in the system to the maximum allowable pressure at those components. It shall maintain minimum operating pressure necessary to eliminate all air. The only air in the system shall be the permanent sealed-in air cushion contained in the diaphragm-type tank.
   2. The expansion tank shall be welded steel, constructed, tested and stamped in accordance with Section VIII of the ASME Code for a working pressure of 125 psi and precharged to the minimum operating pressure.
   3. The manufacturer shall be Wessels, Amtrol or approved equal with at least 5 years’ experience in the fabrication of diaphragm-type ASME expansion tanks.
2.7 AIR SEPARATORS

A. Tangential and coalescing media type:
   1. Furnish and install Spirotherm, Bell & Gossett, Wheatley, Armstrong, Taco, Amtrol or approved equal air separator on the HVAC circulating water systems.
   2. All fittings shall be fabricated steel, rated for 150 psig design pressure and be selected for less than 1 foot of water pressure drop and entering velocity not to exceed 4 feet per second at specified GPM.
   3. Units shall eliminate 99.6% of system air (including entrained air and microbubbles). Performance curves from the unit manufacturer shall be furnished as part of the submittal for each unit. Units may include internal copper coalescing medium to facilitate maximum air elimination and suppress turbulence or be furnished with galvanized steel strainer and stainless steel collector tube for a similar purpose.
   4. Provide integral high capacity float actuated air vent at top fitting of tank or cast iron float actuated air vent rated at 150 psig which shall be threaded to the top of the separator. Unit shall have bottom blow down connection.

2.8 AIR ELIMINATION VALVE (AUTOMATIC)

A. Air shall be eliminated to the atmosphere as fast as it is separated from system water, through a float activated remote pressure operated, air elimination valve installed at the top of the air separator.
   B. The air elimination valve shall have a high removal rate at low pressure differentials and shall be fully open for the removal of air at all pressures in the operating range from 2 to 150 psig. It shall be tightly sealed against loss of system water and prevent entrance of air in negative pressure situations.
   C. The air elimination valve shall be constructed of metal and all working parts shall be non-corrosive. Working pressure shall be 125 psi.
   D. Provide minimum 3/8” drain line from vent and route to nearest floor drain or floor sink or other approved drainage location.
   E. Manufacturer: Amtrol, Hoffman or approved equal.

2.9 SUCTION DIFFUSERS

A. Furnish and install as shown on plans, an angle pattern flow straightening fitting equipped with a combination diffuser-strainer-orifice cylinder, flow straightening vanes, start-up strainer, permanent magnet and adjustable support foot. The combination diffuser-strainer-orifice cylinder shall be designed to withstand pressure differential equal to the system pump shutoff head and shall have a free area equal to five times the cross section area of the pump suction opening. The length of the flow straightening vanes shall be no less than 2.5 times the diameter of the system suction connection.
   B. Fitting to be of cast iron construction with flanged connections unless otherwise noted. See plan for sizes.
   C. The fitting shall have a stainless steel combination diffuser-strainer-orifice cylinder with 3/16” diameter perforation to protect system pump. Provide with stainless steel straightening vanes. Start-up strainer to be 16 mesh bronze. All internal components to be replaceable.
D. Manufacturer: Bell & Gossett, Taco, Wheatley, Victaulic or approved equal.

2.10 CHEMICAL POT FEEDER

A. Provide 5-gallon pot feeder with removable cover, bottom drain valve, and shut-off valves. Provide balancing valve and check valves as shown on Drawings.

B. Mount on wall and pipe across pump(s) as shown on Drawings. Provide clearance under the pot feeder for draining into a 5-gallon bucket.

C. Manufacturer: Dearborn, Garrett-Callahan, or approved equal.

PART 3 – EXECUTION

3.1 INSTALLATION

A. All equipment, unless otherwise shown or noted on the Drawings, is to be installed in accordance with industry standards and manufacturer-recommended installation instructions.

B. Grouting Pump Base: For all base mounted flexibly coupled pumps fill the pump base frame with grout after completing pump/motor alignment.

C. Provide vibration isolation, inertia bases, seismic snubber, flexible pipe connections, etc., as specified in related specification sections.

D. Mechanical contractor to assist testing and balancing contractor in verifying correct pump rotation and system operation.

E. Flush and clean equipment, in accordance with manufacturer’s start-up instructions, and in presence of manufacturer’s representative. Test controls and demonstrate compliance with requirements. Replace damaged or malfunctioning controls.

F. Isolation for Service: Provide pump installations with a discrete isolation valve on both the supply and intake side of the pump to permit service of the pump and any related strainer, check or balancing valves. Triple duty valves are not equivalent for this shut-off service.

G. Balancing Coordination and Impeller Trimming: Coordinate final pump flow with test and balance contractor. For pumps larger than 5 horsepower, if the system tests and balance indicate that flow exceeds the specified flow by greater than 20%, it is not acceptable to reduce flow merely by adjusting balance valves to create additional head or reducing VFD peak flows. Excess system flow must be reduced by trimming the impeller to match the load.

3.2 MANUFACTURER’S START-UP SERVICES

A. The manufacturer shall provide start-up service in the form of a factory trained service technician. The service technician shall verify correct installation, verify pump systems mounting, verify piping installation, verify control wiring, verify power wiring, and check for proper operation. The service technician shall provide final adjustments to meet the specified performance requirements. Fully staffed parts and service personnel shall be within four hours travel from the jobsite.

END OF SECTION 23 21 23
SECTION 23 23 00 – REFRIGERANT PIPING

PART 1 – GENERAL

1.1 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this section shall comply with all the requirements of General Conditions, Supplemental Conditions, General Requirements, Basic Materials and Methods, and other Sections in Division 23 specified herein.

1.2 SCOPE

A. Includes, but not limited to:
   1. Furnish and install piping and piping specialties for refrigeration systems serving split system air conditioning units.

1.3 REFERENCES

A. Welding: Qualify procedures and personnel according to ASME Boiler and Pressure Vessel Code: “Welding and Brazing Qualifications” and American Welding Society (AWS) Standards
C. American Society of Mechanical Engineers (ASME) Standard: Comply with ASME B31.5, “Refrigeration Piping.”
E. American Society for Testing and Materials (ASTM) Standards

1.4 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions, apply to this Section.

1.5 SUMMARY

A. This Section includes refrigerant piping used for air-conditioning applications.

1.6 SUBMITTALS

A. Product Data: For each type of valve and refrigerant piping specialty indicated. Include pressure drop, based on manufacturer’s test data, for thermostatic expansion valves, solenoid valves, and pressure-regulating valves.
B. Shop Drawings: Show layout of refrigerant piping and specialties, including pipe, tube, and fitting sizes, flow capacities, valve arrangements and locations, slopes of horizontal runs, oil traps, double risers, wall and floor penetrations, and equipment connection details. Show interface and spatial relationship between piping and equipment.
   1. Refrigerant piping indicated is schematic only. Size piping and design the actual piping layout,
including oil traps, double risers, specialties, and pipe and tube sizes, to ensure proper operation and compliance with warranties of connected equipment.

C. Welding Certificates: Copies of certificates for welding procedures and personnel.

D. Field Test Reports: Indicate and interpret test results for compliance with performance requirements.

E. Maintenance Data: For refrigerant valves and piping specialties to include in maintenance manuals.

1.7 QUALITY ASSURANCE

A. Qualifications: A refrigeration contractor licensed by the State shall install refrigerant piping.

1.8 COORDINATION

A. Coordinate layout and installation of refrigerant piping and suspension system components with other construction, including light fixtures, HVAC equipment, fire-suppression-system components, and partition assemblies.

B. Coordinate pipe sleeve installations for foundation wall penetrations.

C. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Section “Roof Accessories.”

D. Coordinate pipe sleeve installations for penetrations in exterior walls and floor assemblies. Coordinate with requirements for fire stopping specified in Section “Through-Penetration Firestop Systems” for materials and methods for sealing pipe penetrations through fire and smoke barriers.

E. Coordinate pipe fitting pressure classes with products specified in related Sections.

PART 2 – PRODUCTS

2.1 COPPER TUBE AND FITTINGS

A. Drawn-Temper Copper Tube: ASTM B 280, Type ACR.

B. Wrought-Copper Fittings: ASME B16.22.

C. Wrought-Copper Unions: ASME B16.22.

D. Brazing Filler Metals: AWS A5.8, Classification BAg-1 (silver)

2.2 REFRIGERANT PIPING


B. Do not use pre-charged refrigerant lines more than 50 feet in length.

2.3 REFRIGERANT FITTINGS

A. Wrought copper with long radius elbows.
B. Acceptable Manufacturers:
   1. Mueller.
   2. Nibco.
   4. Elkhart Products Corp.
   5. Or approved equal.

2.4 SUCTION LINE TRAPS

A. Manufactured standard one-piece traps.

2.5 CONNECTION MATERIAL

A. Brazing Rods:
   1. Copper to Copper Connections:
      a. AWS Classification BCuP-4 Copper Phosphorus (6% silver).
      b. AWS Classification BCuP-4 Copper Phosphorus (15% silver).
   2. Copper to Brass to Steel Connections
      a. AWS Classification Bag-5 Silver (45% silver).
   3. Do not use rods containing Cadmium.

2.6 FLUX

A. Acceptable Manufacturers:
   1. “Stay –Silver white brazing flux” by J.W. Harris Co.
   2. High quality silver solder flux by Handy & Harmon.
   3. Or approved equal.

2.7 EXPANSION VALVES

A. For Pressure type distributors, externally equalized with stainless steel diaphragm, and same refrigerant in thermostatic elements as in system.

B. Size valves to provide full rated capacity of cooling coil served. Coordinate selection with evaporator coil and condensing unit.

C. Acceptable Manufacturers:
   1. Alco.
   2. Henry.
   4. Parker.
   5. Singer.
   7. Or approved equal.

2.8 FILTER DRIER

A. On lines 0.75” outside diameter and larger, filter-drier shall be replaceable core type with non-
ferrous casing and Schraeder type valve.

B. On lines smaller than 0.75” outside diameter, filter-drier shall be sealed type using flared copper fittings.

C. Size shall be full line size.

D. Acceptable Manufacturers:
   1. Alco.
   3. Parker.
   4. Sporlan.
   5. Virginia.
   6. Or approved equal.

2.9 SIGHT GLASS

A. Combination moisture and liquid indicator with protection cap.

B. Sign glass shall be full line size.

C. Sight glass connections shall be solid copper or brass, no copper-coated steel sight glasses allowed.

D. Acceptable Manufacturers:
   1. Alco.
   2. Esco.
   4. Parker.
   5. Sporlan.
   6. Or approved equal.

2.10 MANUAL REFRIGERANT SHUT-OFF VALVE

A. Provide each liquid line and suction line at both condensing unit and evaporator on systems larger than five tons.

B. Anchor pipe near each flexible connector.

C. Connectors shall be for refrigerant service with bronze seamless corrugated hose and bronze braiding.

D. Acceptable Manufacturers:
   2. Vibration Absorber Model VAF by Packless Industries.
   4. Style “BF” Spring-flex refrigerant connectors by Vibration Mountings.
   5. Or approved equal.

2.11 REFRIGERANTS

A. ASHRAE 34, R-410a.
B. Use refrigerants with lower global warming potential (GWP) as they become commercially available.

PART 3 – EXECUTION

3.1 PIPING APPLICATIONS

A. Aboveground, within Building: Type ACR drawn-copper tubing.

3.2 PIPING INSTALLATION

A. Install refrigerant piping according to ASHRAE 15.

B. Basic piping installation requirements are specified in Division 23 Section “Common Work Results for HVAC”.

C. Install piping as short and direct as possible, with a minimum number of joints, elbows, and fittings.

D. Arrange piping to allow inspection and service of compressor and other equipment. Install valves and specialties in accessible locations to allow for service and inspection.

E. Install piping with adequate clearance between pipe and adjacent walls and hangers or between pipes for insulation installation. Use sleeves through floors, walls, or ceilings, sized to permit installation of full-thickness insulation.

F. Belowground, install copper tubing in protective conduit. Vent conduit outdoors.

G. Install copper tubing in rigid conduit in locations where copper tubing will be exposed to mechanical injury.

H. Slope refrigerant piping in accordance with air conditioning equipment manufacturer’s recommendations. Slope suction lines down toward compressor or one”/10 feet. Locate traps at vertical rises against flow in suction lines.

I. Refrigeration system connections shall be copper-to-copper, copper-to-brass, or copper-to-steel type properly cleaned and brazed with specified rods. Use flux only where necessary
   1. Circulate dry nitrogen through tubes being brazed to eliminate formation of copper oxide during brazing operation.

J. Insulate all suction and hot gas lines. Insulate liquid lines where pipe may be in close contact to humans.

K. Install unions to allow removal of solenoid valves, pressure-regulating valves, and expansion valves and at connections to compressors and evaporators.

L. When brazing, remove solenoid-valve coils and sight glasses; also remove valve stems, seats, and packing, and accessible internal parts of refrigerant specialties. Do not apply heat near expansion valve bulb.

M. Hanger, support, and anchor products are specified in Division 23 Section “Hangers and Supports for HVAC Piping and Equipment.”

N. Install the following pipe attachments:
1. Adjustable steel clevis hangers for individual horizontal runs less than 20 feet long.
2. Roller hangers and spring hangers for individual horizontal runs 20 feet or longer.
3. Pipe rollers for multiple horizontal runs 20 feet or longer, supported by a trapeze.
4. Spring hangers to support vertical runs.

O. Install hangers for copper tubing with the following maximum spacing and minimum rod sizes:
   1. NPS 1/2: Maximum span, 60”; minimum rod size, 0.25”.
   2. NPS 5/8: Maximum span, 60”; minimum rod size, 0.25”.
   3. NPS 1: Maximum span, 72”; minimum rod size, 0.25”.

3.3 PIPE JOINT CONSTRUCTION

A. Braze joints according to Division 23 Section “Common Work Results for HVAC”.

B. Fill pipe and fittings with an inert gas (nitrogen or carbon dioxide) during brazing to prevent scale formation.

3.4 FIELD QUALITY CONTROL

A. Test and inspect refrigerant piping according to ASME B31.5, Chapter VI.

   1. Test refrigerant piping, specialties, and receivers. Isolate compressor, condenser, evaporator, and safety devices from test pressure.
   2. Test high- and low-pressure side piping of each system at not less than the lower of the design pressure or the setting of pressure relief device protecting high and low side of system.
      a. System shall maintain test pressure at the manifold gauge throughout duration of test.
      b. Test joints and fittings by brushing a small amount of soap and glycerine solution over joint.
      c. Fill system with nitrogen to raise a test pressure of 150 psig or higher as required by authorities having jurisdiction.
      d. Remake leaking joints using new materials, and retest until satisfactory results are achieved.

B. Make evacuation and leak tests in presence of Owner’s representative after completing refrigerant piping system. Positive pressure test will not suffice for procedure outlined below:

   1. Draw vacuum on each entire system with vacuum pump to 200 microns using vacuum gauge calibrated in microns. Do not use cooling compressor to evacuate system nor operate it while system is under high vacuum. Isolate compressor from system piping using shut-off valves prior to pulling vacuum.
   2. Break vacuum with refrigerant to be used and re-establish vacuum test. Vacuum shall hold for 24 hours at 200 microns without compressor running.
   3. Conduct test at 70 °F ambient temperature minimum.
   4. Do not sure systems until tests have been made and systems started up as specified. Inform Owner’s Representative of status of systems at time of final inspection and schedule start-up and testing of prevented by outdoor conditions before this time.
5. After testing, fully charge system with refrigerant and conduct test with Halide Leak Detector.

6. Install valves and specialties in accessible locations. Install refrigeration distributors and suction outlets at same end of coil.

3.5 ADJUSTING

A. Adjust thermostatic expansion valve to obtain proper evaporator superheat requirements.

B. Adjust high- and low-pressure switch settings to avoid short cycling in response to fluctuating suction pressure.

C. Adjust set-point temperature of the conditioned air or chilled-water controllers to the system design temperature.

D. Perform the following adjustments before operating the refrigeration system, according to manufacturer’s written instructions:
   1. Open shutoff valves in condenser water circuit.
   2. Check compressor oil level above center of sight glass.
   3. Open compressor suction and discharge valves.

E. Open refrigerant valves, except bypass valves that are used for other purposes.

F. Check compressor-motor alignment, and lubricate motors and bearings.

3.6 CLEANING

A. Before installing copper tubing other than Type ACR, clean tubing and fittings with trichloroethylene.

B. Replace core of filter-dryer after system has been adjusted and design flow rates and pressures are established.

3.7 SYSTEM CHARGING

A. Charge system using the following procedures:
   1. Install core in filter-dryer after leak test but before evacuation.
   2. Evacuate entire refrigerant system with a vacuum pump to a vacuum of 500 micrometers. If vacuum holds for 12 hours, system is ready for charging.
   3. Break vacuum with refrigerant gas, allowing pressure to build up to 2 psig.
   4. Charge system with a new filter-dryer core in charging line. Provide full operating charge.

END OF SECTION 23 23 00
SECTION 23 31 13 – METAL DUCTS

PART 1 – GENERAL

1.1 DESCRIPTION

A. General: Provide Ductwork and accessories in accordance with the contract documents.

B. System Description: Duct system design, as indicated, has been used to select size and type of air-moving and air-distribution equipment and other air system components. Changes to layout or configuration of duct systems must be specifically approved by the Architect.

1.2 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this Section shall comply with all the requirements of Section pertaining Basic Mechanical Requirements.

1.3 REFERENCES

A. Comply with Sheet Metal and Air Conditioning Contractors National Association (SMACNA), HVAC Duct Construction Standards, latest Edition, Metal and Flexible recommendations for fabrication, construction, details, and installation procedures, except as otherwise indicated on the Drawings or in these Specifications.

1. SMACNA “HVAC Duct Construction Standards – Metal and Flexible

2. SMACNA “Accepted Industry Practice for Industrial Duct Construction” for duct pressures above 5+” W.G. positive pressure or below -5” W.G. negative pressure.

3. All ductwork and equipment shall be seismically supported and braced per “Seismic Restraint Manual Guidelines for Mechanical Systems”, including Appendix E where applicable.

B. Comply with American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards and recommendations, except as otherwise indicated on the Drawings or in these Specifications.


C. Provide products conforming to the requirements of the following:

1. ADC 1062-R4 - Certification, Rating and Test Manual. Each item shall bear the ADC certified rating seal.


and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip. Type 304 or 304 stainless steel.


8. TIMA AAC-101 - Standard for fiberglass duct liner with erosion proof facing.

9. Underwriters Laboratories (UL) 181 - Factory-Made Air Ducts and Connections, Class 1

D. Conform to National Fire Protection Association (NFPA)

1. 90A “Standards for the Installation of Air Conditioning and Ventilating Systems” and NFPA 90B “Installation of Warm Air Heating and Air Conditioning Systems.”


E. Alternatives: The SMACNA standards and publications referenced in this Section of the specifications establish ductwork construction requirements.

1. Alternatives to these standards and publications may be submitted. Approval will be based on demonstration that such alternatives are equivalent and satisfy the functional requirements described in the referenced standards, and that the alternative meets the requirements of the 2010 California Mechanical Code, including Section 602.1.

2. Such demonstration shall include evidence that the alternatives proposed were tested in accordance with SMACNA procedures and with test results certified by an independent testing laboratory.

F. Certification: Fire, fire/smoke and smoke dampers shall be UL-listed, FM-approved and comply with applicable building code requirements. All materials, including sealants and adhesives, shall have a flame-spread index of 25 or less, and smoke developed index of 50 or less, as tested by ASTM E84 (NFPA 255) method.

1.4 DEFINITIONS

A. FRP: Fiber-reinforced plastic.

1.5 SCOPE

A. All work to be furnished and installed under this Section should include, but not necessarily be limited to, the following applicable items:

2. Ductwork Specialties.
3. Flexible Connections.
5. Duct Access Panel and doors.
6. Duct-mounting access doors.
7. Backdraft Dampers.
8. Control Dampers.
10. Fire and Smoke Dampers.
14. Motorized Control Dampers. (Isolation Dampers)
15. Fire Dampers.
17. Combination Fire and Smoke Dampers.
18. Turning Vanes.
19. Flexible Ducts.
20. Duct Accessory Hardware.

1.6 DUCTWORK TYPES

A. VAV Supply Air Ductwork Upstream of Terminal Units: Medium pressure Ductwork shall be sheet metal ductwork designed for velocities up to 4000 fpm and pressures up to +4” wg. Ductwork shall be externally insulated, or internally lined, as shown on the Drawings. Seal Class A.

B. Supply Air Ductwork Downstream of Terminal Units: Ductwork shall be sheet metal ductwork designed for velocities up to 2500 fpm and pressure up to +2” wg. Ductwork shall be externally insulated, except provide one” duct liner downstream of all terminal units, as shown on drawings. Seal Class B.

C. Outside and Other Supply Air Ductwork: Ductwork shall be sheet metal ductwork designed for velocities up to 2500 fpm and pressure up to +3” wg. Outside Ductwork shall not be insulated, unless otherwise shown. Seal Class B.

D. Stairwell Pressurization Ductwork: Ductwork shall be sheet metal ductwork designed for velocities up to 4000 fpm and pressures up to +3” wg. Stairwell pressurization ductwork shall not be insulated. Seal Class B.

E. Return Air Ductwork: Ductwork shall be sheet metal ductwork designed for velocities up to 2500 fpm and pressure up to -2” wg. Ductwork used for return air boots and elbows and other return air ductwork where shown on the Drawings shall be lined with one” (1”) duct liner. Seal Class B.

F. General Exhaust Ductwork: General exhaust ductwork shall include all exhaust ductwork which is not otherwise specified. Ductwork shall be sheet metal ductwork designed for velocities up to 2500 fpm and pressure up to -2” wg. General exhaust duct shall be uninsulated, except horizontal exhaust ductwork from/in toilets shall be lined with one” (1”) duct liner. Seal Class C.

G. Flexible Ductwork: Ductwork connections to HVAC terminal units and air devices shall be made with flexible ductwork connection where shown on the Drawings. Maximum allowable length is 5'-0”.

H. Other Ductwork: As shown or as required. Duct construction, leakage and sealing class to match the application per applicable ASHRAE/SMACNA Standards.

1.7 QUALITY ASSURANCE

A. Acceptable Manufacturers: Provide ductwork accessories complying with the specifications and produced by one of the following:
   1. Duro-Dyne.
   2. Elgin Sheet Metal Products.
4. Prefeco.
5. Ruskin.
6. United Sheet Metal.
7. Vent-Fabrics, Inc.
8. Ventlok.
9. Young Regulator Co.
10. Or approved equal.

1.8 SUBMITTALS

A. Prior to construction, submit for approval on all materials and equipment.
   2. Ductwork Specialties.
   3. Flexible Connections.
   5. Duct Access Panels and Doors.
   7. Control Dampers.
   8. Diffusers, Grilles, and Registers.
   9. Fire and Smoke Dampers.
  10. VAV Boxes and Coils.
  11. Duct Construction Standards – Metal and Flexible.

B. Product Data: For the following:
   1. Backdraft dampers.
   2. Volume dampers.
   3. Motorized control dampers.
   4. Fire dampers.
   5. Ceiling fire dampers.
   6. Combination fire and smoke dampers.
   7. Turning vanes.
   8. Duct-mounting access doors.
  10. Flexible ducts.
  11. Duct Accessory hardware.

C. Shop Drawing submittals shall include, but not be limited to, the following:
   1. Ductwork submittals shall include ductwork fabrication drawings and submittal data on ductwork specialties and construction details.
   2. Ductwork fabrication drawings shall be drawings to scale on building floor plans and shall indicate duct sizes, duct material, duct insulation type, locations of transverse joints, fittings, ductwork bottom elevation, offsets, ductwork specialties, concealed damper regulators, fire and fire/smoke dampers and all other information required for coordination with other trades and fabrication of ductwork. All fire and fire/smoke partitions shall be clearly designated on the ductwork shop drawings. Ductwork fabrication drawings shall be coordinated with other trades and building construction prior to submittal for approval.
   3. Duct specialties and construction details (including, but not limited to, assemblies, dimensions weights, loads, required clearances, method of field assembly, components, and location and size of each field connection) shall include, but not limited to information on duct construction and
Section 23 31 13 | Metal Ducts

4. Penetrations through fire-rated and other partitions.

5. Seam and joint construction.

6. Equipment installation based on equipment being used on Project.

7. Hangers and supports, including methods for duct and building attachment, vibration isolation, and seismic restraints.

8. Cut sheets of ductwork accessories, clearly indicating materials, construction dimensions, ratings, approvals and other pertinent information.

9. Manufacturers’ UL approved installation instructions for fire, fire/smoke, and smoke dampers.

10. Duct system leakage test procedures and reporting forms.

11. Additional information as required.

D. Shop Drawings: Provide shop drawings of sheet metal ductwork and plenums as follows:

1. Draw to a scale not less than 1/8” to one foot, with sheet sizes equal to Contract Drawings.

2. Show duct sizes, where possible use even duct sizes.

3. Show fitting details.

4. Show coordination with lighting fixtures, fire dampers, smoke dampers, piping, diffusers, grilles, registers, fans, major electrical runs, cable trays, and bus ducts.

E. Shop Drawings: Provide drawings for field erected mechanical equipment.

1. Draw to a scale of ½” to one foot, with sheet sizes equal to Contract Drawings.

2. Show plan, sections, elevations, and details of all joints and enclosures.

3. Detail access doors and hardware.

4. Detail coil, damper, humidifier, filter, and fan installations.

F. Certifications: Provide a duct schedule, certified by an officer of the sheet metal fabrication Contractor, that the ductwork conforms to SMACNA standards, and for each sheet metal system furnished on the project include:

1. System name.

2. Duct material.

3. Duct gauge.

4. SMACNA rectangular reinforcement number.

5. SMACNA intermediate reinforcement number.

6. SMACNA transverse reinforcement number.

7. Rod diameter and type.

8. Sealant type.

10. Duct system design pressure.

G. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items as shown and coordinated with each other, based on input from installers of the items involved:

1. Ceiling suspension assembly members.

2. Other systems installed in same space as ducts.

3. Ceiling- and wall-mounting access doors and panels required to provide access to dampers and other operating devices.

4. Ceiling-mounting items, including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.

H. Field Manual: Provide one copy of the SMACNA “HVAC Duct Construction Standards – Metal and Flexible” and maintain copy on the project site.

I. Welding certificates.

J. Field quality-control test reports.

1.9 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver products to the site in containers with manufacturer’s stamp or label affixed.

B. Deliver ductwork materials to the site in suitable packaging to prevent damage and exposure to weather and construction dust.

C. Protect products against dirt, water, chemicals, and mechanical damage.

D. Do not install damaged components – remove from project site.

PART 2 – PRODUCTS

2.1 DUCTWORK MATERIALS

A. General: Construct all ducts and plenum of gauges, and with joints, bracing, reinforcing, and other construction details in accordance with the specified construction standards.

B. Sheet Metal: Ductwork shall be constructed using prime G60 galvanized lock-forming quality or coil steel in widths up to 60”, conforming to ASTM A525 and using gauges selected by application, based upon applicable SMACNA Standards.

C. Stainless Steel: Ductwork shall be constructed using 316L sheet or roll stainless steel in widths up to 60” and using gauges selected by application, based upon applicable SMACNA Standards and NFPA 96 requirements.

D. Black Steel: Ductwork shall be constructed using sheet or roll black steel in widths up to 60” and using gauges selected by application, based upon applicable SMACNA standards and NFPA 96 requirements (future application).

E. Aluminum: Ductwork shall be constructed using sheet or roll aluminum in widths up to 60” and using gauges selected by application, based upon applicable SMACNA standards.
F. Ducts shall be constructed of material gauges and reinforcement in accordance with the following SMACNA pressurization classifications:

1. Supply air ductwork in constant volume systems – 4” W.G.
2. Supply air ductwork in VAV systems upstream of VAV boxes – 4” W.G.

G. Ductwork materials shall be stenciled on maximum 10’ centers with the manufacturer’s name and material gauge. Stenciling shall be visible after duct is fabricated and installed.

H. Exposed Ductwork Materials: Where ductwork is indicated to be exposed to view in occupied spaces, provide materials which are free from visual imperfections including pitting, seam marks, standing seams, roller marks, oil canning, stains, discolorations, and other imperfections, including those which would impair painting. All exposed duct routings with all fittings, joints, reinforcements, etc. shall be submitted to the Architect for review of aesthetic concerns. Any revisions required due to aesthetic reasons shall be incorporated in the installations. All exposed supply and return ductwork shall be internally lined with 1” duct liner.

I. Metals shall be manufactured by United States Steel, Kaiser, Rolok, or equal.

J. Duct dimensions indicated on Drawings are net, inside, clear dimensions. For internally lined ducts, add lining thickness to determine metal duct dimensions.

2.2 SHEET METAL MATERIALS

A. Comply with SMACNA’s “HVAC Duct Construction Standards – Metal and Flexible” for acceptable materials, material thicknesses, and duct construction methods, unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Lock-forming quality; complying with ASTM A 653/A 653M and having G90 coating designation; ducts shall have mill-phosphatized finish for surfaces exposed to view.

C. Carbon-Steel Sheets: ASTM A 366/A 366M, cold-rolled sheets; commercial quality, with oiled, matte finish for exposed ducts.

D. Stainless Steel: ASTM A 480/A 480M, Type 304.

E. Aluminum Sheets: ASTM B 209, alloy 3003, temper H14; with mill finish for concealed ducts and standard, 1-side bright finish for exposed ducts.

F. Extruded Aluminum: ASTM B 221, alloy 6063, temper T6.

G. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.

H. Tie Rods: Galvanized steel, 0.25” minimum diameter for lengths 36” or less; 3/8-” minimum diameter for lengths longer than 36”.

2.3 MISCELLANEOUS DUCTWORK MATERIALS

A. General: Provide miscellaneous materials and products of the types and sizes indicated and where
not otherwise indicated, provide type and size required to comply with ductwork system requirements including proper connection of ductwork and equipment.

B. Duct Sealant: Provide non-hardening, non-migrating mastic or liquid elastic sealant (type applicable for the fabrication/installation detail) as compounded and recommended by the manufacturer specifically for sealing joints and seams in ductwork. Sealers shall be as follows:

1. Sealer shall have high solids content.
2. Sealer shall have a high adhesive and cohesive strength and shall bond to both degreased and non-degreased metals.
3. Sealer shall conform to NFPA 90-A requirements and be UL labeled for ductwork applications.
4. Sealer and related installation materials and methods shall be:
   a. Hardcast Type 601 Iron Grip Duct Sealant.
   b. United McGill Corporation United Duct Sealer.
   c. Foster Type 30-02 High Velocity Duct Seal.
   d. Transcontinental Equipment Ltd. Multipurpose Water Based Duct Sealer.

C. Ductwork Support Materials: Except as otherwise indicated, provide hot-dipped galvanized steel fasteners, anchors, rods, straps, trim, and angles for support of ductwork.

2.4 RECTANGULAR DUCTWORK

A. Rectangular ductwork shall be constructed and reinforced to SMACNA standards of galvanized sheet steel. Fabricate elbows, transitions, offsets, branch connections and other construction according to SMACNA’s “HVAC Duct Construction Standards –Metal and Flexible” and complying with requirements for metal thickness, reinforcing types and intervals, tie-rod applications and joint types and intervals. Diagonally crossbreak all panels on ducts 30” wide and larger, or bead using automatic bead machine with beads at 12” on center or less.

B. Slip drive joints, standard seams, flanges, or welding as required by SMACNA Duct construction Standards. Ductmate, MEX Industries, or equal are acceptable joint methods, but must be sealed as described previously.

C. Lengths: Fabricate rectangular ducts in lengths appropriate to reinforcement and rigidity class required for pressure class.

D. Deflection: Duct systems shall not exceed deflection limits according to SMACNA’s “HVAC Duct Construction Standards – Metal and Flexible.”

E. Traverse Joints: Prefabricated slide-on joints and components constructed using manufacturer’s guidelines for material thickness, reinforcement size and spacing, and joint reinforcement.

1. Acceptable Manufacturers:
   a. Ductmate Industries, Inc.
   b. Nexus Inc.
   c. Ward Industries, Inc.
   d. Or approved equal.

F. Formed-On Flanges: Construct according to SMACNA’s “HVAC Duct Construction Standards Metal and
Flexible, Figure 1-4, using corner, bolt, cleat, and gasket details.

1. Acceptable Manufacturers:
   a. Ductmate Industries, Inc.
   b. Lockformer.
   c. Or approved equal.

2. Duct Size: Maximum 30” wide and up to 2” wg pressure class.

3. Longitudinal Seams: Pittsburgh lock sealed with noncuring polymersealant.

G. Cross Breaking or Cross Beading: Cross break or cross bead duct sides 19” and larger and 0.0359” thick or less, with more than 10 sq. ft of non-braced panel area unless ducts are lined.

H. Secure insulation between perforated sheet metal inner duct of same thickness as specified for outer shell. Use mechanical fasteners that maintain inner duct at uniform distance from outer shell without compression insulation.
   1. Sheet Metal Inner Duct Perforations: 3/32” diameter, with an overall open area of 23% .

2.5 ROUND DUCTWORK

A. Round and oval ductwork shall be constructed to SMACNA round ductwork requirements of galvanized sheet steel according to “HVAC Duct Construction Standards – Metal and Flexible.”

B. Diameter as applied to flat-oval ducts in this Article is the diameter of a round duct with a circumference equal to the perimeter of a given size of flat-oval duct.

C. Round, Spiral Lock-Seam Ducts: Fabricate supply ducts according SMACNA’s “HVAC Duct and Construction Standards – Metal and Flexible.” Spiral lock seams, only, to 50” diameter. Larger than 50” may be welded longitudinal or spiral lock seam. Lap or snap lock seams are not permitted for round ductwork of any size. Fabricate ducts larger than 72” in diameter with butt-welded longitudinal seams. Provide beaded sleeve joints or flanges with gasket joints.

D. Duct Joints:
   1. Ducts up to 20 Inches in Diameter: Interior, center-beaded slip coupling, sealed before and after fastening, attached with sheet metal screws.
   2. Ducts 21” to 72 Inches in Diameter; Three-piece, gasketed, flanged joint consisting of two internal flanges with sealant and one external closure band with gasket.
   3. Ducts Larger than 72 Inches in Diameter: Companion angle, flanged joints per SMACNA “HVAC Duct Construction Standards – Metal and Flexible,” Figure 3-2.

E. Round Ducts: Prefabricated connection system consisting of double-lipped, EPDM rubber gasket. Manufacture ducts according to connection system manufacturer’s tolerances.
   1. Acceptable Manufacturers:
      a. Ductmate Industries, Inc.
      b. Lindab Inc.
      c. Or approved equal.

F. Flat oval may be utilized in space restricted areas.
1. Prefabricated connection system consisting of two flanges and one synthetic rubber gasket. Acceptable Manufacturers:
   a. Ductmate Industries, Inc.
   c. SEMCO Incorporated.
   d. Or approved equal.

G. 90-Degree Tees and Laterals and Conical Tees: Fabricate to comply with SMACNA’s “HVAC Duct Construction Standards – Metal and Flexible,” with metal thicknesses specified for longitudinal-seam straight ducts.

H. Diverging-Flow Fittings: Fabricate with reduced entrance to branch taps and with no excess material projecting from fitting into branch tap entrance.

I. Elbows shall be 5-gore mitered and spot & sealed. All elbows shall be long radius type with centerline radius to duct diameter of 1.5, exceptions will only be allowed at restricted space locations.

J. Fabricate elbows using die-formed, pleated, or mitered construction. Bend radius of die-formed, pleated elbows shall be 1.5 times duct diameter. Unless elbow construction type is indicated, fabricate elbows as follows:

1. Mitered-Elbow Radius and Number of Pieces: Welded construction complying with SMACNA’s “HVAC Duct Construction Standards – Metal and Flexible,” unless otherwise indicated.

2. Round Mitered Elbows: Welded construction with the following metal thickness for pressure classes from minus 2- to plus 2” wg:
   a. Ducts 3 to 36 Inches in Diameter: 0.034”.
   b. Ducts 37 to 50 Inches in Diameter: 0.040”.
   c. Ducts 52 to 60 Inches in Diameter: 0.052”.
   d. Ducts 62 to 84 Inches in Diameter: 0.064”.
   e. Round Mitered Elbows: Welded construction with the following metal thickness for pressure classes from 2- to 10” wg:
   f. Ducts 3 to 26 Inches in Diameter: 0.034”.
   g. Ducts 27 to 50 Inches in Diameter: 0.040”.
   h. Ducts 52 to 60 Inches in Diameter: 0.052”.
   i. Ducts 62 to 84 Inches in Diameter: 0.064”.

3. Flat-Oval Mitered Elbows: Welded construction with same metal thickness as longitudinal-seam flat-oval duct.

4. 90-Degree, 2-Piece, Mitered Elbows: Use only for supply systems or for material-handling class A or B exhaust systems and only where space restrictions do not permit using radius elbows. Fabricate with single-thickness turning vanes.

5. Round Elbows 8 Inches and Less in Diameter: Fabricate die-formed elbows for 45- and 90- degree elbows and pleated elbows for 30, 45, 60 and 90 degrees only. Fabricate nonstandard bend-angle configurations or nonstandard diameter elbows with gored construction.

6. Round Elbows 9 through 14 Inches in Diameter: Fabricate gored or pleated elbows for 30, 45, 60, and 90 degrees unless space restrictions require mitered elbows. Fabricate nonstandard bend-angle configurations or nonstandard diameter elbows with gored construction.
7. Round Elbows Larger Than 14 Inches in Diameter and All Flat-Oval Elbows: Fabricate gored elbows unless space restrictions require mitered elbows.

8. Die-Formed Elbows for Sizes through 8 Inches in Diameter and All Pressures 0.040” thick with 20-piece welded construction.

9. Flat-Oval Elbow Metal Thickness: Same as longitudinal-seam flat-oval duct specified above.

10. Pleated Elbows for Sizes through 14 Inches in Diameter and pressure through 10-Inch wg: 0.22”.

2.6 FLEXIBLE DUCTS

A. General: Insulated flexible duct shall be a factory fabricated assembly consisting of an non-woven nylon inner liner, fiberglass insulation, polyethylene vapor barrier outer jacket, steel spring wire helix, adjustable metal male/female collars, pressure rating 1.5 in. positive to ½ in. negative, maximum air velocity of 4000 fpm (continuous), and temperature range of 20 °F to 200°F.

B. Standards: Flexible duct shall be listed as Class I Air Duct per UL 181 and shall comply with NFPA 90A and 90B.

C. Flexible one” thick insulated round ductwork may be utilized where shown on the Drawings and at the last eight 98’ feet to each air outlet and inlet, unless shown otherwise on the plans.

D. Maximum of only one 90-degree bend in any length.

E. No intermediate joints are allowed.

F. Low Pressure Duct: Type M-KE. Rated at +6” wg. positive and -1” wg. negative pressure (pressure rating for duct larger than 18” shall be at +4” wg). CPE Inner liner permanently bonded to coated spring steel wire helix and wrapped with fiberglass insulation blanket with a thermal conductance of 0.23 or less. Outer jacket to be fiberglass reinforced aluminum foil and mylar laminated vapor barrier jacket with Perm rating of 0.1 when tested per ASTM E96-66. Use at duct connection to air outlets. Maximum allowable length 5’-0”. Use minimum of 3’-0” long flexible duct.

G. Medium/High Pressure Duct: Type M-KC. Rated at +16” wg. positive and -2” wg. negative pressure, construction materials similar to low pressure duct, with coated woven fiberglass inner liner permanently bonded to coated helical steel wire. Use at high pressure duct connection to VAV terminal units. Maximum allowable length 3’-0” unless otherwise noted on plans.

H. Seismic Flex Duct: Type M-KC. Rated at 16” wg positive and -2” wg. negative pressure construction materials similar to low pressure duct, with coated woven fiberglass inner liner permanently bonded to coated helical steel wire. Use on all round ducts crossing building seismic joints, and as indicated on drawings. Length of duct to be determined by the seismic joint displacement.

I. Low permeability outer vapor barrier of fiberglass reinforced film laminate shall complete the composite.

J. Indoor R-values shall be 4.2.

K. Fire Ratings: Flexible duct shall have a flame spread rating of less than 25 and a smoke developed rating of less than 50.
L. Clamps:

1. Terminal unit inlet flexible duct inner liner shall be secured using Ideal or approved equal all stainless steel 9/16” wide band clamps. Air device flexible duct outer jackets shall be secured using 0.35” wide self-locking nylon straps as manufactured by Panduit Corporation, Ideal or an approved equal.

2. Stainless-steel band with cadmium-plated hex screw to tighten band with a worm-gear action, in sizes 3 through 18” to suit duct size.

M. Terminal Unit Duct Connections: Provide 45° angle taps or bellmouth fittings as detailed on the drawings for all flexible duct connections serving terminal units.

N. Acceptable Manufacturers: (Model numbers listed are by Thermaflex)

1. Thermaflex.
2. Cody/West.
3. Casco Silentflex II.
4. Or approved equal.

2.7 DUCTWORK ACCESSORIES

A. Acceptable Manufacturers:

1. Ruskin.
2. Vent-Fabrics Inc.
3. Ventlok
4. Young Regulator Co.
5. Elgin.
6. Duro-Dyne.
8. Or approved equal.

B. Flexible Connections:

1. Provide flexible connectors at the discharge and inlet of fans, air handlers, rotating mechanical equipment, and where shown on the Drawings for proper vibration isolation.

2. Flexible connections shall be minimum 9” wide, (3” metal, 3” fabric, 3” metal) and be UL- labeled, 30 oz. glass fabric-lined and coated on both sides with neoprene, complete with factory metal edge, 24-gauge galvanized metal frame, and attachment accessories.

3. Use flame-retardant or noncombustible fabrics, coatings, and adhesives complying with UL 181, Class 1.

4. Flexible connections shall be fabricated and installed in accordance with Fig. No. 2-17 of the SMACNA HVAC Duct Construction Standards, with minimum 2” gap between fixed and moving ducts, or approved equal.

5. Metal-Edged Connectors: Factory fabricated with a fabric strip 3-1/2” wide attached to two strips of 2-0.75” wide, 0.028” thick, galvanized sheet steel or 0.032” thick aluminum sheets. Select metal compatible ducts.

   a. Minimum Weight: 26 oz./sq. yd.
   b. Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
c. Service Temperature: Minus 40 to plus 200 °F.

   a. Minimum Weight: 24 oz./sq. yd.
   b. Tensile Strength: 530 lbf/inch in the warp and 440 lbf/inch in the filling.
   c. Service Temperature: Minus 50 to plus 250 °F.

8. Neoprene-only connectors are not allowed.

9. Acceptable Manufacturers:
   b. Duro Dyne Corp.
   c. Q Industries.
   d. Consolidated Kinetics.
   e. Elgen.
   f. Ductmate Industries, Inc.
   g. Ward Industries, Inc.
   h. Or approved equal.

C. Concealed Damper Regulators: Ventlok Model 677, with 2-5/8” paintable coverplate and countersunk screws, suitable for 1/2” square hot rolled rod, or approved equal with mitergears and rod attachments, as required. Provide for volume control and balancing dampers in inaccessible ceilings. Provide special wrenches, as used with the regulators (one for each dozen regulators), to the Owner's representative after final balancing.

1. Bird Screens: 14 gauge, 1/2” galvanized mesh in galvanized steel frame. Provide in all duct/fan openings that lead to outdoor, and additionally where shown on drawings.

2. Insect Screens: Type 316 stainless steel insect screen mesh, 8x8, 0.023” wire thickness, 50% Free Area, in galvanized steel frame. Provide at duct air intakes below Level 1, as shown on drawings.

3. Safety Screens: Screens shall be No. 16 gauge, 1/2” galvanized steel mesh in removable galvanized steel frame. Provide safety screens meeting OSHA requirements for protection of maintenance personnel on all fan inlets and fan outlets to which no ductwork is connected.

D. Turning Vanes: Provide turning vanes in the size and type indicated with the following additional construction features. Vane runners shall automatically align vanes.

1. Fabricate 1.5” wide, double-vane, curved blades of galvanized sheet steel set ¾" o.c.; support bars perpendicular to blades set 2” o.c.; and set into vane runners suitable for duct mounting.

2. Blades: 4-1/2” galvanized steel ducts for over 18”.

3. Construction: Single wall blade, constructed in accordance with Fig. No. 2-3 and Fig No. 2-4 of the SMACNA HVAC Duct Construction Standards, 1995 Edition.

4. Types: Fixed blades for 90 degree elbows, adjustable for transition elbows and fixed for 45 degree elbows where shown.

5. Acceptable Manufacturers:
   a. Ductmate Industries, Inc.
   b. Duro Dyne Corp.
c. Metalaire, Inc.
d. Ward Industries, Inc.
e. Or approved equal.


E. Inspection Plates: Provide Inspection plates as detailed on the Drawings. If not detailed, provide a minimum opening of 4” x 4” with a 6 x 6” cover plate. The cover plate shall be one gauge heavier than the ductwork, gasketed and secured with a minimum of eight sheet metal screws.

1. Inspection plates shall be provided in ductwork at locations recommended or required by the ductwork accessories manufacturer, and others for inspection and observation of devices.

2. Do not substitute inspection plates for duct access doors.

F. Test Openings:

1. Ventlok No. 699 instrument test holes in locations as required to measure pressure drops across each item in the system, e.g., O.A. louvers, filters, fans, coils, intermediate points in duct runs, etc. Test holes in stainless steel duct systems shall be 316 stainless steel or an approved corrosion resistant design.

2. Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of Pitot tube and other testing instruments, and of length to suit duct insulation thickness.

3. Adhesives: High strength, quick setting neoprene based, waterproof, and resistant to gasoline and grease.


1. Manufacturers: ASTM C 1071; surfaces exposed to airstream shall be coated to prevent erosion of glass fibers.
   a. Thickness: 1” indoor and 2” for outdoor application.
   b. Thermal Conductivity (k-Value): 0.26 at 75 °F mean temperature.
   c. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.
   d. Liner Adhesive: Comply with NFPA 90A or NFPA 90B, and with ASTM C 916.
   e. Mechanical Fasteners: Galvanized steel suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in duct.
      1) Tensile Strength: Indefinitely sustain a 50-lb- tensile, dead-load test perpendicular to duct wall.
      2) Fastener Pin Length: As required for thickness of insulation and without projecting more than 1/8” into airstream.
      3) Adhesive for Attaching Mechanical Fasteners: Comply with fire-hazard classification of duct liner system.
H. Sealant Materials:
1. Joint and Seam Sealants, General: The term “sealant” is not limited to materials for adhesive or mastic nature but includes tapes and combinations of open-weave fabric strips and mastics.
3. Tape Sealing System: Woven-fiber tape impregnated with gypsum mineral compound and modified acrylic/silicone activator to react exothermically with tape to form hard, durable, airtight seal.
4. Water-Based Joint and Seam Sealant: Flexible, adhesive sealant, resistant to UV light when cured, UL 723 listed and complying with NFPA requirements for Class 1 ducts.
5. Solvent-Based Joint and Seam Sealant: One-part non-snag, solvent-release-curing, polymerized butyl formulated with a minimum of 75% solids.
6. Flanged Joint Mastic: One-part, acid-curing, silicone, elastomeric joint sealant complying with ASTM C 920, Type S, Grase NS, Class 25, Use O.
7. Flange Gaskets: Butyl Rubber or EPDM polymer with polyisobutylene plasticizer.

I. Miscellaneous: Provide miscellaneous materials for ductwork accessories, including hinges, refrigerator latches, sash locks, bolts and wing nuts, gaskets and pitot tubes as recommended by the ductwork accessories manufacturer for the application indicated.
1. Miscellaneous materials for duct accessories shall be provided under this Contract.
2. Common miscellaneous materials such as nuts, bolts, washers, brackets, supports, etc. that are required for installing the ductwork accessories furnished under other divisions shall be provided with all necessary miscellaneous materials (nuts, bolts, gaskets, pitot tubes, tubing, etc.) by this Contract.

2.8 DUCT SILENCERS

A. Acceptable Manufacturers:
1. Industrial Acoustics Company (IAC)
2. Commercial Acoustics.
4. Or approved equal.

B. General Description: Factory-fabricated and -tested, round or rectangular silencers with performance characteristics and physical requirements as indicated.

C. Fire Performance: Adhesives, sealants, packing materials, and accessory materials shall have fire ratings not exceeding 25 for flame-spread index and 50 for smoke-developed index when tested according to ASTM E 84.

D. Rectangular Units: Fabricate casings with a minimum of 0.034”-thick, solid galvanized sheet metal for outer casing and 0.022”-thick, ASTM A 653/A 653M, G60, perforated galvanized sheet metal for inner casing.

E. Round Units:
1. Outer Casings:
Section 23 31 13 | Metal Ducts

Metal Ducts

- Up to 24 Inches in Diameter: 0.034” thick.
- 26 through 40 Inches in Diameter: 0.040” thick.
- 42 through 52 Inches in Diameter: 0.052” thick.
- 54 through 60 Inches in Diameter: 0.064” thick.
- Casings fabricated of spiral lock-seam duct may be one size thinner than that indicated.

Interior Casing, Partitions, and Baffles:
- At least 0.034” thick and designed for minimum aerodynamic losses.

Sheet Metal Perforations: 1/8” diameter for inner casing and baffle sheet metal.

Fill Material: Inert and vermin-proof fibrous material, packed under not less than 5% compression.
- Erosion Barrier: Polymer bag enclosing fill and heat-sealed before assembly.

Fabricate silencers to form rigid units that will not pulsate, vibrate, rattle, or otherwise react to system pressure variations.
- Do not use nuts, bolts, or sheet metal screws for unit assemblies.
- Lock form and seal or continuously weld joints.
- Suspended Units: Factory-installed suspension hooks or lugs attached to frame in quantities and spaced to prevent deflection or distortion.
- Reinforcement: Cross or trapeze angles for rigid suspension.

Source Quality Control:
- Acoustic Performance: Test according to ASTM E 477.
- Record acoustic ratings, including dynamic insertion loss and self-noise power levels with an airflow of at least 2000-fpm face velocity.
- Leak Test: Test units for airtightness at 200% of associated fan static pressure or 6” wg static pressure, whichever is greater.

ACCESS DOORS

Fabricate doors airtight and suitable for duct pressure class.

Access Duct mounted devices: Provide Ruskin Type ADH22 or approved equal dual wall, insulated, hinged access doors in ductwork and plenums as required for access to fire, smoke and fire/smoke dampers, air flow measuring devices, coils, automatic dampers, duct smoke detectors, sampling tubes, humidifiers and other duct mounted devices. Minimum door size shall be 14” x 14” unless a smaller size is required due to duct dimensions. Access doors shall be constructed in accordance with Fig. No. 2-10 through 2-11 of the SMACNA HVAC Duct Construction Standards.

Walk-through access doors: Provide Ruskin Type GPAD or approved equal walk-through access doors for access into ductwork interiors, plenums in low to medium pressure systems. Minimum door size shall be 24”x 60” for filters and more frequent maintenance, unless smaller size is required due to duct dimension. Access door should be insulated (R=5.5) double wall type with leakage of less than 0.1 cfm/inch of door perimeter based on AMCA 500 tests.
D. In sheet metal work, hollow core double construction of same or heavier gauge material as duct in which installed.

E. Use Ventlok or approved hinges and latches on all doors; 100 Series hinges and latches on low pressure system doors and 333 Series on high pressure systems.

F. Construct doors up to 18” maximum dimension with one” overlap fit and gasket with ¾” by 1/8” sponge rubber, fit larger doors against 1.5” by 1/8” flat stock or angle frame and gasket with 0.75” by 1/8” sponge rubber or felt.

G. Door swing to be opposite airflow.

H. Door: Double wall, duct mounting, and rectangular; fabricated of galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class. Include vision panel where indicated. Include 1-by-1” butt or piano hinge and cam latches.
   1. Acceptable Manufacturers:
      a. American Warming and Ventilating.
      b. CESCO Products.
      c. Ductmate Industries, Inc.
      d. Flexmaster U.S.A., Inc.
      e. Greenheck.
      g. Nailor Industries Inc.
      h. Ventfabrics, Inc.
      i. Ward Industries, Inc.
      j. Or approved equal.
   2. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.
   3. Provide number of hinges and locks as follows:
      a. Less than 12” Square: Secure with two sash locks.
      b. Up to 18” Square: Two hinges and two sash locks.
      c. Up to 24” x 48”: Three hinges and two compression latches with outside and inside handles.
      d. Sizes 24” x 48” and Larger: One additional hinge.

I. Door: Double wall, duct mounting, and round; fabricated of galvanized sheet metal with insulation fill and 1” thickness. Include cam latches.
   1. Acceptable Manufacturers:
      a. Ductmate Industries, Inc.
      b. Flexmaster U.S.A., Inc.
      c. Or approved equal.
   2. Frame: Galvanized sheet steel, with spin-in notched frame.
   3. Seal around frame attachment to duct and door to frame with neoprene or foam rubber.
   4. Insulation: 1” thick, fibrous-glass or polystyrene-foam board

J. Acceptable Manufacturers:
1. CESCO.
2. Vent Products.
3. Air Balance.
4. Ruskin.
5. Or approved equal.

2.10 PLENUMS

A. General:

1. Construct plenums with gauges, joints, bracing, reinforcing, and other construction details per UMC, ASHRAE, or SMACNA unless specified otherwise, and comply with requirements of NFPA.

2. Construct of low carbon galvanized sheet metal of lock forming quality (LFQ), and minimum 1.25 oz. per square foot galvanized, except where otherwise indicated. Sheet metal gauge and LFQ visibly marked thereon by manufacturer.

B. Design/Construction:

1. SMACNA pressure class 3” W.G. where fan static pressure is 1.5” or less.

2. SMACNA pressure class 6” W.G. where fan static pressure is over 1.5”.

C. Panels: Width and gauges of panels, reinforcing and seals shall be established based upon SMACNA Standards for casing construction.

D. Sealing: Seal air tight joints with bead of butyl rubber; and screws or bolts at 6” on center.

E. Provide access doors, windows, lining, etc. as indicated or required in accordance with the Specifications.

F. Erect plenums on curbs with appropriate base channels. Coordinate dimensions with Architectural Drawings.

2.11 HANGERS AND SUPPORTS

A. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4” thick.

2. Exception: Do not use powder-actuated concrete fasteners for lightweight-aggregate concrete or for slabs less than 4” thick.

3. Galvanized-steel straps attached to aluminum ducts shall have contact surfaces painted with zinc-chromate primer.

B. Hanger Material: Galvanized sheet steel or threaded steel rod.

1. Hangers Installed in Corrosive Atmospheres: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.

2. Strap and Rod Sizes: Comply with SMACNA’s “HVAC Duct Construction Standards-Metal and Flexible” for steel sheet width and thickness and for steel rod diameters.
3. Galvanized-steel straps attached to aluminum ducts shall have contact surfaces painted with zinc-chromate primer.

C. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with all duct materials.

D. Trapeze and Riser Supports: Steel shapes complying with ASTM A 36/A 26M.
   3. Supports for Aluminum Ducts: Aluminum support materials unless materials are electrolytically separated from ducts.

2.12 BALANCING AND CONTROL DAMPERS

A. General: Provide all balancing (volume control), automatic, splitter, combination fire/smoke and fire dampers shown or noted on Drawings. All damper control devices shall be installed so as to be fully concealed in finished rooms and spaces.

1. Acceptable Manufacturers:
   a. Ruskin
   b. Air Balance
   c. Potteroff
   d. Greenheck
   e. Penn Ventilation Company, Inc
   f. Or approved equal.

B. Balancing Dampers: Balancing dampers shall be provided in all branch ducts, in air outlet take-offs and where shown on drawings and shall consist of single blade dampers in rigid round duct and rectangular duct up to 10” high and up to 12” wide, and opposed blade dampers (OBD) for dampers, if height or width exceed above sizes or when both height and width exceed the above single blade size limit. Damper construction shall be in accordance with SMACNA and ASHRAE guidelines for the application and shall consider both pressures and velocities. Air pressure drop through each volume damper not to exceed 0.05” wg. Provide hand locking quadrants.

C. Splitter Dampers: Splitter Dampers shall be fabricated of steel not lighter than 16 gauge. The leading edge of the damper shall not be hemmed. Each splitter shall be a minimum of 12” long or 1.5 times the width of the smaller two branches it controls, whichever is greater. Dampers shall be carefully fitted, and shall be controlled by locking quadrants. Dampers larger than 3 square feet shall be controlled by means of rods hinged near the leading edge of the damper with provisions for firmly anchoring the rod and bearings supporting the axle.

D. Backdraft Dampers: Provide all aluminum (counter balance) type backdraft dampers with an extruded frame and roll formed blades with silicon impregnated felt seals. Multiple-blade parallel action gravity balanced, with center-pivoted blade. Blade height shall not exceed 4”, blade width shall not exceed 6” and blade linkage shall be provided to gang operate dampers by section. Shall be assembled in a rattle-free manner with 90-degree stop, steel ball bearings, and axles. Adjustment device to permit setting for varying differential static pressure. Install at outside air intakes, exhaust outlets, and where shown on Drawings. For backdraft dampers at round fan outlets, see related sections.

1. Frame: 0.052”-thick, galvanized sheet steel, with welded corners and mounting flange.
2. Blades: 0.052"-thick, roll-formed aluminum.
5. Tie Bars and Bracket: Galvanized steel.

E. Control Dampers -Automatic (AVD’s):
1. Rectangular:
   a. Outside Air: Ruskin Model CD80 VG1, all stainless steel construction including frame, bearing, shaft, linkage, jamb seals, fasteners, etc., or approved equal.
   b. Other locations: Ruskin Model CD-60 opposed blade control damper with neoprene jamb and blade edge seals or approved equal.
2. Round: Ruskin Model CDRS-25 with closed cell neoprene seal sandwiched between the two blades.
3. Automatic control damper actuators shall be provided under Division 13 unless otherwise shown.

F. Motorized Control Dampers:
1. General Description: AMCA-rated, opposed-blade design; minimum of 0.1084"-thick, galvanized-steel frames with holes for duct mounting; minimum of 0.0635"-thick, galvanized-steel damper blades with maximum blade width of 8".
   a. Secure blades to 1.5”-diameter, zinc-plated axles using zinc-plated hardware, with nylon blade bearings, blade-linkage hardware of zinc-plated steel and brass, ends sealed against spring-stainless-steel blade bearings, and thrust bearings at each end of every blade.
   b. Operating Temperature Range: From minus 40 to plus 200 °F.
   c. Provide closed-cell neoprene edging.
   d. Motorized control dampers used as system isolation dampers shall be low leakage (less than 4.0 cfm/sq.ft).
   e. Dampers used as part of smoke control system shall meet the requirements of CBC, Section 909.
   f. Acceptable Manufacturers:
      1) Air Balance, Inc.
      2) Duro Dyne Corp.
      3) Greenheck.
      5) Metaaire, Inc.
      6) Nailor Industries Inc.
      7) Penn Ventilation Company, Inc.
      8) Ruskin Company.
      9) Or approved equal.

G. Low Leakage Control Dampers:
1. Frame to be 5” x 1” x 16-gauge galvanized steel hat channel with corner braces. Dampers under 14” high to have low profile top and bottom.
2. Blades to be 6” wide, 16-gauge galvanized steel at 6” approximately 6” centers, opposed blade design.
3. Seals to be EPDM on blade edges, suitable for -50 °F to +250 °F. Jamb seal to be flexible metal compression type.
4. Bearing to be synthetic.
5. Linkage to be exposed on larger unit and concealed on units under 14” high.
6. Axles to be 1.5” plated steel hex.
7. Control shaft to be 6” x 1.5” diameter. Outboard support bearing to be supplied with all single section dampers for field mounted operators. Factory installed jack shaft supplied on multiple section dampers.
8. Finish to be mill galvanized: Unit to meet leakage rate of 10 cfm/sf at 4” W.G. when tested in accordance with AMCA Standard 500.
9. Manufacturer: Ruskin #CD36, Startwout, American Warming, Air Balance, or approved equal.

H. Airfoil Dampers (Heavy Duty):
1. Frames to be 10”x2”x12-gauge steel channel
2. Blades to be 7-0.75” wide, .080 thick extruded aluminum airfoil design.
3. Axles to be 0.75” diameter plated steel.
4. Bearings to be stainless steel sleeve type pressed into frame.
5. Linkage to be out of airstream with 10-gauge galvanized steel clevis type arms on 7/8” diameter brass trunnions at 3” radius. Tie bar to be 3/8” diameter plated steel.
6. Crank lever for operator to be provided.
7. Provide with mill finish on blades and frame.
8. Maximum temperature rating to be 300°F.
9. Options:
   a. Silicone rubber blade seals.
   b. Flexible stainless steel jamb seals.
   c. Bearings with integral shaft seals.
   d. Bearings bolted to frame.
   e. Bolt holes in frame.
   f. Finishes.
   g. Electric or pneumatic operator.
10. Manufacturer: Ruskin #CD60, Startwout, American Warming, Air Balance, or approved equal.

I. Manual Operators: Non-insulated accessible ductwork shall be Young Regulator Company, Catalog No. 403. Accessible insulated ductwork shall be Young Regulator Company, Catalog 443. Provide with molded neoprene gaskets to prevent leakage. Approved equal units by Duro-dyne or Vent Fabrics, Inc. will be acceptable.
2.13 VOLUME DAMPERS

A. General Description: Factory fabricated, with required hardware and accessories. Stiffen damper blades for stability. Include locking device to hold single-blade dampers in a fixed position without vibration. Close duct penetrations for damper components to seal duct consistent with pressure class.

B. Pressure Classes of 3-Inch wg or Higher: End bearings or other seals for ducts with axles full length of damper blades and bearings at both ends of operating shaft.

C. Standard Volume Dampers: Multiple- or single-blade, parallel- or opposed-blade design as indicated, standard leakage rating, with linkage outside airstream, and suitable for horizontal or vertical applications.
   1. Steel Frames: Hat-shaped, galvanized sheet steel channels, minimum of 0.064” thick, with mitered and welded corners; frames with flanges where indicated for attaching to walls and flangeless frames where indicated for installing in ducts.
   2. Roll-Formed Steel Blades: 0.064”-thick, galvanized sheet steel.
   3. Aluminum Frames: Hat-shaped, 0.10”-thick, aluminum sheet channels; frames with flanges where indicated for attaching to walls; and flangeless frames where indicated for installing in ducts.
   4. Roll-Formed Aluminum Blades: 0.10”-thick aluminum sheet.
   5. Extruded-Aluminum Blades: 0.050”-thick extruded aluminum.
   8. Tie Bars and Brackets: Galvanized steel.

D. Low-Leakage Volume Dampers: Multiple- or single-blade, parallel- or opposed-blade design as indicated, low-leakage rating, with linkage outside airstream, and suitable for horizontal or vertical applications.
   1. Steel Frames: Hat-shaped, galvanized sheet steel channels, minimum of 0.064” thick, with mitered and welded corners; frames with flanges where indicated for attaching to walls and flangeless frames where indicated for installing in ducts.
   2. Roll-Formed Steel Blades: 0.064”-thick, galvanized sheet steel.
   4. Bearings: Oil-impregnated bronze thrust or ball.
   5. Blade Seals: Vinyl or Neoprene.
   7. Tie Bars and Brackets: Galvanized steel.

E. Jackshaft: 1”-diameter, galvanized-steel pipe rotating within pipe-bearing assembly mounted on supports at each mullion and at each end of multiple-damper assemblies.
   1. Length and Number of Mountings: Appropriate to connect linkage of each damper in multiple-damper assembly.
F. Damper Hardware: Zinc-plated, die-cast core with dial and handle made of 3/32"- thick zinc-plated steel, and a 0.75" hexagon locking nut. Include center hole to suit damper operating-rod size. Include elevated platform for insulated duct mounting.


H. Acceptable Manufacturers:
1. Air Balance, Inc.
2. Metalaire, Inc.
3. Nailor Industries Inc.
4. Penn Ventilation Company, Inc.
5. Ruskin Company.
6. Or approved equal.

2.14 VOLUME DAMPER CONTROL CABLE ASSEMBLIES

A. Manufacturer:
1. Young Regulator Company.

B. Concealed Ceiling Regulator:
1. Damper controller and cable shall be concealed above the ceiling. Cable to consist of Bowden cable .054" stainless steel control wire encapsulated in 1-16" flexible galvanized spiral wire sheath. Control kit shall consist of 2-5/8" diameter die cast aluminum housing with 3" diameter zinc plated (polished chrome is optional) cover and 14-gauge steel rack and pinion gear drive converting rotary motion to push-pull motion. Control shaft shall be D-style flatted and 0.25" diameter with 265-degree rotation providing graduations for positive locking and control, and 1.5" linear travel capability. Control kit is designed to be imbedded in the ceiling flush with the finished surface. Control kit shall be manually operated using Young Regulator Model 030-12 wrench. Control kit shall be Young Regulator Model 270-301.

C. Controller Mounted in Plenum of Slot Diffusers:
1. Damper controller and cable shall be concealed above the ceiling. Cable to consist of Bowden cable .054" stainless steel control wire encapsulated in 1-16" flexible galvanized spiral wire sheath. Control kit shall be designed for use with internally or externally controlled round or rectangular dampers and shall consist of 14-gauge steel rack and pinion gear drive converting rotary motion to push-pull motion. Control shaft shall be D-style flatted and 0.25" diameter with 265-degree rotation providing 1.5" linear travel capability. Control kit mounting bracket be field mounted on ceiling framework, behind grilles on or inside plenum slot diffusers and other various types of diffusers. Control kit shall be manually operated using Young Regulator Model 030-12 wrench. Control kit shall be Young Regulator Model 270-275.

2. Damper(s) to be constructed of heavy duty galvanized steel spiral shell design with rolled-in stiffening beads for superior rigidity. Spiral shell shall have one crimped end and one straight end for ease of installation. Damper to include "V" style 20 gauge galvanized steel blade secured with 1/2" diameter steel shafts and high strength Teflon bushings requiring no lubrication. Damper shall include all necessary hardware to ensure compatibility with Bowden remote cable control system. Damper(s) shall be Young Regulator Model 5020-CC.
2.15 FIRE DAMPERS

A. General: Provide “dynamic” rated fire dampers at duct penetrations of rated floors, fire walls, elsewhere as shown in the drawings and where required by Code. Fire dampers shall comply with Uniform Building Code Standard No. 43-7, be inspected and approved by an approved inspection agency and be labeled at the factory in accordance with Uniform Building Code Standard 43-7, Section 43.714. Dampers shall be UL-labeled California State Fire Marshal approved and shall meet all of the requirements of NFPA 90A, UL Standard 555.

1. Provide 1.5 hour rated dampers where penetrations are required in one-hour fire rated assemblies.
2. Provide 1.5 hour rated dampers where penetrations are required in 2-hour fire rated assemblies.
3. Provide 3 hour rated dampers where penetrations are required in 4-hour fire rated assemblies; 4-hour occupancy separating walls are excepted.
4. Dampers shall be activated by a UL-approved fusible ink which shall automatically close the damper upon operation. Fusible links shall operate at approximately 50 °F above the maximum temperature in the duct system in normal operation but not less than 165 °F. Hinged dampers shall have stainless or cadmium-plated spring steel catches. All dampers shall have spring closer to ensure positive shutoff at velocities up to 5000 fpm and pressures up to 10" wg.
5. Dampers installed in one-hour and 2-hour rated assemblies shall be UL-rated at 1.5 hours per UL Standard 555.
6. Dampers shall be sized so that free area space is not less than 100% of the connected duct free work area. Dampers shall be installed so as to provide a positive barrier to the passage of air when in the closed position. Dampers shall be installed with angle iron frames and slip joint connections when in the closed position. Dampers shall be installed with angle iron frames and slip joint connections per manufacturer’s installation requirements and SMACNA Standards such that they are self-supporting in the case of duct destruction due to heat. The installing contractor shall be responsible for coordinating locations which require special sleeves.
7. Mounting Orientation: Vertical or Horizontal as indicated.
8. Frame: Curtain type with blades outside airstream; fabricated with roll-formed, 0.034”-thick galvanized steel; with mitered and interlocking corners.
9. Blades: Roll-formed, interlocking, 0.034”-thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034”-thick, galvanize-steel blade connectors.
12. Provide access doors as specified under ductwork for all internally actuated fire dampers. Where duct access are installed in non-accessible locations, provide ceiling or wall access doors. Label duct access doors “FIRE DAMPER ACCESS” with 1/2’ high stencil black letters.
   a. Minimum Thickness: 0.052 or 0.138” thick as indicated and of length to suit application.
   b. Exceptions: Omit sleeve where damper frame width permits direct attachment of perimeter mounting angles on each side of wall or floor, and thickness of damper frame complies with
sleeve requirements.

B. Shall be Ruskin Type DIBD2 Style B, DIBD2 Style LR or approved equal. Dampers installed in 4 hour rated assemblies shall be Ruskin type DIBD23 Style B or DIBD23 Style LR or approved equal.

C. Acceptable Manufacturers:
   1. Air Balance, Inc.
   2. Greenheck.
   4. METALAIRE, Inc.
   5. Nailor Industries Inc.
   7. Ruskin Company.
   8. Or approved equal.

D. Ceiling Fire Dampers:
   1. Labeled according to UL 555C; comply with construction details for tested floor- and roof- ceiling assemblies as indicated in UL’S “Fire Resistance Directory.”
   2. Frame: Galvanized sheet steel, round or rectangular, style to suit ceiling construction.
   5. Acceptable Manufacturers:
      a. Air Balance, Inc.
      b. Greenheck.
      d. METALAIRE, Inc.
      e. Nailor Industries Inc.
      f. Penn Ventilation Company, Inc.
      g. Ruskin Company.
      h. Or approved equal.

2.16 COMBINATION FIRE/SMOKE DAMPERS

A. Provide low leakage fire/smoke dampers at all locations shown on the Drawings or as required.

B. Dampers shall be multi-blade type combination fire/smoke dampers and shall possess UL labeled 3 hour rated fire dampers at 3-hour and greater penetrations, and 1.5 hour rated fire dampers at less than 3-hour penetrations, in accordance with UL 555s and UL 555 for 1.5-hour rating, and shall meet all requirements of the latest edition of NFPA 90A and 101 and California State Fire Marshal.

C. All dampers to conform to manufacturer’s installation instructions. Details on plans are for reference only.

D. Dampers shall be tested and certified in accordance with AMCA Standard 500 and shall be leakage Class I per UL Standard 555s or better. Leakage Class II may be used if damper size is smaller than available Leakage Class I Dampers.

E. Fire/smoke dampers and operators shall be UL-listed and labeled in the sizes used on the project and
all dampers on the project shall be the same manufacturer. UL-labeling of damper sizes on the project shall be clearly indicated on shop drawing submittals.

F. Dampers shall be suitable for opening and closing at static pressure difference up to 6” wg and at air velocities up to 3500 fpm.

G. Fusible links: Replaceable, 154 °F rated.

H. Frames and Blades: 0.064”-thick, galvanized sheet steel.

I. Mounting Sleeve: Factory-installed, 0.052”-thick, galvanized sheet steel; length to suit wall or floor application.

J. All combination fire/smoke dampers shall include an operating shaft which, when rotated, causes the damper to operate between open and closed. Operating shaft and damper combination shall be suitable for linking to and operation by 120 volts, single phase electric damper operator having sufficient torque characteristics. Fire and smoke dampers in supply air ducts shall be airfoil blades Ruskin Model FSD60 or approved equal. In other ducts they shall be FSD36 or approved equal.

K. Each combination fire/smoke damper shall be furnished complete with factory sleeve, damper operator, end switches and thermal link factory-installed. The installing contractor shall be responsible for coordinating locations which require a special sleeve. Actuators shall be electric type as specified or required and shall be of the spring fail closed type that will close upon loss of power. Damper operators shall by UL-listed as fire damper operators, shall bear the appropriate UL fire damper operator label and shall be rated for continuous operations at 250 °F.

L. Dampers shall be installed with angle iron frames and slip joint connections per manufacturer's recommendations and SMACNA Standards such that they are self-supporting in the case of duct destruction due to heat. Provide access doors as specified under Ductwork for all internally actuated dampers and for maintenance inspection of all externally actuated dampers.

M. Install in ducts passing through floors, walls, and ceilings as required by code. Refer to Architectural and Mechanical plans for damper locations.

N. Where duct access doors are installed in non-accessible locations, provide ceiling or wall access doors. Label duct access doors “FIRE/SMOKE DAMPER ACCESS” with 1/2” high black stencil letters.

O. Access doors shall be tight-fitting hinged or sliding and shall have 1” high label reading “FIRE DOOR – DO NOT OBSTRUCT.”

P. Two double pole double throw (DPDT) limit switch shall be provided factory-installed on each fire/smoke dampers to give positive indication at remote location of both open or closed positions.

Q. Control wiring of smoke dampers and fire/smoke dampers shall be provided under separate contract. Coordinate power wiring to fire/smoke dampers and smoke damper with electrical work.

R. Provide fire and fire/smoke dampers in locations as required by chapter 7 of CBC.

S. Provide sleeves, slip joints, retaining angles, duct access doors, ceilings, access panels, etc., as required to check and service the fire dampers. Slip or break away joints are not allowed to be taped or sealed.

T. Dampers to be designed for use in dynamic systems, where applicable.
U. Damper Motors: Two-position action.
   1. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
   2. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.
   3. Outdoor Motors and Motors in Outside-Air Intakes: Equip with O-ring gaskets designed to make motors waterproof. Equip motors with internal heaters to permit normal operation at minus 40 °F.
   4. Nonspring-Return Motors: For dampers larger than 25 sq. ft., size motor for running torque rating of 150 in. x lbf and breakaway torque rating of 300 in. x lbf.
   5. Electrical Connection: 115 V, single phase, 60 Hz.
   6. Provide position indicating switches equivalent to Ruskin TS150.

V. Dampers used as part of smoke control system shall meet the requirements of CBC, Section 909.

W. Combination Wall Fire/Smoke Damper:
   1. Install at rated corridor wall penetrations and where shown on plans.
   2. Low leakage fire/smoke damper (Leakage Class I) with electric actuator constructed and tested in conformance with UL-555 and UL-555S.
   3. Fire damper shall have 6” wide galvanized steel blades with silicone rubber edge seals. Fire damper shall be equipped for vertical wall penetrations with manufacturer supplied sleeve and fail closed on loss of power. Each damper shall be equipped with a controlled 15 second electric heat-actuated release device.
   4. Stall and instantaneous type actuators are not acceptable. Manufacturer shall provide factory assembled sleeve of 16” minimum length.
   5. Installation shall be in accordance with damper manufacturer’s instructions. Provide smoke detector to electrical installer for installation, unless otherwise shown on electrical plans.
   6. Coordinate power and smoke detector connections with electrical installer. Provide matching wall grille to maintain appearance and fire rating.
   7. Integral smoke detection and actuating devices may be used if listed and approved for such service. Comply with UBC Chapters 7 and 9.
   8. Ruskin #FSD-37, Ruskin #FSD-60, Ruskin #FSD60FA, Pottorff #FSD-40 Series or approved equal by Nailor, Air Balance, or Fire/Seal.

2.17 SMOKE DAMPERS

A. General: Provide smoke dampers at all locations shown on Drawings or required. Dampers shall meet all requirements for fire/smoke dampers except that the dampers shall not incorporate a thermal link feature.
2.18 AIR FLOW MEASURING STATIONS

A. General: Provide airflow measuring stations at all minimum outside air ducts, single zone variable air volume fans and where indicated on the drawings. Air flow measuring stations including sensor, mounting hardware, fittings, etc. are to be provided under Division 23 with pressure ports. Connection to pressure ports and signal conversion for control use will be under Division 13 under contract EMCS 5500I. The airflow measuring station shall be capable of producing steady, non-pulsating total and static pressure signals with an accuracy of +2% of actual flow.

B. Acceptable Manufacturers:
1. Paragon.
2. Air Monitor.
3. Ultratech.
4. Air Sentinel
5. Or approved equal.

Model numbers given are for Paragon.

C. Construction: The airflow measuring elements shall be constructed of anodized extruded aluminum, forming two integral chambers for total and static pressure averaging, without the forward projecting or protruding sensors. The elements shall be mounted in 16 gauge galvanized steel welded casing with 90 degree connecting flanges in the configuration and size equal to that of the duct into which it is mounted.

D. Arrangement: Each airflow measuring station shall be complete with required number of airflow measuring elements in accordance with accepted practices as defined for system testing in the ASHRAE Handbook. Total pressure drop across any station shall not exceed 0.05 W.G. at 2000 FPM. The elements shall come pre-mounted and pre-piped in the casings ready to be connected by the Automation System Contractor.

E. Minimum number of elements shall be in accordance with the following:

<table>
<thead>
<tr>
<th>Circular</th>
<th>Rectangular Duct</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Duct (Dia.)</td>
</tr>
<tr>
<td>1</td>
<td>Less than 12&quot;</td>
</tr>
<tr>
<td>2</td>
<td>12&quot; through 36&quot;</td>
</tr>
<tr>
<td>3</td>
<td>37&quot; through 82&quot;</td>
</tr>
<tr>
<td>4</td>
<td>83&quot; and over</td>
</tr>
</tbody>
</table>

F. Models and type:
1. Airflow measuring station - FE-1500.
2. Fan Inlet airflow measuring station - FE-1050.

2.19 DIFFUSERS, GRILLES, AND REGISTERS

A. All diffusers, grilles, and registers shall be selected to provide proper air distribution for the intended occupant application. All supply air devices shall be selected to provide a maximum air velocity of 50 fpm at three feet above the floor, unless otherwise noted. Manufacturer’s representative shall carefully review Architectural and Mechanical drawings and ensure diffuser/grille/register selections will provide proper air distribution at NC 25 or less. Diffusers, grilles, and registers not providing proper distribution or excessive noise at scheduled air flow shall be replaced by manufacturer at no
additional expense to the State.

B. All frames shall be selected to fit the ceiling type. Verify and coordinate frames with Architectural Drawings.

C. Each diffuser, grille and register shall be individually capable of balancing via duct mounted balancing dampers or attached opposed blade dampers. Provide unit opposed blade damper where individual duct mounted balancing dampers are not provided.

D. Sizes, capacities and patterns shall be as shown on the Drawings.

E. Acceptable Manufacturers:
   1. Price
   2. Titus
   3. Krueger
   4. Carnes
   5. Or approved equal.

2.20 DISPLACEMENT DIFFUSERS

A. Displacement outlets shall be constructed with an equalization baffle behind the operative diffuser face for uniform, low velocity, distribution of supply air. Both the equalization baffle and face shall be securely retained in the diffuser frames. The diffuser frames shall be constructed of high strength aluminum extrusion for rigidity and protection of the operative face and side panels. There shall be no visible fasteners on the front or side panels. The material and finish of the operative face shall be coordinated with the design team, side and end panels may be provided in painted steel. All perforated materials shall be fastened to the frame with vibration dampening. The frame and internal baffling elements shall be constructed of aluminum. If painted, the paint shall be powder coat polyester, epoxies and their derivatives are unacceptable. Visible nonmetallic components are unacceptable. The diffuser shall be supplied with concealed mounting brackets that do not require puncturing the diffuser to install.

B. Diffuser Manufacturer shall provide references for a minimum of 10 installed and commissioned projects where architectural coordination of finishes, features and customized materials and construction were successfully realized. Manufacturer shall provide sound and pressure drop data derived from tests in accordance with ASHRAE standard 70. Performance data for thermal comfort shall be tested and reported as described by ASHRAE standard. Diffuser manufacturer shall conduct a mockup to be witnessed by the design team to prove the performance and finish of all outlets.

C. Acceptable Manufacturers: Price or approved equal.

2.21 VARIABLE AIR VOLUME TERMINAL BOXES

2.22 Note: VAV access has been overlooked at times and shall be addressed to ensure that access is not difficult and that they can be easily reached.

A. Furnish and install variable volume zone boxes of the sizes and capacities shown on the Drawings.

B. The control assemblies shall be pressure independent and shall be able to be reset to any air flow between zero and maximum scheduled CFM. The valves shall be normally open. The differential static pressure of the basic assembly shall not exceed 0.25” W.G. for all sizes with inlet velocities of 2,000 FPM or less.
C. The air valve shall be die cast aluminum; damper shafts shall operate in rustproof Delrin or equal, self-lubricating bearings. The air valve shall seat against durable gaskets and not exceed a 2% leakage rate per Air Diffusion Council Standards.

D. The control device shall be designed to maintain constant flow regardless of inlet flow deflection. Duct inlets at 90 degrees or less to the control device shall not alter the maximum or minimum factory setting by more than 10%. The assembly shall incorporate a multi-point averaging differential pressure sensor mounted on the inlet.

E. The assemblies shall be contained in a welded 26-gauge galvanized steel box internally lined with 0.75”, 1.5-pound insulation complying with NFPA 90A and UL-181 standards.

F. Provide acoustically lined sheet metal discharge attenuator on all VAV boxes. First outlet shall be 10-feet downstream of air valve. Discharge plenum shall be mounted downstream of reheat coils where applicable.

G. Hot Water Coil: Where scheduled on drawings, provide two row hot water heating coil with aluminum fins mechanically bonded to copper coils. Coil velocity shall not exceed 700 FPM and static pressure loss shall not exceed 0.1” W.G. Coil shall be pressure tested to 200 PSIG.

H. Controls to be DDC direct digital. Provide boxes without operator. Provide factory mounted low voltage transformer of sufficient capacity to power the DDC controls. Coordinate control with temperature Control Contractor. Provide factory mounted operator and thermostat control if not provided by Control Contractor.

I. Manufacturer: Titus ESV-3000, Metal-Aire, Krueger, or approved equal.

2.23 GENERATOR (ENGINE) EXHAUST

A. Provide Selkirk Metalbestos Model “IPS,” or approved equal, double-wall, insulated exhaust pipe, suitable for positive pressure applications and UL labeled with the words “Suitable for Positive Pressure.”

   1. At the Contractor’s option, with generator manufacturer’s approval, generator exhaust may be fabricated of Schedule 40 black steel pipe, with welded fittings and joints, and insulated with 4” calcium silicate insulation with aluminum jacket.

B. Provide all accessories for complete installation including flexible connectors, expansion compensators, fittings, drain section, clamps, guides, support assemblies, wall penetration assemblies, roof thimbles, flashings, storm collars, stack caps, exit cones, and sealants, as required.

C. Contractor shall submit sizing calculations. Exhaust system shall be designed to not exceed the generator manufacturer’s recommended exhaust backpressure.

D. Provide drain from exhaust pipe drain section to indirect waste receptor. Coordinate with Plumbing Contractor for location of receptor.

PART 3 – EXECUTION

3.1 DUCT AND PLENUM LINER

A. General: The liner shall be applied to the inside of the duct with heavy density or faced side to the air
stream and shall be secured in the duct with adhesive, completely coating the clean sheet metal. All joints in the insulation shall be “buttered” and firmly butted tightly to the adjoining liner using fireproof adhesive. Where a cut is made for duct taps, etc. the raw edge shall be accurately and evenly cut and shall be thoroughly coated with fireproof adhesive. On ducts over 24” in width or depth, the liner shall be further secured with mechanical fasteners.

1. Plenum linings and exterior duct wrap and board insulation shall be secured with adhesive pins.

2. Weld pins may be used at contractor’s option for interior lining at ductwork only.

B. The fasteners shall be A. J. Gerrard Company pronged straps, or approved equal, secured to the ducts by fireproof adhesive. The clips shall be 18” maximum spacing and shall be pointed up with fireproof adhesive. Liner shall be accurately cut and ends thoroughly coated with fireproof adhesive so that when the duct section is installed, the liner shall make a firmly butted and tightly sealed joint. Duct liner for velocities over 2500 fpm shall be as specified except a perforated metal liner shall be used over duct liner for securement, in lieu of fasteners. This applies to supply ducts upstream of VAV units with airflow greater than 32,000 cfm. Duct liner installation and fasteners shall comply with SDGS Fig. 2-19 through 2-22.

3.2 DUCTWORK INSTALLATION

A. General: Assemble and install ductwork in accordance with recognized industry practices and according to SMACNA’s “HVAC Duct Construction Standards- metal and Flexible,” unless otherwise indicated, which will achieve airtight and noiseless systems, capable of performing each indicated service. Install each run with a minimum of joints (fewest possible joints). Align ductwork accurately at connections, within 1/8” misalignment tolerance and with internal surfaces smooth. Support ducts rigidly with suitable ties, braces, hangers, and anchors of the type which will hold ducts true-to-shape and prevent buckling.

B. Ductwork is generally diagrammatically indicated and shall be generally installed as indicated. Do not scale Drawings for exact locations on ducts. Install ducts to best suit field conditions and cooperate with other trades. Do not penetrate Structural members without consent. Check with Structural drawings prior to locating any penetrations. Duct sizes are indicated as net inside dimensions on the Drawings. The indicated dimensions shall be altered at the job site for the purpose of avoiding interferences and clearance difficulties to other dimensions producing the same air handling characteristics, provided such altered dimensions are approved by the Architect. Ducts shall be constructed in accordance with the latest edition of codes and standards identified in Part 1 as shown on the Drawings.

C. Duct Sizing: Where duct sizes are not specifically shown on the plans or must be modified due to physical limitations, supply ducts may be sized as a maximum velocity of 1500 fpm or 0.08” sp friction per 100 feet, whichever provides the larger duct, and return/exhaust/intake ducts may be sized at a maximum velocity of 1000 fpm or 0.06” sp friction per 100 feet, whichever provides the larger duct.

D. Static-Pressure Classes: Unless otherwise indicated, construct ducts according to the following:

1. Main Supply Ducts: 4” wg, medium pressure.

2. Supply Ducts (before Air Terminal Units): 4” wg, medium pressure.

3. Supply Ducts (after Air Terminal Units): 2” wg, low pressure.

4. Return Ducts (Negative Pressure): 2” wg, low pressure.
5. Exhaust Ducts (Negative Pressure): 4” wg, medium pressure.

E. Clean and pretreat surfaces before application of sealant. Conform to the manufacturer’s cleaning procedures. Protect duct interiors from the elements and foreign materials until building is enclosed. Follow SMACNA’s “Duct Cleanliness for New Construction.”

F. Seam and Joint Sealing:
   1. Seal all joints and seams. Apply sealant to male end connectors before insertion, and afterward to cover entire joint and sheet metal screws. Install sealants to conformance with manufacturer’s instructions and according to SMACNA’s “HVAC Duct Construction Standards – Metal and Flexible” for duct pressure class indicated.
   2. For pressure classes lower than 2” wg, seal transverse joints.
   3. Seal ducts before external insulation is applied.

G. Paint interiors of metal ducts that do not have duct liner, for 24” upstream of registers and grilles. Apply one coat of flat, black, latex finish coat over a compatible galvanized-steel primer. Paint materials and application requirements shall be specified.

H. Fire-Rated Partition Penetrations: Vertical ducts or horizontal ductwork penetrating fire rated ceilings, roofs, walls, and floors shall be fire separated with UL listed and labeled fire-smoke dampers, sleeves and fire stopping sealant. Provide additional fire stopping between damper frames and fire walls.

I. Non-Fire Rated Partition Penetrations: Where ducts pass through interior partitions and exterior walls and are exposed to view, conceal spaces between construction openings and cuts or duct insulation with sheet metal flanges of same metal thickness as ducts. Overlap openings on 4 sides by at least 1.5”.

J. Install round and flat-oval ducts in lengths not less than 12 feet unless interrupted by fittings.

K. Fittings: Install fabricated fittings for changes in directions, size, and shape and for connections.

L. Install couplings tight to duct wall surface with a minimum of projections into duct. Secure couplings with sheet metal screws. Install screws at intervals of 12”, with a minimum of 3 screws in each coupling.

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

N. Inserts: Install concrete inserts for support of ductwork in coordination with formwork, as required to avoid delays in the work.

O. Completion: Complete fabrication of work at the project as necessary to match shop-fabricated work and accommodate installation requirements.

P. Run Location: Locate ductwork runs, except as otherwise indicated, vertically and horizontally and parallel and perpendicular to building lines, and avoid diagonal runs wherever possible. Locate runs as indicated by diagrams, details, and notations or, if not otherwise indicated, run ductwork in the shortest route which does not obstruct usable space or block access for servicing the building and its equipment. Hold ducts close to walls, overhead construction, columns, and other structural and...
permanent-enclosure elements of the building. Limit clearance to 0.5” where furring is shown for enclosure or concealment of ducts, but allow for insulation thickness, if any. Where possible, locate insulated ductwork to assure 1.0” clearance of insulation. In finished and occupied spaces, conceal ductwork from view, by locating in mechanical shafts, hollow wall construction or above suspended ceilings unless otherwise shown. Do not encase horizontal runs in solid partitions, except as specifically shown. Coordinate the layout with suspended ceiling and lighting layouts and similar finished work.

Q. Coordination: Coordinate duct installation with installation of accessories, damper, coil frames, equipment, controls, and other associated work of the ductwork system.

R. Flexible Ductwork:

1. General: Flexible ductwork shall be provided as shown on Drawings. Flexible ducts shall be installed in a fully extended condition free of sags and kinks, using only the minimum length required to make the connection, subject to the maximum lengths allowed. Bends in any length of flexible duct shall not exceed 45° for HVAC terminal unit connections or 135° degrees for air outlet connections and shall not exceed that recommended by the flexible ductwork manufacturer. Unless otherwise shown on the Drawings, the length of any one run of flexible ductwork shall not exceed 3’ to terminal units or 5’ to air outlets.

2. Supports: Where flexible duct extension exceeds 48”, horizontally, a support shall be provided. Duct shall be suspended on 48” centers with a minimum one” (1”) wide flat banding material. Refer to SDCS Fig. 3-9 and 3-10 for additional requirements.

3. Air Outlet Flexible Duct Connections: All joints and connections shall be made by turning back the insulation and securing the inner liner with self-locking nylon straps and sealing with two wraps of duct tape. The insulation shall then be placed over the joint, attached with self-locking nylon strap and sealed on the exterior with an approved foil duct tape. Flexible duct length to be between 3’ and 5’

S. Duct Mounted Devices:

1. Install duct mounted sensors and control devices as required. Provide access doors at each duct mounted control device. Coordinate location of devices and installation requirements with related Contractor. Duct access doors are required at the following locations:
   a. At all fire dampers and combination fire and smoke damper locations as shown on plans. Multiple access doors may be required on larger ducts.
   b. At all duct static pressure sensors for each VAV system.
   c. At all duct smoke detectors where walk-in access is not possible.
   d. At all AVD and BDD dampers where they cannot be accessed from AHU or plenum.
   e. For systems AHU-N11, AHU-S11, and AHU-201, provide 3 additional access doors per unit.
   f. At all duct reheat coils, on upstream and downstream of coil.
   g. At all duct static pressure sensors and at all public areas, furnish access panel as required and as specified under 08305 and as shown on detail 19/A9.4.4. Locate within access panel zone as directed by architect.

2. Install duct type smoke detectors furnished by Special Systems Contract. Provide access doors at each sampling tube assembly. Coordinate location of detectors and installation requirements with Special Systems contract.
   a. Smoke detectors are to be installed at locations shown in accordance with smoke
detector listing requirements. Contractor shall include all necessary and incidental costs of their installations in the shown configurations.

b. Smoke detectors are required in:
   1) Discharge ducts of all stair pressurization fans.
   2) Supply and return ducts of all AHU’s with provisions for outdoor air.
   3) Exhaust/relief ducts for AHU’s relief/exhaust fans greater than 2000 CFM.
   4) Discharge ducts of fan coils greater than 1999 CFM.

c. Provide discharge ducts at all stair pressurization fans, where they already do not exist for mounting the duct smoke detectors. The size and configuration of discharge duct shall be as required to mount the detector in accordance with the manufacturer’s recommendations. Additionally, configure duct discharge to direct the air away from the exiting persons.

3. Provide duct test ports in ductwork at locations shown on the drawings and as required to properly balance all air systems. Test ports shall be located per ANSI/ASHRAE Standard 111 to allow accurate pitot-tube traverse measurements in ductwork.

T. Grilles, Registers, and Diffusers:

1. Install flush, squared, tightly sealed, and entirely covering sheet metal ductwork and gaskets.
2. Thread sheet metal mounting screws tightly into sheet metal.
3. All frames shall be selected to fit the ceiling type.
4. Verify with Architectural Drawings.
5. Each diffuser, grille, and register shall be individually capable of balancing via duct mounted balancing dampers, or attached opposed blade dampers.
6. Provide unit opposed blade damper where individual duct mounted balancing dampers are not provided.
7. Duct connections shall fit securely into necks or collars behind face area.
8. Provide all necessary transition pieces and cut collars to make connections from ductwork to neck sizes.
9. Where ducts connect directly to necks or collars provide a minimum straight duct section of two times the duct diameter to the last elbow.
10. Where minimum straight duct sections are not physically possible provide sheet metal plenum sized for approximately 500 fpm air velocity with duct tapped directly to side of plenum.
11. Where building walls, floors, and ceilings form portions of duct or plenum, provide gasketed angles or channels at junction points, securely bolted and sealed to building structure.
12. Connect diffusers or light troffer boots to low pressure ducts directly or with minimum 60” lengths of flexible duct clamped or strapped in place. Flex duct length shall not exceed 84”.

3.3 HANGERS AND SUPPORTING

A. All ductwork supports shall be per Section IV of the SMACNA “HVAC Duct Construction Standards - latest Edition” with all supports directly anchored to the building structure. Supports shall be on
maximum 8'-0" centers with additional supports as required to prevent sagging.

B. Hangers and supports shall conform to SMACNA section "Hangers and Supports". Cut off or remove nails, strap-ends and other projections, flush with concrete after forms are removed.

C. Attachment to Structure: Provide hanger attachment to the building structure as specified in section pertaining to "Basic Materials and Methods", and in accordance with SDCS Fig. 4-1 through 4-3. Securely fasten all piping to the building construction by means of hangers, supports, guides, anchors, and sway braces to maintain pipe alignment, to prevent sagging, and to prevent noise and excessive straining on piping due to movement under operating conditions. Adequately mount and anchor all material and equipment as required. Include lateral bracing as required to prevent horizontal seismic movement. Refer to CBC and Structural Drawings for seismic requirements. Do not support piping or ductwork from fans or any other pieces of equipment. Powder driven fasteners shall not be used to support rectangular ducts of 40" maximum dimension. Support round duct, 30" and larger, with two hangers at each support point.

D. Hangers: Hangers shall be strap or rod sized in accordance with SDCS Table 4-1 and 4-2. Strap hanger attachment to rectangular duct shall consist of a turning strap under the duct a minimum of one" (1") and securing the strap with one screw into the bottom of the duct and one screw to the side of the duct. Rectangular duct supported or trapeze hangers shall be attached to the trapeze. Round duct attachments shall be constructed in accordance with SDCS Fig. 4-4. Maximum spacing between hangers shall not exceed ten (10) feet.

E. Horizontal Ducts: Support horizontal ducts within 24" of each elbow and within 48" of each branch inspection.
   1. Ducts larger than 50" in their greatest dimensions shall be supported by means of hanger rods bolted to angle iron or half round trapeze hangers. Duct shall have at least one pair of supports 8'-0" on centers according to the following:
      a. Angle Rod

      | Length | Angle         | Diameter |
      |--------|--------------|----------|
      | 4'-0"  | 1.5 x 1.5" x 1/8" | 0.25"    |
      | 6'-0"  | 1.5 x 1.5" x 1/8" | 0.25"    |
      | 8'-0"  | 2" x 2" x 1/8" | 5/16"    |
      | 10'-0" | 3" x 3" x 1/8" | 3/8"     |

F. Vertical Ducts: Support vertical ducts at maximum intervals of 16 feet and at each floor. Ducts shall be supported where they pass through the floor lines with 1.5" x 1.5" x 0.25" angles for ducts up to 60'. Above 60°, the angles must be increased in strength and sized on an individual basis considering space requirements.

G. Install upper attachments to structures with an allowable load not exceeding one-fourth of failure (proof-test) load.

H. Install concrete inserts before placing concrete.

I. Install powder-actuated concrete fasteners after concrete is placed and completely cured. (Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4" thick.)
3.4 ALUMINUM EXHAUST DUCT

A. General: Aluminum exhaust duct shall be rectangular or round duct fabricated with minimum 14-gauge aluminum with liquid tight continuous external welds and constructed in accordance with applicable SMACNA Standards. Duct shall have access panels on the side of the duct large enough to permit inspection and cleaning at each change of direction and at 50’ on center for horizontal and vertical runs. No turning vanes or other interior intrusions shall be installed in aluminum exhaust ductwork. All changes in direction shall be with radius elbows (center line radius equals 1.5 x duct width). Access panels shall be liquid tight when in place. Slope exhaust duct to drain towards hood connections or exhaust grilles for drainage of condensation. Refer to Section 3.3 for general fabrication requirements.

3.5 DUCTWORK ACCESSORIES

A. Provide duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel and fibrous-glass ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.

B. Flexible Connections: Make connections to equipment with flexible connectors according to Section “Duct Accessories.” Comply with SMACNA’s “HVAC Duct Construction Standards – Metal and Flexible for branch, outlet and inlet, and terminal unit connections. Install flexible connections where ducts connect to fans, including roof exhausters and at building seismic joint locations indicated on drawings. Install immediately adjacent to equipment in ducts associated with fans and motorized equipment supported by vibration isolators. Isolate fans from direct contact with all sheet metal work. There shall be a minimum of 3” slack in the connections, and a minimum of 3” distance between the edges of the ducts.

C. Dampers: Install balancing, splitter and backdraft dampers where shown on the Drawings and wherever necessary for complete control of the airflow, including all supply, return and exhaust branches, “division” in main supply, return and general exhaust ducts, each individual air supply outlet and outside air ducts. Where access to dampers through a fixed suspended ceiling is necessary, this Contractor shall be responsible for the proper location of the access doors. Install backdraft dampers on exhaust fans or exhaust ducts nearest to outside and where indicated.

D. Provide balancing dampers at points on supply, return, and exhaust systems where branches lead from larger ducts as required for air balancing. Coordinate requirements with TAB contractor. Install a minimum of two duct widths from branch takeoff.

E. Install volume dampers in ducts with liner; avoid damages to and erosion of duct liner:

1. Where volume damper adjustment is not readily accessible through finished ceilings, provide volume damper remote control cable adjustment. Locate concealed ceiling regulators in coordination with Architect.

F. Fire, Fire/Smoke and Smoke Dampers: Install fire, fire/smoke and smoke dampers as detailed on the Drawings, in strict accordance with the damper manufacturers UL approved installation instruction, in accordance with NFPA Standards, the requirements of the State Fire Marshal, and applicable codes. Ensure that dampers are installed in the open position.

G. Flashing: Install flashing where ducts pass through roofs, outside and exhaust plenum architectural walls at fan rooms or exterior walls. Suitable flashing shall be provided to prevent rain or air currents from entering the building. The flashing shall be of not less than No. 24 gauge 316 stainless steel.
H. Turning Vanes: Install turning vanes per SMACNA Standards. Turning vanes in ducts carrying air under pressure of 1.5” water gauge or more shall be anchored to the cheeks of the elbow in such a way that the cheeks will not breathe at the surfaces where the vanes touch the cheeks. In most cases, this will necessitate the installation of an angle iron support on the outside of the cheek parallel to the line of the turning vanes. Install turning vanes in all mitered elbows in all ducts, so that tips are parallel with the sides of the ducts. Vanes shall be single thickness type with extended trailing edge. Tips of acoustical turning vanes on outside radius shall be flush with acoustical lining.

I. Access Doors:

1. Install access doors so that the doors open against the system air pressure and that their latches are operable from either side, except where the duct is too small to be entered.

2. Install to allow for inspecting, adjusting, and maintaining accessories and terminal units as follows:
   a. On both sides of duct coils.
   b. Downstream from volume dampers and equipment.
   c. Adjacent to fire or smoke dampers, providing access to reset or reinstall fusible links.
   d. To interior of ducts for cleaning; before and after each change in direction, at maximum 50-foot spacing.
   e. On sides of ducts where adequate clearance is available.

3. Provide access to each fire damper link to permit resetting.


5. Install hinged access doors in ductwork to provide access to all fire damper, mixed air plenums, upstream and downstream of reheat coils, automatic dampers, etc.

6. Where the ducts are insulated, the access doors shall be double skin doors with one” of insulation in the door. Where access doors are located above a suspended ceiling, this Contractor shall be responsible for the proper location of the ceiling access doors, if the ceiling system does not provide proper access. Coordinate mounting of access doors and walk-in access doors in ducts, plenum walls, hard ceilings and at special architectural enclosures with Architect and other trade contractors.

7. Install the following sizes for duct-mounting, rectangular access doors:
   a. One-Hand or Inspection Access: 8 by 5”.
   b. Two-Hand Access: 12 by 6”.
   c. Head and Hand Access: 18 by 10”.
   d. Head and Shoulders Access: 21 by 14”.
   e. Body Access: 25 by 14”.
   f. Body Plus Ladder Access: 25 by 17”.

8. Install the following sizes for duct-mounting, round access doors:
   a. One-Hand or Inspection Access: 8” in diameter.
   b. Two-Hand Access: 10” in diameter.
   c. Head and Hand Access: 12” in diameter.
   d. Head and Shoulders Access: 18” in diameter.
e. Body Access: 24” in diameter.

9. Install the following sizes for duct-mounting, pressure relief access doors:
   a. One-Hand or Inspection Access: 5” in diameter.
   b. Two-Hand Access: 10” in diameter.
   c. Head and Hand Access: 13” in diameter.
   d. Head and Shoulders Access: 19” in diameter.

J. Test Operations: Install test openings for pitot transverse of all supply, return, and exhaust duct connections to fan powered equipment, after each duct mounted balancing damper and at other locations required for proper measurement of airflow in all duct systems.

K. Remote damper regulators shall be installed away from ceiling system joints. Mount regulators equally spaced and flush with the ceiling surface and to form a parallel line with the ceiling joints, light fixtures, linear diffusers, and sprinkler heads. Submit shop drawings showing damper regulators for Architect’s approval.

L. Label access doors according to requirements.

3.6 DUCT SMOKE DETECTORS

A. Install duct smoke detectors furnished under separate contract.

B. Coordinate installation with sampling tubes and sensors properly located to meet codes and sequences of operation as specified.

3.7 AIRFLOW MEASURING STATION

A. Install airflow measuring station in accordance with the manufacturer’s instructions in locations where they will produce specified accuracy of measurements.

B. Coordinate fan mounted airflow measuring stations with the fan manufacturer and provide all pivot mounting hardware and signal connection fittings for connections to transducers.

C. Coordinate installation, calibration and adjustment of airflow measuring station with Special Systems.

D. Install identifying tag number on each airflow measuring station listing the system/zone/fan served and Automation System address.

3.8 SEISMIC REQUIREMENTS

A. All HVAC equipment and machinery shall be anchored to withstand forces generated by earthquake motions. As a minimum, equipment and equipment frames shall be designed to withstand a force of 100% of the weight of the equipment and frame acting at its center of gravity. Anchorage of the equipment and/or frame to the structure shall be for a force of three times gravity also acting at the center of gravity.

B. All ductwork, regardless of size, and equipment shall be seismically braced per CBC, and SMACNA Manual.
3.9 INSTALLATION – OTHER

A. Fans: Align fans, motors, and drives. Install fans to render bearings accessible for lubrication without dismantling fans or ducts. Provide extended bearing oilers as required. Mount all fans on vibration isolators as specified. For fans developing static pressures of 5” wg and higher, cover flexible connectors with loaded vinyl sheet held in place with metal straps.

B. Filters: Ensure that all filters are clean at completion of installation. Interpret this as meaning the cleaning of cleanable filters providing new clean disposable or replaceable media filters, as specified. Provide manometer at each filter bank.

C. Insulation: Properly and neatly apply insulation on all material and equipment and apparatus, as specified, including all fittings. Apply insulation over clean, dry surfaces with adjoining sections firmly butted together and canvas smoothly pasted over. When vapor barriers are specified, install continuous overall external surfaces of the entire system.

D. Provide test holes at fan inlets and outlets and elsewhere as indicated.

E. Install cut test holes where indicated and required for testing and balancing purposes.

3.10 SUPPLY DIFFUSER AND REGISTER LOCATIONS

A. Coordination location of supply outlets with ceiling mounted smoke detectors. Locate outlets or outlet distribution so as to prevent air flow from inhibiting the operation of smoke detectors. Locate ceiling outlets a minimum of 3’-0” from smoke detectors.

3.11 AIR CONDITIONING DRAIN PAN SLIME PREVENTION

A. At completion of construction install one “No-Slime Strip” (Gold Coast chemical, Hollywood, Fl, 800-333-3403) into each condensate drain pan. Chemical agent shall be on-corrosive to metal; have a Ph level of 7; kill mold, mildew and algae; and control organic build-up, scale and corrosion deposits.

3.12 FIELD QUALITY CONTROL

A. Do not insulate or conceal ductwork before inspection by the Airport Inspector of Record. If ductwork is insulated and concealed prior this inspection the Contractor shall remove insulation and ceiling to permit inspection at no additional cost to the Airport. The Contractor shall replace the insulation and ceiling after final inspection at no additional cost to the Airport.

B. Ductwork Deflection Criteria:

1. Maximum inward and/or outward deflection at sheet metal panels shall be 0.75” under maximum static pressure operating conditions. Additional intermediate stiffening angles shall be installed where deflections exceed 0.75”.

2. Maximum inward and/or outward deflection at sheet metal elbows and joints shall be 0.25” under maximum static pressure operating conditions. Additional stiffening angles shall be installed where deflections exceed 0.25”.

C. Seismic calculations shall be the responsibility of the Contractor.
C. Ductwork Leakage Criteria:

1. All transverse and longitudinal joints (seams) and duct wall penetrations shall conform to SMACNA’s Class A sealing requirements.

2. Where ductwork is not installed to the high construction level required per SMACNA the Contractor may be requested to provide system pressure testing and verification as directed by the Airport Representative to prove that system is within allowable leakage levels. Leak test in accordance with SMACNA “HVAC Air Duct Leakage Test Manual” at 150% (1-1/2 times) of maximum working pressure. Provide test fans, temporary power and instrumentation in accordance with SMACNA testing specifications.

3. Variable air volume (VAV) supply system ductwork from fan to VAV terminals (boxes) shall have a maximum leakage of 1% of design cfm.

4. Variable air volume (VAV) supply system ductwork from VAV terminals (boxes) to diffusers/registers shall have a maximum leakage of 2% of design cfm.

5. Variable air volume (VAV) return system ductwork shall have a maximum leakage of 2% of design cfm.

D. Acceptance of duct systems shall be contingent upon conformance with the requirements specified in Section 23 05 93 “Testing, Adjusting and Balancing.”

3.13 CLEANING AND PROTECTION

A. General: Clean ductwork internally, section-by-section of dust and debris as it is installed. Clean external surfaces of foreign substances which might cause corrosive deterioration of the metal or, where ductwork is to be painted, might interfere with painting or cause paint damage.

B. Repairs: Strip protective paper from stainless ductwork surfaces and repair finish or replace ductwork portion wherever it has been damaged.

C. Temporary Closure: At ends of ducts which are not connected to equipment or air distribution devices at the time of ductwork installation, provide temporary closure of polyethylene film or other covering which will prevent the entrance of dust, debris and animals until such time that connections are to be completed.

D. Blowout coils and condensate piping with compressed air. Install a clean set of filters in each system prior to testing and balancing. Proceed with testing and balancing. All dampers shall be locked in place.

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

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

   1. Create other openings to comply with duct standards.
   2. Disconnect flexible ducts as needed for cleaning and inspection.
   3. Remove and reinstall ceiling sections to gain access during the cleaning process.

G. Vent vacuuming system to the outside. Include filtration to contain debris removed from HVAC systems, and locate exhaust down wind and away from air intakes and other points of entry into building.
H. Clean the following metal duct systems by removing surface contaminants and deposits:

1. Air outlets and inlets (registers, grilles, and diffusers).
2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
5. Return-air ducts, dampers, and actuators except in ceiling plenums and mechanical equipment rooms.

I. Mechanical Cleaning Methodology:

1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet.
6. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.

J. Cleanliness Verification:

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

3.14 TESTING

A. General: Testing shall be in accordance with the SMACNA HVAC Air Duct Leakage Test Manual (DLTM).

B. Provide duct integrity and leakage testing and reports for all supply, outside air, return and exhaust ducts installed on the project.

C. Tests shall include, but are not limited to:

1. Test Complete Systems: Duct systems shall be tested as complete systems (e.g. from air handling equipment to terminal units/air outlets, from terminal units to air outlets or from air...
outlets to exhaust (return fans). Duct systems shall not be tested in partial sections, unless approved in writing by the Architect.

2. Preparation for Testing: Duct system installation must be complete, including, but not limited to, fittings, spin-ins, taps, access doors, hangers, test ports/holes, dampers and other system components. Temporary caps shall be installed at the system inlet (supply air system), system outlet (exhaust/return air systems) and at all terminal unit/air device taps.

3. Leakage Calculations: Prior to testing a duct system, the permissible leakage rate in cfm shall be calculated based on the square feet of duct surface and the duct system leakage classification specified.
   a. Maximum Allowable Leakage: Comply with requirements for Leakage Class 3 for round and flat-oval ducts, Leakage Class 12 for rectangular ducts in pressure classes lower than and equal to 2” wg (both positive and negative pressures), and Leakage Class 6 for pressure classes from 2- to 10” wg.

4. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.

5. Test Configuration: The configuration for testing shall be identical to DLTM using a variable volume blower as a test air source, an orifice plate meter with an inclined manometer to measure leakage cfm and a manometer to measure duct static pressure.
   a. Conduct tests at static pressure equal to maximum design pressure of system or section being tested. If pressure classes are not indicated, test entire system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure. Give seven days’ advance notice for testing.

6. Acceptable Results: Duct systems shall be tested, resealed and retested until acceptable results are obtained, e.g. the measured leakage rate is equal to or less than the calculated permissible leakage rate. Remake leaking joints and retest until leakage is equal to or less than maximum allowable.

7. Documentation: Duct system leakage testing results shall be recorded on forms which include the following information as a minimum:
   a. Duct System Tested.
   b. System Leakage Classification Specified.
   c. Duct System Square Footage.
   d. Permissible Leakage Rate in CFM.

D. Leakage Classifications:

1. VAV Supply Ductwork Upstream of Terminal Units: Ductwork shall be tested to leakage Class 6 at +3 wg.
2. VAV Supply Ductwork Downstream of Terminal Units: Ductwork shall be tested to leakage Class 12 at +2” wg.
3. Constant Volume Supply Air and Outside Air Ductwork: Ductwork shall be tested to leakage Class 6 at +3” wg.
4. Return Air Ductwork: Ductwork shall be tested to leakage Class 12 at -2” wg.
5. General Exhaust Ductwork: Ductwork shall be tested to leakage Class 12 at -2” wg.
6. Smoke Exhaust Ductwork: Ductwork shall be tested to leakage Class 6 at -3" wg.

3.15 ADJUSTING

A. Adjust duct accessories for proper settings.

B. Adjust fire and smoke dampers for proper action.

C. Final position of manual-volume dampers is specified in Division 23 Section “Testing, Adjusting, and Balancing.”

END OF SECTION 23 31 13
SECTION 23 33 19 – DUCT SILENCERS

PART 1 – GENERAL

1.1 DESCRIPTION

A. General: Provide sound traps (attenuators) in accordance with the Contract documents.

1.2 QUALITY INSURANCE

A. Acceptable Manufacturers: Provide sound trap units complying with these specifications and produced by one of the following:

1. Industrial Acoustics Company (IAC).
2. Koppers Company, Inc.
3. Peabody Noise Control.
4. Rink Corporation.
5. Or approved equal.

1.3 REFERENCES

A. Codes and Standards: Provide pumps which conform to the requirements of:

1. Association of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)
2. National Fire Protection Association (NFPA)
3. Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)
4. Underwriters Laboratories (UL)
5. American Society for Testing and Materials (ASTM)
6. Air Movement and Control association (AMCA)

1.4 SUBMITTALS

A. Shop Drawing submittals shall include, but are not limited to, the following:

1. Cut sheets clearly indicating the size, type, ratings, insertion loss, regenerated noise, materials, construction, connection types, performance and other pertinent data for each sound attenuator to be provided on the project.
2. Independent test laboratory reports on performance of each silencer type being provided.

1.5 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Deliver sound traps in factory-fabricated water-resistant wrapping.
B. Handle sound traps carefully to avoid damage to material components, enclosure and finish.
C. Store sound attenuators in a clean, dry space and protect from the weather.

PART 2 – PRODUCTS

2.1 DUCT SOUND TRAPS
A. General: Provide duct sound traps of the size and capacity scheduled or shown on the Drawings and having dynamic insertion losses and static pressure losses equivalent to those scheduled.

B. Construction: Sound traps shall have outer casings constructed of not less than 22 gauge galvanized steel in accordance with SMACNA and ASHRAE recommended construction for high pressure ductwork. All seams shall be lock-formed and sealed airtight. Internal panels shall be of not less than 26 gauge galvanized perforated steel corrugated in direction of airflow. Internal passages shall be essentially straight though with consistently exact dimensions to ensure uniform performance. All internal parts shall be fastened by spot-welding on not more than 3” centers. Sheet metal screws, bolts, or other mechanical fasteners will not be allowed. Fill lock-formed seams with mastic. Units shall be airtight at a differential air pressure of 8” water gauge.

C. Filler: Acoustical filler material shall be inorganic mineral or glass fiber of a density sufficient to obtain the scheduled acoustical performance and shall be packaged under a minimum 5% compression to eliminate voids due to vibration and setting. Filler shall be inert and vermin and moisture proof.

D. Combustion Rating: Maximum combustion ratings shall be flame spread, classification of 20, smoke developed rating of 20 and a fuel contribution of 20 when tested in accordance with ASTM E84, NFPA 255, and UL 723.

E. Acoustic Performance: Silencer ratings shall be determined in a duct-to-reverberant room test facility which provided for airflow in both directions through the test silencer in accordance with ASTM E477. The test set-up and procedure shall be such that all effects due to end reflection, directivity, flanking transmission, standing waves and test chamber sound absorption are eliminated. Acoustic ratings shall include Dynamic Insertion Loss (DIL) and Self-Noise (SN) Power Levels both for forward flow (air and noise in same direction) and reverse flow (air and noise in opposite directions) with airflow of at least 2000 fpm entering face velocity. Data for rectangular and tubular type silencers shall be presented for tests conducting using silencers no smaller than 24” x 24”, 24” x 30”, or 24” x 36” cross sections.

1. The manufacturer shall submit certified test data on dynamic insertion loss, self-noise power levels, and aerodynamic performance for reverse and forward flow test conditions. Test data shall be for a standard product. All rating tests shall be conducted in a single independent facility and shall utilize the same silencer.

2. Tests shall be run with air flowing through the silencer at not less than three different flow rates and also at zero flow. All ratings shall be based on test data from a nationally known qualified independent laboratory. Airflow and pressure loss data taken in accordance with the AMCA procedures shall be obtained from the same silencer used for acoustical performance test.

F. Aerodynamic Performance: Static pressure loss of silencers shall not exceed those listed in the silencer schedule at the airflow scheduled. Airflow measurements shall be made in accordance with ASTM E477 and applicable portions of ASME, AMCA, and ADC airflow test codes. Tests shall be reported on the identical units for which acoustic data is presented.

PART 3 – EXECUTION

3.1 INSTALLATION

A. General: Install sound attenuators in accordance with the manufacturers written installation instructions and appropriate SMACNA standards.

B. Supports: Sound attenuators shall be supported as specified for ductwork, except for additional
weight and that each attenuator shall be independently supported at each corner.

C. Transitions: Provide inlet and outlet transitions at duct sound attenuators with 15 degree angles where space permits, but in no case with more than 30 degree angles on the inlet side and 45 degree angles on the outlet side.

D. Arrangement: Arrange “ribs” of the attenuators parallel to approaching or exiting air flow whenever sound attenuator is near an elbow. Flow direction just before or after the elbow shall be used to determine parallel direction. This is to ensure approximately equal flow through each open space between ribs on stacked sound traps. Where ribs are installed horizontally, provide required reinforcing or stiffening of casing walls to prevent sagging.

END OF SECTION 23 33 19
SECTION 23 34 00 – HVAC FANS

PART 1 – GENERAL

1.1 DESCRIPTION

A. General: Provide Fans in accordance with the contract documents.

1.2 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this section shall comply with all the requirements of:
   1. General Conditions.
   2. Supplemental Conditions.
   4. Basic Materials and Methods.
   5. Other Sections in Division 23 specified herein.

1.3 REFERENCES

A. Codes and Standards: Provide air handling units conforming to the requirements of the latest edition of the following:
   1. Air Movement and Control Association (AMCA):
      b. 210 Laboratory Methods of Testing Fans for Rating [Unit shall bear AMCA Certified Rating Seal].
      c. 300 Reverberant Room Method for Sound Testing of Fans [Unit shall bear AMCA Certified Rating Seal].
      d. 301 Methods for Calculating Fan Sound Ratings from laboratory Test Data.
      e. 500 Test method for Louvers, Dampers, and Shutters.
      a. 9 Load Ratings and Fatigue Life for Ball Bearings.
      b. 11 Load Ratings and Fatigue Life for Roller Bearings.
      c. 900 Test Performance of Air Filter Units.
   3. Air-condition and Refrigeration Institute (ARI):
      a. 350 Sound Rating of Non-Ducted Indoor Air-condition Equipment.
      b. 410 Forced-Circulation air-cooling and Air-Heating Coils.
      c. 430 Central-Station Air-Handling Units.
      d. 440 Room Fan-Coil Air Conditioners.
   4. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE):
      a. 15 Safety Code for Mechanical Refrigeration
   5. National Electrical Manufacturers Association (NEMA): Except for motors, provide electrical components required as part of air handling units, which comply with NEMA Standards.
   6. National Fire Protection Association (NFPA): Provide air handling unit internal insulation having flame spread rating not higher than 25 an smoke developed rating not higher than 50:
a. 70 National Electrical Code.
b. 90A Standard for the Installation of Air Conditioning and Ventilating Systems.
c. 90B Standard for the Installation of Warm Air Heating and Air Conditioning Systems.

7. Sheet Metal and Air Conditioning Contractors’ National Association, Inc. (SMACNA): Comply with applicable SMACNA standards including “HVAC Duct Construction Standards – Metal and Flexible.”

8. Occupational Safety and Health Administration (OSHA)

9. National Electrical Code (NEC)

1.4 SCOPE

A. All work to be furnished and installed under this Section shall comply with all the requirements, and shall include, but not necessarily be limited to, the following:

1. Spun Aluminum and Steel Housed Centrifugal Exhaust Fans
   a. General Duty Exhaust Fans.
   b. Exhaust Fans for roof or sidewall mount.
   c. Upblast Exhaust Fans for high temperature kitchen exhaust.

2. Roof Mounted Supply (Hood and Louvered Style).

3. Small Cabinet Fans (Ceiling Mounted and Inline).

1.5 NOTE: Ventilation of electric rooms with Battery Racks shall be included in the scope. More details shall be added under Part 2 - Products or Part 3 - Execution.

1.6 QUALITY ASSURANCE

A. Manufacturers Qualifications: Provide air handling units that are the standard product of an equipment manufacturer regularly engaged in the production of such units who issues complete catalog information on such products. Units shall not be fabricated by the Contractor.

B. Acceptable Manufacturers:
   1. FläktWoods.
   2. Howden American Fan Company.
   4. Loren-Cook.
   5. PennBarry.
   6. Hartzell.
   7. Or approved equal.

C. Certifications: Provide certified ratings of units based on tests performed in accordance with ARI 430, “Central-Station Air Handling Units.”

D. AMCA Seals: Provide fans which are rated per AMCA standards and bear the AMCA-certified rating seal for airflow and sound performance. Submitted sound data shall be in accordance with AMCA standards.

E. Electrical Standards: Provide electric motors and products which have been listed and labeled by Underwriters' Laboratories, Inc. (UL) and comply with National Electrical Manufacturer’s Association (NEMA) standards. All direct drive fans to be UL listed.
F. Vibration Testing: Factory vibration testing shall be provided as specified.

1.7 SUBMITTALS

A. Shop drawing submittals shall include, but not be limited to, the following:
   1. Cut sheets clearly indicating fans, construction, dimensions, certified sound levels, ratings, capacities, weight loading, required clearances, field connection details, methods of support and accessories.
   2. Fan curves with fan selection point clearly indicated.
   3. Fan drive selection calculations.
   4. Draw to a scale of $\frac{1}{4}''$ per one foot.
   5. Include field fabricated mixing boxes, dampers, and duct connections.
   6. Motor data as required.
   7. Additional information as required.

B. Product Data: Submit manufacturer’s technical product data for air handling units showing dimensions, weights, capacities, ratings, fan performance with operating point clearly indicated, motor electrical characteristics, and finishes of materials, installation instructions, sound and vibration test report, and bearing life calculations.

C. Maintenance Data: Submit maintenance instructions, including instructions for lubrication, filter replacement, motor and drive replacement, and spare parts lists. Include this data, product data, show drawings, and wiring diagrams in operating and maintenance manuals.

1.8 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver unit to the site in containers with manufacturer’s stamp or label affixed.

B. Deliver fans and accessories carefully to avoid damage to material components, enclosure, and finish.

C. Handle fans and accessories carefully to avoid damage to material components, enclosure, and finish.

D. Store fans and accessories in a clean, dry space, and protect from the weather.

E. Do not install damaged unit – remove from project site.

1.9 ENVIRONMENTAL REQUIREMENTS

A. Do not operate units for any purpose, temporary or permanent, until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.

1.10 WARRANTY

A. Provide one-year (12 months) warranty. The warranty shall include parts, labor, travel costs, and living expenses incurred by the manufacturer to provide factory authorized service.
1.11 SAFETY PROVISIONS

A. Provide all open drives and fan wheels subject to maintenance and potential entanglement with protective guards or screens meeting OSHA requirements.

PART 2 – PRODUCTS

2.1 GENERAL FAN REQUIREMENTS:

A. Ratings: Fans shall be licensed to bear the AMCA-certified ratings seal and tested per ARI. Ratings of fans shall be not less than the values shown on the Drawings, based on 69.8 °F and 29.92" of Hg atmospheric pressure. Provide extended bearing lubrication fittings where necessary to assure accessibility of all lubrication points.

B. Construction: Fan construction shall be in accordance with AMCA classes of construction for the intended duty. Fan wheels, shafts, and drives shall be statically and dynamically balanced at the factory as a unit. Balancing shall be factory-certified. Steel components shall be painted with enamel primer and a final coat of enamel paint.

C. Motors: Fan motors shall be open drip-proof (ODP) or totally-enclosed, fan-coded (TEFC) type as required for the application. Motors 3/4 hp and larger shall be premium efficiency type. Temperature rise shall not be greater than 40 °C above ambient temperature. Motors shall be selected to be non-overloading with the fan provided. Provide two speed, two winding motors where indicated on schedules.

D. Drives: For belt-driven fans, provide drives with a minimum belt horsepower capacity of 150% of the motor nameplate horsepower on one less than the total number of belts, for belt drives with two or more belts. All exhaust fans requiring 1.5 hp or larger motor shall include the fan drive selection calculations with the submittal. All drives shall have adjustable sheaves to allow adjustment of ±20%.

1. Acceptable Manufacturers:
   a. Gates Chain GT-Drive Model “HTD”
   b. Or approved equal.

E. Motor Sheaves: Motor sheaves shall be Browning Type, MVP, or approved equal, fixed or adjustable type with double locking feature. Motor sheaves shall be selected for the rated fan rpm and shall be adjustable to as close as 10% above and below the rated fan speed.

F. Fan Sheaves: Provide nonadjustable sheaves with removable machined bushings. Sheaves shall be machined on all surfaces. Sheaves with over three grooves shall be dynamically balanced and the manufacturer shall so designate on each sheave. Fan sheaves with three grooves or less shall be statically balanced and weights required for balancing shall be welded to the sheaves.

1. Acceptable Manufacturers:
   a. Browning.
   b. Eaton.
   c. Yale and Towne.
   d. Dodge Manufacturing Company.
   e. Fort Worth Steel and Machinery Company.
   f. Or approved equal.

G. Belts: Provide standard “V-groove” belts suitable for the service intended with the required
capacities. The belts shall be closely matched and tagged prior to delivery to the job site. If the belts do not appear to be properly matched during operation, they shall be rechecked and, if necessary, replaced.

1. Acceptable Manufacturers:
   a. Gates.
   b. Durkee-Atwood.
   c. Goodyear.
   d. Browning.
   e. Uniroyal.
   f. Or approved equal.

H. Speed Control: All single phase direct drive fans shall be provided with compatible internally mounted solid state speed controllers, unless noted otherwise.

I. Bearings: Manufacturers: Provide SKF, Sealmaster, Timken or Fafnir, externally or internally-mounted, grease-lubricated, self-aligning ball bearings. Bearings shall have grease type Zerk fittings and shall be selected for a minimum L-10 life as defined by AFBMA of 100,000 hours, unless specified otherwise. Internally mounted bearings shall have grease lines extended to the outside of casing.

J. Motor Mounts: Motors shall be mounted on an adjustable base rigidly supported on the fan and shall have extended shaft, if necessary, to accommodate adjustable pitch sheaves.

K. Accessories: Provide, as indicated on the Drawings and specified in other paragraphs of this Section, all related accessories to match the fan section, including access sections, diffusion sections, transition sections, flexible connections, vibration eliminators, and belt guards.

L. Submission: For shop drawings, include complete dimensional and physical data, CFM, SP, HP, discharge arrangement, rotation, class, base details, and fan curves.

2.2 CENTRIFUGAL FANS (SPUN ALUMINUM AND STEEL HOUSED CENTRIFUGAL EXHAUST FANS)

A. Construction: Fans shall be forward curve, backward inclined or airfoil type as scheduled on the drawings. The class rating, arrangement, motor location, discharge, rotation wheel and casing and scroll configuration shall be suitable for the intended use and as shown on the drawings. The housing shall be constructed of heavy gauge steel with all seams continuously welded. Housing shall be structurally braced with structural supports. Blades shall be continuously welded to both a deep spun inlet shroud and to the backplate. Bearing shall be pillow block type. Provide 1” diameter threaded drain hole in bottom of scroll. Plug drain hole for fans not subject to rain.

B. Direct Drive Exhaust Fans:

1. The fan wheel shall be centrifugal backward inclined, constructed of aluminum and shall include a wheel cone carefully matched to the inlet cone for precise running tolerances. Wheels shall be statically and dynamically balanced. The fan housing shall be constructed of heavy gauge aluminum with a rigid internal support structure and a bird screen.

2. Motors shall be mounted out of the airstream on vibration isolators. Fresh air for motor cooling shall be drawn into the motor compartment through a large space between the fan shroud and the motor cover. Motors shall be readily accessible for maintenance. A disconnected switch shall be factory installed and wired from the fan motor to a junction box within the motor compartment.

a. Variable speed capability: For all direct drive fans with motors through ¾ hp, the fan shall
be equipped with a DC electronic commutation type motor (ECM). Motor shall be speed controllable to 20% of full speed (80% turndown). Speed shall be controlled by a potentiometer dial mounted at the motor or by a 0-10 vdc signal. Motor shall be 85% efficient at all speeds.

b. A conduit chase shall be provided through the curb cap to the motor compartment for ease of electrical wiring.

c. All fans shall bear the AMCA Certified Ratings Seal for sound and air performance. Each fan shall bear a permanently affixed manufacturer’s engraved metal nameplate containing the model number and individual serial number for future identification.

C. Belt-Drive Exhaust Fans

1. Fan wheel shall be centrifugal backward inclined, constructed of aluminum and shall include a wheel cone carefully matched to the inlet cone for précis running tolerances. Wheels shall be statically and dynamically balanced. The fan housing shall be constructed of heavy gauge aluminum with a rigid internal support structure and a bird screen.

2. Motors shall be heavy duty ball bearing type, carefully matched to the fan load, and furnished at the specified voltage, phase and enclosure. Drive frame assembly shall be constructed of heavy gauge steel. Motors and drives shall be mounted on vibration isolators, out of the airstream. Fresh air for motor cooling shall be drawn into the motor compartment through a large space between the fan shroud and the motor cover. Motors and drives shall be readily accessible for maintenance.

3. Precision ground and polished fan shafts shall be mounted in permanently sealed, lubricated pillow block ball bearings. Bearings shall be selected for a minimum L10 life in excess of 100,000 hours (L50 life of 500,000 hours) at maximum cataloged operating speed. Drives shall be sized for a minimum of 150% of driven horsepower. Pulleys shall be of the cast type, keyed and securely attached to the wheel and motor shafts. Motor pulleys shall be adjustable for final system balancing.

4. A disconnect switch shall be factory installed and wired from the fan motor to a junction box installed within the motor compartment. A conduit chase shall be provided through the base to the motor compartment for ease of electrical wiring.

5. All fans shall bear the AMCA Certified Ratings Seal for sound and air performance. Each fan shall bear a permanently affixed manufacturer’s engraved metal nameplate containing the model number and individual serial number for future identification.

D. Spun Aluminum Exhaust Fans for Roof or Sidewall Mount

1. Direct Drive:

   a. Spun aluminum exhaust fans shall be up blast centrifugal direct drive type. The fan wheel shall be centrifugal backward inclined, constructed of aluminum and shall include a wheel cone carefully matched to the inlet cone for precise running tolerances. Wheels shall be statically and dynamically balanced. The fan housing shall be constructed of heavy gauge aluminum with a rigid internal support structure.

   b. Motors shall be mounted out of the airstream on vibration isolators. Fresh air for motor cooling shall be drawn into the motor compartment free of discharge contaminants. Motors shall be readily accessible for maintenance. A disconnect switch shall be factory installed and wired from the fan motor to a junction box within the motor compartment. A conduit chase shall be provided through the curb cap to the motor compartment for ease
1) Variable speed capability: For all direct drive fans with motors through ¾” hp, the fan shall be equipped with a DC electronic commutation type motor (ECM). Motor shall be controllable to 20% of full speed (80% turndown). Speed shall be controlled by a potentiometer dial mounted at the motor or by a 0-10 vdc signal. Motor shall be 85% efficient at all speeds.

c. All fans shall bear the AMCA Certified Ratings Seal for sound and air performance.

d. Each fan shall bear a permanently affixed manufacturer’s engraved metal nameplate containing the model number and individual serial number for future identification.

e. Fan Arrangement:

1) Roof Mounted Upblast Exhaust Fans: A leak-proof fan housing shall be constructed with a one-piece wind band with an integral rolled bead for added strength. Fans shall be Model CUE as manufactured by Greenheck.

2) Sidewall Mounted Exhaust Fans: A leak-proof fan housing shall be constructed with a one-piece wind band with an integral rolled bead for added strength. Fan shall be provided with a mounting plate, which is attached and sealed to the wall prior to locating the entire unit.

2. Belt-Drive:

a. Fan wheel shall be centrifugal backward inclined, constructed of aluminum and shall include a wheel cone carefully matched to the inlet cone for precise running tolerances. Wheels shall be statically and dynamically balanced. The fan housing shall be constructed of heavy gauge aluminum with a rigid internal support structure. The wind band shall be welded to the one-piece curb cap and on all sized with UL/cUL-762.

b. Motors shall be heavy duty ball bearing type, carefully matched to the fan load and furnished at the specified voltage, phase and enclosure. Drive frame assembly shall be constructed of heavy gauge steel. Motors and drives shall be mounted on vibration isolators, out of the airstream. Fresh air for motor cooling shall be drawn into the motor compartment through a tube sized for sufficient fresh air to provide motor cooling. Motors and drives shall be readily accessible for maintenance.

c. Precision ground and polished fan shafts shall be mounted in permanently sealed, lubricated pillow block ball bearings. Bearings shall be selected for a minimum L10 life in excess of 100,000 hours (L50 life of 500,000 hours) at maximum catalogued operating speed. Drives shall be sized for a minimum of 150% of driven horsepower. Pulleys shall be of the cast type, keyed, and securely attached to wheel and motor shafts. Motor pulleys shall be adjustable for final system balancing.

d. A NEMA 3R disconnect switch shall be factory installed and wired from the fan motor to a junction box installed within the motor compartment. A conduit chase shall be provided through the base to the motor compartment for ease of electrical wiring.

e. All fans shall bear the AMCA Certified Ratings Seal for sound and air performance.

f. Each fan shall bear a permanently fixed manufacturer’s engraved metal nameplate containing the model number and individual serial number for future identification.

g. Fan Arrangement.

1) Roof Mounted Upblast Exhaust Fans A leak-proof fan housing shall be constructed with
a one-piece wind band with an integral rolled bead for added strength.

2) Sidewall Mounted Exhaust Fans A leak-proof housing shall be constructed with a one-piece wind band with an integral rolled bead for added strength. Fan shall be provided with a mounting plate, which is attached and sealed to the wall prior to locating the entire unit.

h. Options:

1) Fans shall be listed by Underwriters Laboratory for UL/cUL 762 Listed for all electrical components and grease removal.

2) Grease Provisions:
   a) Drain connection shall be constructed of aluminum and allow for a single point drainage of grease, water or other residues.
   b) Grease Trap shall include the drain connection and shall be constructed from aluminum. The unit shall collect grease and water from the fan and extract the grease from the water for ease of grease disposal.

3) Easy Clean Options: Hinge kit shall be constructed of heavy gauge aluminum hinges and shall include hold open cables for field installation. Non-stick wheel shall be constructed of aluminum with a nonstick coating similar to Teflon as manufactured by DuPont. Clean out port shall have a hole on the outside of the wind band and a grease repellant compression rubber fit, allowing access to entire wheel for cleaning.

4) Curb Extensions: Shall be mounted between roof curb and roof mounted fans to meet NFPA requirements of 40 in. minimum discharge above the roof when mounted on a minimum 8 in. high roof curb.

5) Wind band Extension shall be constructed from heavy gauge aluminum tube that raises the discharge an additional 36”.

E. Upblast Exhaust Fans for High Temperature Kitchen Exhaust

1. General: Provide for charbroil and solid fuel burning exhaust applications.

2. Spun steel exhaust fans shall be centrifugal belt driven type. Fan wheel shall be centrifugal backward inclined type. The wheel shall be constructed of steel and coated with a non-stick coating similar to Teflon as manufactured by DuPont. Wheel shall include a wheel cone carefully matched to the inlet cone for precise running tolerances. Wheels shall be statically and dynamically balanced.

3. The fan housing shall be constructed of 16 gauge galvanized steel with a rigid internal support structure and shall be leak-proof. The fan housing shall be constructed with a one piece wind band with an integral rolled bead for added strength and shall be joined to the curb cap with a continuously welded seam.

4. Fan's wind band shall have a clean out port, a large diameter hole on the outside of the fan's wind band with a grease repellant compression rubber fit, allowing access to entire wheel for cleaning.

5. Motors shall be heavy duty ball bearing type, carefully matched to the fan load, and furnished at the specified voltage, phase, and enclosure. Drive frame assembly shall be constructed of heavy gauge galvanized steel. Motors and drives shall be readily accessible for
maintenance. Precision ground and polished 1” minimum diameter fan shafts shall be mounted in cast pillow block lubricated ball bearing. Bearings shall be selected for a minimum L10 life in excess of 100,000 hours (L50 of 500,000 hours) at maximum cataloged operating speed. Dual drives shall be sized for a minimum of 150% of driven horsepower. Pulleys shall be of the cast type, keyed, and securely attached to the wheel and motor shafts.

6. Motor pulleys shall be adjustable for final system balancing. All fans shall have a dual belt and pulley system.

7. A NEMA-3R disconnect switch shall be factory installed and wired from the fan motor to a junction box installed outside the motor compartment.

8. Certification and Identification:
   a. All fans shall bear the AMCA Certified Ratings Seal for sound and air performance.
   b. Each fan shall bear a permanently affixed manufacturer’s engraved metal nameplate containing the model number and individual serial number for future identification.
   c. Fans shall be Listed by Underwriters Laboratory for UL/cUL 762 for all electrical components and grease removal. Grease Trap shall include the drain connection. The unit shall collect grease and water from the fan and extract the grease from the water for ease of grease disposal.

9. Hinge kit shall be constructed of heavy gauge hinges and shall include hold open cables for field installation.

F. Motors, Drives, Belts, etc. shall conform to requirements for the General fans given above.

G. Accessories: Provide protective screen, backdraft dampers, belt guards, special construction, adjustable motor support rails, as required, and additional accessories as scheduled on the drawings.

H. Acceptable Manufacturers: Models as scheduled manufactured by:
   1. Greenheck.
   2. Carnes.
   3. Loren Cook.
   4. PennBarry.
   5. Ventilator.
   6. Or approved equal.

2.3 MIXED FLOW FANS

A. General: Provide direct drive fans, constructed, factory tested in accordance with AMCA and ARI. Fan performance shall be rated and certified in accordance with AMCA Standard 210 for fans mounted inside cabinets. Fan wheels statically and dynamically balanced. Fans to be completely installed in the air handling units at the factory. Models, types, sizes, acoustical performance and capacities as scheduled on the drawings.

B. Acceptable Manufacturers:
   1. FläktWoods.
   2. Howden American Fan Company.
   4. Or approved equal.
C. Construction:

1. Fan casing shall be constructed with integral rolled flanges. The bearing support and guide vane unit shall be with mounting studs allowing centering of fan assembly when fitted into casing. Provide extended lube lines for lubricating the bearings from outside of casing. Casing design and construction shall allow easy removal and replacement of motor from the inlet side.

2. Bearings shall be selected for a minimum L10 life of 100,000 hours (average life of 500,000 hours). Fan shafts shall be selected for operation not to exceed 75% of first critical speed.

3. Motors shall comply with requirements and shall be suitable for satisfactory and safe operation under variable air flow (100% down to 10%) across them. The motors shall be certified to be compatible with the connected variable frequency drives.

D. Accessories:

1. Supply Fans:
   a. Inlet Guard.
   b. Outlet Guard, if unducted, or walk-in plenum discharge.
   c. Flexible Connector (by fan manufacturer).
   d. Matching Flanges and companion duct flanges.
   e. Air stream operated backdraft damper, when more than one fan.
   f. Mounting feet for fan and accessories.
   g. As indicated or scheduled on drawings.

2.4 VANE AXIAL SUPPLY/RETURN/EXHAUST FANS

A. General: Provide direct drive and manually adjustable fixed pitch vane axial type supply and exhaust fans of the type, size, and capacity scheduled.

B. The fan shall deliver the volume and pressure specified in the fan schedule when tested in accordance with AMCA Standard 210.

C. The fan casing will consist of two sections, each 3/16” minimum thickness mild steel, joined with bolted flanges. The motor will be supported by the fabricated steel structure of 3/16” minimum thickness welded to one of the ducts. The other duct will be removable for access to the impeller. Drilled flanges will be provided for attachment of accessories or ductwork. The casing shall have an integral support frame and plate for mounting the motor on direct drive fans. The casing and drilled flanges shall be hot dip galvanized.

D. Fan Impellers: The impeller hub shall be cast in high strength heat-treated aluminum alloy precision-machined and balanced. Blades shall be of aerofoil section cast from silicon aluminum alloy and mounted on thrust bearings with grease retaining features such that the bearings shall be fully submerged in grease. All hub and blade materials shall be examined by X ray before machining. The manufacturer shall have available laboratory evidence that impeller hubs and blades are suitably designed for normal running conditions and that fluctuating stresses in use are sufficiently low to ensure that no premature failure will occur due to metal fatigue.

E. Fixed Adjustable Pitch Fans: The fan impeller pitch angle shall be manually adjustable in the field.

F. Balancing: After assembly the fan shall be dynamically balanced. The vibration levels shall not exceed
the values given below:

a) Peak-to-Peak

<table>
<thead>
<tr>
<th>Nominal Fan</th>
<th>Displacement (Mils)</th>
<th>Velocity (in/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 500 RPM</td>
<td>3.0</td>
<td>0.0785</td>
</tr>
<tr>
<td>501 to 1000 RPM</td>
<td>2.5</td>
<td>0.0800</td>
</tr>
<tr>
<td>1001 to 1500 RPM</td>
<td>2.0</td>
<td>0.145</td>
</tr>
<tr>
<td>1501 to 2000 RPM</td>
<td>1.8</td>
<td>0.150</td>
</tr>
<tr>
<td>2001 to 2500 RPM</td>
<td>1.5</td>
<td>0.157</td>
</tr>
<tr>
<td>2501 to 3600 RPM</td>
<td>1.2</td>
<td>0.157</td>
</tr>
</tbody>
</table>

G. Certification: The fan manufacturer shall supply a test certificate for each fan showing the voltage, current, frequency, kilowatts input, degree of balanced and control characteristic (actuator movement against control signal). The fan pitch angle for adjustable fixed pitch fans shall be adjusted at the factory to meet scheduled conditions.

H. Characteristics: The aerodynamic design of the fan shall be such that the maximum power absorbed by the impeller occurs within the normal working range such that the fan has a non-overloading characteristic.

I. Attachment: The impeller shall be secured to the motor or fan shaft by a key and keyway. Axial location shall be provided by a collar or a shoulder on the drive shaft together with a retaining washer and a screw fitted into a tapped hole in the end of the shaft. The screw shall be locked in position.

J. Motors: Motors shall be totally enclosed air-over (TEAO) with Class F insulation and 1.15 service factor. Motor bearings shall be selected for a minimum L-10 life of 100,000 hours. Grease lubrication lines shall be brought to outside of the fan casing and labeled. Motor wiring shall be factory-extended to a junction box installed on the outside of the fan housing.

K. Provide all required accessories as shown and including, but not limited to:
   1. Inlet bell mouth fittings with guards (if not ducted).
   2. Outlet cone.
   3. Air stream operated backdraft dampers.
   4. Flange mounted flexible connections (by fan manufacturer).
   5. Floor support brackets, suspension clips or vertical mounting brackets as required for isolated fan mounting.

2.5 PROPELLER WALL FANS

A. Construction: Fans shall be axial type, belt or direct driven as scheduled. Blades shall be die-formed and welded to a steel hub. A polished steel fan shaft shall be mounted in permanently lubricated, sealed ball bearing pillow blocks. The drive frame assembly shall be formed steel. The fan panel shall have pre-punched mounting holes, formed flanges with welded corners, and a deep formed venturi. Fans shall be AMCA rating seals for air and sound performance.

B. Accessories: Provide all required accessories as shown and including, but not limited to: mounting collar, factory-wired and mounted NEMA 1 disconnect switch, gravity backdraft damper and fan
2.6 IN-LINE FANS

A. Construction: Fans shall be belt or direct driven in-line type with heavy gauge galvanized steel housing with duct mounting collars and shall be painted with enamel primer and a final coat of enamel paint. One or both sides shall be hinged or shall have hinged access doors for cleaning, inspection, or service without dismantling the unit in any way. On belt drive models the motor shall be mounted on other than the hinged side exterior, isolated from the airstream. The motor shall be isolated from the airstream by a motor enclosure and shall draw cooling air from outside the fan housing.

B. Wheels: The fan inlet shall be spun venturi throat overlapped by an all-aluminum backward inclined centrifugal wheel with spun cone for maximum performance. The fan wheel shall be statically and dynamically balanced.

C. Bearings: Permanently lubricated sealed ball bearings pillow block type.

D. Wiring: Flexible wiring leads shall be installed in conduit from the fan motor to an externally mounted junction box, motor speed controller (single phase units only) and disconnect switch, permitting access for service without disconnecting field wiring.

E. All fans shall bear the AMCA-certified ratings seal for both air and sound performance.

F. Accessories: Provide all required accessories as shown and including, but not limited to: inlet and outlet duct collars, support saddles or mounting angles, backdraft dampers and belt guards for belt driven fans.

2.7 UTILITY EXHAUST FANS

A. Construction: Fans shall be belt or direct driven, single width, single inlet centrifugal blowers with discharge arrangement as shown on the drawings. The blower housing shall be of continuously welded construction which can be adjusted for discharge position. Housing supports shall have formed flanges and pre punched mounting holes. The blower wheel shall be steel of the forward curved type and shall be statically and dynamically balanced. A polished steel fan shaft shall be mounted in ball bearing pillow blocks. Bearings shall be grease lubricated.

B. Finish: Entire exterior of the fan assembly shall be phosphatized, primed and finished with a baked enamel.

C. Motors: Motors for interior mounted fans shall be open drip proof (ODP) type and motors for exterior mounted fans shall be totally enclosed fan cooled (TEFC). Motors shall be 1750 rpm type of the horsepower and voltage scheduled.

D. Accessories: Provide all required accessories as shown and including, but not limited to: vented weather hood with expanded metal outlet guard, access doors, shaft seals, factory-mounted and wired NEMA 3R disconnect switch, felt tipped automatic aluminum backdraft dampers, vibration isolators, belt guard, and drain connections.

2.8 ROOF EXHAUST FANS

A. Construction: Fans shall be centrifugal, belt or direct driven as scheduled. Construction of the fan housing, fan wheel and inlet cone shall be aluminum. Wheels shall be aluminum, non-overloading backward curved, centrifugal type and shall be statically and dynamically balanced to assure smooth
and vibration-free operation. The entire drive assembly shall be mounted on vibration isolators. Fans shall be constructed to withstand winds up to 150 mph.

B. Drives: The wheel shaft on belt drive models shall be ground and polished shafting mounted in heavy duty sealed pillow block bearings. Drives shall be sized for a minimum of 150% of driven horsepower. Pulleys shall be fully machined cast iron type, keyed and securely attached to the wheel and motor shafts.

C. Motors: Motors and drives shall be isolated from the exhaust airstream and mounted on vibration isolators. Motors shall be of the heavy duty type with permanently lubricated, sealed ball bearings.

D. Certification: All fans shall bear the AMCA ratings seals for both air flow and sound performance with bird screen in place.

E. Accessories: Provide all required accessories as shown and including, but not limited to: aluminum bird screen, backdraft dampers, prefabricated insulated aluminum roof curb, factory-mounted and wired external NEMA 3R disconnect switch and solid state fan speed controllers (direct drive units only) with a conduit through the roof curb for field wiring.

2.9 UPBLAST PROPELLER EXHAUST FANS

A. Construction: Fans shall be up blast propeller type, belt driven, constructed of heavy gauge welded and painted steel housing and UL listed as a “Power ventilator for smoke control systems”. The propellers shall be all steel construction with the blades riveted to a heavy gauge hub. The fan shall be fitted with welded steel wind band, back draft damper, painted aluminum rain hood, bird screen, steel Venturi spun in base & welded curb cap corners. The propellers shall be statically and dynamically balanced and fixed to the shaft by a taper-lock bushing or a square key. The top of the lower housing shall be covered with butterfly dampers to produce a weather tight seal over the propeller. The fan shall be fitted with heavy-duty, spring-loaded, damper actuator arms which will open the dampers automatically when the airstream temperature reaches 165 °F. The unit shall be tested for 500 °F for a minimum of 4 hours. The damper actuators shall operate with or without electrical power to the fan.

B. Drives shall be sized for a minimum of 150% of driven horsepower. Pulleys shall be fully machined cast iron type, keyed and securely attached to the propeller and motor shafts. The propeller shaft shall be ground and polished shafting mounted in heavy duty sealed pillow block bearings. The belts and bearings shall be protected from the airstream and the bearings shall be accessible by removing by removing an interior cover. The bearings shall be fitted with lube lines to be regreasable from the exterior of unit. The unit shall be fitted with a shaft cooler to protect the bearings from excessive heat.

C. Motors: Motors and drives shall be out of the airstream under a removable weather cover. Motors shall be of the heavy duty type, totally enclosed fan cooled (TEFC) with permanently lubricated, sealed ball bearings.

D. Certification: All fans shall bear the AMCA ratings seals for both air flow and sound performance.

E. Accessories: Provide all required accessories as shown and including, but not limited to: backdraft dampers, pre-fabricated insulated galvanized steel roof curb, factory-mounted and wired external NEMA 3R disconnect switch with a conduit through the roof curb for field wiring.

F. Finish: The fan assembly shall be phosphatized, primed and finished with a baked enamel paint finish. Submit standard color options for Architect’s approval.
2.10 SMALL CABINET FANS (CEILING MOUNTED AND INLINE CABINET)

A. Ceiling mounted exhaust fans:

1. Acceptable Manufacturers:
   a. Greenheck.
   b. Panasonic.
   c. Loren Cook.
   d. PennBarry.
   e. Or approved equal.

2. Provide centrifugal direct drive type ceiling exhaust fan. The fan wheel(s) shall be of the forward curved centrifugal type and dynamically balanced.

3. Noise Data: Provide some or octave band noise values at the required air delivery.

4. Fan Housing: The fan housing shall be constructed of heavy gauge galvanized steel. The housing interior shall be lined with 1.5" acoustical insulation. The outlet duct collar shall include an aluminum backdraft damper on all sizes and shall be spring loaded on larger units above 200 cfm.
   a. Integral backdraft damper shall be totally chatterproof with no metal-to-metal contact.
   b. Entire fan, motor and wheel assembling shall be easily removable without disturbing the housing.
   c. Outlet shall be adaptable for horizontal or vertical discharge.

5. Motor speeds shall not exceed 1100 RPM and all fan motors shall be suitably grounded and mounted on rubber-in-shear vibration isolators.

6. Grille: For 300 cfm and smaller fans the grilles shall be constructed of high impact polystyrene and for larger sizes the grille shall be constructed of aluminum. Grilles shall be non-yellowing.

7. The access for wiring shall be external. The motor disconnect shall be internal and of the plug type. The motor shall be mounted on vibration isolators.

8. All fans shall bear the AMCA Certified Ratings Seal for sound and air performance and shall be UL/cUL Listed.

B. Duct mounted cabinet fan:

1. Manufacturer:
   a. Greenheck.
   b. Panasonic.
   c. Loren Cook.
   d. PennBarry.
   e. Or approved equal.

2. Provide centrifugal direct drive type inline fan. The fan wheel(s) shall be of the forward curved centrifugal type and dynamically balanced.

3. Noise Data: Provide some or octave band noise values at the required air delivery.

4. Fan Housing: The fan housing shall be constructed of heavy gauge galvanized steel. The housing interior shall be lined with 1.5" acoustical insulation. The outlet duct collar shall include an aluminum backdraft damper on all sizes and shall be spring loaded on larger units above 200 cfm.
   a. Integral backdraft damper shall be totally chatterproof with no metal-to-metal contact.
b. Entire fan, motor, and wheel assembly shall be easily removable without disturbing the housing.

c. Outlet shall be adaptable for horizontal or vertical discharge.

5. Motor speeds shall not exceed 1100 RPM and all fan motors shall be suitable grounded and mounted on rubber-in-shear vibration isolators.

6. Grille: For 300 cfm and smaller fans the grille shall be constructed of high impact polystyrene and for larger sizes the grille shall be constructed of aluminum. Grilles shall be non-yellowing.

7. The access for wiring shall be external. The motor disconnect shall be internal and of the plug in type. The motor shall be mounted on vibration isolators.

8. All fans shall bear the AMCA Certified Ratings. Seal for sound and air performance and shall be UL/cUL Listed.

PART 3 – EXECUTION

3.1 INSTALLATION

A. General: Install fans where shown, in accordance with manufacturer’s written instructions and recognized industry practices to ensure that fans, outside intakes, and relief vents comply with requirements and serve intended purposes. Comply with NEMA standards and requirements of NEC.

B. Coordinate motor starters with controls contractor.

C. Curb-mounted Fans: All fans mounted on roof curbs shall be securely attached to the roof curb with appropriate fasteners located 8” on center with a minimum of two fasteners per side by the Contractor. The roof curb shall be securely attached to the building structure.

D. Housekeeping Pads/Vibration Isolation requirements

E. Examine site to verify if site is ready to receive work. Provide layout drawings of air handlers and fan locations to electrical installer.

F. Install 3” flexible duct connection at inlets and outlets of horizontal units.

G. Control installers shall install all wiring associated with control signals into the fan starters.

H. Electrical Installer shall install all line voltage power wiring and conduit.

3.2 COORDINATION

A. General: The Contractor shall be responsible for coordinating installation requirements and provisions with the work of other Divisions.

B. Coordinate all required fan motor horsepower, voltages and locations with Electrical Contractor prior to purchase.

C. Coordinate all roof mounted fan/relief vent curb openings with general construction work prior to roofing installation.
3.3 START-UP SERVICES

A. General: The fan supplier shall provide fan checkout, start-up, testing and adjusting of system components for the vane axial and mixed flow fan systems in the form of a factory trained service technician. The service technician shall verify correct installation, verify unit mounting, verify fan rotation, verify spring isolator adjustments, verify control wiring, verify power wiring, start-up the fans, and check for proper operation. The service technician shall provide final adjustments to meet the specified performance requirements. The fan supplier shall also train the Owner’s Engineer in the proper operation and maintenance of these fans in accordance with requirements. Fully staffed parts and service personnel shall be within four hours travel from the job site.

END OF SECTION 23 34 00
SECTION 23 34 23 – HVAC POWER VENTILATORS

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions, apply to this Section.

1.2 SUMMARY

A. This Section includes the following:
   1. Roof exhaust fans.
   2. In-line centrifugal fans.

1.3 REFERENCES

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in the National Fire Protection Association (NFPA) 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. Air Movement and Control Association (AMCA) Compliance: Products shall comply with performance requirements and shall be licensed to use the AMCA-Certified Ratings Seal.

C. National Electrical Manufacturers Association (NEMA) Compliance: Motors and electrical accessories shall comply with NEMA standards.

D. Underwriters Laboratories (UL) Standard: Power ventilators shall comply with UL 705. Fans used for smoke control shall be UL Power Ventilator for Smoke Control Systems listed.

E. American Society for Testing and Materials (ASTM) Standards

F. International Organization for Standardization (ISO) Standards

1.4 PERFORMANCE REQUIREMENTS

A. Project Altitude: Base air ratings on actual site elevations.

B. Operating Limits: Classify according to AMCA 99.

1.5 SUBMITTALS

A. Product Data: Include rated capacities, furnished specialties, and accessories for each type of product indicated and include the following:
   1. Certified fan performance curves with system operating conditions included.
   2. Certified fan sound-power ratings.
3. Motor ratings and electrical characteristics, plus motor and electrical accessories.
4. Material gauges and finishes, including color charts.
5. Dampers, including housings, linkages, and operators.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
3. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.

C. Maintenance Data: For power ventilators to include in maintenance manuals as specified.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver fans as factory-assembled unit, to the extent allowable by shipping limitations, with protective crating and covering.
B. Disassemble and reassemble units, as required for moving to final location, according to manufacturer’s written instructions.
C. Lift and support units with manufacturer’s designated lifting or supporting points.

1.7 COORDINATION

A. Coordinate size and location of structural-steel support members.
B. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Section pertaining to “Cast-in-Place Concrete.”
C. Coordinate installation of roof curbs, equipment supports, and roof penetrations as specified.

PART 2 – PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Loren Cook.
2. Greenheck.
3. Aerovent.
4. Or approved equal.
2.2 INLINE FAN

A. Certifications: Fan shall be manufactured at an ISO 9001 certified facility. Fan shall be listed by Underwriters Laboratories (UL 705) and bear the AMCA certified ratings seal for sound and air performance. Fans located outdoors shall be factory fitted for such applications.

B. Construction: The fan shall be of bolted and welded construction utilizing corrosion resistant fasteners. Housing shall be minimum 18-gauge steel with airflow straightening vanes and integral duct flanges. Adjustable motor plate shall utilize threaded studs for positive belt tensioning. Access door and mounting feet shall be located in the specified position. Unit shall bear an engraved aluminum nameplate and shall be shipped in ISTA certified transit tested packaging.

C. Coating: All steel fan components shall be coated with an electrostatically applied, baked polyester powder coating. Each component shall be subject to a five stage environmentally friendly wash system, followed by a minimum 2 mil thick baked powder finish. Paint must exceed 1,000-hour salt spray under ASTM B117 test method.

D. Wheel: Wheel shall be centrifugal backward inclined, constructed of 100% aluminum, including a precision machined cast aluminum hub. Wheel inlet shall overlap an aerodynamic aluminum inlet cone to provide maximum performance and efficiency. Wheel shall be balanced in accordance with AMCA Standard 204-96, Balance Quality and Vibration Levels for Fans.

E. Motor: Motor shall be heavy duty type with permanently lubricated sealed ball bearings and furnished at the specified voltage, phase and enclosure.

F. Bearings: Bearings shall be designed and individually tested specifically for use in air handling applications. Construction shall be heavy duty re-greasable ball type in a cast iron housing selected for a minimum L50 life in excess of 200,000 hours at maximum cataloged operating speed.

G. Belts and Drives: Belts shall be oil and heat resistant, non-static type. Drives shall be precision machined cast iron type, keyed and securely attached to the wheel and motor shafts. Drives shall be sized for 150% of the installed motor horsepower. The variable pitch motor drive must be factory set to the specified fan RPM. Fans used as part of smoke control system shall meet the requirements of Section 909 of LAMC.

2.3 ROOF EXHAUST FANS

A. Description: Fan shall be a spun aluminum, roof mounted, direct driven, upblast or downblast high pressure centrifugal exhaust ventilator.

B. Certifications: Fan shall be manufactured at an ISO 9001 certified facility. Fan shall be listed by Underwriters Laboratories (UL 705). Fan shall bear the AMCA certified ratings seal for sound and air performance.

C. Construction: Fan shall be of bolted and welded construction utilizing corrosion resistant fasteners. The spun aluminum structural components shall be constructed of minimum 16-gauge marine alloy aluminum, bolted to a rigid aluminum support structure. The aluminum base shall have a one-piece inlet spinning and continuously welded curb cap corners for maximum leak protection. The wind band shall have a rolled bead for added strength. A 2-piece top cap shall have stainless steel quick release latches to provide access into the motor compartment without the use of tools. An integral conduit chase shall be provided into the motor compartment to facilitate wiring connections.
motor, bearings and drives shall be mounted on a minimum 14-gauge steel power assembly, isolated from the unit structure with rubber vibration isolators. These components shall be enclosed in a weather-tight compartment, separated from the exhaust airstream. Lifting lugs shall be provided to help prevent damage from improper lifting. Unit shall bear an engraved aluminum nameplate. Nameplate shall indicate design CFM, static pressure, and maximum fan RPM. Unit shall be shipped in ISTA certified transit tested packaging.

D. Wheel: Wheel shall be centrifugal backward inclined, constructed of 100% aluminum, including a precision machined cast aluminum hub. Wheel inlet shall overlap an aerodynamic aluminum inlet cone to provide maximum performance and efficiency. Wheel shall be balanced in conformance with AMCA Standard 204-96.

E. Motor: Motor shall be an electronically commutated motor rated for continuous duty and furnished either with internally mounted potentiometer speed controller with leads for connection to 0-10 vdc external controller.

F. Where indicated on plans, provide fan with grease drain, UL 762 listed assembly, and applicable accessories for kitchen exhaust duty.

2.4 SIDEWALL PROPELLER FANS

A. Description: Fan shall be a wall mounted, direct driven, aluminum propeller exhaust fan.

B. Certifications: Fan shall be manufactured at an ISO 9001 certified facility. Fan shall be listed by Underwriters Laboratories (UL 705) and UL listed for Canada (cUL 705). Fan shall bear the AMCA Certified Ratings Seal for Sound and Air Performance.

C. Construction: Fan shall be of bolted and welded construction utilizing corrosion resistant fasteners. The motor shall be mounted on a 14-gauge steel mounting plate and power assembly. The power assembly shall be bolted to a minimum 14-gauge steel wall panel with continuously welded corners and an integral venturi. Unit shall bear an engraved aluminum nameplate. Nameplate shall indicate design CFM and static pressure. Unit shall be shipped in ISTA Certified Transit Tested Packaging.

D. Coating: All steel fan components shall be Lorenized with an electrostatically applied, baked polyester powder coating. Each component shall be subject to a five stage environmentally friendly wash system, followed by a 1.5 to 2.5 mil thick baked powder finish. Paint must exceed 1,000 hours salt spray under ASTM B117 test method.

E. Propeller: Propeller shall be cast aluminum airfoil design with cast aluminum hub. The blade pitch shall be factory set and locked using set screws and roll pin. The hub shall be keyed and locked to the shaft utilizing two set screws or a taper lock bushing. Propeller shall be balanced in accordance with AMCA Standard 204-05, Balance Quality and Vibration Levels for Fans.

F. Motor: Motor shall be NEMA design B with class B insulation rated for continuous duty and furnished at the specified voltage, phase and enclosure.

2.5 CEILING MOUNTED CENTRIFUGAL EXHAUST FANS

A. Description: Fan shall be ceiling mounted, direct driven, centrifugal exhaust fan.

B. Certifications: Fan shall be manufactured by an ISO 9001 certified company. Fan shall be listed by
Underwriters Laboratories (UL 705) and UL listed for Canada (cUL 705) or UL Laboratories (UL 507) and UL listed for Canada (cUL 507). Fan shall bear the AMCA Certified Ratings Seal for sound and air performance.

C. Construction: Fan wheel housing and integral outlet duct collar shall be injection molded from a specially engineered resin exceeding UL requirements for smoke and heat generation. The outlet duct shall have provision for an aluminum backdraft damper with continuous aluminum hinge rod. The inlet box shall be minimum 22 gauge galvanized steel. Motor shall be isolation mounted to a one piece galvanized stamped steel integral motor mount/inlet. A field wiring compartment with disconnect receptacle shall be standard. To accommodate different ceiling thickness, an adjustable pre-punched mounting bracket shall be provided. A white, non-yellowing, high impact styrene injection molded grille shall be provided as standard. Unit shall be designed with provision for field conversion from ceiling to inline. Unit shall be shipped in ISTA Certified Transit Tested Packaging.

D. Wheel: Wheel shall be centrifugal forward curved type, injection molded of polypropylene resin. Wheel shall be balanced in accordance with AMCA Standard 204-05, Balance Quality and Vibration Levels for Fans.

E. Motor: Motor shall be open drip proof type with permanently lubricated sealed bearings and include impedance or thermal overload protection and disconnect plug. Motor shall be furnished at the specified voltage.

2.6 AXIAL FAN REFURBISHMENT

A. Installation Consultation:
   1. The manufacturer must send an authorized representative of the factory to the jobsite to advise and familiarize the installing contractor with the proper rigging, alignment and installation of the equipment.

B. Check, Test, Startup and Warranty:
   1. Equipment must be checked out, tested, and placed into operation by the installing contractor under the supervision of an authorized representative of the factory. The installing contractor must be responsible for warranty service and maintenance during the first year of equipment operation.

2.7 SOURCE QUALITY CONTROL


B. Fan Performance Ratings: Establish flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests and ratings according to AMCA 210, “Laboratory Methods of Testing Fans for Rating.”

PART 3 – EXECUTION

3.1 INSTALLATION

A. Install power ventilators level and plumb.
B. Vibration- and seismic-control devices are specified in Division 23 Section “Mechanical Vibration Controls and Seismic Restraints.”
   1. Secure vibration and seismic controls to concrete bases using anchor bolts cast in concrete base.

C. Install floor-mounting units on concrete bases. Concrete, reinforcement, and formwork requirements are specified in sections pertaining to “Cast-in-Place Concrete.”

D. Install floor-mounting units on concrete bases designed to withstand, without damage to equipment, the seismic force required by code. Concrete, reinforcement, and formwork requirements are specified in “Cast-in-Place Concrete” specifications.

E. Secure roof-mounting fans to roof curbs with cadmium-plated hardware. Refer to sections pertaining to “Roof Accessories” for installation of roof curbs.

F. Ceiling Units: Suspend units from structure; use steel wire or metal straps.

G. Vibration-control devices are specified in Division 23 Section “Mechanical Vibration Controls and Seismic Restraints.”

H. Install units with clearances for service and maintenance.

I. Label units according to requirements specified in Division 23 Section “Mechanical Identification.”

3.2 CONNECTIONS

A. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Division 23 Section “Duct Accessories.”

B. Install ducts adjacent to power ventilators to allow service and maintenance.

C. Ground equipment.

D. Tighten electrical connectors and terminals according to manufacturer’s published torque-tightening values. If manufacturer’s torque values are not indicated, use those specified in UL 486A and UL 486B.

3.3 FIELD QUALITY CONTROL

A. Equipment Startup Checks:
   1. Verify that shipping, blocking, and bracing are removed.
   2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
   3. Verify that cleaning and adjusting are complete.
   4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
   5. Verify lubrication for bearings and other moving parts.
6. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.

7. Disable automatic temperature-control operators.

B. Starting Procedures:
1. Energize motor and adjust fan to indicated rpm.
2. Measure and record motor voltage and amperage.

C. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation. Remove malfunctioning units, replace with new units, and retest.

D. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

E. Shut unit down and reconnect automatic temperature-control operators.

F. Refer to Division 23 Section “Testing, Adjusting, and Balancing” for testing, adjusting, and balancing procedures.

G. Replace fan and motor pulleys as required to achieve design airflow.

H. Repair or replace malfunctioning units. Retest as specified above after repairs or replacements are made.

3.4 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Adjust belt tension.

C. Lubricate bearings.

3.5 CLEANING

A. On completion of installation, internally clean fans according to manufacturer’s written instructions. Remove foreign material and construction debris. Vacuum fan wheel and cabinet.

B. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

3.6 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner’s maintenance personnel to adjust, operate, and maintain power ventilators.

1. Train Owner’s maintenance personnel on procedures and schedules for starting and stopping, troubleshooting, servicing, and maintaining equipment and schedules.
2. Review data in maintenance manuals in accordance with the “Closeout Procedures.”
3. Review data in maintenance manuals in accordance with “Operation and Maintenance Data.”
4. Schedule training with Owner, through Architect, with at least 7 days’ advance notice.
SECTION 23 36 00 – AIR TERMINAL UNITS

PART 1 – GENERAL

1.1 DESCRIPTION

A. General: Provide Air Terminal Units in accordance with the contract documents.

1.2 REFERENCES

A. The latest editions of the standards listed, as well as all other applicable codes, standards, and good engineering practices shall be used as “minimum” design standards.

1. Electrical devices and wiring shall conform to the latest standards of National Electrical Code (NEC)
2. All devices shall be Underwriters Laboratories (UL) listed and so identified.
3. National Electrical Manufacturers Association (NEMA)

1.3 QUALITY ASSURANCE

A. Acceptable Manufacturers:
   1. Titus
   2. Krueger
   3. Trane
   4. Anemostat
   5. Tuttle & Bailey
   6. Or approved equal.

B. Certification: Provide manufacturer and independent test lab certification of test results.

C. Preparation: HVAC terminal units to be clean and free of all foreign matter prior to shipping. Units and associated equipment such as controls, shall be factory set and shall be packaged in a manner to prevent dust and other foreign matter from entering the unit, controls, and similar items during shipment. All external controls, operators, and sensors shall be covered by rigid metal shields during shipment and storage.

1.4 SUBMITTALS

A. Shop drawing submittals shall include, but not be limited to, the following:
   1. Cut sheets on each terminal unit, clearly marked to show sizes, configuration, construction, unique features, controls, clearances, accessories, performance data, sound data, operating sequence and other pertinent information.
   2. Performance characteristics for each type and size of terminal unit.
   3. Wiring and control diagrams and air flow sensor calibration curves for each terminal unit type.
   4. Copies of factory-certified sound, leakage and performance test results from actual tests of units of the same model and construction to those which will be provided for the project.
   5. Written report of the test results including noise criteria (NC) in sound power as tested in an
independent test lab reverberant room with terminal unit operating at the scheduled airflow. When reporting NC levels, no credits or reduction shall in any way be considered for room plenum, ceiling, and similar item effects. Sound data shall be for discharged and radiated noise.

6. Certified dimensioned drawings showing the locations of all openings, support points, connections, sizes for same, overall dimensions of all boxes and any other pertinent information that may affect the installation of the boxes.

7. Additional information as required.

1.5 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver Air terminal units in factory-fabricated water resistant packaging.

B. Handle Air terminal units carefully to avoid damage to components, enclosures, and finish.

C. Store Air terminal units in a clean, dry space and protect from weather.

D. DDC Controllers for the air terminal units furnished under Division 13 shall be properly safeguarded and handled with extreme care by the Air Terminal Unit Manufacturer.

PART 2 – PRODUCTS

2.1 MATERIALS

A. General: Provide Air terminal units of standard materials and components designed and constructed as recommended by the manufacturer and as required for a complete installation in compliance with these Specifications. Units with electrical equipment and components shall be constructed in accordance with NEMA and NEC and U.L. listed and shall include disconnects or fused disconnects where required by the NEC.

2.2 SINGLE DUCT VAV AIR VALVE TERMINAL UNITS

A. General: Provide pressure independent single duct VAV terminal units consisting of a sheet metal housing with a control damper, damper operator, heating coil, where scheduled, and multipoint averaging flow sensor and electronic (DDC) controls. Transducers for flow sensors, damper operators and DDC control units shall be furnished under Special Systems and shipped to be factory installed by the Terminal Unit Supplier. Single duct VAV air valve/terminal units shall be fully compatible with the temperature controls as specified in Special systems. Terminal unit capacities, settings and sizes shall be as scheduled and shown on the Drawings.

B. Housing: Shall be constructed of 22-gauge minimum galvanized sheet metal with mechanical seals and gaskets to minimize housing leakage. Housing shall be insulated with one inch (1”), 1.5 PCF density coated fiberglass insulation meeting the requirements of NFPA 90A and UL 181 and protected with perforated steel liner. Housing shall be provided with a round or oval inlet for use with flexible duct (1800 fpm maximum velocity) and a rectangular outlet for slip and drive connection to sheet metal ductwork (1600 fpm maximum velocity), or as indicated on drawings.

C. Control Dampers: Shall be of a low leakage, opposed blade or single blade design with galvanized steel blades and self-lubricating bearings. Dampers shall be selected to limit sum of total pressure (TP) drop through the damper and reheat coil to 0.40” W.G., at maximum flow setting with damper open.
D. Damper Operator: Damper operator shall be furnished under Special Systems and shall be an electric type rigidly mounted to the terminal unit and connected to the damper with an adjustable linkage and shall be factory-mounted. All exposed operational/linkage components shall be protected with removable metal covers installed by the Terminal Unit manufacturer.

E. Heating Coils: Heating water coils shall be provided on single duct VAV terminal units, where scheduled or shown on the Drawings. Hot water heating coils shall be 2 row unless otherwise noted, constructed with 0.010” aluminum plate fin with collars drawn, belled and firmly bonded to 1/2” diameter 0.035” wall copper tubes. Coil headers shall be copper, brass or bronze. No soldering or tinning shall be used in the bonding process. Coils shall have galvanized steel casing and air vents. Coil header and U-bends shall be insulated and shall not be exposed. Coils shall be provided with manual air vents. Factory test coils with 300 psig air pressure under water. Coil face velocity shall not exceed 700 fpm. Coils shall have a maximum of 12 fins per inch. Coil air and water pressure drops shall not exceed scheduled maximums.

F. Leakage: Overall leakage for the control damper and pressurized (upstream) portions of the housing shall be less than 3% of nominal cfm at 3” SP, as rated by ADC Test Code 1062 R4. Downstream of damper, the box shall comply with the duct leakage ratings.

G. Controls: Pressure independent volume controls shall be factory-installed, including the multipoint air flow sensor for inlet volume measurement, and related accessories and components. Controls shall provide adjustable minimum and maximum cfm limits, adjustable throttling range and a constant throttling range option and shall be field adjustable to be normally closed or normally open. Adjustments for control settings and gauge tees for flow measurement and balancing shall be easily accessible. DDC controllers and damper operators shall be furnished by the Temperature Control Contractor for factory-installation, wiring and testing by the terminal unit manufacturer. Controllers shall be located for easy access from the ceiling below the unit and coordinated with ceiling access panel locations. Temperature control functions and sequences shall be as specified, and as shown on the Drawings. An air flow sensor calibration curve label shall be attached to each terminal unit in a location visible from the unit controller.

H. Unit Performance: The following performance tests shall be performed by an independent testing lab to verify compliance prior to equipment submittal. Acceptability of the testing facilities shall be subject to review by the Architect. Test results and criteria which shall be considered acceptable are as follows:

1. Discharge and radiated sound power levels shall be less than as scheduled on the drawings for each size of box.
2. CFM fluctuation at any given flow setting over static pressure range shall be a maximum of +10%.
3. Dampers and unit casing shall prevent leakage in excess of 3% of maximum rated terminal unit capacity when operating against 3” of static pressure (SP).

I. Samples: A sample production run unit of each type and size of terminal unit specified on the project shall be submitted for examination and approval by the Architect and Owner. If approved, the units shall remain at the job site for comparison with units as shipped to project. The units may be installed in the project at an accessible, marked location. The unit manufacturer shall test and certify that each terminal unit provided for the project has been constructed and tested as specified and are the same as the sample units.

J. Shipment Testing: A random sampling of the terminal unit supplied for the project and selected by the Architect or Owner's Representative may be tested for conformance to this specification.
contractor shall allow sufficient time during construction and space for the Architect to perform all testing as may be required. If the results of the Shipment Testing show that any of the units do not perform as specified, then additional units shall be tested.

K. Should for any reason the testing described above under “Samples” and “Shipment Testing” prove that any of the units do not perform as specified, the unit manufacturer shall be responsible for all subsequent labor, travel, travel expenses, and incidental expenses, penalties, or other costs required to prove that the units perform as specified. This shall include, but not be limited to, the labor, travel and incidental expenses of Architect and Owner.

PART 3 – EXECUTION

3.1 INSTALLATION

A. General: Except as otherwise indicated, install Air terminal units including components and controls required for operation, in accordance with manufacturer’s instructions.

B. Location: Locate each unit accurately in the position indicated in relation to other work. Position unit with sufficient clearance for normal service and maintenance, including clearance for cabinet removal. Install unit such that all components (including control valves) can be accessible through the ceiling access panel provided under Architectural work. Carefully coordinate exact locations with Architectural reflected ceiling plans.

C. Supports: Minimum support requirements for terminal units shall be as follows. Terminal units weighing less than 150 pounds shall be supported by four 16-gauge, one inch (1”) wide sheet metal straps with ends turned under bottom of unit at corners and secured by two maximums of 0.75” long by 0.25” diameter sheet metal screw per strap. The other strap end shall be attached to the structure by 0.25” diameter threaded bolt into the concrete insert or into drilled-hole threaded concrete expansion anchor. Boxes over 150 pounds in weight shall be supported the same as described above except 0.25” diameter sheet metal screws shall be located with one screw on the side of the unit and one screw on the bottom of the unit. Seal all screw penetrations into the terminal unit air stream. Refer to Seismic Restraint requirements.

D. Leveling: Level terminal units to the tolerances recommended by the manufacturer.

E. Flow Graphs: Graphs shall be provided to coordinate pressure at flow measuring taps with unit primary cfm.

F. Unit Connections: Duct connections shall be the larger of the connections detailed on the Drawings and the terminal unit manufacturers recommendations.

3.2 TESTING

A. General: Installed terminal units shall be leakage tested with the connected ductwork as described herein.

B. Calibration: Installed terminal units shall be calibrated to confirm that factory settings have not been violated. Contractor to provide report stating the same.

3.3 The mechanical contractor through his balancing contractor and coordinating his work with special systems contractor shall confirm the actual calibration. The responsibility of this effort and confirmation report is part of mechanical contractor’s work as required by the. The special systems contractor shall assist mechanical contractor in this effort only.
3.4 TRAINING
   A. Provide training of Owner's representatives.

3.5 IDENTIFICATION
   A. Identify and label each Air Terminal Unit with the approved identification tag showing unit number as on the mechanical drawings and its Automation System address.

END OF SECTION 23 36 00
SECTION 23 37 13 – DIFFUSERS, REGISTERS, AND GRILLES

PART 1 – GENERAL

1.1 DESCRIPTION

A. General: Provide Air Outlets, including ceiling- and wall-mounted diffusers, registers, and grilles in accordance with the contract documents.

1.2 REFERENCES

A. The latest editions of the standards listed, as well as all other applicable codes, standards, and good engineering practices shall be used as “minimum” design standards.

1. National Fire Protection Association (NFPA) Standard
2. American National Standards Institute (ANSI)
3. Sheet Metal and Air Conditioning Contractors’ National Association (SMACNA)
5. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)

1.3 QUALITY ASSURANCE

A. Acceptable Manufacturers: Air outlets manufactured by Titus, Price, Metal-Aire, Krueger, Anemostat, Air Factor, Carnes, or Tuttle & Bailey will be acceptable if the devices furnished comply with these Specifications, the conditions scheduled, and are similar in appearance and performance to the units scheduled.

B. Compliance: When directed by the Architect, test air outlets to verify compliance with these Specifications. Perform all revisions required to comply with terminal velocity, noise level or maximum temperature variation requirements at no cost to the Owner.

C. Air Distribution Equipment: Maximum space temperature variation shall not exceed 2 °F through the conditioned area from 2’ above the floor, to 7’ above the floor. The scheduled Air Outlets are based upon one listed manufacturer. The air outlets by other manufacturers shall be selected by the manufacturer to suit the volume, throw and noise level scheduled as shown on the Drawings and maintain maximum terminal velocities of 50 fpm, unless otherwise indicated.

1.4 SUBMITTALS

A. Product Data: For each product indicated, include the following:

1. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.

2. Diffuser, register, and Grille Schedule: Indicate Drawing designation, room location, quantity, model number, size, and accessories furnished.

B. Shop Drawing submittals shall include, but not be limited to, the following:

1. Submit dimensioned drawings for all custom and special dimension linear slot diffusers and air outlets and details.

2. Submit dimensioned floor plans and elevations drawings showing exact location of air...
outlets in relation to other ceiling elements.

3. Submit test data and results as specified herein. Test results shall be certified by an authorized officer of the company.

4. Submit coordinated shop drawings showing duct connections to linear slot diffusers, plenums, Return Hoods and Blank-offs provide.

C. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:

   1. Ceiling suspension assembly members.
   2. Method of attaching hangers to building structure.
   3. Size and location of initial access modules for acoustical tile.
   4. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
   5. Duct access panels.

D. Samples for Initial Selection: For diffusers, registers, and grilles with factory-applied color finishes.

E. Sample for Verification: For diffusers, registers, and grilles, in manufacturer’s standard sizes to verify color selected.

1.5 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver air outlets in factory-fabricated water-resistant wrapping.

B. Handle air outlets carefully to avoid damage to material component, enclosure, and finish.

C. Store air outlets in a clean, dry space and protect from the weather.

D. Contractor shall be responsible for the timely procurement, storing, inventoring and handling of all linear slot diffuser plenums, return hoods and blank-offs that are furnished.

PART 2 – PRODUCTS

2.1 AIR OUTLETS GENERAL REQUIREMENTS

A. General: Provide air distribution devices of the size, shape, and type, constructed of materials and components and with finishes as scheduled and shown on the Drawings. Grilles, registers and ceiling outlets shall be provided with sponge rubber or soft felt gaskets. If a manufacturer other than the one scheduled is used, the sizes shown on the Drawings shall be checked for performance, noise level, face velocity, throw, pressure drop, etc., before the submittal is made. Selections shall meet the manufacturer’s own published data for the above performance criteria. The throw shall be such that the velocity at the end of the throw in the five foot occupancy zone will not be more than 50 fpm nor less than 25 fpm. Noise levels shall not exceed those published in the ASHRAE Guide for the type of space being served (NC level) for the actual room construction.

B. Compatibility: Air distribution devices shall be fully compatible with the surfaces in which they are installed and shall be provided with all required mounting accessories for installation in the actual construction at the installation location.
C. Finishes: All ceiling and wall mounted air devices shall be painted white or off-white unless specified otherwise and all air devices shall be the same color. Where the factory finish on all devices is not the same as determined by the Architect, then the Contractor shall be responsible for coordinating field painting of air devices. The Contractor shall be responsible for all costs associated with painting of white or off-white air devices. The Architect’s decision on white color compatibility is final.

D. Linear Supply and Return Slot Diffusers (LD1, LD2, LD3)

E. Linear slot diffusers shall be extruded aluminum type as specified, and as shown on the architectural and mechanical drawings. Linear diffuser “tees” shall be provided. Supply air plenums, return air hoods and blank-offs shall be furnished and installed except “LD1” supply plenums shall be provided.

2.2 AIR OUTLETS

A. The general features of the types of air outlets and devices used are listing in the following paragraphs. Additional requirements are implied by the model numbers scheduled on the drawings for a given manufacturer. The indicated manufacturer’s product is basis of design and other manufacturers may be required to provide different sizes to result in the intended performance and equivalent noise levels.

B. Linear Slot Diffusers (LD1, LD2, LD3):

1. Linear slot type supply and return diffuser “tees” shall be of length and width as scheduled or shown on the Drawings. The diffusers shall be continuous extruded aluminum construction with minimum wall thickness of .062 and finishes as specified by the Architect. The diffusers shall be installed above the ceiling or in sidewall as shown, and located as indicated on the Architectural and Mechanical Drawings. The diffusers shall integrate into the ceiling and wall systems. Diffusers mounted in ceilings shall be capable of supporting the ceiling system. Joints at ends and corners of “tees” shall be mitered type. The supply linear slot diffusers shall have an internal, fixed, curved, aerodynamically shaped outlet designed to provide the maximum amount of induced secondary room air. The return air slot shall be located so that the supply air pattern will not be affected. The supply air from the ceiling slot diffuser shall be discharged horizontally along the ceiling unless otherwise indicated. All portions of linear slot diffuser not used for supply shall be provided with factory made return air hoods unless otherwise noted on drawings. Return air hoods shall be 24GA, factory made insulated & painted flat black to fit over the diffuser “tees”.

2. Linear diffuser lengths indicated on Mechanical Drawings are active sections for supply and return applications. For installed length of linear diffusers refer to Architectural Drawings.

3. Coordinate air pattern controller sections of linear diffuser “tees”, with the diffuser plenum lengths and locations. Pattern controller length shall be 24” maximum.

4. Blank off portions of linear diffusers with factory made blank-offs painted flat black where shown on drawings.

5. The slot diffusers shall be designed, tested, and constructed in a manner so as to comply with the performance criteria and sound level requirements specified hereinafter. Diffuser plenums shall be manufactured by the same manufacturer as the “tees” and shall be constructed of at least 24 gauge galvanized steel, insulated with minimum of 1/2" thick acoustical lining, and shall be reinforced as required. The air volume, length and duct connection size shall be as scheduled or shown on the Drawings. The diffuser manufacturer shall coordinate the attachment, support, tee spacing, and similar features of the diffuser with the ceiling and wall Contractor.
6. The entire assembly shall be tested as a unit at the manufacturer’s laboratory. Submit certified copies of the test results to the Engineer for review. The test data shall include AK factors for an Alnor velometer, sound data, diffuser static pressure drop, horizontal air throw, and drop for the air supply rates per lineal foot of diffusers. The test data shall be based on a 55°F air supply temperature, a 20°F temperature differential and an 85°F heating supply air temperature.

7. The diffuser flange exposed to view shall be painted factory standard white finish or finish as selected by the Architect. All other surfaces shall be painted flat black.

8. The Architect shall have the option to witness additional tests after receipt of certified test results to verify compliance with these Specifications.

9. Where shown on Architectural drawings provide integrated linear slot diffuser to mount devices such as sprinkler heads, speakers, strobe lights, etc. Coordinate the exact locations of such devices through approved shop drawings of the respective trade. Provide necessary mounting hardware, collars, escutcheons, supports to match the device mounting requirements. Submit coordinated shop drawing for Architect’s approval.

C. Other Air Outlets: As shown or scheduled.

2.3 GRILLES AND REGISTERS

A. Adjustable Sidewall Return and Exhaust Register

1. Product: Titus 350RL

2. Acceptable Manufacturers:
   a. Anemostat.
   b. Price Industries.
   c. Titus.
   d. Krueger.
   e. Or approved equal.

3. The fixed deflection blades shall be available parallel to the long or short dimension of the grille. Construction shall be of steel with a 1-0.25” wide border on all sides. Screw holes shall be countersunk for a neat appearance. Corners shall be welded with full penetration resistance welds.

4. Deflection blades shall be contoured to a specifically designed and tested cross-section to meet published test performance data. Blades shall be firmly held in place by mullions from behind the grille and fixed to the grille by welding in place. Blade deflection angle shall be available at 35°F.

5. Optional opposed-blade volume damper shall be constructed of heavy gauge steel. Damper must be operable from the face of the grille.

6. The grille finish shall be #26 white. The finish shall be an anodic acrylic paint, baked at 315°F for 30 minutes. The pencil hardness must be HB to H. The paint must pass a 100-hour ASTM B117 Corrosive Environments Salt Spray Test without creepage, blistering, or deterioration of film. The paint must pass a 250-hour ASTM D870 Water Immersion Test. The paint must also pass the ASTM D2794 Reverse Impact Cracking Test with a 50” pound force applied.

7. The manufacturer shall provide published performance data for the grille. The grille shall be tested in accordance with ANSI/ASHRAE Standard 70-1991.

8. Registers and Grilles: Provide registers which contain a key-operated multi-louvered opposed blade damper operable from the face side, unless scheduled otherwise. Supply air registers shall
be of the double deflection type, unless scheduled otherwise. Return air grilles and registers shall have fixed face blades and match the face of the supply air registers, unless scheduled otherwise. Provide concealed fastening for all registers and grilles.

9. Supply Grille: Devices shall be continuous, stainless steel slot diffusers with mitered corners. Diffusers shall have 0.25” slots with 0 degrees or 15 degrees deflection as scheduled and shall be suitable for use in the ceiling, wall or floor type in which the diffuser is installed. Slot diffusers shall have concealed mounting hardware and mitered corners. Provide internally insulated supply air plenums as shown on the Drawings. Floor grilles are shall provide supply plenums and duct connections.

10. Wall Supply Grilles: Grilles shall be all aluminum construction with 0.75” airfoil double deflection blades, mitered frames and an opposed blade balancing damper where scheduled or shown on the Drawings. Grilles shall be suitable for mounting in the wall type in which it is installed. The entire grille shall have a factory applied white or off-white baked enamel finish. Grilles shall have concealed mounting hardware and shall be provided with flush mounting frames where scheduled or required for the installation detailed on the Architectural Drawings.

11. Wall Return Grilles: Grilles shall be all aluminum construction with 0.75” airfoil double deflection blades, mitered frames and an opposed blade balancing damper where scheduled or shown on the Drawings. Grilles shall be suitable for mounting in the wall type in which it is installed. The entire grille shall have a factory applied white or off-white baked enamel finish. Grilles shall have concealed mounting hardware and shall be provided with flush mounting frames where required.

2.4 CEILING DIFFUSER OUTLETS & INLETS

A. Thermally Powered VAV Ceiling Diffuser:

1. Product: Acutherm Thermafuser Model TF-HC.

2. Acceptable Manufacturers:
   a. Acutherm.
   b. Price Industries.
   c. Titus.
   d. Kreuger.
   e. Or approved equal.

3. Ceiling Diffusers: Provide diffusers with corrosion resistant treated surfaces and finished in off-white baked enamel unless otherwise specified, scheduled, or shown on the Drawings. Provide opposed volume control dampers with supply air diffusers where scheduled. Where applicable, provide adapters with diffusers to permit connection to round supply duct. The interior of all perforated plate and linear diffusers shall be painted flat black. Perforated plate supply air diffusers shall have pattern control blades installed in the diffuser neck. Pattern controllers attached to the perforated plate are not acceptable. Provide concealed fastening on all surface mounted ceiling diffusers.

4. Louver Face Ceiling Supply Diffusers: Diffusers shall be all aluminum construction with mitered corner V-bevel border style surface frames suitable for use with the ceiling in which it is installed. The entire grille shall have a factory applied white or off-white baked enamel finish. Air devices shall be 4-way diffusion pattern unless noted otherwise on the drawings. An opposed blade balancing damper shall be provided where scheduled. Device neck size shall be as shown on the Drawings.
5. Face Ceiling Exhaust and Return Air Outlets: Devices shall be aluminum/steel construction with an aluminum face and aluminum or steel pans. Frames shall have mitered corners and be suitable for lay-in or concealed fastener surface installation to suit the ceiling construction. Perforated faces shall have a concealed hinge mechanism such that the plate remains attached to the frame when opened. Exposed external parts shall have a factory applied white or off-white baked enamel finish. Visible internal parts shall be factory painted flat black. All steel components shall be fully phosphatized prior to painting and there shall be no unpainted steel parts. An opposed blade balancing damper shall be provided where scheduled. Device neck size shall be as shown on the drawings. Air device frame shall be suitable for use with the ceiling in which the device is installed. Models and sizes as scheduled.

6. Perforated Face Ceiling Supply Air Outlets: Devices shall be aluminum/steel construction with an aluminum face and aluminum or steel pans. Frames shall have mitered corners and be suitable for lay-in or concealed fastener surface installation to suit the ceiling construction. Perforated faces shall have a concealed hinge mechanism such that the plate remains attached to the frame when opened. Exposed external parts shall have a factory applied white or off-white baked enamel finish. Visible internal parts shall be factory painted flat black. All steel components shall be fully phosphatized prior to painting and there shall be no unpainted steel parts. Diffusers shall incorporate internal pattern control louvers. The use of pattern control devices attached to the perforated plate is not acceptable. Air devices shall be 4-way diffusion pattern unless noted otherwise on the drawings. An opposed blade balancing damper shall be provided where scheduled. Device neck size shall be as shown on the drawings. Air device frame shall be suitable for use with the ceiling in which the device is installed. Models and sizes as scheduled.

7. Thermally powered VAV diffusers shall be a complete VAV terminal and thermostat self-contained in a nominal 24” square diffuser. They shall be thermally powered with one cooling thermostat/actuator, one heating thermostat/actuator and one changeover thermostat/actuator. External wiring or pneumatics shall not be allowed.

8. The VAV diffuser shall have a micrometer type temperature set point adjustment with an indicator and temperature scale to adjust the cooling set point and a separate micrometer type temperature set point adjustment with an indicator and temperature scale to adjust the heating set point. The adjustment shall be right above the hinged appearance panel and shall not require tools. Each set point shall be separately adjustable between 70°F and 78°F. The initial set point shall be factory set at 74°F.

9. In the cooling mode the VAV diffusers shall open on a rise in room temperature and in the heating mode they shall close on a rise in room temperature. The changeover thermostat shall be factory installed and adjusted to engage the heating mode when the supply air temperature rises above 80°F and return to the cooling mode when the supply air temperature falls below 68°F. During changeover the diffuser shall close to the minimum setting. Nothing, including the changeover mechanism, shall extend above the inlet of the diffuser.

10. The VAV diffusers shall have four perimeter dampers to provide 66 linear” of variable discharge area at the perimeter of the diffuser for maximum Coanda effect and to avoid dumping.

11. All VAV diffuser shall have a solid (no holes or slots) hinged appearance panel that can be unlatched and folded down to hang allowing hands to be free for adjusting temperature set points. Instructions for the VAV panel shall be on the inside of the appearance panel.

12. The VAV diffusers shall have positive induction of secondary room air over the room thermostats/actuators at all flows from fully closed to fully open.
13. The VAV diffusers shall have a single spring disconnect which will open the dampers for balancing without tools. VAV diffusers requiring tools, adjustment of set points or adjustment of supply air temperature to open for balancing shall not be allowed.

14. The manufacturer shall warrant that the diffuser shall be free from defects in materials and workmanship for a period of ten years from date of shipment.

15. Supply air to the VAV diffuser shall be constant temperature (may be reset to another constant temperature). Supply air shall be limited to no lower than 50°F/10°C on cooling and no higher than 120°F/49°C on heating. The heating high limit shall be as low as possible but no lower than 80°F/27°C.


2.5 PERFORATED CEILING RETURN/EXHAUST GRILLE

A. Perforated Ceiling Return/Exhaust Grille:

1. Product: Titus PAR.

2. Acceptable Manufacturers:
   a. Anemostat.
   b. Titus.
   c. Price Industries.
   d. Krueger.
   e. Or approved equal.

3. Grilles shall have a perforated face with 3/16” diameter holes on ¼” staggered centers and no less than 51% free area. Perforated face shall be steel or aluminum according to the model selected. The back pan shall be one piece stamped heavy gauge steel of the sizes and mounting type shown on the plans and outlet schedule. The diffuser neck shall have 11/8” depth for easy duct connection.

4. Face size shall be 24” x 24” in t-bar ceilings and 16” x 16” in gypsum board ceilings.

5. The perforated face must be easily unlatchable from the back pan to facilitate access to an optional damper.

6. The finish shall be #26 white. The finish shall be an anodic acrylic paint, baked at 315°F for 30 minutes. The pencil hardness must be HB to H.

7. The paint must pass a 100-hour ASTM B117 Corrosive Environments Salt Spray Test without creepage, blistering, or deterioration of film. The paint must pass a 250-hour ASTM D870 Water Immersion Test. The paint must also pass the ASTM D2794 Reverse Impact Cracking Test with a 50” pound force applied.

8. Optional damper shall be constructed of heavy gauge steel. Damper must be operable from the face of the diffuser by unlatching the diffuser face. The diffuser must be designed such that complete removal of the face is not required during damper adjustment.

2.6 SOURCE QUALITY CONTROL

A. Verification of Performance: Rate diffusers, registers, and grilles according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

PART 3 – EXECUTION

3.1 EXAMINATION

A. Examine areas where diffusers, registers, and grilles are to be installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.

3.2 INSTALLATION:

A. General: Install air distribution devices in accordance with manufacturer's written instructions and recognized industry practices to ensure that products serve intended functions. Grille connections, linear diffuser plenum, etc. shall be made in accordance with SMACNA standards.

B. Install diffusers, registers, and grilles level and plumb.

C. Coordination: Coordinate with other trades, including ductwork, and ductwork accessories, as necessary to interface air distribution devices properly with other work. Where ceiling outlets are furnished and installed by ceiling contractor, coordinate plenum sizes and locations to suit field conditions. Ceiling and wall air outlet frame types, their construction and finish shall be compatible with the ceiling or wall construction and shall be as approved by the Architect.

D. Locations: Locations of air distribution devices shown on Mechanical Drawings are approximate, with locations indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Locations shall be coordinated with other trades to make symmetrical patterns and shall be governed by the established pattern of the lighting fixtures. Make final locations where indicated, as much as practicable. Where air distribution devices are installed in acoustical tile and other ceilings, they shall be either centered on tile or ceiling joints as directed by Architect. Coordinate exact location of all ceiling air devices with Architectural reflected ceiling plans. Where architectural features or other items conflict with installation, notify Architect for a determination of final location. Coordinate exact locations of wall air outlets with the interior elevations shown on Architectural Drawings. All devices installed in UL floor/ceiling or roof/ceiling assemblies shall be compatible with the assembly specified on the Architectural Drawings.

E. Mounting Provisions: Coordinate mounting provisions and accessories required for proper installation of air devices in finish and construction at the point of installation. Refer to details on the Mechanical and Architectural Drawings for special installation details and provide all mounting accessories shown or required for the complete and proper installation of each air device. Ceiling air outlets in lay-in acoustical or panel ceilings shall be independently supported from the structure above by two 12 gauge wires attached to air outlets at opposite diagonal ends.

F. Air Outlet Plenums: Air outlet plenums for linear and ceiling air outlets shall be supported independently from the structure (not from the ceiling), similar to ductwork. Air outlet plenums for linear slot diffuser (LD2 and LD3) shall be furnished. Contractor shall co-ordinate their location and make duct connection and plenum modifications if necessary due to field conflicts.

G. Accessories: Where scheduled, the grilles, registers and ceiling outlets shall be provided with deflecting devices and manual balancing damper. These devices shall be the standard product of the
manufacturer, subject to review by the Architect, and equal to brand scheduled.

H. Security Air Devices: Tamper resistant air devices in Secure Areas shall be installed in accordance with Manufacturer’s recommendations for the construction types used on the project. In all cases, tamper resistant air devices shall be securely mounted to the building construction. Submit shop drawing showing details of attachment to the building structure.

I. Install diffusers, registers, and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

3.3 FIELD QUALITY CONTROL

A. Test: Test installed devices to demonstrate satisfactory compliance with specified and indicated requirements.

B. Air Balancing: Balance the airflow through each air device to the volumes shown on the Drawings.

C. Adjustment: Adjust air distribution devices to provide air distribution patterns shown on the drawings or required. This includes any readjustments that may be necessary after the occupants have moved in or where the indicated throw direction and volumes result into unsatisfactory throws and air movements, as determined by the Owner/Architect.

D. Linear slot diffuser shall be installed in straight line parallel to the adjoining architectural elements (such as a wall, ceiling edge, etc.). All defective installation as determined by the architect shall be corrected to the architect’s satisfaction.

3.4 ADJUSTING

A. After installation, adjust diffusers, registers, and grilles to air patterns indicated, or as directed, before starting air balancing.

END OF SECTION 23 37 13
SECTION 23 41 00 – PARTICULATE AIR FILTRATION

PART 1 – GENERAL

1.1 DESCRIPTION

A. General: Provide filters and accessories in accordance with the contract documents. Drawings and general provisions of the Contract, including General and Supplementary Conditions, apply to this section.

1.2 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this section shall comply with all the requirements of General conditions, Supplemental Conditions, Division 1 - General Requirements, Basic Materials and Methods, and other Sections in Division 23 specified herein.

1.3 REFERENCES

A. Codes and Standards: Provide products conforming to the requirements of the following:


1.4 SCOPE

A. All work to be furnished and installed under this Section shall comply with all the general requirements, and shall include, but not necessarily be limited to, the following:

1. Air filters and Associated Hardware
2. Photocatalytic Air Cleaning Units
3. Activated Carbon and Odoroxidant Media
4. Air Filter Gauges
5. Activated-Carbon Panel Filters
6. Activated-carbon, Deep-V Filters
8. Cylindrical-Canister filters.
10. Supported adsorber bag filters.
12. Side-Service Housings.
13. Filter gauges.

1.5 QUALITY ASSURANCE

A. Manufacturer: Filter manufacturer must have been in the business of manufacturing filters for minimum of 5 years.

B. Local Supplier: Filters provided must have local suppliers and/or manufacturer’s representative within 40 miles of Airport.
C. UL Rating: All filters shall be UL listed.

1.6 SUBMITTALS

A. Prior to construction, submit for approval on all materials and equipment.
   1. Manufacturer’s name and catalog data
   2. Installation data
   3. Capacities and resistances
   4. Materials of construction

B. Product Data: Submit manufacturer’s technical product data including, dimensions, weights, required clearances and access, rated flow capacity including initial and final pressure drop at rated air flow, efficiency and test method, fire classification, installation instructions, furnished specialties, and accessories for each model indicated.

C. Shop Drawings: Submit manufacturer’s shop drawings for filter rack assemblies indicating dimensions, materials, and methods of assembly of components. Include plans, elevations, sections, details, and attachment to other work.
   1. Show filter rack assembly, dimensions, materials, and methods of assembly of components.
   2. Include setting drawings, templates, and requirements for installing anchor bolts and anchorages.

D. Samples: Submit one sample filter cartridge of each type of filter required.

E. Operation and Maintenance Data: Submit information for all products in accordance with the requirements, including for each type of filter and rack to include in emergency, operation, and maintenance manuals.

F. Maintenance Materials: Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
   1. Provide one complete set(s) of filters for each filter or filter bank.
   2. Provide on complete 100% refill supply for each filter requiring loose-fill media.
   3. Provide one container(s) of red oil for inclined manometer filter gauge.


H. Field quality-control reports.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Delivery: Handle air cleaning equipment to prevent damage. Do not install damaged air cleaning equipment; replace with new.

B. Deliver products to the site in containers with manufacturer’s stamp or label affixed.

C. For the factory built air handling units, filter supplier shall coordinate the filter housing and rack dimensions with the air handling unit (AHU) supplier for proper fit and space requirements. Both AHU supplier and Filter supplier shall certify that such a coordination has taken place, prior to the shipment of filter housing and rack to the AHU supplier for installation at the factory.
D. Storage: Store air filters and equipment in a clean, dry place, protected against dirt, water, chemical and mechanical damage.

E. Do not install damaged products. Remove damaged materials from project site.

PART 2 – PRODUCTS

2.1 GENERAL

A. Provide filters of types as specified herein and as scheduled for 100% of the air supplied by the fan or air handling units for all air conditioning and outside air systems. Provide complete filter assembly consisting of retainers, support grids, framing and stabilizers to ensure uniform dust loading and prevention of sagging and oscillation of the filter media and filters. Provide a certified test report using ASHRAE Standard 52.1.

B. Air By-Pass: Construct filters so as to prevent the passage of unfiltered air. Provide felt, rubber, or neoprene gaskets, or other permanent means, to prevent air by pass between filter frames and supporting members (housing and casings).

C. Finish: Protect steel filter parts against corrosion with a baked on enamel, epoxy resin, polyvinyl coating, zinc-coating, cadmium plating, two coats of oil paint, two coats of lacquer, or coat with alkyd paint after phosphate cleaning.

D. Identification: Provide each filter with an identification device mounted in a location where it will be visible after installation; show model number and all other data necessary for ordering renewal media.

E. Supports: If required, provide supports (screen, grid, or frame type) for filters adequate to position the media for uniform air distribution without tearing, and to prevent excessive motion and deflection under varying air flow conditions.

F. Replacement Filters: Provide all replacement filters and filter media that are the same as specified hereinafter for the applicable type filter.

G. Definitions:

1. Efficiency: Per ASHRAE Test Standard 52.1 unless otherwise noted.

2. Dust holding capacity: Per ASHRAE Test Standard 52.

H. Acceptable Manufacturers:

1. Filters: Model numbers given throughout are listed for Eco-Air products.
   a. Eco-Air Products, Inc.
   b. American Air Filter.
   c. Weststates Carbon.
   d. Farr.
   e. Flanders.
   f. Camfil-Farr.
   g. Genesis.
   h. Or approved equal.

2. Accessories:
b. Air Filter Gages – Dwyer.
c. Metal Filters – Eco-Air Metal Masters.

2.2 FILTER CARTRIDGES

A. Panel Filters - Construction grade
   1. Disposable Filters
   2. Fiberglass or polyester media and cardboard frames, completely disposable, thickness as scheduled. Permanent washable types not acceptable.

2.3 PLEATED MEDIA FILTERS (Type F-1, F-1A and F-1B):

A. General: Provide medium efficiency, pleated, disposable type filters where scheduled or shown on the drawings.

B. UL-listing: Filters shall be listed by Underwriters' Laboratories, Inc. as Class II.

C. Filter Media: Filter media shall be of the nonwoven cotton fabric type. The filter shall have an average atmospheric dust spot efficiency of 25-30% when tested in accordance with ASHRAE Test Standard 52.1.
   1. Shall be of a high-loft, reinforced, non-woven cotton/synthetic blend.
   2. Media support is continuously laminated to an expanded metal grid on the air leaving side.
   3. Radial wedge pleat design.
   4. Media frame is constructed from two pieces of die-cut high wet-strength carrier board. The frame is seigned with diagonal and horizontal support members bonded to the media on the air entering and leaving sides.
   5. U.L. 900.
   6. Basis of Design:
      a. Eco-Air C35 Series.
      b. SFM #3175-394:104.
      c. U.L. #R9608 (N).

D. Pleated Media filters (ASHRAE Dust-Spot Efficiency 505)
   1. Filter media of high efficiency micro-fine glass fiber reinforced with a synthetic backing.
   2. Media support is continuously laminated to an expanded metal grid on the air leaving side.
   3. Pleat design shall be a radial wedge pleat.
   4. The enclosing frame is constructed from moisture-resistant chipboard. Perforated steel support grilles are placed on the upstream and downstream sides. The entire unit is then sealed to insure a positive media-to-frame bond.
   5. U.L. 900.

E. Types and Capacity: Ratings and capacity for pleated filters shall be as follows.

1. Four Inch (Type F-1): The effective filter media shall not be less than 5.8 square feet of media per 1.0 square foot of filter face area and shall not contain not less than 8 pleats per linear foot. Initial resistance at 500 fpm approach velocity shall not exceed 0.18” w.g. Two Inch (Type F-1A): The effective filter media shall not be less than 3.1 square feet of media per 1.0 square foot of filter face area and shall contain not less than 10 pleats per linear foot. Initial resistance at 500 fpm approach velocity shall not exceed 0.24” w.g.

2. One Inch (Type F-1B): The effective filter media shall not be less than 1.6 square feet of media per 1.0 square foot of filter face area and shall not exceed less than 14 pleats per linear foot. Initial resistance at 500 fpm approach velocity shall not exceed 0.40” w.g.

F. Media Support Grid: The filter media shall be a welded wire grid with an effective open area of not less than 96%. The welded wire grid shall be bonded to the filter media to eliminate the possibility of media oscillation and media pull away. The media support grid shall be formed in such a manner that it effects a radial pleat design, allowing total use of filter media.

G. Enclosing Frame: The filter enclosing frame shall be constructed of a rigid, heavy-duty, high wet-strength beverage board, with diagonal support members bonded to the air entering and air exit side of each pleats, to ensure pleat stability. The inside periphery of the enclosing frame shall be bonded to the filter pack, eliminating the possibility of air bypass. Frame shall be 24” x 24” unless otherwise shown or if needed to be different in size for fan coils and packaged air handling units.

H. Acceptable Manufacturers:

1. Environmental Filter Corporation (EFC), Type EP
   a. Farr.
   b. Eco-Air.
   c. American Air Filter.
   d. Or approved equal.

2.4 MEDIUM AND HIGH EFFICIENCY BAG FILTERS (Type F-2 and F-4):

A. General: Provide high efficiency bag filters where scheduled and shown on the drawings. Filters shall be 24” x 24” face size unless otherwise shown. U.L. 900 construction and so listed.

B. Acceptable Manufacturers: Environmental Filter Corporation (EFC) type EPS 95 or equal by Farr, Eco-Air or American Air Filter.

C. UL-Listing: Filter shall be listed by Underwriters Laboratories, Inc. as Class II.

D. Filter Media: Filter media shall be three ply, dual stage mechanical efficiency, synthetic media. The prefilter layer shall consist of coarse synthetic fibers designed to arrest large particles. The middle ply shall be made from spun bonded polypropylene fibers. The final media ply shall be spun bonded polypropylene backing with high strength characteristics. The media shall withstand 100% humidity for extended period and be non-shedding construction. The media shall have average atmospheric dust spot efficiency of 95% when tested in accordance with ASHRAE test standard 52.1. Replaceable factory-assembled cartridges incorporating a fine fibered all-glass medium encased in a non-woven backer mat material.

1. Open area on the cartridge face available for air passage: not less than 90% of the total face area.
E. Pocket Design: Flexible internal support stitching shall maintain individual pockets in a controlled form under all rated air flow conditions. Stitching shall be sealed with thermoplastic resin. At any point, the size of the upstream and downstream air-passage in exact proportion to the volume of unfiltered and filtered air being handled at that point. Edges shall be finished with stitch to prevent air bypass. Pockets shall be bonded to galvanized steel casings and assembled into galvanized steel header. Headers shall be gasketed with polyfoam on vertical sides to prevent leakage when installed. Filters shall be formed into tapered pleats using controlled media spacing. Filter shall maintain its rigid operational shape at any flow from 0 to 200% of rated flow. Provide 8 pockets for every 24” x 24” size filter.

1. Each pocket shall be individually sewn with stringently regulated stitching to create a uniformly shaped channel. Each stitch line to be sealed with a thin thermoplastic bead to prevent air bypass. All pocket edges shall be finished with a 4-thread stitch to maintain maximum airflow and durability.

F. Capacity: Types, Ratings, and capacities for high efficiency bag filters shall be as follows:

1. 22” deep (Type F-2 and Type F-4): The effective filter media shall not be less than 15.5 square feet of media per 1.0 square foot of filter area and shall not contain less than 3 pockets per linear foot. Initial resistance at 500 fpm approach velocity shall not exceed 0.56 w.g. Filters up to 22” in depth shall be designed to operate in Variable Air volume Systems.

G. Media Support Grid: Each pocket shall be secured to an individual support module which is both mechanically fastened and chemically bonded with a galvanized steel header.

H. Header Frame: Header frame shall be 26 gauge galvanized metal design with roll formed soft edge both up and downstream with flush metered corners. Frame shall have anti-reversing side fasteners clipped to the module and frame to prevent media pullaway.

I. Performance:

1. Initial and final resistance not to exceed the scheduled values.
2. Media area must equal or exceed that of the specified products.
3. Determine the average efficiency using the ASHRAE Standard 52.1 Test Method using atmospheric dust.

J. Test Report:

1. Submit an independent test laboratory report showing the pressure drop of the clean filter cartridge elements at flow rates from 75% to 125% of the manufacturer’s published rated capacity for the filter cartridge elements.
2. Perform this test in an ASHRAE test duct system in accordance with the applicable portion of ASHRAE Standard 52.1.

2.5 MEDIUM AND HIGH EFFICIENCY RIGID FILTERS

A. Separator Type U.L. 900

1. Filter Construction
   a. Totally rigid type, constructed by pleating a continuous sheet of moisture-resistant all-glass media into closely-spaced pleats with hemmed edge aluminum separators. A pack shall be
sealed in a 24 gauge galvanized steel frame with fire-retardant urethane resin potting compound.

b. Media area per 24x24x12 size filter shall be 91 square feet per 65% and 85% efficient filters and 116 square feet per 95% efficient filters.

c. U.L. 900 construction and so listed.

d. Basis of design: Eco-Air Ecopac, SFM #3175-394:106, U.L.#R6908 (N)

B. Lofted Media Type U.L. 900

1. Filter Construction

   a. Totally rigid type with a lofted high-density microfine glass filter media laminated to a non-woven backing. The media shall be supported by an expanded metal support grid bonded to the media to eliminate media oscillation. Media finger supports shall be manufactured of an industrial strength board and be permanently installed on both air leaving sides, (4) per side.

2. Enclosing Frame

   a. The enclosing frame shall be manufactured of 26 gauge galvanized steel and furnished with horizontal and diagonal support members to stabilize and protect the media pack.

   b. Basis of Design: Eco-Air Rigid Air, SFM #3175-392:103; U.L. #R6908 (N)

2.6 PANEL AIR FILTERS

A. Refer to the schedule and air filter specification for details.

B. The side access filter cabinet shall match the air handler cabinet with similar construction and finish. Hinged access doors with positive-latching fasteners shall be provided at both ends of the housing. Sheet metal screws shall not be used.

2.7 EXTENDED AREA AIR FILTERS

A. Refer to the schedule and air filter specification for details.

B. Holding frames and side access housings shall be provided under Section 23 31 13 pertaining to metal ducts by the filter manufacturer.

C. The rooftop unit manufacturer shall install the holding frames or framing modules in the unit at the factory in strict accordance with Section 23 31 13 pertaining to Metal Ducts.

D. Side access filter housings may be supplied by the central station air handler manufacturer if:

   1. The housing construction meets or exceeds that of the specified housing; and

   2. Such housings are offered as a standard product by the air handler manufacturer

   3. The housings provide equal or greater filter face area.

2.8 MODULAR FRAMING SYSTEM (UPSTREAM OR DOWNSTREAM ACCESS)

A. Medium and high efficient extended surface ASHRAE-rated filters shall be installed in extruded (mill finish) (anodized) aluminum framing modules factory-cut, pre-punched and packaged with all
necessary stiffening members and thread cutting screws for field assembly into modules up to 12' high and 14' wide using only a screwdriver or socket wrench.

B. The framing members shall be permanently gasketed with a reinforced nylon pile seal to prevent the bypass of unfiltered air. Each horizontal row of filters shall have a positive spring-loaded sealing device which will allow easy installation and removal of cartridges from either upstream or downstream access as specified and shall secure the seal between cartridges while the bank is in operation.

C. A separate track shall be incorporated for 2" panel pre-filters (if desired or specified) which can be serviced from upstream without disturbing the final filters.

D. Basis of design: Eco-Air K-Trac

2.9 FILTER RACKS

A. General: Pleated and bag filters shall be installed in flat filter racks as required to provide maximum filter velocity as scheduled or shown on the Drawings. Racks shall be provided under this Section for installation on air handling units which shall be specified.

B. Filter Racks: Provide Air Guard, BLC Industries, Farr or equal, extruded aluminum construction with front access, unless otherwise shown, modular filter racks suitable for mounting on the air handling equipment which it serves. Racks shall be equipped with gaskets and spring type positive sealing fasteners to hold filters in place. Fasteners shall be removable without the use of tools. Frame depth and construction shall be suitable for the filters in the bank. Both pre and final filter shall be gasketed to prevent bypass.

C. Filter racks for large filter banks shall be joined together to create rigid frame and shall be self-supporting. Provide additional reinforcing members or braces to result into a sturdy and firm filter bank.

D. Provide factory made side access housing for air handling unit where scheduled or shown on drawing. Housing shall be aluminum construction and shall facilitate servicing and removal of filters without opening the air handling unit access doors.

1. Housing for 2", 4" and 6" Filters (Single Stage)
   a. Housing shall be factory manufactured of 16 gauge galvanized steel and reinforced to eliminate twisting or racking.
   b. 16-gauge access doors shall be gasketed along the periphery to maintain a proper seal.
   c. Filter track shall be aluminum extruded type and furnished with a polypropylene fin seal gasket.
   d. Basis of Design: Eco-Air Surepleat.

2.10 FILTER MAGNAHELIC GAUGES:

A. General: Provide filter magnahelic gauges for each individual pleated media and bag filter bank handling 2,000 cfm or more in any air handling or fan coil unit. For filter banks with multiple rows (pre and final filters), provide gauges for both rows. The gauges shall be diaphragm-actuated dial and pointer type magnahelic filter pressure drop gauges mounted on the unit exterior in an accessible location as the unit is installed and shall have an engraved nameplate identifying the filter monitored. Gauges shall be Dwyer Model No. 2002 AF (0-2" w.g. range) or an approved equal. A Dwyer
Model No 1823-5 differential pressure switch or an approved equal with No. A-603 "T" kit shall be furnished and installed with each magnahelic gauge for remote monitoring by the building automation system. The differential pressure switch shall be set as recommended by the filter manufacturer. The magnahelic gauge shall be provided with red and green scale overlays to indicate safe zone with dirty filter indication readings as recommended by the filter manufacturer.

B. Filter gauges shall be connected to high and low side of filters with copper tubing through gasketed openings in casings. Aluminum tubing will not be allowed.

2.11 AIR FILTER GAGES

A. Dial type, diaphragm-actuated with external zero adjustment and 3-7/8" diameter dial.

B. With two (2) static pressure tips, 2-way valves, tubing and mounting plate (and adjustable signal flag).

C. Range as recommended by filter manufacturer.


2.12 GAS - PHASE FILTERS (TYPE F-3)

A. General:

1. Media shall be a blend of dry granular medias effective against a broad range of gas contaminants. One media shall be high grade virgin coconut shell activated media for heavy molecular gases and one shall be potassium permanganate impregnated activated alumina media for light molecular weight gases. Media shall be UL listed. Media banks shall be fitted with fire sprinklers. Media shall be Purafil APB 850 or approved equal by Bioclimatic, Eco-Air or Circul-Aire.

B. Modules:

1. The media shall be contained in bulk-filled disposable devices capable of providing a minimum media depth of one" in the direction of air flow. Module shall eliminate bypass, provide gas-to-media contact efficiency of approximately 100% provide a contact time of 0.2 seconds minimum, dampen any effect from changes in relative humidity, and reduce media settling.

2. Resistance shall be no more than 0.5 w.g. in. at 500 FPM approach velocity.

3. Modules shall be easily replaced and disposed of with no need of any additional on-site maintenance.

4. Each module shall hold at least 25 lbs. of media for a 24"W x 6"H x 18"D module.

C. Media:

1. The media blend shall remove those contaminant gases present in an air- port environment such as oxides of sulfur and nitrogen, ozone, hydrogen sulfide and volatile organic compounds. The media shall have the following properties:

   a. ACTIVATED CARBON: Ash content, 2-3 %

   1) CTC % of 50 to 60 %, surface area of 1200 m²/gram
2) Bulk delivery of 32 lbs/ft$^3$
3) Mesh size - 4 x 6 (90% minimum) and hardness factor of 97.

b. POTASSIUM PERMANGANATE
   1) Minimum 4% potassium permanganate content, moisture contact of 15% maximum and leach test of 180 minutes

c. Vendor shall test for and provide characteristics of moisture content, bulk density, media granule size, and active chemical content.

d. Media shall have contaminant retentions of 8% sulfur dioxide, 6% nitrogen dioxide, 2.5% nitric oxide, 20% ozone, and 12% hydrogen sulfide.

e. Media manufacturer shall maintain a quality control program that tests for and maintains records for lot numbers, manufacture dates and test results.

f. Manufacturer shall provide at no cost to the user media testing service which will determine media change out frequency and life remaining. Life analysis test reports shall be part of this service. Passive test devices such as treated paper, etc., are not acceptable.

D. Activated-Carbon Panel Filters

1. Description: Factory-fabricated unit with activated-carbon media.

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

3. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Drawings or comparable product by one of the following:
   a. AAF International.
   b. Airguard.
   c. Camfil.
   d. Farr Co.
   e. Filtration Group.
   f. Flanders/CSC Corp.
   g. Or approved equal.

4. Media: Flat-panel, disposable multilayer filter with an inlet layer of polyester fibers, a layer of activated-carbon granules bonded to fibers, and a layer of polyurethane foam; housed in a cardboard frame.

5. Media: Flat-panel, disposable honeycombed cellulose with cells filled with activated-carbon granules and a perforated mesh grid; housed in a cardboard frame.

6. Media: Pleated, multilayer filter with an inlet layer of cotton and synthetic fibers and a layer of activated-carbon granules bonded to synthetic fibers; media formed into deep-V-shaped pleats, held by self-wire grid, and housed in a cardboard frame.

7. Mounting Frames: Welded, galvanized, sheet-steel frame and galvanized-steel fasteners with polyurethane gaskets; capable of bolting together into built-up filter banks.

8. Capacities and Characteristics as indicated on the Drawings.

E. Filter Frames:

1. Gas filter holding frames shall be 16 gauge galvanized steel with flush, mitered and welded corners. They shall have tracks for proper module retention/positioning and gasketing to prevent bypass. Frames shall be electrodeposited enamel for maximum corrosion prevention.
Frames shall be suitable for downstream serving.

2. Front- and Rear-Access Filter Frames
   a. Framing System: Stainless-steel framing members with access for either upstream (front) or downstream (rear) filter servicing, cut to size and pre-punched for assembly into modules. Vertically support filters prevent deflection of horizontal members without interfering with either filter installation or operation.
   b. Prefilters: Incorporate a separate track, removable from front and back.
   c. Sealing: Factory-installed, positive-sealing device for each row of filters to ensure seal between gasketed filter elements to prevent bypass of unfiltered air.

F. Side-Service Housings
   1. Description: Factory-assembled, side-service housings constructed of aluminum with flanges to connect to duct or casing system.
   2. Pre-filters: Integral tracks to accommodate 2” – (50-mm-) thick, disposable or washable filters.
   3. Access Doors: Hinged with continuous gaskets on perimeter and with positive-locking devices. Arrange so filter cartridges can be loaded from either access door.
   4. Sealing: Incorporate positive-sealing gasket material on channels to seal top and bottom of filter cartridge frames to prevent bypass of unfiltered air.

G. Filter Gages
   1. Description: Diaphragm type with dial and pointer in metal case, vent valves, black figures on white background, and front recalibration adjustment.
      a. Diameter: 4-1/2”.
      b. Range: 0- to 2.0” wg.
   2. Accessories: Static-pressure tips, tubing, gauge, connections, and mounting bracket.

PART 3 – EXECUTION

3.1 INSTALLATION

A. General: Install filter racks, housings, and filters in accordance with the manufacturers’ written installation instruction.

B. Coordination: The contractor shall coordinate equipment and filter bank connection requirements, blanking-off and sealing around filters and provide transitions as required for proper installation of filters. Coordinate filter installations with duct and air-handling unit installations.

C. Filter Bank Construction:
   1. Filter banks of individual holding frames: install leak tight and structurally sound to eliminate air bypass.
   2. Filter banks three filters high or higher: provide 3” wide 16 gauge (galvanized) (stainless) steel stiffeners between each vertical row of filters. Caulk frames before installing. After installation caulk any gaps appearing at the leading edge of the holding frames. Use DAP “Butyl Gutter and Lap Sealer.” After erection of the filter bank and careful caulking, tape the joints between filter
frames on the downstream side with 1” duct tape.

3. HEPA filter frames over 6” deep do not require stiffeners, only taping and caulking. HEPA filter frames must be bolted together; welding will not be acceptable.

3.2 AIR FILTERS:

A. General: Install all filters protecting equipment prior to unit startup. Under no circumstances shall any air handling unit or fan and coil unit which is shown or specified to be furnished with filters be operated without filters in place. Filters on units used during construction shall be replaced as necessary and as directed by the Architect.

B. Position each filter unit with clearance for normal service and maintenance. Anchor filter holding frames to substrate.

C. Install filters in position to prevent passage of unfiltered air.

D. Coil Cleaning: In the event that units are operated without filters in-place or with filters which have been damaged as to allow air to bypass filter, the Contractor shall steam clean all coils and fans in that particular system before balancing the system.

E. Filter Sizes: In all cases, filters shall be of the proper size and installed in filter racks in such a manner that there will be no leakage of air around filters. Filters which have been torn, distorted or damaged in any other way will not be acceptable.

F. Temporary Pre-filters: Provide Filter type F-1B filter over all filters as temporary pre-filter during construction. Replace these temporary filters before testing and balancing is commenced.

1. Protect all 40% or higher efficient filters upstream of air handling units during construction with temporary blankets of 2” polyester or fiberglass filter media or 2” disposable panel filters, U.L. 900 listed.

2. Provide a spare set of these temporary pre-filters or media and install them during construction if required when the pressure drop of the temporary media reaches 0.5”W.G. during construction. If the spare set is not used, deliver the spare set to the owner at job completion.

G. Testing and Balancing: All testing and balancing of air-side systems shall be done using clean filters. Where required, filters which have been used, shall be replaced prior to testing and balancing of air systems.

3.3 Note: 1) HEPA filtering not mentioned and section shall be included regarding HEPA Filtering of Special Systems Rooms that clearly lists the scope of this section, including HEPA Filtering of Special Systems Rooms. 2) Ventilation of Special Systems Rooms shall be included in Scope of Work with price to include coordination to determine adequate sizing. These include electric rooms with battery racks.

A. Clean Filters: After finishing of testing and balancing and upon completion of the project and before final acceptance, remove all filters that were used during testing, and replace with new set.

B. Spare Filters: Furnish one complete stock of additional replacement filters and media, sufficient to replace all filters on the project to the Owner for maintenance use. Filters shall be delivered in their original, unopened containers, and stored as directed by the Owner.

C. Corrosion Protection: The entire filter frame assembly shall be corrosion proof coated and/or isolated.
to prevent galvanic corrosion between dissimilar metals. Welded areas shall be hot dip galvanized after fabrication or coated with epoxy based paint.

D. Do not install gas-phase filters until fan system is clean and there is no risk of construction debris loading the filter.

3.4 SPARE FILTERS

A. Furnish one new complete spare set of cartridges for each filter bank listed below on completion and acceptance of the work:
   1. Medium and high efficient bag filters.
   2. Medium and high efficient rigid filters.

B. Install spare set in A. above only if and when directed. If not installed, deliver to owner in sealed carton.

C. Replace all panel filters which are not temporary pre-filters with a new set at job completion and furnish owner with an additional set in sealed cartons.

D. Furnish owner with one set of spare trays loaded with carbon, if carbon housings or absorbers are provided.

3.5 FILTER GAUGES

A. General: Install filter gauges and differential pressure switches per the manufacturers; written installation instructions. Where multiple filter banks (e.g. pre-filters and final filters) are installed, individual gauges and differential pressure switches shall be provided for each filter bank.

B. Filter gauges are to be installed across each filter bank, mounted where directed. One gauge may serve immediately adjacent pre-filter/final filter banks.

C. Differential Pressure Switches: Coordinate remote monitoring connections for filter differential pressure switches with the Building Automation Systems (BAS).

D. Install filter-gauge, static-pressure taps upstream and downstream from filters. Install filter gauges on filter banks with separate static-pressure taps upstream and downstream of filters. Mount filter gauges on outside of filter housing or filter plenum in an accessible position. Adjust and level inclined gauges.

3.6 FIRE SPRINKLER PROTECTION

A. Provide fire sprinkler system inside the air handling system per NFPA-13 requirements. Coordinate design and installation or sprinkler system with the air handling unit manufacturer and the building fire-sprinkler contractor.

3.7 FIELD QUALITY CONTROL

A. Filter cartridges shall be capable of easily being loaded and unloaded through access doors in the housings or access sections.

B. Manufacturer’s Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installation, including connections.
C. Perform Tests and Inspections:
   1. Manufacturer’s Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations including connections, and to assist in testing.

D. Tests and Inspections:
   1. Test for leakage of unfiltered air while system is operating.

E. Air filter will be considered defective if it does not pass test and inspections.

F. Prepare test and inspection reports.

3.8 START-UP PROCEDURE

A. No fan shall be operated unless all particulate filters as specified are installed, along with temporary pre-filters. Replace temporary filters used during construction and testing with new, clean filters.

B. When the pressure drop of the temporary media reaches 0.5" W.G. during construction, replace it with the spare set. If not used, deliver the spare set to the owner at job completion.

C. Carbon trays, if provided, shall not be installed until just prior to beneficial occupancy and all paint is dry and cleaning solvents are completely evaporated. Test and balance contractor shall allow for resistance of carbon trays by simulating their resistance on the system.

3.9 CLEANING

A. After completing system installation and testing, adjusting, and balancing air-handling and air-distribution systems, clean filter housings and install new particulate filter media.

END OF SECTION 23 41 00
PART 1 – GENERAL

1.1 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this section shall comply with all the requirements of General Conditions, Supplemental Conditions, General Requirements, Section pertaining to Basic Materials and Methods, and other related Sections.

1.2 SCOPE

A. All work to be furnished and installed under this Section shall comply with all the requirements, and shall include, but not necessarily be limited to, the following:
   1. Shell and tube heat exchangers
   2. Plate and frame type heat exchanger.

1.3 RELATED WORK SPECIFIED ELSEWHERE

A. Section 23 05 00: Basic Materials and Methods
B. Section 23 05 93: Testing, Adjusting and Balancing
C. Section 23 07 00: HVAC Insulation
D. Section 23 21 23: Hydronic Piping

1.4 QUALITY ASSURANCE

A. Manufacturer’s Qualifications: Provide systems that are the standard product of an equipment manufacturer regularly engaged in the production of such units who issues complete catalog information on such products. Units shall not be fabricated by the Contractor.

B. Codes and Standards: Provide components conforming to the requirements of the latest edition of the following:
   1. American Society of Mechanical Engineers (ASME): Boiler and Pressure Vessel Code
      a. Section VIII D1: Rules for Construction of Pressure Vessels including Addendums
      b. Section VIII D2: Rules for Construction of Pressure Vessels including Addendums
      c. Section IX: Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators including Addendums
      d. B31.1 Power Piping
   2. National Electrical Manufacturers Association (NEMA): Provide electrical components that comply with NEMA Standards.
      a. 70: National electrical Code

1.5 SUBMITTALS
A. Product Data: Submit manufacturer’s technical product data for units showing dimensions, weights (shipping, installed, and operating), capacities, ratings, performance with operating point clearly indicated, motor electrical characteristics, finishes of materials, and installation instructions.

B. Shop Drawings: Submit manufacturer’s shop drawings indicating dimensions, weight (shipping, operating), required clearances, methods of assembly of components, and location and size of each field connection.

C. Maintenance Data: Submit maintenance instructions, including instructions for lubrication, tube replacement, motor and drive replacement, and spare parts lists. Include this data, product data, shop drawings, and wiring diagrams in operating and maintenance manuals.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver units to the site in containers with manufacturer’s stamp or label affixed.

B. Store and protect units against dirt, water, chemical, and mechanical damage. Do not install damaged units - remove from project site.

C. Rigging: Comply with the manufacturer’s rigging and installation instructions.

1.7 WARRANTY

A. Provide general one-year (12 months) warranty. The warranty shall include parts, labor, travel costs, and living expenses incurred by the manufacturer to provide factory authorized service.

PART 2 - PRODUCTS

2.1 SHELL AND TUBE HEAT EXCHANGERS

A. General:
   1. Furnish and install shell and tube type hot water to hot water heat exchangers of capacity required. Install in accordance with manufacturer’s recommendations.
   2. Heat exchanger selections shall be verified by the manufacturer to provide required heat transfer surface area for specified capacity and pressure drop conditions.

B. Type:

C. Materials:
   1. Shell - steel.
   2. Tubes - 0.75” OD copper.
   3. Heads - cast iron or steel.
   4. Tube sheets - steel.
   5. Tube supports - steel.

D. Construction:
1. Provide manufacturer’s data report for pressure vessels, Form No. U-1 as required by the provisions of the ASME Code Rules, is to be furnished for the owner upon request. This form must be signed by an authorized inspector, holding a National Board commission, certifying that construction conforms to the latest ASME Code for pressure vessels. The ASME “U” symbol should also be stamped on the heat exchanger. The manufacturer must be registered with the National Board.

E. Manufacturer: Bell & Gossett, Patterson-Kelley, or approved equal.

PART 3 – EXECUTION

3.1 INSTALLATION

A. All equipment, unless otherwise shown or noted on the Drawings, is to be installed in accordance with industry standards and manufacturer-recommended installation instructions.

B. Flush and clean equipment, in accordance with manufacturer’s instructions.

3.2 MANUFACTURER’S START-UP SERVICES

A. The manufacturer shall provide start-up service in the form of a factory trained service technician. The service technician shall verify correct installation, verify piping installation, and check for proper operation. Fully staffed parts and service personnel shall be within four hours travel from the job site.

END OF SECTION 23 57 19
SECTION 23 73 23 – CUSTOM INDOOR CENTRAL STATION AIR HANDLING UNITS

PART 1 – GENERAL

1.1 SUMMARY

A. Section includes factory-assembled indoor air handling units, custom factory air-handling units, variable-air-volume, and components.

1.2 DESCRIPTION

A. Provide factory-assembled indoor air handling units and components in accordance with the Contract Documents. Units may be one piece or multiple piece construction bolted together in the field. At Contractor's option, the units can be completely field erected if they meet the requirements of the Specifications.

1.3 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this section shall comply with all the requirements of General Conditions, Supplemental Conditions, Section 23 05 00 - Basic Materials and Methods, and other Sections in Division 23 specified herein.

1.4 REFERENCES

A. Additional Codes and Standards: Provide air handling units conforming to the requirements of the latest edition of the following:

1. Air Movement and Control Association (ACMA):
   a. 99 Standards Handbook
   b. 210 Laboratory Methods of Testing Fans for Rating [Unit shall bear AMCA Certified Rating Seal]
   c. 300 Reverberant Room Method for Sound Testing of Fans [Unit shall bear AMCA Certified Rating Seal]
   d. 301 Methods for Calculating Fan Sound Ratings from Laboratory Test Data
   e. 500 Test Method for Louvers, Dampers, and Shutters

   a. 9 Load Ratings and Fatigue Life for Ball Bearings
   b. 11 Load Ratings and Fatigue Life for Roller Bearings
   c. 900 Test Performance of Air Filter Units

3. Air-Conditioning and Refrigeration Institute (ARI):
   a. 410 Forced-Circulation Air-Cooling and Air-Heating Coils
   b. 430 Central-Station Air-Handling Units
4. National Electrical Manufacturers Association (NEMA): Except for motors, provide electrical components required as part of air handling units, which comply with NEMA Standards.

5. National Fire Protection Association (NFPA): Provide air handling unit internal insulation having flame spread rating not higher than 25 and smoke developed rating not higher than 50:
   a. 70 National electrical Code
   b. 90A Standard for the Installation of Air Conditioning and Ventilating Systems
   c. 90B Standard for the Installation of Warm Air Heating and Air Conditioning Systems

6. Sheet Metal and Air Conditioning Contractors’ National Association, Inc. (SMACNA): Comply with applicable SMACNA standards including “HVAC Duct Construction Standards - Metal and Flexible.”

7. Underwriters Laboratories, Inc. (UL): Except for motors, provide electrical components required as part of air handling units, which have been listed and labeled by UL.

8. Units shall be listed and labeled by either UL or ETL for air handler construction.

9. California Building Code (CBC) Standards

1.5 PERFORMANCE REQUIREMENTS

A. Delegated Design: Design vibration isolation and seismic-restraint details, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

B. Structural Performance: Casing panels shall be self-supporting and capable of withstanding 150% of maximum design internal static pressure.

C. Seismic Performance: Air-handling units shall be designed to withstand the effects of earthquake motions determined according to ASCE/SEI 7, to remain in place without separation of any parts when subjected to the seismic forces specified in the CBC and be fully operational after the seismic event.

1.6 QUALITY ASSURANCE

A. Manufacturer: Provide products produced by the following:
   1. Huntair
   2. Energy Labs
   3. Buffalo Air Handling Company
   4. Governair
   5. Mammoth
   6. Miller-Picking Corporation
   7. Pace Corporation
   8. Temtrol
   9. Haakon
   10. Or approved equal.

B. Manufacturer’s Qualifications: Provide air handling units that are the standard product of an equipment manufacturer regularly engaged in the production of such units who issues complete catalog information on such products. Units shall not be fabricated by the Contractor.
C. **Coil Certification:** Coils shall be designed and rated in accordance with ARI Standard 410.

D. **Fan Certification:** Fans shall be designed and rated in accordance with AMCA 210-85 Standards for Category 'A' (free inlet and discharge) Classifications and shall be tested in an AMCA certified laboratory.

E. **Certification:** Provide certified ratings of units based on tests performed in accordance with ARI 430, “Central-Station Air Handling Units.”

F. **Electrical Standards:** Provide electric motors and other electrical products which have been listed and labeled by UL and comply with NEMA Standards.

G. **Vibration Testing:** Factory-vibration testing shall be provided as specified.

H. **Pressure Leakage Testing:** Housing shall be factory leak tested as specified. Field assembled units shall be field tested for conformance to leakage class.

I. **Damper Leakage:** Dampers shall be factory-certified per AMCA Standard 500-74.

J. **Acoustical Testing:** Provide acoustical acceptance testing in a mocked up project installation as specified.

K. **Unit Mock-up:** Provide a full scale mock-up for larger unit with minimum capacity of 35,000 CFM, and two fans at the factory of one representative air handling unit, completely fabricated and assembled with all components in place before fabricating other units. The unit shall be inspected by the owner’s representative to verify acceptability of housing construction methods, joint sealing techniques, OEM components used and overall quality and finish. Only on acceptance of unit with suggested modifications, if any, shall the other air handling units be manufactured.

L. **Unit Run Test:** Factory run test for the mocked-up unit at design speed and simulated discharge static pressure, and furnish report for housing integrity (panel deflection), leakage, acoustical acceptability, vibration, electrical system operation, module fit, workmanship and finish appearance prior to shipment from the factory. A complete vibration spectrum shall be conducted as required. Any fan, motor, drive and base assembly vibration shall be brought to within specified levels prior to unit shipment.

M. **Factory inspection and testing of mocked up air handling unit for vibration, acoustical performance and unit run testing shall be witnessed by the owner’s representative. The Contractor shall pay for air fare, accommodations, and similar expenses so that three owner’s representatives can witness the test.**

1.7 **SUBMITTALS**

A. **Product Data:** Submit manufacturer’s technical product data for air handling units showing:
   1. Dimensions and weights.
   2. Cabinet material, metal thickness, finishes, insulation, and accessories.
   3. Fan, including:
      a. Certified fan performance curves with system operating conditions indicated.
      b. Certified fan-sound power ratings.
c. Fan construction and accessories.
d. Motor ratings, electrical characteristics, and motor accessories.
e. Fan assembly vibration and balance test report.

4. Certified coil-performance ratings with system operating conditions indicated.

5. Retain both subparagraphs below if items are furnished as part of air-handling units.

6. Dampers, including housings, linkages, and operators.

7. Filters with performance and characteristics.

8. Sound Performance data.

B. Shop Drawing submittals shall precede mock-up testing and include, but not be limited to, the following:

1. Certified Drawings showing overall dimensions of complete assembly, weights, support requirements, sizes, location of connections, accessories, parts list, required clearances, field connection details and methods of support. Draw to scale of one half inch to one foot. Include field fabricated mixing boxes, dampers, ducts, and connections.

2. Cut sheets on all air handling equipment, clearly marked to show sizes, configuration, construction, features, accessories and other pertinent information.

3. Curves showing fan performance and system operating point plotted on curves. Data to substantiate that fan can operate in a stable range, and that the fan motor is sized accordingly. Fan performance curves shall be for free inlet and discharge conditions.

4. Coil performance selection data showing all criteria identified on equipment schedule. Certify the coils will meet performance criteria on equipment schedules.

5. Complete information on the Variable Air Volume modulation VFD to be furnished.

6. Sound power levels for each size and type of air handling unit and fans at operating conditions specified.

7. Detailed shop Drawings showing all dimensional data, including, but not limited to, gauges of sheet metal, panel reinforcing, size and weight per linear foot of structural base members, floor reinforcing, base reinforcing at internal equipment supports, construction details, damper information, filter frames, etc. Information shall be complete in all respects necessary for Architect/Engineer to evaluate the complete construction of the unit.

8. Product warranties and guarantees.

9. Written instructions for installation including assembly where not factory-assembled.

10. Motor and VFD data as required.

C. Maintenance Data: Submit maintenance instructions, including instructions for lubrication, filter replacement, motor and drive replacement, and spare parts lists. Include this data, product data, shop drawings, and wiring diagrams in operating and maintenance manuals.

D. Seismic Qualification Certificates: For air-handling units, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of
assembled components or on calculation.

2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

E. Source quality-control reports.

F. Field quality-control reports.

1.8 ENVIRONMENTAL REQUIREMENTS

A. Do not operate units for any purpose, temporary or permanent, until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.

1.9 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver air handling units in factory-fabricated water-resistant wrapping in containers with manufacturer's stamp or label affixed. Spring isolated components shall be transported properly secured to prevent damage during shipment.

B. Handle air handling units carefully to avoid damage to material components, enclosure, and finish.

C. Store air handling units in a clean, dry space and protect from the weather, dirt, water, chemical, and mechanical damage.

D. Do not install damaged unit – remove from project site.

1.10 WARRANTY

A. Provide one-year (12 months) warranty from date of startup or 18 months from date of shipment, whichever occurs first. The manufacturer's warranty shall include parts and labor to provide factory authorized service.

PART 2 – PRODUCTS

2.1 MANUFACTURERS

A. Acceptable manufacturers shall be HuntAir (Basis of Design), Energy Labs, Temtrol or approved equal. By listing manufacturers, it is not intended to imply that their standard construction is approved or that they are equal. All manufacturers must meet, or exceed, minimum requirements of these specifications and all other standard or optional features provided by the basis of design air handler.

2.2 GENERAL

A. Air Handling Units: Provide draw-through type air handling units complete with sound supply and exhaust fan sections, attenuating housing, direct drive fans, variable speed drives, air filter sections, heating coil section, cooling coil section, access section(s), condensate drain pan and piping, economizer air dampers, floor drains, discharge and return plenums, bellmouth duct connections, lights and accessories, and other attached sections indicated on Drawings, specified herein or required to accomplish the specified control sequences.
B. Provide units as single factory assembled package, or in split sections for field assembly if necessary for installation.

C. Capacity: Unit characteristics, size, type, capacity, and arrangement shall be as scheduled and shown on the Drawings.

D. Any exceptions to the specifications must be clearly defined in the submittal process. The contractor shall be responsible for any additional expenses that may occur due to any exception made.

E. Vestibule piping requirements: all piping located integral within the air handler vestibule(s) is to be factory installed and supported. Piping shall terminate outside of the unit.

F. Fans shall be selected for variable volume operation. The scheduled multi-fan arrangement and configuration shall be the basis of selection. Alternate configurations which are equal, or smaller in size and weight, energy and acoustic performance will be considered. Include information indicating pertinent differences, either positive or negative, to design indicated on documents. Unit component maximum face velocity is to remain as designed to conserve motor horsepower. The mechanical contractor and supplier shall bear all costs for design of mechanical, plumbing, electrical, structural, architectural and controls that may be associated with any proposed configuration. Provide analysis of unit power consumption for code and LEED® compliance.

G. All major components used to assemble air handling units with the exception of electrical devices, drives, bearings and controls shall be manufactured by the air handler manufacturer

H. Motors shall be inverter duty NEMA MG-1 premium efficiency TEFC type. All wiring shall be routed to a single external junction box for each fan section.

2.3 HOUSING

A. Leakage Class: Housing shall be airtight, of single unit or sectionalized design with suitable gaskets between sections. Panel materials shall be galvanized steel of lock-forming quality with zinc coating; weight shall be G-90 (1.25 oz. / square foot) as per ASTM A-525. The Housing construction shall result in total leakage for the entire unit to be less than 1/2% of its design air flow at 6" W.G. negative or positive pressure for single piece unit and 3/4% of design air flow at same conditions for multi-piece field joined unit.

B. Unit Base: Each module/unit shall be constructed on a heavy duty Tubular or “I” section steel base which shall support all panels and major components. The base shall consist of electrically welded structural members. Internal members shall be properly sized to allow rigging and handling of the unit. After construction the base shall be cleaned, primed with a rust inhibiting primer, and finished with a rust inhibiting exterior enamel (Rustoleum or equal). Modules shall be manufactured and shipped in a single piece. Construction shall be suitable to withstand rigors of shipping and rigging. Each base shall include properly located lifting lugs. Minimum depth of floor frame shall be 6" and must be continuous around all outer edges.

C. Wall and Roof Panels: All wall and roof panels shall be double-wall construction for each section of the unit. Cabinet shall have a minimum 20-gauge G90 galvanized exterior casing panels and a minimum 16-gauge G90 galvanized inner panel. Panels to be of standing seam construction with seams turned outward resulting in smooth inside and outside walls and no reinforcing channels or angles projecting. The space between the double wall panels shall be minimum of 2”, unless otherwise
shown, or more if required for structured rigidity for different size units. Provide reinforcing of panels to limit panel deflections to 1/200th of span at unit operating pressures. Welded flanges shall be provided at unit inlets and outlets for connection of ducts, dampers and flex connectors. All joints shall be gasketed and sealed with an industrial adhesive sealant to result into air tight construction. The sealants shall conform to ASTM C-834-76 and Federal Specifications TTS-230 C Class B. Inner panel may be omitted at the outer walls of entrance vestibules.

1. Panels to be screwed together on maximum 8" centers with minimum 5/16" zinc plated screws sealed with a continuous bead of polyurethane caulking applied between the matching panel seams prior to assembly, and with a final bead following assembly on both the exterior and interior panel seams to produce an air tight unit.

2. AHU unit housing shall be constructed to prevent conditioned air bypass or mitigation through unit walls, roof and floor around any interior partition or component blank-off walls such as for filters, coils or fan bulkheads.

D. Floor: Floor shall be continuously welded double-wall construction with floor sheet constructed of 10 gauge checkered plate welded construction complying with ASTM A-569 suitable for 150 lb/square foot live load. The floor shall be water tight with drains and cap plates as shown on the Drawings. 3" drain lines shall be connected to the drains and shall run to the edge of the units and terminated with hose end and cap. Provide R-11 fiberglass insulation capped by 20 gauge galvanized sheet to form the second “wall”. The floor shall be completely coated with 5 to 6 mils of corrosion resistant epoxy primer after fabrication and welding in accordance with epoxy manufacturer's recommendation.

E. Insulation: The walls and roof of each unit shall be internally insulated with adhesive fastened insulation of double density pre-molded rigid board. Insulation shall be 2", 3 PCF fiberglass with neoprene coating. Insulation for discharge plenum shall be 4", 3 pcf fiberglass with neoprene coating. Insulation shall meet NFPA-90A, NFPA 90B and ASTME E 84 for smoke and flame spread requirements of 25 or less and smoke development of 50 or less, and shall be marked to show compliance with UL-181. Insulations shall be secured to the casing surfaces and framework with adhesive over entire surface and stick clips, grip nails, or weld pins with fasteners on approximate 24” centers. The insulation shall be protected from delamination or fretting by coating exposed edges with adhesive or mastic. All adhesive and sealants shall meet the smoke and flame spread requirements of NFPA-90A. Insulation shall have a thermal conductivity K factor of .24 (Btu in. /hr sq.ft. °F) and a noise reduction coefficient of 0.70/ per one” thick based on a type “A” mounting. All cut edges of the board insulation shall be completely enclosed by the unit panels. A finish bead of caulking will be applied over all foil to panel seams and/or inner liners to main panel seams to completely encapsulate the insulation.

1. All insulation edges shall be protected with metal lagging. Insulation systems using stickpins or adhesives are not acceptable.

F. Interior Liners to be minimum 16-gauge G90 perforated inner liner in the fan sections, all other sections to be solid liner metal throughout the unit for the walls and roof. A finish bead of caulking shall be applied between the panels and the exterior liner seams to completely seal the wall panels.

G. Outside casing, joining bolts, hardware and door hinges shall be finished with paint or coating suitable for exposure to marine environments. Roof panels on indoor units shall be flat with smooth exteriors the same as the side panels.

H. Coil Access/Pull: All heating water and chilled water coils shall include a removable cover plate mounted in the side of the unit casing for future coil repair/removal. This cover plate shall be located on the side of the unit required for coil removal with the unit installed as shown on the Drawings. The Contractor and unit manufacturer shall coordinate exactly where coil access cover must be located on each unit. All unit submittal Drawings must show the access cover. The access cover shall be the
same gauge as the unit housing, with gasket or sealant strips and attachment screws provided. Where the units are closely spaced to prevent end removal of coils, provide coil racks for independent removal of each heating and cooling coil from the face side.

I. Drain Pan: Provide a rigid and watertight drain pan with pipe drain connection under the complete coil section of each unit. Drain pans shall be minimum 14 gauge 304 stainless steel with continuous welded construction and 3" deep rim and shall extend up to 24" beyond coil. Double slope the pans to provide positive drainage. Coil drain pans shall cover the coil and all valves and headers shall be provided with sloped bottoms to drain locations (numbers as shown on drawings) piped to outside of the unit as shown on Drawings. On coils with multiple stacked banks, provide separate stainless steel drain pans for each vertical section with pipe draining condensate to lower pan. These separate drain pans shall be of the same construction as the main drain pan.

J. Filters: Provide as part of the factory package, filter tracks, filter sections and filter magnahelic gauges to accommodate the filters of the type and size as included in the Specifications as shown on the Drawings.

K. Dampers: Provide as part of the factory package, automatic dampers for economizer operation and cooling coil bypass. Dampers shall be installed such that they can be operated by operators provided under special systems. Damper types, construction, leakage ratings shall comply with as specified in Air Distribution.

L. Vibration Isolators and Seismic Restraints: Provide Vibration Isolators and Seismic Restraints complying with specifications and as scheduled on Drawings for each supply and return fans and air handling unit. Provide thrust restraints on fans that may move more than 0.25" from their static condition to their operating condition. Thrust restraints shall provide spring isolation to ensure that seismic restraints do not short-circuit the vibration isolation of the fans.

M. Water Coils: Provide heating coils and cooling coils rigidly installed within drain pan and complying with specifications and as scheduled on Drawings.

N. Variable Frequency Drives: Provide Variable Frequency drives in compliance with specifications for each supply and return fan designated for variable volume operation.

O. Lighting and Power: Lights in each section of air handling units shall be provided under Electrical work. Coordinate lighting fixture location and illumination level with electrical division to insure that lighting level and coverage are adequate to facilitate inspection and service of inner components.

P. Provide sleeves with caps on both upstream and downstream sides of gas phase (odor) filters for running of fire sprinkler pipes (1.5" pipe) in them in the future.

Q. Stiffeners of angle steel shall be supplied as required to maintain a casing deflection criteria of 1/100 at 1.5 times the working pressure.

R. Maintenance Rails: Provide overhead lifting rails in sections where motor service will be required.

S. Provide duct bellmouth fittings for connections of external ducts.

2.4 BASE CONSTRUCTION

A. Unit bases shall be constructed from structural steel tubing or C-channel around the entire
perimeter of the unit and provided with intermediate structural tubing as required to support all internal components. All tubing, channel and angle joints shall be solid welded.

B. The unit base shall be covered with a 16-gauge floor with caulked seams. Base shall be provided with removable lifting lugs minimum (4) per section, properly located to assure uniform loading. Maximum spacing between lifting lugs shall be 120”.

C. Maximum base deflection shall be 0.25” on 20 ft unsupported span.

D. Floor insulation shall be installed beneath the floor panels in the same manner as the wall and ceiling insulation.

E. Drain pans shall be 304 Stainless Steel double-walled construction with solid welded seams for complete water capture and containment. Pans under cooling coils shall extend a minimum 12” passed the leaving face of the coil in direction of airflow. Drain Pans shall be fully recessed in the unit floor and all headers and return bends shall be located over the drain pan for collection of all condensate forming on headers and return bends. All coils shall be easily removable without cutting or removing any portion of the drain pan. Pans shall be insulated between the liner and the main pan. Pans shall be IAQ Double Sloping to a single drain. Drain connection shall be a minimum 1-0.25” diameter MIPS thread extending out through the channel base the same side as the coil connections unless other wise indicated on the drawings. Pans shall be provided for cooling coils, humidifiers, outside air intakes and under other components as required. Mastic coated drain pans are not acceptable as they are “non- Cleanable”. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil section(s).

2.5 INSPECTION AND ACCESS PANELS AND ACCESS DOORS

A. Access Doors: Hinged, gasketed access doors shall be provided into the fan section, the space between coils, and to other areas of the unit requiring regular inspection or maintenance. Removal hatches or panels without hinges are not acceptable for those areas. Doors shall be constructed and insulated as described for the housing. All doors shall be located as required for service access with units installed as shown on the Drawings. Each door shall be 36” x 72” unless otherwise indicated on the Drawings. Reinforced, minimum 16 gauge, insulated dual panel with airtight continuous gaskets.

B. Each door shall be equipped with manually operated pressure equalizing ports to be operable from both sides. Provide with heavy duty hinges, Ventlok No. 370 or equal (minimum three), and latches (two each) operable from both sides of the doors. Latches Ventlok No. 310 or equal. Install doors so that the air pressure differential keeps the doors normally closed. Provide painted signs appropriately worded as follows on both sides of doors to the air handling unit housing.

1. CAUTION: Door closes with air pressure, or
2. CAUTION: Door opens with air pressure.

C. Access doors shall be double wall construction with G-90 galvanized exterior panels and G-90 galvanized interior panel. Door jamb & frame shall be constructed of extruded aluminum with continuously welded corners for rigidity. Door panels shall be insulated with expandable urethane foam insulation completely encapsulated and sealed between the door panels and frame. Provide doors located and sized to allow for routine maintenance including motor replacement and filter replacement, electrical components and any other sections or components requiring access or maintenance.

D. Doors shall be provided with a minimum (2) dual acting heavy duty key locking composite latches

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through 48” high, (3) latches through 72” high. Latches shall be operable from both the interior and exterior of the unit. Door latches on doors into fan sections shall be provided with a hasp or other mechanism to facilitate locking of the doors. Door hinge shall be heavy duty Stainless Steel. Door shall be sealed with continuous hollow closed cell foam gasket.

E. Doors to be provided with double high performance closed cell replaceable neoprene bulb type gasket seals around the entire perimeter of the door / frame.

F. Doors shall open against static pressure unless obstructed by internal components. If obstructed by internal components on the positive sections requiring access, the doors shall open with pressure and shall be provided with a safety restraining mechanism. Doors used to access rotating equipment shall be provided with an OSHA approved safety latching mechanism requiring a tool to open and shall also have a highly visible, permanently fixed, caution sign on the exterior of the door. Doors with access to moving parts must also have locking hardware and meet current UL mechanical protection guidelines. Standard door size shall be 24” wide by 60” high unless restricted by height or section width.

G. Doors in the fan shall be provided with thermal pane wire glass viewing windows and door interlocked kill switches as called out on the unit drawings in the specifications. Doors in the Electronic Filtration System section shall be UV rated and provided with thermal pane wire glass viewing windows and door interlocked kill switches as called out on the unit drawings in the specifications. Minimum window size to be 12” x 12” provided door size permitting.

H. Doors in fan sections shall be sized to allow removal of fans and motors.

I. Locations and Applications:
   1. Refer to drawings

2.6 FAN, DRIVE, AND MOTOR SECTION

A. General: Provide direct drive fans (supply and return fan arrays for systems) constructed, factory tested in accordance with AMCA for the duty specified, minimum class II, or III as required, and ARI. Fan performance shall be rated and certified in accordance with AMCA Standard 210 for fans mounted inside cabinets. Fan wheels statically and dynamically balanced. Fans to be completely installed in the air handling units at the factory. Models, types, sizes, acoustical performance and capacities as scheduled on the drawings.

B. Acceptable Manufacturers:
   1. FläktWoods.
   2. Howden.
   4. Sheldon.
   5. Or approved equal.

   Supply fans to be of mixed-flow design only. Other designs shall not be considered.

C. Motors for use in multiple fan arrays that operate at varying synchronous speeds as driven by an approved VFD shall be as manufactured by:
   1. ABB.
   2. Baldor.
   3. Siemens.
4. Toshiba.
5. Or approved equal.

D. All fans shall be selected to deliver the specified airflow quantity at the specified operating Total Static Pressure and specified fan/motor speed. The fan array shall be selected to operate at a system Total Static Pressure that does not exceed 90% of the specified fan's peak static pressure producing capability at the specified fan/motor speed. Each fan/motor cube or cell shall include a 12 gauge, G 90U Galvanized steel intake wall, 14 gauge spun steel fan inlet funnel, and an 10 gauge G90 Galvanized steel motor support plate rail and structure. All fans shall be selected to deliver the specified airflow quantity at the specified operating Total Static Pressure and specified fan/motor speed.

E. All motors shall be standard foot mounted type, TEFC or TEAO motors selected at the specified operating voltage, RPM, and efficiency as specified or as scheduled elsewhere. Motors shall meet the requirements of NEMA MG-1. Motor HP shall not exceed the scheduled HP as indicated in the AHU equipment schedule(s). Steel cased motors and/or ODP motors are not acceptable. All motors shall include permanently sealed bearings and shaft grounding to protect the motor bearings from electrical discharge machining due to stray shaft currents. Each fan/motor assembly shall be dynamically balanced to meet AMCA standard 204-96, exceeding category BV-5, to meet or exceed an equivalent Grade G.55, producing a maximum rotational imbalance of .022" per second peak, filter in (.55mm per second peak, filter in). All fan and motor assemblies with 27" dia. and less shall be balanced to meet or exceed the G.55 residual unbalance. Motors shall comply with specifications and shall be suitable for satisfactory and safe operation under variable air flow (100% down to 10%) across them. The motors shall be certified to be compatible with the connected variable frequency drives.

F. The multiple fan array AHU unit shall be provided with coplanar acoustical silencers that reduces the bare fan discharge sound power levels by a minimum of 15 db re 10^-12 watts throughout the eight octave bands with center frequencies of 63,125, 250, 500, 1000, 2000, 4000, and 8000 HZ when compared to the same unit without the silencers. The silencers shall not increase the fan total static pressure, nor shall it increase the airway tunnel length of the Air Handling Unit when compared to the same assembly without the silencer array.

G. The fan array shall consist of multiple fan and motor “cubes” or “cells”, spaced in the air way tunnel cross section to provide a uniform air flow and velocity profile across the entire air way tunnel cross section and components contained therein. In order to assure uniform velocity profile in the AHU cross section, the fan cube dimensions must be variable, such that each fan rests in an identically sized cube or cell, and in a spacing that must be such that the submitted array dimensions fill a minimum of 90% of the cross sectional area of the AHU air way tunnel. There shall be no blank off plates or “spacers” between adjacent fan columns or rows to position the fans across the air way tunnel. The array shall produce a uniform air flow profile and velocity profile within the airway tunnel of the air handling unit to equal the specified cooling coil and/or filter bank face velocity by +/- 10% when measured at a point 36” from the intake side of the fan array intake plenum wall, and at a distance of 72” from the discharge side of the fan array intake plenum wall. Submittals for units providing less than the scheduled quantity of fans and/or spacing of the fans for multiple fan arrays shall submit CFD modeling of the air flow profile for pre-bid approval that indicates uniform velocity and flow across all internal components without increasing the length of the AHU unit or changing the aspect ratio of the unit casing as designed.

H. Each individual cube or cell in the multiple fan arrays shall be provided with an integral back flow prevention device that prohibits recirculation of air in the event a fan or multiple fans become disabled.
I. Each fan & motor assembly shall be removable through a 30” wide, free area, access door located on the discharge side of the fan wall array without removing the fan wheel from the motor. All fan/motor access doors shall open against pressure.

J. Each air handling unit shall contain one or more electrical control panels consisting of a surface mounted or fully recessed NEMA rated enclosure for the application that shall include all supply and return fan motor VFD, disconnects and overload protection, One (1) for each fan motor in multiple fan array. Means for monitoring and controlling individual fan and motor status for each of the multiple fans and motors in the array shall be provided.

K. Each VFD shall be able to have communication interface with the BAS system shall be provided by the AHU manufacturer when scheduled or indicated, and shall require a single interface point at the multiple fan array system control panel by the project controls contractor. The AHU unit shall be completely factory-wired, requiring only field wiring of main power wiring to the line side of the main power disconnect switch, a separate 120/60/1 power supply.

L. Each fan in the multiple fan array(s) shall be provided with means to prevent re-circulation of system airflow at the fan array when any one fan in an array is disabled. Back flow prevention devices and the system effects attributed to them must be included in the submitted fan with disconnect switch for receptacles and light fixtures when indicated and required performance data for fan brake horsepower and acoustics. In addition, AMCA certified bare fan performance data for the submitted fans shall be clearly indicated in the submittal data and that value shall be subtracted from the submitted fan arrangement performance data to indicate the system effects attributed to the means of back flow prevention for the multiple fan array. Back draft damper data that is based on straight runs of ductwork upstream and downstream of the damper per AMCA testing procedures, and not per the submitted mounting arrangement in the AHU unit(s), will not be approved.

M. All motors in the Fan array shall be provided with individual Motor Protection for thermal overload protection. All motor circuit protectors shall be located in main enclosure.

N. All motor circuit protectors shall be mounted and located in a remote motor circuit protector panel as needed that is separate from the main enclosure. Motor circuit protector enclosure must be located and mounted at a minimal distance from motors in the Fan wall array.

O. Fan Shaft Bearings:
   1. Pre-lubricated and Sealed, Ball Bearings: Self-aligning, pillow-block type with an L10 rated life of 200,000 hours according to ABMA 9. Bearings are to be mounted on the fan structural bracing. Provide extended bearing lubrication lines and zerk fittings to assure accessibility of all lubrication points without disassembly of unit access.
   2. Bearings shall be selected for a minimum L10 life of 100,000 hours (average life of 500,000 hours). Fan shafts shall be selected for operation not to exceed 75% of first critical speed.

P. Fan Casing: Fan casing shall be constructed with integral rolled flanges. The bearing support and guide vane unit shall be with mounting studs allowing centering of fan assembly when fitted into casing. Provide extended lube lines for lubricating the bearings from the outside of casing. Casing design and construction shall allow easy removal and replacement of motor from the inlet side.

Q. Accessories
   1. Supply Fans:
a. Inlet Guard.

b. Outlet Guard, if unducted or walk-in plenum discharge.

c. Flexible Connector (by fan manufacturer).

d. Matching flanges and companion duct flanges on AHU walls.

e. Air stream operated backdraft damper, when more than one fan.

f. Mounting feet for fan and accessories

g. As indicated or scheduled on drawings.

2.7 AIR HANDLING UNITS (SINGLE PACKAGED, LESS THAN 8000 CFM)

A. Manufacturer: Provide products produced by the Manufacturer listed.

B. Type, size, capacity and other requirements as scheduled.

1. Casings, including dividing panels between components, shall be sectionalized construction of formed channel section panels with a 16-gage minimum galvanized steel outer sheet. Panels shall be bolted together on 10” centers maximum with cadmium plated bolts so that all panels are removable. Sheet metal screws are not acceptable. All interior and exterior casing parts including fan housing base and wheel shall be cleaned and painted with one coat of zinc rich rust inhibiting primer and two coats of Grey epoxy (7 mil dry film thickness), caulk over raw edges. Casing panels shall be insulated with 1” thick 1.5# density fiberglass. The entire casing shall be constructed on a structural channel sub base complete with lifting lugs for shipment. Interior and exterior panel sections and joints shall be caulked and gasketed air tight. Total housing leakage shall not exceed 1% of the rated CFM at 125% of the system static pressure.

2. Sub base shall be weatherproof, all-welded structural steel with perimeter channels, mounting clips and cross channel reinforcing. Floor sheet shall be 16-gage sheet metal. All drain pans shall be 16 gauge 304 stainless steel.

3. Access doors shall be provided for all sections and constructed of galvanized steel of the same gauge as the casing with a solid galvanized inner liner. Doors shall be gasketed to insure air and water tightness. Drip gutters shall be provided. Each door shall be hinged and fitted with three latches. Hinges and latches shall be adjustable.

4. Fans shall have backwardly curved airfoil wheels or forward curve with fully welded, double inlet housings. Fan performance shall be rated and certified in accordance with AMCA Standard 210 for fans mounted inside a cabinet. Fan shaft and wheel shall be dynamically balanced.

5. Fan shafts shall be selected for operation not to exceed 75% of the first critical speed. Bearings shall be mounted on structural steel framework integral with housing and shall be pillow block types selected for a minimum L10 life of 100,000 hours (average life of 500,000 hours). Fan wheel assembly shall be statically and dynamically balanced at rated speed in the factory and given a final test with motor and drive in place after installation in cabinet.

6. Fan and motor shall be mounted internally in the fan section cabinet on an integral structural steel base with the fan housing discharge isolated from the casing at the factory by means of a neoprene flexible connection. This entire assembly shall be mounted inside the casing on laterally stable, specified vibration isolators. Snubbers shall provide seismic restraint after 0.25” of movement from normal operating position. Steel base shall be provided with the same finish as specified for cabinet.

7. V-belt drives shall be fixed on all motors 15 HP and larger, variable pitch on 10 HP and smaller. Drives shall be designed for 150% of the motor nameplate horsepower rating and shall have two
or more belts with matched belt sets.

8. Motors, coils, automatic dampers, filters and other components shall conform to applicable performance standards for these components as described in their respective sections.

9. Filters shall be in side service housing with magnahelic gauge complying with specifications.

10. Sound Power Levels as specified.

C. Cabinet size shall be limited such that the unit fits within the space available and all connections can be made without hindering required code and maintenance clearances.

2.8 COILS

A. Chilled and Hot Water shall be ripple fin of min .008 thick. Aluminum fin for heating coils and copper fin for cooling coils, extended surface rated in accordance with ARI 410 for water, steam or ethylene/propylene glycol water mixture. The tubes shall have a minimum .020-wall thickness of seamless copper expanded into the fin collars to provide a permanent mechanical bond. No metallic or thermal bonding materials are acceptable. Return Bends shall be a minimum of one tube thickness greater than the main tubes .049 brazed replaceable copper. "U" type shaped tubes is not acceptable. Coil headers shall be non-ferrous seamless copper and provided with brass or copper male pipe connections. Pipe connections shall be same end connections. Each Coils supply & return connections shall be raised / lowered a minimum 6" from the bottom / top of the coil to allow room for piping connection hookup especially between stacked coils, coils near floors & coils near roofs. Each coil shall be provided with capped vent & drain connections extended to the exterior of the cabinet. All coils shall be fully drainable with no trapped tubes. Coils shall be counter flow design with connections either left or right hand as specified. All piping connections to be extended out to the same side of the unit, piping insulation to be provided by installing contractor. The use of internal restrictive devices such as turbolater springs or ribbons to obtain turbulent construction is not acceptable.

B. Coil casings shall be minimum 16 gauge 316 Stainless Steel, with formed 0.75" flanges on all sides of the coil with the tube sheets having pressed or extruded tube holes. The coil casing shall be reinforced so that the maximum unsupported length is 60". The reinforcements shall be of the same material as the casing. Both ends of the coil to be sealed off from the main air stream by full height blank off's on both the entering air and leaving air sides. Blank off's to be the same material as the coil casing. Headers and return bends to be further insulated with a closed cell neoprene gasket the full height & width of the coil casing to reduce condensation.

C. All coils are tested and rated in accordance with the Air Conditioning and Refrigeration Institute (ARI) Standard 410 and certified in accordance with the ARI certification program. All tubes shall be tested at a minimum 450 PSIG and all assemblies tested under water at 450 PSIG for a minimum of 5 minutes and rated for 450 PSIG working pressures. Individual tube and core tests before installation of header are not considered satisfactory. Hydrostatic tests alone will not be acceptable.

D. Stacked coils: mounted with integral stacking flanges on the coil. Racks to be designed to allow coil removal through the roof of the unit if required. All coils to be removable from either side of the unit by easily removable end panels. Individual end panels to be supplied for each coil on the Supply & Return side of the cabinet to allow single coil piping breakdown for coil removal.

E. Coil Supply & Return piping connections extending through the cabinet wall shall be sealed by Rubber Grommets with caulking on the exterior of the casing.
2.9 FILTERS (MODULAR FRAMING SYSTEM)

A. Filters shall be arranged for Face, Rear or side loading as indicated on the detail drawings. Face loading is preferred where space allows. Face or rear loading to be in gasketed Universal Holding Frames. The filter rack assemblies to blanked off to the sides, roof and floor and properly sealed to minimize filter bypass.

B. The Pre-filter section shall be factory fabricated as an integral part of the air handling unit. Filters to be arranged for face (rear) loading into a gasketed Universal holding frame. Filters to be equal to Camfil Farr 30/30, 4” deep pleated panel filters, MERV 8, UL Class 2. Two (2) sets of the filters shall be provided.

C. Intermediate and/or High Efficient filters. The filter section shall be factory fabricated as an integral part of the air-handling unit. Filters to be arranged for face (rear) loading into a gasketed positive sealing Universal Holding Frame. Filters to be equal to Camfil Farr Hi-Flo ES, MERV 14, UL Class 2. Two (2) sets of filters to be provided.

D. Each filter bank to be provided with a Dwyer Series 2000 Magnehelic Air Filter Gauge with adjustable signal flag. Gauges to be flush mounted. Exterior unit gauges to be covered with a weatherproof enclosure to protect the gauge and prevent hazing of the glass. One gauge shall be provided for each type of filter in filter bank.

E. Provide walk-in filter access sections upstream / downstream of each filter rack with adequate space for filter service.

F. Filter banks to be sized so maximum filter face velocity does not exceed 400 fpm at design CFM.

G. Provide photocatalytic air cleaning system and pre-filters.

2.10 PHOTOCATALYTIC OXIDATION (PCO) AIR CLEANING UNIT

A. PCO unit shall be Genesis Air, or approved equal, factory-fabricated and tested two-part integral system for treatment of air by Ultra-violet C Band radiation using high output UVC lamps and TiO2 media (1 set of media) to create an oxidation reduction reaction on the various Volatile Organic Compounds present. The complete assembly shall be installed into an Air Handling Unit access section.

B. Equipment Requirements

1. The PCO System shall be designed for face velocity to 500 fpm or less.

2. UV-C Emitters shall provide type C ultra-violet light with a wavelength of approximately 2537 Angstroms. UVC lamps shall be high output and not produce detectable Ozone concentrations. Sufficient UV-C lamps shall be provided in order to generate no less than 5 milliwatts of power per square” of TiO2 catalyst face area at ambient temperatures to 450 °F.

3. The PCO media shall be a 6 in. deep (pleated at one pleat per”) honeycomb substrate laminated with 100-200 nanometers of TiO2. The PCO assembly shall be installed perpendicular to the air flow.

4. Ozone Generation

C. Electrical Requirements:

1. Wiring, conduit, and junction boxes shall be installed within housing plenums in accordance with NFPA 70; National Electrical Code. Electrical service shall be 115 volts, 1 phase, 60 Hz. No power wiring or contacts shall be exposed to the air stream. Provide safety door switches for access doors which may expose maintenance personal to UVC exposure plus a lock-out switch. Conduit into plenum junction boxes shall be sealed to prevent condensation. Single point wiring connections shall be provided.

D. Control Requirements

1. The PCO System shall include a Direct Digital Control System (DDC) for monitoring, reporting and control to connect with the Building Management System. The DDC System shall be powered from the same circuit as the UVC. Sensors shall be installed by the AHU manufacturer. Controls external to the DDC System and connection to the Building Management System shall be completed by the Controls Contractor.

2. Provide a Control Panel for factory installation by the AHU manufacturer. The Control Panel shall be able to control the Ion Generator functions except high voltage calibration. The Control Panel shall include a digital voltmeter to read high voltage output, LED status indicators and include a BMS interface to control Ion Generator start/stop operation.

3. DDC Points Required to be monitored at the control panel with BACnet interface module; Current Draw, Differential Press, CO₂, TVOC, Particulates 0.3 μm, 1.0 μm, 2.5μm.

E. Assembly and Erection

1. The AHU manufacturer shall receive, install and complete all interconnecting control and power wiring located within the AHU. The electrical contractor shall complete single point power connections. The controls contractor shall complete connection to the Building Management System.

2. All equipment shall be assembled and installed in a workman like manner to the satisfaction of the owner, architect, and consulting engineer.

3. All equipment shall be protected from dust and damage on a daily basis throughout construction.

4. Clean all components prior to commissioning.

5. Installation of the UV Lamps and TiO₂ honeycomb shall be by the installing contractor when commissioning air purification system on site.

F. Commissioning & Training

1. A manufacturer’s factory representative shall provide start-up and training of owner’s personnel in the proper operation and maintenance of all equipment.

2. Provide 5 copies of Operating and Maintenance Manuals.

G. Inspection Services

1. A manufacturer’s Service Technician shall provide inspection services to insure satisfactory air purification system operation. The Inspection program shall include at minimum, factory
startup, commissioning, and one annual site inspection of air handling and PCO equipment, monitoring and validation of PCO System and the submission of a written report to the owner and consulting engineer of record.

2.11 FINISH

A. Factory applied finish for casings:
   1. Exterior casing finish shall be suitable for exposure to marine environment.

2.12 DAMPERS

A. General Requirements for Dampers: Leakage rate, according to AMCA 500, “Laboratory Methods for Testing Dampers for Rating,” shall not exceed 5% of air quantity at 2000 fpm face velocity through damper and 3” wg (1000-Pa) pressure differential.

B. Blades shall be type 316 stainless steel. Blades shall be of a single unit airfoil design 6” wide.

C. Frames shall be type 316 stainless steel channel with grooved inserts for vinyl seals. Standard Frames shall be 2” x 4” x 5/8” on the linkage side, 1” x 4” x 1” on the other 3 sides.

D. Pivot rods shall be 7/8” hexagon stainless steel interlocking into the blade section. Bearings shall be of a double sealed type with a Celcon inner bearing on a rod within a Polycarbonate outer bearing inserted into the frame to prevent the outer bearing from rotating.

E. The bearing shall be designed so there are no metal-to-metal or metal-to-bearing riding surfaces. The interconnecting linkage shall have a separate Celcon bearing to eliminate friction inside the linkage.

F. All blade linkage hardware shall be stainless steel or non-corrosive, reinforced cadmium plated steel, installed in a frame outside the airstream.

G. Multiple damper motors are to be used rather than jack shaft assemblies.

H. Acceptable Manufacturers:
   1. Ruskin.
   2. T.A. Morrison (TAMCO).
   3. Or approved equal.

2.13 FLOW MEASURING PROVISIONS

A. Fan flow measurement: Supply and return fan inlets shall be provided with factory-mounted airflow measuring devices. This device shall not obstruct the inlet cone to the fan, nor add any pressure losses or sound level increases to the fan performance.

B. Outside Air Measurement:
   1. Configure Outside Air Intake dampers:
      a. Configure the outside air dampers to enable measurement of the minimum outside air and total CFM required for the project area served by the AHU. Provide dedicated min OSA section if sensor is not capable of measuring Min. OSA values.

C. Sensor Performance:
1. Installed airflow accuracy: +/- 2% of reading with +/- 0.25% repeatability.

2. Installed temperature accuracy: 0.15 °F temperature accuracy

3. Airflow range: 0-5000 fpm,

D. Transmitter:

1. Flow measuring array to include a transmitter for flow and temperature analog output signal for the building energy management system in either 4-20 mA or 0-10 VDC, or BACnet digital compatible. Coordinate signal output with controls installer.

2. Transmitter to include an airflow gauge to provide direct readout in cfm. Mount on the outside of the air handler if air handler is located in a mechanical room. Mount in a NEMA 3R control cabinet if located outside.

3. Device to provide switch selectable BACnet outputs. Device to be UL listed.

E. Airflow measuring station manufacturer: Ebtron or equal.

2.14 ELECTRICAL

A. Each fan motor shall be wired to its respective VFD provided by fan manufacturer integral to unit. See specifications and 2.1, G above for requirements.

B. All wiring shall be 6600 volt rated type XLPE, RW90 stranded copper, enclosed in conduit run internal to the unit. All junction boxes shall be CSA approved. Three phase loads to be color coded for phase matching.

C. All unit VFD’s shall be wired to a surface or recessed mounted vestibule electrical panel for a single point three phase power connection. Control panel shall be NEMA Type 3R enclosure with a single hinged access door. The control panel shall include:

1. Non-fused main disconnect switch, lockable in the off position
2. Dual element fuses
3. Distribution block

D. All wiring shall be numbered, and all remote connection terminals and components in the control panel shall be identified by tag suitable attached. Wiring diagram shall be provided for each unit showing all components, wire number and remote connection terminals.

E. Electrical wiring for lighting and power supply to fan motors shall be run in separate conduits internal to the unit. No external conduit runs are permitted. If the unit requires section splits, junction boxes shall be furnished at each section to allow the electrical contractor to make final connections in the field. Wiring to be clearly labeled at junction points to facilitate reconnection. Air handler manufacturer shall allow a minimum 1.5” clearance above the entire width of each interior bulk headers (coils, filters, fan blank-off, etc.) for field-wiring of any 110v or 24v runs internally to the unit as required by the controls contractor and reduce the number penetrations of the exterior panels.

F. All electrical wiring and components shall be installed to conform to NEC and UL listing requirements. Provide a UL or ETL listing and label for the entire air handler.
2.15 LIGHTS

A. Provide vapor proof marine type 150-watt light fixtures in each accessible section complete with a protective metal cage and sealed glass enclosure. Lights to be wired to a common switch mounted in a weatherproof box adjacent to the fan access door complete with a convenience outlet. Outlet shall have an indicator light. Power shall be 120v/1/60.

B. All wiring to lights shall be in conduit and internal to the unit. No external conduit runs for the lights are allowed.

C. Air handler manufacturer shall allow a minimum 1.5” clearance above the entire width of each interior bulk headers (coils, filters, fan blank off, etc.). This will be to allow wiring of any 110v or 24v runs internally to the unit as required by the controls contractor and reduce the number penetrations of the exterior panels.

D. If the unit requires splitting, junction boxes shall be furnished at each section to allow the electrical contractor to make final connections in the field. Wiring to be clearly labeled at junction points to facilitate reconnection.

E. Duplex receptacles shall be installed at the light switch at each fan section and unit vestibule.

2.16 AIR LEAKAGE TESTING

A. Before shipment the unit manufacturer shall factory pressure test (positive pressure) each air handling unit to ensure the leakage rate of the casing does not exceed 1.0% of the unit air flow at 1.5 times the rated static pressure. Testing shall be done on one unit of each type.

B. The test shall be conducted in accordance with SMACNA duct construction manual. A calibrated orifice shall be used to measure leakage airflow.

C. Units which are shipped in sections and field assembled shall be pressure tested for leaks prior to connecting of ductwork.

D. Leakage Testing: Temporary caps and enclosures shall be provided at inlets and outlets for the purpose of leakage testing.

2.17 SOUND POWER LEVELS

A. Air handling unit sound power levels shall be submitted for review. Sound power data shall be given at the outlet connections and inlet connections in addition to cabinet radiated sound power. Raw fan sound power data shall be derived from testing on the identical fans as used in the units. Data extrapolated from different fans is not acceptable.

B. Attenuation assumed for cabinet configuration, type of insulation, opening location and sizes shall be verified through actual test measurements. Sound power data is tested at the factory by an acoustical engineer in complete accordance with ARI 260-2001, “Sound Rating of Ducted Air Moving and Conditioning Equipment.” These test reports will be submitted to the Architect before units ship from the factory.

C. The submittal shall include a complete description of the methods and procedures used to develop the sound power levels being submitted.
D. Sound Testing: Before shipment the unit manufacturer shall factory sound test One (1) unit. Fans to be tested in complete accordance with AMCA 300-1996, “s Method for Sound Testing of Fans”, in a testing laboratory certified by AMCA to perform the test for both 210 performance and 300 sound. These test reports will be submitted before units ship from the factory.

2.18 CLEANING AND WRAPPING FOR SHIPMENT

A. Unit shall be cleaned, swept & vacuumed clean.

B. Cleaned unit shall be shipped on an open flatbed truck double wrapped in plastic to protect from road contamination at shipment.

2.19 DELIVERY, STORAGE, AND HANDLING

A. Unit shall ship with all openings securely covered with wood and / or nylon reinforced plastic wrap and to be watertight. Each unit securely strapped down on an open flatbed truck.

B. Units must be stored in a clean dry area and protected from the weather and construction traffic. Carefully follow manufacturers’ storage instructions if installation does not immediately follow arrival at the job site.

C. Follow manufacturers rigging guidelines for movement and installation of equipment.

PART 3 – EXECUTION

3.1 EXAMINATION

A. Install in accordance with manufacturer’s instructions.

B. Examine site to verify if site is ready to receive work. Provide a layout drawing of air handler and fan locations to electrical installer.

C. Examine casing insulation materials and filter media before air-handling unit installation. Reject insulation materials and filter media that are wet, moisture damaged, or mold damaged.

D. Examine roughing-in for hydronic and condensate drainage piping systems and electrical services to verify actual locations of connections before installation.

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

3.2 MOCK-UP INSPECTION AND TESTING

A. General: Contractor to arrange and schedule the acceptance of Air Handling Unit Mock-up in a timely manner such that it does not delay related construction on the project.

B. Mock-up Construction Sequence:
   1. Contractor shall submit mock-up unit shop drawings for Architects' review.
   2. After acceptance of shop drawings, the contractor proceeds with the fabrication of air handling unit.
   3. Contractor inspects the mocked-up unit and performs necessary tests in preparation for
4. Contractor certifies that the mock-up construction complies with specification and that the unit has been successfully pre-tested.

5. Owner's representatives to inspect the unit to ensure compliance with the specifications. If major deficiencies are found at this stage, the mock-up testing shall be aborted and rescheduled later. The Contractor shall pay for the time and expenses incurred by the Owner's representatives for any aborted mock-up tests.

C. Mock-up Performance Test:

1. On successful inspection of mock-up unit, contractor shall proceed with the operational testing.

2. The operational testing shall simulate the operation of Air Handling Unit in its designed configuration and all performance, vibration and noise related test data shall be recorded. Sound data shall be for casing radiated noise at 5'-0" outside of unit on both sides and top of unit along the length at 10' intervals.

3. Should the unit fail to meet the specified requirements, contractor shall make necessary modifications and re-test. The contractor shall pay for the time and expenses incurred by the Owner's representatives for any failed performance tests.

4. At the conclusion of successful performance testing, the contractor shall submit all test data and reports to Architect for Owner's records.

3.3 AIR HANDLING UNIT INSTALLATION

A. General: Install air handling units in accordance with the manufacturer's written recommendations and as detailed on the Drawings. Multi-piece Units: Contractor shall provide special hoisting and rigging equipment required for assembling of multi-piece air handling units. Field assembling of the units shall be performed by manufacturer's representative or be certified, in writing, by the air handling unit manufacturer.

B. Coordinate shipping and rigging of the units to ensure that units can pass through available building openings.

C. Housekeeping Pads: Install floor mounted air handling units on reinforced concrete housekeeping pads with continuous neoprene pads as specified. Coordinate the size and location of housekeeping pads with concrete work.

D. Drain Connections: Pipe condensate via a vented P-trap to a primed floor drain. Provide P-traps on air handling unit condensate drain connections with seal depths at least equal to the total static pressure of the unit as installed. P-traps shall be constructed of pipe and tees. Elbows and flexible piping or connectors shall not be used. All unused openings of tees shall be closed with removable plugs which shall serve as cleanouts. Extend condensate drains to nearest floor or hub drain.

E. Filters: Install construction filters prior to unit start-up for ductwork blowout. After ductwork has been blown clear of construction dust, install initial set of filters for continuous operation of each air handling unit.

F. Coil Pull Space: Air handling units shall be installed with adequate space to allow unit coils to be removed. Coil pull space and any required demolition of building construction shall be clearly
indicated on As-built Drawings. The Contractor shall insure that all field-piping, valves, ductwork, and other obstructions are not in the way or can be easily removed with flanges to facilitate coil removal.

G. Coil Vents and Drains: Provide manual air vents and drain valves with hose connections and caps for each coil section.

H. Sealing of Penetrations: Inspect and seal all pipe and conduit penetrations after the piping, electrical and control system hook-ups are completed.

I. Air Handler Mounting:
   1. Isolation and Seismic Control: Comply with requirements for vibration isolation and seismic control devices.
   2. Arrange installation of units to provide access space for service and maintenance.
   3. Air handling units shall not be used for temporary heating and ventilating unless expressly approved by Owner. If used during construction, see SMACNA’s “IAQ Guidelines for Occupied Buildings under Construction” for procedures to protect HVAC system.
   4. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing with new, clean filters.
   5. Install filter-gauge, static-pressure taps upstream and downstream of filters. Mount filter gauges on outside of filter housing or filter plenum in accessible position. Provide filter gauges on filter banks, installed with separate static-pressure taps upstream and downstream of filters.

3.4 START-UP

A. General: The equipment manufacturer shall furnish a factory service engineer to start all units. The factory engineer must be a full time factory employee. In addition, the start-up supervisor shall instruct and train the Owner on unit operation and maintenance techniques as specified.

B. Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installation, including connections.

C. Test and Inspections:
   1. Leak Test: After installation, fill water coils with water, and test coils and connections for leaks.
   2. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   3. Filter Operational Test: Operate filters to demonstrate compliance with requirements. Test for leakage/bypass of unfiltered air while system is operating.
   4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. Air-handling unit or components will be considered defective if unit or components do not pass tests and inspections.

E. Prepare test and inspection reports.

F. Perform startup services
1. Complete installation and startup checks according to manufacturer’s written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Verify that bearings and other moving parts are lubricated with factory-recommended lubricants.
6. Verify that outdoor and return air mixing dampers open and close, and maintain minimum outdoor air setting.
7. Comb coil fins for parallel orientation.
8. Install new, clean filters.
9. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.

G. Starting procedure for air-handling units include the following:
1. Energize motors and verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicate rpm.
2. Measure and record motor electrical values for voltage and amperage.
3. Manually operate dampers from fully closed to fully open positions and record fan performance.

H. Cleaning
1. After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems and after completing startup service, clean air-handling units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new, clean filters.

I. Demonstration
1. Engage a factory-authorized service representative to train Owner’s maintenance personnel to adjust, operate, and maintain air handling units.

3.5 TESTING AND BALANCING
A. General: Refer to specifications for air handling unit components testing and balancing.
B. Vibration Testing: Provide field vibration testing as specified.
C. Adjusting
1. Adjust damper linkages for proper damper operation.
2. Comply with requirements in Section 23 05 93 Testing, Adjusting, and Balancing.
3.6 IDENTIFICATION

A. Refer to specifications for applicable painting, nameplates, and labeling requirements.

END OF SECTION 23 73 23
SECTION 23 81 25 – DIRECT EXPANSION (D/X) AIR CONDITIONING UNITS

PART 1 – GENERAL

1.1 APPLICABLE REQUIREMENTS

   A. All work to be furnished and installed under this section shall comply with all the requirements of General Conditions, Supplemental Conditions, General Requirements, Section 23 05 00 - Basic Materials and Methods, and other Sections in Division 23 specified herein.

1.2 SCOPE

   A. All work to be furnished and installed under this Section shall comply with all the requirements, and shall include, but not necessarily be limited to, the following:

      1. Split air conditioning unit.
      2. Controls and control connections.
      3. Electrical power connections.

1.3 REFERENCES

   A. Codes and Standards: Provide air handling units conforming to the requirements of the latest addition of the following:

      1. Air Movement and Control Association (AMCA):
         a. 99 Standards Handbook
         b. 210 Laboratory Methods of Testing Fans for Rating [Unit shall bear AMCA Certified Rating Seal]

      2. Air-Conditioning and Refrigeration Institute (ARI):
         a. 210 Unitary Air-Conditioning Equipment
         b. 270 Sound Rating of Outdoor Unitary Equipment

      3. National Electrical Manufacturers Association (NEMA): Except for motors, provide electrical components required as part of air handling units, which comply with NEMA Standards.

      4. National Fire Protection Association (NFPA): Provide unit internal insulation having flame spread rating not higher than 25 and smoke developed rating not higher than 50:
         a. 70 National Electrical Code
         b. 90A Standard for the Installation of Air Conditioning and Ventilating Systems
         c. 90B Standard for the Installation of Warm Air Heating and Air Conditioning Systems

      5. Sheet Metal and Air Conditioning Contractors’ National Association, Inc. (SMACNA): Comply with applicable SMACNA standards including “HVAC Duct Construction Standards - Metal and Flexible.”

      6. Underwriters Laboratories, Inc. (UL): Except for motors, provide electrical components required as part of units, which have been listed and labeled by UL.
1.4 QUALITY ASSURANCE

A. Manufacturer’s Qualifications: Provide units that are the standard product of an equipment manufacturer regularly engaged in the production of such units who issues complete catalog information on such products. Units shall not be fabricated by the Contractor.

1.5 SUBMITTALS

A. Product Data: Submit manufacturer’s technical product data for systems with air handler units, evaporator coils, and outdoor condensing units showing dimensions, weights, capacities, ratings, fan performance with operating point clearly indicated, motor electrical characteristics, finishes of materials, installation instructions, sound and vibration test report, and bearing life calculations.

B. Maintenance Data: Submit maintenance instructions, including instructions for lubrication, filter replacement, motor and drive replacement, and spare parts lists. Include this data, product data, shop drawings, and wiring diagrams in operating and maintenance manuals; in accordance with requirements.

1.6 ENVIRONMENTAL REQUIREMENTS

A. Do not operate units for any purpose, temporary or permanent, until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Deliver units to the site in containers with manufacturer’s stamp or label affixed.

B. Protect units against dirt, water, chemical, and mechanical damage. Do not install damaged units - remove from project site.

1.8 WARRANTY

A. Provide general one (1) year warranty from date of installation and 5-year warranty on compressors under provisions. The warranty shall include parts, labor, travel costs, and living expenses incurred by the manufacturer to provide factory authorized service.

PART 2 – PRODUCTS

2.1 SPLIT SYSTEM AIR CONDITIONING UNIT WITH INDOOR FAN COIL

A. Acceptable Manufacturers:
   1. Mitsubishi
   2. Daikin
   3. Sanyo
   4. Or approved equal.

B. Indoor Fan Coil Unit
   1. General:
      a. Factory fabricated fan coil units of the size, type configuration and capacity as scheduled on the drawings. Units shall be self-contained, factory assembled and pre-wired with condensate pump.
b. All pressure drops, horsepower and dimensions shown are maximum allowable. All capacities shown are minimum allowable. All units must have AMCA certified performance data for fans tested in the unit casings. Bare fan certification without casing is not acceptable.

c. Manufacturers unable to meet these criteria will only be considered as an alternate to specified and as a deduct to base bid. Manufacturers listed by name do not imply that their standard construction meets the specifications nor that they are approved. All manufacturers are required to meet all details of this specification without exception.

2. Unit cabinet shall be galvanized steel with powder coated baked enamel finish.

3. Fan Assembly
   a. Direct-drive, double-inlet fan wheels shall have forward-curved blades, and be statically and dynamically balanced, with scrolls and fans constructed of galvanized steel.
   b. Rotating assembly shall provide a rigid support for motor and fan assembly. Assembly shall be accessible and entire assembly shall be removable for maintenance.
   c. Motor shall be minimum two speed permanent split capacitor type.

4. Coils shall be ARI certified. All coil shall be constructed of non-ferrous seamless copper and pressure tested in the factory.

5. Filter shall be one" thick pleated.

6. Unit Suspension: Units shall be provided with factory welded mounting clips for mounting of units.

7. Electrical: The unit electrical power shall be 115 volts, 1 phase, 60 hertz.

8. Controls
   a. Unit shall have a wired controller to perform input functions necessary to operate the system.
   b. The controller shall consist of an On-Off switch, Cool/Dry-Fan selector, Thermostat setting, Timer Mode, High-Low fan speed, Auto Vane selector, Test Run switching and Check Mode switching.
   c. Temperature changes shall be by 2 °F increments with a range of 65 – 87 °F.
   d. The control system shall consist of 2 microprocessors interconnected by a single non-polar two wire cable.
   e. Wiring shall run direct from the indoor unit to the controller with no splices.
   f. Manufacturer shall provide 2 conductor 18 Ga. stranded wire for connection to remote controller.
   g. The microprocessor located in the indoor unit shall have the capability of sensing return air temperature and indoor coil temperature, receiving and processing commands from the wired controller, providing emergency operation and controlling the outdoor unit.
   h. Normal operation of the remote controller provides individual system control in which one remote controller and one indoor unit are installed in the same room.
   i. The control voltage from the controller to the indoor unit shall be 12 volts, DC.
j. The control voltage between the indoor unit and the outdoor unit shall be 12 volts, DC.

k. The system shall be capable of automatic restart when power is restored after power interruption.

l. The system shall include self-diagnostics including total hours of compressor run time.

m. The microprocessor within the wall mounted remote controller shall provide automatic cooling, display set point and room temperature, 24-hour on/off timer so that automatic operation function display, check mode for memory of most recent problem.

C. Outdoor Condensing Unit:

1. General: Provide remote outdoor compressor units consisting of hermetic compressor with overload protection, direct drive condenser fan, aluminum fin/seamless copper tube coil, strainer, high and low pressure switches, accumulator, and thermostatic expansion valve.

2. Low Ambient Control: System shall be capable of operating at 0°F ambient temperature.

3. Unit Cabinet: Galvanized steel with powder coat enamel finish.

4. Condenser Fans: Direct drive propeller type. Motors to be totally enclosed, single phase, with Class B insulation and permanently lubricated bearings. Fan shall be mounted for low noise. Fan blades to be statically and dynamically balanced.

5. Coil: Aluminum fins mechanically bonded to copper tubes.

6. Refrigerant Components: Liquid tube shutoff valve with sweat connection, suction tube shutoff valves with sweat connection, refrigerant, and accumulator as required.

7. Compressor: Hermetically sealed two-speed compressor mounted on rubber mountings. Protection to include internal thermal overloads. An internal pressure relief valve to provide high-pressure protection to the refrigerant system. Provide external service valves for the refrigerant circuit. A crankcase heater shall be factory mounted on the outside of the compressor.

8. Electrical: Unit electrical power shall be 208/230 volts, 1 phase, 60 hertz. The outdoor unit shall be controlled by the microprocessor located in the indoor unit. The control voltage between the indoor unit and the outdoor unit shall be 12 volts, DC.

PART 3 – PRODUCTS

3.1 EXAMINATION

A. Verify that mounting surfaces are ready to receive work.

B. Verify that proper power supply is available.

3.2 INSTALLATION

A. Install in accordance with manufacturer’s instructions.

B. Provide layout drawings of units, locations and power requirements to electrical installer.

C. Install air filters in unit during installation phase. Do not operate the unit without filters in place.

D. For suspended units, mount the fan coil units on springs or from spring hangers as required and as
shown on Drawings. Provide Mason #DNHS combination isolator hangers to fully support horizontal units hung from building framing.

E. For units mounted at grade, provide 4” high concrete pad extending 6” beyond edge of condensing unit on all sides. Attach condensing unit to concrete pad with concrete anchors and angle brackets.

F. For units mounted on roof, mount on 6” high sleepers extending 6” beyond edge of unit on all sides. Install sleepers in accordance with architectural roofing requirements and secured to roof in accordance with structural requirements. Attach unit to sleepers with anchors bolts.

G. Install condensate drain piping and traps in accordance with manufacturer’s instructions and as shown on the Drawings.

H. Install copper refrigerant piping and insulate lines.

I. Install controller and all wiring associated with control signals between air handling unit and condensing unit. Conceal low voltage wiring in building structure, or inside the refrigerant pipe insulation, or in conduit.

J. Electrical installer shall install all line voltage power wiring and conduit. Coordinate with electrical work.

K. Install a new set of filters prior to final air balance and substantial completion.

NOTE: All condenser units shall be set on equipment pads and protected with bollards or fencing.

3.3 MANUFACTURER’S START-UP SERVICES

A. The manufacturer shall provide start-up service in the form of a factory trained service technician. The service technician shall verify correct installation, verify unit mounting, verify fan rotation, verify spring isolator adjustments, verify control wiring, verify power wiring, start-up the fans, and check for proper operation. The service technician shall provide final adjustments to meet the specified performance requirements. Fully staffed parts and service personnel shall be within four hours travel from the job site.

END OF SECTION 23 81 25
SECTION 23 81 26 – SPLIT SYSTEM AIR CONDITIONERS

PART 1 – GENERAL

1.1 WORK INCLUDED

A. Split-System Air-Conditioning Units consist of furnishing transportation, labor, materials, and equipment to furnish and install split-system air-conditioning and heat pump units consisting of separate evaporator-fan and compressor-condenser components. Units are designed for exposed or concealed mounting, and may be connected to ducts.

1.2 REFERENCES

A. Air-Conditioning and Refrigeration Institute (ARI)
B. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)
C. National Fire Protection Association (NFPA)

1.3 SUBMITTALS

A. Product Data: Include rated capacities, furnished specialties, and accessories for each type of product indicated. Include performance data in terms of capacities, outlet velocities, static pressures, sound power characteristics, motor requirements, and electrical characteristics.

B. Shop Drawings: Diagram power, signal, and control wiring.

C. Samples for Initial Selection: For units with factory-applied color finishes.

D. Operation and Maintenance Data: For split-system air-conditioning units to include in emergency, operation, and maintenance manuals.

E. Warranty: Special warranty specified in this Section.

F. California Title 24 Acceptance Testing, completed for each system by HVAC Contractor or balance Contractor.

1.4 QUALITY ASSURANCE

A. Product Options: Drawings indicate size, profiles, and dimensional requirements of split-system units and are based on the specific system indicated.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.


D. Coefficient of Performance: Equal to or greater than prescribed by ASHRAE 90.1, “Energy Efficient Design of New Buildings except Low-Rise Residential Buildings.”
E. Unit shall be rated per ARI Standards 210/240 and listed in the ARI Directory as a matched system.

1.5 COORDINATION

A. Coordinate size and location of concrete bases for units. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork are specified in Cast-In-Place Concrete Section.

B. Coordinate size, location, and connection details with roof curbs, equipment supports, and roof penetrations specified in Roof Accessories Section.

1.6 WARRANTY

A. Warranty Period: Five years from date of Substantial Completion.

1.7 SYSTEM STARTUP

A. Engage a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer’s written instructions.

PART 2 – PRODUCTS

2.1 MANUFACTURERS

A. Daikin
B. Sanyo
C. Mitsubishi
D. Or approved equal.

2.2 INDOOR FAN COIL UNIT

A. General:

1. Factory fabricated fan coil units of the size, type configuration and capacity as scheduled on the drawings. Units shall be self-contained, factory assembled and pre-wired with condensate pump.

2. All pressure drops, horsepower and dimensions shown are maximum allowable. All capacities shown are minimum allowable. All units must have AMCA certified performance data for fans tested in the unit casings. Bare fan certification without casing is not acceptable.

3. Manufacturers unable to meet these criteria will only be considered as an alternate to specified and as a deduct to base bid. Manufacturers listed by name do not imply that their standard construction meets the specifications nor that they are approved. All manufacturers are required to meet all details of this specification without exception.

B. Unit cabinet shall be galvanized steel with powder coated baked enamel finish.

C. Fan Assembly:

1. Direct-drive, double-inlet fan wheels shall have forward-curved blades, and be statically and dynamically balanced, with scrolls and fans constructed of galvanized steel.

2. Rotating assembly shall provide a rigid support for motor and fan assembly. Assembly shall be accessible and entire assembly shall be removable for maintenance.
3. Motor shall be minimum two speed permanent split capacitor type.

D. Coils shall be ARI certified. All coil shall be constructed of non-ferrous seamless copper and pressure tested in the factory.

E. Filter shall be one inch (1") thick pleated.

F. Unit Suspension: Units shall be provided with factory welded mounting clips for mounting of units.

G. Electrical: The unit electrical power shall be 208/230 volts, 1 phase, 60 hertz.

H. Controls
   1. Unit shall have a wired controller to perform input functions necessary to operate the system.
   2. The controller shall consist of an On-Off switch, Cool/Dry-Fan selector, Thermostat setting, Timer Mode, High-Low fan speed, Auto Vane selector, Test Run switching and Check Mode switching.
   3. Temperature changes shall be by 2 °F increments with a range of 65 - 87 °F.
   4. The control system shall consist of 2 microprocessors interconnected by a single non-polar two wire cable.
   5. Wiring shall run direct from the indoor unit to the controller with no splices.
   6. Manufacturer shall provide 2 conductor 18 Ga. stranded wire for connection to remote controller.
   7. The microprocessor located in the indoor unit shall have the capability of sensing return air temperature and indoor coil temperature, receiving and processing commands from the wired controller, providing emergency operation and controlling the outdoor unit.
   8. Normal operation of the remote controller provides individual system control in which one remote controller and one indoor unit are installed in the same room.
   9. The control voltage from the controller to the indoor unit shall be 12 volts, DC.
   10. The control voltage between the indoor unit and the outdoor unit shall be 12 volts, DC.
   11. The system shall be capable of automatic restart when power is restored after power interruption.
   12. The system shall include self-diagnostics including total hours of compressor run time.
   13. The microprocessor within the wall mounted remote controller shall provide automatic cooling, display set point and room temperature, 24-hour on/off timer so that automatic operation function display, check mode for memory of most recent problem.

2.3 OUTDOOR CONDENSING UNIT:

A. General: Provide remote outdoor compressor units consisting of hermetic compressor with overload protection, direct drive condenser fan, aluminum fin/seamless copper tube coil, strainer, high and low pressure switches, accumulator, and thermostatic expansion valve.

B. Low Ambient Control: System shall be capable of operating at 0°F ambient temperature.

C. Unit Cabinet: Galvanized steel with powder coat enamel finish.
D. Condenser Fans: Direct drive propeller type. Motors to be totally enclosed, single phase, with Class B insulation and permanently lubricated bearings. Fan shall be mounted for low noise. Fan blades to be statically and dynamically balanced.

E. Coil: Aluminum fins mechanically bonded to copper tubes.

F. Refrigerant Components: Liquid tube shutoff valve with sweat connection, suction tube shutoff valves with sweat connection, refrigerant, and accumulator.

G. Compressor: Hermetically sealed two-speed compressor mounted on rubber mountings. Protection to include internal thermal overloads. An internal pressure relief valve to provide high-pressure protection to the refrigerant system. Provide external service valves for the refrigerant circuit. A crankcase heater shall be factory mounted on the outside of the compressor.

H. Electrical: Unit electrical power shall be 208/230 volts, 1 phase, 60 hertz. The outdoor unit shall be controlled by the microprocessor located in the indoor unit. The control voltage between the indoor unit and the outdoor unit shall be 12 volts, DC.

2.4 ACCESSORIES

A. Control equipment and sequence of operation are specified in HVAC Instrumentation and Controls and Sequence of Operation sections.

B. Thermostat: Low voltage with sub base to control compressor and evaporator fan.

C. Automatic-reset timer to prevent rapid cycling of compressor.

D. Refrigerant Line Kits: Soft-annealed copper suction and liquid lines factory cleaned, dried, pressurized, and sealed; factory-insulated suction line with flared fittings at both ends.

PART 3 – EXECUTION

3.1 INSTALLATION

A. Install units level and plumb.

B. Install evaporator-fan components using manufacturer’s standard mounting devices securely fastened to building structure.

C. Install ground mounting, compressor-condenser components on 4”-thick, reinforced concrete base; 4” larger on each side than unit. Concrete, reinforcement, and formwork are specified in cast-in-place concrete Section. Coordinate anchor installation with concrete base.

D. Install and connect pre-charged refrigerant tubing to component’s quick-connect fittings. Install tubing to allow access to unit.

3.2 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
B. Install piping adjacent to unit to allow service and maintenance.

C. Duct Connections: Duct installation requirements are specified in metal ducts section. Drawings indicate the general arrangement of ducts. Connect supply and return ducts to split-system air-conditioning units with flexible duct connectors. Flexible duct connectors are specified in duct accessories section.

D. Ground equipment in conformance with Grounding and Bonding Section.

E. Electrical Connections: Comply with requirements in Electrical Sections for power wiring, switches, and motor controls.

3.3 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

B. Perform the following field tests and inspections and prepare test reports:
   1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
   2. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. Remove and replace malfunctioning units and retest as specified above.

3.4 DEMONSTRATION

A. Engage a factory-authorized service representative to train Department maintenance personnel to adjust, operate, and maintain units.

3.5 MANUFACTURER'S START-UP SERVICES AND COMMISSIONING

A. The manufacturer shall provide start-up services by a factory trained service technician. The service technician shall verify correct installation, verify unit mounting, verify fan rotation, verify spring isolator adjustments, verify control wiring, verify power wiring, start-up the fans, and check the units for proper operation. The service technician shall provide final adjustments to meet the specified performance requirements. Fully staffed parts and service personnel shall be within four hours travel from the job site.

B. Refer to Section 23 08 00 for Commissioning requirements.

END OF SECTION 23 81 26
SECTION 23 82 19 – FAN COIL UNITS

PART 1 – GENERAL

1.1 DESCRIPTION

A. General: Provide Fan Coil Units in accordance with the contract documents.

1.2 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this Section shall comply with all the requirements of General Conditions, Supplemental Conditions, General Requirements, Section 23 05 00 – Basic Materials and Methods, and other Sections in Division 23 specified herein.

1.3 REFERENCES

A. Codes and Standards: Provide units conforming to the requirements of the latest addition of the following:

1. Air Movement and Control Association (AMCA):
   b. 210 – Laboratory Methods of Testing Fans for Rating [Unit shall bear AMCA Certified Rating Seal]
   c. 300 – Reverberant Room Method for Sound Testing of Fans [Unit shall bear AMCA Certified Rating Seal]
   d. 301 – Methods for Calculating Fan Sound Ratings from Laboratory Test Data

2. American national Standards Institute (ANSI)
   a. 9 – Load Ratings and Fatigue Life for Ball Bearings
   b. 11 – Load ratings and Fatigue Life for Roller Bearings
   c. 900 – Test Performance of Air Filter Units

3. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)

4. National Electrical Manufacturers Association (NEMA): Except for motors, provide electrical components required as part of air handling units, which comply with NEMA Standards.

5. National Fire Protection Association (NFPA): Provide air handling unit internal insulation having flame spread rating not higher than 25 and smoke developed rating not higher than 50:
   a. 70 – National Electrical Code
   b. 90A – Standard for the Installation of Air Conditioning and Ventilating Systems
   c. 90B – Standards for the Installation of Warm Air Heating and Air Conditioning Systems

6. Sheet Metal and Air Conditioning Contractors’ National Association, Inc. (SMACNA): Comply with applicable SMACNA standards including “HVAC Duct Construction Standards – Metal and Flexible.”

7. Air-Conditioning and Refrigeration Institute (ARI)
1.4 SCOPE

A. Work to be furnished and installed under this Section shall include the following:
   1. Fan Coil Units
      a. Small Cabinet Fan Coil Units

1.5 QUALITY ASSURANCE

A. Certification:
   1. Provide manufacturer’s certification of fan coil unit capacity and compliance with ARI Standard 441.
   2. Provide certified ratings of units based on tests performed in accordance with ARI 430, “Central-Station Air Handling Units.”

B. Manufacturer’s Qualifications: Provide units that are the standard product of an equipment manufacturer regularly engaged in the production of such units who issues complete catalog information on such products. Units shall not be fabricated by the Contractor.

C. UL Listing: Fan Coil Units shall be UL listed as complete assembly. Except for motors, provide electrical components required as part of air handling units, which have been listed and labeled UL.

1.6 SUBMITTALS

A. Product Data: Submit manufacturer’s technical product data for units showing dimensions, weights, capacities, ratings, fan performance with operating point clearly indicated, motor electrical characteristics, and finishes of materials, installation instructions, sound ratings, and bearing life calculations.

B. Shop Drawing submittals shall include, but not be limited to, the following:
   1. Cut sheets on all fan coil units, clearly marked to show sizes, dimensions, weight loadings, required clearances, field connection details, configuration, construction, features, accessories, methods of support and other pertinent information.
   2. Fan curves or tables with selection point clearly indicated.
   3. Motor, coil capacities and filter data as required in their respective sections.
   4. Draw to a scale of one half inch to one foot.
   5. Include field fabricated mixing boxes, dampers, and duct connections.

C. Maintenance Data: Submit maintenance instructions, including instructions for lubrication, filter replacement, motor and drive replacement, and spare parts lists. Include this data, product data, shop drawings, and wiring diagrams in operating and maintenance manuals.

1.7 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver units to the site in containers with manufacturer’s stamp or label affixed
B. Deliver fan coil units in factory-fabricated water-resistant wrapping.

C. Handle fan coil units carefully to avoid damage to material component, enclosure and finish.

D. Store fan coil units in a clean, dry space and protect from the weather.

E. Store and protect unit against dirt, water, chemical and mechanical damage. Do not install damaged units – remove from project site.

1.8 ENVIRONMENTAL REQUIREMENTS

A. Do not operate units for any purpose, temporary or permanent, until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.

1.9 WARRANTY

A. Provide one-year (12 months) warranty. The warranty shall include parts, labor, travel costs, and living expenses incurred by the manufacturer to provide factory authorized service.

PART 2 – PRODUCTS

2.1 FAN COIL UNITS

A. General:

1. Except as otherwise indicated, provide fan coil unit manufacturer’s standard materials and components as indicated by his published product information, designed, constructed, and assembled by the manufacturer. Units shall be certified in accordance with ARI 440-84. Unit capacities shall be certified in accordance with ARI Standard 441-66. Unit sound data shall be rated in accordance with ARI Standard 443-70.

2. Factory fabricated, chilled water, fan coil units of the size, type, configuration, and capacities as scheduled on the drawings.

3. All pressure drops, horsepowers and dimensions shown are maximum allowable. All capacities shown are minimum allowable. All units must have AMCA certified performance data for fans tested in the unit casings. Bare fan certification without casing is not acceptable.

4. Units shall be capable of providing modulating cooling with control valves and sensors to be provided by the Controls Contractor.

B. Acceptable Manufacturer shall be as scheduled on the drawings, or approved equal:

1. McQuay
2. International
3. Trane
4. Carrier
5. Or approved equal.

C. Capacity: Heating and cooling capacities and fan characteristics shall be as scheduled or shown on the Drawings and shall be ARI-certified.

D. Cabinets: Cabinets shall be fabricated of 18 gauge, cold rolled steel or galvanized steel factory- painted, designed to provide a rigid structure for lasting durability and peak performance. Cabinets shall
be reinforced for maximum rigidity. Removable panels shall be provided on each side of cabinet for ease of installation and maintenance. The entire interior of the cabinet shall be insulated both thermally and acoustically with 1/2" thickness of fiberglass neoprene insulation with black flame resistant coating. Insulation shall meet NFPA 90A and ASTM E84-70 with flame spread of less than 25 and smoke developed of less than 50 requirements and be UL-listed and labeled.

E. Coils: unit shall be equipped with standard capacity 4-row chilled water cooling coil. Coils shall have copper tubes with aluminum fins bonded to the tubes by mechanical expansion. Coils shall have a working pressure of 400 psig at 200 F. Each coil shall have sweat connections for copper tubes and shall have manual air vent(s).

F. Water Coils: The coils shall consist of minimum 0.5" OD, 0.020" wall thickness copper tubes, mechanically expanded into aluminum fins. Coils shall have a maximum of 12 fins per" and coil water and air pressure drops shall not exceed the scheduled maximums. All copper tubes and headers shall be constructed of seamless copper. All water coils shall be furnished with an air vent and drain valve. Coils shall be tested at 350 psig air pressure and are suitable for 250 psig working pressure. Hot water coils shall be mounted in preheat position, unless otherwise noted.

G. Drain Pans: All drain pans shall be fabricated of 304 Stainless Steel construction, and insulated with a closed cell polyurethane or polyisocyanurate that is sprayed and into every crevice of the drain pans. Drain pan shall have an integral auxiliary drain pipe connection located above primary drain connection to provide an auxiliary drain connected to “tell-tale” drain piping. Insulation shall be Underwriters’ Laboratories, Inc. listed and labeled. Drain pans shall be pitched for positive drainage with the fan coil unit installed level.

H. Fans: Belt-driven, double-width fan wheels shall have forward-curved blades and be statically and dynamically balanced. Fan drive shall consist of variable-pitch motor pulley, fixed-pitch fan pulley and V-belt. Fans and scrolls shall be of galvanized steel.

I. Fan Wheels: Fan wheels shall be mounted on a solid steel shaft with ball bearings, all fan wheels shall be heavy duty, galvanized steel, double inlet, forward-curved blade, centrifugal direct-drive or belt-drive type, as scheduled. The wheels shall be dynamically and statically balanced for smooth, quiet operation.

J. Motors: Single Phase motors shall be high efficiency, permanent split capacitor ball bearing type motors with thermal overload protection for direct drive fans and high efficiency, open- dripproof motors for belt drive fans and shall be provided with resilient mount. For dual drive motors, each motor shall be protected with thermal overload protection. For direct driven fractional horsepower fan coil units, provide a solid state speed controller mounted at Fan Coil Unit to adjust speed for balancing air flow. For large fan coil units, motors shall be three-phase premium efficiency type. See related sections for additional motor requirements. Fan motors shall be single-speed, 1750 rpm, 60 Hz, single phase 115 volts (60 Hz), suitable for continuous duty at 104-°F (40 °C).

K. Casing: Construction shall be heavy gauge galvannealed steel, painted with baked on polyurethane based powder coating, lined with 7/8” closed-cell thermal/acoustical insulation. Knockouts acceptable for 3/8-in threaded rod shall be provided at the top and bottom of all unit corners for hanging the unit. Supply and return duct connections shall be approx. one” long (04 - 40 only). Removable side panels shall be provided for access to the fan/motor assembly. A Type 304 stainless steel, coated, double-sloped IAQ drain pan shall extend under the full length and width of the coil(s) with a 3/4 –in FPT connection.

L. Filters: Provide Type F-1B - Basin Boy throwaway filters of glass fiber, one” (1”) thick unless scheduled
or shown otherwise on the Drawings. Filters shall be 2” pleated media, MERV-7, as indicated on the equipment schedule.

M. Factory Finish: Finish shall be bonderized, phosphatized, baked-on primer, and baked-on enamel.

N. Accessories: Provide units with accessories as scheduled or shown on the Drawings and as required for a complete installation. Typical accessories shall include, but not be limited to: supply, return and outside air duct connections, internally insulated return air plenums, filter racks, filters, access doors and similar accessories.

O. Single Point Power Connection: Provide single point power connection, including fan motor relay, disconnect switch, and power supply to VAV controller. Fan relay motor shall be provided in a NEMA-12 enclosure.

PART 3 – EXECUTION

3.1 INSTALLATION

A. General: Install fan coil units, including components required for operation, in accordance with manufacturer’s instructions and the specifications.

B. Examine site to verify if site is ready to receive work. Provide a layout drawing of fan coil unit locations to electrical installer.

C. Location: Locate each unit accurately in the position indicated in relation to other work. Position unit with sufficient clearance for normal service and maintenance, including clearance for cabinet removal.

D. Tolerance: Level fan coil units to the tolerance recommended by the manufacturer.

E. Damaged Fins: Comb out any damaged fins or replace coil if fins cannot be combed to a like-new condition.

F. Vibration Isolation: Provide unit vibration isolation as schedule (isolation springs).

G. Drain Pans: Install auxiliary drain pans under all concealed fan coil units. Drain pan shall have a safety flood switch wired for unit shutdown.

H. Condensate Drain Piping: Install piping and traps in accordance with manufacturer’s instructions and Code Requirements.

I. Auxiliary Drains: Pipe auxiliary drains on fan coil units to drain pans on concealed units and as tell-tale drains to an approved location.

J. Filters: Two sets of filters shall be supplied for each fan coil unit. One set shall be installed at initial unit start-up after all ductwork has been blown out and shall be used during balancing and testing, (install minimum 30% efficiency air filters in unit during installation phase), the second set shall be installed at the time of substantial completion (install a new set of filters prior to final air balance and substantial completion). Any additional filter sets required during the construction period shall be the responsibility of the Contractor.

1. Do not operate the unit without filters in place.
K. Wiring: Control Contractor shall install all wiring associated with control signals for the unit.

L. Electrical installer shall install all line voltage power wiring and conduit. Coordinate with electrical work.

3.2 TESTING

A. General: Test unit to verify proper operation and correct any defects found.

B. Adjusting: Adjust fan speed by setting solid state speed controller or adjusting belt sheaves.

C. Training: As specified

3.3 MANUFACTURER’S START-UP SERVICES

A. The manufacturer shall provide start-up service by a factory authorized service technician. The service technician shall verify correct installation, verify unit mounting, verify fan rotation, verify spring isolator adjustments, verify control wiring, verify power wiring, start-up the fans, and check for proper operation. The service technician shall provide final adjustments to meet the specified performance requirements. Fully staffed parts and service agency shall be located within four hours travel from the job site.

END OF SECTION 23 82 19
SECTION 23 82 36 – RADIANT HEATERS

PART 1 – GENERAL

1.1 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this section shall comply with all the requirements of General Conditions, Supplemental Conditions, Section 23 05 10 - Basic Materials and Methods, and other Sections in Division 23 specified herein.

1.2 SCOPE

A. All work to be furnished and installed under this Section shall comply with all the requirements, and shall include, but not necessarily be limited to, the following:
   1. Fin tube radiation.

1.3 RELATED WORK SPECIFIED ELSEWHERE

A. Section 23 05 93: Testing, Adjusting and Balancing
B. Section 23 07 00: HVAC Insulation
C. Section 23 21 23: Hydronic Pumps

1.4 REFERENCES

A. Codes and Standards: Provide components conforming to the requirements of the latest edition of the following:
   1. American Society of Mechanical Engineers (ASME): Boiler and Pressure Vessel Code
      a. Section VIII D1 Rules for Construction of Pressure Vessels including Addendums
      b. Section VIII D2 Rules for Construction of Pressure Vessels including Addendums
      c. Section IX Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators including Addendums
      d. B31.1 Power Piping
   2. National Electrical Manufacturers Association (NEMA): Provide electrical components that comply with NEMA Standards.
   3. National Fire Protection Association (NFPA) 70
   4. National Electrical Code (NEC) Standards

1.5 QUALITY ASSURANCE

A. Manufacturer's Qualifications: Provide systems that are the standard product of an equipment manufacturer regularly engaged in the production of such units who issues complete catalog information on such products. Units shall not be fabricated by the Contractor.

1.6 SUBMITTALS

A. Product Data: Submit manufacturer's technical product data for units showing dimensions, weights...
(shipping, installed, and operating), capacities, ratings, performance with operating point clearly indicated, motor electrical characteristics, finishes of materials, and installation instructions.

B. Shop Drawings: Submit manufacturer’s shop drawings indicating dimensions, weight (shipping, operating), required clearances, methods of assembly of components, and location and size of each field connection.

C. Maintenance Data: Submit maintenance instructions, including instructions for lubrication, tube replacement, motor and drive replacement, and spare parts lists. Include this data, product data, shop drawings, and wiring diagrams in operating and maintenance manuals.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Deliver units to the site in containers with manufacturer’s stamp or label affixed.

B. Store and protect units against dirt, water, chemical, and mechanical damage. Do not install damaged units - remove from project site.

C. Rigging: Comply with the manufacturer’s rigging and installation instructions.

1.8 WARRANTY

A. Provide general one-year (12 months) warranty. The warranty shall include parts, labor, travel costs, and living expenses incurred by the manufacturer to provide factory authorized service.

PART 2 – PRODUCTS

2.1 FIN TUBE RADIANT (HYDRONIC)

A. General:

1. The contractor shall furnish and install wall fin as shown on the plans. Ratings shall be Independent Bill Review approved. Units shall be installed in a neat and workmanlike manner in accordance with specifications and manufacturer recommendations.

B. Heating Elements:

1. Element types, as indicated on plans, shall have integral fin collars which space the fins and provide fin-to-tube surface firmly bonded by mechanical expansion of the tube to ensure durability, eliminate noise from loose fins and assure performance at cataloged ratings. Elements shall be positively positioned front-to-back, with provisions for silent horizontal expansion and contraction.

C. Enclosures:

1. Enclosures shall be constructed of 14-gauge steel and shall mount into a continuous roll formed captive channel mounting strip which permits hinge type mounting and access at the top and invisible fastening onto rigidized, 14-gauge steel enclosure brackets at the bottom. Enclosure brackets shall be spaced at not more than four foot intervals.

2. Front panels shall be individually removable to facilitate cleaning, servicing or replacement. All accessories shall fasten to the enclosure assembly in a manner which prevents contact with the back wall during installation.
D. Standard Finish:
1. All enclosures, mounting strips and accessories are cleaned, phosphatized and painted with one coat of beige, baked enamel finish as standard.
2. Other color baked-on enamel finishes are available. Provide color as selected by Engineer.

E. Accessories and Options:
1. End panels, inside and outside corners and enclosure extensions shall be die formed and shall lock to enclosure assembly without visible fasteners.
2. Access panels or extensions shall be installed for valves, balancing cocks, etc.
3. Back panels, sill extensions, mullion channel, bottom inlet grilles, front inlet grilles, tamperproof screw assemblies and pilaster covers shall be provided where required. To prevent dirt streaking, contractor shall either apply dirt guard gasket to mounting strip or caulk along top of mounting strip.

F. Manufacturer: Vulcan, or approved equal by Trane, Modine, or Sterling.

2.2 CEILING LINEAL RADIANT PANELS (HYDRONIC)

A. Acceptable Manufacturers:
1. Price.
2. Or approved equal.

B. Linear radiant panels shall use extruded aluminum with integrated heat sinks on the back to transfer heat between copper tubes and the panel face. The linear radiant panel is to radiate or absorb heat from or to the zone below.

C. Water Tubes: Tubes shall consist of ASTM B75 1.5" nominal copper tubing. Water connections shall be one end only. Water connections shall be suitable for solder, compression fittings, push-on fittings or threaded connection.

D. Heat Sinks: Heat sinks shall be extruded aluminum and copper pipe will be mechanically fastened to the heat sink. A non-hardening heat transfer paste is required between the tubing and the heat sink.

E. Extruded Aluminum Plank: The panel shall be constructed of 1.2mm thick extruded aluminum

F. Paint Finish: All visible components shall be powder coated with highly emissive powder coat polyester paint for optimal radiative properties as well as durability and easy cleaning. Manufacturer shall provide water pressure drop data as well as heat and cool output data derived from tests in accordance with DIN 14037 (heating)

G. Standard Color Protech PX622W457.

H. Linear radiant panel capacity shall be tested and certified by manufacturer in accordance with DIN 14037 (heating) to meet the performance listed on the schedule. Should any performance rating, chilled water supply temperature, water pressure drop, etc. deviate from the schedule, manufacturer shall submit updated capacity as described, as well as computational fluid dynamic modeling demonstrating that any changes do not impact the air distribution in a room that would cause a detriment to the PMV and ADPI rating from the design conditions. Manufacturer shall have factory testing facility available to perform performance test of units in accordance with said standard, as required. Upon request, up to
1% of units for the project can be tested in accordance with the standard. Request will be made with order and prior to shipment of chilled sails. Engineer will have the option of witnessing this test.

I. Water connections shall be shipped sealed to limit the introduction of dust and dirt during shipping and construction.

PART 3 – EXECUTION

3.1 INSTALLATION

A. All equipment, unless otherwise shown or noted on the Drawings, is to be installed in accordance with industry standards and manufacturer-recommended installation instructions.

B. Provide expansion compensators, flexible pipe connections, etc. as specified in related specification sections.

C. Flush and clean equipment, in accordance with manufacturer’s instructions.

3.2 MANUFACTURER’S START-UP SERVICES

A. The manufacturer shall provide start-up service by a factory trained service technician. The service technician shall verify correct installation, verify piping installation, and check for proper operation. Fully staffed parts and service personnel shall be within four hours travel from the job site.
SECTION 23 82 39 – UNIT HEATERS

PART 1 – GENERAL

1.1 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this section shall comply with all the requirements of General Conditions, Supplemental Conditions, Common Work Requirements for HVAC, and other Sections in Division 23 specified herein.

1.2 SCOPE

A. All work to be furnished and installed under this Section shall comply with all the requirements, and shall include, but not necessarily be limited to, the following:

1. Electric duct mounted heat coils.

1.3 REFERENCES

A. Codes and Standards: Provide components and pumps conforming to the requirements of the latest addition of the following:

1. American Society of Mechanical Engineers (ASME): Boiler and Pressure Vessel Code
   a. Section VIII D1 Rules for Construction of Pressure Vessels including Addendums
   b. Section VIII D2 Rules for Construction of Pressure Vessels including Addendums
   c. Section IX: Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators including Addendums
   d. B31.1 Power Piping

2. National Electrical Manufacturers Association (NEMA): Provide electrical components that comply with NEMA Standards.

   a. 70 National Electrical Code

1.4 QUALITY ASSURANCE

A. Manufacturer’s Qualifications: Provide systems that are the standard product of an equipment manufacturer regularly engaged in the production of such units who issues complete catalog information on such products. Units shall not be fabricated by the Contractor.

1.5 SUBMITTALS

A. Product Data: Submit manufacturer’s technical product data for units showing dimensions, weights (shipping, installed, and operating), capacities, ratings, performance with operating point clearly indicated, motor electrical characteristics, finishes of materials, and installation instructions.

B. Shop Drawings: Submit manufacturer’s shop drawings indicating dimensions, weight (shipping, operating), required clearances, methods of assembly of components, and location and size of each field connection.
C. Maintenance Data: Submit maintenance instructions, including instructions for lubrication, tube replacement, motor and drive replacement, and spare parts lists. Include this data, product data, shop drawings, and wiring diagrams in operating and maintenance manuals.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver units to the site in containers with manufacturer’s stamp or label affixed.

B. Store and protect units against dirt, water, chemical, and mechanical damage. Do not install damaged units - remove from project site.

C. Rigging: Comply with the manufacturer’s rigging and installation instructions.

1.7 WARRANTY

A. Provide general two-year (24 months) warranty. The warranty shall include parts, labor, travel costs, and living expenses incurred by the manufacturer to provide factory authorized service.

PART 2 – PRODUCTS

2.1 ELECTRIC DUCT MOUNTED HEATING COILS

A. Electric duct heaters shall be Acu-Zone™ model AZON-I-E or AZON-II-E manufactured by Acutherm, Hayward, CA.

B. Each unit shall be a complete open coil duct heater with modulating SCR proportional controller, airflow sensor, discharge air sensor and room thermostat to provide a constant supply air temperature at both design and very low airflows. Units that do not provide a constant supply air temperature shall not be allowed.

C. The discharge thermostat shall be field adjustable. It shall be factory set for a constant supply temperature of approximately 90˚F/32˚C to minimize room air stratification. The discharge air temperature thermostat shall be factory installed in the AZON-I-E models and shall be field installed by others for AZON-II-E models. An electronic mode control room thermostat shall be supplied for field installation by others.

D. The unit shall be packaged in a heavy duty galvanized steel box complete with electric heating elements, controls and safety devices for over temperature control. The controls enclosure shall be NEMA 1 and a cover shall be easily removable for access to a single point electric supply connection and a room thermostat connection. AZON-II-E models also have a discharge air thermostat connection. The unit shall be CSA (C & US) labeled for safety and reliability.

E. Electric heating elements shall be open coil type constructed from the highest-grade nickel-chrome resistance wire ensuring that the wires will not age or oxidize to provide longer life. Each unit shall have an automatic reset thermal cutout, a safety feature to prevent overheating, that will reset after cooling down. Each unit shall also incorporate a manual reset thermal cutout for redundancy and to prevent the heater frame from overheating.

F. Model AZON-I-E shall have a round inlet and outlet as scheduled. Inlet and outlet for model AZONE-II-E shall be either round, square or rectangular as scheduled.
G. The manufacturer shall warrant that all Acu-Zone electric heaters shall be free from defects in materials and workmanship for a period of two years from date of shipment.

PART 3 – EXECUTION

3.1 INSTALLATION

A. All equipment, unless otherwise shown or noted on the Drawings, is to be installed in accordance with industry standards and manufacturer-recommended installation instructions.

B. Clean equipment, in accordance with manufacturer’s start-up instructions, and in presence of manufacturer’s representative. Test controls and demonstrate compliance with requirements. Replace damaged or malfunctioning controls.

C. HVAC contractor shall coordinate all electrical requirements with Electrical contractor.

3.2 MANUFACTURER’S START-UP SERVICES AND COMMISSIONING

A. The manufacturer shall provide start-up service in the form of a factory trained service technician. The service technician shall verify correct installation, verify pump systems mounting, verify piping installation, verify control wiring, verify power wiring, and check for proper operation. The service technician shall provide final adjustments to meet the specified performance requirements. Fully staffed parts and service personnel shall be within four hours travel from the job site.

B. Refer to Section 23 08 00 for Commissioning requirements.

END OF SECTION 23 82 39
San Francisco International Airport

Mechanical Design Standards

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Rev. 11/15/2017
CHAPTER 1
GENERAL

SECTION 101 - GENERAL

101.1 INTENT
The Mechanical systems consist of HVAC, Plumbing, and Automatic Controls located in the Terminal Building, Concourses and Auxiliary Buildings. The goals and objectives are to develop a Mechanical design to achieve an efficient, economical, maintainable and reliable installation consistent with the long term goals and objectives of the San Francisco International Airport (SFIA). This is not intended to be a code review or master specification.

The space environment shall be designed to be controllable within acceptable year around comfort and health levels. The Design Engineer shall utilize the latest state-of-the-art, energy conservative, readily available equipment and components based on proven design techniques.

The design guide is intended to supplement California Building Codes, City and County of San Francisco (CCSF) regulatory requirements, Net Zero Energy Standards and Objectives, and design specifications. It is not intended to override or void any codes, regulatory or design. The standards are intended to provide basis of design and design criteria to support programming, planning and establish general design objectives. This is not to simply the design process but rather to establish a baseline for design evaluation, system assessment, value engineering, and overall challenge points to achieve exceptional design.

Deviation from the design criteria must be submitted for review. Design options, value engineering, and alternative systems must be submitted with engineering justification.

101.2 GENERAL
The designer shall prepare the design, construction documents, drawing and specifications for HVAC equipment, ductwork and piping, exhaust equipment, controls, insulation, structural, plumbing, fire protection, automatic control systems and operational services such as aircraft and vehicle fuel and glycol systems. The designer shall coordinate the Mechanical design with the applicable sections of the Architectural, Electrical, Structural, Civil and SFIA standards and criteria.

Mechanical systems must be coordinated and integrated with all other building systems and features. Mechanical systems shall be adapted to support all performance objectives, typically involving sustainability, workplace performance (productivity and efficiency), fire safety, security, historic preservation, and improved operations and maintenance.

All Construction Documents shall be developed by the designer and reflect a complete engineered design. The installing contractor may perform certain engineering tasks, such as the Fire Protection, but the designer is responsibility for the total overall design.

101.3 SFIA MECHANICAL ENGINEER
All references in this document to the “SFIA MECHANICAL ENGINEER” refer to the individual listed below. For questions, updates or requests for deviations to this document contact:

John Chinn, PE
Senior Mechanical Engineer
P. O. Box 8097
San Francisco, CA 94128
Email: john.chinn@flysfo.com
Phone: (605)821-7807
Cell: (650)821-7838

101.4 REGULATORY REQUIREMENTS
Specify that work shall be per Underwriters, Public Utility, Local, State and Federal Codes, Ordinances and applicable regulations. Work shall also comply with latest editions of all applicable codes, ordinances and regulations in effect as of the date of the Contract Documents. If discrepancies occur between the Contract Documents and any applicable codes, ordinances, acts, or standards, the most stringent requirements shall apply.

Drawings will be reviewed for code compliance and permitted through SFIA Building Inspection and Code Enforcement (BICE).
SFIA Mechanical Design Standards

SECTION 102 - DESIGN CRITERIA

102.1 SYSTEM CRITERIA
The mechanical systems for all facilities at the San Francisco International Airport are to be based on straight-forward, proven design techniques utilizing the latest state-of-the-art development in readily available equipment and hardware. The overriding criteria for the use of systems and equipment shall be safety, sustainability, reliability, life cycle cost, and the comfort of the traveling public.

It is most important that the systems installed serve the public well, are readily serviceable and maintainable, are stable, reliable, and direct in their operation, and provide flexibility for future change and development. All equipment, appurtenances, and hardware shall be accessible for adjustment and maintenance. Suitable access is required to permit removal and replacement of equipment items. Provisions are to be made for centralization of operating and maintenance diagnostics, controls, measuring, monitoring, alarms, and trending analytics.

It is anticipated that there will be changes and development in many areas of the airport facilities and the mechanical systems will have to be revised or expanded to accommodate these changes. In addition, development in state-of-the-art technology may suggest updating systems and system components in the future. All designs of mechanical systems must include built-in flexibility in keeping with the nature of change that is ever present for air transportation facilities.

In addition, energy conservation and cost savings will also be guiding criteria in the design of mechanical systems. All facilities must meet the energy conservation requirements included in these standards. Both initial system and equipment costs and life cycle owning and operating costs are to be important considerations in concept design efforts and these considerations must be carried through final design and construction. Life-cycle cost analysis requires a minimum of 2 options for comparison. All new central systems must be justified with a life-cycle analysis. Modifications of existing systems do not require life-cycle analysis.

102.2 MECHANICAL DESIGN CRITERIA - FLEXIBILITY
Special provisions are to be made in determining terminal and concourse building heating and air conditioning load requirements to properly allow for the dynamic nature of the application of these loads. During normal operation these loads can vary dramatically from zone to zone and the peak load can fluctuate significantly within each zone. This is due to the rapid mass movement of people within the building, as well as, the shifting solar load on glass walls, infiltration loads associated with people and baggage movement in and out of the building, and outside air ventilation requirements.

Heating and air conditioning system controls must provide system flexibility so as to be able to deal with the shifting internal cooling loads as well as coordinating for future interconnection with planned development of existing systems. The HVAC system must be able to handle varying perimeter loads during heating and cooling seasons while the internal and other loads fluctuate between no load and peak conditions. In addition, appropriate air quality conditions must be maintained in the spaces while the natural ambient (outside) conditions are very often of less than ideal quality.

102.3 DESIGN PARAMETERS

A. Indoor Design Temperatures: It is intended that the mechanical systems (in general) maintain indoor design conditions in all occupied spaces normally accessible to the public as follows (unless specified otherwise):
   1. Summer: 72 degrees F, 50% percent maximum relative humidity
   2. Winter: 68 degrees F

B. Outdoor Design Temperatures: Outdoor design conditions to be used for system designs are as follows:
   1. Summer: 83 degrees F dry bulb/ 64 degrees F wet bulb.
   2. Winter: 35 degrees F

These design criteria conditions are based on the recommended conditions listed for San Francisco in the ASHRAE Fundamentals Handbook at the 0.5% summer condition and the 99.8% winter condition. That is, based on historical data, the outdoor temperatures can be expected to exceed the summer design conditions 0.5% of the time and exceed the winter design conditions 0.2% of the time. The more stringent design condition is required for winter criteria due to inherent outdoor infiltration condition present in most airport situations. The standards establish only baseline criteria for equipment sizing.
Net Zero Energy goals and operational goals should be evaluated as part of the Energy Model to achieve Sustainability goals. See Standards & Criteria for Thermal Comfort Modeling in the SFO Net Zero Energy Standards for alternative design parameters.

102.4 VENTILATION STANDARDS
Ventilation Standards for occupied spaces are to be based upon the latest revision of ASHRAE Standard 62, “Ventilation for Acceptable Indoor Air Quality.” The minimum required ventilation rate of outdoor air per person is to be 15 CFM per person, with several special use areas in the buildings having significantly higher requirements.

Design engineer shall investigate increasing outdoor air ventilation rates to all occupied spaces by at least 30% above the minimum rates for LEED Indoor Environmental Quality credits.

102.5 ENERGY EFFICIENCY REQUIREMENTS
Energy efficiency is an important consideration in the design of the mechanical systems for all SFO International Airport facilities. Heating, ventilating and air conditioning systems are to be designed to exceed the requirements of the latest revision of ASHRAE Standard 90.1 - “Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings,” and the San Francisco Building Code. Refer to the latest SFO Sustainability Design Guide. All new facilities must be certified as LEED Gold at a minimum. All Commercial Interior renovations over 5,000SF must be certified as LEED Gold at a minimum and reach Net Zero Energy objectives.

Equipment selections must be specified to meet or exceed these standards. The equipment and systems described herein must be selected to obtain the optimum in conserving owning and operating costs considering energy efficiency, initial costs, maintainability, and comfort. Energy use budgets and criteria are described in detail in this section of the Mechanical Design Standards.

102.7 NOISE CRITERIA
The mechanical (HVAC) system shall be designed to minimize noise in the occupied space. The system and components shall be designed so as not to transmit or generate sound above a specified noise level in the space. Sound attenuators, duct liner, lower duct velocities and appropriate ductwork fittings and components shall be utilized as required to attain acceptable sound levels. Vibration isolation shall also be evaluated and utilized. Sound attenuators shall be isolated from the building structure.

Sound tests shall be conducted in accordance with accepted procedural standards in and around all major sound producing equipment to either confirm adequate attenuation or to identify problem areas requiring additional modifications as required by the Project Manager.

Maximum noise levels in the occupied space produced by HVAC equipment shall be in accordance with the following NC (noise criteria) curves.

<table>
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<th>Category</th>
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<tr>
<td>A. Offices</td>
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<tr>
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<tr>
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<td>NC-25</td>
</tr>
<tr>
<td>F. Exercise Rooms</td>
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</tr>
<tr>
<td>G. Conference Rooms</td>
<td>NC-30</td>
</tr>
<tr>
<td>H. Lobbies, Corridors and Waiting Areas</td>
<td>NC-40</td>
</tr>
<tr>
<td>I. Quiet Rooms and Meditation Rooms</td>
<td>NC-25</td>
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Where mechanical noise is to be utilized for sound masking, RC (room criteria) curves shall be utilized as described in the ASHRAE Handbook, "Fundamentals."

Equipment and ductwork noise levels to permit attaining sound pressure levels in all 8 octave bands in Tenant occupied spaces shall conform to noise criteria NC-35 curves. Motor drives for pumps or any equipment shall operate with noise levels not exceeding OSHA 8 hour 90dBA Time Weighted Average (TWA). Noise levels shall be determined in accordance with IEEE Standard #85 Test *procedure for Air-Borne Noise Measurements on Rotating Electric Equipment.
Engineering Firms will be required to submit sound attenuation analysis.

102.8 SUPPORTS AND PENETRATIONS
All supports for mechanical and plumbing equipment shall be designed, detailed and specified by a California licensed Structural Engineer. Penetrations and reinforcement of penetrations through structural floors and/or walls shall be designed, detailed and specified by a California licensed Structural Engineer.

102.9 HVAC COMPUTER BASED LOAD ANALYSIS
The HVAC loads calculations shall be performed with a computer-based program using the latest ASHRAE Handbook of Fundamentals Heat Balance Method (HB), Radiant time Series (RTS) Method, or Transfer Function Method (TFM), developed for the hourly analysis of heating and cooling loads in commercial buildings. Preferred program is Carrier HAP. All projects are required to submit load calculations.

The program shall be capable of calculating each zone’s peak heating and cooling load as well as the whole-building “block” loads. The program shall, at a minimum, calculate: solar gains through fenestration, internal gains from occupants including latent heat for cooling purposes, internal gains from lighting and equipment, outside air loads (sensible and latent) from ventilation and infiltration, and heat gains or losses through fenestration, walls, floors and roofs. The heating load calculations must be done without credit for occupants and internal gains.

The HVAC loads calculations report shall include all input and output used in the heating and cooling calculation program, and shall include zone peak heating and cooling loads results, and whole building “block” loads, air-handling unit coil selections, and psychrometric process charts.

102.10 PREDICTIVE ENERGY MODELING
A building energy analysis shall be performed to demonstrate that the building design meets or exceeds the energy performance goals established for the project. Predictive Energy Modeling will be required to support Net Zero Energy objectives. Iteration process to support design collaboration, engineering, life cycle cost, and integrated design across all aspect of the new space will be required. See Chapter 8 for Energy Analysis.

The building energy analysis shall be performed using the ASHRAE Standard 90.1 Energy Cost Budget methodology, and must demonstrate compliance with the latest editions of ASHRAE Standard 90.1. The analysis shall be included in each design submission. Predictive Energy Modelling program shall be Integrated Environmental Solutions – Virtual Environment (IES VE).

The analysis shall evaluate the energy performance of the building design including the proposed building envelope, HVAC systems and components, the lighting systems, and domestic hot water systems, as well as the proposed control strategies for these building systems. The analysis shall be based on actual parameters and values found in the proposed building design and not simply on defaults assigned by the simulation program. The analysis shall be performed using a simulation program. The simulation program shall be a computer-based program for the analysis of energy in buildings. Simulation programs must be capable of simulating: 8,760-hours per year, hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC system operation defined separately for each day of the week and holidays, thermal mass effects, the number of required HVAC zones, part-load performance curves for mechanical equipment, capacity and efficiency correction curves for mechanical equipment, air-side and water-side economizers, and temperature controls. Public domain or commercial software shall utilize the IES VE modeling software. Alternative simulation programs, meeting the above stated requirements, may be used with prior approval. The building energy analysis report shall include all input and output used in the simulation programs, including: established energy goals for the project, detailed descriptions of the budget and proposed building models, actual local utility rates, descriptions of any and all energy conservation measures, an analysis of results with final conclusions and recommendations.

102.11 MAINTENANCE SERVICE
A. Service Access. Space shall be provided around all HVAC system equipment as recommended by the manufacturer and in compliance with local code requirements for routine maintenance. Access doors or panels shall be provided in ventilation equipment, ductwork and plenums as required for in-site inspection and cleaning. Equipment access doors or panels shall be readily operable and sized to allow full access. Large central equipment shall be situated to facilitate its replacement. The HVAC design engineer shall be cognizant of the necessity to provide for the replacement of major
equipment over the life of the building and shall insure that provisions are made to remove and replace, without
damage to the structure, the largest and heaviest component that cannot be further broken down.

In addition, adequate methods of access shall be included for items such as: chillers, boilers, air-handling units, heat
exchangers, cooling towers, reheat coils, VAV terminals, pumps, water heaters and all devices that have maintenance
service requirements.

To facilitate equipment access, maintenance, removal and replacement, a freight elevator stop shall be provided to
serve each floor housing HVAC systems and equipment.

Where stairs are required, they must allow for safe transport of equipment and components. Ship’s ladders are not
permitted for access and maintenance of any equipment.

B. Vertical Clearances. Mechanical equipment rooms shall have clear ceiling heights of not less than 12 feet. Catwalks
with stairways shall be provided for all equipment that cannot be maintained from floor level. Where maintenance
requires the lifting of heavy parts (100 lbs. or more), hoists and hatchways shall be installed.

C. Horizontal Clearances. Mechanical rooms shall be configured with clear circulation aisles and adequate access to all
equipment. The arrangement shall consider the future removal and replacement of all equipment. The mechanical
rooms shall have adequate doorways or areaways and staging areas to permit the replacement and removal of
equipment without the need to demolish walls or relocate other equipment. Sufficient space areas (noted by outlining
manufacturer’s recommendations) for maintenance and removal of coils, filters, motors, and similar devices shall be
provided. Air-handling units require a minimum clearance of 2'-6” in on all sides, except the sides that filters and coils
are accessed, where clearance shall be equal to the length of the coils plus 2'-0”.

1. Housekeeping Pads. Housekeeping pads shall be at least 6 inches wider on all sides than the equipment
they support and shall be 6 inches thick.

2. Mechanical Rooms. All mechanical rooms must be mechanically ventilated to maintain room space
conditions as indicated in ASHRAE 62 and ASHRAE 15. Water lines shall not be located above motor control
centers or disconnect switches and shall comply with requirements of NFPA 70. Mechanical rooms shall
have floor drains in proximity to the equipment they serve to reduce water streaks or drain lines extending
into aisles. Mechanical rooms shall not be used as return air, outdoor air, or mixing plenums. Mechanical
equipment rooms must be designed in accordance with the requirements of ASHRAE Guideline15: Safety
Code for Mechanical Refrigeration.

3. Electrical Equipment Rooms. No water lines are permitted in electrical rooms, except for fire sprinkler piping.
Avoid placing restrooms, kitchens or utility rooms above Electrical Equipment Rooms.

4. Communications Closets. Communications closets must be cooled in accordance with the requirements of
EIA/TIA Standard 569. Closets which house critical communications components shall be provided with
dedicated air-conditioning systems that shall be connected to the emergency power distribution system.

5. Elevator Machine Rooms. A dedicated heating and/or cooling system must be provided to maintain room
mechanical conditions required by equipment specifications. In the event the building is equipped throughout
with automatic sprinklers, hoist way venting is not required.

6. Emergency Generator Rooms. The environmental systems shall meet the requirements of NFPA Standard
110: Emergency and Standby Power Systems and meet the combustion air requirements of the equipment.
Rooms must be ventilated sufficiently to remove heat gain from equipment operation. The supply and
exhaust louvers shall be located to prevent short circuiting. Generator exhaust shall be carried up to roof
level in a flue or exhausted by way of compliance with the generator manufacturer’s installation standards.
Horizontal exhaust through the building wall shall be avoided.

SECTION 103 - SUBMITTALS

103.1 DESIGN SUBMITTALS
Regardless of requirements outlined by the Design Analysis Report, or lack of, the Designer shall submit the following at the
100% phase of the project to the SFIA Mechanical Engineer:

1. Space load calculations shall be modeled.
2. Ventilation calculations defined by ASHRAE 62.
3. Equipment sizing and selection (AHU, FCU, Pump, Expansion tank, water heater, etc.)
4. Duct sizing and static pressure analysis
5. Hydronic piping sizing and static pressure analysis
6. Plumbing sizing and code analysis
7. Building pressurization analysis
8. Smoke Control Analysis
9. REVIT Building Model
10. Energy Analysis, Building Performance Energy Model
11. Life cycle cost analysis
12. Displacement Ventilation Air Flow, Computational Fluid Dynamics
13. Building Air Flow Modeling, Computational Fluid Dynamics
15. Additional calculations as requested by the SFIA Engineering Group

Each item shall be included as a single, book-marked PDF file. No paper copies are required or will be accepted. All equipment shall be labeled as identified on the contract drawings. Each filename should include the contract number.

103.2 AS-BUILT SUBMITTALS
The Engineer shall submit the information outlined, with corrections made due to field changes in Construction.
SECTION 201 – HVAC SYSTEM DESCRIPTION

This Chapter outlines basic HVAC system parameters and options. All sustainability based system upgrades or alternative solutions shall be evaluated to best achieve Net Zero Energy program objectives. It is the responsibility of design professionals to provide a collaborative solution with all aspects of building and system design.

201.1 AIR HANDLING SYSTEMS

The most appropriate designs for an airport terminal necessitate that the space conditioning system be flexible and responsive to wide swings in thermal loads. Factors include constantly changing people loads, high people door usage, air infiltration, shifting passenger densities, shifting solar loads, and baggage handling transfers in and out of the building. These items change in timing and intensity depending on changes in aircraft schedules and special peak passenger periods.

The air handling unit selection must consider the primary system design. For the San Francisco International Airport, the air handling units will utilize hot and chilled water from a four-pipe distribution system. Separate cooling and heating coils shall be required. The heating coils shall be selected for a minimum 20 degrees F temperature differential (180 degrees F to 160 degrees F). The cooling coils shall be selected for an approximate 10 degrees F temperature differential (42 degrees F to 52 degrees F) or as required by the psychometrics of the specific system design. This criterion shall be coordinated with the Central Plant.

Packaged air handling units should be used for applications below 25,000 CFM. Customized, built-up air handling units may be used in applications above 25,000 CFM.

Cooling and heating coils are to be sized and arranged for water velocities in the 6 fps range. Air cooling coils shall be designed to have a maximum air face velocity of 600 fpm. Air heating coils shall have a maximum air face velocity not to exceed 800 fpm. Fin spacing shall be as wide as possible to provide the specified leaving coil conditions. Condensate traps shall be 1 inch deeper than suction pressure. Drain pans shall be sloped to center.

DX cooling coils shall be row split (in lieu of face split) where multiple coil sections are required. All supply air handling units shall be draw-through, built-up systems except in instances where sound control would favor the application of blow-through units. Each unit shall consist of a non-overloading supply air fan with selected for maximum efficiency. Fan selection shall be based on noise criteria requirements. Fan walls are the preferred system type, however, other fan type may be considered if economy, efficiency and noise criteria parameters can be assured. Fan static pressure shall be based on final filters at end of life and pre-filters at midlife. Fan walls shall be provided with variable frequency drive (VFD) and redundant back-up VFD.

In addition, each air handling unit system shall contain separate cooling and heating coils (includes cooling only units), a final filter section, a throwaway filter section, a photo catalytic oxidation (PCO) filter, an air blender section to eliminate air stratification, a mixed air plenum for outside air and return air duct damper connections, and a sound attenuation section if required. Integral face and bypass dampers shall be considered for pre-heat coils in appropriate areas. Each air handling unit section shall be provided with an access door and non-breakable plenum light (coordinate with corresponding electrical designs). Heating coils shall be located upstream of the cooling coils, with space in between the two coil sections to facilitate access for maintenance and inspection. Air-tight shutoff type dampers shall be provided for the outside air damper.

The following air handling systems may be used for various applications at the San Francisco International Airport terminal and concourse areas. These include single-zone systems, Multi-zone systems, variable volume systems, heat pump systems, and roof-top HVAC systems.

All equipment visible from public line of sight shall be reviewed by the SFIA Architectural review committee. Non-standard equipment color and finishes may require additional screening.

201.2 DESIGN SUBMITTAL REQUIREMENTS

A. Provide load calculations or building performance model
B. Provide performance data sheets and air handler shop drawings
C. Provide selection fan curves
D. Sound spectrum for air handler inlet and outlet conditions
201.3 SINGLE-ZONE SYSTEMS
Single-zone type air handling systems will effectively handle any particular local area (zone) of a facility. However, a multitude of different temperature zones may necessitate a high number of single-zone air handling units. The disadvantages of such a design would be the requirement for more mechanical room space, higher maintenance costs, and increased capital cost due to the number of individual units that would be required. The use of single-zone air handling units on a large scale is not economical. A multitude of single zone units serving large, main spaces would also reduce the flexibility required to accommodate future space modifications.

Single-zone air handling units do have suitable application, however, to serve certain perimeter zones of the terminal building and concourses. They also have application in many areas in the various support facilities, where their use would prove to be the most suitable solution.

201.4 HEAT-PUMP SYSTEMS
Heat-pumps are a viable alternative for decentralized buildings.

201.5 ROOF-MOUNTED HVAC SYSTEMS
Another alternative, viable in many building applications, is the decentralized, roof mounted, packaged HVAC system. Rooftop HVAC equipment shall not be incorporated into the designs for the San Francisco International Airport terminals. This equipment does have application however, for some of the support facilities. Whenever a roof-top unit is utilized in the mechanical design of a building, the following concerns should be addressed in detail:

A. Maintenance - is the equipment readily accessible?
B. Energy Efficiency - select equipment to be energy efficient.
C. Noise and Vibration - proper vibration isolation is usually not provided unless special requirements are specified.
D. Aesthetics - this equipment can have a negative impact on the appearance of a building, depending on the elevation of other buildings or facilities in the vicinity. An architectural enclosure shall be provided around roof-mounted mechanical equipment.

201.6 VARIABLE AIR VOLUME SYSTEMS
In a variable air volume (VAV) system, the air volume supplied to the conditioned space is modulated to maintain the space temperature utilizing a constant supply air temperature. This system can offer the best approach to meet two major goals; energy efficiency and moderate initial capital costs.

The VAV system shall contain the air-handling system components described above for air handling systems, plus fan inlet vane controls or variable frequency fan motor drives. The air distribution system shall be of a single design. The appropriate variable volume terminal boxes shall then be provided to control the airflow to the space.

It is important with VAV systems that proper outside air ventilation rates be maintained, as well as building pressurization. Additional HVAC equipment or controls may be required with VAV systems to control pressurization. This issue will be addressed in the temperature control system requirements. The advantages of VAV systems both in flexibility and energy efficiency outweigh the additional control requirements.

Variable air volume systems are recommended for a number of areas in the San Francisco International Airport terminal buildings and in office areas, concourses and many other interior zone applications.

Systems shall be designed to deliver a minimum 0.5” WC at the most remote VAV box.

201.7 PERIMETER SYSTEMS
Any expanse of exterior glass wall area, in the Terminal, Concourses, or other areas will require a perimeter thermal conditioning system. These systems are to be designed to handle at least the conduction and infiltration loads of the perimeter walls plus potentially some radiant solar and internal loads near the perimeter, depending on the application.

There are three suitable methods to handle the perimeter loads.

A. A perimeter finned-tube hot water radiation system.
B. Radiant slab system.
C. A forced air system at the perimeter. Air circulation at the perimeter reduces pockets of stagnant hot or cold air.

If a perimeter forced air system is to be provided it should be a constant volume system in order to provide the necessary "throw" at the sill diffusers during mild weather. The perimeter system is preferably located at the sill rather than overhead to counteract down-draft at the windows during the winter. Some perimeter areas with low ceilings (9 ft. or less above finished floor) may use ceiling supply for the perimeter system; in addition these areas could be VAV with reheat if the system supplies only the perimeter and can handle both heating and cooling peak load conditions.

Perimeter finned-tube hot water radiation systems can be used to meet the perimeter loads. Ensure that the perimeter radiation system and forced air distribution systems don't work against each other causing them both to constantly cycle. Caution should be used in providing sill system components so that they do not easily collect trash.

201.8 HVAC FOR UNFINISHED (TENANT) AREAS
HVAC systems for unfinished future tenant areas shall be designed to provide for heating and cooling. The interior space(s), (defined as that space 12 +/- feet from the exterior wall) shall be designed for VAV with only cooling primary air ductwork routed to the terminal units. The VAV units shall be sized to deliver approximately 1.25 CFM of supply air per square foot. Prior to setting air flows the anticipated use of tenant areas shall be reviewed for functions that may require airflow rates above this amount (i.e. kitchens, bars, etc.). Additional CFM shall then be built into the air handling system design to easily handle these special areas. Controls will be connected to the VAV terminal unit only if some cooling or ventilation is required in the space.

The exterior glass walls shall utilize a perimeter forced air system as described previously. The perimeter system shall be complete in the unfinished area. The interior system shall be complete only to the VAV terminal system components.

SECTION 202 – SPECIAL SYSTEMS

202.1 AIR CURTAINS
Air curtains, plastic curtains and rapid operation doors are to be considered for use at doors and openings at all maintenance type facilities and also at baggage doors and openings.

Overhead fan-coil units or fan powered terminal boxes may be used as a modified type of air curtain at each concourse jetway entrance. The fan-coil units shall be activated, if not already in operation, whenever the jetway door is opened utilizing a 30-second time delay, and the supply air temperature is to be controlled from a space thermostat.

Air curtain type units shall be used at all terminal entrance vestibules. These air curtain units are controlled by vestibule thermostats.

202.2 CATALYTIC AIR CLEANING SYSTEM
Air filtration is an important consideration in the design of HVAC systems to serve airport facilities. Provide a catalytic air cleaning system in all new air handling units, which consists of MERV 13 rated filters, Ultraviolet Germicidal Irradiation (UVGI) and Photocatalytic Oxidation (PCO).

Ultraviolet Germicidal Irradiation (UVGI) is used to damage or kill various organisms on surfaces on the evaporator coil and surface in the air handler. Photocatalytic Oxidation (PCO) render bacteria cells, mold spores, and viruses inactive and accelerates the breakdown most volatile organic compounds (VOCs).

The key benefits of this system are:
A. Significant reduction of microbiological elements (viruses, bacteria and fungi/mold).
B. The reduction of organic odors caused by VOCs, like engine exhaust fumes.
C. Highly efficient particle removal.

202.3 SPLIT DX SYSTEM
Provide an independent Split DX to serve Special System Rooms (SSR), Server Rooms and Elevator Machine Rooms. Systems shall be sized to serve the cooling load in the room.
SECTION 203 - VENTILATION SYSTEMS

203.1 OUTDOOR AIR REQUIREMENTS
Outside air shall be brought in through the air handling systems to satisfy minimum ventilation requirements plus provide building pressurization and minimize air infiltration at building entrance door areas.

Existing outdoor air requirements on air handling equipment in the terminals were designed around previous revisions of ASHRAE Standard 62. Minimum outside air ventilation amounts shall be provided in accordance with the latest revision to ASHRAE Standard 62 and California Mechanical Code, there may be a conflict in the required amount of outdoor air. The Engineer shall coordinate those requirements with the Building Inspection and Code Enforcement (BICE) Department and provide electronic copies of correspondence and documentation of final design direction to the Project Manager. It is the responsibility of the Engineer to provide documentation that the existing equipment can comply with any modifications in outdoor air.

Outside air intakes shall be located high and away from landside vehicle traffic and airside jet exhaust to the greatest extent possible, a minimum of seven feet above grade. Most ventilation air will be brought in through air intakes in the mechanical penthouses. Computerize Fluid Dynamics modelling shall be utilized to validate intake air locations. All effort shall be made to provide distance and dilution as primary air quality solutions. See 202.2 and 203.5 for air quality controls and filtration.

203.2 CO2 MONITORING
Monitor CO2 concentrations within all densely occupied spaces. CO2 monitors must be between 3 and 6 feet above the floor. CO2 monitors must have an audible or visual indicator or alert the building automation system if the sensed CO2 concentration exceeds the setpoint by more than 10%. Calculate appropriate CO2 setpoints using methods in ASHRAE 62.1–2010, Appendix C.

For spaces where air contaminants are likely, evaluate potential sources of additional air contaminants besides CO2. Develop and implement a materials-handling plan to reduce the likelihood of contaminant release. Install monitoring systems with sensors designed to detect the specific contaminants. An alarm must indicate any unusual or unsafe conditions.

203.3 RETURN AIR \ TRANSFER AIR
Return air from the conditioned space back to the air handling unit should be via ductwork and ceiling plenums. The pressure drop in the return air system shall be minimized in the design. Return air fans should not be required in most cases. Maximum velocity shall be 500 fpm over net free area for general return and transfer air and 200 fpm over net free area for smoke control areas.

Eggcrate grilles shall be used in return air plenums that are used for smoke control. Perforated face grilles shall not be used.

203.4 VENTILATION RATES
As described earlier in this document, the outside air ventilation rate shall be as recommended in the latest edition of ASHRAE Standard 62. Careful consideration shall be given to these new recommended rates, particularly considering recent attention in the HVAC industry to indoor air quality. A summary of the applicable rates published in ASHRAE Standard 62, as applicable to airport building spaces, is presented below:
<table>
<thead>
<tr>
<th>Area</th>
<th>(CFM/person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting Rooms, Ticketing</td>
<td>15</td>
</tr>
<tr>
<td>Baggage &amp; Gate Areas</td>
<td>15</td>
</tr>
<tr>
<td>Retail Shops</td>
<td>15</td>
</tr>
<tr>
<td>Dining Areas</td>
<td>20</td>
</tr>
<tr>
<td>Bars/Cocktail Louges (non-smoking)</td>
<td>30</td>
</tr>
<tr>
<td>Office Space</td>
<td>20</td>
</tr>
</tbody>
</table>

Outside air requirements, unless otherwise specified, shall be as follows for "normal" occupancy levels.

The occupancy load in many public areas of the airport (i.e., concourses, hold rooms, ticketing areas, baggage claim, etc.) is highly variable. As an alternate to the ventilation air flows indicated as based on "normal" occupancy levels, it is acceptable to calculate the minimum ventilation rate on 10 CFM per person, based on peak load occupancy; unless exhaust requirements override this amount.

203.5 FILTRATION

Air filtration is an important consideration in the design of HVAC systems to serve airport facilities. Air should be brought in at the roof or penthouse level wherever possible in an attempt to use the highest quality air available. As a minimum, outside air is to be filtered by the use of 2” dry type pre-filter sections having a minimum rating of Minimum Efficiency Reporting Value, MERV 8 (30% - 35% efficient with a maximum allowable particle size of 10.0 micron), 12” dry type filter section having a minimum rating of MERV 13 (89% - 90% efficient with a maximum particle size of 1.0 micron), ultraviolet germicidal irradiation (UVGI) and photocatalytic oxidation (PCO). Filters for small air-handling units serving maintenance or non-public areas should be provided with 4” dry type pre-filter section having a minimum rating of MERV 10 (50% - 55% efficient with a maximum particle size of 3.0 micron).

Ventilation shall be provided in all ground level spaces that may have occasional or full-time occupancy. This ventilation shall be such as to minimize any possibility of an accumulation of radon gas; however, shall not be less than one (1) air change per hour.

Unoccupied crawl spaces in contact with the ground, shall be ventilated likewise to eliminate radon gas hazards at a rate of one (1) air change per hour - on a time clock to run not less than four one-hour periods in each 24-hour day.

SECTION 204 - HEATING, VENTILATION, EXHAUST SYSTEMS

204.1 GENERAL

This section covers areas of the building that are primarily mechanically heated and/or ventilated only; no air conditioning to be included. Basically, ventilation rates, filtration etc., mentioned previously for HVAC systems will apply unless otherwise indicated. Special exhaust requirements are also discussed.

204.2 BAG MAKEUP AND TUG DRIVE AREA

A. Ventilation: These spaces shall be maintained under a negative pressure in relation to the main terminal (public space) area. This will be accomplished with the use of exhaust fans. The exhaust shall exceed the 100% O.A. make-up air quantities by approximately 10 percent in the bag make-up area. Ventilation rates shall be a minimum of 6 air changes per hour in the bag make-up area and 10 air changes per hour in the tug drive area, if internal combustion engines are utilized. If all electric vehicles are utilized, the air change rate may drop to 2.0 air changes per hour of makeup air.

B. Heating: The bag make-up area shall have a 100% outside air make-up unit filters and with heating coils or indirect gas-fired equipment. In addition hot water unit heaters or low intensity infrared heaters shall be strategically located throughout the area and near overhead doors to maintain space temperature. Consideration will be given to providing low intensity infrared heat in lieu of some unit heaters, depending on overhead door activity. This will be based on input from the individual airlines which will utilize this space. Consideration shall also be given to recover heat from the exhaust air stream.

C. The tug drive shall be tempered with low intensity infrared heaters placed at bag drop-off areas.

204.3 TRUCK DOCK VENTILATION

An exhaust system shall be provided to ventilate truck docks on the apron level. This exhaust system shall provide 10 air changes per hour in the truck dock area. This ventilation system will provide the added benefit of creating air movement and reducing carbon monoxide build up.
TOILET EXHAUST

The ventilation (exhaust) rate for all toilet room facilities shall be a minimum of 2.0 CFM/SF of floor space or 15 air changes per hour, whichever is the larger requirement. Toilets with extremely high traffic, such as those located in concourse areas, should have a minimum daytime exhaust rate of 2.5 CFM/SF or 19 air changes per hour, whichever is the larger requirement.

Under no circumstance shall a positively pressurized toilet exhaust duct run through a return air plenum or occupied space.

KITCHEN EXHAUST

All kitchens shall be air conditioned. The exhaust requirements shall be based on the number and size of the exhaust hoods installed within the facility. All ovens, fryers and grilles shall have dedicated exhaust hoods serving the equipment. Kitchen exhaust systems shall be designed in accordance with NFPA 96, “Standard for the Installation of Equipment for the Removal of Smoke and Grease-Laden Vapors from Commercial Cooking Equipment.” Heat recovery from kitchen hood exhaust should be considered in the final design if grease build up or collection can be avoided. In addition, make-up air systems for large kitchens must be evaluated. Make-up air should be supplied at the kitchen hoods. Packaged, factory designed and NFPA approved kitchen exhaust hoods with make-up air systems are acceptable.

Under no circumstance shall a positively pressurized kitchen or hood exhaust duct run through a return air plenum or occupied space.

SERVICE LEVEL

A. Ventilation: Provide dampered air intakes and exhaust fans in all electrical and mechanical equipment rooms for adequate ventilation. Air intakes should be from the ramp or apron area. Compliance with applicable fire codes is essential.

B. Heating: Provide hot water or gas-fired unit heaters to heat the storage and equipment room areas where a heat loss is involved.

ATRIUM/HIGH-BAY AREAS

The atrium of the terminal building shall contain a relief air system in the high bay area which will relieve air to exterior due to pressure or temperature build up. A make-up air unit shall also serve the high bay area to provide ventilation air and pressurization when required. These systems shall also be incorporated into a smoke removal system as required by NFPA and the California Building Code for high rise structures.

DISPLACEMENT VENTILATION

Displacement ventilation (DV) is a means of providing cool supply air directly to the occupants in a space. The fresh air, supplied near the floor at a very low velocity, falls towards the floor due to gravity and spreads across the room until it comes into contact with heat sources. It is ideal for high-bay areas for cooling and ventilation only.

Diffusers shall be mounted near the floor level deliver 65°F supply air at less than 75 fpm velocity. Air flow causes a thermally stratified space and vertical air movement towards the return located high in the space.

A single air handling unit shall not be used for displacement ventilation and an overhead forced air system. They should have different supply air temperatures.

AIR INTAKE MINIMUM SEPARATION DISTANCES

Provide separation between exhaust outlet and outside air intakes. Minimum separation distances in Table 204.9.

<table>
<thead>
<tr>
<th>Exhaust Discharge</th>
<th>Distances to Nearest Outside Air Intake*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft Jet Engine Exhaust</td>
<td>25</td>
</tr>
<tr>
<td>Cooling Tower</td>
<td>20</td>
</tr>
<tr>
<td>Fan Exhaust</td>
<td>15</td>
</tr>
<tr>
<td>Plumbing Vents</td>
<td>15</td>
</tr>
<tr>
<td>Kitchen Exhaust</td>
<td>25</td>
</tr>
<tr>
<td>Generator Stack</td>
<td>25</td>
</tr>
</tbody>
</table>

*Minimum separation between exhaust and outside air intake in feet.
SECTION 205 - EQUIPMENT IDENTIFICATION

205.1 GENERAL
All major air handling equipment shall have a unique equipment designation. Engineer shall obtain designation from the SFIA Mechanical Engineer (or the SFIA Mechanical Maintenance group).

SECTION 206 - PC AIR SYSTEMS

206.1 GENERAL
All gates shall be furnished with a stand-alone, DX PC Air unit. When replacement units are installed that are of larger capacity than the original, a hydronic and load analysis shall be performed by the Engineer to verify piping, pumping and chiller capacity. Design calculations and report shall be submitted to the SFIA Mechanical Engineer.

SECTION 207 - EQUIPMENT SUPPORTS

207.1 DESIGN
All equipment supports shall be manufactured systems or designed and detailed by a Professional Engineer licensed in the State of California. Supports shall be coordinated with Architectural and Structural disciplines. Under no circumstances shall the Construction Documents direct a Contractor to provide supports without detailed performance specifications outlining criteria and requirements of supports and their design and installation.

SECTION 208 - ENERGY SOLUTIONS & SYSTEM ALTERNATIVES

208.1 MECHANICAL SYSTEM ALTERNATIVES
As part of the Net Zero Energy program objectives, HVAC system and control alternatives must be evaluated against baseline systems. Such alternative systems shall include but is not limited to the following:

1. Slab hydronic heating and cooling systems
2. Stack natural ventilation and cooling systems
4. Local heat pump systems
5. Heat pump systems with geothermal condenser systems
6. Heat Recovery chillers and tank system storage systems
7. Chilled Beam systems
8. Radiant and convection heating
9. Ventilation alternatives for air quality control
10. Passive systems
11. Non-distributed systems
12. Heat recovery systems
13. Advanced control, technology, and sequencing systems

These systems are only examples of alternatives that should be evaluated as part of the Net Zero Energy program objectives. Coordinate with all disciplines in collaboration to determine the best value using Predictive Energy Modelling.
CHAPTER 3
AIR DISTRIBUTION SYSTEMS

SECTION 301 - AIR DISTRIBUTION SYSTEMS

301.1 DUCTWORK DESIGN
Ductwork layout and sizing shall be done using the best practices to ensure minimum energy loss by thermal transfer and friction. Ductwork shall generally be designed for low pressure, i.e., 2.0 in. w.g. or less. In no instance shall the pressure exceed 4.0 in. w.g. All medium pressure ductwork shall be sized based on the static regain method. All low pressure ductwork shall be sized using either the static regain method or the equal friction method. Existing main ductwork upstream of VAV boxes is considered medium pressure. All ductwork systems shall be designed to minimize noise transmission through the ductwork and avoid noise generation from components or fittings.

Ductwork air velocities shall not exceed the following limits:
A. Mains (equipment rooms and non-occupied spaces) 3000 fpm
B. Mains (occupied spaces) 2000 fpm
C. Branch (or mains w/diffuser connection) 1200 fpm
D. Branch with diffusers 1000 fpm
E. Aspect ratios shall not exceed 4:1 for mains.

Exceptions shall be submitted for review. Allowances can be acceptable depending on the design options and cost impact.

301.2 DUCTWORK REQUIREMENTS
Ductwork shall be either rectangular or round (spiral) as appropriate for the specific application. All designs shall be in accordance with SMACNA "HVAC Duct Construction Standards" and the technical criteria in this manual. All supply air distribution ductwork shall be galvanized sheet metal with flanges, seams, supports, etc., to match the appropriate duct classification as defined by SMACNA unless moisture in the system dictates the use of aluminum or stainless steel materials. Kitchen exhaust ductwork shall be welded stainless steel. Ductwork shall be designed in classification and maximum air velocities for all accordance with ASHRAE: Handbook of Fundamentals, ductwork. Duct Design Chapter, and constructed in accordance with the ASHRAE: HVAC Systems and Equipment Handbook, Ductwork construction shall be tested for leakage prior Duct Construction Chapter, and the SMACNA Design to installation.

Ductwork Classification - Static Pressure Air Velocity Duct Class:
- 250 Pa (1.0 in W.G.) < 10 m/s DN < (2000 FPM DN) Low Pressure
- 500 Pa (2.0 in W.G) < 10 m/s DN < (2000 FPM DN) Low Pressure
- 750 Pa (3.0 in W.G.) < 12.5 m/s DN < (2500 FPM DN) Medium Pressure
- 1000 Pa (+4.0 in W.G.) < 10 m/s DN > (2000 FPM UP) Medium Pressure

Although SMACNA allows spin-in fitting for medium pressure ductwork, the fact they are difficult to differentiate in field inspections from low pressure fitting, spin-in fittings are not allowed at SFIA. Spin-in fittings shall not be represented on plans or sketch for medium pressure systems. Spin-in fittings are allowed on low pressure systems.

All branch take-offs shall be with a 45 degree boot or tap.

Exposed ductwork used as an architectural feature shall be round and constructed of sufficient gage metal to prevent dings or dents. Ductwork material shall be either aluminum finish or suitable for painting. No external insulation shall be provided on architecturally exposed ductwork. Lined ductwork shall be used in exposed areas when radiated sound level exceeds that required.

All 90 degree elbows in both medium and low pressure ductwork shall contain double-walled, air foil type turning vanes, unless long radius elbows are used. Ductwork near air-handling units and outside air ductwork will be lined, as required for thermal performance, noise control and condensation control. The Design Consultant shall designate the calculated duct static pressure on the drawings to establish duct construction classification.
Flexible round duct shall be a maximum of 7 feet in length and be of a material acceptable by the San Francisco Building Code. Elbow into diffusers with flex is acceptable with a long radius turn. Crimping the flex duct at the elbow or under obstructions is prohibited. Aluminum flex duct is prohibited.

301.3 DAMPERS
All volume control dampers shall be opposed-blade type and isolation/shut-off dampers shall be parallel blade type. Outside air intake dampers shall have air-tight seals at both the edges and ends of the blades. The seals shall be of a material that will not disintegrate with exposure to jet exhaust fumes.

Control dampers shall be provided on all main branch take-offs and on the main ductwork downstream of a branch take-off.

All fire dampers shall be U.L. listed and conform to the standards and requirements of the California Building Code. Fire dampers shall be located at all fire zone penetrations and will have access doors provided for service and maintenance.

All combination fire-smoke dampers (FSD) shall be U.L. listed and conform to the standards and requirements of the California Building Code. Fire-smoke dampers shall be located were required by code and have access doors provided for service and maintenance. FSD shall feedback to building Fire Alarm System.

301.4 DIFFUSERS
Various types of diffusers are to be considered based on architectural input. Consideration shall be given to quality, durability, capacity, aesthetics, throw and noise level. Coordinate with the architect all diffuser types and locations. Linear slot diffusers shall be individual, 4-foot maximum sections with individual supply boots. Perforated face diffusers are not to be used.

Sidewall and perimeter diffusers shall be selected based on quality, durability, aesthetics, capacity, throw and noise level. Coordinate with architect all diffusers types and locations. Continuous linear slot diffusers shall be individual 4 (four) foot maximum sections with an individual supply boot. NC levels at the diffuser and at the neck connection should be consistent with design sound levels in rooms.

301.5 GRILLES
Standard core 1/2" x 1/2" x 1/2" eggcrate grilles shall be used in return air plenums/systems. Eggcrate grilles shall have a minimum free area of 90%. Perforated face, louvered-face or other face types shall not be used in return air systems in smoke control areas.

301.6 TRANSFER AIR
Transfer air openings are required in all walls to structure in return air plenums and smoke control zones. Transfer air openings shall be sized for a maximum velocity of 200 fpm in smoke zones and 500 fpm in return air plenums that are not used for smoke control. Sizing shall accommodate the entire return air/smoke control system to the point of installation.

301.7 VAV TERMINAL AIR UNITS
Designer shall ensure all components of VAV terminals are completely accessible for maintenance and no additional HVAC or Tenant equipment is required to be removed from operation in order to complete maintenance activities. Control modules shall have a minimum twenty-four (24) inches of clear space to allow for maintenance activities.

301.8 SECURITY GRATES
Security grates shall be installed on all ductwork and transfer air openings larger than 144 square inches between public spaces and private spaces. All roof penetrations larger than 144 square inches with a direct path of access to indoors shall be required to have a security gate.
SECTION 401 – OVERVIEW

401.1 EXISTING CAMPUS HEATING/COOLING SYSTEMS OPERATION
Chilled water and heating hot water for the HVAC systems in the Terminal buildings are supplied from the Central Plant.

SECTION 402 – EQUIPMENT

402.1 CHILLED WATER SYSTEM
The chilled water system shall be configured with multiple water circulation loops. The primary loop is the “chiller loop”, which uses chiller pumps in parallel and header to circulate water through the chillers which are piped in parallel.

The second circulation loop shall be a variable flow system. The secondary loop distributes the chilled water from the primary “chiller” loop to the terminal buildings. Pumps in parallel supply the distribution piping with chilled water. The pumps shall be staged on and off based on chilled water demand.

Variable chilled water flow is provided in response to signals from differential pressure controllers in the secondary loop circuit. The controllers shall cycle the secondary loop pumps to maintain sufficient pressure differences between the secondary supply and return mains to provide chilled water to the most remote tertiary sub-circuit.

The water service to the end use equipment is provided from the tertiary loop variable chilled water flow pumps which are provided at each tertiary equipment area. These systems to be equipped with differential pressure controllers and the tertiary pumps shall vary to provide adequate flow to the most remote sub-circuit.

Flow measuring devices will be required in each loop and sub-circuit.

402.2 HEATING SYSTEM
Heating in all building spaces shall be provided by high-temperature hot water from hot water generators (boilers) located in the Central Plant. The hot water system will consist of a primary “boiler” loop; a secondary high-temperature hot water distribution loop; heat exchangers and a tertiary distribution loop serving the Terminals. Hot water boiler pumps shall be equal in number to the boilers and shall circulate and maintain a constant temperature in the primary boiler loop (reset with outside temperature). The secondary loop will consist of pumps in parallel supplying a variable flow as required by demand and differential pressures. The tertiary loop pumps shall provide a variable flow sufficient to maintain a differential pressure between supply and return legs of the most remote unit on the tertiary loop.

402.3 HYDRONIC REQUIREMENTS
Chilled or Heating Water shall be sized for a maximum of 10 feet pressure drop per 100 feet of equivalent pipe for any run, but no more than an average of 4 feet pressure drop per 100 feet of equivalent pipe for the entire connected system. Circuit setters or balancing valves shall not be used for equipment isolation.

A. Hydronic design temperatures for Secondary Loops:
   1. Chilled Water Supply Temperature: 40°F
   2. Chilled Water Return Temperature:  60°F
   3. Heating Water Supply Temperature: 300°F
   4. Heating Water Return Temperature:  200°F

B. Hydronic design temperatures for Building Tertiary Loops:
   1. Chilled Water Supply Temperature:  40°F
   2. Chilled Water Return Temperature:  60°F
   3. Heating Water Supply Temperature: 180°F
   4. Heating Water Return Temperature:  140°F

402.4 PIPING AND VALVES
Piping for both the central plant and the distribution systems shall be designed to minimize pressure losses and maximize energy use efficiency. Valves to be specified for equipment servicing shall be selected to minimize losses while open, and have suitable pressure drop characteristics for intended use. The piping shall be designed to allow for central plant equipment expansions.

Control valves shall be sized for the correct and appropriate Cv value at the design flow rate. All valves shall be suitable for extended service operation without extensive requirements for lubrication or servicing. Control valves shall be Flow Control Industries Delta P valves.

Tees, valves and blind flanges shall be provided to allow for additions of equipment and piping to the central plant without interruption of services. Double block and bleed valves required for high pressure systems. Piping systems shall be sized for ultimate loads. Tees, valves and blind flanges shall be provided on distribution piping systems for expansion of distribution systems; sectional valves shall be provided in the distribution piping for piping system repairs and at key locations to provide isolation and servicing of equipment. On compressed air lines, quick disconnect connections shall be installed down stream of sectional valves to enable use of portable compressors in emergencies. The piping design and materials selection shall be in accordance with ANSI/ASME Standard B31.9 Building Services and ANSI/ASME Standard B31. Power Piping.

402.5 PUMPS
Pumps shall be selected for maximum operating efficiency, (i.e., slightly to the right of maximum efficiency point on the pump curve). The motor shall exceed BHP by a minimum of 10%. The preferred operating motor speed is 3500rpm.

Single pumps to be used in throttling applications without variable speed drives shall have relatively flat performance curves and be selected for operation on the pump performance curve to the right of the point of highest efficiency. Multiple pumps for parallel operation shall have relatively steep performance curves. Multiple pumps for series operation shall have relatively flat performance curves. Pumps for variable speed drive (VSD) applications shall have relatively steep performance curves. All pumps shall be specified with suction and discharge flange taps for pressure gauge connections. Provide all VSD pumps with matching VSD compatible motors. Pumps VSD shall be mounted close to pump motor.

The final selection of pump types and the application arrangement shall be made to maximize pump efficiency without excessive initial pump costs. All pumps that are selected for both current and future needs will be sized for the future requirements, where practical, and equipped with the necessary accessories. The lower initial performance requirement will be met by balancing valves or by the use of a trimmed impeller to provide energy efficient operation in start-up performance.

Standby pumps and accessories shall be provided for both heating and cooling systems. Pumps shall be arranged in a parallel configuration and header so as to maximize pumping flexibility.

Generally: Vertical turbine pumps shall be used for pumping cooling tower water. Hydronic water applications shall use end suction pumps for flow rates below 500 GPM. Horizontal split-case, double suction pumps shall be used for flow rates above 500 GPM.

Vertical split case, double suction pumps will be allowed for use with flow rates above 500 GPM, only in existing rooms when adequate space for horizontal arrangements does not exist.

Mount pumps to housekeeping pad with seismic isolation. Pump installation shall include inlet isolation valve, outlet isolation valve, suction diffusers, triple-duty valves with inlet strainer, inlet pressure gauge, outlet isolation gauge and temperature gauges. Double block and bleed valves required for high pressure systems. All valves shall be accessible and gauges shall be readable.

402.6 MOTORS
Electric motors shall conform to NEMA Standards. All 3-phase motors shall be high efficiency type. Motors shall not be selected for operation in the service factor range.

The minimum system installed power factor shall be 90% with a goal to attain a 95% system power factor. Motors larger than 15hp shall have power factor correction.

Motors shall be specified to be provided with adequate thermal protection, integral or external control and branch circuit protection, and starters suitable for use with the motors. Motor and starter types shall be selected to minimize voltage
fluctuations and current surges. Motors and starters shall be provided with auxiliary contacts for control and operation interface with the central Energy Management Control (EMC) system and any other control functions included.

402.7 WATER TREATMENT
Chemical treatment systems shall be provided at the Central Plant for the protection of the chilled water, condenser water and hot water systems from scale, corrosion, biological growths and suspended solids.

Any system connecting shall not have glycol or separate chemical treatment system. Any chilled water, condenser water and/or hot water systems not connected to the Central Plant hydronic distribution system shall have a chemical treatment system.

SECTION 403 - DESIGN CRITERIA

403.1 GENERAL REQUIREMENTS
The hydronic systems design shall be based upon the criteria following:

A. Piping shall be designed in accordance with the technical criteria in Section IV of this manual. Water pipe sizing shall be based on the stricter of the two following parameters:

<table>
<thead>
<tr>
<th>Pipe Size*</th>
<th>Max. Velocity (fps)</th>
<th>Max. Pressure Drop** (ft per 100ft pipe)</th>
<th>Materials</th>
<th>Fittings</th>
<th>Isolation Valve</th>
</tr>
</thead>
<tbody>
<tr>
<td>½” thru 2”</td>
<td>4</td>
<td>8.5</td>
<td>Type K Copper</td>
<td>Soldered</td>
<td>3-Piece Ball Valve</td>
</tr>
<tr>
<td>2 ½” thru 4”</td>
<td>6</td>
<td>4.5</td>
<td>Type K Copper</td>
<td>Soldered</td>
<td>3-Piece Ball Valve</td>
</tr>
<tr>
<td>6” thru 12”</td>
<td>8.5</td>
<td>2.5</td>
<td>Sch 40 Steel</td>
<td>Welded/Flanged****</td>
<td>Lug Butterfly Valve</td>
</tr>
<tr>
<td>14” thru 20”</td>
<td>10.5 (14)***</td>
<td>2.5</td>
<td>Sch 40 Steel</td>
<td>Welded/Flanged****</td>
<td>Lug Butterfly Valve</td>
</tr>
<tr>
<td>24” thru 42”</td>
<td>11 (14)***</td>
<td>1.5</td>
<td>Sch 40 Steel</td>
<td>Welded/Flanged****</td>
<td>Lug Butterfly Valve</td>
</tr>
</tbody>
</table>

* Minimum ½” for coil connection only. Provide ¾” minimum for branch lines.
** Based on new, clean steel pipe
*** Number in parenthesis is velocity limit applicable to long straight runs where noise is not critical (such as pipe tunnels, etc.). Maximum pressure drop still applies.
**** Mechanical coupling is an option for CHW only in mechanical rooms.

B. Due to availability issues and relative cost, 5-inch piping and valves shall not be used.
C. Pressure drops in piping systems shall be calculated to allow for aging and corrosion of the interior surface. Therefore, all water piping systems shall be designed with the following friction factors ("C" values) based on the Hazen Williams Friction Factor formula.

<table>
<thead>
<tr>
<th>&quot;C&quot; Value</th>
<th>&quot;C&quot; Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed Water Systems</td>
<td>120</td>
</tr>
<tr>
<td>Closed, Treated Water Systems</td>
<td>130</td>
</tr>
<tr>
<td>Open Water Systems</td>
<td>100</td>
</tr>
<tr>
<td>(New clean steel pipe)</td>
<td>(140)</td>
</tr>
</tbody>
</table>

D. Hot and chilled water distribution systems should be designed for variable volume flow.
E. Hydronic systems should be designed for widest practical delta T and the closest possible approach of the return water temperature to the terminal equipment supply air temperature.
F. The terminal equipment must be selected not only for its full load capacity, but also for its performance over the full range of partial loads. Laminar fluid flow in the coils shall be avoided.
G. Integral face and bypass coils should be utilized with preheat coils.
H. The impact of the change in volume due to thermal expansion of the distribution system fluids during all operations must be addressed in the design process. Show anchorage points, pipe guides, flex joints and expansion loops.
I. Control valves in hydronic systems must not be oversized. The flow characteristics and pressure drops are to be selected for the appropriate Cv value corresponding to the design flow to be controlled.
J. Provide automatic air vents at all coils and at the high points of all piping. Provide drains at the low points of all piping. Vents shall be accessible and well-marked.
K. Provide isolation shut-off valves at all equipment and branch lines. Double block and bleed valves required for high pressure systems. All isolation valves shall be accessible.
L. Hydronic systems controls shall be automatic and adjustable to optimize pumping and thermal efficiency.
1. When close control is essential, do not use three-way valves either for output control in constant-volume-flow systems or for blending control in any variable-volume-flow systems, since their characteristics are of the linear type. Provide equal-percentage valves.

2. When using three-way valves for throttling, avoid pressure under one port being significantly higher than under the other.

3. Use mixing three-way valves with caution for flow diversion or diverting valves for mixing since the valves have tendencies to slam shut at reduced flows.

4. Use two-way valves at terminal coils in variable flow systems.

5. Hot water coil valves shall fail to the open position.

403.2 EXPANSION REQUIREMENTS
In modular buildings that are designed for to be expanded as the Airport capacity increases (such as Concourses and the Terminal) all hydronic systems shall be sized for the maximum build out of the facility. Piping flow diagrams shall indicate all calculated flow rates of all general spaces anticipated for future construction.

403.3 CHILLED WATER SYSTEM
The chilled water system is configured with multiple water circulation loops. The primary loop is the "chiller loop", which uses chiller pumps in parallel and header to circulate water through the chillers which are piped in parallel.

The pumps are connected in parallel on suction and discharge headers with a 1-to-1 ratio of chiller pumps to chillers. Pumps provide a constant flow to each chiller.

The secondary circulation loop shall be a variable flow system. The secondary loop distributes the chilled water from the primary loop to the secondary loop which loops through the terminals and concourses. Pumps in parallel supply the distribution piping with chilled water. The pumps shall be staged on and off based on chilled water demand (based on differential pressure).

Variable chilled water flow in the secondary loop is provided in response to signal/signals from differential pressure controllers in the secondary loop circuit. The controllers shall cycle the secondary pumps to maintain sufficient pressure differences between the secondary supply and return mains.

The tertiary circulation loop shall be a variable flow system. The tertiary loop distributes the chilled water from the secondary loop to the terminal building, concourses and areas to be served with Central Plant cooling. Tertiary pumps are located in terminal mechanical rooms. Pumps in parallel supply the distribution piping with chilled water. The pumps shall be staged on and off based on chilled water demand.

Variable chilled water flow in the tertiary loop is provided in response to signal/signals from differential pressure controllers in the tertiary loop circuit. The controllers shall control the tertiary loop pumps to maintain sufficient pressure differences between the tertiary supply and return mains to provide chilled water to the most remote sub-circuit.

Flow measuring devices will be required in each loop and sub-circuit. For each new tertiary loop provide a BTU meter with data logging.

403.4 HEATING SYSTEM
Heating in all building spaces shall be provided by high-temperature hot water from boilers located in the Central Plant. The hot water system will consist of a boiler loop; a secondary high-temperature hot water distribution system loop and heat exchanger with tertiary distribution loop serving the terminal units. Hot water boiler pumps are equal in number to the boilers and circulate and maintain a constant temperature in the boiler loop. The secondary loop consists of pumps in parallel supplying a variable flow, as required by demand and differential pressures, to the secondary loop.

The water service to the end use equipment is provided from the tertiary loop variable hot water flow pumps which are provided at each tertiary equipment area. These pumps are to be controlled to maintain supply water temperature in the tertiary loop, with these systems to be equipped with differential pressure controllers to insure adequate flow to the most remote sub-circuit.

Provide one stand-by pump for each loop system. Tertiary loops reduce the hot water temperature to 180/140 degrees F (supply/return) through heat exchangers.
Flow measuring devices will be required in each loop and sub-circuit. For each new tertiary loop provide a BTU meter with data logging.
SECTION 501 – GENERAL

501.1 GENERAL
A complete system of automatic controls shall be provided to maintain space conditions within allowable limits. When heating and cooling is incorporated in one system for personnel comfort, the automatic temperature controls shall not be capable of simultaneous heating and cooling and shall provide a "dead band."

The system shall consist of all necessary control devices, control valves, control dampers, damper motors, electric switches, relays, gages, panel boards, and fittings, including all necessary accessories required for a complete and operative control system. All control wiring and control system electric power is to be furnished to provide a complete of environmental control and central panel functions.

Control systems shall be electronic, digital systems controlling all HVAC equipment utilizing local microprocessor control panels located in the applicable adjacent equipment rooms. The field panels shall be capable of interfacing with central (EMCS) equipment provided by a different vendor.

The local field panels shall be tied to the master Energy Management Control System (EMCS) server, but capable of stand-alone operation.

501.2 EMCS LEVELS AND ARCHITECTURE
EMCS shall be Direct Digital Control (DDC) based system for providing lower operating costs and ease of operation. The BAS (Building Automation System) shall adjust building systems to optimize their performance and the performance with other systems in order to minimize overall power and fuel consumption of the facility.

BAS shall utilize 'open' communication protocols, such as BACnet, to minimize the costs of providing integration and to allow interoperability between building systems and control vendors. A/E to specify and include functional design manual, hardware manual, software manual, operation & maintenance manual, and as-built drawings with sequence of operations. BAS shall have energy management and monitoring software.

EMCS Architecture shall include standalone zone or terminal controls with local control panel (LCP) for centralize HVAC equipment. Building level controls (BLC) shall integrate all LCP in the building, Boarding Area, and Terminal. The all new projects shall provide full communication with the EMCS system. Projects must provide fiber, server, address, graphics, and programming to integrate new HVAC control systems with the existing EMCS system.

501.3 INTEGRATION:
All BLC systems shall be capable for standalone operation at the local level. And all BLC systems shall be coordinated and provided with full integration, control, communication, monitoring, and connectivity to the front end SFIA EMCS. Design and coordination shall be indicated in drawings and in control architectural diagrams. Details of IT network connections and server addresses must be specified with communication fiber routing as part of the BLC system design. Front end EMCS graphic upgrades and additions must be included as part of every new BLC. For all integration work, drawings and/or specifications shall clearly state responsibility of each contractor as follows:

"Controls System 'A' will be the lead system for this integration. Controls System 'B' will need to be compatible with the protocol used by Controls System 'A'. Manufacturer of Controls System 'B' will be responsible for ensuring this compatibility."

501.4 ENHANCED COMMISSIONING
Enhanced Commissioning is mandatory on all LEED projects. The intent of Enhanced Commissioning is to further support the design, construction, and eventual operation of a project that meets the owner’s project requirements for energy, water, indoor environmental quality, and durability.
As part of Enhanced Commissioning the following activities must be completed for mechanical, electrical, plumbing, and renewable energy systems and assemblies in accordance with the latest revisions of ASHRAE Guidelines for HVAC&R systems, as they relate to energy, water, indoor environmental quality, and durability.

A. Develop/Review Owner’s Project Requirements (OPR), Basis of Design (BOD), and project design.
B. Develop/Implement a Commissioning (Cx) Plan.
C. Confirm incorporation of Cx requirements into the construction documents.
D. Develop construction checklists.
E. Develop a system test procedure and verify system test execution.
F. Maintain an issues and benefits log throughout the Cx process.
G. Prepare a final Cx process report.
H. Review contractor submittals.
I. Verify systems manual updates and delivery.
J. Review building operations 10 months after substantial completion.
K. Develop an on-going commissioning plan.
L. Front End EMCS control and integration

501.5 MEASUREMENT AND VERIFICATION
Measurement and Verification (M&V) is mandatory on all LEED projects. The intent of M&V is to provide for the ongoing accountability of building energy consumption over time.

Develop and implement a Measurement and Verification (M&V) plan consistent with the International Performance Measurement & Verification Protocol (IPMVP). The M&V period must cover at least 1 year of post-construction occupancy. Provide a process for corrective action if the results of the M&V plan indicate that energy savings are not being achieved.

SECTION 502 - ENERGY MANAGEMENT CONTROL SYSTEM (EMCS)

502.1 ENERGY MANAGEMENT CONTROL SYSTEM (EMCS)
New EMCS systems shall be a direct digital controls system. New EMCS shall be open-communication protocol BACNET and be manufactured by commercial manufacturer. Each new control loop shall be a standalone system designed to be programmed and operated from a building PLC work station. All mechanical rooms will be equipped with local equipment level PLCs. All zone level controls shall be standalone loops and designed to communicate back to the equipment level PLCs.

Building PLCs shall communicate information, control functions, alarms, and monitoring data back to the Front End. EMCS Architecture and IT servicer interface must be integrated as part of the renovation or new building project. Cable, conduit, fiber, and switch, IT server, and address shall be provided as part of the new project. It is the responsibility of the of the new building or renovation project to provide the communication and integration back to the EMCS server. All work shall be provided such that new EMCS shall be monitored, controls, alarmed, and programmable from the master workstation. Provide all front end programming, graphics, and hardware to suit the new EMCS installed as part of the building renovation or new building design. For all integration work, drawings and/or specifications shall clearly state responsibility of each contractor as follows:

“Controls System ‘A’ will be the lead system for this integration. Controls System ‘B’ will need to be compatible with the protocol used by Control System ‘A’. Manufacturer of Control System ‘B’ will be responsible for ensuring this compatibility.”

Additional requirements for the EMCS are detailed below in the following subsections.

502.2 EMCS NAMING STANDARD
All points within the EMCS shall comply with SFO Naming Convention. SFO Engineer shall provide the most current SFO Naming Convention to the Contractor. If Naming Convention for a system does not exist, Contractor shall provide a submittal of all points to SFO Engineering for review and approval prior to starting construction. Comply with latest SFO Information Infrastructure Management (IIM) standards.

502.3 EMCS GRAPHICS
Comply with latest Energy Management Control System (EMCS) specification.
502.4 SOFTWARE
The EMCS and all equipment under its control must follow ASHRAE Guideline 36P High Performance Sequence of Operation for HVAC Systems. The Design Consultant shall review the current stage in the development of universal protocol and make every practical effort to incorporate this into the temperature control automation system.

The software shall have, but are not limited to, the following capabilities:
- A. Run Time
- B. Optimum Start/Stop
- C. Economizer Controls
- D. Time of Day Scheduling
- E. Chilled Water Outdoor Air Reset
- F. Hot Water Outdoor Air Reset
- G. Variable Condenser, Hot, and Chilled Water Pumping
- H. Night Set Back
- I. Status
- J. Change of Status
- K. Smoke Venting and Control
- L. Ambient High/Low Alarms
- M. Energy Totalizing
- N. Electrical System Monitoring
- O. Maintenance and Alarm Reports
- P. Heating/Cooling Mode

502.5 TREND LOGGING AND GRAPHING
Trend logs and graphing capability shall be provided.

502.6 ALARM PRINTOUTS
All alarms shall be on the display monitor, providing information on the type of alarm, time and date of occurrence. Change of state alarms are to be programmed to be disabled or enabled at the option of the operator.

502.7 SYSTEM ACCESS CONTROL
Provide access control (passwords) for system operation.

502.8 REPORT CAPABILITY
The software shall be capable of being user programmed to generate custom user designed reports.

Basic Report Printouts required are as follows:
- A. Alarm Summary
- B. Run Time Summary
- C. Maintenance Reports
- D. Energy Usage Reports
- E. Utility Consumption Reports

502.9 Automated Fault Detection and Diagnostics (AFDD)
The EMCS software and sequence of operations shall comply with all Automatic Fault Detection and Diagnostics (AFDD) requirements in ASHRAE Guideline 36P High Performance Sequence of Operations for HVAC Systems. The AFDD system must detect faults based on sensor inputs, as well as suggest likely cause(s) based on fault condition. The AFDD logic must send direct errors from the EMCS Front End to SFO Main Saver work order system for maintenance, troubleshooting and/or calibration.

SECTION 503 – CONTROL COMPONENTS

503.1 THERMOSTATS
Zone thermostats mounted in public areas shall be sensors only with controllers. Zone thermostats in private areas shall be programmable.
503.2 CARBON MONOXIDE AND NITROGEN DIOXIDE SENSORS
Carbon monoxide and nitrogen dioxide sensors shall be provided in the service drive or wherever internal combustion engine traffic is utilized in an enclosed space. Sensors shall increase air flow and/or alarm out-of-tolerance conditions.
SECTION 601 – GENERAL

601.1 GENERAL
Mechanical equipment and layout shall be selected to maximize equipment performance; and minimize equipment servicing, repair and maintenance. Equipment selection shall also consider durability, reliability, maintainability and serviceability. Equipment arrangement and layout shall allow for safe and efficient accessibility for equipment removal, replacement, repair and maintenance. Provide sufficient service corridors, pathways, fall protection, and door access to deliver replacement equipment and parts.

During the design phase, coordination with other design disciplines is essential to provide for the necessary access to equipment. All otherwise inaccessible equipment and equipment components shall be provided with OSHA approved catwalks, platform, or etc. to allow maintenance. The catwalks, platforms, and adequate lighting, etc. shall provide for maximum safety to both personnel and equipment while allowing access for equipment maintenance. Standardization of equipment and materials shall be used to the maximum extent possible. Standardization and interchangeability will minimize the space and expense of the maintenance spare parts inventories. Items for consideration for standardization shall include, but not be limited to: Air handling units and components, terminal units, control components, heat exchangers, pumps, valves, and fans.

SECTION 602 - DESIGN REQUIREMENTS

602.1 DESIGN
The design shall, in general, include equipment layouts with maintenance and repair clearances indicated. Special maintenance items or equipment, or necessary auxiliary equipment shall be specified to be provided and installed with the equipment it is to serve. Avoid locating equipment requiring frequent service or repair above ceilings or in occupied spaces. Hydronic systems and associated gauges check valves, and shutoff valves all need to be design for ease of access, inspection, and maintenance. Air side systems and components should also be designed and configured for ease of access inspection, and maintenance.

602.2 EQUIPMENT SELECTION
Equipment shall be selected for stable operation at both full and part-load conditions. Equipment selections shall be below maximum limits for capacity, speed, temperature and pressure. The equipment installation design and specification shall include sufficient instrumentation for measuring, indicating, monitoring, operating and servicing at full and part loads.

602.3 BEARINGS
Use permanently lubricated bearings on fans, if available. Equipment which cannot be furnished with permanently lubricated bearings shall have lubrication lines extended to the exterior of the unit.

602.4 CONSTRUCTION REQUIREMENTS
Require the contractor to include in the shop drawing submittals manufacturers recommended spare parts lists, maintenance and service clearances, special maintenance equipment or requirements and recommended maintenance schedules. Conflicts between equipment and maintenance requirements or clearances shall be submitted, along with contractors’ solutions to the conflicts, for approval. Approval of conflict resolution shall be required before equipment installation.

Require the contractor to revise all flow diagrams, control diagrams and additional information to reflect any revisions to designed systems and/or required performance capabilities to suit the actual equipment installed. Require the contractor to provide instruction for operating personnel on the operation, attendance and maintenance of equipment. Include all data necessary to establish an efficient and effective preventive maintenance program.

602.5 FAN HOUSING
All supply fan housings shall have ladder rungs mounted on the side of each unit next to the coil pipe connections to provide access to the top of each unit without stepping on insulated pipes.
602.6 ACCESS DOORS

All air handling units shall be equipped with access doors for each compartment (coils, filter, fan, etc.), with piano hinges, door handles, and a viewing window in each compartment access door. The doors should be sturdy enough to permit opening the door using one handle.

Provide in accessible locations access doors of adequate size at all fire damper locations for the purpose of inspection as well as for replacing fusible links.

For combination fire-smoke dampers (FSD) provide ceiling access doors and duct access doors. Access doors shall be properly located and size for adequate access to the FSDs. Duct access doors shall be properly labeled.

Labeling and service access shall be provided for all controllers and duct sensors.

SECTION 603 - SPACE REQUIREMENTS

603.1 MECHANICAL ROOMS

Mechanical room space requirements and dimensions shall be coordinated with the architect so that appropriate space is provided for the equipment and its service and maintenance.

603.2 MECHANICAL CHASES

Mechanical chase space requirements shall also be determined and coordinated, including space for supply and return air ductwork, outside ventilation air, exhaust air, hot and chilled water piping, domestic water piping, sanitary drainage, and roof drains, etc. All chases with plumbing equipment shall have a minimum one floor drain.

603.3 EQUIPMENT CLEARANCE

Provide a minimum of four feet (clear space) around all sides of boilers and chillers, plus tube pull space. Provide three feet (clearance space) around all sides of pumps, and air handling equipment. These are minimum design requirements, if manufacturers recommendations exceed these values, Design Consultant shall comply with the more stringent requirement.

All rooftop equipment shall be serviceable through existing roof access.

Drawings shall show minimum clearances for service and access to equipment.

603.4 CONVEYOR RIGHT OF WAY

In certain areas baggage conveyors will be routed through ceiling plenums. The space requirement for these conveyors will be approximately 4 feet deep by 4 feet wide per conveyor, plus the additional space needed for personnel cat walks (preferable 4 feet wide). Therefore, all ductwork must be routed to avoid conveyors and structural members. Physical space may prohibit ductwork crossing baggage conveyors. Careful coordination is required.

Design Consultant shall coordinate with all systems and disciplines throughout the design process to insure adequate space is available and to avoid interferences.
SECTION 701 - PLUMBING SYSTEMS

701.1 GENERAL
This section applies to the systems used to receive, transport or discharge liquid waste or sewage; the systems used to receive and distribute potable water; the systems used to receive and distribute fuel gas; the systems used for the collection and transport of rain water and cooling coil condensate drains, etc.

701.2 DESIGN SUBMITTAL REQUIREMENTS
A. Provide enlarged detailed plumbing plans for restroom and concession areas.
B. Provide pipe elevations including invert elevations and slopes on all drainage piping.
C. Reference related civil utility drawings for continuation of piping connecting to drainage stub-outs connecting to site utility mains.
D. Provide a pipe size and drainage fixture unit table, calculation, and piping diagrams indicating pipe sizes and drainage fixture unit loading for the sanitary soil, waste and vent system(s).
E. Provide existing system load analysis to validate tie-in connections and existing system capacity to support new work and new loads.
F. Provide piping diagrams indicating pipe sizes and water supply fixture unit loading for the domestic cold water, domestic hot water and recycled water systems.
G. Provide natural gas piping diagram showing pipe sizes, developed lengths of pipe lengths and gas loads in (BTUH/CFH) for each equipment connection, pipe main and branch lines. Diagram to include all meters, gas valves, regulators, gas vent pipes and related equipment.
H. All data such as ultimate water and gas service demand, sanitary and storm analysis report shall be submitted for review.

701.3 SYSTEM REQUIREMENTS
A. Facilities for the physically handicapped shall be provided in all public building restrooms.
B. Provision shall be made within the terminal building and each of the concourses for future expansion of the plumbing systems at such time that the complex is expanded to meet increased usage.
C. Buildings, in the Terminals and Concourse areas, shall be provided with roof drains and a drainage collection system. The roof drainage system shall be connected to the exterior storm sewer system. Overflow roof drain system shall be piped separately and terminated at grade level.
D. An industrial waste sewer shall be provided for all liquid wastes that would be detrimental to the public sewer system or detrimental to the operation of a sewage treatment plant. Industrial waste shall be collected, treated and disposed of as required by the authority having jurisdiction.
E. Reclaim water system shall be provide for all new restroom facilities.
F. Plumbing systems are defined to be within the building up to 5 feet from the building perimeter. All systems beyond this point shall comply with utilities design guides and specifications.

SECTION 702 - PLUMBING DESIGN PARAMETERS

702.1 GENERAL
All plumbing systems shall conform to the requirements of the codes and standards.

702.2 FIXTURE COUNT
To determine the minimum number of fixtures required for the terminal and concourse areas a plumbing fixture count method shall be used. The plumbing fixture method is a method of adjusting the numbers of people on which the number of fixtures are determined in setting the design for the plumbing facilities. After the numbers of people are appropriately adjusted, the fixture per persons for the type of building or occupancy from the uniform plumbing code shall be used for determining the minimum plumbing facilities.

The plumbing fixture method typically allows for additional fixtures for peak loads not adequately accounted for by the codes. The basis for the plumbing fixture count method is based on historical airport experience and the following criteria:
A. Projected Peak Occupancy (per area).
B. Thirty-three percent of passengers and 15 percent of visitors will use concourse facilities. (Departures and arrivals levels.)
C. Fifteen percent of visitors and fifteen percent of passengers will use terminal building facilities.
D. The percentage of men and women of total occupancy is estimated at 50 percent male/50 percent female.
E. Each level and area shall be sub-divided into terminal public space, restaurant, office and retail to determine fixture count for each particular occupancy.
F. Urinals shall be utilized in lieu of water closets in men’s toilets to the maximum ratio allowed by code.

Fixture counts and/or flow rates shall be shown on all isometric drawings.

702.3 CALCULATIONS
Design calculations shall be based on ASPE Data Book (Chapter 8) and the California Plumbing Code, latest edition. Recognized acceptable engineering practices shall be applied for areas where design criteria have not been established specifically by these codes and standards.

Several areas of the Terminal and Concourses experience dramatic pressure fluctuations. The engineer shall make every effort to ensure that new designs do not amplify current conditions. In these areas, static and dynamic pressure calculations shall be performed and submitted.

No assumptions shall be made on plumbing system capacities. All connections to existing plumbing systems shall have capacity calculations proving capacity. The design consultant shall submit all calculations directly to the SFIA Mechanical Engineer in PDF format.

702.4 TERMINAL
The terminal building plumbing facilities shall be designed for optimum passenger use and the total future terminal size to prevent under-sizing of initial terminal building plumbing facilities.

702.5 CONCOURSES
The plumbing facilities in the concourses shall be designed for the current initial passenger use. Expansion in concourse passenger service will be in conjunction with concourse construction expansions. Those expansions will include the necessary additional plumbing facilities. Plumbing utility systems (pipe sizes and arrangement) shall be designed to allow for future facilities expansion.

702.6 SAND TRAPS
Sand or dirt from plumbing fixtures or floor drains shall be connected and disposed of by means of sand traps prior to flow entering Airport system. Design capacity and accessibility shall be subject to SFIA approval.

702.7 INDUSTRIAL WASTE
Industrial waste sewer shall be provided for areas where fueling of aircraft and vehicles take place.

702.8 GREASE AND OIL SEPARATORS
Grease, fats and oils in waste water from kitchen sinks, dishwashers, floor drains or other fixtures, shall be collected and intercepted with grease or oil separator prior to entering Airport sanitary sewer system.

Location of grease or oil separator shall be such that hot grease, fats or oils, shall have adequate time to cool and separate out before waste water enters Airport system. Separators shall be easily accessible for proper cleaning.

702.9 FLOOR DRAINS
Buildings shall be provided with floor drains that have traps and cleanouts. The location and types of all cleanouts shall be noted on the drawing. All drains exiting the building shall have a double cleanout so that the drain line may be cleaned into and out of the building.

Mechanical rooms shall contain general area floor drains and equipment drains for condensate and other miscellaneous drainage. Equipment drains shall not serve dual duty.
All floor drains in chases, basement areas, restrooms, mechanical rooms and entry vestibules shall have trap primers.

702.10 BACKFLOW PREVENTION
The potable water supply system shall be designed, installed and maintained in such a manner as to prevent the contamination from non-potable liquids, solids or gases being introduced into the potable water system through cross-connections or any other connections to the system. Protective measures and the requirement for backflow prevention devices shall meet or exceed the requirements of the California Plumbing Code, San Francisco Building Code Amendments and the requirements of water utility. If there is any conflict between these requirements the most stringent requirement shall apply in the design and/or modification to the existing potable water system. Should existing systems be found that do not comply with the latest backflow prevention requirements, the design will include upgrading the backflow prevention of that system being renovated, added to and/or constructed. All domestic water connections to mechanical, plumbing and fire protection systems, including lawn sprinkling systems, shall be protected from backflow by use of backflow preventers installed in the piping. Plumbing designs shall meet best management practices for cross connection control.

702.11 COORDINATION
It is the responsibility of the plumbing engineer/designer to provide design, specification and detail of all plumbing connections to systems outside of the building (IE: water, storm drainage, sanitary sewer, natural gas, etc). The interface point shall note elevations (building reference and civil reference), sizes and acceptable means of connection of differing materials and allowable tolerances of connection. “See Civil” notes shall not be used to solely identify this connection.

SECTION 703 – PLUMBING SYSTEMS

703.1 STORM DRAINAGE SYSTEM
A. Storm Drainage piping system shall consist of roof drains, overflow drains, area drains, and storm sewer building mains and branch lines for roof drains/overflow drains discharging into a gravity drainage piping system, settlement joints, and connection to the existing pipes and site sewer mains.
B. Horizontal storm drain and overflow drain lines including roof drain bowl shall be wrapped with ¼” thick fiberglass insulation to prevent condensation. Exception, pipes located above the vehicle service roads.
C. Storm water pipe sizing shall be per the California Plumbing Code with the rainfall intensity based on a 1.6 inches per hour rainfall intensity.
D. A minimum slope of one-eighth (1/8”) inch per foot or 1% for gravity storm drainage shall be used.
E. Due to ground settlement, all underground storm drain piping shall be supported from the underside of the floor slab and or the vertical faces of the pile caps using Type 316 stainless steel hangers.

703.2 SANITARY SOIL WASTE AND VENT SYSTEM
A. Sanitary sewer system shall consist of sanitary soil, waste and vent connections to plumbing fixtures with gravity drainage piping system for the plumbing fixtures, stub-outs for future tenants including connections to existing pipes, pipe settlement joints, pipe supports, seismic bracings, and connections to site sewer.
B. Underground piping shall be wrapped with 8 mil polyethylene tube encasement in accordance with AWWA C105.
C. A minimum slope of one-fourth (1/4”) inch per foot or 2% for gravity sanitary sewer lines shall be used where possible.
D. Due to ground settlement, all underground soil, waste and vent piping shall be supported from the underside of the floor slab using Type 316 stainless steel hangers, supports and anchors.

703.3 GREASE WASTE SYSTEM
A. Provide 4 inch grease waste line stub-outs for food concession tenants located below the footprint of each food concession space. Provide grease waste piping from the stub-out to the location of future above ground grease interceptor. Provide 4 inch sanitary waste and 4 inch vent stub-outs for future grease interceptor installation.
B. Provide grease interceptor for the Airside Loading Dock floor drains including H20 rated manholes. Grease interceptor shall be supported from the floor slab with type 316 stainless steel supports.
C. Due to ground settlement, all underground grease waste drain piping shall be supported from the underside of the floor slab and/or the vertical faces of the pile caps using Type 316 stainless steel hangers, supports and anchors. Underground piping shall be wrapped with 8 mil polyethylene tube encasement in accordance with AWWA C105.
703.4 DOMESTIC COLD WATER SYSTEM

A. Water Pressure: The available water pressure is in the range of 120-125 psi. Domestic water system pressure shall be limited to 65 PSI through an existing pressure reducing station on the existing incoming cold water main. Existing pressure reducing station to remain as is.

B. Water flow velocity: To avoid any erosion, corrosion and excessive noise generation, the domestic cold water piping shall be sized for a maximum flow velocity of 4 feet per second (FPS) for pipes two inches and smaller; and 6 feet per second (FPS) for larger pipes.

C. System Sizing and Estimated Loads: The domestic water main shall be sized to accommodate the water loads serving fixtures with potable water connections. Plumbing fixtures requiring potable water connections are sinks, lavatories, janitor sinks, hose bibbs, trap primers, drinking fountains and bottle fillers, water heaters, and emergency showers/eyewashes, passenger boarding bridges’ cabinets, and concession plumbing fixtures/equipment. Refer to paragraph for recycled water system. Allowances shall be provided in the domestic water main pipe sizing to accommodate for mechanical make-up water, concession areas and jet bridges.

D. Plumbing fixtures to include sinks, lavatories, drinking fountains and bottle fillers. Refer to paragraph for recycled water system. Allowance shall be provided in the domestic water main pipe sizing to accommodate for mechanical make-up water, concession areas and jet bridges.

1. Toilet Rooms, Janitor Closets, Drinking Fountains and Break Rooms: Allowance shall be provided in the domestic water main pipe sizing to accommodate for public toilet rooms, janitor closets, break rooms, drinking fountains and bottle fillers.

2. Concession Areas: Allowance shall be provided to accommodate future concession areas. Domestic cold water for each future concession tenant shall be metered.

3. Jet Bridges: Allowance shall be provided to accommodate a water supply for jet bridges. Each jet bridge shall be provided with a 1½” cold water supply line, water meter, combination emergency shower/eyewash, and a 1” water line with a backflow preventer for the water cabinet.

4. Mechanical make-up water: Allowance shall be provided to accommodate mechanical make-up water supply for chilled water and heating hot water systems.

5. Provide isolation valve for each battery of water closets, urinals, lavatories; each group of fixtures and for each isolated fixture. Valves shall be located in the plumbing chase and in accessible locations. Provide access panel were required.

E. Smart domestic water meters shall be connected to EMCS. Meters shall record in units of one hundred cubic feet (hcf).

F. Per SFO Mechanical Engineering, installation of water meters are “Owner-provided and Contractor-installed”. SFO Mechanical Engineering will procure water meter hardware from SFPUC. After procurement, the Contractor shall provide all additional material and labor to install the SFO provided water meter, including but not limited to, communication, power and integration into the EMCS. All Contractor supplied materials and labor shall be submitted and approved by SFO Mechanical Engineering prior to procurement and construction.

703.5 DOMESTIC HOT WATER SYSTEM

A. General: Domestic hot water for the restrooms, janitor sinks and break room sink shall be provided by an electric water heater located in a janitor room adjacent to the restrooms. Plumbing fixtures shall be supplied with hot water from a pumped re-circulating hot water supply line.

B. Domestic hot water supply and return lines shall be insulated in accordance with Title 24.

C. Temperature: Hot water shall be produced and stored at a minimum of 140°F to prevent the growth of Leginollia. The hot water shall be tempered down to 120°F by use of an ASSE 1017 thermostatic mixing valve installed adjacent to the water heater. Hot water distribution shall be provided with a re-circulating line and pump to provide on-demand hot water to the lavatory faucets. Circulating lines shall be piped close to the hot water supply line to the lavatories, maximum distance shall be 2’-0” from the angle supply stops. Provide balancing valve for each circulating loop.

D. Lavatories: Water supply to lavatories shall be supplied with tepid water. Plumbing code required point of use ASSE 1070 thermostatic mixing valve shall be used to temper the water. Specified faucet is furnished with an ASSE 1070 device.

E. Flow velocity: To avoid any erosion, corrosion and excessive noise generation, the domestic hot water piping system shall be sized for a maximum flow velocity of 4 feet per second (FPS) for pipes two inches and smaller; and 5 feet per second (FPS) for larger pipes. 5 FPS is the code maximum per CPC.
703.6 RECLAIM WATER SYSTEM
   A. General: A recycled water piping system shall be provided for flushing of water closets, and urinals. Currently there is no on-site recycled water supply but a recycled water system will be provided by SFO in the future. The recycled water piping system shall be temporarily connected to the existing domestic water main downstream of the existing water meter assemblies. A reduced pressure backflow preventer shall be provided at the point of connection to the domestic water system to prevent a cross connection between the recycled water system and the domestic water system.
   B. Recycled water signage, pipe identification and valve identification tags shall be provided in accordance with the CPC.
   C. System Sizing and Estimated Loads: The recycled water main shall be sized to accommodate the water closet and urinal fixture loads.
   D. Flow velocity: To avoid any erosion, corrosion and excessive noise generation, the recycled water piping system shall be sized for a maximum flow velocity of 4 feet per second (FPS) for pipes two inches and smaller; and 6 feet per second (FPS) for larger pipes.

703.7 CONDENSATE DRAINAGE SYSTEM
   A. Mechanical AC Units: Condensate drain lines from Mechanical AC units to approved indirect waste receptors such as floor sinks or funnel drains shall be provided. Condensate drain lines shall be wrapped with ½” thick insulation to prevent condensation.
   B. Provide pumped condensate drainage system and 1 inch stub-outs for each Passenger Boarding Bridges including condensate lines terminated at floor sinks.

SECTION 704 - PLUMBING SYSTEM COMPONENTS

704.1 GENERAL
   A. It has not been determined how many water services or meters will be provided, however, it is preferred that the terminal building complex should be provided with one central water meter, with the main water entrance located at the terminal building with branch services to each of the concourses. Remote buildings may have separate meters.
   B. Electric (instantaneous type or small storage tank) domestic water heaters shall be provided at each toilet room. Larger requirements for domestic hot water such as restaurants, etc., shall have gas-fired or steam hot-water heaters. No central hot water system shall be provided in the terminal building complex or in the concourses.
   C. Exterior grease traps and grease separators shall be provided for fixtures in kitchen and food service concessions areas as these facilities may require.
   D. All water supply to fixtures shall be protected by an approved vacuum breaker.
   E. A detailed area chart/plan shall be prominently displayed in the main equipment rooms showing the locations of all main piping and valves.

704.2 PLUMBING FIXTURE AND EQUIPMENT
   A. Plumbing fixtures shall be commercial grade and water conservation type. Vitreous china fixtures, flushometer valves, lavatory sensor faucets and soap dispensing system shall be TOTO, or equal. High efficiency low consumption plumbing fixtures shall be provided for the restrooms. Lavatory and break room sink faucets and electric water coolers shall conform to lead free law and water efficiency standards. ADA compliant fixtures shall be provided at accessible locations.
   B. An accessible plumbing chase shall be provided for maintenance access to the plumbing behind a battery of water closets, urinals and lavatories. A minimum inside clearance of 36” on single side and 48” on back to back assemblies shall be provided and an access door shall be provided to enter the chase.
   C. Water-closets shall be high-efficiency 1.28 gallons per flush water closets shall be provided. Fixture shall be wall mounted white vitreous china commercial grade type water closets with white elongated open front seats with concealed sensor operated (hydropower self-generating) piston type flushometers.
   D. Urinals shall be high-efficiency 0.125 gallon per flush urinals. Fixture shall be wall mounted white vitreous china commercial grade type with concealed sensor operated (hydropower self-generating) piston type flushometers.
   E. Urinals shall connect directly downstream of water closet sanitary sewer main for allowance of future low flow fixtures.
   F. Lavatories shall be white vitreous china under counter mounted commercial grade type. Wall mounted at single toilet rooms. Lavatory faucets shall be chrome plated sensor operated (hydropower self-generating) metering faucets. Maximum discharge of 0.09 gallons per 10 second cycle. Grid drains shall be provided for and p-trap and water supplies shall be wrapped with preformed insulation. Locate lavatory sensor faucet controller in the plumbing chase directly behind each lavatory.
G. All lavatory faucets in public and private toilet rooms shall be provided with flow restricting devices on all outlets. Provide single tempered water faucet at lavatories with 105°F supply temperature.

H. All lavatories (including physically handicapped) can be wall hung or counter mounted. Wheelchair access must be provided for handicapped fixtures. A minimum 29” clear knee space is required with maximum 34” rim height or as defined by the latest version of the ADA.

I. Janitor mop sinks shall be 24” x 24” x 12” high floor mounted square terrazzo type with stainless steel caps on all sides. Faucet shall be a wall mounted service sink faucet with vacuum breaker spout with pail hook and wall brace.

J. Electric water coolers with bottle filler (hydration stations) shall be provided and located adjacent public/staff toilet rooms and as indicated on architectural floor plans. ADA compliant height units shall be provided.

K. Break room sinks shall be a under counter mounted single compartment sink, type 304 stainless steel with satin finish. Sink shall be furnished with a single lever faucet and a ¼ HP food waste disposal. Flow on sink faucet shall be limited to 1.5 gpm.

L. Emergency safety fixtures shall be provided as follows:
   1. Janitor Closets: Provide emergency eyewash/drench hose unit in each janitor closet.
   2. Jet Bridges: Provide emergency safety station. Combination emergency shower with eye/face wash at each jet bridge for ground personal use.

M. Floor drains with a trap priming device shall be provided for the following areas:
   1. Toilet rooms containing two or more water closets or a combination of one water closet and one urinal.
   2. Janitor rooms.
   3. Mechanical rooms.
   4. Loading docks.
   5. Trash rooms.
   6. Other areas as needed.

N. Stop valves shall be provided on all fixtures including water coolers.

O. All fixture types shall be located in the design documents and called out on the contract drawings.

P. Roof vents (DMV) shall be of 3-inch diameter minimum.

Q. Drains from service and slop sinks shall be minimum of 3-inch diameter.

R. Minimum potable water line size shall be 3/4-inch except for branch to fixture which may be 1/2-inch.

S. Provide a floor drain below all non-carpeted interior vestibule areas. (Drain shall be located below steel mat.)

T. A minimum of one hose bibb shall be located in each mechanical and pump room for general wash down.

U. All sump pumps must have a remote alarm, strobe/light, and sign in a nearby occupied area.

704.2 PIPING
Refer to the specifications for pipe material types. PVC shall not be used inside the building without written permission of the SFIA Mechanical Engineer and BICE Inspector. All sanitary sewer piping shall slope at no less than ¼” per linear foot for allowance of future low flow fixtures.

704.3 EXPANSION SETTLEMENT JOINTS
   A. Expansion settlement joints for incoming and outgoing underground building utility mains shall be provided. Flexible connections shall be provided to accommodate a minimum of twelve inches (12”) of differential settlement and accompanying lateral movement for pipes entering or leaving the building and at other transition conditions where differential settlement may occur.
   B. Expansion settlement joints shall be wrapped with 8 mil polyethylene tube encasement in accordance with AWWA C105. All necessary supports, hangers and anchors shall be Type 316 stainless steel.

SECTION 705 - ENERGY CONSERVATION IN PLUMBING SYSTEMS DESIGN

705.1 HOT WATER
Hot water for domestic water use shall be designed in accordance with ASHRAE 90.1 and OSHA requirements. ASHRAE 90.1 establishes minimum requirements for hot water generator recovery efficiency, storage tank insulation, pipe insulation, temperature controls, pump operation, equipment automatic shutdown and conservation of hot water.

705.2 TEMPERATURE
The domestic hot water system shall be designed for a supply temperature of 120°F for circulated systems and 140°F for storage systems per OSHA requirements. For the public spaces provide lavatories with 105°F water at each point of use.
705.3 SAFETY DEVICES
Safety devices shall be provided on the hot water generators and storage devices. Safety devices shall be as required by code and as a minimum shall include energy cut-off devices, relief valve and/or temperature or combination temperature and pressure relief valves. All water heaters, regardless of size, shall have an expansion tank on the domestic cold water inlet.

SECTION 706 - NATURAL GAS

706.1 SIZING
Gas piping shall be sized per the requirements of the California Plumbing Code.
   A. Gas specific gravity: 0.65
   B. Gas thermal capacity: 834 BTU per 1,000 cubic feet

706.2 METERING
Smart metering for all buildings shall be connected to EMCS.

706.3 GAS SYSTEMS PROTECTION
Architect and Engineer of Record for design of facilities shall design protective measures for all gas piping systems at SFIA. Protective measures shall be coordinated with the utility company so that all gas systems above ground level are provided for the entire gas system, including upstream and downstream piping from the meter.

All gas piping, meters, pressure regulators, appurtenances and systems shall be fully protected from possible collisions with vehicles, baggage cart tugs, support equipment, etc. To the greatest extent possible, gas systems shall be located away from areas where it is possible for vehicles and/or equipment to strike it directly and/or indirectly through adjacent walls that offer inadequate protection from such vehicle strikes. In addition, gas systems shall be protected from grade level to ceiling as strikes can occur at nearly all elevations that are not either protected and/or concealed in ceilings.

As part of the Net Zero Energy program, all efforts shall be made to avoid and eliminate the use of natural gas in all new facilities. Optional sources of heating shall be assessed and reviewed to comply with Net Zero Energy and Carbon Neutrality objectives.
SECTION 801 - GENERAL
There are many factors unique to the airport terminal and other airport buildings that enter into the design of an energy efficient facility. These factors include architectural, mechanical and electrical considerations -- all interrelated. The process of Energy Analysis shall comply with the guideline outlined in the Net Zero Energy program. Collaborative, iterative, and comprehensive approach must be utilized to capture an optimized balance of energy efficiency, lifecycle cost analysis, and sustainability objectives.

The San Francisco International Airport terminal, concourses and other buildings shall include design features that emphasize energy conservation. Some of these features have been outlined earlier but will be summarized in this section for emphasis.

Buildings in excess of 5,000 square feet shall have a computer energy model performed to establish energy consumption. Energy budgets shall be established and shall meet the requirements of ASHRAE 90.1. This standard allows tradeoffs between mechanical and electrical systems and the building envelope. These tradeoffs shall supersede specific requirements presented in following discussion. See Section 102 for Predictive Energy Modeling and Section 208 for HVAC System Alternatives.

801.1 CODES AND STANDARDS
All Energy Conservation Analyses shall meet the requirements of:
A. California Building Code
B. California Energy Code
C. California Green Building Code (CalGreen)
D. San Francisco Green Building Code
E. San Francisco Energy Code
F. California Title 24
G. ASHRAE 90.1
H. ASHRAE Guideline 36P High Performance Sequence of Operation for HVAC Systems
I. Net Zero Energy Standard

Where the requirements of this chapter or the Codes and Standards themselves deviate from one another, the more stringent of the two shall apply.

801.2 LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN (LEED)
The Consultant shall review the current LEED Rating System and develop design strategies for maximizing the project’s energy efficiency. Following the LEED Rating System, the Consultant and The City shall determine which level of LEED Green Building Certification is achievable for the project. At a minimum all new construction projects and tenant improvement projects over 5,000 SF must be LEED Gold. Following this decision, the Consultant shall tailor the design documents to achieve this certification. The LEED Rating System document can be obtained at the following website: http://www.usgbc.org

Consult the San Francisco Green Building Code for mandatory LEED credits that must be achieved in additional to the prerequisites.

SECTION 802 – ENERGY & ATMOSPHERE

802.1 OPTIMIZE ENERGY PERFORMANCE
Reduce the environmental and economic harms of excessive energy use by achieving energy efficiency for the building and its systems. Analyze efficiency measures during the design process and account for the results in design decision making. Project potential energy savings and holistic project cost implications related to all affected systems.

Complete a whole-building energy simulation that demonstrates an improvement of 20% for new construction, 15% for major renovations, or 15% for core and shell projects in the proposed building performance rating compared with the baseline building performance rating. Calculate the baseline building performance according to ASHRAE Standard 90.1. Such analysis shall include all on-site building energy use, including exterior and security lighting, elevators, all process loads, and receptacle loads.
802.2 ADVANCED ENERGY METERING

Install energy meters on all whole-building energy sources used by the building. Install individual energy end uses that represent 10% or more of the total annual consumption of the building.

Meters must be permanently installed, record at intervals of 15 minutes, and transmit data to a remote location. Either the meters or the data collection system must be capable of reporting hourly, daily, monthly, and annual energy use. The system must be capable of storing all meter data for at least 36 months. The data must be remotely accessible and interface with the EMCS. Device names and data point names must follow SFO naming convention standard.

Metered information must transmit data using open-protocol programming and communication such as BACnet or SFO-approved equal. Mechanical equipment must transmit data into EMCS. Natural Gas meters must transmit data into EMCS. Domestic Water meters must transmit data into EMCS. All electrical equipment must transmit data into the SFO Electric Shop Schneider Electric Power Monitoring Expert (PME) server. All metered data must eventually transmit data into ITT Data Lake and Message Bus.

Access to each utility’s data management system must be available remotely via mobile phones, computers, and tablets for monitoring, reporting, and alarming. All meters shall be tested, calibrated and commissioned. Provide all meters with isolation valves for servicing or replacement.

Mechanical energy consumption must be recorded using BTU meters at the following locations:
A. Each chiller
B. Main chiller loop supplying the terminals
C. Chilled water usage at each pump room
D. Each boiler
E. Main boiler loop supplying the terminals
F. Heating hot water usage at each pump room

Electricity meters must record both consumption and demand. Whole-building electricity meters should record the power factor, if appropriate. Disaggregation of loads should be separated into the following categories:
A. Each tenant (for billing). Refer to SFO Electric Metering Shop Requirements for more details
B. All circuits under 100 Amps inside power distribution panels shall be measured and tracked with Branch Circuit Power Meters (BCPMs)
C. HVAC (VFDs, fans, pumps, and all other major mechanical equipment)
D. Plumbing loads
E. Interior Lighting
F. Exterior Lighting
G. Plug loads
H. 400 Hz (airplane charging system)
I. Pre-Conditioned Air (PCA) system
J. Photovoltaic (PV) solar renewable energy
K. Baggage handling system
L. People-moving equipment (elevators, escalators, and other associated equipment)
M. Other renewable energy sources
N. Security systems
O. Communications
P. Fire & Life Safety
Q. Electrical equipment

Electrical metering shall be provided and installed by Electrical subcontractor. Meters shall be integrated into SFO Electric Metering Shop’s Schneider Electric Power Monitoring Expert (PME) Server. Refer to SFO Electric Metering Shop Requirements for more details.

Natural Gas meters must record consumption for each tenant (if applicable) and each central plant boiler.
Domestic Water meters must record consumption at each gate and tenant. Additionally, consumption must be recorded at the main pipe feeding each boarding area and walkway between boarding areas. See Section 804.2 for additional metering requirements.

The data collection system must use a local area network, building automation system, wireless network, or comparable communication infrastructure. The system must be capable of storing all meter data for at least 36 months. The data must be remotely accessible and interface with the EMCS.

802.3 ENHANCED COMMISSIONING & MONITOR BASED COMMISSIONING

Enhanced Commissioning and Monitor Based Commissioning are mandatory on all LEED projects. The intent of Enhanced Commissioning is to further support the design, construction, and eventual operation of a project that meets the owner’s project requirements for energy, water, indoor environmental quality, and durability.

As part of Enhanced Commissioning the following activities must be completed for mechanical, electrical, plumbing, and renewable energy systems and assemblies in accordance with the latest revisions of ASHRAE Guidelines for HVAC&R systems, as they relate to energy, water, indoor environmental quality, and durability.

A. Develop/Review Owner’s Project Requirements (OPR), Basis of Design (BOD), and project design.
B. Develop/Implement a Commissioning (Cx) Plan.
C. Confirm incorporation of Cx requirements into the construction documents.
D. Develop construction checklists.
E. Develop a system test procedure and verify system test execution.
F. Maintain an issues and benefits log throughout the Cx process.
G. Prepare a final Cx process report.
H. Review contractor submittals.
I. Verify systems manual updates and delivery.
J. Verify operator and occupant training delivery and effectiveness.
K. Verify seasonal training.
L. Review building operations 10 months after substantial completion.
M. Develop an on-going commissioning plan.

Monitoring Based Commissioning involves developing procedures and identifying points to be measured and evaluated to assess performance of energy and water consuming systems. Include the procedures and measurement points in the commissioning plan. Address the following:

A. Establish roles and responsibilities.
B. Establish measurement requirements (meters, points, metering systems, data access).
C. Develop list of points to be tracked, with frequency and duration for trend monitoring.
D. Set the limits of acceptable values for tracked points and metered values (where appropriate, predictive algorithms may be used to compare ideal values with actual values).
E. Establish the elements used to evaluate performance, including conflict between systems, out-of-sequence operation of systems components, and energy and water usage profiles.
F. Develop an action plan for identifying and correcting operational errors and deficiencies.
G. Provide training on how to prevent and address errors.
H. Develop plan for preventative maintenance needed to maintain performance.
I. Set the frequency of analyses in the first year of occupancy (at least quarterly).

802.4 RENEWABLE ENERGY

The LEED Project Administrator shall confer with SFIA on renewable energy opportunities for municipal construction projects, including photovoltaics, solar hot water and wind power. Space allocation and infrastructure for future renewable energy installations shall be included in municipal construction projects, as advised by SFIA, including but not limited to structural capacity, wiring conduits, supply and return piping, and control wiring. The LEED Project Administrator shall submit documentation verifying that either:

A. At least 1 percent of the building’s energy costs are offset by on-site renewable energy generation, achieving LEED credit EA 2, including any combination of: photovoltaic, solar thermal, wind, biofuel-based electrical systems, geothermal heating, geothermal electric, wave, tidal, or low impact hydroelectric systems, or as specified in Section 25741 of the California Public Resources Code; or,
B. In addition to meeting LEED prerequisite EA 1 Energy Performance requirement, achieve an additional 10 percent compliance margin over Title 24, Part 6, California Energy Standards, for a total compliance margin of at least 25 percent.

SECTION 803 – INDOOR AIR QUALITY

803.1 MINIMUM INDOOR AIR QUALITY (IAQ) PERFORMANCE
Contribute to the comfort and well-being of building occupants by establishing minimum standards for indoor air quality (IAQ). For mechanically ventilated spaces, meet the minimum outdoor air intake flow for mechanical ventilation systems using the ventilation rate procedure from ASHRAE 62.1 or a local equivalent, whichever is more stringent.

For variable air volume systems, provide a direct outdoor airflow measurement device capable of measuring the minimum outdoor air intake flow. This device must measure the minimum outdoor air intake flow with an accuracy of +/-10% of the design minimum outdoor airflow rate, as defined by the ventilation requirements above. An alarm must indicate when the outdoor airflow value varies by 15% or more from the outdoor airflow set point.

803.2 THERMAL COMFORT (DESIGN)
Provide occupants with quality thermal comfort to increase productivity, comfort, and well-being. Meet the requirements for both thermal comfort design and thermal comfort control.

Design the heating, ventilating, and air-conditioning (HVAC) systems and the building envelope to meet the requirements of ASHRAE Standard 55 – Thermal Comfort Conditions for Human Occupancy.

Provide individual thermal comfort controls for at least 50% of individual occupant spaces. Provide group thermal comfort controls for all shared multi-occupant spaces, and for any individual occupant spaces without individual controls. Thermal comfort controls allow occupants, whether in individual spaces or shared multi-occupant spaces, to adjust at least one of the following in their local environment: air temperature, radiant temperature, air speed, and humidity.

803.3 CONTROLLABILITY OF SYSTEMS (THERMAL COMFORT)
Provide individual thermal comfort controls for at least 50% of individual occupant spaces. Provide group thermal comfort controls for all shared multi-occupant spaces, and for any individual occupant spaces without individual controls. Thermal comfort controls allow occupants, whether in individual spaces or shared multi-occupant spaces, to adjust at least one of the following in their local environment: air temperature, radiant temperature, air speed, and humidity.

SECTION 804 – WATER EFFICIENCY

804.1 INDOOR WATER USE REDUCTION
For the fixtures and fittings listed in Table 804.1, as applicable to the project scope, reduce aggregate water consumption by a minimum of 30% from the baseline. The baseline water consumption for fixtures and fittings are shown in Table 804.1.

<table>
<thead>
<tr>
<th>Table 804.1 Baseline water consumption for fixtures and fittings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Commercial Fixtures, Fittings &amp; Appliances</strong></td>
</tr>
<tr>
<td>Water Closets (Toilets)</td>
</tr>
<tr>
<td>Urinals</td>
</tr>
<tr>
<td>Public Lavatory Faucets</td>
</tr>
<tr>
<td>Private Lavatory Faucets</td>
</tr>
<tr>
<td>Kitchen Faucets</td>
</tr>
<tr>
<td>Showerhead</td>
</tr>
</tbody>
</table>

All newly installed toilets, urinals, private lavatory faucets, and showerheads that are eligible for labeling must be WaterSense labeled (or a local equivalent for projects outside the U.S.).

804.2 WATER METERING
Track water consumption in an effort to manage water usage and identify opportunities for additional water savings.

Install permanent water meters for the following water subsystems, as applicable to the project:
A. Meter domestic water systems serving at least 80% of the indoor fixtures and fittings included in the indoor water use reduction, either directly or by deducting all other measured water use from the measured total water consumption of the building and grounds.

B. Meter domestic hot water use of at least 80% of the installed domestic hot water heating capacity, including both tanks and on-demand heaters.

C. Meter reclaimed water, regardless of rate. A reclaimed water system with a makeup water connection must also be metered so that the true reclaimed water component can be determined.

D. Tie into EMCS (Energy Management & Control System).
APPENDIX B – MASTER LIST OF MANUFACTURERS

This section provides the Master List of Manufacturers approved by SFO for the use of HVAC Systems, organized by section and subsection. All final decisions regarding products shall be made at the Owner’s discretion. If Contractor presents items that are not specified or named equals, there may be a charge to the Contractor for evaluation of those products.

BASIC MECHANICAL REQUIREMENTS

EQUIPMENT IDENTIFICATION – NAMEPLATES
   1. Wilcox.
   2. Brady.
   3. Or approved equal.

23 05 13 – MOTORS, STARTERS, AND VARIABLE FREQUENCY DRIVES

VARIABLE FREQUENCY DRIVES
   1. Asea-Brown-Bowery
   2. Toshiba.
   5. Reliance.
   7. Or approved equal.

SHAFT GROUNDING SYSTEM
   1. Albany.
   2. Oregon.
   3. Or approved equal.

23 05 19 – METERS AND GAGES FOR HVAC PIPING

METAL-CASE, LIQUID-IN-GLASS THERMOMETERS
   1. Palmer-Wahl Instruments, Inc.
   2. Trerice H.O. Co.
   3. Weiss Instruments, Inc.
   4. Weksler Instruments Operating Unit; Dresser Industries, Instrument Division.
   5. Or approved equal.

DUCT-TYPE, LIQUID-IN-GLASS THERMOMETERS
   1. Milijoco Corp.
   2. Palmer-Wahl Instruments, Inc.
   3. Trerice, H.O. Co.
   5. Or approved equal.

THERMOWELLS
   1. AMETEK, Inc.
   3. Ernst Gage Co.
5. Milijoco Corp.
6. NANMAC Corporation.
7. Noshok, Inc.
9. REO TEMP Instrument Corporation.
10. Tel-True Manufacturing Company.
11. Trerice H.O. Co.
12. Weiss Instruments, Inc.
13. Weksler Instruments Operating Unit; Dresser Industries Instrument Div.
14. WIKA Instrument Corporation.
15. Winters Instruments.
16. Or approved equal.

PRESSURE GAUGES
1. AMETEK, Inc.; U.S. Gauge Div.
3. Ernst Gage Co.
4. Eugene Ernst Products Co.
5. KOBOLD Instruments, Inc.
7. Milijoco Corp.
8. Noshok, Inc.
10. REO TEMP Instrument Corporation.
11. Trerice, H.O. Co.
12. Weiss Instruments, Inc.
13. Weksler Instruments Operating Unit; Dresser Industries; Instrument Div.
14. WIKA Instrument Corporation.
15. Winters Instruments.
16. Or approved equal.

TEST PLUGS
1. Flow Design, Inc.
2. MG Piping Products Co.
4. Peterson Equipment Co., Inc.
5. Sisco Manufacturing Co.
6. Trerice H.O. Co.
8. Or approved equal.

23 05 48 – VIBRATION AND SEISMIC CONTROLS FOR HVAC

AVAILABLE MANUFACTURERS
1. Mason.
2. Amber/Booth.
4. Or approved equal.

VIBRATION ISOLATORS
2. Mason Industries, Inc.
3. Amber/Booth Company, Inc.
4. Ace Mounting Co., Inc.
5. Or approved equal.

VIBRATION ISOLATION EQUIPMENT
2. Mason Industries.
3. Amber Booth.
4. Or approved equal.

23 07 00 – MECHANICAL INSULATION

MANUFACTURERS
1. Schuller (formerly Manville).
2. Owens-Corning.
5. Pittsburgh-Corning.
7. Halstead.
8. Rubatex.
9. Or approved equal.

23 21 13 – HYDRONIC PIPING

VALVES – GATE, GLOBE, CHECK, OR BUTTERFLY
1. Crane.
2. Delta control Products.
3. Hammond.
5. Milwaukee.
7. Or approved equal.

BALL AND DRAIN VALVES
1. Apollo.
2. Hammond.
3. Milwaukee.
5. Watts.
6. Or approved equal.

LUBRICATED NATURAL GAS SERVICE PLUG VALVES
1. Homestead.
2. Resun.
3. Rockwell.
4. Or approved equal.

HYDRONIC SYSTEM PRESSURE REDUCING VALVES
1. Cash-Acme.
2. Cla-Val.
3. Watt.
4. Wilkins.
5. Or approved equal.

STEAM SYSTEM PRESSURE REDUCING VALVES
1. Sarco.
2. Fisher.
3. Hoffman.
4. Spence.
5. Or approved equal.

HYDRONIC PRESSURE RELIEF VALVES
1. Cash-Acme.
2. Cla-Val.
3. Watts.
4. Wilkins
5. Or approved equal.

STEAM SYSTEM PRESSURE RELIEF VALVES
1. Sarco.
2. Fisher.
4. Lonergan-Kunkle.
5. Or approved equal.

SOLENOID VALVES
1. ASCO.
3. Automatik.
4. Or approved equal.

HYDRONIC BALANCING VALVES AND CIRCUIT SETTERS
1. Griswold.
2. Wheatley.
3. Amstron.
5. Bell&Gossett.
6. Or approved equal.

THERMOMETERS AND GAUGES
1. Weksler.
2. Ashcroft.
3. Trerice.
4. Marshalltown.
5. WIKA.
7. Or approved equal.

HORIZONTAL SPLIT CASE PUMPS
1. PACO.
2. Bell and Gossett.
3. Taco.
5. Ingersoll-Rand.
6. Peerless.
7. Weinman.
8. Or approved equal.

END SUCTION BASE-MOUNTED PUMPS
1. Paco.
2. Bell & Gossett.
3. Allis-Chalmers.
4. Ingersoll-Rand.
5. Peerless.
7. Or approved equal.

IN-LINE CENTRIFUGAL PUMPS
1. Paco.
2. Bell & Gossett.
3. Armstrong.
4. Taco.
5. Weinman.
6. Or approved equal.

SHELL AND TUBE HEAT EXCHANGERS
1. Bell & Gossett.
2. Taco.
3. Patterso-Kelly.
4. Yula.
5. Adamson.
6. Or approved equal.

LOW PRESSURE Y-TYPE PIPELINE STRAINERS – THREADED ENDS, 2” AND SMALLER
1. Sarco.
2. Keckley.
3. Wheatley.
5. Or approved equal.

FLANGED ENDS, 2-1/2” AND LARGER
1. Sarco.
2. Keckley.
3. Wheatley.
5. Or approved equal.

AIR VENTS WITH VALVES
1. Provided by Hoffman #79 or equal by:
   2. Amtrol.
   3. Watts.
   4. Dole.

UNIONS
1. EPCO.
4. Victaulic.
5. Tyco-Grinnell.
7. Or approved equal.

FLANGE GASKETS
1. Garlock Style 3200.
2. Or approved equal.

PIPE SLEEVES
1. Adjus-to-Crete.
2. AMI.
3. Shamrock.
4. Or approved equal.

PIPE COATING
1. Twice Wrap 20 Mill Scotch Wrap PVC No. 51, 50% overlap.
2. Prefabricated extruded plastic cover with joints sealed with two coats of 20 Mill Scotch Wrap No. 51.

EXPANSION COMPENSATORS
1. Keflex #311.
2. Or approved equal.

FLEXIBLE EXPANSION JOINT/SEISMIC CONNECTOR FOR STEEL PIPE
1. Metraflex #Metraloop.
2. Unisource V-SF21 Style.
3. Or approved equal.

FLEXIBLE CONNECTION FOR STEEL PIPE
1. Metraflex #SST.
2. Or approved equal.

FLEXIBLE CONNECTION FOR COPPER PIPE
1. Metraflex #BBS.
2. Unisource V-BF11 Style.
3. Or approved equal.

FLEXIBLE RUBBER CONNECTORS (PUMP CONNECTIONS) – FOR HEATING HOT WATER SERVICE PUMP CONNECTIONS
1. Garlock #204HP.
   No known equals.

FLEXIBLE RUBBER CONNECTORS (PUMP CONNECTIONS) – FOR CHILLED WATER AND NON-CRITICAL PUMP CONNECTIONS
1. Garlock #206 EZ-FLO.
2. Or approved equal.

PIPE ALIGNMENT GUIDES
1. Metraflex #Style IV.
2. Or approved equal.
SOLDER COPPER TUBE AND FITTING JOINTS - SOLDER
1. JW Harris “Bridgit”.
2. Englehard “Silvabrite 100”.
3. Or approved equal.

SOLDER COPPER TUBE AND FITTING JOINTS – FLUX
1. Laco “Flux-Rite 90”.
2. MW Dunton “Nokorode CDA Flux.”
3. Hercules “Fluid Action Solder Flux.”
4. Or approved equal.

23 21 23 – HYDRONIC PUMPS

FLEXIBLE COUPLED END SUCTION PUMPS
1. Bell & Gossett.
2. Taco.
3. Paco.
4. Peerless.
5. Armstrong.
6. Or approved equal.

CLOSED COUPLED END SUCTION PUMPS
1. Bell & Gossett.
2. Taco.
3. Paco.
4. Peerless.
5. Or approved equal.

IN-LINE FLEXIBLE COUPLED PUMPS
1. Bell & Gossett.
2. Taco.
3. Paco.
4. Peerless.
5. Armstrong.
6. Or approved equal.

IN-LINE CLOSED PUMPS
1. Bell & Gossett.
2. Taco.
3. Paco.
4. Peerless.
5. Armstrong.
6. Or approved equal.

IN-LINE WATER LUBRICATED CIRCLATING PUMPS (SECOND PUMPING AND BOOSTER APPLICATIONS)
1. Bell & Gossett.
2. Taco.
3. Armstrong.
5. Or approved equal.
AIR SEPARATORS
1. Spirotherm.
2. Bell & Gossett.
3. Wheatly.
5. Taco.
6. Amtrol.
7. Or approved equal.

AIR ELIMINATION VALVE (AUTOMATIC)
1. Amtrol.
2. Hoffman.
3. Or approved equal.

SUCTION DIFFUSERS
1. Bell & Gossett.
2. Taco.
3. Wheatley.
4. Victaulic.
5. Or approved equal.

CHEMICAL POT FEEDER
1. Dearborn.
2. Garrett-Callahan.
3. Or approved Equal.

23 23 00 – REFRIGERANT PIPING

REFRIGERANT FITTINGS
1. Mueller Streamline.
2. Nibco, Inc.
4. Elkhart Products Corp.
5. Or approved equal.

FLUX
1. J.W. Harris Co.
2. Handy & Harmon.
3. Or approved equal.

EXPANSION VALVES
1. Alco.
2. Henry.
4. Parker.
5. Signer.
7. Or approved equal.

FILTER DRIER
1. Alco.
3. Parker.
4. Sporlan.
5. Virginia.
6. Or approved equal.

SIGHT GLASS
1. Alco.
2. Asco.
4. Parker.
5. Sporlan.
6. Or approved equal.

MANUAL REFRIGERANT SHUT-OFF VALVE
1. Anamet.
2. Packless Industries.
3. Superior Valve Co.
4. Vibration Mountings.
5. Or approved equal.

23 31 13 – METAL DUCTWORK

MANUFACTURERS
1. Duro-Dyne.
2. Elgin Sheet Metal Products.
4. Prefeco.
5. Ruskin.
6. United Sheet Metal.
7. Vent-Fabrics, Inc.
8. Ventlok.
9. Young Regulator Co.
10. Or approved equal.

SLIP DRIVE JOINTS
1. Ductmate
2. MEX Industries
3. Or approved equal

RECTANGULAR DUCTWORK – TRAVERSE JOINTS
1. Ductmate Industries, Inc.
2. Nexus Inc.
3. Ward Industries, Inc.
4. Or approved equal.

RECTANGULAR DUCTWORK – FORMED-ON FLANGES
1. Ductmate Industries, Inc.
2. Lockformer.
3. Or approved equal.

ROUND DUCTS
1. Ductmate Industries, Inc.
2. Lindab Inc.
3. Or approved equal.

ROUND DUCTWORK – PREFABRICATED CONNECTION SYSTEM CONSISTING OF TWO FLANGES AND ONE SYNTHETIC RUBBER GASKET
1. Ductmate Industries, Inc.
3. SEMCO Incorporated.
4. Or approved equal.

FLEXIBLE DUCTS
1. Thermaflex.
2. Cody/West.
3. Casco Silentflex II.
4. Or approved equal.

DUCTWORK ACCESSORIES
1. Ruskin.
2. Vent-Fabrics, Inc.
3. Ventlok, Young Regulator Co.
4. Elgin.
5. Duro-Dyne.
7. Or approved equal.

FLEXIBLE CONNECTIONS
1. “Vent-Glass” by Vent-Fabrics, Inc. or approved equal by:
2. Duro-Dyne Corp.
3. Q Industries.
5. Elgen.
6. Ductmate Industries, Inc.
7. War Industries, Inc.
8. Or approved equal.

CONCEALED DAMPER REGULATORS
1. Ventlok Model 677, with 2-5/8" paintable coverplate countersunk screws, suitable for ½" square hot rolled rod, or approved equal with mitergears and rod attachments, as required.

TURNING VANES
1. Ductmate Industries, Inc.
2. Duro-Dyne Corp.
3. METALAIRE, Inc.
5. Or approved equal.

DUCT SILENCERS
1. Industrial Acoustic Company (IAC).
2. Commercial Acoustics.
4. Or approved equal.
ACCESS DOORS
1. Ruskin Type ADH22.
2. Or approved equal dual wall, insulated, hinged access doors in ductwork and plenums.

ACCESS DOORS – HINGES
1. Ventlok.
2. Or approved equal hinges or latches.

ACCESS DOORS – DOOR, DOUBLE WALL, DUCT MOUNTING, AND RECTANGULAR
American Warming and Ventilating.
1. CESCO Products.
2. Ductmate Industries, Inc.
3. Flexmaster U.S.A., Inc.
5. Nailor Industries.
6. Ventfabrics, Inc.
7. Ward Industries, Inc.
8. Or approved equal.

ACCESS DOORS – DOOR, DOUBLE WALL, DUCT MOUNTING, AND ROUND
1. Ductmate Industries, Inc.
2. Flexmaster U.S.A., Inc.
3. Or approved equal.

ACCESS DOOR MANUFACTURER
CESCO.
1. Vent Products.
2. Air Balance.
3. Ruskin.
4. Or approved equal.

BALANCING AND CONTROL DAMPERS
1. Pacific Air Products
2. Ruskin.
3. Air Balance.
4. Pottroff.
5. Greenheck.
7. Approved equal by
8. Swartwout.
10. Vent Products.
11. Or approved equal.

MOTORIZED CONTROL DAMPERS
1. AirBalance, Inc.
2. Duro-Dyne Corp.
5. METALAIRE, Inc.
7. Penn Ventilation Company, Inc.
8. Ruskin Company.
9. Or approved equal.

LOW LEAKAGE CONTROL DAMPERS
1. Ruskin #CD36.
2. Startwout.
3. American Warming.
5. Or approved equal.

AIRFOIL DAMPERS
1. Ruskin #CD60.
2. Swartwout.
3. American Warming.
5. Or approved equal.

VOLUME DAMPERS
1. AirBalance, Inc.
2. METALAIRE, Inc.
3. Nailor Industries, Inc.
4. Penn Ventilation Company, Inc.
5. Ruskin Company.
6. Or approved equal.

VOLUME DAMPERS – 18-GAUGE GALVANIZED STEEL FRAME, OPPOSED, 6” WIDE, 18 GAUGE GALVANIZED STEEL BLADES, CONCEALED LINKAGE IN FRAME.
1. Titus #AG-35-B.
2. Ruskin #CD35/OBD.
3. Or approved equal.

VOLUME DAMPER CONTROL CABLE SYSTEM ASSEMBLIES
1. Young Regulator Company

FIRE DAMPERS
2. Air Balance, Inc.
5. METALAIRE, Inc.
6. Nailor Industries Inc.
7. Penn Ventilation Company, Inc.
8. Ruskin Company.
9. Or approved equal.

CEILING FIRE DAMPERS
1. Air Balance, Inc.
2. Greenheck.
4. METALAIRE, Inc.
5. Nailor Industries Inc.
7. Ruskin Company.
8. Or approved equal.

**COMBINATION WALL FIRE/SMOKE DAMPER**
1. Ruskin #FSD-37.
2. Ruskin #FSD-60.
3. Ruskin #FSD60FA.
4. Pottorff #FSD-40 Series.
5. Approved equal by:
7. Air Balance.
8. Fire/Seal.
9. Or approved equal.

**AIR FLOW MEASURING STATIONS**
1. Paragon.
2. Air Monitor.
3. Ultratech.
4. Air Sentinel.
5. Or approved equal.

**DIFFUSERS, GRILLES, AND REGISTERS**
1. Price.
2. Titus.
4. Carnes.
5. Or approved equal.

**DISPLACEMENT DIFFUSERS**
1. Price.
2. Or approved equal.

**VARIABLE AIR VOLUME TERMINAL BOXES**
1. Titus ESV-3000.
2. Metal-Aire.
4. Or approved equal.

**GENERATOR (ENGINE) EXHAUST**
1. Selkirk Metalbestos Model “IPS.”
2. Or approved equal.

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**23 33 19 – DUCT SILENCERS**

1. Industrial Acoustic Company (IAC).
2. Koppers Company, Inc.
3. Peabody Noise Control.
4. Rink Corporation.
5. Or approved equal.

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**23 34 00 – FANS**

1. **MANUFACTURERS**
2. Woods.
4. Howden.
5. Buffalo-forge.
7. Greenheck.
8. Loren-Cook.
11. Hartzell.
12. Or approved equal.

DRIVES
1. Gates Chain GT-Drive Model “HTD”.
2. Or approved equal.

FAN SHEAVES
1. Browning.
2. Eaton.
3. Yale and Towne.
5. Fort Worth Steel and Machinery Company.
6. Or approved equal.

BELTS
1. Gates.
2. Durkee-Atwood.
4. Browning.
5. Uniroyal.

6. BEARINGS
7. SKF.
8. Sealmaster.
10. Fafnir.
11. Or approved equal.

CENTRIFUGAL FANS
1. Greenheck.
2. Carnes.
3. Cook.
4. Penn.
5. Ventilator.
6. Or approved equal.

MIXED FLOW FANS
1. Woods.
2. Howden.
4. Sheldon.
5. Joy.
6. Or approved equal.

SMALL CABINET FANS (CEILING MOUNTED AND INLINE CABINET)
1. Greenheck SP-A.
2. Panasonic.
3. Cook.
4. Penn.
5. Carnes of equivalent performance.
6. Or approved equal.

DUCT MOUNTED CABINET FAN
1. Greenheck CSP-A.
2. Panasonic.
3. Cook.
4. Penn.
5. Carnes of equivalent performance.
6. Or approved equal.

23 34 23 – HVAC POWER VENTILATORS

MANUFACTURERS
2. Greenheck Fan Corp.
3. Aerovent; a Twin City Fan Company.
4. Or approved equal.

23 36 00 – AIR TERMINAL UNITS

1. Titus.
2. Krueger.
3. Trane.
4. Anemostat.
5. Tuttle and Bailey.
6. Or approved equal.

23 37 13 – DIFFUSERS, REGISTERS AND GRILLES

MANUFACTURERS
1. Titus.
2. Metal-Aire.
4. Anemostat.
5. Air Factor.
6. Carnes.
7. Tuttle & Bailey.
8. Or approved equal.

GRILLES AND REGISTERS
1. Anemostat, a Mestek Company.
2. Price Industries.
3. Titus.
5. Or approved equal.

CEILING DIFFUSER OUTLET & INLETS
1. Acutherm.
2. Price Industries.
3. Titus.
5. Or approved equal.

PERFORATED CEILING RETURN/EXHAUST GRILLE
1. Anemostat, a Mestek Company.
2. Titus.
5. Or approved equal.

23 41 00 – PARTICULATE AIR FILTRATION

ACCEPTABLE MANUFACTURERS – FILTERS
1. Eco-Air Products, Inc.
5. Flanders.
7. Genesis.
8. Or approved equal.

ACCESSORIES
1. Framing Modules – Eco-Air K-trac.
3. Metal Filters – Eco-Air Metal Masters.
4. Or approved equal.

PLEATED MEDIA FILTERS
1. Environmental Filter Corporation (EFC), Type EP or equal by:
2. Farr.
3. Eco-Air.
5. Or approved equal.

MEDIUM AND HIGH EFFICIENCY BAG FILTER (TYPE F-2 AND F-4)
1. Environmental Filter Corporation (EFC) type EPS 95 or equal by:
2. Farr.
3. Eco-Air.
5. FILTER RACKS
6. Air Guard.
7. BLC Industries.
9. Or approved equal.
FILTER MAGNAHELCI GAUGES
1. A Dwyer Model No 1823-5 Differential Pressure Switch.
2. Or approved equal with No. A-603 “T” kit

GAS PHASE FILTERS – MEDIA
1. Purafil APB 850.
2. Approved equally by:
4. Eco-Air.
5. Circul-Aire.
6. Or approved equal.

ACTIVATED CARBON PANEL FILTERS
1. AAF International.
2. Airguard.
3. Camfil.
4. Farr Co.
5. Filtration Group.
6. Flanders/CSC Corp.
7. Or approved equal.

23 57 19 – LIQUID TO LIQUID HEAT EXCHANGERS
1. Bell & Gossett.
2. Patterson-Kelley.
3. Or approved equal.

23 73 23 – CUSTOM FACTORY AIR HANDLING UNITS

MANUFACTURERS
1. Buffalo Air Handling Company.
2. Governaire.
3. Mammoth.
5. Pace Corporation.
6. Temtrol.
10. Or approved equal.

FAN, DRIVE, AND MOTOR SECTION
1. Woods.
2. Howden.
4. Sheldon.
5. Joy.
6. Or approved equal.

MOTORS FOR USE IN MULTIPLE FAN ARRAYS
1. Baldor.
2. Siemens.
3. Toshiba.
4. Or approved equal.

**DAMPERS**
1. Ruskin.
2. T.A. Morrison (TAMCO).
3. Or approved equal.

**AIRFLOW MEASURING STATION**
1. Ebtron.
2. Or approved equal.

**23 81 25 – SPLIT DIRECT-EXPANSION AIR CONDITIONING UNITS**
1. Mitsubishi.
2. Daikin.
4. Or approved equal.

**23 81 26 – SPLIT SYSTEM AIR CONDITIONERS**
1. Mitsubishi.
2. Daikin.
4. Or approved equal.

**23 82 19– FAN COIL UNITS**
1. McQuay.
2. International.
3. Trane.
4. Carrier.
5. Or approved equal.

**23 82 36 – RADIATION HEATERS**
1. Vulcan.
2. Approved equal by.
3. Trane.
4. Modine.
5. Sterlin.
6. Or approved equal.

**23 82 39 – HEAT TRANSFER**

**ELECTRIC DUCT HEATERS**
1. Acutherm.
2. Or approved equal.
Appendix C – Sample Commissioning Checklists

Instructions: Contractor shall submit a completed and signed copy of this checklist as an indication of compliance with all installation criteria specified in the Construction Documents.

Electrical Installation:

- Final wiring connections are complete.
- Control Panels are installed plumb and level
- Wiring is installed in a neat and workmanlike manner
- Wiring has been tagged with permanent labels per Construction Documents.
- Code-required electrical services clearance for all electrical components has been provided per Construction Documents.
- Installed junction boxes for any control wiring such that no motor starter or disconnect switches are used as junction boxes.
- An electrical receptacle is located within the control panel.
- Wiring is installed in conduit where required.
- There are no spices installed in panel boards.
- Rain-tight fittings installed where required
- Equipment has been properly grounded.

Signed: ___________________________ Date: ________ Company: ______________

BAS Integration:

- Sensors, controls, and points have been installed and verified operational.
- Sequences and interlocks have been programmed per Construction Documents.
- Wiring is installed in a neat and workmanlike manner.
- Alarms are operational and register at the BAS Operator’s Interface.
- Zone thermostats control unit operation.
- A 5 °F dead band between heating and cooling modes is available, either through BAS programming or via the thermostat.
- Control system has been programmed with occupied, unoccupied and holiday schedules, and these schedules have been documented for the owner.
- Control system has been programmed with nighttime set back set points, and these set points have been documented for the owner.
Point-to-point record sheets are attached.
Signed: ___________________________ Date: __________ Company: __________________

Startup:
☐ Commissioning Authority notified of and witnessed testing per Construction Documents.
☐ Startup procedures and completed startup report attached.
☐ Internal controls have been verified operational.
☐ Safeties tested, adjusted and demonstrated to CxA.
☐ Running and warning indicators tests have been demonstrated to CxA per Construction Documents.
Signed: ___________________________ Date: __________ Company: __________________

FPT Readiness:
☐ Test and Balance (TAB) is complete with preliminary reports submitted to CxA. Balanced settings are marked clearly and indelibly on balance devices or set with mechanical stops.
☐ Completed and signed copies of all start-up checklists/test forms provided to CxA.
☐ Damaged factory finishes have been replaced, repaired or touched up.
☐ Equipment not painted at factory has been painted with a finish coat of paint (no primer).
☐ All known issues have been corrected or reported to the CxA and the systems are ready for the functional performance test phase of commissioning.
☐ EQUIPMENT READY FOR FUNCTIONAL TESTING – Contractor’s pre-functional testing is complete; contactor has verified that functional performance testing (FPT) of the equipment and associated system demonstrates acceptable results as specified in FPT procedures.
Signed: ___________________________ Date: __________ Company: __________________

This checklist is not intended to represent all the requirements of the Construction Documents within this section. Completion of the items on this checklist does not release the Contractor from their contractual obligation to complete all the work as detailed within the entire specification section.

Signed: ___________________________ Date: __________________ Contractor’s Commissioning Coordinator
1.1 EXAMPLE FUNCTIONAL PERFORMANCE TESTS:

AH-1 SYSTEM FUNCTIONAL PERFORMANCE TESTS

OBJECTIVES

A. To perform comprehensive testing of all control related components and their driven devices (e.g. VFDs, temperature sensors, dampers and actuators). Demonstrate that the DDC system Operator’s Graphics for the air-handling unit (AH) are accurate schematic representations, which include the specified data points and information.

B. Specifically this test will check that:
   1. Temperature sensors are located and calibrated such that they are accessible for maintenance and the measurement accurately represents the average temperature of the specified fluid and location
   2. Coil control valves fully shut off flow to coils when closed and fully open when commanded
   3. Supply Air Temperature (SAT) control is operating per Sequences of Operation.
   4. Alarms are implemented and are operating properly
   5. VFD panel readout accurately reflects same as BAS.

EQUIPMENT TESTED

A. Air Handling Numbers: AH-P1 includes Supply Fan AH-P1.

BASIS OF TEST

A. Project specifications and drawings
B. Controls and equipment submittals
C. Control logic based on the sequences of operation as shown below

AHU-1 SEQUENCE OF OPERATIONS

A. Run conditions:
   1. When supply fan is stopped, both valves will close, the minimum outside air damper will close and the return air damper will close.
2. The supply fan is individually started and stopped through a time-of-day, day-of-week, and holiday schedule (24/7) or thru operator’s command. Csr1 (current switch/relay) mounted at variable speed drive will provide start/stop and status function. The return air damper will open first, then when damper open status is confirmed, start the supply fan.

B. High static shutdown:
1. The unit shall shut down and generate an alarm upon receiving a high static shutdown signal (dps2).
2. Manual reset is required to restart the system.

C. Supply air smoke detection:
1. The unit shall shut down and generate an alarm upon receiving a supply air smoke detector status.

D. Supply fan:
1. The supply fan shall run at all times, unless shutdown on safeties. To prevent short cycling, the supply fan shall have a user definable (adj.) Minimum runtime.
2. Alarms shall be provided as follows:
   a. Supply fan failure: commanded on, but the status is off.
   b. Supply fan in hand: commanded off, but the status is on.
   c. Supply fan runtime exceeded: status runtime exceeds a user definable limit (adj.).

E. Supply air duct static pressure control:
1. The controller shall measure duct static pressure and shall modulate the supply fan vfd speed to maintain a duct static pressure setpoint of 1.5 in h2o (adj.). The supply fan vfd speed shall not drop below 10% (adj.).
   a. Alarms shall be provided as follows:
      1) High supply air static pressure: if the supply air static pressure is 25% (adj.) Greater than setpoint.
      2) Low supply air static pressure: if the supply air static pressure is 25% (adj.) Less than setpoint.
      3) Supply fan vfd fault.

F. Supply air temperature setpoint- optimized:
1. The controller shall monitor the supply air temperature and shall maintain a supply air temperature setpoint reset based on supply fan vfd speed.
2. The supply air temperature setpoint shall be reset based on supply fan speed per the following table: sf speed sat setpoint

<table>
<thead>
<tr>
<th>sf speed</th>
<th>sat setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>55 °F</td>
</tr>
<tr>
<td>75%</td>
<td>60 °F</td>
</tr>
</tbody>
</table>
G. Heating and cooling coil valves:
   1. The controller shall measure the supply air temperature and modulate the heating and cooling coil valves in sequence to maintain setpoint.
   2. The cooling shall be enabled whenever:
      a. The supply fan status is on
      b. In addition, the heating valve is not active.
   3. Alarms shall be provided as follows:
      a. High supply air temp: if the supply air temperature is 5 °F (adj.) Greater than setpoint.

H. Low supply air temperature alarm:
   1. The controller shall alarm if the supply air temperature is less than 45 °F (adj.).

I. Building static pressure control:
   1. The first floor space static pressure sensor is for monitoring only.

J. Pre and final filter status:
   1. The controller shall monitor the pre and final filter status.
   2. Alarms shall be provided as follows:
      a. Final filter change required: final filter differential pressure exceeds a user definable limit (adj.).

K. Mixed air temperature:
   1. Alarms shall be provided as follows:
      a. High mixed air temp: if the mixed air temperature is greater than 90 °F (adj.).
      b. Low mixed air temp: if the mixed air temperature is less than 45 °F (adj.).

L. Return air temperature:
   1. Alarms shall be provided as follows:
      a. High return air temp: if the mixed air temperature is greater than 90 °F (adj.).
      b. Low return air temp: if the mixed air temperature is less than 45 °F (adj.).

M. Supply air temperature:
1. The controller shall monitor the supply air temperature.
2. Alarms shall be provided as follows:
   a. High supply air temp: if the mixed air temperature is greater than 120 °F (adj.).
   b. Low supply air temp: if the mixed air temperature is less than 45 °F (adj.).

PREREQUISITES

A. The following items must be completed prior to performing the testing procedures:
   1. Final installation of this system component, including final connection to the bas system – installation verification forms accepted.
   2. Equipment to be controlled is operational.
   3. Bas system operator’s graphical interface is complete for the systems involving these components.

MINIMUM PARTICIPANTS

A. The following personnel should be present for the testing:
   1. Owner’s witnesses
   2. Contractor’s representative: commissioning coordinator
   3. Test technician: BAS system contractor
   4. Commissioning Authority

TEST EQUIPMENT

A. The following test equipment is required to complete this procedure:
   1. Calibrated temperature measuring instruments capable of reading the temperature of the fluid within the specified tolerance and accuracy per the project documents
   2. Calibrated differential air pressure or flow measuring instrument capable of measuring the differential air pressure or air flow per the project documents

PROCEDURE

A. Participants sign in on the log below.
B. Record the equipment data on the next table.
C. Verify the prerequisites as shown. If any prerequisite fails, remedy the failure and verify the remedy before continuing.
D. Follow the step-by-step instructions in each step following.
E. Command and view all points from the BAS graphic user interface. Describe any deviation, or elaboration, on the test procedure in the Notes sections. Attach additional pages for notes if necessary. To facilitate photocopying, do not write on the backs of forms.

PARTICIPANT SIGN-IN

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
<th>Initials</th>
<th>Company</th>
<th>Email</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner’s Witness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contractor’s Cx Coordinator</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tech: BAS system contractor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commissioning Authority</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TEST EQUIPMENT RECORD

A. Record the make, model, serial number and last calibration date for each piece of equipment used during the test.

<table>
<thead>
<tr>
<th>Make</th>
<th>Model</th>
<th>Serial Number</th>
<th>Last Calibration Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PREREQUISITES

A. Verify the following prerequisites. Initial the pass or fail line and record the date and time.

- Final installation of system components, including final connection to the BAS system – installation verification forms accepted. [Pass: ___ Date: ___ Fail: T]
- Equipment to be controlled is operational. [Pass: ___ Date: ___ Fail: T]
- BAS System operator’s graphical interface is complete for the systems involving these components. [Pass: ___ Date: ___ Fail: T]

B. Establish Trends for all points listed in the following table. The trends must be recording before performing the tests in the next section. Trend must run for a period of 72 hours minimum and be recording during the completion of the remainder of the test procedures.
<table>
<thead>
<tr>
<th>Trend</th>
<th>Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Fan Start/Stop AH-P1</td>
<td>COV*</td>
</tr>
<tr>
<td>Mixed Air Temperature</td>
<td>2 min</td>
</tr>
<tr>
<td>Outside Air Temperature</td>
<td>2 min</td>
</tr>
<tr>
<td>Filter Status</td>
<td>2 min</td>
</tr>
<tr>
<td>Return Air Temperature</td>
<td>2 min</td>
</tr>
<tr>
<td>Smoke</td>
<td>2 min</td>
</tr>
<tr>
<td>Supply Air Temperature</td>
<td>2 min</td>
</tr>
<tr>
<td>Duct Static</td>
<td>2 min</td>
</tr>
<tr>
<td>High Limit Switch</td>
<td>COV*</td>
</tr>
<tr>
<td>AH-P1 Supply Fan Status</td>
<td>2 min</td>
</tr>
<tr>
<td>Supply Fan Airflow</td>
<td>2 min</td>
</tr>
<tr>
<td>Outside Air Airflow</td>
<td>2 min</td>
</tr>
<tr>
<td>AH-P1 Damper Position</td>
<td>2 min</td>
</tr>
<tr>
<td>AH-P1 Cooling Valve</td>
<td>2 min</td>
</tr>
<tr>
<td>AH-P1 Heating Valve</td>
<td>2 min</td>
</tr>
<tr>
<td>SF Fan Speed AH-P1</td>
<td>2 min</td>
</tr>
<tr>
<td>SF VFD Alarm</td>
<td>2 min</td>
</tr>
</tbody>
</table>

COV = Change of Value but at least once every 24 hours

END OF PREREQUISITES

PROCEDURE

TESTING PROCEDURE

1.1 The majority of the testing will be accomplished via trend analysis. Please keep in mind and follow the requested waiting times between certain steps to allow the system time to respond to the changes being made.

1.2 In addition to waiting the appropriate times, recording the time of test steps is critical in allowing the tester to locate the events in the trend logs.

1.3 Ensure the system is running normally before beginning the test.

1.4 Record the date of the test: __________

A. Hot Water and Chilled Water Valve Leak-by Test
   1. Time: _______ Set the fan VFD to 25% or less to provide a low airflow condition
   2. Time: _______ Override the hot water coil valve to 0% open
3. Time: _____ Override the chilled water coil valve to 0% open
4. Time: _____ Close the manual isolation valves to the hot water coil
5. Time: _____ Close the manual isolation valves to the chilled water coil
6. Time: _____ Allow the system to run for 10 minutes
7. Time: _____ Record the outside air temperature and supply air temperatures
   a. OAT: __________
   b. SAT: __________
8. Time: _____ Open the manual isolation valves on the hot water coil
9. Time: _____ Allow the system to run for 10 minutes
10. Time: _____ Record the outside air temperature and supply air temperatures
    a. OAT: __________
    b. SAT: __________
    c. The SAT should not change more than .5 °F during this time period, if it does, this may indicate a leaking control valve
11. Time: _____ Open the manual isolation valves on the chilled water coil
12. Time: _____ Allow the system to run for 10 minutes
13. Time: _____ Record the outside air temperature and supply air temperatures
    a. OAT: __________
    b. SAT: __________
14. The SAT should not change more than 0.5 °F during this time period, if it does, this may indicate a leaking control valve
15. Time: _____ Clear all overrides including the fan VFD speed and allow the system to return to normal operation

B. Duct Static Pressure Control Test
1. Time: _____ Record the current Supply Fan duct static pressure set point, static pressure, and VFD speed.
   a. Supply Fan duct static pressure set point __________
   b. Supply Fan duct static pressure __________
   c. Supply Fan VFD Speed __________
2. Time: _____ Change the Supply Fan Static Pressure Setpoint by 0.25” w.c.
3. Allow the system to run for 5 minutes (or until stable)
4. Time: _____ Record the current Supply Fan duct static pressure set point, static pressure, and VFD speed.
   a. Supply Fan duct static pressure set point __________
   b. Supply Fan duct static pressure __________
   c. Supply Fan VFD Speed __________
5. Change the duct static pressure set point back to its original value
6. Allow the system to run for 5 minutes (or until stable)
7. Time: _____ Record the current Supply Fan duct static pressure set point, static pressure, and VFD speed.
   a. Supply Fan duct static pressure set point ________
   b. Supply Fan duct static pressure ________
   c. Supply Fan VFD Speed ________

C. Building Pressure Control Test
   1. Time: _____ Record the current building static pressure
      a. Building Static Pressure ______
      b. Verify Building is slightly positive
      c. Confirm the variation in Building Space Static in section 6 above

D. Supply Air Temperature

<table>
<thead>
<tr>
<th>Control Test SF</th>
<th>SPEED</th>
<th>SAT Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>55 °F</td>
<td></td>
</tr>
<tr>
<td>75%</td>
<td>60 °F</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>65 °F</td>
<td></td>
</tr>
<tr>
<td>25%</td>
<td>70 °F</td>
<td></td>
</tr>
</tbody>
</table>

1. Time: _____ Record the current VFD Speed and supply air temperature set point
   a. VFD Speed: ________
   b. SAT Setpoint: ________

2. Time: _____ Change the supply air temperature set point by changing the supply fan VFD speed to 100%. (Note – Monitor duct static pressure to ensure it does not rise above 3.0" w.c.)

3. Time: _____ Record the new supply air temperature set point
   a. SAT Setpoint: ________ (Should be 55 °F)
      1) Allow the system to run for 1 minute
      2) Record the supply air temperature
   b. SAT: ________

4. Time: _____ Change the supply air temperature set point by changing the supply fan VFD speed to 75%. (Note – Monitor duct static pressure to ensure it does not rise above 3.0" w.c.)

5. Time: _____ Record the new supply air temperature set point
   a. SAT Setpoint: ________ (Should be 60 °F)
1) Allow the system to run for 10 minutes
2) Record the supply air temperature
   b. SAT: 

6. Time: _______ Change the supply air temperature set point by changing the supply fan VFD speed to 50%.
7. Time: _______ Record the new supply air temperature set point
   a. SAT Setpoint: _______ (Should be 65 °F)
      1) Allow the system to run for 10 minutes
      2) Record the supply air temperature
   b. SAT: 

8. Time: _______ Change the supply air temperature set point by changing the supply fan VFD speed to 25%.
9. Time: _______ Record the new supply air temperature set point
   a. SAT Setpoint: _______ (Should be 70 °F)
      1) Allow the system to run for 10 minutes
      2) Record the supply air temperature
   b. SAT: 
      1) Clear all overrides and alarms to restore the unit to normal operation

E. Alarm Tests

NOTE: These alarms have not been explicitly included in the written SOO. It is good practice to perform these alarm tests and have thus been included here.

Supply Fan Failure Test (Note: Owner to determine whether or not AHU can be shut off)
1. Time: _______ Record the current supply fan command and current supply fan status.
   a. Supply Fan Command: 
   b. Supply Fan Status:

2. Time: _______ Turn off supply fan at disconnect. Command fan on at BAS.
3. Time: _______ Supply fan failure alarm should sound. Record the time when the alarm sounds
4. Clear all overrides and alarms to restore the unit to normal operation

F. Supply Fan in Hand Test

1. Time: _______ Record the current supply fan command and current supply fan status.
   a. Supply Fan Command: 

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b. Supply Fan Status: 

2. Time: ______ Operate the supply fan in hand. Command the fan off at BAS.

3. Time: ______ Supply fan in hand alarm should sound. Record the time when the alarm sounds
   a. Clear all overrides and alarms to restore the unit to normal operation

G. Supply Fan Runtime Exceeded Test

1. Time: ______ Record the current fan runtime and the current supply fan runtime limit.
   a. Supply Fan Runtime: 
   b. Supply Fan Runtime Limit: ______

2. Time: ______ Change the supply fan runtime limit below the current supply fan runtime and record value.
   a. Supply Fan Runtime Limit: ___

3. Time: ______ Supply fan runtime exceeded alarm should sound. Record the time when the alarm sounds
   a. Clear all overrides and alarms to restore the unit to normal operation

H. High Supply Air Temperature Test

1. Time: ______ Record the current supply air temperature alarm set point and current supply air temperature.
   a. High Supply Air Temperature Alarm Setpoint: _____
   b. Current Supply Air Temperature: ______

2. Time: Change the high supply air temperature alarm set point to 2°F below the current supply air temperature and record the value
   a. High Supply Air Temperature Alarm Setpoint: _____

3. Time: ______ Record the supply air temperature when the alarm sounds
   a. Supply air Temperature: ______

4. Time: ______ Record the new supply air temperature set point
   a. Supply air Temperature Setpoint: ______
   b. Clear all overrides and alarms to restore the unit to normal operation

I. Low Supply Air Temperature Test

1. Time: ______ Record the current supply air temperature alarm set point and current supply air temperature.
   a. Low Supply Air Temperature Alarm Setpoint: ______
   b. Current Supply Air Temperature: ______
2. Time: Change the low supply air temperature alarm set point to 2˚F above the current supply air temperature and record the value
   a. Low Supply Air Temperature Alarm Setpoint:_____
3. Time: ______Record the supply air temperature when the alarm sounds
   a. Supply air Temperature:________
4. Time: ______Record the new supply air temperature set point
   a. Supply air Temperature Setpoint:________
   b. Clear all overrides and alarms to restore the unit to normal operation

J. High Return Air Temperature Test
1. Time: _____Record the current return air temperature alarm set point and current return air temperature.
   a. High Return Air Temperature Alarm Setpoint:_____
   b. Current Return Air Temperature:________
2. Time: Change the high return air temperature alarm set point to 2˚F below the current return air temperature and record the value
   a. High Return Air Temperature Alarm Setpoint:_____
3. Time: _____Record the return air temperature when the alarm sounds
   a. Return air Temperature:________
4. Time: _____Record the new return air temperature set point
   a. Return air Temperature Setpoint:________
   b. Clear all overrides and alarms to restore the unit to normal operation

K. Low Return Air Temperature Test
1. Time: _____Record the current return air temperature alarm set point and current return air temperature.
   a. Low Return Air Temperature Alarm Setpoint:_____
   b. Current Return Air Temperature:________
2. Time: Change the low return air temperature alarm set point to 2˚F above the current return air temperature and record the value
   a. Low Return Air Temperature Alarm Setpoint:_____
3. Time: _____Record the return air temperature when the alarm sounds
   a. Return air Temperature:________
4. Time: _____Record the new return air temperature set point
   a. Return air Temperature Setpoint:________
   b. Clear all overrides and alarms to restore the unit to normal operation
L. **High Mixed Air Temperature Test**
   1. Time: ______ Record the current mixed air temperature alarm set point and current mixed air temperature.
      a. High Mixed Air Temperature Alarm Setpoint: ______
      b. Current Mixed Air Temperature: _________
   2. Time: Change the high mixed air temperature alarm set point to 2˚F below the current mixed air temperature and record the value
      a. High Mixed Air Temperature Alarm Setpoint: ______
   3. Time: ______ Record the mixed air temperature when the alarm sounds
      a. Mixed air Temperature: ______
   4. Time: ______ Record the new mixed air temperature set point
      a. Mixed air Temperature Setpoint: ______
      b. Clear all overrides and alarms to restore the unit to normal operation

M. **Low Mixed Air Temperature Test**
   1. Time: ______ Record the current mixed air temperature alarm set point and current mixed air temperature.
      a. Low Mixed Air Temperature Alarm Setpoint: ______
      b. Current Mixed Air Temperature: _________
   2. Time: Change the low mixed air temperature alarm set point to 2˚F above the current mixed air temperature and record the value
      a. Low Mixed Air Temperature Alarm Setpoint: ______
   3. Time: ______ Record the mixed air temperature when the alarm sounds
      a. Mixed air Temperature: ______
   4. Time: ______ Record the new mixed air temperature set point
      a. Mixed air Temperature Setpoint: ______
      b. Clear all overrides and alarms to restore the unit to normal operation
   5. High Building Pressure Test
   6. Time: ______ Record the current building pressure alarm set point.
   7. High Building Pressure Alarm Setpoint: ______
   8. Time: ______ Change the high building pressure alarm set point to 0.2 in. w.c. above the current building pressure set point and record the value

N. **Low Building Pressure Test**
1. Time: ______ Record the current building pressure alarm set point.
   a. Low Building Pressure Alarm Setpoint: ________

2. Time: ______ Change the low building pressure alarm set point to 0.2 in. w.c. below the current building pressure set point and record the value.
   a. Low Building Pressure Alarm Setpoint: ________

O. 

High Static Test

1. Time: ______ Record the current static pressure alarm set point.
   a. High Static Alarm Setpoint: __

2. Time: ______ Change the high static alarm set point to 0.2 in. w.c. above the current static pressure set point and record the value.
   a. High Static Alarm Setpoint: __

3. Time: ______ Override and increase the VFD speed in small increments (+5%) until the duct static pressure exceeds the alarm set point and the high static alarm sounds on the BAS.

4. Time: ______ Record the static pressure when the alarm sounds.
   a. Static Pressure: _______

5. Time: ______ Record the new static pressure set point.
   a. Static Pressure Setpoint: ______
   b. Clear all overrides and alarms to restore the unit to normal operation.

P. 

Low Static Test

1. Time: ______ Record the current static pressure alarm set point.
   a. Low Static Alarm Setpoint: __

2. Time: ______ Change the low static alarm set point to 0.2 in. w.c. below the current static pressure set point and record the value.
   a. Low Static Alarm Setpoint: __

3. Time: ______ Override and decrease the VFD speed in small increments (+5%) until the duct static pressure exceeds the alarm set point and the low static alarm sounds on the BAS.

4. Time: ______ Record the static pressure when the alarm sounds.
   a. Static Pressure: _______

5. Time: ______ Record the new static pressure set point.
   a. Static Pressure Setpoint: ______
b. Clear all overrides and alarms to restore the unit to normal operation

Q. **Freeze Protection**

1. Time: Record the current temperature of the air entering the cooling coil, chilled water valve position and freeze protection set point
   a. Temp: __________
   b. CHWV: __________
   c. Freeze Protection Setpoint: ______

2. Time: Override the temperature of the air entering the cooling coil to +0.5°F above the freeze protection set point

3. Time: Begin lowering the temperature of the air entering the cooling coil by 0.5°F increments until the freeze protection sequence starts and the unit shuts down. The chill water valve should open to 100% and an alarm should display on the BAS
   a. Record the temperature at which the sequence initiated.
   b. Temp: __________

4. **Filter Change Required**
   a. Time: Record the current filter differential pressure limit.
      1) Filter differential pressure limit: ______
   b. Time: Change the Filter differential pressure limit below the current differential pressure (say 0.2” w.c) and note.
      1) Filter differential pressure limit: ______
   c. Time: Filter change required alarm should sound. Record the time when the alarm sounds
   d. Clear all overrides and alarms to restore the unit to normal operation

R. **Supply Fan Fire Alarm Failure Test**

1. Time: Record the current supply fan command and current supply fan status.
   a. Supply Fan Command: __________
   b. Supply Fan Status: __________

2. Time: Issue a fire alarm signal at BAS

3. Time: Supply fan failure alarm should sound. Record the time when the alarm sounds and Supply Fan shuts off.
   a. Clear all overrides and alarms to restore the unit to normal operation

S. **Trend Review**

1. After completion of the trend period collect the trend data and review it for the following:
a. The fan should run 24x7 throughout the trending period

2. Fan Speed with static pressure set point adjustment
   a. The fan VFDs should modulate to maintain the fixed static pressure set point

3. Building Pressure Control
   a. The building pressure differential varies as expected along with changes in supply duct static pressure

4. Supply air temperature set point reset
   a. The supply air temperature should reset based on reset table.

5. Supply air temperature
   a. The supply air temperature should be maintained within ±2°F at all times

6. Chilled Water Valve
   a. The chilled water valve should modulate to maintain the supply air temperature set point

7. Hot Water Valve
   a. The hot water valve should modulate to maintain the supply air temperature set point and maintain low limit discharge air temperature

8. Simultaneous heating and cooling
   a. At no time should both the hot water and chilled water valves be open

9. Alternating heating and cooling
   a. The unit should not be rapidly alternating between heating and cooling

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Final Test Results

☐ Pass ☐ Fail

Date: ______________________

END OF TESTING PROCEDURE
Standards Adoption

The “Building Systems – HVAC” Version 3.1, March 2018 standards were adopted by the Standards Committee on April 5th, 2018, and are effective immediately.

Confirmed:

[Signature]

Geoffrey W. Neuman, Standards Committee Chair