SECTION 23 02 00 - PIPING SYSTEMS INSULATION

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

PART 1 - GENERAL

1.01 SCOPE

A. General:

1. Furnish all labor and materials necessary for the complete installation of thermal insulation systems on all hot and cold piping systems, equipment, and vessel surfaces which require insulation for:

a. conservation of or protection from heat;

b. conservation of or protection from cold;

c. freeze protection;

d. prevention of condensation or dripping;

e. comfort or safety for occupants and personnel;

f. and energy efficiency.

2. Where insulation is applied to surfaces that may operate below ambient temperatures:

a. provide vapor barriers to prevent moisture transfer into the insulation system, and;

b. provide vapor stops at specified intervals along the length/barrel of the pipe to prevent moisture migration within the insulation system.

3. Provide insulation to result in ease of operation, maintenance, access, and/or replacement of equipment.

4. The insulation shall be complete and effective throughout the project.

B. Definition of above ambient and below ambient piping system operational temperature.

1. For the purposes of this specification, piping systems that operate at temperature above 75°F are defined as operating at above ambient temperature. Where the terms “warm” or “hot” are used in the context of this specification, these terms apply to piping systems operating at above ambient temperature.

2. For the purposes of this specification, piping systems that operate at temperature below 75°F are defined as operating at below ambient temperature. Where the

terms “cool” or “cold” are used in the context of this specification, these terms apply to piping systems operating at below ambient temperature.

C. Piping systems to receive insulation include, but are not necessarily limited to:

1. Domestic cold water, including filtered cold water
2. Domestic hot water and hot water return
3. Condensate drainage (cooling coil condensate drainage)
4. Storm/roof drainage including overflow drainage
5. Sanitary and grease waste where specified in 2.03 below
6. Chilled water
7. Heating water
8. Piping accessories and specialties
9. Vessels, tanks, pumps, and similar surfaces in piping systems.

1.02 WORKMANSHIP AND QUALIFICATIONS

A. All work shall be performed IN THE BEST PRACTICE OF THE TRADE by a Contractor or Subcontractor regularly engaged in the insulation field and having a minimum of ten (10) years experience in insulating systems comparable to those in the project. Insulation systems shall be consistent for each system.

B. Architect/Engineer shall retain sole discretion regarding proper application and professional appearance of the work. Where directed by Architect/Engineer, Contractor shall, at Contractor’s expense, remove the insulation and reinsulate to achieve an installation satisfactory to the Architect/Engineer.

1.03 SUBMITTALS

A. **Provide summary tabular data followed by highlighted cut sheets on products**

1. Summary tabular data: Provide a summary schedule of insulations tabulating in matrix form:

a. piping service;

b. insulation system;

c. Insulation thicknesses;

d. mastics, adhesives, cements, and joint sealants;

e. insert materials;

f. fittings type;

g. vapor stop construction;

h. jacket type, including fiberglass fabric or other cloths;

i. coatings/paint

j. and other requirements indicated by these specifications and the drawings.

2. Detailed product data: Provide highlighted cut sheets of all the tabulated products. Also include: fittings systems; fire reactivity characteristics, including flame spread/smoke developed ratings; K-factors; and vapor permeability data:

a. Vapor permeability (in perm-inch, per ASTM E96 Method B – wet cup) shall be provided for all piping systems operating below ambient temperatures. Include properly documented data for wet cup performances, including:

1) Insulation

2) Jackets

3) Mastics, joint sealants, and accessories.

B. **Resumes: Submit detailed professional resume of insulation superintendent assigned to the job who will be on site at all times insulation work is being done. This craftsman shall have a minimum of ten years experience in the insulation field.**

C. **See Part 3 for further requirements, including mock-ups submittals.**

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

E. **Submit mock-up (in-field submittal acceptable) of all insulation systems to be provided, including applicable examples of the following conditions where they occur on a repeated basis:**

1. pumps, piping, elbows, tees, flanges, unions

2. valves, control valves, balance/measurement valves, strainers,

3. Conditions which penetrate or protrude through the insulation system.

a. taps, nipples, ports, stand-offs, wells

b. other accessories or appurtenances as may be routinely encountered in the respective piping systems.

1.04 RELATED SECTIONS

A. Section 22 10 00 – Basic Materials and Methods for Plumbing Work

B. Section 22 11 00 – Plumbing Specialties

C. Section 23 00 10 – General Requirements for Mechanical Work

D. Section 23 01 00 – Basic Materials and Methods for Mechanical Work

E. Section 23 08 58 – Custom Air Handling Units

F. Section 23 08 90 – Air Distribution

PART 2 – PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Flame/Smoke Ratings: All above grade insulation shall have composite (insulation, jacket or facing, and adhesive or cement used to adhere the jacket to the insulation) fire and smoke hazard rating as tested under procedure ASTM E-84 and NFPA 255 not exceeding a flame spread rating of 25 and smoke developed rating of 50.

B. Insulation Accessories

1. Accessories such as adhesives, mastics, sealants, cements, cloth for fittings, coatings, and finishes shall be permanently fire and smoke resistant. Chemicals used for treatment paper in jacket laminates shall be unaffected by water or humidity.

2.02 INSULATION SYSTEMS AND MATERIALS

A. Insulation Type FG – Fiberglass

Insulation Type MW – Mineral Wool

Note: For the purpose of this specification, Fiberglass and Mineral Wool insulation types are interchangeable.

1. General: One-piece molded fiberglass insulation system with the following characteristics:

a. Insulation of molded of heavy density resin bonded inorganic glass fibers. Insulation operating temperature from 0°F to 850°F (without heat-up schedule). Insulation density of 3.5 to 5.5 pounds per cubic foot (pcf), size dependent. Insulation K-value not to exceed 0.23 Btu-in/hr-ft^2-ºF at 75ºF.

b. All-service jacket composed of aluminum foil, reinforced with a glass scrim bonded to a polymer film exterior surface. Jacketing may include a kraft paper interleaving with an outer film layer leaving no paper exposed. Jacket shall include a self-sealing lap. Jacket service temperature range of -20°F to 150°F.

c. Basis of design for Insulation Type FG: Owens Corning Fiberglas™ Pipe Insulation with SSL II® with ASJ Max.

1) Acceptable Alternative: Johns Manville Micro-Lok® *HP* Ultra

d. Basis of design for Insulation Type MW: Knauf Insulation Earthwool® 1000° with ASJ+ SSL+.

2. Fittings: Pre-molded fittings matching base insulation material and thickness. At contractor's option, fittings may be fabricated of mitered sections matching base insulation material and thickness.

3. Fittings covers: Glass fabric and mastic or pre-molded 25/50 rated PVC fitting covers as manufactured by Proto or Zeston.

a. PVC fitting covers are not allowed on steam or steam condensate piping systems.

b. Where PVC fitting covers are allowed, the insulation material below the covers is to match the base insulation material. Low density mineral wool or fiberglass insulation material (packing) is not acceptable.

B. Insulation Type FB – Fiberglass blanket

1. General: Fiberglass blanket insulation system with the following characteristics:

a. Insulation of uniformly textured inorganic glass fibers formed with formaldehyde free plant based binding agent. Insulation operating temperature from 0°F to 250°F. Insulation density of 1.0 pounds per cubic foot (pcf). Insulation K-value not to exceed 0.26 Btu-in/hr-ft^{2}-ºF at 75ºF.

b. Foil skrim kraft (FSK) jacket.

c. Basis of design: CertainTeed SoftTouch™ Duct Wrap Insulation

C. Insulation Type FG-PT

1. General: High density vertical fiber fiberglass insulation system with the following characteristics:

a. Insulation of semi-rigid fibrous glass board material, with factory applied jacket. The insulation is adhered with the end grain perpendicular to the jacket providing a flexible product that is easily wrapped around pipes, tanks or irregularly shaped objects, while providing good rigidity and abuse resistance.

b. Insulation K-value not to exceed 0.26 Btu-in/hr-ft^{2}-ºF at 75ºF.

c. Compressive strength at 10% deformation no less than 125 lb/ft^{2}.

d. Insulation service temperature from 0°F to 650°F.

e. All-service jacket composed of aluminum foil, reinforced with a glass scrim bonded to a polymer film exterior surface. Jacket shall include a self-sealing lap. Jacket service temperature range of -20°F to 150°F.

f. Basis of design for: Owens Corning Fiberglas™ Pipe and Tank Insulation with ASJ Max.

D. Insulation Type CG – Cellular glass

1. General: Complete system of cellular glass insulation, sealants, mastics and jackets as manufactured by Owens Corning Corporation.

2. Insulation:

a. Insulation K-value not to exceed 0.29 Btu-in/hr-ft^2-ºF at 75°F.

b. ASTM E96 Method B (wet cup) perm rating shall be 0.0.

c. Average compressive strength shall be equal to or in excess of 90 psi.

d. Fittings shall be provided as factory fabricated shapes for standard pipe fittings, valves, piping accessories, etc.

3. Fittings: Prefabricated fittings matching base insulation material and thickness. At contractor's option, fittings may be fabricated of mitered sections matching base insulation material and thickness. Finish fittings with glass fabric and mastic.

4. Insulation shall be secured with manufacturer's approved fiber reinforced tape (3M Scotch Brand No. 880) or with aluminum bands with matching seals, minimum of two bands per insulation segment.

5. Joint sealant for below ambient piping systems:

a. All joints and seams (longitudinal/axial seams and butt joints along the run of piping) shall be sealed full depth with Owens Corning Pittseal™ 444N or Pittseal™ CW (Low VOC) and compressed firmly together.

6. Bore coating:

a. Provide anti-abrasive bore coating of interior wall of insulation at all elbows where straight pipe runs exceed 20 feet on either side of elbow

b. Low temperature applications: Owens Corning Pittcoat™ 16 Low Temperature anti-abrasive (LTAA) coating, or approved equal.

c. High temperature applications: Hydrocal B11.

7. Corrosion inhibiting coating:

a. Coordinate with Section 23 01 00 Basic Materials and Methods and ensure proper preparation and application of coating prior to application of insulation.

8. Jacketing indoors:

a. Where applied inside the building's conditioned envelope, provide triple-ply jacketing of white polypropylene + fiberglass scrim + metalized polyester film similar and equal to Alpha Associates, Inc. Style VR-R-HD.

E. Insulation Type FE – Flexible elastomeric

1. General –Closed cell flexible elastomeric insulation with:

    a. closed cell structure having 0.05 perm-inch maximum water vapor permeability per ASTM E-96 Procedure A (dry cup) through 1” wall;

    b. Insulation K-value not to exceed 0.254 Btu-in/hr-ft^2-ºF through 1” wall;

    c. continuous operating temperature from -40°F to 220°F (180°F for self-seal);

    d. flame spread/smoke developed ratings not exceeding 25/50 in thicknesses up to 2”;

    e. “Microban” anti-microbial protection

    f. Formaldehyde free, low VOC materials

    g. Density range of 3 to 6 lbm/cu. Ft.

    h. In tubing and pipe sizes up to to 10” IPS.

    i. Basis of Design: Armacell AP / Armaflex® black tube insulation. Provide white tube insulation where indicated in 2.03 below.

        1) Acceptable alternate: K-Flex® Insul-Tube®

2. Adhesive: Armaflex 520 BLV

3. Fittings: Fabricated of mitered sections matching base insulation material and thickness. Bends of 45° or less are to be simple mitered insulation segments. Bends greater than 45° are to be multi-segment bends in accordance with the manufacturer’s instructions.

4. Finish coating: Provide Armaflex WB finish coating in areas where piping insulation is exposed in finished areas of the building that are normally visible to building occupants. Provide minimum of three coats for complete coverage. Finish coating is not required for piping above 8 feet above finished floor or where an external protective jacket is specified. Tint to match adjacent surfaces where indicated or where directed by the Architect.

F. Insulation Type FE-HT – Flexible elastomeric for high temperature applications

1. General –Closed cell flexible elastomeric insulation with:

    a. Closed cell structure having 0.08 perm-inch maximum water vapor permeability per ASTM E-96 Procedure A (dry cup);

    b. Insulation K-value not to exceed 0.254 Btu-in/hr-ft^2-ºF at 75°F through 1” wall;

    c. Continuous operating temperature from -40°F to 300°F;

    d. Flame spread/smoke developed ratings not exceeding 25/50;

e. Formaldehyde free, low VOC materials

f. Density range of 3 to 6 lbm/cu. Ft.

g. In tubing and pipe sizes up to to 2-1/2" IPS.

h. Basis of Design: Armacell UT / Solaflex® black tube insulation.

2. Adhesive: Armaflex HT625

3. Fittings: Fabricated of mitered sections matching base insulation material and thickness. Bends of 45° or less are to be simple mitered insulation segments. Bends greater than 45° are to be multi-segment bends in accordance with the manufacturer's instructions.

4. Finish coating: Provide Armaflex WB finish coating in areas where piping insulation is exposed in finished areas of the building that are normally visible to building occupants. Provide minimum of three coats for complete coverage. Finish coating is not required for piping above 8 feet above finished floor or where an external protective jacket is specified. Tint to match adjacent surfaces where indicated or where directed by the Architect.

G. Insulation Type PE – Polyethylene foam pipe and sheet insulation

1. Closed cell polyethylene foam pipe insulation as follows:

a. Insulation K-value not to exceed 0.27 Btu-in/hr-ft^2-ºF at 75°F.

b. 0.02 perm-inch vapor permeability;

c. black color;

d. -297°F to 200°F operating temperature limits;

e. Basis of Design: Armacell Imcoa® black tube insulation and ImcoSheet® black sheet insulation.

2. Adhesive: Armaflex 520 BLV

3. Fittings: Fabricated of mitered sections matching base insulation material and thickness. Bends of 45° or less are to be simple mitered insulation segments. Bends greater than 45° are to be multi-segment bends in accordance with the manufacturer's instructions.

4. Finish coating: Provide Armaflex WB finish coating in areas where piping insulation is exposed in finished areas of the building that are normally visible to building occupants. Provide minimum of three coats for complete coverage. Finish coating is not required for piping above 8 feet above finished floor or where an external protective jacket is specified. Tint to match adjacent surfaces where indicated or where directed by the Architect.

H. Mastics

1. Type VB: Vapor barrier mastic: Childers CP-30 LO. In occupied buildings or for projects subject to LEED or Green Building requirements: Childers CP-35.

2. Type NVB: Non-vapor barrier mastic: Childers CP-10/11.

I. Accessories common to all systems

1. Inserts

a. Provide cellular glass inserts at pipe support locations for pipe sizes 1-1/2" and larger. Thickness to match adjacent insulation thickness, but not less than 1" thick. Inserts shall be full circumference of pipe and not less than 24" in length. Increase length to 36" for pipe sizes 8" and larger.

b. Inserts for insulation Type FE and PE

1) Where piping is supported on strut channel framing with pipe clamps, regardless of pipe size, shall be Armacell® ArmaFix® EcoLight insulation pipe supports with PET core and self-sealing PVC outer cladding.

c. Where insulation thickness is less than 1", taper insert to thickness of adjacent insulation. Provide glass fabric and mastic to seal inserts to adjacent insulation.

d. Wood inserts are not allowed.

e. For steel piping systems conveying warm or hot fluids, where pipe size exceeds 12", provide fabricated steel pipe covering protection saddles equal to Anvil Fig. 160 through 165.

2. Insulation protection shields

a. At points where pipe hangers or supports occur, provide galvanized steel pipe protection shields encompassing 180 degrees of the circumference of the pipe insulation and conforming to the contour of the insulated pipe.

b. Minimum length and gauge of shields shall be as follows: 1-1/4" and smaller: 12" long, 18 gauge; 1-1/2" thru 3": 18" long, 18 gauge; 4" thru 6": 24" long, 16 gauge; 8" thru 12": 24" long, 16 gauge; 14" and larger: 24" long, 14 gauge.

c. For insulation Type FE, FE-HT and PE in pipe sizes 1-1/4" and smaller where external protective jacketing is not provided, provide two spiral wraps, each with 50% overlap, around insulation surface using Venture Tape 1507 (black). Length of tape wrap to extend 1" minimum past the insulation protection shields.

d. Shields shall be banded to pipe insulation at not less than two locations.

J. External protective jackets

1. Provide external protective jackets when piping is exposed to outdoors, exposed indoors below eight feet (8 ft.) AFF or where susceptible to damage due to maintenance/service access or procedures. Refer also to specific requirements by piping system in 2.03 below.

2. Type EPJ1: Aluminum jacketing

    a. Factory fabricated aluminum jacketing system of 0.016" aluminum with smooth finish and a modified Pittsburgh Z-Lock on the longitudinal seam. Secure jacketing with stainless steel bands.

    b. Where piping insulation is subject to being stepped on or otherwise receive unintended wear or damage during construction or afterwards, jacketing thickness shall be 0.032".

    c. Jacket shall include a moisture lining consisting of a 3-mil thickness of a co-extrusion of polyethylene and DuPont's Surlyn®, which has been heat laminated to the metal jacketing.

    d. Aluminum jacketing is to be provided for the entire piping system for insulation types EG and SA as these insulation systems do not have a factory applied or other field applied jacket system.

3. Type EPJ2: External protective jacketing for use indoors.

    a. 3M™ Venture Clad™ 1577CW; 7.0 mils thickness; flat natural aluminum finish.

4. Type EPJ3: External protective jacketing for use outdoors or below grade.

    a. 3M™ Venture Clad™ 1579GCW; 15.0 mils thickness; flat natural aluminum finish.

5. Type EPJ4: External protective jacket for use on cellular glass pipe insulation located outdoors or below grade.

    a. Pittwrap® SS self-sealing vapor barrier jacketing

K. Removable insulation covers, required for warm/hot service piping

1. All flanges, valves, pressure regulating valves, strainers, expansion joints, steam trap bodies, and any other hot surfaces which may require disassembly/removal/replacement shall be covered with a removable/reusable coverings similar and equal to Thermaxx hot insulation jackets. Jackets shall be designed for temperatures up to 599°F.

2. Jackets shall be box type or custom fitted to the component it is to be installed on. Insulation shall be 1.5" thick needled fiberglass mat plus 10 mm Pyrogel. Jacketing shall be PTFE fiberglass composite 16.5 oz/sq. yd. minimum.

3. Jackets shall be sewn with two (2) parallel rows of stitching with minimum 4 to 6 stitches per inch. The thread shall durably withstand the skin temperatures without degradation.

4. Jackets shall be fastened using hook and loop (Velcro) straps and 1” Slide Buckles. Hog rings, staples and wire are not are not acceptable methods of closure. No raw cut jacket edges shall be exposed.

5. Provide a permanently attached Aluminum or stainless steel nameplate on each jacket to identify its location, size and tag number.

2.03 PIPING SYSTEM INSULATION REQUIREMENTS BY PIPING SYSTEM

A. Domestic Cold Water, including Filtered Domestic Cold Water

1. General: This piping system potentially operates at below ambient temperature. Provide vapors stops as indicated in Part 3.

2. Scope:

a. Insulate above grade cold water mains and branches, including those in crawlspaces.

1) Exception: Indoor piping within mechanical rooms at the building service entry is to be uninsulated. This includes backflow preventer assemblies, water meter assemblies, and isolation valves and piping specialties at the service entry. Insulate piping downstream of the last valve in such assemblies.

b. Insulate runouts to fixtures.

c. This specification for domestic cold water also applies to softened cold water, non-potable cold water, make-up water piping serving hydronic systems, cooling towers, etc.

d. Piping downstream of trap primer assemblies is not required to be insulated. Piping below slabs on grade or below grade is not required to be insulated.

3. Basis of design insulation system Option “A”:

a. This insulation system is required where piping is located outdoors.

b. Insulation type: Type FE

c. Thickness: 3/4” when not subject to freezing temperatures; 1-1/2” when subject to freezing temperatures, including piping in exterior walls.

d. Inserts: Provide per 2.02 above.

e. Insulation protection shields: Provide at hanger locations for all pipe sizes per 2.02 above.

f. Finish coating: Provide as specified and where indicated in 2.02 above.

g. External protective jacket:

1) Indoors: Type EPJ2 where indicated in 2.02 above.

2) Outdoors or below grade: Type EPJ3.

3) Refer to Section 23 01 00 for HDPE chilled water piping for below grade applications.

4. Basis of design insulation system Option “B”:

a. This insulation type is allowed for piping indoors including crawlspaces, etc.

b. Insulation type: Type FG or MW

c. Thickness: 1” when not subject to freezing temperatures; 2” when subject to freezing temperatures, including piping in exterior walls.

d. Mastics: Type VB

e. Inserts: Provide per 2.02 above.

f. Insulation protection shields: Provide at hanger locations for all pipe sizes per 2.02 above.

g. External protective jacket:

1) Indoors: Type EPJ1 where indicated in 2.02 above.

2) Indoors: Type EPJ2 as an alternative to Type EPJ1 above.

B. Domestic Hot Water and Hot Water Return

1. General: This piping system operates at above ambient temperature.

2. Scope: Insulate all domestic hot water and hot water return piping, including piping below slab/grade.

3. Basis of design insulation system Option “A”:

a. This insulation type is allowed for piping above grade indoors including attics, crawlspaces, etc.

b. Insulation type: Type FG or MW

c. Thickness: 1” when not subject to freezing temperatures; 2” when subject to freezing temperatures, including piping in exterior walls.

d. Mastics: Type NVB

e. Inserts: Provide per 2.02 above.

f. Insulation protection shields: Provide at hanger locations for all pipe sizes per 2.02 above.

g. External protective jacket:

1) Indoors: Type EPJ1 where indicated in 2.02 above.

2) Indoors: Type EPJ2 as an alternative to Type EPJ1 above.

4. Basis of design insulation system Option “B”:

a. This insulation system is required where piping is located outdoors or below grade / below slab.

b. Insulation type: Type FE-HT

c. Thickness: 3/4” when not subject to freezing temperatures; 1-1/2” when subject to freezing temperatures, including piping in exterior walls.

d. Inserts: Provide per 2.02 above.

e. Insulation protection shields: Provide at hanger locations for all pipe sizes per 2.02 above.

f. Finish coating: Provide as specified and where indicated in 2.02 above.

g. External protective jacket:

1) Indoors: Type EPJ1 where indicated in 2.02 above.

2) Indoors: Type EPJ2 as an alternative to Type EPJ1 above.

3) Outdoors or below grade: Type EPJ3.

4) Refer to Section 23 01 00 for HDPE chilled water piping for below grade applications.

C. Condensate Drains

1. General: This piping system typically operates at below ambient temperature. Use mastic Type VB and provide vapor stops as indicated in Part 3.

2. Scope: Insulate all condensate drain piping and traps.

a. Insulation type: Type FE or PE

b. Thickness: 3/4” indoors; 1” outdoors.

c. Inserts: Provide per 2.02.

d. Insulation protection shields: Provide at hanger locations for all pipe sizes per 2.02 above.

e. Finish coating: Provide as specified and where indicated in 2.02 above.

f. External protective jacket:

1) Indoors: Type EPJ1 where indicated in 2.02 above.

2) Indoors: Type EPJ2 as an alternative to Type EPJ1 above.

3) Outdoors: Type EPJ3.

D. Storm/Roof Drainage, Including Overflow Drainage

1. General: This piping system potentially operates at temperatures below ambient temperature. Provide vapor stops as indicated in Part 3.

2. Scope: Insulate all interior storm / roof drain piping including overflow drain piping, up to and including bottom of the drain body.

3. Basis of design insulation system Option “A”:

a. Insulation type: Type FG or MW

b. Thickness: 1 inch

c. Mastics: Type VB

d. Inserts: Provide per 2.02 above.

e. Insulation protection shields: Provide at hanger locations for all pipe sizes per 2.02 above.

f. External protective jacket:

1) Indoors: Type EPJ1 where indicated in 2.02 above.

4. Basis of design insulation system Option “B”:

a. Insulation type: Type FB

b. Thickness: 2 inches

c. Mastics: Type VB

d. Inserts: Provide per 2.02 above.

e. Insulation protection shields: Provide at hanger locations for all pipe sizes per 2.02 above.

f. External protective jacket:

g. Indoors: Type EPJ1 where indicated in 2.02 above.

E. Recovered Water and Sanitary and Grease Waste Where Indicated Below

1. General: This piping system typically operates at below ambient temperature. Provide vapor stops as indicated in Part 3.

2. Scope:

   a. Insulate all grease waste piping within the crawl space and below grade.

   b. Insulate all above grade sanitary waste piping receiving cooling coil condensate (fin water), up to and including bottom of the drain body. Insulate lavatory/sink tailpieces, p-traps and piping where serving as condensate receptors. Insulate waste piping serving drinking fountains and electric water coolers. Insulate p-traps and piping to a minimum of 15 feet from indirect waste receptor or water cooler.

3. Basis of design insulation system “A”:

   a. Insulation type: Type FE

   b. Thickness: 3/4”

   c. Inserts: Provide per 2.02 above.

   d. Insulation protection shields: Provide at hanger locations for all pipe sizes per 2.02 above.

   e. External protective jacket:

      1) Indoors: Type EPJ1 where indicated in 2.02 above.

      2) Indoors: Type EPJ2 as an alternative to Type EPJ above.

      3) Outdoors: Type EPJ3.

4. Basis of design insulation system “B”: This insulation type is intended to be used at exposed lavatory/sink tailpieces and p-traps when used as a condensate receptor:

   a. Insulation type: Type FE (white)

   b. Thickness: 3/4”

   c. Insulation protection shields: Provide at hanger locations for all pipe sizes per 2.02 above.

5. Below Grade

   a. Insulation type: CG

   b. Thickness: 1”

   c. External protective jacket: EPS4

F. Chilled Water

1. General: This piping system operates at temperatures below ambient temperature. Provide vapor stops as indicated in Part 3.

a. Insulation type: Type CG

b. Thickness: 2 inches

c. Mastics: Type VB

d. Insulation protection shields: Provide at hanger locations for all pipe sizes per 2.02 above.

e. External protective jacket:

1) Indoors: Type EPJ1 where indicated in 2.02 above.

2) Indoors: Type EPJ2 as an alternative to Type EPJ1 above.

3) Outdoors: Type EPJ4 plus EPJ1.

4) Below grade (crawlspace): Type EPJ4

f. Refer to Section 23 01 00 for HDPE chilled water piping for below grade applications.

G. Heating Water

1. General: This piping system typically operates at above ambient temperature.

a. Exception: Refer to 3 below.

2. Indoors above grade

a. General: This piping system typically operates at above ambient temperature.

b. Insulation type: Type FG or MW

c. Thickness:

1) Design temperature below 140°F

a) Pipe size ≤ 1-1/2”, 1” thickness

b) Pipe size ≥ 2”, 1-1/2” thickness

2) Design temperature above 140°F

a) Pipe size ≤ 1-1/2”, 1-1/2” thickness

b) Pipe size ≥ 2”, 2” thickness

d. Mastics: Type NVB

e. Inserts: Provide per 2.02 above.

f. Insulation protection shields: Provide at hanger locations for all pipe sizes per 2.02 above.

g. External protective jacket:

1) Indoors: Type EPJ1 where indicated in 2.02 above.

2) Indoors: Type EPJ2 as an alternative to Type EPJ above.

3. Indoors at heating coils in the reheat position

a. Heating water piping serving heating coils downstream of cooling coils or otherwise in a re-heat position within a supply air duct system, including terminal box heating coils, will operate at below ambient temperature during certain conditions. Heating water piping serving heating water coils as described above shall be insulated as specified below. Use mastic Type VB and provide vapor stops as indicated in Part 3.

b. Insulation type: Type CG

c. Thickness: 2 inches

d. Insulation protection shields: Provide at hanger locations for all pipe sizes per 2.02 above.

e. External protective jacket:

1) Indoors: Type EPJ1 where indicated in 2.02 above.

2) Indoors: Type EPJ2 as an alternative to Type EPJ above.

4. Outdoors and below grade (Crawlspace)

a. Insulation type: Type CG

b. Thickness: 2 inches

c. Inserts: Provide per 2.02 above.

d. Insulation protection shields: Provide at hanger locations for all pipe sizes per 2.02 above.

5. External protective jacket:

a. Crawlspace: Type EPJ4 plus EPJ1.

b. Refer to Section 23 01 00 for HDPE chilled water piping for direct buried applications.

2.04 PIPING ACCESSORIES AND SPECIALTIES

A. Where insulation systems specified above for piping cannot be properly applied to thermometer wells, gauge piping, air vents, valves, and similar irregular surfaces, insulation system for such accessories and specialties shall be as follows:

1. Systems operating below ambient temperature:

a. Insulation type: FE

b. Thickness: 3/4” minimum

c. Other accessories: Provide as specified for insulation Type FE, as applicable to the field conditions.

2. Systems operating above ambient temperature:

a. Insulation type: FE-HT

b. Thickness: 3/4” minimum

c. Other accessories: Provide as specified for insulation Type FE-HT, as applicable to the field conditions.

2.05 VESSELS, PUMPS, AND SIMILAR SURFACES IN PIPING SYSTEMS

A. General: Provide insulation for all hot, warm, cool, or cold vessels or similar surfaces to conserve energy, promote comfort, limit temperature swings in mechanical or occupied areas, protect workers from hot surfaces, prevent condensation, prevent moisture migration in the insulation system, protect from freezing, etc. Such vessels shall include, but not necessarily be limited to: Heat exchangers/converters; hot water generators/storage tanks, chilled and heating water expansion tanks, air separators, chemical filter/feeders, etc.

B. Provide factory insulation for such items whenever available from factory.

C. Approved field insulation system for hot or warm surface vessels and similar surfaces shall be:

1. Insulation type: Type FG-PT

2. Thickness:

a. 1 ½ inches for design temperatures up to 140°F.

b. 2 inches for design temperatures 141 to 200°F.

D. Approved insulation systems that potentially operate below ambient temperature shall be:

1. Insulation type: FE

2. Thickness: 3/4” minimum

3. Other accessories: Provide as specified for insulation Type FE, as applicable to the field conditions.

PART 3 – EXECUTION

3.01 GENERAL

A. **Mock-ups:**

1. **Provide/submit mock-ups (usually in the smaller pipe/surface sizes) for each insulation system** demonstrating understanding of and compliance with specifications (and as an opportunity to evaluate alternate/improved methods which may be proposed by the contractor). At a minimum, include all elements as prescribed in 1.03-E above.

2. **Similar piping packages:** where similar piping assemblies exist repeatedly (e.g., terminal units), provide mock-up of entire assembly.

3. **Mock-ups shall be considered part of submittal requirements, and shall be reviewed on site and accepted prior to initiating or performing insulation work.**

4. **All insulation to receive jacketing or cladding is required to be reviewed by the Architect/Engineer, in the field, prior to applying jacketing or cladding.**

B. Comply with Manufacturer's Recommendations: At a minimum, install all systems according to manufacturer's written instructions and recommendations, and in accordance with service temperature ratings. Where specifications exceed the minimum requirements of the manufacturers, the more restrictive shall be performed unless specifically not recommended by the manufacturer. Provide all fittings, joint sealants, mastics, coatings, jackets, etc. as required by the type of service.

C. Materials Compatibility: All adhesives, joint sealants, sealers, vapor barrier coatings, mastics, paints, jackets, etc., shall be compatible with materials to which they are applied and shall not corrode, soften, or attack such materials in either the wet or dry state.

D. Dry Pipe: Apply insulation after the surfaces have been thoroughly cleaned and are dry.

E. Cured Coatings: Apply insulation systems after piping system has been coated (and acceptably cured where applicable). Ensure all mastics and sealants are fully cured prior to applying coatings or jacketing and prior to flowing fluids in pipe.

F. Exposed Joints and Testing: Leave piping joints uninsulated until piping has been tested and proven tight.

G. Where piping systems operate at below ambient conditions:

1. Apply vapor barrier joint sealant bead between insulation and bare pipe at all insulation butt joints, fittings, flanges, valves, strainers, coils, equipment, taps, accessories, etc. Install sealant bead generously applied between the pipe and the insulation for a minimum of 1" from end of insulation joint. Apply so when insulation is compressed on the pipe, sealant extrudes out to form a bead beyond in the joint. Wipe bead level with contour of insulation.

2. In addition, provide vapor stop sealant "end" condition with glass fabric applied with mastic at conditions intended to be left permanently exposed (if any such

exposed conditions occur) and where insulation system is interrupted at piping fittings, valves, specialties, equipment, changes in insulation materials, etc. Mastic shall adhere/seal pipe and insulation together.

H. Continuous Insulation and Vapor Barriers: All insulation systems shall be continuous and without butt joints through floor, roof, wall, partition, and ceiling openings and sleeves.

1. Apply insulation on all cold service surfaces, where vapor barrier jackets are used, with a continuous unbroken vapor seal.

2. Joints at all such conditions shall be approximately 12” from the plane of the penetration for purposes of space for acceptable jointing and observation/inspection

I. Insulation Termination: Where insulation is discontinued, special care shall be taken to taper the insulation to the pipe to allow for glass fabric jacket or waterproof jacket/vapor stop to completely seal off the end of the insulation.

J. Butterfly valve thermal breaks: where installed in systems which can operate below the ambient temperature, provide thermal breaks at lever handle behind notched positioning plate. Remove plate, apply 1/8” thick cork tape or foam tape, and reinstall plate/lever handle.

K. External protective jacketing: Provide external protective jacketing as specified in Part 2.

L. Roof/wall penetrations: Where insulated piping penetrates walls or roofs, use only RIGID type insulation materials at the penetration (e.g., pre-insulated piping systems or cellular glass; and not fiberglass, flexible elastomeric, or similar systems). Sleeve the penetration and apply jacket at the penetration assembly:

1. 0.032 in. thick aluminum jacket, with lengthwise seam thoroughly caulked,

2. Min. 14 ga. stainless steel where penetration assembly calls for welding jacket to penetration assembly.

M. Pipes in service paths: When pipe routing across traffic or maintenance/service paths cannot be avoided and said piping insulation is subject to being stepped on or otherwise receive unintended wear or damage during construction or afterwards, provide high density insulation system with metal jacketing similar to above, except thickness of 0.032” min. High density insulation system shall be cellular glass for all systems except steam in service paths.

N. Occupant protections: All jacketing and banding shall be installed in a manner that will protect occupants from cuts, scrapes, or other injuries.

O. Fire rated penetrations: Coordinate with requirements of Section 23 01 00, Parts 2 and 3 where insulated pipes penetrate fire rated partitions/walls, ceilings, floors, or roofs.

P. Crawlspaces: Route all domestic water, fire water, and other piping systems potentially subject to freezing, below insulation barrier and with expanded metal or other suitable insulation support over the piping. Refer also to drawings for similar installation, and verify all details/conditions with Architect/Engineer prior to installation. Obtain Architect/Engineer’s review prior to close-up or concealing the condition.

Q. Route all piping in crawlspace-type conditions similarly, ensuring that the insulated piping is installed between the floor insulating barrier and the floor (thus assisting in freeze protection).

R. Coordinate with piping trades to accomplish intent.

3.02 INSTALLATION REQUIREMENTS BY INSULATION TYPE

A. Insulation Types FG, MW, FB and FG-PT – Fiberglass and Mineral Wool Pipe Insulation, Fiberglass Blanket, and Fiberglass Pipe and Tank Insulation

1. General:

a. Fit insulation over piping and draw jacket tight and smooth. Install insulation with longitudinal seams above the center of the pipe.

b. Seal self-sealing lap closure strip (if used) using lap sealing tool or plastic squeegee. Staple laps with outward clinching staples along edge at 3 inches on center.

c. Cover circumferential (butt) joints with factory furnished matching pressure sensitive butt strips installed with reasonable pressure being applied with a plastic squeegee or sealing tool. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 3 inches on center.

d. Seal all joints and seams with one generously applied coat of specified mastic.

2. Fittings and fitting covers: Provide as specified in Part 2.

3. Inserts: Provide as specified in Part 2.

4. Insulation protection shields: Provide at hanger locations for all pipe sizes as specified in Part 2.

5. External protective jacket indoors: Provide as specified and where indicated in Part 2.

B. Insulation Type CG – Cellular Glass Insulation

1. Refer to Section 230100 and coordinate with other trades for the application of corrosion inhibiting coating on steel piping systems operating at below ambient temperatures. The specified coating must be applied to the piping system(s) prior in installation of the insulation systems.

2. Provide insulation bore coating as specified in Part 2.

3. Secure insulation to piping system with manufacturer’s approved fiber reinforced tape (3M Scotch Brand No. 880) or with aluminum bands with matching seals, minimum of two bands per insulation segment.

4. Fittings: Prefabricated fittings matching base insulation material and thickness. At contractor's option, fittings may be fabricated of mitered sections matching base insulation material and thickness. Finish fittings with glass fabric and mastic.

    a. The A/E will request destructive examination a random sampling of the application of the joint sealants and vapor stops. Contractor's proposal shall include repair and / or re-insulation of up to 5% of such conditions.

5. Jacketing indoors: Provide as specified in Part 2. Seal in place using specified mastic.

    a. Draw jacket tight and smooth.

    b. Cover circumferential (butt) joints with minimum 3-inch-wide strips, of specified insulation jacket material. Secure strips with adhesive.

    c. Overlap jacket longitudinal seams at least 1-1/2 inches. Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive longitudinal lap.

    d. Seal joints and seams with minimum of one generously applied coat of specified mastic.

C. Insulation Types FE, FE-HT and PE – Flexible Elastomeric, Flexible Elastomeric – High Temperature and Polyethylene

1. To the extent possible, insulation is to be un-slit insulation tubing installed without longitudinal joints. Install insulation as piping is being fabricated to accomplish this intent.

2. Fittings: Fabricate of mitered sections matching base insulation material and thickness. Bends of 45° or less are to be simple mitered insulation segments. Bends greater than 45° are to be multi-segment bends in accordance with the manufacturer's instructions.

3. Seal all joints with specified adhesive.

    a. Provide secondary sealing of joints and seams 3M™ Venture Tape™ Line Set Tape™ 1507 (black).

4. Vapor Stops: Provide in piping systems subject to condensation:

    a. At piping intervals not to exceed 9 feet, at least once in each supply and return pipe serving coils, within four feet on both sides of all valves, and immediately on both sides of all fittings, valves, and accessories, provide sealant vapor stop end condition.

    b. Create the vapor stop condition with Venture Tape 1507 (black) 1.5 mil tape wrapped around the insulation and protruding segment of pipe. The adjoining insulation segment is then slipped over the taped pipe, butted firmly against the applied insulation, and securely joined with specified adhesive.

5. External protective jacketing: Provide as specified and where indicated in Part 2. Where Venture Tape™ jacketing is required, the secondary sealing joint tape indicated in 3.a above may be omitted.

6. External finish coating.

a. Provide as specified in Part 2.

3.03 PIPING SPECIALTIES, VESSELS AND SIMILAR IRREGULAR SURFACES

A. Where possible, fabricate shapes and fittings from insulation matching insulation material and thickness of the specified piping system. Fabricate shapes and fittings to match contours and shapes of the appurtenance being insulated. Refer also to Part 2.

B. Apply insulation, adhesives, jackets, mastics, cloths, tapes, etc. as recommended by the manufacturer and according to the BEST practices of the trade for a neat and professional appearance.

C. Where differing insulation types abut, join / bridge the two insulation types using specified mastics. **Address this condition in the mock-up requirements of 23 02 00-3.01.A.**

D. For specialty conditions, subject to Architect/Engineer approval:

1. Low temperature cork tape: Flexible self-adhesive vulcanizing vapor barrier tape insulation similar and equal to Nu Calgon Cork Insulation Tape. Apply for minimum 200% coverage with lapped joints, depth/thickness sufficient to prevent condensation. Limited to service temperatures of 158°F.

2. Low temperature foam tape: 1/8” thick self-adhesive reinforced ArmaFlex pressure sensitive foam tape, overlapping and multiple plies as required for the particular application. Limited to temperatures of 180°F.

3. Other insulation materials and applications recommended by the insulation contractor and approved by the Architect/Engineer.

3.04 PROTECTION OF/RELOCATION OF EQUIPMENT NAMEPLATES

A. Keep tags/nameplates visible and legible: Do not cover or obscure nameplates, or other factory tags. In such cases, carefully remove tags and permanently affix to equipment in conspicuous location via mechanical fasteners or tag chains.

3.05 PAINTING

A. Refer to specification section 23 01 00 and to Division 9 for painting requirements.

END OF SECTION

SECTION 23 06 20 - ELECTRIC HEATERS

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

PART 1 - GENERAL

1.01 SCOPE

A. Provide and install electric heaters as indicated on the drawings and specified herein. Installation shall be complete in all respects, including but not limited to: trim and controls. Heating equipment to be included are:

1. Electric Baseboard Heaters

1.02 RELATED SECTIONS

A. 23 00 10 - General Requirements for Mechanical Work

1.03 QUALITY ASSURANCE

A. Units approved and labeled by Underwriters' Laboratories.

1.04 SUBMITTALS

A. Provide submittal of manufacturer's installation instructions under provisions of Section 23 00 10.

B. Include complete manufacturer's descriptive literature, operating instructions, maintenance and repair data under provisions of Section 23 00 10.

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

PART 2 - PRODUCTS

2.01 ELECTRIC BASEBOARD HEATERS

A. General: Contractor shall furnish and install electric baseboard heater(s). Performance shall be as indicated on the equipment schedule in the plans. Unit heaters shall have UL (Underwriter's Laboratories) design certification.

B. Casing: Heavy gauge die formed steel with stamped intake louvers, epoxy/polyester powder finish. Provide all necessary mounting brackets, pedestals, etc.

C. Heating Elements: Stainless steel with aluminum-fins

D. Controls: Unit heaters shall be equipped with a 24V control transformer (with suitable primary voltage) a factory supplied terminal board for connection of low

voltage thermostat and accessory field wiring, over-temperature protection, and related control relays/contactors having appropriate contact ratings. The electric heat shall be energized by the thermostat upon call for heat.

E. Acceptable Manufacturers

1. Basis of Design: Indeeco BCI

2. Other acceptable manufacturers: TPI

PART 3 - EXECUTION

3.01 INSTALLATION

A. Verify exact locations of equipment prior to installation and install to provide easy access for maintenance and routine service.

B. Install complete electrical and control connections in accordance with manufacturer's written instructions.

C. Coordinate with Division 26 for electrical (power) connections, including disconnecting means and KW, volts, and phase.

3.02 CONTRACTOR'S COMMISSIONING

A. Electric Equipment: provide factory represented start-up and tests to confirm proper operation and controls.. **Submit written report of start-up and test results, including statement confirming proper installation and operation once it is satisfactory.**

3.03 VERIFICATION OF CONTRACTOR'S TESTING

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

B. Schedule, organize, and assist Commissioning Verifications as required. Refer also to Section 23 08 00 and perform work as described therein.

END OF SECTION

SECTION 23 07 50 - CHEMICAL WATER TREATMENT

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

PART 1 - GENERAL

1.01 SCOPE

A. Provide cleaning, flushing, and passivation for the following systems:

1. Chilled water

2. Heating water

B. Contractor shall provide chemical treatment compatible with the existing campus chemical treatment and under the best practices of the trades and applicable systems within the project. Systems shall include, but not be limited to:

1. Examination and understanding of systems to be treated, water analysis, **submittals**.

2. Temporary pumping/circulation/flushing equipment and all related piping (e.g., pipe bypasses around coils, slipstream piping for monitoring, injection piping, taps coordination, circulation connection, etc.)

1.02 RESPONSIBILITY

A. Single chemical treatment subcontractor: The chemicals and consulting services shall be furnished by a single chemical subcontractor, which shall be responsible for determination of the cleaning/passivation process chemicals selection, etc.

1. Exception: Where flushing/cleaning operations are to be performed by a contractor to fulfill the requirements of this Section, such performance may be by a separate subcontractor.

B. Coordination with mechanical trades: The temporary/start-up chemical feed devices shall be furnished to the mechanical contractor by the chemical subcontractor for installation. All needed valves, piping, etc. shall be in the responsibility of this section.

1.03 QUALIFICATIONS

A. Chemical water treatment shall be provided by contractor or subcontractor specializing in water treatment systems of the types required. Contractor/subcontractor shall have minimum of five years experience and shall have local (within 60 mile travel to project site) representatives with water analysis laboratories and full-time service personnel.

B. For existing systems being modified/expanded, contact existing chemical treatment contractor for proposal under this Section. Said proposal shall be submitted to Owner after the bid/proposal date, and shall be contingent upon Owners acceptance.

1.04 REGULATORY REQUIREMENTS AND PROHIBITED CHEMICALS

A. Conform to applicable EPA, Texas Department of State Health Services, Texas Commission on Environmental Quality (TCEQ) and other applicable regulations and codes for addition of non-potable chemicals to building mechanical systems, and for delivery to public sewage systems.

B. Toxic chemicals, such as and including chromates, shall not be used in treatment of any systems whatsoever. In addition, chemicals used shall be acceptable to local and state Building, Health, Environmental, and Industrial Hygiene officials.

1.05 SUBMITTALS

A. **Submit product data.** Include chemical treatment materials, chemicals, pumping equipment, and manufacturer's installation requirements.

B. **Submit specification copy mark-ups in accordance with Section 23 00 10 – General Requirements for Mechanical Work.**

C. **Submit detailed plan for Engineer's and Owner's review and approval prior to any piping being installed.** Plan shall describe in full detail the individual steps associated with this process before any piping is installed. Plan must include a drawing indicating phasing of systems to be cleaned, locations of drains or other temporary connections required for cleaning system, recommended time for cleaning agent circulation and clean water flushing, and cut sheet of proposed temporary pump(s).

D. As part of Contractor's testing, **submit field reports** as required by Part 3 below.

1. Include analysis of system water after cleaning/flushing and after treatment. Refer also to Part 3.

1.06 OPERATION AND MAINTENANCE DATA

A. **Include step-by-step instructions** on test procedures, including target concentrations.

1.07 RELATED SECTIONS

A. Section 23 00 10 - General Requirements for Mechanical Work

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

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Acceptable Vendors:

1. ChemCal, Inc.

2. GE Water & Process Technologies

3. Nalco

2.02 MATERIALS

A. System Cleaner

1. Liquid alkaline compound with emulsifying agents and detergents to remove grease and petroleum products, SUEZ FerroQuest (FQ) 7101 or approved equal.

2.03 CLOSED LOOP SYSTEMS (CHILLED WATER, HEATING WATER)

A. Chemical Cleaning: The closed-loop system shall be thoroughly flushed, cleaned, and flushed prior to system operation.

1. Use liquid alkaline cleaning compound with emulsifying agents, designed to remove rust, oil, grease, mill scale, dirt, etc.

2. When appropriate, provide algaecide treatment as part of cleaning.

B. Treatment: After flushing, cleaning, neutralizing, and flushing, treat system with sequestering agent and corrosion inhibitors that are compatible with the system.

1. Sequestering agent to reduce deposits and adjust pH shall be polyphosphate or approved alternate.

2. Corrosion inhibitors shall be liquid boron-nitrite, sodium nitrite and borax, sodium tolyltriazole, low molecular weight polymers, phosphonates, sodium molybdate, or sulfites.

PART 3 - EXECUTION

3.01 PREPARATION

A. Start-up and capacity metering: Systems shall be operated, filled, started, and vented prior to cleaning.

1. Use water meter(s) to record and report capacity in each system. Provide temporary metered connections for systems not provided with permanent meter.

2. **Submit capacities and record system capacities (gallons) in Records for Owner.** Record on stamped brass tags at makeup assemblies for each system.

B. Bypass piping for unprotected equipment: Mechanical Contractor shall provide temporary bypass piping around (or other suitable measures upstream of) all equipment (e.g., coils, dirt/air separators, etc.). Maintain bypass condition until all flushing, cleaning, neutralizing, and flushing operations have been completed.

1. Coordinate pricing and execution of this work to ensure it is provided.

2. **Coordinate with Architect/Engineer for methods of compliance, and submit proposed methods for acceptance prior to system fill and cleaning.**

C. Protected equipment:

1. Clean strainers and chemical filters/feeders before, during, and after cleaning process.

a. Exception: strainers bypassed during cleaning and flushing do not require removal and cleaning.

2. Do not circulate when strainers/filters are removed for cleaning.

3. Remove strainer start-up screens after final cleaning/flushing procedures are completed.

3.02 CLEANING SEQUENCE FOR HYDRONIC SYSTEMS

A. Add cleaner to systems at concentration as recommended by manufacturer.

B. Circulation – General:

1. Provide temporary pumps meeting flow capacity of the system in the project scope. Include provisions for temporary connection to the piping system and temporary power to the pumps as required by the project conditions.

2. Where the project scope or phasing requires chemical treatment (cleaning, neutralizing, flushing, treating, monitoring, testing) for only part of the respective hydronic system, provide permanent or temporary valves or crossover piping with valves to restrict circulation to pertinent parts of the system.

3. Water Discharge:

a. Confirm water chemistry during cleaning and neutralizing steps, and obtain permission from respective sanitary sewer/industrial waste authority prior to discharging to sanitary sewer.

b. If required, discharge to tanks and properly dispose of.

c. It is not acceptable to discharge to storm drains.

C. Metallic Piping Closed Water Systems (excluding domestic water):

1. Record and submit/report the metered system capacity at each fill.

2. Arrange piping to bypass equipment.

3. At each step, protect equipment as specified in 3.01-C above.

4. Initial clean water flush – fill piping system with clean potable water. Limit temperature of water to a maximum of 140°F.

a. Arrange operation of pump(s) and manual valves to assure a minimum of velocity throughout the system of:

1) 10 feet per second pipe velocity in steel systems.

2) 3-5 feet per second in copper systems.

b. Filtration should be 25 micron.

c. Drain after initial flush.

5. Refill with clean water passivation chemicals, and neutralizer as required. Circulate for 48 hours or as needed determined by the Chemical Treatment Contractor, then drain systems as quickly as possible.

   a. Arrange operation of pump(s) and manual valves to assure a minimum of velocity throughout the system of 3 to 5 feet per second pipe velocity

6. Circulate for 48 hours or as needed determined by the Chemical Treatment Contractor,, then drain again.

7. After cleaning and before adding chemical initial charge, system must be flushed to meet these minimum requirements:

   a. Conductivity no higher than 20 mmho above domestic water level

   b. No foam

   c. Copper level less than 0.5 ppm

   d. Iron less than 1.0 ppm

   e. pH 9.4 or less

   f. Less than 1 ppm phosphates (ortho-phosphate PO4)

8. Final Clean Water Flush: The system will be continuously flushed while discharging chemicals into the sanitary system as approved locally. As the existing treated water is being discharged, a fresh water make-up source will be utilized to ensure air is not introduced into the system. Continue to drain the system while adding domestic water to dilute the treated water. The chemical treatment company will monitor the outgoing water composition and compare the composition with the incoming water. Flush with fresh water until the conductivity is reduced to that of the make-up water and iron level is 1.0 ppm or less. The final system water should be approved by the chemical treatment company. Filtration should be 5 micron.

9. Final Chemical Fill: Once the chemical treatment company has determined the system has been brought back to the correct composition, the chemical treatment company will inject the final chemicals into the system. Once the system is filled with the final chemicals it is important that the water is not to be left stagnant. Chemical treatment shall be comparable to existing treatment program.

D. HDPE Piping Closed Water Systems (excluding domestic water): Follow procedure above with the following additional requirements:

   1. Minimum duration of clean water flush should be calculated using a formula of 1 hour per 1000 linear feet of pipe and until system water is comparable to make up water source.

E. Neutralizing Agents: Use neutralizer agents on recommendation of system cleaner supplier.

F. Strainer screens and Filter/Feeder filters: Prior to each step in chemical water treatment remove, clean, and replace all strainer screens and filters in pot feeders. After all cleaning and flushing has been completed, remove start-up screens provided with strainers and hang start-up screens from respective strainer blowdown valve.

G. Low points: Inspect, remove sludge, and flush low points with clean water after cleaning process is completed. Include disassembly of components as required.

H. Minimum reporting requirements: Record dates, gallons, duration of circulation (hours), temperature of circulation, observations on water clarity/color, and other relevant information, and **submit in Cleaning and Flushing Report** signed by the chemical subcontractor and the Division 23 contractor (on-site superintendent).

I. Pre-requisite for thermal equipment start-up: Cleaning and flushing operations shall be completed prior to the start-up and operation of thermal equipment in the system (e.g., coils, etc.).

1. The Cleaning and Flushing Report shall be submitted prior to commencement of water systems circulation or their treatment, testing, adjusting, and balancing (TAB).

2. Contractor shall submit a written certification that the systems are clean and ready for use.

3. Provide copy of report to TAB subcontractor when scheduling water system TAB.

3.03 CONTRACTOR'S TESTING

A. **Thorough documentation: submit report(s) in booklet form (electronic and/or hard copy) documenting that treatment processes are completed and operating properly. At a minimum, include the following, typical for each piping system.**

1. Documentation of cleaning procedures

a. Untreated water analysis

b. System fill capacity in gallons (using make-up system meter)

c. Scope of piping/systems involved

d. Duration of cleaning and circulation

e. System temperatures during cleaning and circulation

f. Identify all strainers and filter/feeder filters that were removed and cleaned, and number of times each was repeated

g. Identify all strainer start-up screens that were removed after final cleaning and flushing

h. Analysis of cleaning water prior to draining/flushing.

i. Dates of work

2. Documentation of flushing procedures provided for entire system cleaning or for entire system at conclusion of entire project where shop flushing occurs.

    a. Sanitary sewer receptors used for flushing (or containment quantities and disposal procedures where sanitary sewer receptors are not available)

    b. **Document and submit appropriate testing of water disposed to sewer and the requirements of the accepting utility for the industrial waste chemical limitations.**

    c. Make-up water capacity used in flushing operations

    d. Water analysis at completion of flushing, documenting acceptable chemicals removed

    e. Dates of work

3. Number of times cleaning and flushing procedures were repeated

    a. Provide documentation prescribed in ‘1’ and ‘2’ above for each repetition.

4. Documentation of neutralization procedures

    a. Duration of circulation

    b. System temperatures during circulation

    c. Neutralization flushing procedures as indicated in “2” above

5. Documentation of treatment procedures

    a. Chemicals used

    b. Final water analysis illustrating proper chemical adjustment and results

6. Documentation of all adjustments to injector pumps and other controls

B. Other data: Provide additional data as may be expected of highest industry standards for chemical water treatment systems applicable to the project.

C. Determination of system readiness: Provide technical service visits to perform field inspections, to confirm readiness of piping systems prior to cleaning and flushing, and make water analyses on site.

    1. **Submit detailed findings in writing** on proper practices, chemical treating requirements, and corrective actions taken.

3.04 VERIFICATION OF CONTRACTOR’S TESTING

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

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

END OF SECTION

SECTION 23 07 90 - AIR COILS

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

PART 1 - GENERAL

1.01 SCOPE

A. Provide and install air coils as indicated by the drawings and these specifications. Installation shall be complete in all respects. Work includes:

1. Terminal unit heating water coils

a. Refer to Section 23 08 90 – Air Distribution.

2. Water coils

3. Coil piping and accessories

1.02 RELATED SECTIONS

A. 23 00 10 - General Requirements for Mechanical Work

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

C. 23 02 00 - Piping Systems Insulation

D. 23 08 58 - Custom Air Handling Units

E. 23 08 60 - Fans

F. 23 08 90 - Air Distribution

G. 23 09 51 - Controls and Instrumentation (DDC)

H. 23 09 70 - Division 23 Testing, Adjusting, Balancing

1.03 REFERENCES

A. ANSI/ARI 410 - Forced-Circulation Air-Cooling and Air-Heating Coils

B. SMACNA - HVAC Duct Construction Standards, Metal and Flexible

1.04 SUBMITTALS

A. **Submit shop drawings and product data** in accordance with Section 23 00 10, General Requirements for Division 23 work.

B. **Submit shop drawings and other product data indicating:**

1. Coils: tubing, fins; header/distributor connection locations, dimensions; and frame materials and configurations;

2. Detailed dimensions, including finned height and length, casing, and overall length, width, and depth;

3. Rows and circuiting

4. Connection sizes and dimensioned locations, including orientation (e.g., 180° from tubes, etc.);

5. Vent and drain connection sizes and dimensioned locations

6. Rough-in dimensions

7. Performance at scheduled/design conditions, including fouling factor(s).

   a. For cooling coils, also provide air pressure drop in a dry coil condition.

8. Accommodations for installation, removal, and replacement for the specific project application.

C. **Submit specification copy mark-ups** in accordance with Section 23 00 10.

D. Where used in terminal assemblies with control dampers and control valves, **submit mock-up** of entire assembly, including insulation.

E. **Submit manufacturer's installation instructions** under provisions of Section 23 00 10.

F. **Submit manufacturer's certificate** under provisions of Section 23 00 10 that coils are tested and rated in accordance with ANSI/ARI 410.

1.05 QUALIFICATIONS

A. Manufacturer: Company specializing in manufacturing the products specified in this Section with minimum ten years documented experience.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Deliver products to site under provisions of Section 23 00 10.

B. Store and protect products under provisions of Section 23 00 10.

C. Protect coil fins from crushing and bending by leaving in shipping cases or protecting within equipment until installation. Store indoors in a protected condition.

D. Protect coils from entry of dirt and debris with pipe caps or plugs.

PART 2 - PRODUCTS

2.01 GENERAL

A. Coils shall be provided by a manufacturer recognized as a major manufacturer of coil products with several types and sizes.

1. Where air handling equipment with integral coils is to be provided in the project, air coils complying with requirements herein shall be provided by the air handling unit manufacturer. Refer also to Section 23 08 58 - Custom Air Handling Units.

B. Coils shall be ARI 410 certified and be of the type and capacity indicated by the plans.

C. Tube material shall be seamless hard drawn copper conforming to ASTM B224 and ASTM E527.

1. Tube and u-bend diameter and wall thickness shall be as indicated in subsections below.

2. Internal tube enhancements (baffles, turbulators, grooves, or riflings) are not acceptable for water coils unless specifically indicated in the drawings/schedules.

D. Fin material shall be aluminum or copper as indicated in the subsections below. Fin Design shall be flat in the direction of airflow.

1. Where copper fins material is indicated, it shall be soft/annealed temper Alloy 110 conforming to ASTM B152-06

2. Where aluminum fins material is indicated, it shall be soft temper Alloy 1100 conforming to ASTM B152-06

E. Fins shall be permanently bonded to the tubes by mechanical expansion of the tubes. Fins shall have full drawn collars to provide continuous surface cover over the entire tube surface such that no bare copper tube is visible between fins.

F. Provide with means of valved drainage and air venting at coil or at piping to coil. Refer also to drawings for drains and/or vents contained within air handler cabinets.

G. Provide with same end supply and return coil connections.

H. Provide capacities, rows, fins per inch, coil circuiting, air pressure drop, water pressure drop, etc., equal to or better than the construction and performance of those scheduled.

I. Multiple/stacked coils: construct coils and assemble within units for individual removal not disturbing adjacent coils or piping above or below.

J. Substitute Manufacturers: Water coils

1. Basis of Design: Heatcraft

2. Other acceptable manufacturers:

a. USA Coil

b. Thermal

c. York

d. AHU Manufacturers listed in Section 23 08 58, as applicable.

2.02 TERMINAL UNIT HEATING WATER COILS

A. Coils shall be ARI 410 certified and be of the type and capacity indicated by the plans. Unless otherwise indicated by the drawings, provide coils with the following:

1. 0.008” aluminum plate fins with collars drawn, belled, and firmly bonded to 5/8” OD, 0.025” thick copper tubes by mechanical expansion of tubes (no soldering or tinning shall be used in the bonding process);

2. flanged casings for bolted connections to ductwork;

3. casing materials to be:

a. minimum 16 gauge stainless steel casing;

b. minimum 16 gauge galvanized steel casing;

4. accommodations for readily achieved coils removal as indicated by drawings;

5. provide connections and mount coils in the casing to accomplish coil drainage and venting.

B. To prevent coil casing air leakage in duct mounted applications, seal all u-bend coil casing penetrations with approved duct sealant. Insulate exposed u-bends/ headers with spray-on foam insulation and trim as required for an even surface approximately even with the u-bend projections. Finish with fiberglass fabric and mastic or, if substrate is acceptable for durable adhesion, Armaflex HT elastomeric foam insulation, thickness as required to approximate flange bolt pattern.

1. Sealants and insulations shall be factory or field provided.

2. Sealants and insulations shall be rated for:

a. service temperatures equaling maximum heating water temperature, but not less than 180F

b. vapor barriered service (for no heating water flow conditions and coils thermally bridging cold supply air)

3. Refer also to 23 02 00 – Pipe Systems Insulation for insulation requirements of piping at duct mounted coils.

4. Submit proposed sealants, insulations, and whether application will be factory or field.

C. **Confirm all expected field conditions prior to submittal and confirm** coil installation styles permit removal from installed condition without disruption of adjacent systems.

2.03 WATER COILS

A. Application:

1. chilled water coils,

2. heating water coils,

B. Certified Coils: Water coil capacities, pressure drops, and selection procedures shall be certified for the capacity scheduled in accordance with ARI Standard 410-87. Non-certified coils will not be accepted.

C. Performance: Water coils performance shall meet or better all project/scheduled conditions, including, but not limited to: face area; air pressure drop; water pressure drop, and leaving air conditions. Face velocity shall not exceed 400 fpm unless otherwise indicated on the Drawings.

D. Tubes and Fins: Coil tubes and fins shall include the following construction/features:

1. The quantity of rows as indicated on drawings.

2. Tubes constructed with 5/8" o.d. with mating u-bends:

a. Coils scheduled for 4000 CFM or greater: minimum 0.035" wall thickness on tubes and u-bends

3. The fins per inch as indicated on the drawings

a. Unless otherwise indicated, do not exceed 10 fins per inch.

4. Fins material as follows:

a. Chilled water coils: 0.0095" thick copper

b. Heating water coils: 0.0095” thick aluminum

5. Place tubes with 1-1/2" center-to-center distance with adjacent rows staggered one half the pitch distance, i.e., 3/4".

6. Slope return bends up in the direction of water flow to facilitate air removal.

7. Circuit coils for complete drainability.

8. Use single serpentine/circuiting coils unless otherwise noted.

E. Headers: Coil headers shall include the following construction/features:

1. Seamless UNS C12200 Type K hard drawn copper tubing with penetrations for connection of core tubing by die-formed intrusion process with a resulting contact depth between header wall and core tubing of not less than 0.090".

2. Equally and symmetrically splayed for maximum header separation and access to tubes, but no less than 7-1/8” from centerlines of headers in 4-row coil. Minimum clearance between headers on splayed construction of 4-row coil shall be 4.5”. Provide correspondingly larger centerlines and clearances for coils with more rows.

3. Joints between core tubing and header of recess swage design to allow a large mating area for build-up of brazing materials.

4. All coil joints including tube to header, inlet, outlet, drain, vent, and return bends joined with high-temperature silver braze.

5. Supply and return connections of Schedule 80 extra heavy, Alloy 85 red brass pipe terminated with male National Pipe Threads

    a. arrange with supply at the bottom, return at the top

    b. exception: where indicated by drawings, or where piping clearances high or low require, provide supply connection at approximately 1/3 up header height and return connections at approximately 2/3 up header height

    c. provide separate vent and drain openings in headers.

6. Coil connections or nozzles of the same diameter (or larger in accordance with coil size and flow rate), as the coil headers.

7. Brazed joints properly fit up, trimmed, and bored such that the full free flow area of both the header connection or nozzle and the header itself is preserved.

8. Coil connections strong enough to prevent damage or wring-off when screwing or unscrewing the threaded coil connection.

9. Coils shall be counterflow, with full face-feed headers.

    a. Exception: 1-row coils with same end connections where so indicated by drawings.

F. Drains and Vents: Each coil assembly shall have drain connections and vent connections factory installed as per the following:

1. 3/8" NPT female half couplings made of brass and brazed, projecting vertically up and down onto the center of the end (or side if/as required).

    a. Where return piping turns down without an opportunity for installing automatic air venting, provide automatic air vent in coil header.

2. These connections shall have holes of 5/8" diameter drilled through the end caps to permit free draining and venting.

3. Each of the (unused) drain and vent connections shall be plugged leak tight at the factory with an NPT hex head, brass pipe plugs wrapped with Teflon tape thread sealant.

4. Couplings shall be sufficiently recessed such that no less than one full inch of clearance is maintained between the outer limits of the coil casing and the open end of the half couplings.

5. The vent and drains shall have at least one-half inch of clearance between the coil casing outer limit and the plug.

6. Upon installing the coil in the respective AHU, extend vents and drains to visible and accessible locations

    a. external to AHU cabinet

    b. Provide valved and capped/plugged terminations or auto air vents where so indicated, insulated in accordance with Section 23 02 00.

G. Casings: Coil casings shall include the following construction/features:

1. Constructed with end flanges of sufficient depth to extend beyond and completely protect tube "U" bends.

2. Casing materials as follows:

    a. Constructed entirely of type 304 stainless steel, no lighter than 16 gauge. (Intermediate welded joints between corners are not acceptable.)

        1) Chilled Water Coils

    b. Constructed entirely of type G120 hot dipped galvanized after drilling/casing fabrication, no lighter than 16 gauge. Provide dielectric protection between any contacting dissimilar metals. (Intermediate welded joints between corners are not acceptable.)

        1) Heating Water Coils

3. Provide coil casing end plates and intermediate tube support sheets with die formed holes to provide support for each tube and provide for free expansion and contraction of the tubes within the casing.

    a. End plates and tube support material shall match the casing material, including dielectric protection between any contact of dissimilar material.

    b. At a minimum, provide equally spaced intermediate tube support sheets in all coils having tube lengths in excess of 48", according to the following:

        1) Above 48” and less than 96” tube length: 1

        2) 96” or above and less than 144” tube length: 2

        3) 144” or above: 3

4. Provide coil casings with 3/8" bolt clearance holes on 6" centers around the entire casing flange on both faces of the coil.

5. All bolts, washers, lock washers, nuts, and other fasteners, brackets, or supports appurtenant to the coil of stainless steel. (typical all coil services).

6. Provide face removable coils.

a. Exception: Provide coil slide-out racks for removal assistance where indicated or allowed by drawings or required by field conditions. Obtain written approval by Engineer **prior to submittals**.

H. Tests: The complete coil core shall be tested under warm water to a pressure of 315 psig and be suitable for operation at 250 psig working pressures. Individual tube and core tests before installation of headers will not be considered satisfactory. Hydrostatic tests alone, with pressurized water in the coil, will not be acceptable.

I. Drain Pans

1. Provide all coils, whether cooling, heating, or other services, with 304 stainless steel drain pans for condensate and/or maintenance/cleaning activities.

a. Refer also to Drawings for additional information related to this intent.

2. Intermediate drain pans: Coordinate with construction of coil assembly to provide intermediate drain pans and drain tubes for all stacked coil assemblies.

3. **Submit/provide safing or other construction detailing** prevention of significant coil bypass at all condensate pan assemblies.

4. Drain pan assemblies which provide for submerged coil or casing materials in normal operation shall not be used.

PART 3 - EXECUTION

3.01 GENERAL

A. General:

1. Install according to field conditions and the best practices of the trade. Coordinate bidding and execution of controls, valves, etc.

2. Install in ducts and casings in accordance with SMACNA HVAC Duct Construction Standards, Metal and Flexible.

3. Support coil sections independently of piping on stainless steel channel or double angle frames and secure to casings. Provide frames for maximum three coil sections. Arrange supports for cooling coils to avoid piercing or short-circuiting drip pans. Provide airtight safing/seal between coil and duct or casing.

4. Where coils are suspended and connected to ductwork, support coils independently of ductwork using threaded rod supports attached to the top of the coil casing/flange in a manner approved by the manufacturer. Connect to ductwork using flanged/gasketed and sealed joints for an airtight seal.

5. Bolt casings to other section, ductwork, or unit casings. Provide airtight seal between coil and duct or unit cabinets.

6. Protect coils so fins and flanges are not damaged. Replace loose and damaged fins. Comb out bent fins. Loose or damaged fins which affect efficiency or service

life shall be cause for coil replacement or deduct for damages as may be determined by the Architect/Engineer.

7. Make connections to coils with unions and flanges, dielectrically protected where dissimilar metals are encountered.

8. Insulate headers, u-bends, etc., located in outside air flow as specified for piping. Refer to Section 23 02 00.

9. **Submit field mock-up of all ducted coil assemblies**, including insulation.

   a. Refer also to Section 23 08 90 – Air Distribution, for terminal unit field mock-ups.

B. Water Coils

1. Valves

   a. Provide flow metering/shut-off valve on supply line and flow balancing/shut-off valve on return line.

   b. Provide control valve on return pipe.

2. Provide strainer on supply piping.

3. Locate water supply at (near) bottom of supply header and return water connection at (near) top.

4. Provide float operated automatic air vents at high points complete with stop valve.

5. Ensure water coils are drainable and provide drain connection at low points.

6. Connect water supply to leaving air side of coil (counterflow arrangement).

7. Cooling Coils:

   a. Provide vapor barrier and vapor stop conditions at duct to coil or AHU to coil connections and at hanger/support conditions where installed in insulated duct systems.

   b. Provide drain pan and drain connection for each cooling coil section. Unless indicated otherwise, fabricate drain pan from minimum 14-gauge 304 stainless steel.

   c. Provide all coils subject to air side condensing performance with properly trapped condensate piping routed to nearest suitable drain.

   d. For cooling coils in AHUs, provide high-level condensate switch in condensate piping assembly for monitoring trouble condition to BAS.

END OF SECTION

SECTION 23 08 58 CUSTOM AIR HANDLING UNITS

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

PART 1 - GENERAL

1.01 SCOPE

Furnish and install custom air handling units (AHU's) as indicated by the drawings and these specifications. Installation shall be complete in all respects. The following sections shall be included as if written herein:

A. 23 00 10 – General Requirements for Mechanical Work

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

C. 23 02 00 – Piping Systems Insulation

D. 23 07 90 - Air Coils

E. 23 08 60 – Fans

F. 23 08 80 – Filters and Accessories

G. 23 08 90 – Air Distribution

H. 23 09 51 – Controls and Instrumentation (DDC)

I. 23 09 70 – Testing, Adjusting, and Balancing

1.02 REFERENCES

A. AFBMA 9 – Load Ratings and Fatigue Life for Ball Bearings

B. AFBMA 11 – Load Ratings and Fatigue Life for Roller Bearings

C. AMCA 99 – Standards Handbook

D. AMCA 210 – Laboratory Methods of Testing Fans for Rating Purposes

E. AMCA 300 – Test Code for Sound Rating Air Moving Devices

F. AMCA 301 – Method of Publishing Sound Ratings for Air Moving Devices

G. AMCA 500 – Test Methods for Louver, Dampers, and Shutters

H. ARI 410 – Forced-Circulation Air-Cooling and Air-Heating Coils

I. ARI 430 – Central-Station Air-Handling Units

J. ARI 435 – Application of Central-Station Air-Handling Units

K. ARI 610 – Central System Humidifiers

L. NEMA MG1 – Motors and Generators

M. NFPA 70 – National Electrical Code

N. SMACNA – HVAC Duct Construction Standards - Metal and Flexible

O. UL 900 – Test Performance of Air Filter Units

1.03 SUBMITTALS

A. **Prepare complete custom air handling unit submittal** that includes pertinent products and equipment from all other specification sections indicated in '1.01' above and as otherwise needed for all products/construction details describing the complete assembly(ies).

1. Exception: 23 09 51- Controls and Instrumentation and 23 09 70 Testing, Adjusting, and Balancing may be provided separately, but at the same time, unless otherwise accepted by Engineer.

B. **In addition to performance data/schedules, include in submittal:**

1. Fully dimensioned and scaled (1/4" scale, or electronic drawn to actual scale) detailed shop drawings of entire assembled and complete unit. Include:

a. Assembly

b. Unit dimensions

1) include maximum physical dimensions of largest piece, with certification by contractor and/or manufacturer of passage through most restrictive building opening/path

a) Demonstrate passage for both conditions of installation and for future replacements.

b) Refer also to Architectural drawings to determine the available passage dimensions and the field required means of placing and replacing the AHUs and/or components serving them.

c. Weight loading, including each as applicable for handling, rigging, and structural loading:

1) include weight per piece

2) weight per section, including all internals

3) entire unit assembly shipping and operating weights

d. Demount/sectionally built unit construction details, including but not limited to:

1) thermal breaks at panels, doors, corners/intersections, floors, roofs, etc.

2) demount/section dimensions and assembly instructions

3) field connection and flexible connection details

4) vibration isolation details, internal and base/external

5) door sealing details

6) specific products to be used

7) Condensate drain dimension to finished floor and verification that dimension is sufficient for condensate trap/drainage

8) Casing penetration details for field-made sleeved penetrations for pipes, conduits, etc.

e. Electrical characteristics and connection requirements including:

1) unit and/or internal field wiring and points of connection

2) motor disconnection and overcurrent protection means

3) motor overload panel or other enclosure assembly containing individual fan disconnects, overload protection, controls/monitoring, and/or other features as indicated or required

4) Complete wiring schematic of all components receiving electrical power, clearly showing field and manufacturer wiring

5) Acknowledgment of and statement of compliance with Division 26 – Electrical

f. Other information appropriate to fully describe the unit.

2. All dimensions, pressure ratings, bearing ratings, and metal materials and gauge information. Include overall unit weight and required clearances for access, routine services, and removal of filters, coils, fans, and other internally housed equipment.

3. Fan curves: Fan array and individual fan curves with respective stall line(s) and operating points clearly plotted (submit complete "family" of curves at multiple rpm’s, not just at design/operating points).

a. Submit the maximum rpm/Hz allowed at the submitted motor horsepower full load amperage, and illustrate fan cfm/static pressure performance on the system curve at this maximum speed.

b. Submit the maximum rpm allowed for the fan class construction at 120% of design CFM and 120% of total static pressure.

4. Fan discharge/rotation/position and statement that these agree with the conditions indicated by the drawings. (If manufacturer recommends other conditions, state so in front cover documentation along with brief explanation and recommendation for modification.)

5. Access door locations with clear opening dimensions. Illustrate view windows, hand holds/grab bars, instrumentation, and other related accessories.

   a. Access doors to unit internals,

   b. Units with vestibules or piping/accessories cabinet: access doors as part of entry vestibules or external cabinets.

      1) As applicable, include pressure equalizing damper/opening assemblies in adjacent cabinet/casing walls.

6. Motor manufacturer/type and manufacturer's literature/statements as prescribed.

   a. Include bearing L10 life

   b. Include motor weight

7. Unit sound data (radiated, intake, and discharge):

   a. Analyze at design conditions (rpm and static) and 110% of design conditions (airflow and static pressure). **Submit for specific configuration(s).**

   b. Include analyses with and without field applied acoustical liners where such are indicated by drawings.

   c. Radiated sound data:

      1) Include contribution of attenuation of radiated sound from insulation/lagging from mechanical rooms, floors, ceilings, and partitioned enclosures, and from other acoustical treatment applied to the individual fan(s), fan section(s), or curb/roof assembly for rooftop AHUs.

   d. Discharge sound data:

      1) Include bare fan(s) sound and combined fans' sound if in an array

      2) Illustrate attenuated sound at unit discharge, including internal casing/content attenuation, internal sound attenuators as may apply, individual fan(s) sound attenuation, and acoustical liners where so indicated by the drawings.

      3) Illustrate attenuated sound at discharge of external casing/content attenuators and duct sound attenuators as may apply.

e. Intake sound data:

1) Include bare fan(s) sound data and combined fans' sound if in an array

2) Illustrate attenuated sound at unit intake, including internal casing/content attenuation, internal sound attenuators as may apply, individual fan(s) sound attenuation, and acoustical liners where so indicated by the drawings.

3) Illustrate attenuated sound at unit intake, including external casing/content attenuators and sound attenuators as may apply.

8. Certified performance for all thermal energy transfer components, including water coils and other components as may be applicable.

9. Coil connections, coil and other internal piping.

10. Coil mounting/removal details, including written removal instructions for coils and for piping serving coils.

a. Unless otherwise specifically indicated on drawings, coils shall be:

1) individually removable and so arranged that remaining coil(s) can stay in service.

2) face removable to upstream or downstream sections that permit coil removal through unit access doors.

a) Exception: If indicated by drawings, slide-out removable coil access panel equal to unit cabinet construction, maintaining thermal breaks.

11. Confirmation that condensate drains are provided with 2-way slopes to prevent ponding in the pan.

12. Spring isolation, resilient isolation, inertia bases, thrust restraints, flexible connections, and other vibration isolation features which respond to design specifics and/or which are recommended by the manufacturer:

a. Internal to the unit for rotating/dynamic components of unit.

b. External to the unit to isolate unit vibration from the building structure.

c. Refer also to other sections (e.g, Fans) for vibration limitations on individual components.

13. Size, type, and location of all hanging vibration isolators, and/or resilient vibration isolation pads between bottom of unit casing and support structure.

a. Unless otherwise recommended by manufacturer, select resilient pads for 20% deflection under respective load.

14. Sound attenuators, acoustical insulation and lagging, and other acoustical attenuation features of the unit.

15. Ultraviolet germicidal irradiation (UVGI) systems and controls.

16. Installation instructions (including videos where such may apply).

17. Deviations: do not embed deviations within submittal data/information. Instead, clearly communicate on cover memorandum any intended or proposed deviations recommended or necessary for satisfying the intent expressed herein and in the drawings. At the Engineer/s discretion, deviations may be reviewed as substitutions.

C. **Provide statement of concurrence with non-condensing cabinet/assembly requirements.**

D. **Provide statement of concurrence with pressure/leak/deflection testing results specified.**

E. **Provide statement of compliance with Division 26 – Electrical.**

F. **Provide specification mark-ups in accordance with Section 23 00 10.**

G. **Submit contract drawing sheets mark-ups:**

1. To clearly communicate any intended deviations recommended or necessary for satisfying the intent expressed herein and in the drawings

2. As described therein: enlarged unit plans/sections with notes, and all related piping schematics and details.

1.04 OPERATION AND MAINTENANCE DATA

A. **Submit O&M Data under provisions of Section 23 00 10**. (If under separate cover, submit at the same time as the product data).

B. **Submit Maintenance Data**: Include instructions for lubrication, filter replacement, motor and drive replacement, spare parts lists, and wiring diagrams. (If under separate cover, submit at the same time as the product data).

1.05 QUALIFICATIONS

A. Manufacturer: Company specializing in manufacturing the Products specified in this section with minimum five years documented experience of the type and class of units within the project. **Submit evidence of same acceptable to the Engineer and Owner. If so requested, include examples of similar unit construction and Engineers of Record contact information.**

1.06 DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, protect and handle products to site under provisions of Section 23 00 10.

B. Accept products on site in factory-fabricated protective containers/covers, with factory-installed shipping skids and lifting lugs. Inspect for damage.

C. Store in clean dry place and protect from weather and construction traffic. Handle carefully to avoid damage to components, enclosures, and finish.

1. Secure approval of Owner's Structural Engineer prior to loading any structure with unit or parts thereof, including any temporary locations used for assembly or staging of unit.

1.07 UNIT START-UP AND OPERATION

A. Manufacturer pre-functional inspection, start-up, and report: Do not operate units for any purpose, temporary or permanent, until:

1. Field testing (e.g., leakage/deflection) has been completed and has passed;

2. ductwork is clean;

3. filters are in place;

4. bearings are lubricated;

5. fan has been test run under observation;

6. manufacturer's technical factory representative has approved start-up after performing pre-functional inspection,

7. manufacturer's technical factory representative shall conduct or supervise start-up;

8. **submit report upon completion of inspection and start-up.**

1.08 QUALITY ASSURANCE

A. Manufacturer's Responsibility:

1. Factory designed and fabricated: Provide factory designed and fabricated custom air handling units, for field assembly as may be needed by the Contractor and under the manufacturer's direct field supervision.

a. Sectionally built field assembled unit having demount points to speed field assembly

b. as required to meet requirements of 1.03.B.1.b above.

2. Factory assembled and tested:

a. All units: Fabricate and assemble unit at factory to demonstrate constructability of all details. Include internals and base (curb). **Submit photo-documentation of assembly process and assembled unit.**

b. Fully assembled or sectionalized units:

1) Factory test unit leakage and deflection to demonstrate compliance.

2) Factory test airflow and static pressure performance.

3) Where requested by Owner, demonstrate final testing to Owner's engineer or commissioning representative.

4) **Provide/submit report of results prior to shipping.**

c. Refer also to 3.02 below.

3. Assembly training: Manufacturer shall provide AHU assembly training for Installing Contractor at Manufacturer's plant prior to shipment of AHU.

a. Provide the training concurrently with the factory assembly of the unit unless otherwise accepted in writing by the Owner.

4. Manufacturer's on-site observation/supervision during assembly installation:

a. Manufacturer and Contractor shall be jointly responsible for scheduling this supervision.

b. Provide in accordance with Part 3.

5. Examination, Coordination, and Performance Warranty: Unit manufacturer warrants by submission of a proposal and submission of submittal/shop drawings, that: it has thoroughly examined the scheduled performance of all components within the respective units; it has coordinated with the respective manufacturers of the components; and that it concurs that the scheduled, specified, and intended performances will be accomplished in all respects by its unit; and that it warrants that its AHU's performance will meet specified thermal, air flow, acoustical, control, and discharge (external) static pressure performance at design airflow.

6. Single point responsibility for complete unit: Unit manufacturer warrants by submission of a proposal and submission of submittal/shop drawing data, that when completed sections are installed in a workmanlike manner in accordance with these specifications, manufacturer's instructions, manufacturer's field supervision, manufacturer's inspection and start-up, finished unit(s) shall meet the capacity, acoustical, thermal, leakage, deflection, and air delivery performances specified.

7. **Unit manufacturer shall submit instructions for making field penetrations through unit casing.**

8. Components shall be furnished clean, well made, and free of any defects which may adversely affect appearance, serviceability, durability, and performance.

B. **Contractor's Responsibility:**

1. Single point responsibility to Owner for unit construction, performance, and completion consistent with schedule: The Contractor shall be fully responsible for achieving satisfactory design details, submittals, procurement, fabrication,

construction (including field assembly using unit splits and/or panelized knock-down components), testing, commissioning, and proof of proper operation, consistent with the design intent.

2. The Contractor shall provide the custom air handling unit manufacturer with all field dimensions, mounting locations and duct openings as required to coordinate the detailed design and fabrication of the unit.

3. Training: The installing Contractor/subcontractor personnel supervising the AHU installation shall attend AHU assembly training at Manufacturer's plant prior to shipment of AHU. Refer also to 1.08.A above.

C. Delegated Design: Where specification requirements oblige the Manufacturer or Contractor to provide supplemental detail design beyond that presented in the drawings, provide such as Delegated Design as required to accomplish the completed, intended work. Such Delegated Design shall include professional engineering where so required or indicated, or where directed by the Architect/Engineer or Owner.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Basis of Design: Energy Labs

B. Substitute manufacturers:

1. Climate Craft

2. CAPS (Custom Air Products & Services, Inc.)

3. Engineered Air

4. Haakon

5. Trane Custom

6. Temtrol

2.02 UNIT CONSTRUCTION

A. General:

1. Casings for air units shall be factory fabricated to accommodate all components indicated by drawings and related specifications (e.g., filters, dampers, coils, fans, electrical, controls where applicable, etc.).

a. Factory assembly of fully assembled or sectionally built units: Factory assemble entire unit with all internals. Factory test for airflow, deflection, and leakage.

2. The manufacturer shall interface with and supervise, in the field, construction/assembly of the unit to ensure casing integrity and air handler/fan

performance to criteria specified/indicated in Mechanical Schedules and these specifications.

3. **Manufacturer shall submit a section-by-section and shipping crate by crate weight analysis** of the entire unit and all its supporting structure, service platforms, and other components/accessories.

B. Supplemental Members

1. The design and supply of the structural steel or other members supporting the unit casing and internal components, shall be the responsibility of the air handling unit manufacturer, as a part of its detailed delegated design responsibilities. Provide shop drawing details and documents sealed by a registered Professional Engineer.

   a. Base rails forming the bottom framing of the units themselves:

      1) Interior units – constructed of hot dipped galvanized steel

C. Casing

1. General: Assembled casing shall be double wall, airtight to specified allowable leakage, insulated throughout. Stiffeners shall be provided, as necessary, to prevent unit casing pulsation or deflection.

2. Panel thickness: Minimum panel/casing thickness shall be as follows:

   a. Walls and roof

      1) 2” thick, using foamed in place insulation

      2) 4” thick using foamed in place or compressed fiberglass insulation

   b. Floors

      1) Minimum of 6” thick to accommodate structural needs as well as integral (recessed) drain pans

   c. Panel/casing: Construction shall be of sufficient strength, leakage, and thermal characteristics to meet all specified performance criteria.

3. Floors/Roofs – rigid platforms

   a. All floors and roofs shall be rigid platforms to support the equipment of the respective sections, its installation/replacement activities, and service requirements. Reinforcement within floors/roofs shall accommodate not only the static and dynamic loading from the unit and its internals, but shall also satisfy:

      1) point loads and other loads to accommodate safety rails, ladders, and other attached accessories; and

2) point loads and other loads which will be experienced by construction trades and Owner's maintenance personnel using the floors and roofs as construction/maintenance platforms.

3) All roofs: Provide reinforcement as necessary to allow multiple man access on roof of unit without damage or deflection exceeding specified limits while unit is operating under normal negative pressures. Basis of loading shall be a minimum of 3 each 200 pound point loads spread over not more than 50 sq. ft.

4. Insulation:

a. At a minimum, panel insulation shall have the following composite performance (including joints/seams):

1) walls and roof: R-10

2) floor (entire floor): R-22

3) Increase the above minimums to respond to climate and field conditions

b. All panels (walls, roof, and floors) shall be sufficiently thermally broken, or otherwise constructed without "through metal," in order to prevent condensation. (Refer also to "I" below.)

c. All insulation shall be protected with sheet metal (solid unless otherwise specifically indicated).

d. Refer also to "K-Thermal Performance" below.

5. Inner and outer shells

a. General: All sheet metal joints throughout the casing, and between panelized sections, shall be tongue and groove type, or other assembly which provides the necessary structure, sealing, and thermal break conditions.

b. Outer shell - walls: at a minimum, outer wall shells of double wall construction shall be:

1) minimum 16 gauge G-90 galvanized steel

2) aluminum with thickness equal to or greater than the strength of 16 gauge steel.

3) Voluntary Alternate: Substitute 16 ga. galvanized steel in lieu of the specified aluminum.

c. Inner shell – walls and ceilings: at a minimum, inner wall and ceiling shells of double wall construction shall be:

1) Wet Sections:

a) Solid inner shell of 18ga. 304 stainless steel.

b) Solid inner shell of aluminum with thickness equal to or greater than the strength of 18 gauge stainless steel.

c) Voluntary Alternate: Substitute 18 ga. 304 stainless steel in lieu of specified aluminum.

2) Dry Sections:

a) Solid inner shell for "dry" sections shall be minimum of 18 gauge G-90 galvanized.

b) Solid inner shell for “dry” sections shall be aluminum, thickness equal or greater than to the strength of 18 gauge galvanized steel.

c) Voluntary Alternate: Substitute 18 ga. G-90 galvanized steel in lieu of specified aluminum.

3) Fan section: where indicated by drawings, provide perforated metal liner for fan sound attenuation. Shell material shall match other dry sections. Panel insulation shall be high-density fiberglass duct liner with anti-microbial coating, consistent with specifications in Section 23 08 90 – Air Distribution. Thickness as required for compression within panel thickness.

a) Draw-through fans: at fan section and downstream discharge section(s).

b) Submit unit sound analysis (radiated, intake, discharge) for specific unit configuration. Refer also to 1.03.B.7 above.

4) Dry/Wet Section Identification

a) Dry/Wet Sections of AHU’s: Dry sections include the section upstream of the intake pre-filter/filter bank(s), upstream of the cooling coil, the fan section, and the final filter section. All other AHU sections are “wet.”

6. Floors

a. General

1) Construct floors of same metal type as used for shell walls and ceilings of same section, unless specifically indicated otherwise.

2) In addition to meeting the casing deflection limits contained herein, floor deflection shall not exceed L/250 under point load of 400 pounds, plus single fan/motor weight (as applicable to the particular section) where L is defined as the floor span.

b. Dry Section Floors:

1) All dry section floors shall have a minimum of 1/4" minimum treadplate as the top of the reinforced floor panel. Provide with unit framing/reinforcement as required to support all point and maintenance loads.

c. Wet Section Floors:

1) The floor surface shall be continuously welded with 2" turned up lip around the base perimeter and at all floor penetrations. Caulk is not acceptable sealing method for the floor.

2) Floors shall fully enclose (inner and outer shell) and form a non-condensing assembly with vapor barriers for the insulation on the bottom of the unit. All points of contact between the floor, vapor barrier, and structure shall be thermally isolated with gasketing of closed cell soft rubber or EPDM.

3) Wet sections shall be provided with 304 stainless steel drain pan. Slope pan as required to positively drain (without ponding) water that accumulates in those sections due to normal operation, abnormal operation, and maintenance activities.

4) Provide suitable maintenance/walking surface at the top of the pan (elevated above the normal drain section ponding level). Said maintenance surface shall be removable/drop-in and in sections weighing less than 40 lbs. Construct at follows:

a) grating of 304 stainless steel or aluminum;

b) expanded metal of 304 stainless steel or aluminum with reinforcement below to support loads imposed without sagging; or

c) 304 stainless steel treadplate walk bridge not less than 18" wide.

5) Maintain insulation types and thicknesses below the wet sections/drain pans to both prevent condensation on bottom surface of drain pan and to comply with casing R-value requirements cited above.

d. Water Coil Drain Pans

1) Water coil drain pans shall be 304 SS of 14-gauge or heavier sheet metal. The coil drain pan shall extend under the entire unit coil section width, plus the larger of:

a) minimum of 6" upstream of the coil, and

b) Minimum of 18" downstream of the coil, and

c) dimensions indicated by scale or otherwise in the drawings,

d) ensure pans extend below headers and return bends from the coil casing to the unit wall.

2) Drain pans shall be rigid and watertight. At all coil banks, provide the bottom row coil drain pans with minimum 1-1/2" NPT stainless steel main and auxiliary drain pipe connections extending 2" beyond the outside wall of the unit casing. All coil drain pans shall be sloped to the outer/draining edge(s) of the unit as indicated by the drawings.

3) Unless otherwise indicated by drawings, slope condensate to single side of unit. If indicated in drawings, drain pans may slope to either side of unit with insulated (1" Imcoshield) internal drain to unit piping connection point; adjoining pans shall be coupled with 304 stainless steel channel over top edges. In addition to floors insulation specified above, pans shall be insulated with minimum two staggered layers of 1/2" Imcosheet (R-8 minimum) insulation adhered to the bottom of the pan.

4) Field condensate piping: A drain line shall be provided from the bottom-most coil drain pan to the nearest suitable receptor. Unless otherwise indicated, the external pipe shall be Type L copper of at least 1-1/2" diameter. The external drain line shall have a minimum 6" deep trap and be insulated with 3/4" Armaflex AP or approved equal. Refer also to drawings and related field conditions for further specifics.

5) Coordinate also with plumbing trades for condensate recovery where applicable.

6) A full-length stainless gutter (intermediate drain pan) with two, end-mounted, removable, 1" diameter 316 stainless steel tube downspouts shall be affixed to the air leaving side of any stacked cooling coil section (drip pans) to shed water directly to the bottom drain pan.

7. Roofs

a. General

1) Construct roofs of same metal type as used for dry sections of inner shells, unless specifically indicated otherwise.

2) Provide reinforcement as necessary to allow multiple man access on roof of unit without damage or deflection beyond specified limits.

b. Interior AHUs: Roofs shall have a ¼” minimum treadplate plate or similar suitable working surface as the top of the reinforced roof panel.

8. Casing details for Stacked coils: Where coils are stacked, casings closure panels for the coils shall be separated and overlapped as required to permit individual coil access to splayed headers and tubes, and to permit individual coil removal, all

without affecting adjacent coils or closure panels of adjacent coils. Assembly shall maintain leak tightness and avoid condensation as prescribed elsewhere.

9. Jointing: Construction shall be welded or may use approved fasteners. At a minimum, fasteners shall be #12 X 1", self-drilling, self-tapping hex head sheet metal screws located no greater than 12 inches on center. Manufacturer shall use fasteners and/or fastening methods not supportive of galvanic corrosion, for all sections, wet or dry. **Submit. Approved fasteners include the following:**

    a. Magni 565 coated screws for all sections.

    b. Galvanized/zinc plated screws for galvanized steel construction dry sections only.

    c. Stainless steel screws for stainless steel construction wet sections, and for aluminum construction sections.

    d. Others where demonstrated by manufacturer's experience to be superior.

10. Casing Penetrations: Duct openings and pipe and conduit (electrical/controls) penetrations at casing exterior partitions and interior partitions shall be, insomuch as is reasonably possible, located and cut at the factory and sealed and insulated in accordance with the Manufacturer's instructions. **Submit details.**

    a. Where field openings become necessary, openings shall be sleeved and sealed per manufacturer's detail of same. Pipe/conduit shall pass through the sleeve with the annular space being sealed and insulated per manufacturer's recommended materials, escutcheons, etc. **Submit field opening details for review and acceptance.**

D. Base Assembly

1. Unit Base: Construct from welded structural channels around the perimeter and at intervals crossing between the perimeter members and supporting the unit above. Formed steel channels are not acceptable. The maximum cross-member spacing shall be 25" on center with members located adequately to support fans, coils, maintenance activities, and other large components.

    a. Exception: Bolted connections are permissible for base, where member dimensions exceed the dimensional limits for transport or installation.

2. Unit Base Materials: Select materials and members/weights to properly accommodate loading, spans between support points, and operating environment.

    a. Indoor locations: G-90 galvanized steel, aluminum, or 304 stainless steel.

3. Base Support:

    a. Housekeeping pad: Reinforced concrete housekeeping pad may be used provided:

        1) the pad plus structural steel, if any, provides sufficient elevation of drain pans (typically minimum of 8") to assure proper drainage.

2) Refer also to drawings.

4. Single section or sectionally built units with de-mounts: Each large component shall be provided with removable lifting lugs. Structural framework shall fully support the unit casing and all components during installation such that deflection “D” (in inches) less than or equal to L/1000 during rigging of that section, where L is defined as the distance (in feet) between lifting lugs.

5. Vibration Isolation: Unless recommended otherwise by the manufacturer, provide vibration isolation pads between unit base (bottom of unit floor casing) and top of unit support members (e.g., channel beams, housekeeping pad, etc., as may be indicated by drawings). Pads shall have two ribbed 3/8" thick elastomeric layers with a galvanized steel plate bonded between the elastomeric layers. Unless otherwise recommended by manufacturer, pads shall be equal to VMC Group Type NR, Style E. **Submit.**

E. Access Doors, Panels, and Rail System

1. Access doors and panels shall be installed to each access section between each coil, and to each service area within the air handler, including but not limited to: fan chamber, coils, filter sections, intake/mixing plenums, discharge plenums, UV lights, and others where so indicated. The construction of the access doors and panels shall equal or exceed the quality of the air handler casing materials as specified herein. Refer also to drawings for locations of doors and panels.

2. The height of each access door shall be as indicated in drawings and shall permit a minimum clear access width of not less than 18 inches (greater width where indicated by drawings). Each access door shall also contain a non-condensing (assembly) double glazed view window of a minimum of nominally 12 inches by 12 inches capable of withstanding the developed/tested pressure of the unit.

   a. Exception: smaller view panels are acceptable for access doors illustrated to be less than 18” in width.

3. Refer to UVGI section below for additional viewing window requirements related to sections with UV lights.

4. The doors shall be hinged using multiple heavy duty hinges. The door shall have a compressible bulb automotive type windlace/gasket, and shall provide a seal to limit leakage beyond the level of detection regardless of pressure direction.

5. Access doors shall open with or against air pressure as indicated by the drawing. Doors shall have multiple heavy-duty roller cam safety catch latches with pressure relief/catch feature, operable from inside or outside.

6. Safety yellow paint and signage:

   a. All doors opening outward with pressure shall be painted safety yellow and provided with min 12” x 12” engraved signage reading “CAUTION: DOOR UNDER PRESSURE” or as otherwise recommended by manufacturer. White lettering in red phenolic background.

b. All doors accessing rotating or other electrical equipment shall be painted safety yellow and provided with minimum 12" x 12" engraved signage reading: "CAUTION: ROTATING EQUIPMENT" or as otherwise may be appropriate.

7. Signage: Provide engraved laminate rigid signage for each door describing internals/section accessed by door, size approximately 18” X 18”. Secure to door with suitable fasteners. Color, lettering size, and message to be **determined in submittal process**

8. Fans/motors removal: AHU manufacturer shall provide complete system for removal of supply fans and motors from the unit. Refer also to Section 23 08 60 – Fans for related requirements.

a. Removable/relocatable jib crane/hoist/winch for motor removal (e.g., fan array systems).

b. Complete rail and chain hoist system where indicated by the drawings. System shall include structural panels, wall angles/shelf angles, pipe columns, structural members (I-beam, double back channels, etc.), etc. as required.

F. Safing and Fan Section(s) Septum Panels

1. Safing refers to the materials around the coils, fans, filters, etc. that prevents air from bypassing these components. Safing material shall be the same as that of the inner shells of double wall construction and according the whether the section is wet or dry.

2. Septum panels refers to the interior unit sections separations at or near the fan(s) and across which the fan total pressure will be experienced. Such panels shall be the same leakage and deflection rated construction as the exterior casing. Conduct leakage and deflection testing as prescribed in 3.02.A.

G. Coils - General:

1. Coils shall be arranged for and piped to provide counter-flow operation. The coils shall be completely enclosed within the coil housing of the air unit casing. All penetrations of the air handler casing shall be neatly sleeved and sealed using a resilient sealant.

2. Face Removable Coils: Unless otherwise indicated, coils shall be face removable/replaceable from the upstream or downstream access section of each respective coil bank (e.g., downstream section face removable, with removal through downstream section door). Removal of coil shall be accomplished without disturbing other coils or their piping, and shall not be used to provide structural stability for the casing. Refer also to drawings.

3. Slide Removable Coils: Where specifically indicated, coils shall be removable via coil slide-out racks.

4. Refer also to other sections governing coils and other heat transfer components.

H. Acoustical Performance: Acoustical panel (casing) ratings shall be determined by the dual reverberation room method in accordance with ASTM specifications E-90-81, E413a, E795, or latest versions thereof. The test set-up and procedure shall be such that all effects due to flanking transmission, standing waves and test chamber sound absorption are eliminated. Data shall be presented for tests conducted using current production samples. The minimum allowable transmission loss (TL) of the panel/casing, including all components, when tested in accordance with ASTM E-90-81 and E413-72, or the latest versions thereof, shall be as follows:

1. Galvanized panel with fiberglass insulation

   a. Sound Transmission Loss (dB) per ASTM E-90 & E-413.

Octave	2	3	4	5	6	7	STC+
Solid Liner	22	38	49	50	57	62	42

   b. Sound Absorption Coefficients per ASTM C-423 & E--795.

Octave	2	3	4	5	6	7	NRC+
No Liner	.26	.71	1.09	1.02	.96	.83	.95

2. Aluminum panel with foam insulation

   a. Sound Transmission Loss (dB) per ASTM E-90 & E-413.

Octave	2	3	4	5	6	7	STC+
Solid Liner	13	18	23	20	31	46	21

   b. Sound Absorption Coefficients per ASTM C-423 & E--795.

Octave	2	3	4	5	6	7	NRC+
No Liner	.20	.69	0.99	1.06	0.95	.90	.90

3. **The manufacturer shall submit certified test data** on transmission loss and absorption coefficients to the Architect/Engineer. All rating tests shall be conducted by a nationally recognized acoustic testing laboratory in their facility, utilizing the same panels. This facility shall be open to inspection at the request of the Architect/Engineer. The testing laboratory shall be totally independent from the manufacturer. Data obtained in the manufacturer's test lab will not be acceptable unless substantiated by test reports conducted by a nationally recognized acoustic testing laboratory.

4. The above ratings represent minimum performance. **Unit manufacturer shall submit full sound performance data** to the Architect/Engineer for evaluation by sound consultant as may be required. Refer also to 1.03 above.

I. Thermal Performance

1. Refer also to 2.02.C.4-"Insulation"above, for minimum composite R values

a. Prevention of surface condensation: Apply Surface Condensation per ASTM D415 "Measuring Humidity with Cooled Surface Condensation," as required. In addition: Provide insulation, thermal breaks, and no through-metal construction of casing assemblies. Resulting construction shall be sufficient to prevent condensation on interior or exterior of unit housing when:

$(Th - T1)/(Th - Tdp) \leq 4.0$

where:

Th = Higher temperature internal or external to casing

T1 = Lower temperature internal or external to casing

Tdp = Dew point at location corresponding to Th

Example:

Temperature outside casing of 80˚F, unit internal temperature of 45˚F, unit would not condense at dew points below 71˚F (corresponds to 80˚F db and 73.5˚F wb / 74% RH).

b. Basis of Surface Condensation Analysis:

1) Indoor Units within conditioned spaces: Submit exterior surface condensation analyses at the following conditions:

a) Conditioned mechanical room conditions for casing and performance shall be presumed to be 80˚F / 75% RH (71.5˚F dewpoint). Interior casing temperature in cooling shall be presumed to be 45˚ F (downstream of cooling coil(s)).

2) Outdoor Units or Indoor Units in Unconditioned Space: Submit surface condensation analyses at not less than two conditions:

a) Exterior surface (cooling season): Use ASHRAE 2% dehumidification conditions for outside ambient, and use 48˚F interior temperature.

b) Interior surface (heating season): Use ASHRAE 1% heating condition for outside/ambient, and use 70˚F / 30% RH for interior conditions.

J. Fire/smoke resistance: Panel design shall meet the following UL Fire Hazard Ratings as per ASTM specification E-84, or the latest version thereof.

Flame Spread – 15
Fuel Contributed – 0
Smoke Developed – 0

K. Finishes:

1. Indoor Units: All external parts of the unit shall be thoroughly cleaned and painted with a prime coat of ZincGrip primer or shall be unpainted G90 galvanized. For external parts not galvanized, provide painting under this Section in accordance with Division 9. Touch-up all scratches and marred galvanized surfaces with Zinc Grip primer.

L. UVGI SYSTEM

1. Provide Ultraviolet Germicidal Irradiation (UVGI) surface disinfection system for the control of germs (virus, bacteria, fungus), odors, and allergens. The UVGI system shall be adequately sized to deactivate microbial growth on all stationary exposed surfaces (direct, reflected, and shadowed) in the AHU sections immediately downstream of the chilled water coils. The UVGI system shall utilize power as indicated by drawings, and shall be designed to provide an even distribution of UV-C energy.

2. The UVGI system must meet UL Standards 1598, UL 153, UL 1995; CSA Standard C22.2 No. 9-M1989, and UL/CSA harmonized Standard C22.2 No. 236-M90/UL1995. The manufacturer's UL file number shall be permanently marked on the exterior of the product.

3. UV Lamps

   a. Lamps shall be non-proprietary, available from multiple vendors on the open market and may not be prioritized in relation to the UV equipment. Lamps shall be Philips, GE, Sylvania, Ushio or pre-approved equal.

   b. Lamps shall NOT introduce ozone into the air stream.

   c. Lamps shall be a single-ended twin tube design so that no external wires (to provide power to the opposing end of the lamp) are exposed within the air path.

   d. Lamp change shall be performed without UV fixture disassembly and without the use of tools.

   e. Lamp life shall be rated by manufacturer at a minimum of 9000 hours, based on 3-hour start/stop cycles; lamp depreciation not to exceed 15% at rated life.

4. Ballasts:

   a. Ballasts shall be CBM, ETL, UL and cUL listed for the UV lamp provided.

   b. Ballasts shall be non-proprietary, available on the open market and not prioritized in relation to the UV equipment.

   c. Ballasts shall be high power factor, class P, Sound Rating A, Type 1 Outdoor, Electronic.

   d. Ballasts shall be "Suitable for Air Handling Spaces" and shall meet the harmonic distortion requirements of ANSI at a minimum operating temperature of –20 degrees F.

5. Accessories:

   a. Provide an integral safety interlock relay switch for AHU access door to interrupt UVGI power when the unit is opened for servicing. The safety interlock switch shall be a sealed roller arm lever and include a built-in X-type magnetic blow-out basic switch for DC applications. Provide pilot light that turns on when interlock switch is on (UV is off), whether or not the door is open.

   b. Provide an external, metal, on/off toggle switch with LED pilot light for manual operation of UVGI system.

   c. Provide an integral visual examination port within the AHU casing of ¼ inch thick laminated safety glass capable of stopping 100% UV-C transmission, which will withstand a 5-pound impact test to facilitate external inspection of lamps.

6. Support Structure: Provide 304 S.S. support structure independent of coils for mounting inside AHU. Structure to be easily removable for coil removal.

7. Manufacturer: Lumalier EXTV series or approved equal.

2.03 ELECTRICAL/CONTROLS:

A. Comply with applicable requirements of Division 26 – Electrical.

B. Coordinate with Section 23 09 51 – Controls and Instrumentation, and with Division 28 – Fire Alarm.

C. Factory vs. field wiring responsibility:

   1. For demount/sectionally built unit construction:

      a. Manufacturer shall provide all wiring and conduit internal and external to the unit that serve electrical components. Manufacturer shall make and seal unit casing penetrations for electrical and controls components. Division 23 and 26 Contractors shall closely coordinate with Manufacturer to accomplish the work in accordance with requirements specified herein.

      b. All internal and external conduit, wiring, j-boxes, pull boxes, LBs, convenience outlets, disconnect switches and other components required to provide power to AHU components shall be provided by Manufacturer in accordance with requirements specified herein.

D. Wiring: All wiring shall be 600v rated type MTW/THWN solid copper in EMT with steel compression fittings and LiquidTite flexible metal conduit (LFMC) (max 3 feet) at equipment, appliance, or similar connections. All junction boxes shall be UL approved and gasketed.

   1. Exception for lighting in dry sections: properly sized MC cable with wet location conductors (THHN/THWN) is also acceptable for lighting and power to non-motor loads. (Power to motor loads shall use conduit.)

E. Marine Lights:

1. Marine lights shall be provided throughout AHUs as indicated on the plans. Lights shall be light-emitting diode (LED) type to minimize amperage draw and shall produce lumens equivalent to a minimum 75W incandescent bulb (1100 lumens). LED lighting shall provide instant-on, white light and have a minimum 25,000 hr life. Light fixture shall be weather-resistant, enclosed and gasketed to prevent water and dust intrusion. Fixtures shall be designed for flexible positioning during maintenance and service activities for best possible location providing full light on work surface of interest and not being blocked by technician.

2. All lights on a unit shall be wired to a single on-off switch, a pair of 3-way switches, or as otherwise indicated by the drawings. Coordinate with Division 26 trades.

F. Convenience Outlets: Provide NEMA 3R ground fault convenience outlets as shown on the Drawings. Wire lights and outlets to an externally mounted J-box for connection by Division 26. Coordinate with Division 26.

G. Penetrations and sealing: Provide “LB,” pull box, or other conduit access devices at all penetrations of cabinet and at penetrations between thermal sections of unit. At completion of wiring, seal all conduit (internally) to prevent the leakage of air or transfer (and condensation) of moisture. This provision shall apply to all factory and field penetrations.

1. Coordinate with Division 26 trades and controls trades to execute this requirement throughout.

H. Electrical/Controls wiring organization:

1. Internal disconnects: Refer to drawings, and provide mounted and wired disconnects internal to unit where indicated (e.g., multiple fans/motorsand UV lights).Wire disconnect switches to externally mounted J-boxes for connection by Division 26.

2. Wire lights and receptacles to externally mounted J-boxes for connection by Division 26.

3. Refer to 2.03.C above for manufacturer and contractor wiring responsibilities.

I. Junction boxes and similar interface points between unit fabrication and field construction:

1. Provide all junction boxes serving as points of connection between manufacturer and field wiring. Sizes shall meet or exceed requirements of the current published edition of the NEC and the particular style of terminators involved.

2. Arrangements/location shall use terminal lug connections and allow field conduit penetrations at top, bottom, and sides.

3. Conductors size 8 AWG or larger shall use mechanical lug terminals, side by side or stacked, singe/double/triple barrel as required.

4. Coordinate with affected Mechanical/Electrical trades to locate junction boxes for constructible and serviceable conditions while meeting clearance requirements of the NEC. Stagger as required to receive field conduit connections. **Detail in**

submittal with scaled elevation drawing(s) of all surfaces receiving disconnect switches and junction boxes.

5. Do not position junction boxes on any removable panel or in any other way that would encumber maintenance/service/replacement of components.

J. Controls - see drawings and Section 23 09 51 for additional control and control wiring requirements.

2.04 FANS

A. Refer to Section 23 08 60 - Fans, drawings, and schedules for requirements.

2.05 COILS

A. Refer to Section 23 07 90 - Air Coils, drawings, and schedules for requirements.

B. Provide copper header drain piping from bottom of coil headers to exterior of unit casing. Assure sufficient cabinet/casing clearances to contain valves accessibly within the unit casing. Typical all coils.

C. Provide copper coil air vent piping from top of coil headers to condensate drain pan of unit. Assure sufficient cabinet/casing clearances to contain valves accessibly within the unit casing. Typical all coils.

2.06 FILTERS:

A. Refer to Section 23 08 80 - Filters & Accessories, to drawings, and to schedules for requirements.

2.07 DAMPERS:

A. Provide AHUs with control dampers, smoke dampers, and/or combination smoke/control dampers, as indicated by drawings;

1. In outdoor air section(s) of AHU

2. In return air section(s) of AHU

3. In supply air section(s) of AHU

B. Control dampers shall meet the requirements of Section 23 09 51 – Controls and Instrumentation and drawings, including the requirements for:

1. Multi-section dampers for control staging and/or pressure ratings;

2. Independent damper sections control

C. Smoke Dampers shall meet the requirements of UL 555S with Class I leakage ratings. Dampers shall have airfoil blades and be rated for 4000 fpm and 8” w.g. in single section sizes up to 48”x48”.

1. Actuator voltage:

a. If so illustrated by Division 26 electrical drawings, provide two position 120 VAC actuators.

b. If Division 26 drawings do not indicate 120 VAC service to the actuators, provide 24 VAC actuators. Coordinate with Building Automatic Contractor to provide 24 VAC power to these actuators as part of the Building Automation System's (BAS) electrical/wiring responsibilities.

c. For all actuators, provide feedback switch to report damper position to BAS.

2. Basis of Design: Ruskin SD60

D. Modulating combination smoke/control damper shall meet the requirements of UL 555S with Class I leakage ratings. Dampers shall have airfoil blades and be rated for 2000 fpm and 4" w.g. in single section sizes up to 48"x48".

1. Actuator voltage shall be 24 VAC. Coordinate with Building Automatic Contractor to provide 24 VAC power to these actuators as part of the Building Automation System's (BAS) electrical/wiring responsibilities.

a. For all actuators, provide feedback switch to report damper position to BAS.

2. Basis of Design: Ruskin SD60M (modulating) with Belimo FSAF24 actuator.

E. Common Requirements:

1. All Dampers: Provide multiple sections as required to accommodate maximum fan static pressures derived from max allowable fan speed at closed dampers (e.g., "shut-off pressure" conditions)

2. Control dampers: Refer to drawings and Section 23 09 51-Controls and Instrumentation, and coordinate accordingly.

3. Smoke and smoke/control dampers: Refer to drawings and Sections 23 08 90 – Air Distribution and 28 31 00 - Fire Detection and Alarm System, and coordinate accordingly.

F. Actuator Locations:

1. Locate actuators where they are readily accessible for observation, visual inspection, and repair/replacement without disassembly of AHU components or ducts. Ensure sufficient clearances between damper actuators and casing walls to accomplish this readily accessible condition.

2. Special conditions requiring Authority Having Jurisdiction (AHJ) acceptance: Should proposed locations of smoke or combination smoke dampers indicated in the drawings provide for the actuator being removed from the damper shaft and subsequently re-installed (e.g., on the outside of the AHU casing), confirm acceptance by the AHJ prior to AHU fabrication, and **provide evidence of same in submittal.**

2.08 FACTORY TESTING PRIOR TO SHIPPING

A. All units: Prior to shipping, fully assemble entire unit and confirm assembly can be accomplished with the actual field conditions to be encountered at the site. Obtain Contractor's representative confirmation of same at factory if needed.

B. Unit Testing

1. Deflection: Refer to 3.02.A and conduct factory and field testing as prescribed therein.

2. Leakage: Refer to 3.02.A and conduct factory and field testing as prescribed therein.

3. Airflow performance testing: Refer to 3.02.A and conduct factory and field testing as prescribed therein.

C. **Submit fully documented report** prior to or upon shipment, with photographs, detailing the assembly process, the finished unit, and all performance results.

1. Do not ship units that have not demonstrated proper assembly or that have not passed leakage, deflection, and airflow tests.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Assemble units in accordance with manufacturer’s written and field instructions, as applicable.

B. Base or curb or pad for installation shall be proven level and true (excepting intended structural camber) prior to and after installation/assembly. **Submit reports evidencing same.**

C. Install in conformance with ARI 435.

D. Install assembled unit on manufacturer’s vibration isolation pads. Refer to drawings and **submittals**.

E. Provide electrical wiring installation in accordance with manufacturer’s submittal and installation requirements of pertinent Division 26 sections.

F. Provide piping, valves, accessories, gauges, thermometers, and supports as specified herein and indicated on the contract drawings.

G. Provide ductwork, accessories, and flex connections as specified herein and indicated on the drawings.

H. Coordinate amongst all trades to prevent installation of any devices, components, or systems on access panels or at other locations which would obstruct or interfere with service or removal of components.

I. Manufacturer's field instruction/supervision: Schedule and obtain manufacturer's field technical installation/assembly supervision to assist in quality assurance of the installation. Site visits by the manufacturer's installation representative shall occur as frequently and at whatever durations are needed to assure proper installation, but not less than two days near the beginning of the assembly installation and one day near the end of the assembly installation.

3.02 CONTRACTOR'S/MANUFACTURER'S COMMISSIONING

A. Factory testing and manufacturer's field testing:

1. General: Testing prescribed below shall be conducted to demonstrate compliance with certain basic performance requirements of the unit(s). If compliance is not achieved, make modifications as may be needed, consistent with specified unit construction, to bring the unit into compliance.

a. Witnessing by Owner's representative: Owner shall have the option, under its cost, of having its technical representatives witness the testing. Manufacturer/Contractor shall schedule testing with the Owner not less than two weeks prior to the date of the testing. Failure to do so shall subject units to delayed shipment and /or retesting for Owner's verification.

b. **Submit fully documented factory tests** prior to or upon shipment, photographically detailing the assembly process, the finished unit, and all performance results.

c. Do not ship units which have not "passed" required factory testing without prior written acceptance by Owner and Engineer.

2. Factory Testing: Units shall be fully assembled with all fit-ups and tolerances confirmed, including base/curb members as applicable. As prescribed in "B" through "D" below, conduct:

a. Deflection testing

b. Leakage testing

c. Fan performance testing

3. Field Testing: After units have been fully assembled, conduct field testing as prescribed in "B" through "D" below. Testing shall be performed by an independent agency (other than the Manufacturer/Contractor, typically a qualified TAB firm), witnessed by the Manufacturer's factory technical field representative, and paid for by the Manufacturer.

a. Deflection Testing

b. Leakage Testing

B. Prescribed Deflection Testing – Casing and Fan Septum

a. General: Deflection testing shall be performed on the casing governing panels as defined below, plus on the fan septum panel or on the multiple fan array as may apply.

b. Deflection limit of L/250 shall be demonstrated, where deflection is expressed in inches and “L” is measured in inches.

c. Governing panels: ‘L’ is defined as the height of the largest panel on the sides; width across the top of the largest panel on the unit; and the larger of width or height of the largest panel for the ends. The fan septum or fan array ‘L’ dimension is the larger of the width or height. These are known as the governing panels.

d. The entire unit shall be tested under both positive and negative pressure conditions as follows:

1) Positive pressure: 10” water column

2) Negative pressure: 10” water column

e. Measurements shall be taken at midpoint of ‘L’ using dial indicators reading in 1/1000ths of an inch. Mounting of dial indicators shall be independent of the unit casing. Multiple measurements shall be made. Dial indicator shall be mounted at midpoint of ‘L.’ Measurements shall then be spaced along the sides, ends and top at midpoint and quarter points of the negative section and the positive section. Spacing shall be adjusted to fall on nearest flange or panel joint. Any section of less than five feet shall require only one measurement at the center.

f. Unit shall be furnished by Manufacturer with proper blank-offs to facilitate the pressure testing.

g. In order to reduce the number of pressure cycles, it is recommended that multiple dial indicators be used at the measurement points. Separate set-ups will be required for the positive pressure tests and negative pressure tests.

C. Prescribed Leakage Testing:

a. General:

1) Factory tests: The entire unit casing shall be tested under both positive and negative pressures. The fan septum panel or fan array panel shall be tested with test pressure across the panel, using positive pressure at the fan discharge side (to test leakage across fan panel with fans blanked off).

2) Field tests: Test with unit set in place, controls, power, and piping penetrations in place, leveled and ready to receive ductwork connections.

b. Test for leakage by sealing all openings and pressurizing to the lesser of:

1) 2.5 times scheduled fan total static pressure at design conditions;

2) or 10” WG

c. Maximum allowable leakage rate is

1) Factory tests: 1.0% of scheduled unit design flow

2) Field tests: 1.5% of scheduled unit design flow

d. Testing shall be repeated, and field modifications shall be performed as necessary to comply with the maximum allowable leakage rate.

D. Prescribed Factory Fan Performance Testing:

a. Test fan(s) airflow and static pressure performance.

b. Simulate external static pressures to confirm fan/airflow performance, varying external static pressures as required.

c. Plot fan performance on fan curves to demonstrate performance consistent with fan curves, or to identify any unaccounted system effects.

E. Failure of the leakage and/or deflection test shall require sealing and bracing of the unit and retesting until criteria are met. Failure of the trim balance to confirm vibration limit shall require rebalancing and re-testing until criteria are met. Contractor shall bear all costs involved in the modifications, balancing, and re-testing, including travel and hourly costs associated with the representatives of the Owner.

F. Fan/Motor Vibration Testing: Refer to Section 23 08 60 - Fans, for requirements.

G. Parallel Fans Speed Adjustment: Ensure dual/parallel fans operating together have speed/sheave adjustments made to operate fans individually at full load. (This setting is required so that operation under single fan only conditions will achieve maximum flow achievable by the fan/motor combination.) Coordinate with TAB trades to accomplish this requirement.

3.03 VERIFICATION OF CONTRACTOR’S TESTING

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

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

END OF SECTION

SECTION 23 08 60 - FANS

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

PART 1 - GENERAL

1.01 SCOPE

A. Provide and install fans as indicated in the drawings and specified herein. Installation shall be complete in all respects, including:

1. interlocks to and coordination with controls, including fire alarm;

2. isolation, control, vertical backdraft dampers where so indicated, and gravity backdraft dampers, each as applicable;

3. motors and drives;

4. covers, belt guards;

5. roof curbs;

6. vibration isolation, including inertia bases where indicated;

7. filters and related accessories;

8. external insulation and acoustical lagging as indicated;

9. flexible connections to ductwork.

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

1. Centrifugal fans (backward inclined, forward curved, airfoil, in housed, plenum, or plug configurations, all/each as indicated in schedules or as required by the Architect/Engineer)

2. In-line centrifugal fans

3. Centrifugal roof/wall exhausters and Upblast centrifugal exhausters

4. Fan assemblies – direct drive plenum fan array

1.02 RELATED SECTIONS

A. 23 00 10 - General Requirements for Mechanical Work

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

C. 23 07 90 - Air Coils

D. 23 08 58 - Custom Air Handling Units

E. 23 08 80 - Filters and Accessories

F. 23 08 90 - Air Distribution

G. 23 09 51 - Controls and Instrumentation (DDC)

H. 23 09 70 - Division 23 Testing, Adjusting, and Balancing

1.03 SUBMITTALS

A. **Provide submittals under provisions of Section 23 00 10 - General Requirements for Mechanical Work.**

B. **Submit complete product data.** Include:

1. Certified fan curves (complete "family" at multiple fan speeds, not just the single curve at design rpm), showing fan performance characteristics:

a. CFM, static pressure, horsepower, amps, efficiency, fan class, maximum rpm for the motor size, and maximum rpm for the fan class. Include fan and system operating point plotted;

b. Maximum operating conditions at motor horsepower: cfm, static pressure, horsepower, amps, rpm, and efficiency.

c. Stall/surge line for individual fan and, where applicable, fan arrays.

d. Where fan arrays are indicated by the drawings, submit performance characteristics for both the individual fan and all fans in the array.

2. Assembly and section drawings detailing all parts, including replacement parts;

3. Materials of construction for all fan parts;

4. Fan discharge/rotation position (for housed centrifugal fans);

5. Sound data at design conditions (radiated, inlet, and discharge);

6. Motor data, including:

a. Manufacturer, efficiency, horsepower, and weight.

b. For all 3 phase motors, submit manufacturer's verification that motors are rated for VFD operation;

7. Installation, start-up, and maintenance/repair instruction.

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

D. **Fan System Effect Calculations**:

1. Manufacturer shall provide and submit system effect calculations based on designed inlet/outlet conditions that may affect fan performance in the vicinity of the fan. For purposes of this requirement, vicinity is intended to include designed conditions within approximately six (6) fan inlet diameters, upstream or downstream, and any AHU discharge condition on the sides, bottom, or top.

2. Exceptions:

    a. Where manufacturer determines that system effect is insignificant to the designed operating condition.

    b. Fans within an air handling unit cabinet where unit external static pressure and fans total static pressure submittals incorporate any system effect that may exist.

    c. Roof/wall exhausters, upblast exhausters, cabinet fans, propeller fans, and similar fans.

PART 2 - PRODUCTS

2.01 GENERAL

A. Performance ratings shall be in accordance with AMCA 210, and fans shall bear the AMCA Certified Rating Seal.

B. Sound ratings shall be in accordance with AMCA 300/301, and fans shall bear the AMCA Certified Sound Rating Seal.

C. Manufacturer's review: Manufacturer shall review each fan condition and application, and shall confirm the intended product is appropriate with respect to materials, accessories, sound levels, and performance. **Any deficiencies or recommendations for improvement shall be explicitly presented in submittals (via spec. copy mark-ups or submittal cover letter/correspondence)**. The absence of such submittal information shall be understood as manufacturer's concurrence with design application.

D. Fans shall be statically and dynamically balanced to eliminate vibration or noise transmissions to occupied areas.

1. Provide factory vibration testing of each fan and of multi-fan assemblies to demonstrate low vibration conditions, including compliance with the more stringent of industry standards, manufacturer’s standards, or specifications herein. **Submit report at time of test, and prior to shipment of fan(s).**

    a. Exception: Unless otherwise indicated in subsections below, the following fans are not required to undergo factory testing prior to shipment: fans less than 1.0 horsepower; rooftop centrifugal fans less than 5.0 horsepower; sidewall propeller fans less than 1.0 horsepower.

E. Vibration isolation: Provide with manufacturer’s appropriate vibration isolation in accordance with the field conditions or as may be presented in the drawings:

1. Spring type, unless otherwise indicated by drawings or within specifications.

2. Housed spring type where needed for lateral support/restriction, and where otherwise required to accommodate field conditions.

3. Exception: External vibration isolation is not required for roof fans intended to mate directly to static roof curbs. (Internal fan base/assembly isolation shall be provided for those types of conditions.)

F. Select fan/motor combinations for non-overloading operation at not less than 110 percent of design CFM at 110 percent of total static pressure (unless otherwise indicated by scheduled equipment). Exceed this minimum requirement where indicated by scheduled equipment.

1. Fans exceeding 0.5 HP shall be constructed at a minimum as Class II. Provide fans constructed for Class III or Class IV where indicated by scheduled equipment or otherwise required by particular conditions involved.

G. Motors

1. Three-phase motors:

a. High efficiency, heavy duty: Three-phase motors shall be heavy duty ball bearing, NEMA Premium efficiency, high power factor motors, equal to Baldor Super Efficient Premium E.

b. VFD rated: All three-phase motors shall be “drive rated” in accordance with the latest applicable IEEE bulletins/standards to ensure they are fully compatible with use with variable frequency drive speed controllers from at least 10 to 120 Hz. This requirement shall apply regardless of whether or not motors are served by variable frequency drives in design documents, so that future devices may be added without concern for motor change. **Submittal shall include motor manufacturer's warranty literature specifically addressing this subject, and shall include statement of compliance.**

2. Single-phase fractional horsepower motors shall be:

a. Premium efficiency ECM (electrically commutated motor): ECM 2.5, 2.5, or 3.0 in accordance with the particular application.

b. High-efficiency permanent split capacitor (PSC) motors.

c. As indicated by the drawings.

3. Unless otherwise indicated, provide ODP (open drip proof) or TEAO (totally enclosed air over) motors for inside installations and TEFC (totally enclosed fan cooled) motors for outside installations.

4. Service factor: All motors shall have minimum of 1.15 service factor.

5. Dual voltage rated: All motors to operate in 208V or 240V systems shall be dual voltage rated for operation at either voltage.

6. Bearings life: All motors shall have bearings rated for L-10 200,000-hour minimum life.

7. Shaft grounding: Provide all three-phase motors with shaft grounding rings equal to Aegis SGR. Mounting shall be in accordance with motor manufacturer's recommendations. **Indicate mounting method in submittals.**

8. Multi-speed: Provide multi-speed or variable speed motors where indicated by scheduled equipment.

H. Adjustable sheaves: Provide belt drive models with variable pitch/adjustable sheaves, Browning or equal approved by Architect/Engineer, for adjustment of fan speed in test and balance functions. Provide size range(s) as required by design or by test and balance findings, including multiple drives if required to accommodate TAB.

Unless otherwise recommended in writing by manufacturer, horsepowers 20 hp and above shall have adjustable sheaves replaced with fixed sheaves upon completion of approved final test and balance. (The Owner shall retain the adjustable sheave for possible future use unless otherwise noted.)

I. Disconnect switches: Unless otherwise indicated, exhaust fans shall be supplied with disconnect switches. Provide NEMA 3R switches where fans or switches are outdoors or otherwise exposed to elements or to wet locations.

J. Variable Frequency Drives: Coordinate with Section 23 09 51 - Controls and Instrumentation, DDC to verify controls/application to variable frequency drives.

K. Roof curbs: For rooftop fans or caps/discharges, provide with factory roof curbs, minimum 14" high (above finished roof), which mate properly with the particular roofing system details and the particular roofing system slope to provide a water/weather tight, level installation.

L. Multi-fan assembly service: Where multiple fans occur within the same cabinet section of air handlers or related equipment, provide all accessories to permit personnel servicing one fan when other fans remain operational (e.g. belt guards, OSHA suction and discharge screens/guards, septum panels separating fans, and/or others as may be required).

M. Rooftop and other fans subject to wind conditions:

1. General: Provide fan construction, curb construction, anchoring, and fastening as required to accommodate building code design wind conditions of the locale, including hurricane conditions up to not less than 125 mph where applicable. Coordinate with other trades as required for anchoring and other detailing. Provide installation satisfying requirements without the use of guy cables (unless guy cables/wires are indicated in drawings).

2. Anchorage: For each fan condition, provide anchorage detailing including: anchor bolts (e.g., diameter, length, grade); anchor bolt material (stainless steel where in exterior conditions); substrate confirmation (e.g., metal structure vs concrete structure); method of anchorage (e.g., through drilling with washer/nut backups, drilled embedment with anchor adhesive, welded member(s) attachment); quantity of anchor/spacing between anchors; and other information necessary for proper installation by the Contractor.

3. Structural Coordination: **Submit reactive forces applied to roof/structure** for review by Architect/Structural Engineer. Where specific design requirements are presented in structural drawings, they shall be considered only preliminary information for the Contractor's convenience in estimating. Adjust these preliminary requirements if needed to accommodate the manufacturer's detailing requirements and the Architect/Structural Engineer's review.

4. Guy Wires: Unless otherwise indicated by the drawings, the intent is to support/anchor fan assemblies without guy wires. If manufacturer instead requires guy wires, provide data sufficient for Contractor's anchorage and installation of them, including points of connection to the fan assembly.

5. Submit all data regarding anchorage and structural coordination as indicated above.

N. Vibration Limitations

1. General: The fan manufacturer shall be responsible for dynamically balancing the fan:

   a. At the factory, with unit assembled, prior to shipping, **complete with test report submitted to Architect/Engineer at the time of testing**

   b. In the field, with the fan set in place, leveled, and ductwork attached.

2. Default allowable vibration: Unless more stringent conditions apply elsewhere in these specifications, vibration velocity shall be less than or equal to 0.20 inches/sec for belt drive applications, and 0.10 inches/sec for direct-drive applications measured on horizontal, vertical, and axial planes at each bearing pad. Vibration amplitudes are peak velocity.

3. Speed ranges: All values recorded shall be filter-in at the fan speed. Confirm the fan/motor vibration velocity limit over the following operating speed range:

   a. Fans with VFDs or other variable speed fans shall be checked from 10 to 200% of rated fan speed, up to available horsepower limits.

   b. Constant speed and multi/variable speed fans shall be checked at 100% of rated fan speed.

4. 'Lock-out' ranges shall not be acceptable under this specification, without written substitution request and acceptance by Owner and Architect/Engineer.

   a. Where performance substitution is allowed, lockouts may be used to correct up to two ranges of excess vibration. The maximum span of each 'lock-out' range shall be limited to an effective fan speed of 50 RPM.

   b. Any 'lock-out' range used shall be clearly identified in the test report and shall be prominently displayed on a typed, laminated legend prominently displayed on the VFD controller cabinet.

5. Field test witness: Field testing shall be witnessed by a qualified representative of the Test and Balance Agency. Coordinate and schedule with General Contractor and/or Owner as required to accomplish this witnessing.

6. Application of Vibration Testing: Provide testing and demonstration of acceptable vibration-free operation in accordance with the following:

   a. For all fans not provided with specific exemptions to the above default allowable vibration.

   b. For all fans having specifically more or less stringent vibration requirements than those described by the above default allowable vibration.

   c. For all fans with suspect excessive vibration occasioned by observations/symptoms, as directed by the Owner or Architect/Engineer.

   d. Exceptions: Fans less than 3hp: factory vibration reporting not required; field vibration testing/reporting not required (unless excessive/suspect vibration observations/symptoms occur).

7. Failure to comply with vibration velocity limit shall require re-balancing and re-testing until criteria is met. Contractor shall bear all costs involved in the modifications, balancing, and re-testing, including travel and hourly costs associated with a Test, Adjust, and Balance (TAB) agency contracted separately by Owner.

O. Manufacturer's Start-up:

1. Provide manufacturer's start-up using factory trained technician/mechanic experienced in the equipment and systems involved.

2. **Submit** start-up report confirming acceptable installation and addressing all specified performance objectives. **Submit** report immediately upon completion of start-up.

2.02 CENTRIFUGAL FANS

A. Acceptable Manufacturers

1. Basis of Design: Greenheck

2. Other acceptable manufacturers:

   a. ACME

   b. Barry

   c. Cook

   d. Twin Cities

   e. Penn

f. Others where scheduled or specified

B. Fans shall be belt driven or direct drive as indicated by the drawings.

1. All belt drive fans shall be provided with belt guards. Belt drives shall be sized for a minimum of 165% of driven horsepower. Pulleys shall be of the fully machined cast iron type keyed and securely attached to the wheel and motor shafts. The motor pulley shall be adjustable for final system balancing.

C. Fan housing shall be constructed of heavy gauge steel with lock formed seams for no air leakage and shall be field rotatable to any of the eight standard discharge positions. The housing and bearing supports shall be constructed of welded steel members to prevent vibration and rigidly support the shaft and bearings.

D. Drives: Fans shall be belt driven or direct drive as indicated by the drawings.

1. All belt drives shall be provided with belt guards. Belt drives shall be sized for a minimum of 165% of driven horsepower. Pulleys shall be of the fully machined cast iron type keyed and securely attached to the wheel and motor shafts. The motor pulley shall be adjustable for final system balancing.

2. Shafts: The fan shaft shall be ground and polished and mounted in heavy duty, extended life permanently sealed ball bearings.

a. The bearings shall be a cataloged type as manufactured by Fafnir, SKF, Sealmaster or approved equal, and stocked locally. Both inboard and outboard bearing shall be the identical size. Bearings shall be heavy-duty, self-aligning ball or roller pillow block type, and selected for a minimum (L-10) of 200,000 hours life at maximum cataloged operating speed.

b. Direct drive motor/fan assembly bearings shall be selected for a minimum (L-10) of 200,000 hours life at maximum cataloged operating speed.

E. Fans shall be airfoil, backward inclined, or forward curved type as indicated by schedules or as required by Architect/Engineer.

1. Airfoil and backward inclined wheels shall be of the non-overloading centrifugal type, constructed of heavy gauge steel or aluminum as indicated by the scheduled equipment.

2. Forward curved fan wheels shall be constructed of heavy gauge steel with uniform stamped steel blades.

F. Wheels shall be statically and dynamically balanced. The wheel cone and fan inlet cone shall be matched for maximum performance and operating efficiency.

G. The fan shaft shall be ground and polished shafting mounted in heavy duty, permanently sealed, self-aligning pillow-block roller or ball bearings. Bearings shall be selected for a minimum of L-10 200,000 hours of life at maximum cataloged operating speed. Bearings shall be a catalogued type as manufactured by Fafnir, SKF, Sealmaster, or approved equal. Where occurring, inboard and outboard bearings shall be the identical size.

H. After assembly, each fan shall be given an electronic vibration analysis while running at the specified operating RPM for constant speed fans, and throughout the specified speed range for variable speed fans. Vibration amplitude and frequency shall be recorded in the horizontal, vertical and axial planes of each bearing to assure smooth, vibration-free operation. The analyzer printout shall be **submitted with or prior to shipment of fan, and shall demonstrate compliance with prescribed balance at all operating speeds (up to not less than 120 Hz or 1.0 FLA, whichever is smaller).**

I. Provide fans with the following accessories and options as applicable to the specific condition:

1. Belt guards

2. Spring type vibration isolators, including thrust restraints where applicable

3. Inlet and outlet guards

4. Calibrated piezo ring airflow measurement within the inlet cone, achieving an accuracy of ±3%.

   a. Provide five tap sensing.

   b. Extend high and low ports to connections for TAB/controls at the outside of the cabinet. Provide permanent placard at ports with the airflow vs. pressure difference equation and graph/chart.

5. Access doors, bolted or hinged

6. Scroll drain connection

7. Weather hood

8. Flanged outlet

9. Airfoil motorized backdraft damper (with low-leakage dampers).

   a. Interlock with fan motor

   b. Include extended base with access door for damper actuator

10. Discharge damper

11. Variable frequency drive (reference Section 23 09 50 and coordinate)

12. Extended copper lubrication lines (for floor/roof/platform access).

13. For all fans 7-1/2 hp and above, provide factory concrete inertia base assembly with housed spring vibration isolators, Mason or equal approved by the Architect/Engineer.

2.03 IN-LINE CENTRIFUGAL FANS

A. Acceptable Manufacturers

1. Basis of Design: Greenheck

2. Other acceptable manufacturers:

   a. ACME

   b. Barry

   c. Cook

   d. Penn

B. As indicated by the drawings, fans shall be either belt driven and be provided with belt guards or direct drive and be provided with motor cover.

C. Fan housing shall be of the square or round design constructed of heavy gauge galvanized steel and shall include duct mounting collars.

D. Service access shall be provided by:

1. A hinging service door assembly supporting the motor, drives, wheel and inlet cone, where the door assembly swings out for cleaning, inspection, or service without dismantling the fan in any way, or;

2. Two removable service doors located perpendicular to the motor mounting panel, of sufficient size to permit easy access to all interior components.

E. As indicated by drawings, fan wheel shall be of the aluminum backward inclined or airfoil type (or other type if indicated by the drawings). Wheels shall be reinforced type to permit highest available rpm ratings for the particular fan. Wheels shall be dynamically and statically balanced and shall overlap the spun inlet venturi for maximum performance.

Unless available only in Class I construction, fans shall be constructed at a minimum of Class II. Provide fans constructed for Class III where indicated by scheduled equipment or as otherwise required by the particular conditions involved.

F. Motor and drives shall be isolated from the air stream. Motors shall be of the heavy duty type with permanently lubricated, sealed ball bearings. The wheel shaft shall be ground with polished shaft mounted in heavy-duty permanently sealed pillow block bearings with minimum of L-10 200,000-hour average life. Drives in belt drive fans shall be sized for a minimum of 165% of driven horsepower. Pulleys in belt drive fans shall be of the fully machined cast iron type, keyed and securely attached to the wheel and motor shafts. The motor pulleys shall be adjustable for final system balancing.

G. Flexible wiring leads shall be provided from the fan motor to an externally mounted junction box and disconnect switch permitting access for service without disconnecting the field wiring.

H. Provide fans with the following accessories and options.

1. Spring type vibration isolators (hanging or base, as applicable).

2. Spring axial restraint/thrust isolators (unless not recommended by manufacturer for particular application). Anchor as required.

3. Motor and belt cover.

4. Direct drive motor cover.

5. Variable frequency drive, where indicated by drawings. Refer also to Section 23 09 51 - Controls and Instrumentation.

6. Motorized backdraft damper (with low-leakage blades), interlocked with fan motor.

7. Manual discharge damper (exception: backdraft discharge damper or control discharge damper where indicated by drawings).

8. Fan speed control:

   a. Solid state speed control for 115V/1 phase motor (direct drive models) located at fan or above ceiling above fan switch/controls (intent is to locate speed control so that it is accessible by authorized personnel only).

   b. Electronically Commutated Motors (ECM):

      1) Speed setting dial,

      2) 0-10 VDC remote control from BAS.

   c. Note: Confirm environmental ranges for speed controller and locate where such requirements are not exceeded (e.g., temperature, humidity too high or too low).

9. Manual starter.

2.04 CENTRIFUGAL ROOF/WALL EXHAUSTERS AND UPBLAST CENTRIFUGAL EXHAUSTERS

A. Acceptable Manufacturers

1. Basis of Design: Greenheck

2. Other acceptable manufacturers:

   a. ACME

   b. Barry

   c. Cook

   d. Penn

   e. Others where specified or scheduled

B. Fans shall be belt driven or direct driven as scheduled or otherwise indicated.

C. Fans shall be of the centrifugal type, with housing of heavy gauge aluminum mounted on a rigid support structure. The shroud shall have a rolled bead for additional strength. Bird screen shall be provided.

D. The fan wheel and inlet cone shall be aluminum and of the high performance, centrifugal blower type. Wheels shall overlap the spun inlet venturi for maximum performance. Wheels shall be reinforced type to permit highest available rpm ratings for the particular fan. Wheels shall be statically and dynamically balanced for vibration-free operation. The entire drive assembly shall be mounted on internal vibration isolators.

Unless only available in Class I construction, fans shall be constructed at a minimum as Class II. Provide fans constructed for Class III where indicated by scheduled equipment or as otherwise required by the particular conditions involved.

E. Motor and drives shall be isolated from the exhaust airstream. Air for cooling the motor shall be taken into the motor compartment from a location free from discharge contaminants. Motors shall be of the heavy duty type with permanently lubricated, sealed ball bearings.

F. The entire drive assembly and wheel, as a unit, shall be removable through the support structure without dismantling the fan housing. The wheel shaft shall be ground and polished steel mounted in heavy duty, permanently sealed pillow block ball bearings with minimum rating of L-10 200,000 hours average life.

G. Drives for belt drive fans shall be sized for a minimum of 165% of driven horsepower. Pulleys for belt drive fans shall be of the fully machined cast iron type, keyed and securely attached to the wheel and motor shafts. The motor pulleys shall be adjustable for final system balancing.

H. A disconnect switch (NEMA 3R where fan is installed outdoors or in other wet locations) shall be factory installed and wired from the fan motor to the disconnect junction box. A conduit chase shall be provided for running electrical and control wiring through the curb cap into the power compartment.

I. Provide the following accessories and options.

1. 14” high (above finished roof) roof curb (insulated)-coordinate with roof type, and with roof pitch where pitched roofs occur

2. Extended base as required for installation of gravity/motorized damper and as otherwise indicated

3. Motorized backdraft damper (with low-leakage blades)

   a. interlock with fan motor

   b. include extended base with access door for damper actuator

4. Fan speed control:

   a. Solid state speed control for 115V/1 phase motor (direct drive models) located at fan or above ceiling above fan switch/controls (intent is to locate speed control so that it is accessible by authorized personnel only).

b. Electronically Commutated Motors (ECM):

1) Speed setting dial,

2) 0-10 VDC remote control from BAS.

c. Note: Confirm environmental ranges for speed controller and locate where such requirements are not exceeded (e.g., temperature, humidity too high or too low).

5. Manual starter for 115V/1 phase motor

6. Approved upblast configuration when serving kitchen hoods, or in similar applications.

7. Vented curb extension to meet NFPA 96 requirements for minimum discharge height of 40" above roof.

8. Curb seal.

9. Other accessories/options indicated by the plans or appropriate for project conditions.

2.05 FAN ASSEMBLIES – DIRECT DRIVE PLENUM FAN ARRAY

A. Fans shall be direct-drive, non-overloading SWSI plenum fans designed for industrial duty and suitable for continuous operation. Fans shall be arranged in an array using one or more welded structural steel assemblies and shall be of the size and quantity indicated by the drawings. Fan assemblies shall be attached directly to base structural members. Attachment to unsupported floor plate or formed sheet metal supports is not acceptable.

B. Fan wheels shall be full or partial width as indicated by the size/performance, shall have a minimum of 12 airfoil blades for superior sound characteristics, and shall be constructed of aluminum to reduce rotational weight and vibration. Fan blades shall be extruded aluminum for uniformity and improved vibration characteristics.

C. Each fan and motor assembly shall be independently isolated within the structural assembly using 1 inch deflection spring isolators. Isolators shall be mounted in a three-point arrangement that provides both vertical and horizontal (thrust) isolation and shall not require field adjustment. Isolation system shall be seismic rated to withstand seismic forces in excess of 2.5G horizontally and vertically (to satisfy specified IBC seismic requirements).

1. Fan, motor, and frame/support assemblies shall be designed such that no natural frequencies exist within the operating RPM range of the fan, eliminating the need for “lockout” frequency settings in the variable speed drive.

D. Motors shall be Premium Efficiency per NEMA MG1 Table 12-12 (TEAO) type, shall have NEMA Class F insulation, shall meet NEMA Standard MD-1 Inverter Duty rating and shall be designed to withstand 1600V peak voltage spikes and rise times ≥0.1 microseconds. Motors shall have greasable ball bearings designed to deliver a minimum L10 life of 500,000 hours at full load and the maximum operating RPM of the associated fan. The opposite shaft end bearing shall be clamped to secure the bearing in the housing. Electrical characteristics and horsepower shall be as indicated by the drawings.

E. For efficient operation in a direct drive application, motors shall be capable of running continuously from 0 to 120Hz and deliver full rated horsepower at 60 to 120Hz operating frequencies. All motors shall maintain a minimum service factor of 1.15 throughout a 60 to 120HZ operating range (or as limited by horsepower/application). Motors shall conform to a G2.0 balance per NEMA S2.19.

F. Motors shall be factory wired to a manufacturer's wiring center or junction box with terminated lugs for line connection to a VFD/or other motor control/starter device as indicated by drawings.

1. The manufacturer's wiring center shall include for each motor circuit a control device providing overload protection, short circuit protection, and a manual disconnect means. All circuits shall be wired to a common main panel terminal block in the wiring center.

2. Each control device shall include an auxiliary output capable of providing remote notification of a motor failure.

3. All motors shall operate at all times and be controlled in unison, maintaining a consistent and uniform airflow pattern over coils, filters and other devices.

4. Each motor shall be provided with a shaft grounding device to harmlessly bleed potential induced shaft voltages to ground, Aegis SGR or equal.

5. All rotating assemblies (including fan and motor), workmanship, materials, performance (noise/vibration) shall be warranted by the unit manufacturer for a full five (5) years from date of unit start-up.

G. All fan arrays shall meet or better the minimum motor efficiency, maximum brake horsepower, and total motor horsepower values scheduled. All fans shall be selected to operate at a point no higher than 90% of the peak static pressure rating as defined by the fan performance curve at the selected operating speed. Manufacturer must ensure maximum fan RPM is below the first critical speed. Fans shall be a minimum of (Class 2) construction.

H. All fan and motor assemblies shall be dynamically balanced by the manufacturer to a maximum allowable vibration of 0.025 inches per second at design RPM and a maximum 0.025 inches per second overall vibration limit. In addition, the manufacturer shall ensure that no critical frequencies exist in the fan operating range by varying motor speed in 1Hz increments from 10% of design RPM to 150% of design RPM.

1. Provide factory vibration testing of individual fan assemblies and of fan array assemblies to demonstrate compliance with specified limits. **Submit report at time of test, prior to shipment.**

I. The fan array shall be provided with factory installed multi-tap Piezo ring airflow measuring devices on each fan. Airflow devices shall be mounted out of the direct air stream so as not to affect system static pressure or sound performance. Sensor accuracy shall be +/-3% or better and detect positive or negative flow direction. System flow measurement accuracy shall be +/-5% or better. Performance shall have been verified in an AMCA registered air chamber. Factory installed assembly shall include:

1. For each fan, flow sensors (for field connection to a transducer provided by others).

2. For each fan, flow sensor with transducer/transmitter having digital display and providing nominally 0-10 VDC analog output to BAS. Transducer accuracy shall be 0.25% of actual, or better.

3. For each fan, flow sensors are to be bi-directional, measuring reverse flow in negative values.

J. Each fan array shall be provided with an acoustic baffle assembly for added sound attenuation. Sound attenuation values shall be as indicated on the schedule.

K. Provide overhead motor removal system to facilitate motor (and fan) removal/replacement.

L. Personnel protection screens & panels: Fans shall be provided with:

1. OSHA inlet screens, or Manufacturer's factory installed vertical blade backdraft damper on fan inlet where OSHA compliant.

2. OSHA outlet guards.

3. OSHA side outlet guards, or side double wall acoustical panels with perforated inner liner, as indicated by the drawings.

M. Backflow avoidance:

1. Provide each fan in array with heavy duty, low leakage backdraft damper to automatically close upon loss of fan flow:

a. Vertical blade near zero system effect backdraft damper, Huntair/FanWall or equal.

2. Where vertical blade backdraft damper is not used/available by a particular manufacturer, provide each fan array with one inlet airflow blank-off plate to be used in case of a motor/fan failure. Plate to include handles and latches for quick installation without tools. Nameplate blank-off plate and store in mechanical room as indicated on drawings.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install fans according to manufacturer's written (and field) instructions.

B. Do not place fans in service until ductwork is clean, filters (return and supply/final, as applicable) are in place, bearings are lubricated, and fans have been test run (with filters) under observation.

C. Install fans with flexible duct connections on intake and discharge, and as indicated on the drawings.

1. Exceptions: roof/wall exhausters.

2. Fans within AHU/equipment for which manufacturer warrants flexible connections are not required, and for which sound/vibration durability issues do not result.

D. Install fans to preclude vibration and to provide maximum maintenance access.

E. Install fans and associated discharge caps/louvers to prevent water leakage/intrusion.

F. Secure roof curbs to roof. Secure roof fans to roof curbs with lag screws/bolts (and other special details where required by wind conditions or drawing details).

G. Provide accessible manual volume dampers in ductwork downstream of in-line or centrifugal fans (for fine tuning of balancing, not intended to be used in lieu of variable sheave or motor speed primary balancing).

H. During storage and installation, keep fan inlets and discharges totally covered and protected to prevent entrance of water, dust, dirt, or construction debris. Failure to do so shall subject equipment to rejection or total interior cleaning.

I. Coordinate with outdoor air intake locations to ensure a minimum of twenty-five feet (25') separation between outdoor air intakes and/or operable windows and exhaust, plumbing vents, and flues.

J. Field insulate centrifugal or in-line fan housings and motor covers as required for condensation control, thermal conservation, or noise control, in accordance with Section 23 08 90 (ductwork and systems in mechanical rooms - Armaflex II sheet insulation).

1. Where insulation is provided in part for acoustic reasons (reduced radiated noise), lag insulation with approved mass loaded vinyl acoustic material compatible with insulation substrate. Attach securely, with overlapping seams/joints. Refer also to Section 23 08 90.

K. On those fans with motorized dampers where dampers are called to close when fan shuts off, wire damper motors to fan power source (interlocked or via relays) to accomplish shutdown. Provide interposing relay and/or transformer where required due to voltages.

L. Controls: Refer also to Section 23 09 51 - Controls and Instrumentation (DDC). Coordinate bidding and execution accordingly.

3.02 CONTRACTOR'S COMMISSIONING

A. Provide all start-up, testing, and systems commissioning in a manner consistent with the equipment, application, and related systems. Work shall include, but not necessarily be limited to:

1. **Manufacturer’s/factory start-up with report**, confirming all specified and manufacturer recommended installation and make-ready work has been performed, confirming proper electrical service and phasing/rotation, and confirming all fan and duct accessories are in place.

a. Take sound measurements in occupied spaces near fan or fan outlets/inlets and propose specific sound reduction methods if sound exceeds ASHRAE standards for the particular space.

2. **Manufacturer’s field vibration testing/analyses and report,** confirming operation without excess vibration and operation within specific limits where

applicable due to industry standards, manufacturer's literature, and/or specifications.

a. Exception: Field vibration testing is not required for the following conditions unless directed by Architect/Engineer due to unsatisfactory operation:

3) Centrifugal fans

4) Roof/wall exhausters

5) in-line centrifugal or mixed flow fans

3. **Contractor's report** confirming proper operation and integration with controls.

4. In addition, where fans are integral components to air handling units or other equipment, refer to relevant related sections and comply with requirements therein.

3.03 VERIFICATION OF CONTRACTOR'S TESTING

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

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

END OF SECTION

SECTION 23 08 80 - FILTERS AND ACCESSORIES

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

PART 1 – GENERAL

1.01 SCOPE

A. Furnish and install all materials, labor, equipment, and accessories for the installation of a complete air filtering system in accordance with the intent of these specifications and the accompanying drawings.

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

1. Medium efficiency (MERV 8) disposable pleated filters

2. High efficiency (MERV 13) disposable pleated filters

3. Multi-stage filter housing/frame

4. Filter gauges

1.02 RELATED SECTIONS

A. 23 00 10 – General Requirements for Mechanical Work

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

C. 23 07 90 – Air Coils

D. 23 08 58 – Custom Air Handling Units

E. 23 08 60 – Fans

F. 23 08 90 – Air Distribution

G. 23 09 51 – Controls and Instrumentation (DDC)

H. 23 09 70 – Division 23 Testing, Adjusting, Balancing

1.03 SUBMITTALS

A. **Provide submittals under provisions of Section 23 00 10 - General Requirements for Mechanical Work.**

B. **Include:**

1. filter ratings, size(s), efficiency, pressure drops at nominal velocity, recommended final resistances;

2. filter schedule indicating equipment served, location, quantity, size, and type as part of the submittal documents.

C. **Provide specification copy mark-ups as required by Section 23 00 10.**

PART 2 - PRODUCTS

2.01 GENERAL

A. Acceptable Manufacturers:

1. Basis of Design: Camfil/Farr (unless otherwise indicated in following sections or by drawings)

2. Other acceptable manufacturers:

a. Flanders

b. American Air Filter

c. Air Guard

B. Efficiency ratings: Filters shall be provided with MERV ratings (Minimum Efficiency Reporting Value) as determined from tests conducted in accordance with the latest published edition of ASHRAE Standard 52.2.

C. Complete filter assemblies: Provide filters, housings, and gauges equal to those indicated on the drawings and/or specified herein. Provide additional housings, racks, gauges and other accessories required by field conditions for complete installation.

1. Optimal filter area: Arrange filter assemblies to accommodate the greatest filter area for the given space/application, while also keeping the number of the filter sizes to a minimum. Refer to drawings and other Sections of these specifications.

2. Custom filter sizes: Provide custom filter sizes to accommodate each piece of equipment as required. Where the application would require a single filter width greater than 24”, provide two filters each at one-half the width (e.g., 30” x 8” filter area is served by two each 15” x 8” filters).

D. Spare filters: In addition to the filters changes required under Section 23 00 10, provide two additional complete sets of all disposable filters (i.e., for two additional change outs at each piece of equipment), typical for all filter sizes/efficiencies applicable to project. Deliver to site at conclusion of project and store in respective mechanical room(s).

E. Bypass prevention: Prevent passage of unfiltered air around filter with durable sealing materials consistent with the respective MERV ratings. Use felt, rubber, neoprene, or gel gaskets/seals at filters or filter racks/frames.

2.02 MEDIUM EFFICIENCY (MERV 8) DISPOSABLE PLEATED FILTERS

A. General: Air filters shall be medium efficiency, pleated, disposable type. Each filter shall consist of a cotton media pleated with an electro-finish wire bonded to a heavy duty paperboard frame. The filter shall be listed by Underwriter's Laboratories as U.L. Class 2.

B. Media: The filter media shall be self-extinguishing, non-woven cotton with polyester trace fibers. The filters shall have MERV-8 rating (minimum) when tested in accordance with the most recent published edition of ASHRAE standard 52.2.

C. Media Backer: The filter media backer shall be 24 ga. 1" x 1" electro-finish wire with a 96% open area. The welded wire backer is bonded to the media to prevent media movement. The pleated wire support allows total use of the filter media.

D. Frame: The filter frame shall be heavy duty paperboard, die cut for dimensional accuracy. The frame webbing is bonded to the filter pack, upstream and downstream, to ensure even pleat spacing. All ends of the filter are bonded to the inside of the frame to prevent air by-pass.

E. Filter Depth: Filter depth shall be:

1. 2" deep when used as pre-filter in dual filter housings;

2. or as indicated by drawings or other sections of these specifications.

F. Pleats and Allowable Resistance:

1. Two-inch (2") deep filter shall have not less than 15 pleats per linear foot with an average effective media area of 4.6 square feet per square foot of filter face area. The initial resistance is scheduled at 500 fpm shall not exceed 0.31" w.g. Actual velocities are lower and vary with unit.

G. Basis of Design: Camfil/Farr 30/30.

2.03 HIGH EFFICIENCY (MERV 13) PLEATED DISPOSABLE FILTERS

A. General: Air filters shall be high performance, 12" deep pleated, rigid and disposable type. Each filter shall consist of high-density microfine glass fiber media, media support grid, contour stabilizers, and enclosing frame.

B. Media: Filter media shall be of high-density microfine glass fibers laminated to a non-woven synthetic backing to form a lofted filter blanket. Filters shall be listed by Underwriters' Laboratories as Class 2, with performance as follows:

1. The filter media shall have a MERV-13 rating (minimum) with an average efficiency of 80-85%. The initial resistance at 500 FPM shall not exceed 0.50" w.g.

C. Media Support Backer: The media support 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 affects a tapered radial pleat design. The grid shall be designed to support the media both vertically and horizontally.

D. Contour Stabilizers: Contour stabilizers shall be permanently installed on both the air entering and air exit sides of the filter media pack to ensure that the tapered radial pleat

configuration is maintained throughout the life of the filter. The filter shall be capable of withstanding 10" w.g. pressure drop without noticeable distortion of the media pack.

E. Frame: The enclosing frame shall be constructed of galvanized steel. It shall be constructed and assembled in such a manner that a rigid and durable enclosure for the filter pack is affected. The periphery of the filter pack shall be continuously bonded to the inside of the enclosing frame, thus eliminating the possibility of air bypass. The enclosing frame shall be equipped with protective diagonal support members on both the air entering and air exiting sides of the filters.

F. Basis of Design: Camfil/Farr Riga-Flo.

2.04 MULTI-STAGE FILTER HOUSING

A. Housing shall be a face or side access as indicated by conditions on the drawings, two-stage filter system consisting of a housing, access doors, tracks, holding frames and integral static taps. Housing shall accommodate any 2" pre-filter and various second stage filters ranging in depths to 12” (generally MERV 8 to MERV 14).

1. The housings' in-line depth shall not exceed 21".

2. The static taps shall be constructed of brass and be equipped with standard pneumatic fittings. Each of three taps shall be permanently installed to provide for individual and/or total pressure drop readings of both pre-filter and second stage filter sections.

B. Both pre-filter and second stage filter shall be permanently gasketed to eliminated air bypass. Leakage upstream to downstream of filter, track/ frame, and slide mechanism, at fully rated airflow, shall be less than 1% at 3" w.g. differential.

C. Housing shall be factory fabricated and assembled of not less than 16-gauge galvanized steel with corner posts of Z-channel bracing to eliminate racking.

1. Access doors shall be constructed of not less than 16-gauge galvanized steel and positioned to facilitate removal and replacement of filters from either side of the housing. Each door shall be equipped with adjustable and replaceable positive sealing latches and replaceable hinges. The peripheral gasket material shall be of high memory sponge neoprene. Holding frame to door contact shall be gasketed with 1" x 1.25" polyurethane foam to effect a positive seal.

2. Tracks shall be replaceable, heavy gauge, anodized aluminum extrusion designed to accommodate Universal Holding Frames. Each extrusion shall be equipped with a replaceable, woven pile, polypropylene, finned seal creating an air barrier between the extrusion and Universal Holding Frame. Track to housing mechanism shall allow for field adjustments.

D. ***[Flander/FFI K-Trac]*** Track/frame assembly shall be factory fabricated and assembly of not less than 0.095 in. Type 6063-T5 aluminum with additional vertical members and bracing to provide support and eliminate racking.

1. The pre-filter track shall be separate to allow upstream removal and insertion of prefilters without disturbing final filters.

2. Each horizontal row of prefilters and final filters shall include factory-installed positive-sealing bars to permit easy changeout of filters. Gasket on filters must be compressed during operation.

3. Modules shall be complete with speed-screws necessary for filed assembly.

E. Filter housing/frame shall be reinforced such that maximum deflection at any point at full loaded filters x 1.5 pressure difference shall not exceed L/250.Each housing shall be equipped with two (2) access doors and 1.5" standing flanges with pre-punched holes to facilitate field installation and/or in-line mating with other housings. Flanges shall be notched to provide water runoff. Housings must be suitable for installation outdoors.

F. Holding frames shall be constructed of heavy gauge, galvanized steel equipped with integral U-Bearing slide channels, centering dimples, multiple fastener lances, and polyurethane foam gasketing to facilitate a positive seal. Holding Frames shall be capable of accommodating any standard size (nominal) 24" x 24" or 12" x 24" filters without modification to frame or housing.

G. Basis of Design: Flanders/FFI K-Trac.

2.05 FILTER GAUGES

A. All filters: Install a differential pressure (DP) measurement device across all filter banks.

B. Local gauges: Provide differential pressure measurement devices with pressure ranges as indicated on the drawings, or as directed by Architect/Engineer.

1. Series 2000 Dwyer Magnehelic gauges: Devices to have die-cast aluminum casings with 4-3/4" diameter face and adjustable signal flag. Accuracy shall be (+/-) 2% of full scale. Set signal flag for filter change pressure drop as indicated by drawings or as directed by Architect/Engineer.

2. Controls coordination: Coordinate with controls trade for shared filter DP taps where differential pressure switches (DPS) or differential pressure transducers (DPT) are used for remote filter monitoring.

a. Series 3000 Dwyer Photohelic Gauges: Coordinate with Section 23 09 51 - Controls and Instrumentation (DDC), for 24VAC power to photohelics and for connection to contact closures.

C. Where not provided under Section 23 09 51, provide electronic DP Transducers with digital readout, similar and equal to those applied for other filters monitoring. Refer also to Section 23 09 51 – Controls and Instrumentation. Locate in recess mount panel in partition near the room/area served. Confirm location with Architect/Engineer prior to rough-in.

1. Provide relocated power (24VAC), BAS signal wiring (0-10V), copper tubing, and room pressure sensor (or connection to an ambient pressure piping system where available in the project) as requested for the monitoring and alarm functions of the BAS.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install air cleaning devices in accordance with manufacturer's instructions.

B. Bypass Prevention: Prevent passage of unfiltered air around filters with felt, rubber, neoprene, or gel gaskets/seals with types and construction details consistent with the MERV rating. Provide effective and removable safing at filter to housing gaps where such gaps cannot be avoided.

C. Prerequisite for fans operation: Do not operate fan system until all filters (outdoor, return, supply) are in place.

D. Replace filters used during construction prior to test and balance.

E. Pressure taps: Install filter gauge static pressure taps (not velocity pressure probes) upstream and downstream of each filter section.

1. Where multi-stage filter housings are close coupled and do not have clearances for pressure taps between the filters, provide galvanized sheet metal “standoff” or “spool” to separate pre-filter and final filter to allow tap(s) for gauges and monitoring.

a. Location: In general, install near middle of filter assembly where velocity and filter loading is likely to be the greatest.

b. Bypass Prevention: Provide at pre-filter standoffs.

2. Provide copper tubing from taps to gauges with "union" type connections to allow easy removal.

3. Provide with accessible valved taps to allow connection of other instrumentation without affecting gauge/control systems.

F. Gauges Mounting: Unless otherwise indicated, gang mount filter gauges for each unit at one readily accessible location as directed by Architect/Engineer. Adjust and level. Avoid mounting on any surface subject to vibration.

G. Nameplates: Provide engraved laminate nameplate at each filter and at each corresponding gauge.

END OF SECTION