

SECTION 23 73 43.19 - OUTDOOR, CUSTOM AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes outdoor, custom air-handling units with capacities, characteristics and configurations indicated on Drawings.
- B. Related Requirements:
 - 1. Section 237000 "Central HVAC Equipment."

1.3 ACTION SUBMITTALS

- A. Product Data: For each air-handling unit.
 - 1. Product information organized to show compliance with each performance requirement of "Performance Requirements" article.
 - 2. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 3. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 4. Include unit dimensions and weight.
 - 5. Include cabinet material, metal thickness, finishes, insulation, and accessories.
 - 6. Fans:
 - a. Include certified fan-performance curves with system operating conditions indicated. For fans operating at variable speeds include curves in 10 percent speed increments starting at design speed down to minimum speed.
 - b. Include fan-sound power ratings in all eight octave bands. Include inlet or outlet sound power levels to coincide with sound requirements indicated on Drawings.
 - c. Include fan construction and accessories. Submit sufficient information to show product compliance with requirements indicated.

- d. Include dimensions and weight.
- e. Include motor ratings, electrical characteristics, and motor accessories.
- 7. Vibration isolation product data with performance ratings. Uniquely identify and include information for each different isolator type and indicate for each air-handling unit where each isolator type is being used.
- 8. Include certified coil-performance ratings with system operating conditions indicated. Product data to include: dimensions, dry and operating weight, volume of fluid contained, materials of construction, and performance ratings with system operating conditions indicated.
- 9. Casing insulation product data and performance ratings.
- 10. Access door and access panel product data and performance ratings.
- 11. Roofing product data and performance ratings.
- 12. Louver product data and performance ratings.
- 13. Paint product data and performance ratings.
- 14. Electrical product data and performance ratings.
- 15. Metal grating product data and performance ratings.
- 16. Dampers product data, including housings, linkages, and operators with performance ratings.
- 17. Filters product data with performance characteristics.
- 18. Heat wheels product data with performance ratings.
- 19. Fixed plate heat exchangers product data with performance ratings.
- 20. Heat pipe heat exchangers product data with performance ratings.
- 21. Air blender product data with dimensions, weights, materials of construction, performance ratings, and installation requirements.
- 22. UV-C lamp systems product data with performance ratings.
- 23. Pumps product data with performance ratings.
- 24. Hydronic pipe, valves, fittings, vents, strainers, and hydronic accessories product data.
- 25. Steam and condensate pipe, valves, fittings, vents, strainers, and steam specialties product data.

26. Pipe insulation and jacket product data.
27. Roof curbs product data.
- B. Shop Drawings: For each type and configuration of indoor, custom air-handling unit.
 1. Prepared by manufacturer's factory employees with review and sign-off by those individuals responsible for manufacturing the air-handling units.
 2. Include plans, elevations, sections, and mounting details. For air-handling units consisting of multiple levels, create drawings for each level showing interrelationship of levels superimposed.
 3. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, methods of field assembly, components, and location and size of each field connection.
 4. Detail fabrication and assembly of indoor, custom air-handling units, as well as procedures and diagrams.
 5. Indicate details of construction with materials description including applicable specified standards and material grades in sufficient detail for reviewers to evaluate point by point compliance with requirements indicated for each air-handling unit.
 6. Use actual dimensions of internal equipment in preparing Shop Drawings. Identify mechanical equipment shown on Shop Drawings with equipment designations on Drawings.
 7. Thickness and finish of all casing materials with cross references indicated where each is used. Uniquely identify and include information for each different casing construction.
 8. Details for each unique casing joint and reinforcing. Indicate wall joints, wall to floor joints, wall to roof joints, floor joints, and roof joints.
 9. Roofing details.
 10. Assembly details of base and casing for units consisting of multiple sections requiring field assembly.
 11. Sizes and dimensioned locations of field connections for ductwork, piping, electrical, and controls.
 12. Base and casing penetration and sealing details for factory-installed conduit.
 13. Base and casing penetration and sealing details for factory-installed piping including coils.
 14. Details of casing connections to field-installed ductwork.

15. Size, shape and layout of base members including localized support of internal components.
16. Base materials, thickness, finishes, lifting provisions, and mounting requirements. Uniquely identify and include information for each different base construction. Clearly indicate for each air-handling unit.
17. Recommended points of field attachment with dimensioned locations.
18. Size and location of each access door, including clearing opening size, with door swing indicated.
19. Size and location of each access panel with service equipment superimposed to show relationship of panel to internal equipment.
20. Drain pans and associated piping, with sizes and locations dimensioned, including relationship to internal equipment.
21. Floor drains and associated piping, with sizes and locations dimensioned, including relation to internal equipment.
22. Coil framework and support including enlarged details showing framework attachment to air-handling unit base, coil attachment to framework, and means for individual coil removal.
23. Mounting details of all internal components, such as fans, filters, and dampers.
24. Hoist rails layout for internal equipment showing size of members, attachments to structure, and serviced equipment superimposed to indicate relationships.
25. Size and location of catwalks, handrails, ladders, and safety cages including construction details and details of attachment to air-handling unit base.
26. Location of receptacles, service lights, and switches.
27. Location of motor controllers and disconnect switches.
28. Size and location of junction boxes used for interface with field electrical power.
29. Point-to-point electrical power wiring diagrams including wire size, conduit size, motor controllers sizes, switch types and ratings, receptacle types and ratings, service light fixture types and ratings.
30. Point-to-point control wiring diagrams including cable types and sizes, conduit sizes, and connected control devices.
31. Point-to-point control tubing diagrams including tubing types and sizes, conduit sizes, and connection controls devices.
32. Control panel drawings drawn to scale showing detailed internal layout.

33. Plans, sections and isometric reviews of hydronic and steam and condensate piping systems showing pipe, fittings, flanges, unions, valves, vents, strainers, accessories, specialties and insulation.
34. Indicate code, operating, and maintenance clearances drawn to scale using dashed lines.
35. Indicate weights of internal components, weight of each separately shipped section, and air-handling unit total weight.

C. Comparison Schedule:

1. Submit a schedule to indicate performance of equipment scheduled on Drawings directly compared to performance of submitted equipment.
2. Clearly identify each line in schedule to indicate "Scheduled" where indicating performance scheduled on Drawings and "Submitted" where indicating performance of submitted equipment.
3. Organize schedule to first indicate performance scheduled on Drawings on one line followed by line directly below that indicates performance of submitted equipment.
4. Comparison schedule shall follow arrangement and organization of scheduled information indicated on Drawings.
5. Submitted equipment shall have a value for each scheduled value indicated.

- D. Delegated-Design Submittal: For vibration isolation indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the professional engineer responsible for their preparation.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Floor plans, sections, and other details, or BIM model, drawn to scale, showing the items described in this Section and coordinated with all building trades.
- B. Source quality-control reports.
- C. Startup service reports.
- D. Field quality-control reports.
- E. Sample Warranty: For manufacturer's warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air-handling units to include in emergency, operation, and maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Panel Filters: One set(s) for each air-handling unit.
 - 2. Absolute Filters: One set(s) for each air-handling unit.
 - 3. Access Door Gaskets: One set(s) for each access door.
 - 4. Fan Belts: One set(s) for each fan with belt-drive assembly.
- B. Tool Kit: Manufacturer to provide a tool kit including special tools required for air-handling unit service. See "Accessories" Article for additional requirements.

1.7 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.
- B. Coordinate sizes and locations of structural-steel support members, if any, with actual equipment provided.

1.8 FACTORY VISITS FOR PRODUCT INSPECTION

- A. While units are being manufactured, and during factory normal working hours, allow escorted access to manufacturing facility for Owner and Owner's designated representative to verify product compliance with requirements indicated.
- B. Manufacturer shall provide Owner and Architect with written notice at least 30 business days before units go into assembly.
- C. Inspection visits shall be scheduled with manufacturer at least 10 business days before visit.
- D. Personnel making visits for purposes of product inspection shall comply with manufacturer requirements for visitors.

1.9 DELIVERY, STORAGE, HANDLING

- A. Deliver air-handling units with factory-installed shipping skids and lifting lugs; pack small components in factory-fabricated protective containers. Cover units with heat-shrinkable plastic sheeting suitable for shipping from point of manufacture to Project.
- B. Handle air-handling units carefully to avoid damage to components, casing, and finish. Do not install damaged components; replace and return damaged components to air-handling unit manufacturer.

- C. Store air-handling units in a clean dry place and protect them from weather and construction activities.
- D. Keep air-handling units fully covered and protected during construction. Remove dirt and debris and clean units to a factory-cleaned condition.
- E. Comply with manufacturer's written rigging and installation instructions for unloading air-handling units and moving them to their final locations.
- F. For air-handling units equipped with key locks on access doors, keep doors locked during construction.
 - 1. If access is required within air-handling units, only open the doors to sections that require access and lock doors at the end of each workday.
 - 2. Protect inside of air-handling units from damage and keep inside of units as clean as the factory-cleaned condition.

1.10 WARRANTY

- A. Warranty: Manufacturer agrees to repair or replace components of air-handling units that fails in materials or workmanship within specified warranty period.
- B. Extended warranties include, but are not limited to, the following:
 - 1. Complete Air-Handling Unit: Two years from date of Substantial Completion for entire air-handling unit and longer where indicated for individual components.
 - 2. Air-Handling Unit Casing: 25 years from date of Substantial Completion.
 - 3. Air-Handling Unit Roofing: 25 years from date of Substantial Completion.
 - 4. Motors: Two years from date of Substantial Completion

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and application.
- B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.
- C. ASHRAE 62.1 Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

- D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- E. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design air-handling units, vibration isolation, including comprehensive engineering analysis, using performance requirements and design criteria indicated.
- F. Casing Structural Performance:
 - 1. Floor: Capable of withstanding positive/negative 8 inches wg of internal static pressure, without exceeding a deflection of $L/300$ of span.
 - 2. Walls and Roof: Capable of withstanding positive/negative 8 inches wg of internal static pressure, without exceeding a midpoint deflection of $L/200$ of span.
- G. Casing Leakage Performance, ASHRAE 111: Class 3 leakage or better at plus or minus 8 inches wg.
- H. Casing Leakage Performance: Comply with more stringent of the following requirements:
 - 1. ASHRAE 111, Class 3 leakage or better at plus or minus 8 inches wg.
 - 2. Not more than 0.5 percent of the total unit airflow at 8 inches wg.
- I. Casing Thermal Performance:
 - 1. Surface Condensation: Air-handling manufacturer shall evaluate potential for condensation and design and manufacture entire unit casing to prevent condensation at most extreme operating conditions encountered.
 - 2. Thermal Break: Incorporate a thermal break at each through metal path to prevent condensation from occurring on interior and exterior of casing.
 - 3. U-Value: Overall U-value or equivalent R-value of casing shall not exceed governing codes and ASHRAE/IES 90.1 while considering the effects of metal-to-metal contact and thermal bridging in calculations.
- J. Air Tunnel Aerodynamic Performance: Position air-handling unit internal components and transition between internal components to maintain uniform airflow; minimize sound levels and energy consumption. Use methods indicated and other means to ensure compliance.
 - 1. Use turning vanes if necessary to direct the air path.
 - a. Design, manufacture, and install vanes in accordance with applicable requirements in ASHRAE and SMACNA guidelines, handbooks, and standards.
 - b. Install vanes firmly in place so that no vane movement occurs at worst-case airflow capacity possible.

2. Use fan inlet and discharge transitions and other devices to maximize system regain and minimize airborne sound levels.
 3. Center system components such as coils, fans, and filters, vertically and horizontally, in the airstream.
 4. Maintain spacing between components such that airflow patterns to adjacent components are as uniform as possible and that component "dead spots" or "jetted areas" are avoided.
 5. Design and install internal structural supports, piping, and conduit that do not block airflow and impede performance of coils, fans, filters, and other unit components, and service space clearances.
- K. Durability Performance: Design and manufacture air-handling units with underlying requirement to provide a highly durable piece of equipment.
1. Unit Life Expectancy: 25 years.
 2. Supporting Documentation: Submit documentation showing proposed products to consider and include design features, components, and materials to satisfy requirement.
- L. Extreme Operating Conditions:
1. Corrosive Environments: Air-handling unit manufacturer shall evaluate the quality and potential corrosiveness of air passing through air-handling units and propose additional protective finishes and better-quality materials of a heavier thickness if required to comply with requirements indicated.
 - a. Unless otherwise indicated, air-handling units for HVAC applications may use up to 100 percent of outdoor air or a mix of outdoor air with return air from habitable areas served.
 - b. Air-handling units circulating Class 3 and Class 4 exhaust air in accordance with ASHRAE 62.1 could potentially be hot, humid, and corrosive and may require added protection.
 2. Humidity and Temperatures: Materials and components of air-handling units shall be suitable for use in low and high humidity and temperature extremes when operating under normal and abnormal conditions without permanent degradation or loss in material performance.
- M. Outdoor Environment:
1. Air-handling units specially designed to withstand effects of wind, rain, ice, snow, seismic, air quality, sun, and other influences associated with outdoor installations.
 2. Comply with requirements of air-handling unit and governing codes.
- N. Safety:

1. Comply with OSHA regulations.
2. Exposed sharp edges and corners of metal shall be protected or rounded to prevent injury to personnel not wearing gloves.
3. Cover exposed ends of screws with plastic or metal covers to prevent injury to personnel coming in contact with screws.

O. Serviceability:

1. Hoisting Provisions: Fans and motors weighing more than 200 lb shall have full-length hoist rails mounted over the equipment to facilitate service, removal, and replacement.
2. Mounting Location: Install internal components in readily accessible locations to facilitate ease of service and replacement.
3. Service Access:
 - a. Internal components shall be serviceable through access sections with doors indicated on Drawings.
 - b. Internal components shall be removable and replaceable through access doors or panels.
 - c. Review requirements for access doors and panels indicated and recommend additional access doors and panels if required for uninhabited service, removal, and replacement of components.
4. Tripping Hazards: Floors in accessible sections of air-handling unit shall be free of standing seams, reinforcing, supports, or section splits located in the walking path that is capable of causing a tripping hazard. Locate section splits immediately adjacent to internal walls.

P. Quality: Type and thickness of materials indicated are the minimum acceptable. Provide better-quality materials of a heavier thickness if required to comply with performance requirements indicated.

1. If manufacturer's standard construction exceeds requirements indicated, use manufacturer's standard construction.
2. If manufacturer's standard construction does not comply with requirements indicated, modify manufacturer's standard construction to comply with requirements.

Q. Vibration Performance: Air-handling unit manufacturer shall evaluate vibration of internal components installed inside of air-handling units and include internal vibration isolation required to limit the vibration transmitted to the building at a low enough level that vibration is not perceived by building occupants.

2.2 CAPACITIES AND CHARACTERISTICS

- A. See equipment schedules on Drawings.

2.3 SOURCE LIMITATIONS

- A. Source all outdoor custom air-handling units from same manufacturer.
- B. Like components furnished with air-handling units shall be from same manufacturer.

2.4 UNIT ARRANGEMENT AND CONFIGURATION

- A. Arrangement: Project-specific arrangement and configuration of air-handling units indicated on Drawings. Do not deviate from requirements indicated without submitting a formal request clearly describing each deviation and reason for each deviation, and only after receiving Architect's written acceptance.
- B. Mounting Requirements: Units mounted on roof curbs.
- C. Multiple Sections: Each air-handling unit shall consist of multiple sections for field assembly to comply with requirements indicated on Drawings.
- D. Multiple Sections, Splits: Air-handling unit manufacturer to determine number of sections and location of section splits required for each air-handling unit in accordance with the following criteria:
 - 1. Physical size and weight of each section, on-site path of travel, and methods for erection and installation. Air-handling manufacturer to review criteria with Installer before preparing Shop Drawings.
 - 2. Maximize physical size of each air-handling unit section considering, shipping, moving, erecting, and installation.
 - 3. Minimize the number of air-handling unit sections requiring field assembly. Preference is for single-piece air-handling units where possible.

2.5 AIR-HANDLING UNIT BASE

- A. Performance:
 - 1. Air-handling unit manufacturer shall design and assemble air-handling unit casing and internal components for attachment and support by air-handling unit structural base.
 - 2. Design air-handling units to be lifted from only the air-handling unit structural base and not the casing.
 - 3. Support air-handling units from only the perimeter base unless otherwise indicated on Drawings.

4. Air-handling unit manufacturer to size and locate intermediate structural base supports as required to comply with structural performance indicated for air-handling unit floors.
 5. Level base before factory assembly of air-handling unit casing and internal components to ensure proper fit and alignment.
- B. Structural Member Size:
1. Air-handling unit manufacturer shall select size of base members and construction of base to withstand the rigors of loading, unloading, shipping, and rigging without damage to air-handling unit components or misalignment of factory-assembled components.
 2. Depth and weight of structural members shall be selected by air-handling unit manufacturer to comply with performance requirements indicated.
 3. Depth of perimeter base members is not less than 1/10 of the unit width.
- C. Structural Member Spacing: Positioned as required to comply with requirements indicated, but not to exceed 24 inches.
- D. Materials: Structural aluminum, ASTM B209, Alloy 6061 T6 or structural stainless steel, ASTM A276/A276M, Type 316L.
1. Perimeter Members: channel or I or W beam shapes or tube.
 2. Intermediate Members (Spanning Full Width of Unit): channel or I or W beam shapes or tube.
 3. Cross Members (Spanning Intermediate Members): channel or tube.
- E. Welding Filler Metals: Comply with AWS welding codes for welding materials appropriate for thickness and chemical analysis of material being welded.
1. Use welding materials with corrosion properties equal to material being welded.
- F. Welding Procedures:
1. Structural Welding Codes: AWS D1.2/D1.2M for aluminum AWS D1.6/D1.6M for stainless steel.
 2. Join structural members to one another using continuous welds.
 3. After welding and fabrication, deburr and grind exposed welds to provide smooth surfaces free of sharp edges.
- G. Penetrations through Base Perimeter: Seal pipe, tubing, and conduit penetrations through base perimeter members to provide a watertight assembly.
- H. Section Joints: Air-handling units consisting of multiple sections for field assembly shall be joined with structural joining plates.

1. Joining plate material type to match base.
 2. Joining plate of thickness required to join sections without resulting in a permanent deflection, minimum 1/2 inch thick.
 3. Continuously weld joining plates to each mating end of base.
 4. Joining plates shall not extend beyond outer edge of adjoining base.
 5. Plates to include at least three equally spaced holes for field connection using factory-furnished threaded hardware of a nominal diameter of at least 1/2 inch (13 mm).
- I. Lifting Provisions: Air-handling unit manufacturer to design and install lifting lugs of size and location required to comply with performance requirements indicated. Lifting lugs extending beyond the base shall be easily removable in the field after unit is installed.
- J. Curb Cap:
1. For air-handling units installed on a continuous perimeter curb, provide air-handling unit base with a continuous structural angle counterflashing.
 2. Angle shall extend down vertical face of curb to completely cover wood nailer.
 3. Coordinate inside dimension of angle counterflashing with curb dimension and roofing. Provide adequate clearance between angle counterflashing and roofing over curb.

2.6 UNIT CASINGS

- A. Casing Assembly:
1. Appearance:
 - a. Exposed exterior surfaces of casing shall have a neat and finished appearance free of standing seams, exposed reinforcing, and other casing protrusions more than 0.25 inch beyond the exterior skin surface.
 - b. Underside of air-handling units with finished installation exposed to view shall have finished appearance matching casing walls. Casing shall be recessed within the perimeter structural base to provide a single contiguous plane.
 - c. Interior surfaces of casing shall have a neat and finished appearance free of standing seams, exposed reinforcing, and other casing protrusions more than 0.25 inch beyond the skin surface.
 2. Dissimilar Metals: Isolate dissimilar metals that are in contact to prevent galvanic action and corrosion.
 3. Framing and Supports: Interconnect and support individual casing wall and roof panels using either formed panel construction or framed construction with structural support

members. For framed casing construction, materials used to construct casing of structural support members shall be as follows:

- a. Casings with Aluminum Outer and Inner Skins: Aluminum extrusions in accordance with ASTM B211 Alloy 6063 T6.
 - b. Casings with Galvanized-Steel Outer and Inner Skins: Galvanized steel.
 - c. Casings with Galvanized-Steel Outer Skin and Aluminum or Stainless Steel Inner Skins: Stainless steel.
 - d. Casings with Stainless Steel Outer and Inner Skins: Stainless steel.
4. Seals: Seal interior and exterior joints and seams to make casing air- and watertight. Trim factory-applied sealant flush with adjacent surface.
 5. Double-Wall Casings: Consisting of insulation sandwiched between an outer and inner metal wall. Use double-wall casings to construct air-handling units unless septum casings are required.
 6. Septum Casings: Triple-wall construction consisting of a solid metal inner wall sandwiched between insulation layers that are covered with metal walls. Use septum casings for applications having performance requirements that are not achievable with double-wall casings.
 7. Penetrations: Seal voids around conduit, piping and tubing penetrations.
 - a. Walls and Roofs:
 - 1) Conduit, Pipe, and Tube Sizes NPS 3 and Smaller:
 - a) Seal void through casing with a nonhardening vapor-barrier caulk covered by an escutcheon on both interior and exterior sides of casing. Back caulk using formed insulation within a sheet metal sleeve.
 - b) Seal void using a friction fit neoprene or EPDM sheet material attached to casing using a bed of adhesive.
 - c) Cover penetration and sealing sheet material with metal escutcheon matching adjacent casing material.
 - 2) Larger Conduit, Pipe, and Tube Sizes: Seal annular void using an adjustable compression-type sealing sleeve.
 - b. Floors: Route conduit, pipe, and tube within a floor-mounted pipe sleeve.
 - 1) Sleeve:
 - a) Fabricate sleeve of aluminum, galvanized-steel, or stainless steel pipe.
 - b) Extend top of sleeve above adjacent floor surface to prevent standing water on floor from entering annular space of sleeve.

- c) Seal sleeve to top of floor for an air- and watertight seal.
 - 2) Seal annular void of sleeve using an adjustable compression seal or nonhardening packing material.
8. Floor Openings with Metal Grating:
- a. Factory install walk-on safety gratings over any floor opening large enough to create a safety hazard for operators including, but not be limited to, supply-, return-, and exhaust-air openings.
 - b. Bar Grating:
 - 1) Materials: Use stainless steel grating for aluminum hot-dip galvanized-steel grating for galvanized-steel floors.
 - 2) Air-handling unit manufacturer shall select depth and thickness of grating bars to limit deflection to 1/360 of span when subjected to a dynamic load of not less than 500 lb.
 - 3) Industry-standard welded grating with bars at least 1-1/2 inches deep by at least 3/16 inch thick with nominal 1-3/16-inch main bar spacing and 4-inch cross bar spacing.
 - 4) Source: Product manufacturer specializing in metal gratings.
 - 5) Grating bearing surface shall extend beyond clear opening in floor at least 2 inches.
 - c. Mounting Frame:
 - 1) Mount grating in a continuous structural angle or bar frame so no ends of grating bars are exposed. Top of frame to be flush with top of grating.
 - 2) Secure grating to frame with threaded hardware so grating does not move when walked on but can be easily removed from top to gain access behind grating.
 - 3) Continuously weld mounting frame to air-handling unit floor.
 - 4) Fasten mounting frame to air-handling unit floor with hardware and seal attachment air- and watertight.
 - 5) For applications with automatic dampers installed at floor openings, elevate height of mounting frame and grating to enclose entire damper assembly including jackshaft so walk-on surface of grating is above damper assembly.
9. Waterproof Floors: Continuously weld floor joints, seams, and penetrations to completely seal floor. Roll all edges of floor up at least 1 inch to create a shallow tub capable of holding standing water.

10. Duct Connections - Direct to Casing: Frame and reinforce unit casing around perimeter of unit duct openings to accommodate direct attachment of field-installed ductwork. Coordinate requirements with Installer to accommodate field connection.
 11. Duct Connections - Elevated Off Casing:
 - a. Terminate with angle flange face elevated 3 inches from exterior surface of casing.
 - b. Flange Thickness: 0.25 inch.
 - c. Flange face with holes located not more than 4 inches o.c., starting at corners, and sized for 0.375-inch-diameter, field-installed hardware.
 - d. Size flange face to mate to full face of duct flange.
 - 1) Clear inside dimension of unit connection to match clear inside dimension of duct.
 - 2) For connections to acoustically lined ducts, increase unit flange face to accommodate thickness of liner so end of duct liner is concealed by air-handling unit flange.
- B. Materials for Outer Skin of Casing Walls and Roofs:
1. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating; minimum (nominal) 18 gauge thick.
 2. Aluminum Solid Sheet: ASTM B209; Alloy 3003-H14, smooth or leather-grain texture finish; minimum (nominal) 0.063 inch thick.
 3. Stainless Steel Solid Sheet: ASTM A240/A240M or ASTM A480/A480M, Type 304; No. 2D or 4 finish; minimum (nominal) 18 gauge thick.
- C. Materials for Inner Skin of Casing Walls and Roofs:
1. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating, minimum (nominal) 18 gauge thick.
 2. Aluminum Solid Sheet: ASTM B209; Alloy 3003-H14, smooth finish; minimum (nominal) 0.040 inch thick.
 3. Stainless Steel Solid Sheet: ASTM A240/A240M or ASTM A480/A480M; Type 304; No. 2D finish; minimum (nominal) 18 gauge thick.
 4. Application: See Drawings for application of different materials indicated.
- D. Materials for Floor Walking Surface:
1. Aluminum Diamond Treadplate: ASTM B632/B632M, Alloy 6061 T6; mill finish; minimum (nominal) 0.125 inch thick.

2. Stainless Steel Diamond Treadplate: ASTM A793; Type 304; mill finish; minimum (nominal) 0.125 inch thick.
3. Application: See Drawings for application of different materials indicated.

E. Materials for Underside of Floor Insulation:

1. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating, minimum (nominal) 18 gauge thick.
2. Aluminum Solid Sheet: ASTM B209; Alloy 3003-H14, smooth finish; minimum (nominal) 0.063 inch thick.
3. Stainless Steel Solid Sheet: ASTM A240/A240M or ASTM A480/A480M; Type 304; No. 2D finish; minimum (nominal) 18 gauge thick.

F. Materials for Internal Walls:

1. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating; minimum (nominal) 16 gauge thick.
2. Aluminum Solid Sheet: ASTM B209; Alloy 3003-H14, smooth finish; minimum (nominal) 0.063 inch thick.
3. Stainless Steel Solid Sheet: ASTM A240/A240M or ASTM A480/A480M, Type 304; No. 2D finish; minimum (nominal) 16 gauge thick.

G. Surfaces in Contact with Airstream:

1. Comply with ASHRAE 62.1 and NFPA 90A.
2. Glass or mineral-fiber insulation installed behind perforated metal shall be encapsulated to prevent insulation fibers from entering the airstream by using a polymer sheet material or tightly woven glass cloth material that does not impact the acoustical absorption properties of insulation.

H. Insulation for Casing Walls and Roofs Not Exposed to Airstream:

1. Materials Not Exposed to Airstream: injected or sprayed polyurethane foam insulation with a minimum nominal density of 2 lb/cu. ft..
2. R-Value: Minimum R-12.
3. Thickness: Minimum 2 inches.
4. Insulation shall completely fill the casing cavity so no voids exist.

I. Insulation for Casing Walls and Roofs Exposed to Airstream:

1. Materials Exposed to Airstream: Glass or mineral-fiber board insulation with a minimum density of 2 lb/cu. ft..
 2. R-Value: Minimum R-12.
 3. Thickness: Minimum 2 inches.
 4. Insulation shall completely fill the casing cavity so no voids exist.
- J. Insulation for Casing Floors:
1. Materials: injected or sprayed polyurethane foam insulation with a minimum nominal density of 2 lb/cu. ft..
 2. R-Value: Minimum R-12.
 3. Thickness: Minimum 2 inches.
 4. Insulation shall completely fill the casing cavity so no voids exist.
- K. Access Doors:
1. Application: Install access doors in air-handling units at locations indicated on Drawings.
 2. Adjustment: Design doors for field adjustment capable of maintaining specified leakage rate.
 3. Mounting Height: Install bottom of door frame within 2 inches of air-handling unit floor walking surface. Where internal conditions require access doors to be mounted higher above air-handling unit floor, include permanent retractable stairs inside and outside of air-handling unit to limit stair risers to 6 inches.
 4. Performance: Leakage as required to satisfy overall unit leakage performance indicated, but not more than 1.0 cfm per door when tested at 10 inches wg.
 5. Fabrication: Formed and reinforced, constructed of same materials and thicknesses as casing.
 6. Swing: Arrange doors to be opened against pressure, unless otherwise indicated on Drawings.
 7. Frame: stainless steel with welded mitered corners.
 8. Handles:
 - a. Secure door closed using not less than two roller-style latches with handles located at quarter points along door height.

- b. If three latches with handles are included, install one at midpoint of door height and equally space others.
 - c. Air-handling unit manufacturer has option to use a multipoint latching mechanism that is operable from a single door handle located at midpoint of door height, but secures door to frame at top, bottom, and handle location.
 - d. Include door handles on outside and inside of door to allow operator access to open and close door from outside and inside of unit.
 - e. Field adjustable to accommodate changes to fit and gasket compression.
 - f. Durable product capable of withstanding repeated opening and closing of door while operating under design pressure without damage.
- 9. Hinges: minimum of three hinges.
- 10. Gasket:
 - a. Design: Specially formed with an internal air chamber specifically designed to seal on two surfaces without taking a permanent set.
 - b. Dual Gaskets: Primary and secondary gasket.
 - c. Location: Install gaskets around entire perimeter of doors or frames.
 - d. Material: EPDM, neoprene, or santoprene.
 - e. Protection: Seat gasket in a protective metal ribbed chamber integral to door or door frame to protect gasket from damage by operator incidental contact.
 - f. Service: Field replaceable.
 - g. Adhesive-backed tape-type gaskets adhered to a single flat surface are unacceptable.
- 11. Size of Door Frame Clear Opening: Large enough to allow for unobstructed access for inspection and maintenance of air-handling unit's internal components.
 - a. Width: At least 24 inches clear inside of door frame.
 - b. Height: Full clear height of unit casing up to a maximum height of 72 inches clear inside of door frame.
 - c. Door sizes indicated on Drawings.
- 12. Safety Latches and Stops:

- a. Safety Latches: Install safety latch with retainers on outward swing doors that do not open against pressure to allow restricted travel for purpose of pressure relief and so that doors do not open uncontrollably due to inside pressure.
 - b. Stops: Install cushioned door stops on inward swinging doors where necessary to limit door travel that could potentially damage the door or internal components.
- 13. Tie-Backs: Install tie-backs with retainers on outward-swinging access doors to hold doors in an open position during service.
- 14. Locks: Include each access door with an integral key lock. Pad locks are unacceptable.
 - a. Incorporate key lock into door handle where feature is available.
 - b. A common key shall be used to lock and unlock access doors of air-handling unit.
 - c. Include three keys.
 - d. Lock access doors at factory to ensure that unauthorized access is in place before air-handling unit packaging and shipment.
- 15. Windows:
 - a. Construction: Fabricate windows with frame mounted in access doors of double-glazed safety glass with an airspace between panes and interior and exterior seals.
 - b. Condensation Control: Install desiccant material in airspace between panes if necessary to prevent condensation from forming on glazing.
 - c. Clear Viewing Size: Minimum 8 inches, square.
 - d. Mounting Location: Center window in door width. For doors up to 60 inches high, locate top of window 6 inches below top of door. For taller doors, locate center of windows at optimal viewing height, approximately 60 inches above floor adjacent to unit.
 - e. Application: Install windows in all access doors.
- 16. Nameplates:
 - a. On each access door, include a nameplate defining the access to service within. Nameplates shall be included for, but not be limited to, the following:
 - 1) Dampers.
 - 2) Filters.
 - 3) Cooling Coils.

- 4) Heating Coils.
 - 5) Fixed Plate Exchangers.
 - 6) Supply Fans.
 - 7) Exhaust Fans.
 - 8) Air-handling unit designation.
 - 9) Where door access is to multiple components, list all components accessed.
For example: Filter/Cooling Coil.
 - 10) For each door that does not open against static pressure, include a warning sign stating: "DANGER: DOOR UNDER PRESSURE. DO NOT OPEN WITH FAN ON."
- b. Lettering Size and Style: At least 1-inch-high, block style.
 - c. Material: Lettering engraved in black plastic on a white plastic back. Engraving shall penetrate through black plastic so lettering reads white.
 - d. Attachment: Attach nameplates to door using high-strength bonding cement and stainless steel screws.
 - e. Mounting Location:
 - 1) For access doors without windows, locate top of nameplate 6 inches from top of door and center in door width.
 - 2) For access doors with windows, locate nameplate directly below window frame and center in door width.
 - 3) Align nameplates of all doors for uniform placement.
- L. Access Door Gutters and Downspouts: Install rain gutters directly above each access door to deflect rain away from doors.
1. Construct gutters of same materials and finish as casing exterior.
 2. Extend gutters beyond vertical edge of doors at least 3 inches.
 3. Install gutter with a downspout located adjacent to access door frame. Construct downspout of aluminum pipe of a size determined by unit manufacturer. Terminate downspout at a height below unit floor.
- M. Access Panels:
1. Performance: Leakage as required to satisfy overall unit leakage performance indicated.

2. Fabrication: Formed and reinforced panels of same material and thickness as casing.
 3. Fasteners: Adjustable, reusable type for multiple operations without degradation due to reuse. Do not use screws capable of stripping.
 4. Arrangement: Panels removable from exterior side of casing.
 5. Gasket: EPDM, neoprene, or santoprene similar to access doors, applied around entire perimeter of panels or frames.
 6. Location and Size:
 - a. Coils: Oversized access panel to allow removal and replacement without impacting adjacent casing.
 - b. Fans: Oversized access panel to allow removal and replacement of entire fan assembly including base without impacting adjacent casing.
 - c. Heat Wheels and Heat Exchangers: Oversized access panel to allow removal and replacement of internal components without impacting adjacent casing.
 7. Nameplates:
 - a. On each access panel, include a nameplate defining the access to service within. Nameplates shall be included for, but not be limited to, the following:
 - 1) Cooling Coils.
 - 2) Heating Coils.
 - 3) Fixed Plate Exchangers.
 - 4) Supply Fans.
 - 5) Exhaust Fans.
- N. Standing-Seam Metal Roof: Construct air-handling unit roof casing with standing seams designed for waterproof roofing applications.
1. Construct air-handling unit roof using same materials and finish as walls.
 2. Slope roof away from primary access side of unit at not less than 1 percent.
 3. For air-handling units shipped in multiple sections, include standing-seam joiners at each split with adhesive, hardware, and cover strips for field joining by Installer.
- O. Roofing Membrane:

1. Cover entire roof with a roofing membrane. Extend membrane down sides of unit a sufficient distance to provide a waterproof roof assembly and secure in place with a metal flashing matching casing material and finish.
 - a. Roofing membrane shall have an elongation of at least 450 percent when tested in accordance with ASTM D412.
 - b. Roofing membrane shall not become brittle at temperatures down to minus 40 deg F.
2. Slope unit roof away from primary access side of unit at a slope in accordance with roofing manufacturer's written instructions, but not less than 1 percent.
3. Application: Factory or field applied as determined by air-handling unit manufacturer; in accordance with roof manufacturer's written instructions.
 - a. Field-applied roofing to be supervised by an air-handling unit manufacturer's factory service representative.

P. Liquid-Applied Roofing:

1. Cover entire roof with a liquid-applied roofing. Extend liquid-applied roofing down sides of unit a sufficient distance to provide a waterproof roof assembly and cover sides with a metal flashing matching casing material and finish.
 - a. Cured roofing shall have an elongation of at least 500 percent at 77 deg F and at least 300 percent at 0 deg F, when tested in accordance with ASTM D412.
 - b. Roofing shall not become brittle at temperatures down to minus 40 deg F.
2. Slope unit roof away from primary access side of unit at a slope in accordance with roofing manufacturer's written instructions, but not less than 1 percent.
3. Application: Factory or field applied as determined by air-handling unit manufacturer; in accordance with roof manufacturer's written instructions.
 - a. Field-applied roofing to be supervised by an air-handling unit manufacturer's factory service representative.

Q. Piping Enclosures:

1. Description: Integral accessible enclosure(s) to house field-installed piping from below and connecting to hydronic coils.
2. Size: Adequate clearance for field installation of piping, valves, accessories, and associated insulation.
 - a. Maintain at least 6 inches of clearance between inside of enclosure and face of pipe insulation at most restricted point.

3. Construction:
 - a. Base, Walls, and Roof: Match air-handling unit.
 - b. Floor: Not required, open to below.
 - c. Access Doors:
 - 1) Size for full front access to piping, valves, and accessories installed within enclosure.
 - 2) Double-door applications with removable center mullions for unrestricted access.
4. Electrical: Factory install and wire service light with switch and receptacle for each enclosure.

2.7 WALL LOUVERS

A. Wall Louvers, Wind-Driven Rain:

1. Source Limitations: Obtain louvers from single source from single manufacturer.
2. Performance:
 - a. Air Pressure Drop, Design: Less than 0.1 inch wg at airflow indicated on Drawings.
 - b. Air Pressure Drop, Rating: Less than 0.1 inch wg at free area intake face velocity of 800 fpm.
 - c. Face Velocity: If louver size is not indicated on Drawings, size louver for 500-fpm velocity across louver free area.
 - d. Free Area: 47 percent or more for a 48-by-48-inch representative sample.
 - e. AMCA 500-L:
 - 1) Wind-Driven Rain Penetration Class: Class A, with wind-driven rain penetration effectiveness of 99 percent at core velocity up to 408 fpm with 50-mph wind and rainfall of 8 inches per hour.
 - 2) Intake Discharge Loss Class: Class 2.
3. Features:
 - a. Depth: 5 inches.

- b. Frame: 0.080 inch thick, ASTM B211, Grade 6063, T5 temper, extruded-aluminum alloy.
 - c. Blades: 0.063 inch thick, ASTM B211, Grade 6063, T5 temper, extruded-aluminum alloy; stationary in horizontal position, double drainable, and sightproof.
 - d. Stationary vertically positioned blades.
 - e. Bird Screen: 0.5-by-0.040-inch expanded flattened aluminum attached to back of louver.
 - f. Finish: Match exterior casing.
4. Air-Handling Unit Factory Assembly:
- a. Install louver face flush with exterior of casing and seal to provide a weathertight installation.
 - b. Secure louver in casing and include additional bracing if required to handle loading of extreme outdoor environmental performance indicated.
5. Application: Factory install louvers in air-handling casing at locations indicated on Drawings and for each outdoor intake and exhaust discharge.

2.8 INTERNAL STRUCTURAL SUPPORTS

A. General:

- 1. Air-handling unit manufacturer shall design and assemble air-handling unit internal structural supports for attachment and support by air-handling unit structural base.
- 2. Factory install structural supports for internal support casing if required to comply with casing structural performance.
- 3. Factory install hoist beams and rails over equipment to comply with performance requirements for service.

B. Structural Member Size and Spacing:

- 1. Size: Air-handling unit manufacturer shall select size of members and construction to do the following:
 - a. Withstand the rigors of loading, unloading, shipping and rigging without damage to air-handling unit components or misalignment of factory-assembled casing and components.
 - b. Comply with performance requirements indicated.
- 2. Spacing: Positioned as required to comply with requirements.

- C. **Materials:** Structural aluminum, ASTM B209, Alloy 6061 T6 or structural stainless steel, ASTM A276/A276M, Type 316L.
 - 1. Structural Supports: channel or I or W beam shapes or tube shapes selected by air-handling unit manufacturer for application.
 - 2. Hoist Beams for Internal Components (Spanning Full Width of Unit): I or W beam shapes.

2.9 FACTORY-MANUFACTURED ROOF CURBS

A. General:

- 1. Air-handling unit manufacturer shall furnish a continuous perimeter curb for each air-handling unit.
- 2. Design curb to support operating air-handling unit from its base with attachments to withstand environmental forces. Curbs with intermediate reinforcing as required.
- 3. Frame curb for ductwork, piping, and conduit located within curb.
- 4. Fabricate curb to maintain top of curb level even where installed on sloping substrate.
- 5. Furnish top of curb to provide for field attachment of unit base to curb.
- 6. Furnish curb with a fully mitered and raised cant where required by adjacent insulation and roofing.
- 7. Include bottom of curb with attachment flange that extends beyond base of curb and is suitable for attachment to substrate.
- 8. Furnish curb with integral crickets if required by roof installation.

B. Size:

- 1. Size curb to provide continuous support of unit base and to fit within footprint of unit perimeter base.
- 2. Height: See Drawings.
- 3. Height: 12 inches from top of curb to finished roofing surface at highest point along perimeter of curb.

C. Materials:

- 1. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating; minimum (nominal) 14 gauge thick. Treat welded areas to protect against corrosion with a zinc-rich coating.

2. Stainless Steel Solid Sheet: ASTM A240/A240M or ASTM A480/A480M, Type 304 grade; No. 2D finish; minimum (nominal) 14 gauge thick.

D. Insulation:

1. Insulate curb to provide thermal performance equal to unit casing.
2. Completely encapsulate insulation within metal curb.

E. Gaskets:

1. Include a continuous gasket between air-handling unit base and top of curb for an air and watertight seal.
2. Select gasket materials suitable for installation while complying with requirements indicated.
3. Furnish gasket materials with air-handling units and curbs for field installation.
4. Air-handling unit manufacturer to provide instruction to installer on proper installation techniques.

2.10 CENTRIFUGAL FAN ARRAYS

- A. Sourcing Option: In lieu of sourcing fan array assemblies from a specialty fan manufacturer, air-handling unit manufacturer has option to furnish in-house fan array assemblies that achieve equal or better performance while complying with other requirements indicated.

B. Operating Performance:

1. Air-handling unit manufacturer shall account for, and include in, submitted fan selections any static pressure drops associated with unit, and system effect due to fan operating in the air-handling unit.
2. Add additional static pressure to fan scheduled total static pressure.
3. If fan motor horsepower is increased, notify Architect.
4. Fans shall have sharply rising pressure characteristics at operating point and stable in operation. Fan horsepower characteristics shall be self-limiting and non-loading.
5. Fan speed, brake horsepower, and sound power levels indicated are maximum acceptable.
6. Scheduled motor horsepower, airflow rate, and static pressure are minimum acceptable. Motor horsepower shall be capable of handling maximum horsepower of fan at scheduled speed.
7. At a minimum, fans shall have AMCA class indicated on Drawings.

- a. Fan operating limits shall be in accordance with AMCA 99 for AMCA class indicated.
 - b. If AMCA class is not indicated, use AMCA 99 as basis for determining AMCA class.
 - c. AMCA class selected shall be capable of accommodating a plus 10 percent increase to fan static pressure indicated on Drawings.
8. Motor starting torque shall exceed fan speed-torque requirements.
9. Airflow Profile:
 - a. Fan arrangement within fan array shall produce a uniform airflow and velocity profile across air-handling unit air tunnel when measured 12 inches upstream of fan inlet and 48 inches downstream of fan inlet.
- C. Vibration Balance:
 1. Each fan/motor assembly shall be factory balanced to AMCA 204, BV-5, Balance Quality Grade G1.0 or better through entire operating speed range from minimum speed to maximum speed. If minimum speed is not indicated on Drawings, assume minimum speed to be 20 percent of design speed.
 2. Identify and record each speed and speed range within the fan operating range that could cause potential vibration problems.
 3. Submit test reports as an informational submittal for Project record.
- D. Vibration Isolation: Install vibration isolation on each fan/motor assembly in the fan array, except vibration isolation may be omitted on fans/motor assemblies balanced to AMCA 204, BV-5, with a maximum residual imbalance of 0.22-in./s peak, filter in.
- E. Operation and Service Requirements:
 1. Remaining fans in array shall continue to operate with one or multiple failed fans.
 2. Each fan/motor assembly of fan array shall be capable of lock-out/tag-out procedure without interrupting operation of other fans in the array.
 3. Each fan/motor assembly shall be controlled through a variable-frequency controller, except for fans with electronically commutated (EC) motors having integral motor controls.
 - a. Include a dedicated variable-frequency controller for each fan/motor assembly in the fan array.
 - b. If fan array is served from a single variable-frequency controller, include a redundant variable-frequency controller with automatic switchover in event of primary variable-frequency controller failure.

4. A single mechanical, electrical, and control device failure shall not result in a fan array available capacity of less than 33 percent of air-handling unit total scheduled airflow capacity.
 5. Fan wheel/motor assembly shall pass through the air-handling unit access door servicing fans. Entire individual fan assembly shall pass through the door to the room where air-handling unit is located.
 6. Design and incorporate features to permit safe, rapid, and economical maintenance.
- F. Airflow Measurement, Local Indication, and Remote Monitoring:
1. Each fan within fan array shall include airflow measurement indication in cfm.
 2. Include airflow totalization of all operating fans in fan array.
 3. Airflow measurement instrumentation shall not restrict or deflect air travel through fan and shall not impact fan air and sound performance.
 4. Include digital display of individual fan airflow and total fan array airflow on face of fan control panel.
 5. Include a 4- to 20-mA output signal for remote monitoring of total fan array airflow.
- G. Fan Array Local Control:
1. Include fan control panel with operator interface to control fan array locally through the fan control panel and to switch to control of fan array through a remote-control source.
 2. Local control shall include on/off operation and speed adjustment for entire fan array and each individual fan/motor in fan array.
- H. Fan Array Remote Control:
1. Include fan control panel with control interface for remote control.
 2. Fan array on/off operation shall be remotely controlled through a single hardwired digital output signal.
 3. Fan array speed shall be remotely controlled through a single hardwired analog (4- to 20-mA) output signal.
- I. Fan Base, Stackable Fan Units:
1. Mount fan/motor on galvanized-steel or powder-coated steel base.
 2. Include base and vibration isolators in accordance with requirements indicated.
 3. Weld structural members to form a rigid base.

4. Size and design the base construction to withstand the rigors of shipping and rigging.
 5. Include the base with lifting lugs or holes.
- J. Fan Frame:
1. Construct frame of aluminum or powder-coated steel.
 2. Reinforce and brace frame to prevent excessive deflection and pulsation.
 3. Include stiffeners to form a rigid frame that is free of structural resonance and vibration.
- K. Fan Panel:
1. Construct fan panel of aluminum or powder-coated steel.
 2. Reinforce and brace fan panel to prevent excessive deflection and pulsation.
 3. Include stiffeners to form a rigid panel that is free of structural resonance and vibration.
- L. Fan Inlet Cone:
1. Include a precision-spun or die-formed, matched inlet and wheel cone to ensure streamlined airflow into the wheel and full loading of fan blades.
 2. Inlet cone shall be a smooth hyperbolic shape.
 3. Inlet cone shall be a single piece, constructed of aluminum or powder-coated steel.
 4. Fasten inlet cone to fan panel using bolts, nuts, and washers to provide a positive and secure attachment that can be field removable.
- M. Fan Wheel:
1. Fan blades shall be a true hollow airfoil shape, welded to backplate and wheel cone.
 2. Construct blades of aluminum, reinforced for AMCA fan class.
 3. Design blades to provide smooth airflow over all surfaces of blade.
 4. Construct fan hubs of aluminum with integral bracing for extra strength and stiffness.
 - a. Castings shall be sound and free of shrink holes, blow holes, cracks, scale, blisters, or other similar injurious defects.
 - b. Clean surfaces of castings by blasting, pickling, or any other standard method.
 - c. Mold-parting fins and remains of gates and risers shall be chipped, filed, and ground flush.

- d. Design hubs to maintain a high resistance to fatigue and low relative wheel imbalance.
 - 5. Hubs shall be keyed and set screwed to motor shaft for positive attachment.
 - 6. Construct wheel backplates of aluminum.
 - 7. Select entire rotating assembly so first critical speed is at least 30 percent greater than fan design speed and at least 20 percent greater than maximum speed in AMCA fan class.
- N. Fan Drive:
- 1. Direct drive, arrangement 4 in accordance with AMCA 99.
 - 2. Adjust wheel width and diameter to match motor speed while providing performance scheduled.
 - 3. Fasten fan wheel directly to motor shaft using a key in motor shaft and setscrew.
 - 4. Construct motor base and pedestal supports of galvanized steel or powder-coated steel.
- O. Fan Motors: See "Fan Motors" Article for ac motors.
- P. Fan Motors, Electronically Commutated (EC):
- 1. Description: EC, variable-speed, dc, programmable brushless motor.
 - 2. Features:
 - a. Integral controller/inverter operates wound stator and senses rotor position to electronically commutate the stator.
 - b. Controller shall control motor speed either through manual adjustment locally at fan array control panel or through a remote 0- to 10-V-dc control signal.
 - c. Motor Mounting: Coordinate with driven equipment; suitable for mounting with motor shaft in either horizontal or vertical position.
 - 3. Performance:
 - a. Altitude: Suitable for operation at site altitude.
 - b. Electrical Characteristics: Suitable for operation with field power source. Coordinate with electrical Installer.
 - c. Energy Efficiency: Complying with governing energy codes; 80 percent or higher maintained throughout entire operating range.
 - d. Power Factor: 0.9 or higher at full load.

- e. Service Factor: 1.0 or higher.
- f. Speed Control: Variable, zero to 100 percent.
 - 1) Synchronous speed rotation with no slip losses.
 - 2) Gradual ramp-up to set point upon receiving a start signal.
 - 3) Soft speed change ramps.
 - 4) Able to overcome reverse rotation without impact.
 - 5) Control airflow within 5 percent of set point regardless of static pressure.
- g. Temperature: Suitable for operation in ambient temperature range encountered.
- h. Thermal Protection:
 - 1) Automatically breaks electrical power to motor when temperature exceeds a safe value.
 - 2) Automatically resets and restores power when temperature returns to normal range.
- 4. Bearings: Sealed and permanently lubricated ball bearings.
- 5. Enclosure: ODP or TEFC.
- 6. Insulation: Class B or Class F.
- 7. Rotor: Permanent magnet with near zero rotor losses that operates independent of motor current.
- 8. Materials and Construction:
 - a. Enclosure and Frame: Aluminum, painted steel, or stainless steel.
 - b. End Brackets: Cast aluminum.
 - c. Shaft: Steel or stainless steel.
 - d. Motor Leads: Pin or screw terminals.
 - e. Nameplates: Manufacturer's standard.
 - f. Paint: Manufacturer's standard.

Q. Fan Enclosure:

- 1. Include each fan in fan array with integral single-wall enclosure constructed of solid aluminum or powder-coated steel sheet.

2. Enclosure shall not increase fan array length beyond size indicated on Drawings.
3. Enclosure shall not add static pressure loss.
4. Enclosure shall provide a physical separation between operating adjacent fans to prevent negative performance.

R. Backdraft Damper:

1. Include each fan in the fan array with a backdraft damper at the fan inlet or outlet to prevent air circulation through a fan that is not operating.
2. Open backdraft damper when fan is operating and close when fan is not operating.
3. Design backdraft damper assembly to operate with little to no static pressure loss with fan operating throughout entire operating range from design to minimum airflow.
 - a. Add damper pressure loss shall to fan scheduled total static pressure.
 - b. If pressure loss requires a change field electrical power, air-handling unit manufacturer shall be responsible for associated cost of change.
4. Fasten backdraft damper assembly to fan panel or enclosure using hardware designed for easy removal by maintenance personnel.
5. Dampers shall not create measurable additional noise above the sound level of fan.
6. Dampers shall not vibrate or rattle.
7. Construct dampers of extruded aluminum, stainless steel, or powder-coated steel.

S. Blank-off Panels:

1. Include 10 percent of blank-off panel(s) with each air-handling unit fan array for use by operators in the field to prevent air circulation through any of the fans in fan array that are not operating.
2. Design blank-off panels for attachment to fan panels using easily removable and reusable hardware.
3. Construct blank-offs of aluminum, stainless steel, or powder-coated steel sheets, not less than 0.07 inch thick.
4. Mount fan blank-off panels in the fan inlet access section for convenient operator access and use in the future.

T. Hardware: Hex-head, high-strength carbon steel with corrosion-resistant coating or 300 series stainless steel.

U. Nameplates:

1. Construct nameplates and rotation arrows of aluminum or 300 series stainless steel.
2. Securely fasten nameplate and rotation arrow to fan housing using pins or sheet metal screws.
3. Locate nameplates in a highly visible location on motor side of fan.
4. Engrave or label the following information on nameplate:
 - a. Manufacturer, address, phone number, and website address.
 - b. Manufacturer model number.
 - c. Serial number.
 - d. Manufacturing date.
 - e. Fan size.
 - f. Fan schedule equipment designation (may be listed on a separate nameplate if there is insufficient space).
 - g. Design airflow.
 - h. Design static pressure.
 - i. Design fan speed.
 - j. AMCA fan class.

V. Air-Handling Unit Factory Assembly:

1. Internal Access: Include each fan with internal access from downstream and upstream sides as indicated on Drawings.
2. Removal and Replacement: Each fan wheel and motor shall be independently removable and replaceable through a removable access door installed in air-handling unit casing.
3. Stackable Fan Arrays: Construct frame work from aluminum, galvanized steel, or stainless steel.
4. Panel-Mounted Fan Array Supports:
 - a. Construct a freestanding and self-supporting structural framework to support each fan individually from and independent of adjacent fans.
 - b. Construct frame work from aluminum, galvanized steel, or stainless steel.

2.11 FAN MOTORS

- A. Source Limitations: Obtain motors from single source from single manufacturer.
- B. Standard: Comply with NEMA MG 1 unless more stringent requirements are indicated.
- C. Description: NEMA MG 1, Design B, as required to comply with capacity and torque characteristics; medium-induction motor.
 - 1. Performance:
 - a. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.
 - b. Efficiency: NEMA Premium Efficiency rating complying with NEMA MG 1.
 - c. Motor Horsepower: Minimum size as indicated on Drawings. Motor shall operate fan under all conditions indicated without exceeding motor nameplate and without use of motor service factor.
 - d. Inverter-Duty Rating: Comply with minimum requirements of Class F or Class H insulation, suitable for "inverter-duty" or "drive-duty" applications in accordance with NEMA MG 1. Motor operation through a variable-frequency controller shall not adversely affect the motor performance, operation, useful life, and warranty.
 - e. Service Factor: 1.15.
 - f. Temperature Rise: Match insulation rating.
- D. Enclosure Type: ODP or TEFC.
- E. Shaft Grounding System:
 - 1. Shaft grounding system to protect bearings from induced voltage.
 - 2. Shaft grounding system shall have low drag (less than 0.05 percent of motor horsepower), and shall operate for a minimum of three years without periodic maintenance or adjustments.
 - 3. Mounting: External or internal to motor enclosure.
- F. Frame:
 - 1. Frames with integrally cast feet unless other requirements of driven equipment require a different arrangement.
 - 2. Frame, front and back end brackets, and front and back end bearing intercaps constructed of cast iron, ASTM A48/A48M, Class 25 or better.
- G. Rotor:

1. Fabricate rotor frame from die-cast aluminum, copper, or associated alloys.
2. Key rotors to motor shaft.
3. Rotating assembly shall be dynamically balanced to within limits defined in NEMA MG 1.
4. Motors shall have the entire rotating assembly between bearing inner caps coated with a corrosion-resistant coating.

H. Stator:

1. Copper windings shall be spike resistant to withstand 1600 peak V.
2. Entire wound and insulated stator coated with a coating to protect against moisture and corrosion.

I. Shaft:

1. Solid shaft fabricated of carbon steel, accurately turned, ground and polished, and inspected for accuracy.
2. End of shaft with drilled hole for use in field measurements.

J. Bearings:

1. Grease-lubricated ball or roller bearings.
2. ABMA 11 L-10 motor bearing life of 100,000 hours.
3. Bearing Lubrication:
 - a. Factory lubricate motor bearings using a premium moisture-resistant polyurea thickened grease with rust inhibitors suitable for extreme operating temperatures encountered.
 - b. Coordinate special requirements that may impact lubrication and include appropriate lubrication.
4. Grease Fittings:
 - a. Equip each bearing housing with an easily accessible grease inlet.
 - b. Fit grease inlets with a grease fitting and protective fitting cap.
 - c. Equip inlets with an automatic grease relief fitting to prevent excessive greasing.
 - d. Equip each bearing housing with grease drain and threaded plug.

K. Conduit Box:

1. Material same as frame.
 2. For motor frames 365T and below, furnish conduit boxes sized with internal volumes in accordance with NEMA MG 1.
 3. For motor frames larger than 365T, furnish conduit boxes one size larger than NEMA MG 1.
 4. Coordinate the location and mounting of conduit box with driven equipment manufacturer.
 5. Factory mount conduit box on motor.
- L. Grounding: NRTL-listed clamp-type grounding lug mounted in conduit box.
- M. Motor Leads:
1. Non-wicking type, Class F temperature rating or better and permanently numbered over entire length for identification.
 2. Lead terminals shall be manufacturer's standard.
- N. Condensate Drains:
1. Motor with drain holes at the lowest point for drainage of condensate.
 2. Each drain hole with a threaded removable plug.
- O. TEFC Motor Fans: Corrosion-resistant construction, non-sparking, metallic or non-metallic, bi-directional, and keyed to shaft.
1. Motor Fan Cover: Steel.
- P. Hardware: Hex-head, high-strength, zinc-plated carbon steel or stainless steel.
- Q. Lifting Eyebolts: Eyebolt threaded into frame receptacle and design to prevent moisture and other foreign material from entering motor cavity when eyebolt is removed.
- R. Nameplates:
1. Construct nameplates of aluminum or stainless steel and attach to motor frame with aluminum, stainless steel, or brass drive pins.
 2. Engrave or stamp data on the nameplate.
 3. At a minimum, include nameplate data in accordance with NEMA MG 1.
- S. Paint: Successfully pass 500-hour salt spray test for corrosion in accordance with ASTM B117.

2.12 VIBRATION ISOLATION

A. General:

1. Provide fans inside air-handling units with base and vibration isolation indicated on Drawings.

B. Inertia Bases:

1. Description: Reinforced structural base designed for concrete infill with integral bolting provisions for fan mounting.
2. Design and Performance:
 - a. Weight of inertia base including concrete infill a minimum of 1.5 times the operating weight of fan.
 - b. Base thickness not less than 1/12 of longest span.
 - c. Minimum base thickness is as follows:
 - 1) Up to 15 HP: 6 inches.
 - 2) 20 to 50 HP: 8 inches.
 - 3) 60 to 75 HP: 10 inches.
 - 4) 100 HP and Larger: 12 inches (300 mm)
3. Construction:
 - a. Base Materials: structural stainless steel, ASTM A276/A276M, Type 304L or structural stainless steel, ASTM A276/A276M, Type 316L.
 - a. Base Structural Members:
 - 1) Perimeter Members: Channel I or W beam shapes or tube.
 - 2) Intermediate Members (Spanning Full-Width Base): Channel or I or W beam shapes or tube.
 - 3) Cross Members (Spanning Intermediate Members): channel or tube.
 - b. Reinforcing Bars: Carbon steel, ASTM A615/A615M, sized for a maximum stress of 20,000 psi (138 000 kPa) when subjected to both static and dynamic loads, and welded in place.
 - c. Floor: Design inertia base with solid floor in bottom for concrete placement after base installation. Seal to prevent leakage or seepage.
 - 1) Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating, minimum (nominal) 18 gauge thick.

- 2) Stainless Steel Solid Sheet: ASTM A240/A240M or ASTM A480/A480M; Type 304L; No. 2D finish; minimum (nominal) 18 gauge thick.
 - d. Isolator Brackets: Gusseted, height-saving brackets.
 - e. Welding Filler Metals: Comply with AWS welding codes for welding materials appropriate for thickness and chemical analysis of material being welded.
 - 4. Air-Handling Unit Factory Assembly: Install fans with inertia bases where indicated on Drawings.
 - a. Coordinate placement of inertia bases with design of air-handling unit structural base. Make provisions for attachment and support.
 - b. Coordinate inertia base mounting provisions with spring isolators.
- C. Spring Isolators:
- 1. Performance:
 - a. Deflection: Minimum deflection indicated on Drawings. Use a greater deflection if required to maintain an isolator efficiency of at least 98 percent under all operating conditions encountered. Calculate isolator efficiency using actual support conditions considering the rigidity of structure.
 - b. Laterally stable freestanding open-spring mounting.
 - c. Spring diameter not less than 0.8 of compressed spring height at rated load and in the installed and operating condition.
 - d. Reserve travel to solid shall be equal to a minimum of 50 percent of rated deflection and in no case less than 25 percent of rated deflection in an installed and operating condition.
 - e. Ratio of horizontal stiffness to vertical stiffness equal to approximately one.
 - f. Design and install so that ends of springs remain parallel.
 - g. Select springs that are non-resonant with equipment related frequencies and natural frequencies of support structure.
 - h. Springs shall not take a permanent set when compressed to coil bind.
 - 2. Construction:
 - a. Coat springs with PVC or neoprene. Color-code springs to allow positive identification after installation.
 - b. Construct baseplates, spring retainers, and other components of aluminum galvanized carbon steel or stainless steel. Etch and paint aluminum components.

- c. Use nuts, bolts, and washers and other associated hardware constructed of zinc-electroplated carbon steel or stainless steel.
- d. Isolators with integral leveling bolts.
- e. Baseplates with holes and isolation grommets for bolting.
- f. Bond nominal 1/4-inch-thick, neoprene friction pad to baseplate.

D. Thrust Restraints:

- 1. In sets of two or more, thrust restraints shall consist of springs in series with neoprene isolators.
- 2. Coordinate and select deflection of thrust restrains with equipment being restrained.
- 3. Thrust restraints complete with rods and adjustment nuts, plus angle brackets and backing plates for attachment to substrate and equipment being restrained.

E. Elastomeric Grommets:

- 1. Elastomeric grommets shall be a combination of neoprene washer and bushing.
- 2. Elastomer shall be 56-durometer maximum.
- 3. Grommets formed to prevent bolts from directly contacting the secured item.

F. Flexible Connections:

- 1. Construct flexible connection galvanized-steel edges firmly attached to waterproof and fire-retardant fabric.
- 2. Fabric shall be 6 inches wide or more.
- 3. Suitable for operation in extreme temperatures encountered.
- 4. NRTL listed for application and complying with NFPA 90A.

G. Air-Handling Unit Factory Assembly:

- 1. Use precompression -type height-saving brackets with isolators having 2-1/2 inch deflection or greater, to limit exposed bolt length.
- 2. Install spring isolators plumb and adjust isolators that are not plumb under operating conditions to make plumb.
- 3. Adjust isolators to prevent stress transfer to equipment.
- 4. Verify that installed isolators and mounting systems permit equipment motion in all directions.

5. Restraint fans with isolated thrust resistors to limit displacement to 1/4 inch. Design for the maximum lateral thrust the fan can develop.
6. Adjust or include additional resilient restraints to flexibly limit fan lateral motion to 1/4 inch during startup and operation of equipment.
7. Anchor restraints to fixed supports having a stiffness greater than the thrust encountered.
8. Include at least 2-inch operating clearance between fan bases and walking surface of air-handling unit floor. Before startup, clean out foreign matter between bases and equipment to prevent short circuit.
9. Flexible Connections:
 - a. Install flexible connections at connections to fans.
 - b. Install flexible connections in accordance with SMACNA standards and manufacturer's written instructions.
 - c. Make fabric joints on the flat run, not the corners, with overlap to provide an area sufficient to make a positive seal.
 - d. Apply adhesive between fabric layers.
 - e. Attach connections using screws or bolts.
 - f. Reinforce fabric if required to keep fabric from collapsing and impacting airflow into fan.

2.13 HYDRONIC COILS

- A. Sourcing Option: In lieu of sourcing hydronic coils from a specialty coil manufacturer, air-handling unit manufacturer has option to furnish in-house hydronic coils that achieve equal or better performance while complying with other requirements indicated.
- B. General: Provide air-handling units with hydronic coils where indicated on Drawings.
- C. Description: Plate fin coils constructed of staggered tubes mechanically expanded into continuous collars that are die formed into plate fins.
- D. Design and Performance:
 1. Capacities, face area, and number of rows indicated on Drawings are minimum acceptable.
 2. Air pressure drop, water pressure drop, fin spacing, and face velocity indicated on Drawings are the maximum acceptable.

3. Coils shall be counterflow design, air to fluid. Fluid supply shall enter air leaving side of coil and exit air entering side.
 4. Design coils to be drainable.
 - a. Coils shall have all circuits drainable when coils are installed in horizontal position and level.
 - b. Coil supply and return header shall be furnished with a drain connection at lowest point on header.
 5. Design coils to be self-venting.
 - a. Supply connection near bottom of supply header.
 - b. Return connection near top of return header.
 - c. Furnish coil return and supply header with a vent connection at highest point on header.
 6. Coils supply and return piping connections on same end of coil.
 7. Coils shall be rated for system operating pressures and temperatures encountered by installation, but not less than 200 psig.
 8. Coil selection criteria, unless otherwise indicated on Drawings, are as follows:
 - a. Face Velocity: Maximum of 500 fpm.
 - b. Fluid Tube Velocity (at Design Flow Rate):
 - 1) Maximum: 6 fps.
 - 2) Minimum: 3 fps.
 - c. Fluid Header Velocity: Maximum of 6 fps.
 - d. Fin Height: Maximum of 48 inches.
 - e. Fin Spacing: Maximum of 12 fins per inch.
 9. Cooling coils shall have no moisture carryover at design conditions. Install moisture eliminators on discharge face of coil if it is necessary to eliminate moisture carryover.
- E. Casing and Tube Sheets:
1. Depth: Extend coil casing and tube sheets a minimum of 1/2 inch beyond face of fins on both entering and leaving side.
 2. Casing and Tube Sheet Materials:

- a. Cooling Coils: Stainless steel, ASTM A240/A240M or ASTM A480/A480M, Type 304L or Type 316L, No. 2D finish.
 - b. Heating Coils:
 - 1) Stainless steel, ASTM A240/A240M or ASTM A480/A480M, Type 304L or Type 316L, No. 2D finish.
 - 2) Galvanized steel, ASTM A653/A653M, G90 coating.
 3. Top and Bottom Casings:
 - a. Flange face minimum of 1-1/2 inches; double flange edge for rigidity and ease of removal with secondary flange face minimum of 1/2 inch.
 - b. Thickness:
 - 1) Coils with Fin Length of up to 72 Inches: Minimum of 16 gauge thick.
 - 2) Coils with Fin Length Exceeding 72 Inches: Minimum of 16 gauge thick.
 4. End Tube Sheets:
 - a. Tube sheet holes rolled to prevent chaffing of tubes during thermal expansion and contraction.
 - b. Flange face minimum of 1-1/2 inches.
 - c. Thickness: Minimum of 16 gauge thick.
 5. Intermediate Tube Sheets:
 - a. Tube sheet holes rolled to prevent chaffing of tubes during thermal expansion and contraction.
 - b. Space intermediate tube sheets a maximum of 48 inches o.c. and locate to provide equal spacing between tube sheet across coil tube length.
 - c. Flange face minimum of 1/2 inch.
 - d. Thickness: Minimum of 16 gauge thick.
 6. Holes: Include number, size, and location of holes in casing and end tube sheets required for coil installation.
- F. Fins:
1. Materials:
 - a. Aluminum: 0.0060 inch 0.0095 inch thick.

2. Collars: Full collars for accurate fin spacing and maximum tube contact while leaving no surface of tube exposed.
3. Fin Configuration: Flat face or enhanced ripple fins as required by performance.

G. Headers:

1. Construct header of seamless copper, ASTM B75/B75M drawn temper of diameter and wall thickness based on coil size, flow rate, design pressure, design temperature, and circuiting.
2. Tube-to Header Connections: Tube-to-header holes shall intrude inward so landed surface area is three times the core tube thickness, to provide enhanced header to tube joint integrity. Tubes shall evenly extend within the ID of the header no more than 0.12 inch.
3. Header Top and Bottom Caps: End caps shall be die-formed and installed on the ID of header such that the landed surface area is three times the header wall thickness.
4. Drains: Include low point of supply and return header with a NPS 1/2 Insert pipe size drain connection. Extend copper or red brass pipe through air-handling unit casing and terminate end with male national pipe threads (MNPT). Pipe shall be threaded on both ends to facilitate easy field removal and replacement.
5. Vents: Include high point of supply and return header with a NPS 1/2 vent connection. Extend copper or red brass pipe through air-handling unit casing and terminate end with MNPT. Pipe shall be threaded on both ends to facilitate easy field removal and replacement.
6. Supply and Return Connections:
 - a. Terminate ends with MNPT.
 - b. Connections to header shall be either copper tube with brazed ASME B16.18 threaded male adapters or red brass pipe with machine-threaded MNPT connections. Pipe shall extend through air-handling unit casing and be threaded on both ends to facilitate easy field removal and replacement.
 - c. Connections NPS 2-1/2 and larger shall have a bronze ASME 16.24 threaded flanges attached to threaded connections to provide for a flanged field connection. Select flange class, Class 150 or Class 300, for system pressure and temperature encountered.
7. Protect openings of supply, return, vent, and drain connections with a threaded cap to prevent entry of dirt into the coil.

H. Tubes:

1. Material: Copper, ASTM B75/B75M annealed temper or ASTM B280 drawn temper;.

2. Tube Nominal Diameter: 1/2 or 5/8 inch before expanding, selected to provide performance indicated.
3. Tube Nominal Wall Thickness: As required by performance, minimum of 0.020 inch 0.035 inch thick.
- I. Tube Return Bends: 180-degree bends brazed to tubes; material, wall thickness, and nominal diameter to match tubes.
 1. Tube Return Bend Nominal Wall Thickness: As required by performance, minimum of 0.020 inch 0.035 inch thick.
- J. Brazing: High-temperature brazing alloy with not less than 5 percent silver when brazing like non-ferrous materials together and more than 30 percent silver when brazing ferrous to non-ferrous materials.
- K. Hardware: Use hex-head bolts, nuts, and washers constructed of Type 304 or Type 316 stainless steel.
- L. Nameplate: Aluminum or stainless steel nameplate with brass or stainless steel chain for each coil, with the following data engraved or embossed:
 1. Manufacturer name, address, telephone number, and website address.
 2. Manufacturer model number.
 3. Serial number.
 4. Manufacturing date.
 5. Coil identification (indicated on Drawings).
 6. Coil fin length.
 7. Coil fin height.
 8. Coil weight with fluid/without fluid.
 9. Coil casing material and thickness.
 10. Coil fin material and thickness.
 11. Coil tube material and thickness.
 12. Coil header material and thickness.
- M. Cleaning: Residual manufacturing oils and solid contaminants shall be removed internally and externally by completely submersing the coil in an environmentally acceptable degreasing solution that is chemically compatible with the coil material.

N. Air-Handling Unit Factory Assembly:

1. Coil Connections: Extend each coil connection through casing access panel and terminate connections, approximately 4 inches beyond exterior face of access panel, and seal each penetration as indicated. Casing access panels shall be removed and reinstalled with coils installed inside air-handling units.
2. Internal Access: Include each coil with internal access from downstream and upstream sides as indicated on Drawings.
3. Removal and Replacement: Each coil shall be independently removable and replaceable through a removable access panel installed in air-handling unit casing.
4. Supports for Coils:
 - a. Construct a freestanding and self-supporting structural framework to support each coil individually from and independent of adjacent coils.
 - b. Construct framework for cooling coils, from aluminum or stainless steel structural shapes.
 - c. Construct frame work for heating coils from aluminum, galvanized steel, or stainless steel structural shapes.

2.14 HEATING COILS WITH INTEGRAL FACE-AND-BYPASS DAMPERS

- A. Source Limitations: Obtain coils from single source from single manufacturer.
- B. General: Provide air-handling units with heating coils with integral face-and-bypass dampers where indicated on Drawings.
- C. Description: Horizontal or vertical tube arrangement as indicated on Drawings with integral face-and-bypass dampers and controls installed to control modulating dampers to achieve discharge air temperature set point.
 1. Each coil consisting of multiple finned heating elements, each with bypasses and interlocking dampers controlled by electric actuators and a discharge airstream thermostat.
- D. Performance:
 1. Each coil able to maintain constant discharge air temperature regardless of variations in entering-air temperature with constant water flow through coil.
 2. Portioning of air across and around the heating element shall result in a uniform temperature within 5 deg F of average temperature when measured anywhere across a vertical plane located 24 inches downstream of leaving face of coil.

- E. Casing: Galvanized steel or Type 304 stainless steel, minimum of 16 gauge thick. Standard casing shall be extended if required air-handling unit manufacturer to accommodate installation arrangement inside of the air-handling unit.
- F. Fins: Rectangular shape, constructed of 0.010-inch-thick aluminum with spacing not closer than 12 fins per inch
- G. Headers: copper, of thickness selected by manufacturer for flow, pressure, and temperature encountered; drain connections at low points, vent connections at high points, and supply and return connections located on discharge face of coil.
 - 1. Insulation: Insulate headers with mineral-fiber insulation covered by a metal jacket.
 - 2. Supply and Return Connections:
 - a. Terminate ends with MNPT.
 - b. Connections NPS 2-1/2 and larger shall have thread-on flanges. Select flange class, Class 150 or Class 300, for system pressure and temperature encountered.
- H. Tubes:
 - 1. Materials: Copper.
 - 2. Nominal Diameter: 5/8 inch.
 - 3. Nominal Tube Wall Thickness: As required by performance, minimum of 0.035 inch thick.
- I. Dampers: Clamshell design arranged to modulate airflow across or around individual heating elements. Constructed of galvanized steel or Type 304 stainless steel, minimum of 16 gauge thick.
- J. Damper Actuators: Face or side mounted; electric motor for proportional control, failing in last position.
- K. Brazing: High-temperature brazing alloy with not less than 5 percent silver when brazing like non-ferrous materials together and more than 30 percent silver when brazing ferrous to non-ferrous materials.
- L. Coating: Where indicated on Drawings, coat coil casings and damper assemblies with air-dried alkyd enamel corrosion-resistant coating.
- M. Hardware: Use hex-head bolts, nuts, and washers constructed of zinc-plated carbon steel or Type 304 stainless steel.
- N. Nameplate: Aluminum or stainless steel nameplate with brass or stainless steel chain for each coil, with the following data engraved or embossed:
 - 1. Manufacturer name, address, telephone number, and website address.

2. Manufacturer model number.
3. Serial number.
4. Manufacturing date.

O. Air-Handling Unit Factory Assembly:

1. Coil Connections: Extend each coil connection through casing access panel and terminate connections, approximately 4 inches beyond exterior face of the access panel as seal each penetration as indicated. Casing access panels shall be removed and reinstalled with coils installed inside air-handling units.
2. Internal Access: Include each coil with internal access from downstream and upstream sides as indicated on Drawings.
3. Removal and Replacement: Each coil shall be independently removable and replaceable through a removable access panel installed in air-handling unit casing.
4. Supports for Coils:
 - a. Construct a freestanding and self-supporting structural framework to support each coil individually from and independent of adjacent coils.
 - b. Construct frame work from aluminum, galvanized steel, or stainless steel structural shapes.

2.15 DRAIN PANS

A. General:

1. Include a drain pan for each cooling coil and at other locations indicated.
2. Continuously weld drain pan seams, joints, and mitered corners to make the assembled drain pan watertight.
3. Drain pans shall be located under the entire coil and provide full coil coverage including coil return bends and headers.
4. Slope drain pans in multiple directions toward low point drain connection at a uniform slope of at least 2 percent from high point to low point.
5. Include stainless steel blank-offs to prevent air from bypassing around coil.

B. Bottom Drain Pans:

1. Mounting Location, Recessed in Floor: Air-handling unit manufacturer has option to recess bottom drain pan into the floor or install drain pan above air-handling unit floor walking surface.

2. Grating: Install removable stainless steel grating on top of drain pan.
3. Double-Wall Construction: Double-wall sheet with space between walls filled with 1-inch insulation.
4. Material: Type 304L stainless steel ASTM A240/A240M or ASTM A480/A480M, a minimum of 16 gauge thick.
5. Minimum Depth: 1.5 inches.
6. Extend drain pan beyond air entering face of coil casing at least 3 inches.
7. Extend drain pan beyond air leaving face of coil casing at least 12 inches.
 - a. Where moisture eliminators are required to prevent moisture carryover, extend drain pan beyond leaving face of moisture eliminator in lieu of the leaving face of coil.
8. Drain Pan Connection:
 - a. Stainless steel threaded half-coupling welded to lowest point of drain pan.
 - b. Location: Both ends.
 - c. Minimum Nominal Connection Size: NPS 1.5.
9. Drain Pipe:
 - a. Air-handling unit manufacturer to connect full size drain pipe to each drain pan connection. Option to use one of following pipe materials:
 - 1) Copper tube with threaded male adapter, brazed or soldered to ends.
 - 1) Aluminum pipe with threaded MNPT ends.
 - 2) Stainless steel pipe with threaded MNPT ends.
 - b. Extend drain pipe and terminate 3 inches beyond exterior face of casing.

2.16 PLEATED PANEL FILTERS

- A. Source Limitations: Obtain filters from single source from single manufacturer.
- B. Description: Factory-fabricated, self-supported, extended-surface, pleated, panel-type, disposable air filters.
- C. Performance:
 1. Filtration Efficiency, ASHRAE 52.2 MERV Rating: 8.

2. Energy Cost Index: Five star rating.
 3. Initial Air Pressure Drop: With face velocity of 500 fpm, clean filter pressure drop shall not exceed the following:
 - a. MERV 8 and MERV 8A:
 - 1) Depth 2 Inches: 0.31 inch wg.
 4. Manufacturer-Recommended Final Air Pressure Drop: 1.0 inch wg.
 5. Pressure Differential without Failure: 2 inches wg.
 6. Temperature Rating: 200 deg F.
- D. Certification:
1. AHRI: Tolerances in accordance with AHRI 850 (I-P) and AHRI 851 (SI).
 2. ASHRAE: Tested and rated in accordance with ASHRAE 52.2.
 3. UL: UL 900 listed.
- E. Size:
1. Nominal Filter Size:
 - a. Face: 20 by 24 inches.
 - b. Depth: 2 inches.
 2. Actual Filter Size: Suitable for installation in an industry-standard filter holding frame.
- F. Filter Media Surface Area: Each filter shall contain the following minimum media surface area for a filter with a nominal 24-by-24-inch face:
1. Depth 2 Inches: 17.3 sq. ft..
- G. Construction:
1. Media: Glass or Cotton and synthetic blend of fibers arranged in a series of pleats attached to and supported by a corrosion-resistant welded-wire grid.
 2. Filter Media Casing: High wet strength (28-point) beverage board that is bonded around the periphery to eliminate air bypass.
 - a. Diagonal support members across upstream and downstream filter face constructed of same material as casing shall ensure pleat spacing and stability.
 3. Adhesive: Fire-retardant bonding adhesive where bonding media to casing.

2.17 ASHRAE-RATED FILTER HOLDING FRAMES

A. Filter Holding Frames for ASHRAE-Rated Filters:

1. Fabricate filter holding frames with mitered corners and reinforce frame to maintain a durable, rugged, true square shape.
2. Construct frames of galvanized or stainless steel. Use stainless steel frames in applications exposed to corrosive airstreams.
3. For applications with pre-filter and final filters sharing the same filter holding frame, frames shall be suitable for supporting and holding both pre-filter and final filters in frame with both filters serviceable from upstream (entering air) side.
4. Frame Depth: At least 2.75 inches.
5. Gaskets: Continuous, suitable for same operating temperature as filters.
6. Filter Clips: Each filter holding frame with spring clip fasteners at each corner. Spring clips shall allow filters to be removed and replaced without use of tools.
7. Frames shall be industry-standard size to provide interchangeability of filters from other manufacturers.

B. Air-Handling Unit Factory Installation:

1. Air-handling unit manufacturer shall furnish filters and provide filter holding frames, retaining clips, and filter support structures.
2. Furnish filter quantity, size, type, and performance indicated on Drawings.
3. Install filter frames in a flat vertical position for horizontal airflow.
4. Install holding frames in accordance with manufacturer's written instructions and to prevent passage of unfiltered air. Include additional gaskets as necessary.
5. Secure individual holding frames together to build a multiple filter bank.
6. Construct aluminum galvanized-steel or stainless steel support structure to hold frames and filters.
 - a. Design support structure for maximum system operating pressures encountered equal to fan shutoff pressure.
 - b. Design and fabricate support structure to limit deflection across filter bank to 1/360 of the span when subjected to a 200-lb lateral force applied at any point on the filter holding frame assembly.

2.18 ABSOLUTE FILTERS

- A. Source Limitations: Obtain filters from single source from single manufacturer.
- B. Description: Factory-fabricated, disposable, packaged high-efficiency particulate air filters consisting of an anodized aluminum hold frame with media formed into mini-pleats and arranged in a V-shape pattern.
- C. Performance:
 - 1. Filtration Efficiency:
 - a. Rating indicated on Drawings.
 - b. IEST Rating at 0.3-micron Size: 99.99 percent.
 - 2. Energy Cost Index: Five star rating.
 - 3. Initial Air Pressure Drop: With face velocity of 500-fpm, clean filter pressure drop shall not exceed the following:
 - a. Gasket Seal Filters:
 - 1) 99.99 Percent Efficiency: 1.0 inch wg.
 - b. Gel Seal Filters:
 - 1) 99.99 Percent Efficiency: 0.9 inch wg.
 - 4. Manufacturer-Recommended Final Air Pressure Drop: 2.0 inches wg.
 - 5. Pressure Differential without Failure: 10 inches wg.
 - 6. Temperature Rating:
 - a. Gasket Seal: 175 deg F.
 - b. Gel Seal: 155 deg F.
- D. Certification:
 - 1. IEST: Tested and rated in accordance with IEST's "Recommended Practice for Testing HEPA Filters."
 - a. Comply with IEST-RP-CC001.6.
 - b. Comply with IEST-RP-CC034.
 - 2. UL: UL 900 listed.
- E. Size:

1. Nominal Face Size: 24 by 24 inches.
 2. Depth: 12 inches.
 3. Actual Filter Size: Suitable for installation in an industry-standard filter holding frame.
- F. Filter Media Surface Area: Each filter shall contain the following minimum media surface area for a filter with a nominal 24-by-24-inch face:
1. Gasket Seal:
 - a. 99.99 Percent Efficiency: 390 sq. ft..
 2. Gel Seal:
 - a. 99.99 Percent Efficiency: 401 sq. ft..
- G. Construction for Gasket Seal Filters:
1. Media: Microfine glass media formed into mini-pleats and arranged in a V-shape pattern.
 - a. Internal Separators: None.
 - b. Media to Filter Frame Seal Material: Polyurethane.
 - c. Faceguard Material: Aluminum.
 - d. Faceguard Location: upstream.
 2. Media-Holding Frame: Anodized aluminum enclosing frame with continuous seamless perimeter neoprene gasket.
 - a. Filter Frame to Mounting Frame Seal Location: Upstream.
 3. Adhesive: Fire-retardant bonding adhesive where bonding media to frame.
- H. Construction for Gel Seal Filters:
1. Media: Microfine glass media formed into mini-pleats and arranged in a V-shape pattern.
 - a. Internal Separators: None.
 - b. Media to Filter Frame Seal Material: Polyurethane.
 - c. Faceguard Material: Aluminum.
 - d. Faceguard Location: upstream and downstream.
 2. Media-Holding Frame: Anodized aluminum enclosing frame with gel seal track and elastic silicone gel sealant.

3. Adhesive: Fire-retardant bonding adhesive where bonding media to frame.

2.19 ABSOLUTE FILTER HOLDING FRAME ASSEMBLY

- A. Source Limitations: Obtain holding frame assembly from absolute filter manufacturer.
- B. Description: Holding frame assembly with access for upstream (front) or downstream (back) filter servicing as indicated, specifically designed for absolute filter banks.
 1. Gasket Seal: Positive-sealing device to ensure seal between each gasket filter to prevent bypass of unfiltered air. Filter latching mechanism to seat each filter firmly against holding frame surface.
 2. Gel Seal: Knife-edge to mate to each filter to prevent bypass of unfiltered air. Positive-locking mechanism for each filter to seat the knife edge into the gel during installation and to remove the filter from the knife edge during filter replacement.
- C. Construction:
 1. Each filter bank with a factory-assembled filter holding framework consisting of a framework superstructure, a base, bracing, and removable swing bolt assemblies designed to accommodate the scheduled sizes and configuration of absolute filters.
 2. Framework:
 - a. Nominal 4 inches, minimum 11-gauge-thick, galvanized-steel or stainless steel channels or tube.
 - b. Continuously weld members. After assembly, grind and polish welds to provide a smooth uniform sealing surface.
 3. Base:
 - a. Continuously weld the framework to a minimum 11-gauge-thick, galvanized-steel or stainless steel base.
 4. Filter Attachment:
 - a. Equip framework with four swing bolts for each filter.
 - b. Include each swing bolt with a bearing clamp and hex nut designed for applying a sufficiently uniform sealing pressure against the periphery of each filter.
 - c. Swing bolts shall be constructed of at least 5/16-inch galvanized or stainless steel.
 - d. Hex nuts shall be capable of being torqued to provide at least 50 percent gasket compression.
 - e. Swing bolt assembly shall provide individual sealing of filters.

5. Pre-Filter Frames:

- a. For filter banks with pre-filters attached on the air entering side of absolute filter, include an ASHRAE-rated filter holding frame.
- b. Pre-filter holding frames shall be held in place by swing bolts and allow for installation and removal of pre-filters without disturbing absolute filter seal.

D. Air-Handling Unit Factory Installation:

1. Air-handling unit manufacturer shall furnish filters and provide filter holding frames, retaining clips, and filter support structures.
2. Furnish filter quantity, size, type, and performance indicated on Drawings.
3. Install filter frames in a flat vertical position for horizontal airflow.
4. Install holding frames in accordance with manufacturer's written instructions and to prevent passage of unfiltered air. Include additional gaskets as necessary.
5. Construct aluminum, galvanized-steel, or stainless steel support structure to hold frames and filters.
 - a. Design support structure for maximum system operating pressures encountered equal to fan shutoff pressure.
 - b. Design and fabricate support structure to limit deflection across filter bank to 1/360 of the span when subjected to a 400-lb lateral force applied at any point on the filter holding frame assembly.

2.20 FILTER GAUGES

- A. Provide a gauge to indicate pressure differential between entering and leaving side of each filter bank. Panel filter bank separate from cartridge filter bank.
 1. Where multiple filters share a common frame, include a separate gauge for each filter bank.
 2. Include a metal spacer constructed of same material as filter frame for one of the filters installed in filter bank to accommodate pressure differential measure across both upstream and downstream filters.
- B. Gauge shall have a nominal 4-inch-diameter face.
- C. Select range of gauge to be approximately twice the dirty filter pressure drop.
- D. Provide each gauge with vent valves to allow for re-zeroing the gauge without removing tubing connections.

- E. Include static pressure sensors on entering and leaving side of each filter bank.
- F. Air-Handling Unit Factory Assembly:
 - 1. Mount each filter gauge on exterior surface of unit casing near associated filter sections.
 - 2. Mount center of gauges 60 inches above bottom of air-handling unit structural base.
 - 3. Connect static pressure sensors to filter gauges using aluminum or stainless steel tubing and compression type fittings.
 - 4. Support tubing at intervals not greater than 60 inches o.c.

2.21 AUTOMATIC DAMPERS

- A. General: Provide air-handling units with automatic dampers where indicated on Drawings.
 - 1. Unless otherwise indicated, use parallel-blade configuration for two-position control, for equipment isolation service, and when mixing two airstreams. For other applications, use opposed-blade configuration.
 - 2. Factory assemble multiple damper sections to provide a single damper assembly of size required by application.
 - 3. Damper actuator shall be factory installed by damper manufacturer as integral part of damper assembly. Coordinate actuator location and mounting requirements with damper manufacturer.
- B. Rectangular Dampers with Aluminum Blades:
 - 1. Source Limitations: Obtain dampers from single source from single manufacturer.
 - 2. Performance:
 - a. Leakage: AMCA 511, Class 1A. Leakage shall not exceed 3 cfm/sq. ft. against 1-inch wg differential static pressure.
 - b. Pressure Drop: 0.05 inch wg at 1500 fpm across a 24-by-24-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
 - c. Velocity: Up to 4000 fpm.
 - d. Temperature: Minus 40 to plus 185 deg F.
 - e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.
 - f. Damper shall have AMCA seal for both air leakage and air performance.

3. Construction:
 - a. Frame:
 - 1) Material: ASTM B211, Alloy 6063 T5 extruded-aluminum profiles, 0.07 inch thick.
 - 2) Hat-shaped channel with integral flange(s). Flange mating face shall be a minimum of 1 inch.
 - 3) Width not less than 5 inches.
 - b. Blades:
 - 1) Hollow, airfoil, extruded aluminum.
 - 2) Parallel- or opposed-blade configuration as required by application.
 - 3) Material: ASTM B211, Alloy 6063 T5 aluminum, 0.07 inch thick.
 - 4) Width not to exceed 6 inches.
 - 5) Length as required by close-off pressure, not to exceed 48 inches.
 - c. Seals:
 - 1) Blades: Replaceable, mechanically attached extruded silicone, vinyl, or plastic composite.
 - 2) Jambs: Stainless steel, compression type.
 - d. Axles: 0.5-inch-diameter plated or stainless steel, mechanically attached to blades.
 - e. Bearings:
 - 1) Molded synthetic or stainless steel sleeve mounted in frame.
 - 2) Where blade axles are installed in vertical position, include thrust bearings.
 - f. Linkage:
 - 1) Concealed in frame.
 - 2) Constructed of aluminum and plated or stainless steel.
 - 3) Hardware: Stainless steel.
4. Airflow Control: Where indicated, provide damper assembly with integral airflow measurement and control.

- a. Source Limitations: Obtain damper assembly from single source from single manufacturer.
- b. A factory-furnished and -calibrated controller shall be programmed, in nonvolatile EPROM, with application-specific airflow set point and range.
- c. Controller and actuator shall communicate to control the desired airflow.
- d. Controller shall receive a 0- to 10-V dc input signal and report a 0- to 20-mA output signal that is proportional to airflow.
- e. Airflow measurement and control range shall be suitable for operation between 150 to 2000 fpm.
- f. Ambient Operating Temperature Range: Minus 40 to plus 140 deg F.
- g. Ambient Operating Humidity Range: 5 to 95 percent relative humidity, noncondensing.
- h. Provide unit with control transformer rated for not less than 85 VA. Include transformer with primary and secondary protection and primary disconnecting means. Coordinate requirements with field power connection.
- i. Include screw terminals for interface to field wiring.
- j. Factory mount electronics within a NEMA 250, Type 1 painted steel enclosure.

C. Damper Actuators:

1. General:

- a. Actuators shall operate related damper(s) with sufficient reserve power to provide smooth modulating action or two-position action and proper speed of response at velocity and pressure conditions to which damper is subjected.
- b. Actuators shall produce sufficient power and torque to close off against the maximum system pressures encountered. Actuators shall be sized to close off against the fan shutoff pressure as a minimum requirement.
- c. Total damper area operated by an actuator shall not exceed 80 percent of manufacturer's maximum area rating.
- d. Include one actuator for each damper assembly where possible. Multiple actuators required to drive a single damper assembly shall operate in unison.
- e. Avoid use of excessively oversized actuators, which could overdrive and cause linkage failure when the damper blade has reached either its full open or closed position.

- f. Use jackshafts and shaft couplings in lieu of blade-to-blade linkages when driving axially aligned damper sections.
 - g. Include mounting hardware and linkages for connecting actuator to damper.
 - h. Select actuators to fail in desired position in the event of a power failure.
 - i. Actuator Fail Positions: As indicated below:
 - 1) Exhaust Air: Close.
 - 2) Outdoor Air: Close.
 - 3) Supply Air: Open.
- 2. Type: Motor operated, with or without gears, electric and electronic.
- 3. Voltage:
 - a. 24V.
 - b. Actuator shall deliver torque required for continuous uniform movement of controlled device from limit to limit when operated at rated voltage.
 - c. Actuator shall function properly within a range of 85 to 120 percent of nameplate voltage.
- 4. Construction:
 - a. Less Than 100 W: Fiber or reinforced nylon gears with steel shaft, copper alloy or nylon bearings, and pressed steel enclosures.
 - b. 100 up to 400 W: Gears ground steel, oil immersed, shaft-hardened steel running in bronze, copper alloy, or ball bearings. Operator and gear trains shall be totally enclosed in dustproof cast-iron, cast-steel, or cast-aluminum housing.
 - c. Greater Than 400 W: Totally enclosed reversible induction motors with auxiliary hand crank and permanently lubricated bearings.
- 5. Field Adjustment:
 - a. Spring return actuators shall be easily switchable from fail open to fail closed in the field without replacement.
 - b. Provide gear-type actuators with an external manual adjustment mechanism to allow manual positioning of the damper when actuator is not powered.
- 6. Two-Position Actuators: Single direction, spring return, or reversing type.
- 7. Modulating Actuators:

- a. Capable of stopping at all points across full range, and starting in either direction from any point in range.
- b. Control Input Signal:
 - 1) Proportional: Actuator drives proportional to input signal and modulates throughout its angle of rotation. Suitable for 0- to 10-V dc signals.
 - 2) Pulse-Width Modulation (PWM): Actuator drives to a specified position in accordance with a pulse duration (length) of signal from a dry-contact closure, triac sink, or source controller.
 - 3) Programmable Multifunction:
 - a) Control input, position feedback, and running time shall be factory or field programmable.
 - b) Diagnostic feedback of hunting or oscillation, mechanical overload, mechanical travel, and mechanical load limit.
 - c) Service data, including at a minimum, number of hours powered, and number of hours in motion.
- 8. Position Feedback:
 - a. Equip two-position actuators with limits switches or other positive means of a position indication signal for remote monitoring of open and close position.
 - b. Equip modulating actuators with a position feedback through current or voltage signal for remote monitoring.
 - c. Include a position indicator and graduated scale on each actuator indicating open and closed travel limits.
- 9. Fail-Safe:
 - a. Where indicated, provide actuator to fail to an end position.
 - b. Internal spring return mechanism to drive-controlled device to an end position (open or close) on loss of power.
 - c. Batteries, capacitors, and other non-mechanical forms of fail-safe operation are acceptable only where uniquely indicated.
- 10. Integral Overload Protection:
 - a. Provide against overload throughout the entire operating range in both directions.
 - b. Electronic overload, digital rotation sensing circuitry, mechanical end switches, or magnetic clutches are acceptable methods of protection.
- 11. Damper Attachment:

- a. Unless otherwise required for damper interface, provide actuator designed to be directly coupled to damper shaft without need for connecting linkages.
 - b. Attach actuator to damper drive shaft in a way that ensures maximum transfer of power and torque without slippage.
 - c. Bolt and setscrew method of attachment is acceptable only if included with at least two points of attachment.
- 12. Temperature and Humidity:
 - a. Temperature: Suitable for operating temperature range encountered by application with minimum operating temperature range of minus 20 to plus 120 deg F.
 - b. Humidity: Suitable for humidity range encountered by application; minimum operating range shall be from 5 to 95 percent relative humidity, noncondensing.
- 13. Enclosure:
 - a. Suitable for ambient conditions encountered by application.
 - b. Provide actuator enclosure with a heater and controller where required by application.
 - c. NEMA 250, Type 2.
 - d. NEMA 250, Type 4 or Type 4X.
- 14. Stroke Time: Select operating speed to be compatible with equipment and system operation.
 - a. Operate damper from fully closed to fully open within 15 seconds.
 - b. Operate damper from fully open to fully closed within 15 seconds.
 - c. Move damper to failed position within 5 seconds.
 - d. Actuators operating in smoke-control systems shall comply with governing code and NFPA requirements.
- 15. Sound:
 - a. Spring Return: 62 dBA.
 - b. Non-Spring Return: 45 dBA.

2.22 MANUAL BALANCING DAMPERS

- A. General: Air-handling unit manufacturer shall furnish and factory install manual balancing dampers inside air-handling units where indicated on Drawings.
- B. Rectangular Manual Balancing Dampers with Aluminum Airfoil Blades:
 - 1. Source Limitations: Obtain dampers from single source from single manufacturer.
 - 2. Performance:
 - a. Leakage: AMCA 511, Class 1A. Leakage shall not exceed 3 cfm/sq. ft. against 1-inch wg differential static pressure.
 - b. Pressure Drop: 0.05 inch wg at 1500 fpm across a 24-by-24-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
 - c. Velocity: Up to 6000 fpm.
 - d. Temperature: Minus 40 to plus 185 deg F.
 - e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.
 - f. Damper shall have AMCA seal for both air leakage and air performance.
 - 3. Construction:
 - a. Frame:
 - 1) Material: ASTM B211, Alloy 6063 T5 extruded-aluminum profiles, 0.07 inch thick.
 - 2) Hat-shaped channel with integral flange(s). Flange mating face shall be a minimum of 1 inch.
 - 3) Width not less than 5 inches.
 - b. Blades:
 - 1) Hollow, airfoil, extruded aluminum.
 - 2) Parallel- or opposed-blade configuration as required by application.
 - 3) Material: ASTM B211, Alloy 6063 T5 aluminum, 0.07 inch thick.
 - 4) Width not to exceed 6 inches.
 - 5) Length as required by close-off pressure, not to exceed 48 inches.
 - c. Seals:

- 1) Blades: Replaceable, mechanically attached extruded silicone, vinyl, or plastic composite.
 - 2) Jambs: Stainless steel, compression type.
- d. Axles: 0.5-inch-diameter plated or stainless steel, mechanically attached to blades.
- e. Bearings:
 - 1) Molded synthetic or stainless steel sleeve mounted in frame.
 - 2) Where blade axles are installed in vertical position, include thrust bearings.
- f. Linkage:
 - 1) Concealed in frame.
 - 2) Constructed of aluminum and plated or stainless] steel.
 - 3) Hardware: Stainless steel.
- g. Locking Regulator:
 - 1) Aluminum or stainless steel standoff with locking regulator mounted to frame in an accessible location for manual adjustment of damper blades.
- h. Additional Corrosion Protection for Corrosive Environments:
 - 1) Provide anodized finish for aluminum surfaces in contact with airstream. Anodized finish shall be a minimum of 0.0007 inch thick.
 - 2) Axles, damper linkage, and hardware shall be constructed of Type 316L stainless steel.

2.23 SMOKE DAMPERS

- A. General: Air-handling unit manufacturer shall furnish and factory install smoke dampers inside air-handling units where indicated on Drawings.
- B. Rectangular Smoke Dampers with Galvanized-Steel Blades:
 - 1. Source Limitations: Obtain dampers from single source from single manufacturer.
 - 2. General: Air-handling unit manufacturer shall furnish and factory install smoke dampers inside air-handling units where indicated on Drawings.
 - 3. Performance:
 - a. Leakage: In accordance with UL 555S, Class 1.

- b. Pressure Drop: 0.07 inch wg at 1500 fpm across a 24-by-24-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
 - c. Velocity: Up to 4000 fpm.
 - d. Temperature: 250 deg F.
 - e. Pressure Rating: 8.0 inches wg.
- 4. Certification: NRTL listed and labeled in accordance with UL 555S, Class 1.
- 5. Construction:
 - a. Frame:
 - 1) Material: Galvanized steel, minimum 0.06 inch thick.
 - 2) Hat-shaped channel with integral flange(s). Flange mating face shall be a minimum of 1 inch.
 - 3) Width not less than 5 inches.
 - b. Blades:
 - 1) Hollow, airfoil shape.
 - 2) Material: Galvanized steel, minimum 0.06 inch thick.
 - 3) Width not to exceed 6 inches.
 - 4) Length as required by close-off pressure, not to exceed 48 inches.
 - c. Seals:
 - 1) Blades: Replaceable, mechanically attached extruded silicone.
 - 2) Jambs: Stainless steel, compression type.
 - d. Bearings:
 - 1) Stainless steel sleeve type mounted in frame.
 - 2) Where blade axles are installed in vertical position, include thrust bearings.
 - e. Linkage:
 - 1) Concealed in frame.
 - 2) Constructed of galvanized steel.
 - 3) Hardware: Steel with corrosion-resistant finish.

6. Actuator:
 - a. Type: Electric, with electrical characteristics compatible with field power supply.
 - b. Action: modulating or two position.
 - c. Control Signal: Individual damper assemblies with multiple actuators shall be factory wired to operate in unison from a single control signal.
 - d. Fail Position: Closed or open, as indicated on Drawings.
 - e. Mounting on Damper: External.
 - f. Quantity: Provide each damper assembly with least number of actuators possible for application.
 - g. Speed of Response:
 - 1) Damper blade operation shall have a controlled movement of at least 5 seconds when travelling from open to close to reduce the potential for damage to duct system and connected equipment.
 - 2) Damper closure shall not be instantaneous under any condition.
 - 3) Operating time for completion of 90-degree damper travel, from open to close, or from close to open, shall not exceed the more stringent of the following:
 - a) NFPA references indicated.
 - b) Governing codes.
 - c) 15 seconds.
7. Blade Position Switches:
 - a. Provide damper assemblies with limit switches to provide remote indication of damper blade positions.
 - b. Provide separate limit switches for remote indication of damper blade open position and damper blade closed position.
 - c. Actuators equipped with remote position indication as an integral part of actuator is acceptable in lieu of separate limit switches only if actuator with integral remote position indication is NRTL listed in accordance with UL 555S.

2.24 FIXED PLATE HEAT EXCHANGERS

A. Fixed Plate Total Heat Exchangers:

1. Source Limitations: Obtain heat exchangers from single source from single manufacturer.

2. Description: A device for purpose of transferring total energy (sensible and latent) from one airstream to another with no moving parts. Design may incorporate parallel, counterflow construction to achieve the energy transfer.
3. Performance: Indicated on Drawings with no cross contamination between exhaust and supply airstreams.
 - a. Maximum Pressure Differential: Suitable for maximum 6 inches wg.
 - b. Maximum Temperature: Suitable for maximum 194 deg F.
4. Casing: Galvanized steel.
5. Plates: Evenly spaced, sealed, and arranged for counter airflow.
 - a. Plate Material and Coating: Chemically treated paper, or polymer on aluminum, with selective hydroscopicity, moisture permeability, and gas barrier properties.

B. Air-Handling Unit Factory Assembly:

1. Internal Access: Provide each fixed plate heat exchanger with internal access from downstream and upstream sides as indicated on Drawings.
2. Removal and Replacement: Each fixed plate heat exchanger shall be independently removable and replaceable through a removable access panel or door installed in air-handling unit casing.
3. Drain Pans: In applications capable of formation of frost, install condensate drain pans to collect and drain water to exterior of air-handling unit casing.
4. Supports for Fixed Plate Heat Exchanger:
 - a. Construct a freestanding and self-supporting structural framework to support heat exchangers.
 - b. Construct frame work from aluminum, galvanized-steel, or stainless steel.
5. Comply with fixed plate heat exchanger manufacturer's written installation instructions.

2.25 AIR BLENDERS

- A. Source Limitations: Obtain blenders from single source from single manufacturer.
- B. Description: Static air mixing devices fabricated in assemblies consisting of multidirectional vanes that are designed to reduce stratification of multiple mixed airstreams and improve uniformity of the air tunnel velocity profile located downstream of air mixer.
- C. Performance:

1. Certification: Documented performance verified by tests performed by an independent agency or factory tests witnessed by a professional engineer that is not a company employee.
2. Mixing: Uniform mixed airstream within 6 deg F of the theoretical average temperature of two or more airstreams.
3. Indicated on Drawings.

D. Construction:

1. Configuration: Indicated on Drawings.
2. Material: galvanized steel or Type 316 stainless steel.
3. Thickness: 0.080 inch.
4. Attachment: Integral mounting flange for attachment to mounting substrate.
5. Welding: Stitch or continuous welds. Filler metals matched to welded materials.
6. Hardware: Stainless steel.
7. OEM Factory Assembly: Single-piece assembly for sizes through 96 inches. For larger sizes, air mixers shall be fabricated in two pieces, bolted together to ensure proper fit and alignment and then disassembled for shipment.
8. Finish: Anodized.

E. Air-Handling Unit Factory Assembly:

1. Internal Access: Provide each air mixer with internal access from downstream and upstream sides as indicated on Drawings.
2. Install air mixer assemblies in an internal separating wall reinforced to limit deflection to L/200 when subjected to a horizontal force of 200 lb at any point on the air mixer assembly.
3. Blank-off and seal assembly to prevent leakage and air bypass around air mixer.
4. Operating Clearance: Maintain upstream and downstream operating clearances in accordance with manufacturer's written installation requirements.

2.26 CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

- A. Source Limitations: Obtain pumps from single source from single manufacturer.

- B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically.
- C. Pump Construction:
 - 1. Casing: Radially split, cast iron, with threaded gauge tappings at inlet and outlet, replaceable bronze wear rings, and threaded companion-flange or union-end connections.
 - 2. Impeller: ASTM B584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For constant-speed pumps, trim impeller to match specified performance.
 - 3. Pump Shaft: Steel, with copper-alloy shaft sleeve.
 - 4. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless steel spring, and Buna-N EPT bellows and gasket. Include water slinger on shaft between motor and seal.
- D. Motor: Rigidly mounted to pump casing.
 - 1. Enclosure: ODP or TEFC totally enclosed, nonventilated.
 - 2. Enclosure Materials: Cast iron or rolled steel.
 - 3. Motor Bearings: Permanently lubricated or grease-lubricated ball bearings.
 - 4. Efficiency: NEMA Premium efficient.
 - 5. NEMA Design: .
 - 6. Service Factor: 1.15.

2.27 AIR-HANDLING UNIT FACTORY DRAIN PIPING AND PIPING INSULATION

- A. General:
 - 1. Air-handling unit manufacturer to factory install piping inside air-handling units.
 - 2. If more than one material is listed, material selection is by air-handling unit manufacturer.
- B. Aluminum Piping:
 - 1. Pipe: Aluminum ASTM B241/B241M, Grade 1061, Temper T6, seamless longitudinal joints with beveled or plain ends; and wall thickness as indicated under applications.

2. Fittings: Cast aluminum, ASTM B26/B26M, Grade 356, Temper T6, ASME B16.1 Class 150; threaded ends.
3. Flanges: Cast aluminum, ASTM B26/B26M, Grade 356, Temper T6, ASME B16.1, Class 150 including bolts, nuts, washers, and gaskets of the following end connections and facings:
 - a. Threaded end connections for threaded joints, welding-neck with butt-joint for welded joints, and blinds for use with flanged joints requiring close-off.
4. Unions: Cast aluminum, ASTM B26/B26M, Grade 356, Temper T6, hexagonal-stock body; female NPT threaded ends.

C. Copper Tubing:

1. Tubing: Drawn-temper, ASTM B88, Type L.
2. Fittings: Wrought-copper and copper alloy, ASME B16.22, pressure fittings.
3. Unions: Cast-copper-alloy, MSS SP-123, hexagonal-stock body; female NPT threaded ends
4. Solder Filler Metals: ASTM B32, lead-free alloys, and water-flushable flux in accordance with ASTM B813.

D. Stainless Steel Piping:

1. Pipe: ASME B36.19/ASME B36.19M, stainless steel ASTM A312/A312M, with beveled or plain ends; seamless or welded longitudinal joints, Grade TP316L, and wall thickness as indicated under applications.
2. Fittings, Threaded: MSS SP-114, Class 150, stainless steel ASTM A351/A351M, Grade CF8M.
3. Fittings, Welded: ASME B16.9, stainless steel ASTM A403/A403M, Grade WP316L, seamless, wall thickness to match adjoining pipe.
4. Flanges: Stainless steel ASTM A182/A182M, Grade F316L, ASME B16.5, Class 150 including bolts, nuts, washers, and gaskets of the following material group, end connections, and facings:
 - a. Material Group: 2.2.
 - b. Threaded end connections for threaded joints, welding-neck with butt-joint for welded joints, and blinds for use with flanged joints requiring close-off.
5. Unions: MSS SP-114, Class 150, stainless steel ASTM A351/A351M, Grade CF8M; female NPT threaded ends.

E. Floor Drain Piping:

1. Schedule 40 aluminum or stainless steel pipe with threaded ends or copper tube with soldered threaded male adapters.
2. Factory install a dedicated drain pipe for each floor drain and extend pipe to access side of air-handling unit.
 - a. Terminate pipe with a threaded pipe cap 3 inches beyond exterior face of air-handling unit casing. Threaded pipe cap material to match pipe material.
 - b. Pipe size to match size of floor drain connection.

F. Fan Drain Piping:

1. Schedule 40 aluminum or stainless steel pipe with threaded ends or copper tube with soldered threaded male adapters.
2. Factory install a dedicated drain pipe for each housed centrifugal fan with a drain connection and extend pipe to access side of air-handling unit.
 - a. Terminate pipe with a threaded pipe cap 3 inches beyond exterior face of air-handling unit casing. Threaded pipe cap material to match pipe material.
 - b. Install a twin sphere EPDM or neoprene pipe connector in the pipe between the fan connection and the pipe penetration through the air-handling unit casing.
 - c. Pipe size to match size of fan drain connection.
 - d. Install a threaded union or thread-on flange in drain pipe at connection to fan.

G. Drain Pan Piping:

1. Schedule 40 aluminum or stainless steel pipe with threaded ends or copper tube with soldered threaded male adapters.
2. Factory install drain piping for drain pan(s). Install a dedicated drain pipe for each drain pan serving different air-handling unit internal components. Where multiple drain pans serve like components interconnect drain piping to a single drain pipe for field connection.
 - a. Where interconnecting cooling coil condensate drain pans from upstream and downstream sides of cooling coil, provide pipe with a water seal trap configured to prevent air bypass.
 - b. Terminate pipe with a threaded pipe cap 3 inches beyond exterior face of air-handling unit casing. Threaded pipe cap material to match pipe material.
 - c. Drain pipe size to match size of drain pan connection.

H. Piping Insulation:

1. Factory insulate bottom cooling coil drain pan pipe with 1-inch-thick, flexible elastomeric insulation where pipe is located under and outside of the air-handling unit casing but within the air-handling unit base.
2. Factory insulate steam and steam condensate piping located inside of air-handling with 2-inch-thick, preformed mineral-fiber pipe insulation.
3. Cover pipe insulation with a factory-applied aluminum or stainless steel jacket.

2.28 AIR-HANDLING UNIT FACTORY HYDRONIC PIPING AND PIPING INSULATION

A. Chilled-Water Piping:

1. Design Pressure and Temperature: See Drawings.
2. Pipe: ASME B36.10M, carbon steel ASTM A53/A53M, with beveled or plain ends; electric resistance weld or seamless longitudinal joints, Grade B; standard weight.
3. Fittings, Threaded: Malleable iron, ASME B16.3; Class 150.
4. Fittings, Butt Welded: ASME B16.9, wrought-steel ASTM A234/A234M, Grade WPB, seamless or welded, wall thickness to match adjoining pipe.
5. Flanges, Weld: Weld-neck, forged carbon-steel, ASME B16.5; Class 150.
6. Unions, Threaded: Malleable iron, ASME B16.39; Class 150.
7. Strainers: Y-pattern; body and cap constructed of cast-iron, ASTM A126, Class B, removable basket constructed of Type 304 or Type 316 stainless steel with openings not larger than 0.032 inch; Class 125 or Class 250.
8. Valves:
 - a. Ball: Two-piece with threaded ends, MSS SP-110, 600 WOG; cast-bronze or forged copper-alloy body, stainless steel vented ball, corrosion-resistant plastic-coated handle, extended stem, and stationary outer sleeve to protect insulation vapor seal.
 - b. Butterfly: Lugged body; MSS SP-67; cast-iron, ductile-iron, or cast-steel body; stainless steel disk, EPDM seat, and lever or gear operator; rated for system pressure, but not less than 250-psig bi-directional dead-end shutoff with downstream flange removed.
 - c. Check: Globe-style, MSS SP-125; cast-iron ASTM A126 body, stainless steel spring, and bronze seat; Class 125 or Class 250.
9. Vents: Cast-iron body, stainless steel float, NPS 1/2 or larger inlet connection.

10. Flow Meters: In-line electromagnetic type with integral display and accuracy within 3 percent of reading.
11. Pressure Gauges: Bourdon-tube, ASME B40.100 with Grade A or Grade B accuracy; metal case with nominal 4-1/2-inch shatter-resistant glass face and NPS 1/2 threaded brass connection.
12. Test Plugs: Brass or stainless steel body with core inserts and gasketed and threaded cap, extension for insulation; threaded NPS 1/2 connection.
13. Thermometers: Bi-metal actuated, ASME B40.200 with 1 percent accuracy; adjustable-angle stainless steel case with nominal 5-inch shatter-resistant glass face. Include thermometers with stainless steel extended-neck thermowells.
14. Air-Handling Unit Factory Assembly: Factory install a complete piping system inside air-handling units as indicated on Drawings.
 - a. NPS 2 and smaller with threaded fittings, strainers, and valves. Larger sizes with welded joints, fittings, and flanges for valves and strainers.
 - b. Arrange piping with sufficient clearance between piping and other components to accommodate removal and replacement of installed components.
 - c. Gradually slope piping for venting and drainage.
 - d. Include threaded drain connections and ball valves with threaded hose-end, cap, and chain at all low points in piping.
 - e. Comply with requirements indicated on Drawings.
 - f. Make connections to coils with a flange or union.
 - g. Connect to each coil inlet with shutoff valve, test plug, strainer pressure gauge and thermometer.
 - h. Connect to each coil outlet with balancing valve, test plug, pressure gauge thermometer flow meter and shutoff valve.
 - i. Connect each coil drain connection with a drain valve, which is full size of drain connection.
 - j. Connect each coil vent connection with automatic vent, which is full size of vent connection.
 - k. Connect to each pump inlet with flange or union, shutoff valve, test plug, strainer and pressure gauge.
 - l. Connect to each pump outlet with flange or union, check valve, balancing valve, test plug, pressure gauge flow meter and shutoff valve.

- m. Include with each strainer a blowdown connection consisting of a nipple and threaded ball valve with threaded hose-end, cap, and chain.

B. Chilled-Water Piping Insulation and Identification:

1. Insulation: Preformed, cellular glass or flexible elastomeric; minimum 2 inches thick.
2. Adhesive: Compatible with insulation material and recommended in writing by insulation manufacturer.
3. Jacket: ASJ.
4. Air-Handling Unit Factory Assembly: Continuously insulate and vapor seal piping system throughout its entire length. Insulate all surface capable of forming condensation.
 - a. Install high-density insulation insert products, consisting of two 180-degree halves, at pipe hangers and supports. Material density sufficient to accommodate loading without deformation.
 - b. Insulation thickness determined by air-handling unit manufacturer to comply with governing codes, ASHRAE/IES 90.1, and minimum thickness indicated and to prevent condensation.
 - c. Insulate piping system only after successful completion of pressure tests.
 - d. Install adhesive-backed acrylic identification labels indicating pipe size service and direction of flow at multiple locations sufficient for operators to easily follow the flow path. Each branch pipe should have at least one label.

C. Heating Water Piping:

1. Design Pressure and Temperature: See Drawings.
2. Pipe: ASME B36.10M, carbon steel ASTM A53/A53M, with beveled or plain ends; electric resistance weld or seamless longitudinal joints, Grade B; standard weight.
3. Fittings, Threaded: Malleable iron, ASME B16.3; Class 150.
4. Fittings, Butt Welded: ASME B16.9, wrought-steel ASTM A234/A234M, Grade WPB, seamless or welded, wall thickness to match adjoining pipe.
5. Flanges, Weld: Weld-neck, forged carbon-steel, ASME B16.5; Class 150.
6. Unions, Threaded: Malleable iron, ASME B16.39; Class 150.
7. Strainers: Y-pattern; body and cap constructed of cast-iron, ASTM A126, Class B, removable basket constructed of Type 304 or Type 316 stainless steel with openings not larger than 0.032 inch; Class 125 or Class 250.
8. Valves:

- a. Ball: Two-piece with threaded ends, MSS SP-110, 600 WOG; cast-bronze or forged copper-alloy body, stainless steel vented ball, corrosion-resistant plastic-coated handle, and extended stem.
 - b. Butterfly: Lugged body; MSS SP-67; cast-iron, ductile-iron, or cast-steel body; stainless steel disk, EPDM seat, and lever or gear operator; rated for system pressure, but not less than 250-psig bi-directional dead-end shutoff with downstream flange removed.
 - c. Check: Globe-style, MSS SP-125; cast-iron ASTM A126 body, stainless steel spring, and bronze seat; Class 125 or Class 250.
- 9. Vents: Cast-iron body, stainless steel float, NPS 1/2 or larger inlet connection.
 - 10. Flow Meters: In-line electromagnetic type with integral display and accuracy within 3 percent of reading.
 - 11. Pressure Gauges: Bourdon-tube, ASME B40.100 with Grade A or Grade B accuracy; metal case with nominal 4-1/2-inch shatter-resistant glass face and NPS 1/2 threaded brass connection.
 - 12. Test Plugs: Brass or stainless steel body with core inserts and gasketed and threaded cap, extension for insulation; threaded NPS 1/2 connection.
 - 13. Thermometers: Bi-metal actuated, ASME B40.200 with 1 percent accuracy; adjustable-angle stainless steel case with nominal 5-inch shatter-resistant glass face. Include thermometers with stainless steel extended-neck thermowells.
 - 14. Air-Handling Unit Factory Assembly: Factory install a complete piping system inside air-handling units as indicated on Drawings.
 - a. NPS 2 and smaller with threaded fittings, strainers, and valves. Larger sizes with welded joints, fittings, and flanges for valves and strainers.
 - b. Arrange piping with sufficient clearance between piping and other components to accommodate removal and replacement of installed components.
 - c. Gradually slope piping for venting and drainage.
 - d. Include threaded drain connections and ball valves with threaded hose-end, cap, and chain at all low points in piping.
 - e. Comply with requirements indicated on Drawings.
 - f. Make connections to coils with a flange.
 - g. Connect to each coil inlet with shutoff valve, test plug, strainer pressure gauge and thermometer.

- h. Connect to each coil outlet with balancing valve, test plug, pressure gauge thermometer flow meter and shutoff valve.
- i. Connect each coil drain connection with a drain valve, which is full size of drain connection.
- j. Connect each coil vent connection with automatic vent, which is full size of vent connection.
- k. Connect to each pump inlet with flange or union, shutoff valve, test plug, strainer and pressure gauge.
- l. Connect to each pump outlet with flange or union, check valve, balancing valve, test plug, pressure gauge flow meter and shutoff valve.
- m. Include each strainer with a blowdown connection consisting of a nipple and threaded ball valve with threaded hose-end, cap, and chain.

D. Heating Water Piping Insulation and Identification:

- 1. Insulation: Preformed, cellular glass or phenolic foam Insert material; minimum 2 inches thick.
- 2. Adhesive: Compatible with insulation material and recommended in writing by insulation manufacturer.
- 3. Jacket: ASJ.
- 4. Air-Handling Unit Factory Assembly: Continuously insulate and seal piping insulation system throughout its entire length.
 - a. Install high-density insulation insert products, consisting of two 180-degree halves, at pipe hangers and supports. Material density sufficient to accommodate loading without deformation.
 - b. Insulation thickness determined by air-handling unit manufacturer to comply with governing codes, ASHRAE/IES 90.1, and minimum thickness indicated and to prevent condensation.
 - c. Insulate piping system only after successful completion of pressure tests.
 - d. Install adhesive-backed acrylic identification labels indicating pipe size service and direction of flow at multiple locations sufficient for operators to easily follow the flow path. Each branch pipe should have at least one label.

E. Piping Hangers and Supports:

- 1. Finish: Galvanized metallic coatings including pregalvanized, hot-dip galvanized, or electro-galvanized.

2. Hangers: MSS-SP-58, Type 1.
3. Supports: MSS-SP-58, Type 4, Type 24, or Type 37.
4. Threaded Rods: Continuous-thread rod, nuts, and washer made of galvanized steel or stainless steel.
5. Strut: MFMA-4, continuous slotted carbon-steel channel with inturned lips.
6. Air-Handling Unit Factory Assembly:
 - a. Ridgely support piping from internal structure in accordance with governing codes and MSS SP-58.

2.29 DRAINS

A. Floor Drains:

1. Drain Body: Fabricate floor drain body of NPS 4 or larger aluminum or stainless pipe and weld a plate of same material to the bottom. Option to fabricate an aluminum or stainless steel rectangular box drain at least 4 by 4 inches of material at least 0.1 inch thick.
2. Drain Connection: Weld a nominal NPS 2 half coupling in side of drain body located within 1 inch from bottom.
3. Drain Cover: Perforated plate, at least 0.1 inch thick, or grating, fabricated from aluminum or stainless steel. Drain cover shall be supported and secured in place by drain body, but not fastened to drain body with fasteners.
4. Fluid Seal: Seal floor drain body to air-handling unit floor for a watertight installation.
5. Mounting: Recess floor drain body into structural base. Top of floor drain to be slightly recessed below air-handling unit finished floor for unobstructed gravity flow from floor into drain.
6. Application: Install floor drains in air-handling unit floors at locations indicated on Drawings.
7. Application: Install floor drains in air-handling unit floors of all sections.
8. Application: Install floor drains in air-handling unit floors of coil coil, heat wheel, heat exchanger, humidifier potentially wet sections and associated access sections.

2.30 FACTORY ASSEMBLED ELECTRICAL

A. Factory install service light fixtures and switches, and receptacles for each air-handling unit.

1. Locate in a convenient and field-accessible location.

2. Installation shall comply with NFPA 70.
3. Wire, Conduit, and Enclosures:
 - a. Minimum Conduit Size: 3/4 inch.
 - b. Materials: Metal, with a corrosion-resistant finish.
 - c. Supports: Support conduits, boxes, and enclosures using corrosion-resistant fastening hardware.
 - d. Conduit: Locate conduit inside the air-handling unit casing. Conduit installed on exterior of air-handling unit casing is unacceptable.
 - e. Wire:
 - 1) Copper, rated for 600 V, solid wire for size No. 10 AWG and smaller and stranded wire for larger sizes.
 - 2) Minimum Wire Size: No. 12 AWG.
 - 3) Each circuit shall have a ground wire.
 - 4) Install wire in conduit.
 - f. Boxes, Conduit Outlet Bodies, and Enclosures:
 - 1) Located in Airstream: NEMA 250, Type 4 Type 4X or Type 12.
 - 2) Located on Exterior of Air-Handling Unit Casing: NEMA 250, Type 3R or Type 4X
 - g. Seals: Seal pathways to prevent air leakage between air-handling unit exterior and interior, and between internal component sections.
 - h. Service Lighting Applications:
 - 1) Provide quantity of 20-A branch circuits required to power service light fixtures.
 - 2) For air-handling units consisting of multiple stacked tiers, provide separate circuits for top and bottom tiers of air-handling units.
 - 3) Factory install a main disconnect switch field power junction box for interfacing air-handling power for service lighting with single-point field power wiring connection.
 - i. Receptacle Applications:

- 1) For air-handling units consisting of multiple stacked tiers, provide separate circuits for top and bottom tiers of air-handling units.
 - 2) Factory wire receptacles to a main disconnect switch for interfacing air-handling power for receptacles with a single-point field power wiring connection.
- B. Main Disconnect Switches: Factory-install main disconnect switch mounted on air-handling unit casing exterior for interface of factory power wiring with field power wiring.
1. Specification Grade; "Heavy Duty Type"; "quick-make," "quick-break" construction.
 2. Three pole, fused.
 3. 600 V rated.
 4. Minimum Short-Circuit Current Rating: As required by electrical power distribution system, but not less than 65,000 A.
 5. Enclosure:
 - a. Located on Exterior of Air-Handling Unit Casing: NEMA 250, Type 3R or Type 4X.
 6. Operating handle shall be of box-mounted type that directly drives switch mechanism.
 7. Disconnect switch shall use a flange-operated visible blade that is close coupled to a vertical-lift-type handle that achieves a positive visible indication of disconnect with cover open or closed.
 8. Disconnect switch shall have a defeatable, front-accessible, mechanical interlock to prevent opening of cover when switch is in "ON" position, and to prevent turning switch "ON" when the door is open.
 9. Include a solid neutral as required by authorities having jurisdiction.
 10. Disconnect switch shall have a ground lug for ground wire termination.
 11. Operating handle shall be lockable in open position.
 12. Horsepower rated.
 13. Feed through or double lugged.
- C. Field Power Junction Box: Factory-install junction box with internal wire terminal block mounted on air-handling unit casing exterior for interface of factory power wiring with field power wiring.
- D. Exterior Service Light Fixtures:

1. LED Luminaires for Outdoors:
 - a. Basis-of-Design Product: Subject to compliance with requirements,.
 - b. Finish: Selected by Architect from available finishes offered by manufacturer.
 - c. Mounting: Wall.
 - d. Intended for direct exposure in outdoor locations and operation in cold- and hot-temperature extremes encountered; dust and moisture resistant.
 - e. Light Color: 4000 K.
 - f. Light Output: 3000 lumens.
 - g. On/Off Operation: Photo cell with local override toggle switch.
 2. Vaportight Fixtures:
 - a. Basis-of-Design Product: Refer to luminaire schedule
 - b. Finish: Selected by Architect from available finishes offered by manufacturer.
 - c. Mounting: Wall.
 - d. Intended for direct exposure in outdoor locations and operation in cold- and hot-temperature extremes encountered; dust and moisture resistant.
 - e. Cast-aluminum housing and guard with heat-resistant, tempered, clear glass globe.
 3. Application: Provide service light fixtures where indicated on Drawings.
 4. Application: Provide one service light fixture on each side of air-handling unit with access doors. Position fixture at midpoint of most remote access doors.
- E. Interior Service Light Fixtures:
1. Fluorescent Luminaires:
 - a. Basis-of-Design Product: Subject to compliance with requirements,.
 - b. Suitable for wet locations and operation in cold- and hot-temperature extremes encountered; dust and moisture resistant.
 - c. High-impact, UV-stabilized, fiberglass-reinforced polyester housing; high-impact acrylic lens.
 2. Application: Provide service light fixtures where indicated on Drawings.
 3. Application: Provide one service light fixture in each accessible section of air-handling units.

4. Application: Provide one service light fixture in fan, coil and filter sections of air-handling units.

F. Toggle Switches for Service Light Fixtures:

1. Single-Pole Switches, 120/277 V, 20 A: Comply with UL 20 and FS W-S-896.
2. Two-Pole Switches, 120/277 V, 20 A: Comply with UL 20 and FS W-S-896.
3. Three-Way Switches, 120/277 V, 20 A: Comply with UL 20 and FS W-S-896.
4. Four-Way Switches, 120/277 V, 20 A: Comply with UL 20 and FS W-S-896.
5. Lighted Single-Pole Switches, 120/277 V, 20 A: Comply with NEMA WD 1, UL 20, and FS W-S-896.
 - a. Description: Handle illuminated when switch is on.
6. Toggle Switch Box and Cover: Mount toggle switch in a metal outlet box with cast-aluminum cover. Weatherproof where exposed to outdoors.
7. Application: Factory install service light switches at locations indicated on Drawings.
8. Application: Factory install a single service light switch to switch all service light fixtures from a single location.
9. Application:
 - a. Factory install a service light switch for each service light fixture or group of service light fixtures accessible from a single access door adjacent to the access door.
 - b. Factory install switching configuration (single, three way, or four way) required to operate a single service light fixture or group of service light fixtures from any access door that opens to respective service light fixtures.
10. Switches with Lighted Handles Applications: Lighted handle feature may be omitted where on/off status of internal lights can be viewed through an access door window.

G. Receptacles:

1. Isolated-Ground Duplex Receptacles, 125 V, 20 A:
 - a. Description: Straight blade; equipment grounding contacts shall be connected only to green grounding screw terminal of the device and with inherent electrical isolation from mounting strap. Isolation shall be integral to receptacle construction and not dependent on removable parts. Two pole, three wire, and self-grounding.
 - b. Configuration: NEMA WD 6, Configuration 5-20R.

- c. Standards: Comply with UL 498 and FS W-C-596.
 - 2. Duplex GFCI Receptacles, 125 V, 20 A:
 - a. Description: Integral GFCI with "Test" and "Reset" buttons and LED indicator light. Two pole, three wire, and self-grounding.
 - b. Configuration: NEMA WD 6, Configuration 5-20R.
 - c. Type: Non-feed through.
 - d. Standards: Comply with UL 498, UL 943 Class A, and FS W-C-596.
 - 3. Receptacle Box and Cover: Mount receptacle in a metal outlet box with cast-aluminum cover. Weatherproof where exposed to outdoors.
 - 4. Applications: Factory install a receptacle in a convenient and field-accessible location on air-handling unit exterior of casing at locations indicated on Drawings.
- H. Power Supply to Fan Motors: As indicated on Drawings.
- I. Power Supply to Fan Motors: Factory install a motor controller variable-frequency controller for each fan motor.
- 1. Locate in a convenient and field-accessible location on unit exterior.
 - 2. Installation shall comply with NFPA 70.
 - 3. Wire, Conduit, and Enclosures:
 - a. Minimum Conduit Size: 3/4 inch.
 - b. Materials: Metal, corrosion resistant and constructed of stainless steel.
 - c. Motor Termination: Flexible conduit, NRTL listed, not to exceed 36 inches long.
 - d. Supports: Support conduits, boxes, and enclosures using corrosion-resistant fastening hardware.
 - e. Wire:
 - 1) Copper, rated for 600 V, solid wire for size No. 10 AWG and smaller and stranded wire for larger sizes.
 - 2) Minimum Wire Size: No. 12 AWG.
 - 3) Each circuit shall have a ground wire.
 - 4) Install wire in conduit.
 - f. Boxes, Conduit Outlet Boxes, and Enclosures:

- 1) Located in Airstream: NEMA 250, Type 4 Type 4X or Type 12.
- 2) Located on Exterior of Air-Handling Unit Casing: NEMA 250, Type 3R.

J. Disconnect Switches:

1. Specification Grade; "Heavy Duty Type"; "quick-make," "quick-break" construction.
2. Three pole, fused.
3. 600 V rated.
4. Minimum Short-Circuit Current Rating: As required by electrical power distribution system, but not less than 65,000 A.
5. Enclosure:
 - a. Located on Exterior of Air-Handling Unit Casing: NEMA 250, Type 3R Type 4 or Type 4X.
6. Operating handle shall be of box-mounted type that directly drives switch mechanism.
7. Disconnect switch shall use a flange-operated visible blade that is close coupled to a vertical-lift-type handle that achieves a positive visible indication of disconnect with cover open or closed.
8. Disconnect switch shall have a defeatable, front-accessible, mechanical interlock to prevent opening of cover when switch is in "ON" position, and to prevent turning switch "ON" when the door is open.
9. Include a solid neutral as required by authorities having jurisdiction.
10. Disconnect switch shall have a ground lug for ground wire termination.
11. Operating handle shall be lockable in open position.
12. Horsepower rated.
13. Feed through or double lugged.

K. Motor Field Power Junction Box:

1. Provide junction box with internal wire terminal block mounted on unit exterior for interface with field power wiring.
 - a. Provide for each motor not installed with a factory disconnect or controller with integral disconnect.
2. Factory install internal wiring and conduit to motor.

L. Motor Controllers:

1. NEMA ICS 2, Class A, full-voltage, non-reversing, motor-rated controller.
2. Configured for control of single- or multispeed motors as indicated.
3. Enclosure: Hinged full-front access door with lock and key.
 - a. Located on Exterior of Air-Handling Unit Casing: NEMA 250, Type 3R.
4. Externally Operated Disconnect: Fused disconnect switch with lockable handle.
5. Short-Circuit Current Rating: As required by electrical power distribution system, but not less than 65,000 A.
6. Hand-Off-Auto Switch: Mounted on face of enclosure.
7. Push-to-Test Run Status Pilot Lights: NEMA ICS 2, heavy-duty type.
8. Control Relays: Time-delay relays.
9. Phase-Failure, Phase-Reversal, Undervoltage Relays: Solid-state sensing circuit with adjustable undervoltage setting and isolated output contacts for hardwired connection.
10. Elapsed-Time Meters: Numerical readout in hours on face of enclosure.
11. Number-of-Starts Counter: Numerical readout on face of enclosure.

M. Variable-Frequency Controllers:

1. Description: NEMA ICS 2; arranged to achieve motor variable speed by adjusting output voltage and frequency.
2. Enclosure: Unit mounted, with hinged full-front access door with lock and key.
 - a. Located on Exterior of Air-Handling Unit Casing: NEMA 250, Type 3R.
3. Externally Operated Disconnect: Fused disconnect switch with lockable handle.
4. Minimum Short-Circuit Current Rating: As required by electrical power distribution system, but not less than 65,000 A.
5. Technology: Pulse-width-modulation (PWM) output with insulated gate bipolar transistors (IGBT); suitable for variable torque loads.
6. Controller shall consist of a rectifier converter section, a digital/analog driver regulator section, and an inverter output section.
7. Output Rating: Three phase; with voltage proportional to frequency throughout voltage range.

8. Output signal shall be programmed to not cause mechanical vibration issues with fan drive assembly.
9. Operating Requirements:
 - a. Input AC Voltage Tolerance: 10 percent.
 - b. Input frequency tolerance of 60 Hz, plus or minus 2 Hz.
 - c. Capable of driving full motor load, without derating.
 - d. Minimum Efficiency: 96 percent at 60 Hz, full load.
 - e. Minimum Displacement Primary-Side Power Factor: 95 percent.
 - f. Overload Capability: 1.05 times the full-load current for 7 seconds.
 - g. Starting Torque: As required by fan and motor drive assembly.
 - h. Speed Regulation: 1 percent.
 - i. Speed Range: 10:1 speed range.
 - j. To avoid equipment resonant vibrations, include critical speed lockout circuitry to allow bands of operating frequency at which controller shall not operate continuously.
 - k. Capable of being restarted into a motor coasting in either the forward or reverse direction without tripping.
10. Controller Adjustability Capabilities: Minimum and maximum output frequency, acceleration and deceleration, and current limit.
11. Self-Protection and Reliability Features: Subjecting the controller to any of the following conditions shall not result in component failure or need for replacement:
 - a. Surge suppression.
 - b. Loss of input signal protection.
 - c. Critical frequency rejection.
 - d. Overtemperature.
 - e. Short circuit at controller output.
 - f. Ground fault at controller output. Variable-frequency controller shall be able to start a grounded motor.
 - g. Open circuit at controller output.

- h. Input undervoltage.
 - i. Input overvoltage.
 - j. Loss of input phase.
 - k. Reverse phase.
 - l. AC line switching transients.
 - m. Instantaneous overload, line to line or line to ground.
 - n. Sustained overload exceeding 100 percent of controller rated current.
 - o. Starting a rotating motor.
12. Motor Protection: Controller shall protect motor against overvoltage and undervoltage, phase loss, reverse phase, overcurrent, overtemperature, and ground fault.
13. Automatic Reset and Restart:
- a. Capable of multiple restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction.
 - b. Capable of automatic restart on phase-loss and overvoltage and undervoltage trips.
14. Visual Indication: On face of controller; indicating the following conditions:
- a. Power on.
 - b. Run.
 - c. Overcurrent and overvoltage.
 - d. Motor speed (percentage).
 - e. Various faults with alarm status.
 - f. Input kilovolt amperes.
 - g. Power factor.
 - h. Input kilowatts and kilowatt-hours.
 - i. Three-phase input and output voltage.
 - j. Three-phase input and output current.
 - k. Output frequency.
 - l. Elapsed operating time (hours).

- m. Diagnostic and service parameters.
- 15. Operator Interface: Start-stop and auto-manual selector with manual-speed-control potentiometer.
- 16. Hardwired Control Signal Interface: A minimum of two analog inputs (0 to 10 V or 0/4 to 20 mA) and four programmable digital inputs.
- 17. Remote Communication Interface: ASHRAE 135 BACnet MS/TP.
- 18. Line Conditioning:
 - a. Input line conditioning.
 - b. Output filtering.
 - c. EMI/RFI filtering.
- 19. Bypass Controller:
 - a. Bypass Controller/Variable-Frequency Controller Selector Switch: Include manual selector switch on face of enclosure for local operator control of preferred controller.
 - b. Bypass Mode: Field-selectable automatic or manual.
 - 1) In automatic mode, include fail-safe control logic to automatically transfer fan motor operation from failed variable-frequency controller to bypass controller.
 - c. Type: Integrated NEMA ICS 2, Class A, full-voltage, non-reversing, motor-rated controller to operate fan motor if variable-frequency controller is not operational.
 - d. Arrangement: Configure power supply to bypass controller and variable-frequency controller to completely isolate power to variable-frequency controller while operating fan motor through bypass controller for safe servicing of variable-frequency controller.
 - e. Enclosure: Install bypass controller in same enclosure as variable-frequency controller.
 - f. Remote Monitoring: Include control relay for remote indication of bypass controller operation.

2.31 FACTORY-ASSEMBLED CONTROLS

A. General:

1. Air-handling unit manufacturer shall furnish and factory install control instruments, control power circuit, control transformers, power supplies, wiring, tubing, raceways, and control panels.
2. Provide for a single-point field connection to 120-V electrical power for all factory-installed controls. Terminate power connection with a toggle switch mounted in control panel.
3. Control panel shall serve as field tie-in point for all electric damper actuators, and control instruments located within air-handling unit. Controls for control dampers, control valves and instruments installed in ductwork and piping are not included as part of air-handling unit factory-installed controls.
4. Control instruments shall be installed in accordance with manufacturer's written instructions.
5. Control panel shall house flow, moisture, pressure and temperature transmitters, transformers, dc voltage power supplies, and wiring terminal strip.
6. Carbon dioxide transmitters shall be mounted on air-handling unit casing exterior with sensor port exposed to the airstream.
7. Factory install the following control instruments:
 - a. Flow station and flow transmitter for each fan.
 - b. Pressure sensors (inlet and discharge) and one combination pressure differential transmitter, switch, and controller for each filter bank installed in the air-handling unit.
 - c. Pressure sensor and combination pressure differential transmitter, switch, and controller at the inlet of each fan.
 - d. Pressure sensor and combination pressure differential transmitter, switch, and controller at the discharge of each fan.
 - e. Carbon dioxide sensor/transmitters at locations indicated on Drawings.
 - f. Moisture and temperature sensors and transmitters at locations indicated on Drawings.
 - g. Temperature switches at locations indicated on Drawings.
 - h. Control instruments indicated on Drawings.

B. Wire and Cable:

1. Single Conductor Control Wiring above 24 V:
 - a. Wire size shall be at least No. 16 AWG.

- b. Conductor shall be 7/24 soft annealed copper stranding with a 2- to 2-1/2-inch lay.
 - c. Conductor insulation shall be 600 V, Type THWN or Type THHN, 90 deg C in accordance with UL 83.
 - d. Conductor colors shall be black (hot), white (neutral), and green (ground).
- 2. Single Twisted Shielded Instrumentation Cable above 24 V:
 - a. Wire size shall be minimum No. 18 AWG.
 - b. Conductors shall be a twisted, 7/24 soft annealed copper stranding with a 2- to 2-1/2-inch lay.
 - c. Conductor insulation shall have a Type THHN/THWN or Type TFN rating.
 - d. Shielding shall be 100 percent 0.35/0.5-mil aluminum/mylar tape, helically applied with 25 percent overlap, and aluminum side in with a No. 18 AWG-7/26 tinned copper drain wire.
 - e. Outer jacket insulation shall have a 600-V, 90 deg C rating and shall be Type TC cable.
 - f. For twisted pair, conductor colors shall be black and white. For twisted triad, conductor colors shall be black, red, and white.
- 3. Single Twisted Shielded Instrumentation Cable 24 V and Lower:
 - a. Wire size shall be minimum No. 18 AWG.
 - b. Conductors shall be a twisted, 7/24 soft annealed copper stranding with a 2- to 2-1/2-inch lay.
 - c. Conductor insulation shall have a nominal 15-mil thickness, constructed from flame-retardant PVC.
 - d. Shielding shall be 100 percent 1.35-mil aluminum/polymer tape, helically applied with 25 percent overlap, and aluminum side in with a No. 20-22 AWG tinned copper drain wire.
 - e. Outer jacket insulation shall have a 300-V, 105 deg C rating and shall be Type PLTC cable.
 - f. For twisted pair, conductor colors shall be black and white. For twisted triad, conductor colors shall be black, red, and white.
- 4. Wire and Cable Installation:
 - a. Comply with manufacturer's written instructions and NFPA 70.

- b. Grounding shall be in accordance with IEEE C2. Ground wire shall be copper. Demonstrate ground resistance.
- c. Wiring and cables shall be installed in conduit. Exposed wire and cable are unacceptable.
- d. Wire and cables may be grouped in a common raceway, except do not group wires and cables from different voltages.
- e. Install control wiring in a separate conduit from power wiring.
- f. Wiring shall be continuous from terminal to terminal without splices.
- g. Do not install low-voltage wire and cable closer than 12 inches from line voltage electrical power wire and cables. Provide an installation free of EMI.
- h. Use insulated spade lugs for wiring connection to screw terminals.
- i. Use shielded cable to transmitters.
- j. Terminate wiring and cables within a control panel, within instrument housing, or in a junction box. Clamp the cable over the jacket, in the junction box. Individual conductors in the stripped section of cable shall be slack between clamping point and terminal block.
- k. Terminate wire and cable in control panel with terminal blocks.
- l. Identify each wire and cable on each end and at each terminal with a number coded identification tag. Each wire and cable conductor shall have a unique tag.
- m. Perform continuity and meager testing on wiring and cable.

C. Raceways:

1. Conduit:

- a. Install wiring and cable in conduit.
- b. Minimum Conduit Size: 3/4 inch.
- c. Materials: Metal, corrosion resistant.
- d. Supports: Support conduits, boxes, and enclosures using corrosion-resistant fastening hardware.
- e. Terminations to Actuators and Instruments: Flexible conduit, NRTL listed, not to exceed 24 inches long.

2. Boxes, Conduit Outlet Boxes, and Enclosures:

- a. Located in Airstream: NEMA 250, Type 4 Type 4X or Type 12.
 - b. Located on Exterior of Air-handling Unit Casing: NEMA 250, Type 4 or Type 4X.
3. Seals: Seal pathways to prevent air leakage between air-handling unit exterior and interior, and between internal component sections.
4. Conduit Installation:
 - a. Conduit shall be continuous and secured in a manner that is electrically continuous throughout.
 - b. Secure threaded conduit entering a cabinet, box or enclosure with a locknut on outside and on inside, such that conduit system is electrically continuous throughout.
 - 1) Install a metal bushing with insulated throat on inside.
 - 2) Locknuts designed to bite into metal, or on inside of enclosure and shall have a grounding wedge lug under locknut.
 - c. Conduit box connectors for conduit entering enclosures shall be insulated throat type.
 - d. Connect conduit with watertight sealing locknuts that are suitable for wet applications.
 - e. Offset conduits where they enter surface-mounted equipment and panels.
 - f. Neatly loop and lace wiring installed in panels and other enclosures.
 - g. Seal conduit runs to prevent the circulation of air by installing seal fittings.
 - h. Install conduit inside of air-handling unit casing. Wiring and conduit running on exterior of air-handling unit casing is unacceptable.
- D. Tubing and Fittings:
 1. Products in this paragraph are intended for use with the following:
 - a. Signal air between pressure instruments, such as sensors, switches, transmitters, controllers, and accessories.
 2. Copper Tubing:
 - a. Seamless phosphor deoxidized copper, soft annealed or drawn tempered, with chemical and physical properties in accordance with ASTM B75/B75M.
 - b. Performance, dimensions, weight and tolerance in accordance with ASTM B280.

- c. Diameter, as required by application, not less than nominal 0.25 inch.
 - d. Wall thickness, as required by application, but not less than 0.030 inch.
- 3. Copper Tubing Fittings: Brass, compression type.
- 4. Polyethylene Tubing:
 - a. Fire-resistant black virgin polyethylene in accordance with ASTM D1248, Type 1, Class C and Grade 5.
 - b. Tubing shall comply with stress crack test in accordance with ASTM D1693.
 - c. Diameter, as required by application, of not less than nominal 0.25 inch.
- 5. Polyethylene Tubing Fittings: Brass, compression type.
- 6. Stainless Steel Tubing:
 - a. Seamless Type 316 stainless steel, Grade TP, cold drawn, annealed and pickled, free from scale.
 - b. Chemical and physical properties in accordance with ASTM A269/A269M.
 - c. Diameter, as required by application, of not less than nominal 0.25 inch.
 - d. Wall thickness, as required by application, but not less than 0.035 inch.
 - e. Furnish stainless steel tubing in 20-foot straight random lengths.
- 7. Stainless Steel Tubing Connectors and Fittings:
 - a. Connectors and fittings shall be stainless steel, with stainless steel collets, flareless type.
 - b. Connect instruments to tubing with connectors having compression connector on one end and IPS or NPT thread on other end.
- 8. Tubing Installation:
 - a. Use copper or stainless steel tubing except use fire-resistant polyethylene for tubing located in control panels.
 - b. Run tubing parallel to, and at right angles to, casing.
 - c. Route multiple runs of tubing in neat parallel lines.
 - d. Support tubing as follows:
 - 1) Support metal tubing with hangers, clips, and tube trays.

- 2) Do not use tapes for mounting tubing.
 - 3) Place a support within 1 foot of each change in direction and each branch take off.
 - 4) Spacing between supports shall not exceed 60 inches.
- e. Tubing shall not interfere with access to dampers and equipment or obstruct passageways of any kind.
 - f. Provide vibration loops in tubing when connecting to equipment that might vibrate.
 - g. Where joining or mating dissimilar metals where galvanic action could occur, provide dielectric isolation.
 - h. Make tubing bends with a bending tool. Hard bends, or wrinkled or flattened bends are unacceptable.
 - i. Install tubing fitting make-up in accordance with manufacturer's written instructions.
 - j. Do not make tubing connections to a fitting before completing make-up connection.
 - k. Properly align tubing with fitting. Springing tube into position can result in excessive stress on both tubing and fitting with possible resulting leaks.
 - l. Do not install fittings close to a bend. Length of straight tubing, not deformed by bending is required for a proper connection.
 - m. Check tubing for correct diameter and wall thickness. Tube ends shall be cut square and deburred. Exercise care during cutting to keep tubing round.
 - n. Wrap threads of fittings with a single wrap of PTFE tape.
 - o. Install tubing with extreme care to keep foreign matter out. Keep open ends of tubing plugged to keep out dust, dirt, and moisture.
 - p. Mark each tube on each end with a number-coded identification. Each tube shall have a unique number.
 - q. Test tubing shall as follows:
 - 1) Test for leaks and obstructions. Disconnect each tubing run before test is run, and blow out trash, condensate, and other foreign material with compressed air.
 - 2) After foreign matter is expelled and the line is free from obstructions, plug the far end of tubing run.

- 3) Connect a pressure source to the near end with a needle valve between air supply and tubing run. Only commercially pure dry compressed air or nitrogen as distributed in gas cylinders is acceptable for this test.

E. Control Panels:

1. Design control panels for grouping and protecting various electric, and/or electronic components.
2. NRTL listed in accordance with UL 50 or UL 50E.
3. Enclosure:
 - a. On Exterior of Air-Handling Unit Casing: NEMA 250, Type 4 or Type 4X.
4. Construct enclosure of steel, not less than the following:
 - a. Enclosure Size Less Than 24 inches: 0.053 inch thick.
 - b. Enclosure size 24 inches and Larger: 0.067 inch thick.
5. Support front panel using a non-removable piano hinge that runs entire height of cabinet.
6. Each panel shall not exceed height of air-handling unit casing and 72 inches high.
7. Secure front panel with a key locking mechanism. Common key the locks, and provide one pair of keys per panel.
8. Front panel with a window of size so all instrument displays are visible with door closed.
9. Mount panels on exterior wall of air-handling unit casing on primary access side of unit.
10. Paint control panel exterior with enamel at least 5 mils thick. Color of panel exterior and interior shall be white.
11. Include panel field power supply with a toggle-type switch located at entrance inside panel to disconnect power.
12. Include panel with a line-voltage nominal 20-A GFCI duplex receptacle for service and testing tools. Wire receptacle on hot side of enclosure disconnect switch and include with a 5-A circuit breaker.
13. Size control panel to provide at least 25 percent spare area on subpanel.
14. Arrange control panel so similar type equipment is grouped together, and a barrier is installed between electrical and electronic equipment.
15. Interior ambient temperature shall not rise above manufacturer's recommended maximum operating temperature for products installed within the panels. Provide filtered louvers and circulating fans, when necessary, to meet criteria.

16. Panel shall serve as a central tie-in point for control devices such as remote sensors, transmitters, power supplies, and transformers.
 - a. Factory install internal wiring in compliance with specified standards.
 - b. Terminate wiring using an electric terminal strip with heavy-duty terminal blocks.
 - c. Include spare terminals, equal to not less than 10 percent of used terminals.
 - d. Include spade lugs for stranded wire.
 - e. Install a maximum of two wires on each side of a terminal.
 - f. Label each end of cable, wire, and tubing within panel following an approved identification system.
17. Polyethylene tubing may be used within panel enclosure in place of copper.
18. Supply each control panel with a complete set of as-built schematics, tubing, and wiring diagrams that are bound in a three-ring protective binder and located within panel.
19. Mount instruments and other products within control panel on an internal panel(s) and provide with nameplates. Provide engraved, laminated phenolic nameplates (black letters on a white background). Nameplates shall have at least 1/4-inch-high lettering.
20. Route tubing, cable and wiring located inside control panel within a raceway that has a continuous removable cover.

F. Pitot Tube Airflow Stations:

1. Fan Inlet Airflow Sensor (Piezometer Ring):
 - a. Source Limitations: Obtain sensors from single source from single manufacturer.
 - b. Provide fans with airflow measurement integral to fan inlet cones for continuously measurement of air volume flow rate.
 - c. Fan inlet airflow sensor shall contain multiple pressure sensor points strategically placed along the circumference of the inlet cone and internally connected to an averaging ring manifold located behind the inlet cone.
 - d. Sensor points shall neither protrude beyond the surface of the inlet cone nor be adversely affected by particle contamination present in the airstream.
 - e. Sensor shall produce steady, non-pulsating signals to achieve accuracy within 5 percent of actual airflow.
 - f. Sensor shall be non-intrusive and not impact fan performance.

- g. Product shall be a standard offering of fan manufacturer and include published literature with supporting test data to validate sensor performance.

G. Thermal Airflow Measurement Stations:

1. Ebtron
2. Source Limitations: Obtain stations from single source from single manufacturer.
3. Description: Airflow station shall consist of one or more sensor probes and a remotely mounted microprocessor-based transmitter.
4. Performance:
 - a. Capable of independently processing up to 16 independently wired sensor assemblies.
 - b. Airflow rate of each sensor assembly shall be equally weighted and averaged by transmitter prior to output.
 - c. Temperature of each sensor assembly shall be velocity weighted and averaged by transmitter prior to output unless temperature sensor has an accuracy of 0.1 deg F.
 - d. Listed and labeled by an NRTL as successfully tested as an assembly in accordance with UL 873 or UL 60730.
 - e. Components shall be interconnected by exposed NRTL-listed plenum-rated cable or non-plenum-rated cable placed in conduit.
 - f. Each flow station shall be factory calibrated at a minimum of six airflow rates and two temperatures to standards that are traceable to NIST.
 - g. Individual Sensor Airflow Accuracy: Within 2 percent of reading over the entire operating airflow range.
 - h. Thermal Airflow Station Assembly Airflow Accuracy: Within 2 percent of reading over the entire operating airflow range.
 - 1) Devices whose accuracy is combined accuracy of transmitter and sensor probes must demonstrate that total accuracy meets performance requirements throughout the measurement range.
 - i. Temperature Accuracy: Within 0.2 deg F over entire operating range of minus 20 to plus 140 deg F.
 - j. Sensor Ambient Operating Temperature Range: Minus 20 to plus 160 deg F.
 - k. Transmitter Ambient Operating Temperature Range: Minus 20 to plus 120 deg F.

- l. Sensor and Transmitter Ambient Operating Humidity Range: Zero to 99 percent, noncondensing.
 - m. Instrument shall compensate for changes in air temperature and density throughout calibrated velocity range for seasonal extremes at Project location.
 - n. Pressure Drop: 0.05 inch wg at 2000 fpm across a 24-by-24-inch area.
 - o. Instruments mounted in throat or face of fan inlet cone shall not negatively influence fan performance by reducing flow more than 1 percent of Project design flow or negatively impact fan-generated sound. Losses in performance shall be documented with submittal data, and adjustments to compensate for performance impact shall be made to fan to deliver Project design airflow indicated.
- 5. Sensor Assemblies:
 - a. Each sensor probe shall contain two individually wired, hermetically sealed bead-in-glass thermistors.
 - b. Mount thermistors in sensor using a marine-grade, waterproof material.
 - c. Thermistor leads shall be protected and not exposed to environment.
 - d. Each sensor assembly shall independently determine airflow rate and temperature at each measurement point.
 - e. Each sensor probe shall have an integral cable for connection to remotely mounted transmitter.
 - f. Sensor Probe Material: Gold anodized, extruded Alloy 6063 aluminum tube or Type 304 stainless steel.
 - g. Probe Assembly Mounting Brackets Material: Type 304 stainless steel.
- 6. Transmitter:
 - a. Integral digital display capable of simultaneously displaying total airflow and average temperature, individual airflow, and temperature readings of each independent sensor assembly.
 - b. Capable of field configuration and diagnostics using an onboard push-button interface and digital display.
 - 1) Include an integral power switch to operate on 24-V ac (isolation not required) and include the following:
 - a) Integral protection from transients and power surges.
 - b) Circuitry to ensure reset after power disruption, transients, and brownouts.

- c) Integral transformer to convert field power source to operating voltage required by instrument.

c. Remote Signal Interface:

- 1) Linear Analog Signals for Airflow and Temperature: Fuse protected and isolated, field selectable, 0 to 10 V dc or 4 to 20 mA.
- 2) RS-485: BACnet-ARCNET, BACnet-MS/TP, and Modbus-RTU.
- 3) 10 Base-T Ethernet: BACnet Ethernet, BACnet-IP, Modbus-TCP, and TCP/IP.
- 4) LonWorks free topology.

H. Flow Transmitters for Pitot Tube Sensors:

- 1. Source Limitations: Obtain sensors from single source from single manufacturer.
- 2. Receives total and static pressure signals from a flow element, amplify, extract the square root, and scale the signal to produce a 4- to 20-mA dc output signal linear to airflow.
- 3. Housed in NEMA 250, Type 1 enclosure.
- 4. Assembly constructed so that shock, vibration, and pressures surges of up to 1 psig will neither harm transmitter nor affect its accuracy.
- 5. Provide transmitter with an automatic zeroing circuit capable of automatically readjusting transmitter zero at predetermined time intervals. Automatic zeroing circuit shall re-zero transmitter to within 0.1 percent of true zero.
- 6. Performance:
 - a. Range: At least 20 percent below minimum airflow and 20 percent greater than design airflow.
 - b. Calibrated Span: Field adjustable, minus 40 percent of the range.
 - c. Accuracy: Within 0.10 percent of natural span.
 - d. Repeatability: Within 0.15 percent of calibrated span.
 - e. Linearity: Within 0.2 percent of calibrated span.
 - f. Hysteresis and Deadband (Combined): Less than 0.2 percent of calibrated span.
- 7. Equip transmitter with an integral digital LED or LCD for continuous indication of airflow.
- 8. Install in control panel.

- I. Humidity Sensors and Transmitters with Digital Display:
 - 1.
 - 2. Source Limitations: Obtain sensors and transmitters from single source from single manufacturer.
 - 3. Performance:
 - a. Accuracy including non-linearity, hysteresis, and repeatability: Within 2 percent from zero to 90 percent relative humidity and within 2.5 percent from 90 to 100 percent relative humidity when operating between 60 to 77 deg F.
 - b. Relative Humidity Range: Zero to 100 percent.
 - c. Factory calibrated and NIST traceable with certificate included.
 - 4. Construction:
 - a. Provide housing with remote sensor probe for ducted applications.
 - 1) Duct Sensor Body: 300 series stainless steel or chrome-plated aluminum, at least 2 inches long for duct-mounted applications.
 - 2) Provide sensor with cable for field installation in conduit.
 - 3) For duct-mounted applications, thread the sensor assembly for connection to a threaded mounting flange.
 - b. Provide general-purpose humidity sensor unless application requires special requirements. Provide sensor with sintered stainless steel filter.
 - c. Housing shall be ABS/PC plastic or powder-coated aluminum.
 - d. Housing Classification: NEMA 250, Type 4 or Type 4X.
 - e. Provide housing with wall-mounting plate.
 - 5. Output Signal: Two-wire, 4- to 20-mA output signal with a drive capacity of at least 500 ohms at 24 V dc.
 - 6. Provide unit with a digital display of relative humidity in percent.
- J. Air Pressure Sensors:
 - 1. Source Limitations: Obtain sensors from single source from single manufacturer.
 - 2. Insertion length shall be at 4 inches.
 - 3. Sensor with four radial holes of 0.04-inch diameter.

4. Brass or stainless steel construction.
5. Sensor with threaded end support, sealing washers, and nuts.
6. Connection: NPS 1/4 compression fitting.

K. Air-Pressure Differential Indicating Transmitter, Switch, and Controller:

1. Source Limitations: Obtain from single source from single manufacturer.
2. Description:
 - a. Three-in-one instrument, including digital display, control relay switches, and a transmitter with a current output.
 - b. Field configurable for pressure, velocity, and volumetric flow applications through user interface.
 - c. Select instrument range based on application. Range shall be approximately 2 times set point.
3. Performance:
 - a. Accuracy Including Hysteresis and Repeatability:
 - 1) Within 1 percent for ranges less than 5 inches wg.
 - 2) Within 0.5 percent at 77 deg F for other ranges.
 - b. Stability: Within 1 percent per year.
 - c. Response Time: 250 ms.
 - d. Overpressure: 5 psig for instrument ranges less than 50 inch wg and 9 psig for 100-inch wg range.
 - e. Temperature Limits: 32 to 140 deg F.
 - f. Thermal Effects: 0.020 percent per deg F.
 - g. Warm-up Period: One hour.
4. Controller Programming through Menu Keys to Access Five Menus:
 - a. Security level.
 - b. Pressure, velocity, or flow application.
 - c. Engineering units.
 - d. K-factor for use with flow application.

- e. Set-point control only; set-point and alarm operation; and alarm operation as high, low, or high/low with manual or automatic reset and delay.
 - f. View high and low readings.
 - g. Digital dampening for smoothing erratic applications.
 - h. Scaling of analog output to fit range and field calibration.
- 5. Display:
 - a. Digital, four-digit display with backlight, with 0.4-inch-high, alphanumeric characters.
 - b. Four indicators; two for set point and two for alarm status.
- 6. Operator Interface:
 - a. Set-point adjustment through keypad on face of instrument.
 - b. Zero and span adjustments accessible through menu.
 - c. Programming through keypad.
- 7. Analog Output Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into a 900-ohm load.
- 8. Digital Output Signal:
 - a. Two SPDT relays.
 - b. Each rated for 1 A at 30 V ac or dc.
- 9. Construction:
 - a. Die cast-aluminum casing and bezel.
 - b. Threaded, NPS 1/8 connections on side and back.
 - c. Vertical plane mounting.
 - d. NEMA 250, Type 1.
 - e. Nominal 4-inch-diameter face.
 - f. Mounting Bracket: Appropriate for installation.

L. Carbon Dioxide Sensors/Transmitters:

1. Source Limitations: Obtain sensors/transmitters from single source from single manufacturer.
2. Description:
 - a. NDIR technology or equivalent technology providing long-term stability and reliability.
 - b. Two-wire, 4- to 20-mA output signal; linearized to carbon dioxide concentration in ppm.
3. Construction:
 - a. House electronics in an ABS plastic enclosure. Provide equivalent of NEMA 250, Type 4.
 - b. Equip with digital display for continuous indication of carbon dioxide concentration.
4. Performance:
 - a. Measurement Range: 0 to 2000 ppm.
 - b. Accuracy: Within 2 percent of reading, plus or minus 30 ppm.
 - c. Repeatability: Within 1 percent of full scale.
 - d. Temperature Dependence: Within 0.05 percent of full scale over an operating range of 25 to 110 deg F.
 - e. Long-Term Stability: Within 5 percent of full scale after more than five years.
 - f. Response Time: Within 60 seconds.
 - g. Warm-up Time: Within five minutes.
5. Provide calibration kit. Turn over to Owner at start of warranty period.

M. Air Temperature Sensors:

1. Platinum Resistance Temperature Detector (RTD): Common Requirements:
 - a. 100 or 1000 ohms at 0 deg C and a temperature coefficient of 0.00385 ohms/ohm/deg C.
 - b. Two-wire Teflon insulated 22-gauge stranded copper leads.
 - c. Performance Characteristics:
 - 1) Range: Minus 50 to plus 275 deg F.

- 2) Interchangeable Accuracy: At 32 deg F within 0.5 deg F.
 - 3) Repeatability: Within 0.5 deg F.
 - 4) Self-Heating: Negligible.
 - d. Transmitter Requirements:
 - 1) Transmitter required for each 100-ohm RTD.
 - 2) Transmitter optional for 1000-ohm RTD, contingent on compliance with end-to-end control accuracy.
2. Platinum RTD, Averaging Sensor:
 - a. Source Limitations: Obtain sensors from single source from single manufacturer.
 - b. 100 1000 ohms.
 - c. Temperature Range: Minus 50 to plus 275 deg F.
 - d. Multiple sensors to provide average temperature across entire length of sensor.
 - e. Rigid probe of aluminum, brass, copper or stainless steel sheath.
 - f. Flexible probe of aluminum, brass, copper or stainless steel sheath and formable to a 4-inch radius.
 - g. Length: As required by application to cover entire cross section of air tunnel.
 - h. Enclosure: Junction box with removable cover; NEMA 250, Type 4.
 - i. Gasket for attachment to duct or equipment to seal penetration airtight.
 - j. Conduit Connection: 1/2-inch trade size.
- N. Air Temperature Switches:
 1. Thermostat and Switch for Low Temperature Control:
 - a. Source Limitations: Obtain switches from single source from single manufacturer.
 - b. General:
 - 1) Two-position control.
 - 2) Field-adjustable set point.
 - 3) Manual reset.
 - 4) NRTL listed.
 - c. Performance:

- 1) Operating Temperature Range: 15 to 55 deg F.
- 2) Temperature Differential: 5 deg F, non-adjustable and additive.
- 3) Enclosure Ambient Temperature: Minus 20 to plus 140 deg F.
- 4) Sensing Element Maximum Temperature: 250 deg F.
- 5) Voltage: 120 V ac.
- 6) Current: 16 full-load A.
- 7) Switch Type: Two SPDT snap switches operate on coldest 12-inch section along element length.

d. Construction:

- 1) Vapor-Filled Sensing Element: Nominal 20 feet long.
- 2) Dual Temperature Scale: Fahrenheit and Celsius visible on face.
- 3) Set-Point Adjustment: Screw.
- 4) Enclosure: Painted metal, NEMA 250, Type 1.
- 5) Electrical Connections: Screw terminals.
- 6) Conduit Connection: 1/2-inch trade size.

O. Air Temperature RTD Transmitters:

1. Source Limitations: Obtain transmitters from single source from single manufacturer.

Requirements in remaining paragraphs are based on Minco's "TT Series." For other transmitters, see Section 230923.27 "Temperature Instruments."

2. House electronics in NEMA 250, Type 1 enclosure. Mount transmitter in control panel.
3. Conduit Connection: 1/2-inch trade size.
4. Functional Characteristics:

a. Input:

- 1) 100-ohm platinum RTD temperature coefficient of 0.00385 ohms/ohms/deg C; two-wire sensors.
- 2) 1000-ohm platinum RTD temperature coefficient of 0.00385 ohms/ohms/deg C; two-wire sensors.

b. Span (Adjustable):

- 1) Exhaust Air: 50 to 100 deg F.
 - 2) Mixed Air: Minus 40 to plus 140 deg F.
 - 3) Outdoor: Minus 40 to plus 140 deg F.
 - 4) Supply Air, Cooling, and Heating: 40 to 120 deg F.
 - 5) Return Air: 50 to 100 deg F.
 - c. Output: 4- to 20-mA dc linear with temperature; RFI insensitive; minimum drive load of 600 ohms at 24 V dc.
 - d. Zero and span field adjustments plus or minus 5 percent of span. Minimum span 50 deg F.
 - e. Match sensor with temperature transmitter and factory calibrate together.
 5. Performance Characteristics:
 - a. Calibration Accuracy: Within 0.1 percent of span.
 - b. Stability: Within 0.2 percent of span for at least six months.
 - c. Combined Accuracy: Within 0.5 percent.
 6. Provide each transmitter with a digital display.
- P. Liquid Flow Meters:
1. General: Extended range of 10 percent above Project design flow and 10 percent below Project minimum flow to signal abnormal flow conditions.
 2. In-Line Body Electromagnetic Flow Meter:
 - a. Source Limitations: Obtain flow meters from single source from single manufacturer.
 - b. Description:
 - 1) No moving parts.
 - 2) Suitable for flow measurement of fluids with electrical conductivity more than 5 micro-Seimens per cm.
 - 3) Inherent bi-directional flow measurement.
 - 4) Flow measurement with three pipe diameters upstream and two pipe diameters downstream.

- 5) Wet calibrate and tag meters to standards traceable to NIST, and provide each meter with a certificate of calibration.
- 6) Transmitter integral to meter.
- c. Performance:
 - 1) Accuracy for Velocities between 3.3 and 33 fps: Within 0.2 percent of reading.
 - 2) Accuracy for Velocities between 1.0 and 3.3 fps: Within 0.75 percent of reading.
 - 3) Accuracy for Velocities Less than 1.0 fps: Within 0.0075 fps.
 - 4) Ambient Temperature: Minus 4 to plus 140 deg F.
 - 5) Process Temperature: Minus 4 to plus 212 deg F.
 - 6) Pressure: 225 psig.
- d. Analog Output Current Signal:
 - 1) Two-wire, 4- to 20-mA dc current source.
 - 2) Signal capable of operating into 1000-ohm load.
 - 3) Isolated.
- e. Digital Output Signal: Two, programmable, digital/pulse outputs configurable for frequency, pulse, or directional flow.
- f. Operator Interface:
 - 1) Keypad.
 - 2) Digital Display: Multiple-line digital display of alphanumerical characters.
 - 3) LED for normal and alarm operation.
- g. Construction:
 - 1) Body: Epoxy-coated carbon steel.
 - 2) Body Liner Material: PTFE.
 - 3) Flow Tube: Type 304 stainless steel.
 - 4) Connection: 150 Class flange Threaded.

- 5) Electrodes: Type 316 stainless steel. Quantity determined by manufacturer based on application.
 - 6) Electronics Enclosure:
 - a) Painted aluminum.
 - a) Removable cover.
 - b) NEMA 250, Type 4 or Type 6.
3. Vortex Shedding Flow Meter with Integral Pressure and Temperature Measurement:
- a. Source Limitations: Obtain flow meters from single source from single manufacturer.
 - b. Description:
 - 1) Mass flow measurement corrected for density using vortex shedding body with integral piezoelectric pressure sensors and 1000-ohm platinum RTD.
 - 2) Meter NPS 1/2 through NPS 12.
 - 3) Each meter shall be factory calibrated at five points from 0 to 250 fps and tagged accordingly against manufacturer's flow standards. Manufacturer shall provide a certificate of calibration for meter.
 - 4) Each meter shall be programmed using Project-specific application data.
 - 5) Meter shall include integral diagnostics to verify installation conditions and proper operation.
 - c. Performance:
 - 1) Volumetric Flow Accuracy for Liquid: Within 0.75 percent of reading for Reynolds numbers 20000 and larger.
 - 2) Volumetric Flow Accuracy for Steam and Gas: Within 1 percent of reading for Reynolds numbers 20000 and larger.
 - 3) Mass Flow Accuracy for Steam and Gas: Within 1.5 percent of reading for Reynolds numbers 20000 and larger.
 - 4) Repeatability: Within 0.1 percent.
 - 5) Long-Term Stability: Within 0.1 percent per year.
 - 6) Ambient Temperature: Minus 40 to plus 185 deg F.
 - 7) Process Temperature: Minus 40 to plus 464 deg F.
 - 8) Pressure: Equal to flange rating.

- d. Output Signals:
 - 1) Analog Current Signal of Flow Rate:
 - a) Two-wire, 4- to 20-mA dc current source.
 - b) Signal capable of operating into 1000-ohm load.
 - 2) Analog Current Signals for Pressure and Temperature: Separate 4- to 20-mA signals for gauge pressure and temperature.
 - 3) Digital Signal:
 - a) Pulse output for flow totalization. Two wire, scaled pulse, 0.5 Hz, 100 mA at 30 V dc.
 - b) HART, FSK protocol.
- e. Operator Interface:
 - 1) Keypad.
 - 2) Digital Display: Two-line digital display of alphanumeric characters. Meter shall display flow rate, flow totalization, pressure, temperature, and support field programming of all parameters.
- f. Construction:
 - 1) Material: Type 316L stainless steel.
 - 2) Connection: Class 150 flange.
 - 3) Enclosure:
 - a) Epoxy-painted cast aluminum.
 - b) Removable screw-on cover.
 - c) NEMA 250, Type 4 or Type 6.
 - d) Electrical Connection: Screw terminals.
 - e) Conduit Connection: Two, 1/2-inch trade size.
- g. Upstream Flow Straightener:
 - 1) Meter manufacturer shall provide flow straightener where required by installation to comply with manufacturer's written installation instructions.
 - 2) Straightener shall be wafer type, constructed of Type 304 stainless steel, designed to be installed between field-installed flanges.
 - 3) Straightener size shall match meter size.

Q. Liquid Pressure Differential Switches:

1. Source Limitations: Obtain switches from single source from single manufacturer.
 2. Description:
 - a. Type 316 stainless steel double opposing bellows operate to actuate an SPDT snap switch.
 - b. Wetted Materials: Type 316 stainless steel.
 - c. Seal: FKM.
 - d. Electrical Connections: Screw terminal.
 - e. Enclosure Conduit Connection: Knock-out or threaded connection.
 - f. User Interface: Thumbscrew set-point adjustment with enclosed set-point indicator and scale.
 - g. High and Low Process Connections: Threaded, NPS 1/4.
 - h. Enclosure: NEMA 250, Type 4 or Type 4X.
 - i. Operating Data:
 - 1) Electrical Rating: 10 A at 120- to 240 V ac.
 - 2) Pressure Limits: 0 to 500 psig.
 - 3) Ambient Temperature Limits: Minus 20 to plus 150 deg F.
 - 4) Process Temperature Limits: 20 to 300 deg F.
 - 5) Operating Range: 2 times set point unless otherwise required by application.
 - 6) Deadband: Adjustable or fixed as required by application.
 - j. Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and application.
- R. Liquid Pressure Transmitters:
1. Liquid Gauge Pressure Transmitter with Adjustable Span:
 2. Source Limitations: Obtain transmitters from single source from single manufacturer.
 - a. Performance:
 - 1) Range: Minus 300 to 300 psig.
 - 2) Span: Field adjustable.

- 3) Minimum Span: 3 psig.
 - 4) Reference Accuracy: Within 0.07 percent of span or better.
 - 5) Stability: Within 0.125 percent of upper range limit for five years.
 - 6) Overpressure Limits: 3626 psig.
 - 7) Process Temperature Limits: Minus 40 to plus 250 deg F.
 - 8) Ambient Temperature Limits: Minus 40 to plus 185 deg F.
 - 9) Temperature Effect: Within 0.025 percent of upper range limit plus 0.125 percent of span.
 - 10) Shock and vibration shall not harm the transmitter.
- b. Analog Output Current Signal:
- 1) Two-wire, 4- to 20-mA dc current source.
 - 2) Signal capable of operating into 1000-ohm load.
 - 3) Digital signal based on HART protocol carried with current signal.
 - 4) Dampening: Field selectable from zero to 30 seconds.
- c. Operator Interface: Zero and span adjustments located behind cover.
- d. Display: Digital, five-digit, two-line display with 0.4-inch-high, alphanumeric characters.
- e. Construction:
- 1) Non-wetted parts of transmitter constructed of aluminum or stainless steel.
 - 2) Enclosure with removable cover on each side.
 - 3) Wetted parts of transmitter constructed of Type 316 stainless steel.
 - 4) Threaded, NPS 1/2 process connection on bottom of instrument.
 - 5) Drain/vent valve on process connection.
 - 6) Two 1/2-inch trade size conduit connections on side of instrument enclosure.
 - 7) Screw terminal block for wire connections.
 - 8) NEMA 250, Type 4X.

- 9) Mounting Bracket: Appropriate for installation.
- f. Three-Valve Manifold:
 - 1) Include with each transmitter an integrally mounted manifold.
 - 2) Construct manifold body of Type 316 stainless steel.
 - 3) Manifold with threaded, NPS 1/2 female process connections.
- 3. Liquid, Pressure-Differential Transmitter with Adjustable Span:
 - a. Source Limitations: Obtain transmitters from single source from single manufacturer.
 - b. Performance:
 - 1) Range: Minus 300 to 300 psig.
 - 2) Span: Field adjustable.
 - 3) Minimum Span: 3 psig.
 - 4) Reference Accuracy: Within 0.07 percent of span or better.
 - 5) Stability: Within 0.125 percent of upper range limit for five years.
 - 6) Overpressure Limits: 3626 psig.
 - 7) Process Temperature Limits: Minus 40 to plus 250 deg F.
 - 8) Ambient Temperature Limits: Minus 40 to plus 185 deg F.
 - 9) Temperature Effect: Within 0.025 percent of upper range limit plus 0.125 percent of span.
 - 10) Shock and vibration shall not harm the transmitter.
 - c. Analog Output Current Signal:
 - 1) Two-wire, 4- to 20-mA dc current source.
 - 2) Signal capable of operating into 1000-ohm load.
 - 3) Digital signal based on HART protocol carried with current signal.
 - 4) Dampening: Field selectable from zero to 30 seconds.
 - d. Operator Interface: Zero and span adjustments located behind cover.

- e. Display: Digital, five-digit, two-line display with 0.4-inch-high, alphanumeric characters.
 - f. Construction:
 - 1) Non-wetted parts of transmitter constructed of aluminum or stainless steel.
 - 2) Enclosure with removable cover on each side.
 - 3) Wetted parts of transmitter constructed of Type 316 stainless steel.
 - 4) Threaded, NPS 1/2 process connection on bottom of instrument.
 - 5) Drain/vent valve on process connection.
 - 6) Two 1/2-inch trade size conduit connections on side of instrument enclosure.
 - 7) Screw terminal block for wire connections.
 - 8) NEMA 250, Type 4X.
 - 9) Mounting Bracket: Appropriate for installation.
 - g. Five-Valve Manifold:
 - 1) Include with each transmitter an integrally mounted manifold.
 - 2) Construct manifold body of Type 316 stainless steel.
 - 3) Manifold with threaded, NPS 1/2 female process connections.
- S. Liquid Temperature Sensors:
- 1. Source Limitations: Obtain sensors from single source from single manufacturer.
 - 2. Resistance temperature (RTD) sensors shall comply with IEC 60751, Class B requirements.
 - 3. Platinum with a value of 100 ohms at 0 deg C and a temperature coefficient of 0.00385 ohm/ohm/deg C.
 - 4. Encase RTD in a Type 316 stainless steel sheath with a 0.25-inch OD.
 - 5. Provide three-wire, PTFE-insulated, nickel-coated, 22-gauge, stranded copper leads.
 - 6. Provide spring-loaded RTDs for thermowell installations.
 - 7. Performance Characteristics:
 - a. Range: Minus 328 to plus 932 deg F.

- b. Interchangeable Accuracy: Within 0.54 deg F at 32 deg F.
 - c. Stability: Within 0.05 percent maximum ice-point resistance shift after 1000 hours at 752 deg F.
 - d. Hysteresis: Within 0.04 percent of range.
 - e. Response Time: 62.8 percent of change in four seconds with water flowing across sensor at 3 fps.
- 8. Thermowells:
 - a. Stem: Straight or stepped or tapered shank formed from solid bar stock.
 - b. Material: Type 304 or Type 316 stainless steel.
 - c. Process Connection: Threaded, NPS 3/4.
 - d. Sensor Connection: Threaded, NPS 1/2.
 - e. Bore: Sized to accommodate sensor with tight tolerance between sensor and well.
 - f. Furnish thermowells installed in insulated pipes and equipment with an extended neck that extends beyond the face of the insulation covering.
 - g. Length: As required by application and pipe size.
 - h. Thermowells furnished with heat-transfer compound to eliminate air gap between wall of sensor and thermowell and to reduce time constant.
- 9. Connection Heads:
 - a. Housing: Low-copper cast-aluminum alloy, complying with NEMA 250, Type 4.
 - b. Terminals: Six or eight as required by sensor.
 - c. Conduit Connection: 1/2-inch trade size.
 - d. Sensor Connection: NPS 1/2.
- 10. Assembly: Sensor manufacturer shall furnish sensor, thermowell, and sensor connection head to provide a matched assembly.
- T. Liquid Temperature Transmitters:
 - 1. Source Limitations: Obtain transmitters from single source from single manufacturer.
 - 2. Enclosure: House electronics in NEMA 250, Type 4 or Type 4X enclosure.
 - 3. Enclosure Connection: 1/2-inch trade size.

4. Functional Characteristics:

- a. Input: 100-ohm platinum RTD temperature coefficient of 0.00385 ohm/ohm/deg C, three-wire sensors.
- b. Default Span (Adjustable):
 - 1) Chilled Water: 0 to 100 deg F.
 - 2) Heating Hot Water: 32 to 212 deg F.
- c. Output: 4- to 20-mA dc, linear with temperature; RFI insensitive; minimum drive load of 600 ohms at 24-V dc.
- d. Zero and span field adjustments, plus or minus 5 percent of span. Minimum span of 50 deg F.
- e. Match sensor with temperature transmitter and factory calibrate together. Each matched sensor and transmitter set shall include factory calibration data traceable to NIST.

5. Performance Characteristics:

- a. Calibration Accuracy: Within 0.1 percent of the span.
- b. Stability: Within 0.2 percent of the span for at least six months.
- c. Combined Accuracy: Within 0.5 percent.

U. Control Transformers:

- 1. Size each transformer for the total connected load, plus an additional 25 percent of the connected load.
- 2. Each transformer shall be at least 100 VA.
- 3. Provide transformer with both primary and secondary fuses.

V. 25-V dc Power Supply:

- 1. Plug-in style suitable for mating with a standard eight-pin octal socket.
- 2. Enclose circuitry within a housing.
- 3. Include line and load regulation to ensure a stable output. To protect both power supply and load, include power supply with an automatic current limiting circuit.
- 4. Performance:
 - a. Output voltage nominally 25 V dc within 5 percent.

- b. Output current up to 100 mA.
- c. Input voltage nominally 120 V ac, 60 Hz.
- d. Load regulation within 0.5 percent from 0- to 100-mA load.
- e. Line regulation within 0.5 percent at a 100-mA load for a 10 percent line change.
- f. Stability within 0.1 percent of rated volts for 24 hours after a 20-minute warmup.

W. Instrument Identification:

- 1. Engraved tag bearing instrument identification.
 - a. Each tag identifying an instrument shall have a unique identification that does not match identification of a similar device.
 - b. Tag field instruments identified by equipment being controlled or monitored, followed by point identification used on I/O schematics.
 - c. Example: DDC-AHU-01.01; PDIT1.
- 2. Letter size shall be minimum 1/4 inch high.
- 3. Letter type shall be sans serif gothic bold style.
- 4. Lettering and background color scheme shall be white letters on black background.
- 5. Tag shall be engraved phenolic constructed of three layers of pressure rigid laminate. Top and bottom layers are color-coded, contrasting white center is exposed by engraving through outer layer. Engrave both sides. Material shall be stain proof, heat resistant, non-conductive, or non-corrosive.
- 6. Tag shall be fastened to equipment/instrument with drive pins or attached with a stainless steel chain.
- 7. Instruments furnished with identification tags provided by original manufacturer do not require an additional tag.

X. Checkout Procedures:

- 1. Check instruments for proper location and accessibility.
- 2. Check instruments for proper installation for direction of flow, elevation, orientation, and other applicable considerations.
- 3. Damper Check-out: Verify that proper blade alignment, either parallel or opposed, has been provided.

Y. Calibration and Adjustment:

1. Calibrate every instrument.
2. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
3. Equipment and procedures used for calibration shall meet requirements of instrument manufacturer's written instructions. Test equipment used in calibration of instruments shall have an accuracy at least double that of instrument being calibrated.
4. Calibrate each instrument in accordance with the accuracy outlined in instruction manual supplied for instrument by manufacturer.
5. Control System Inputs and Outputs:
 - a. Check analog inputs using a precision voltage or current source at zero, 50, and 100 percent of span.
 - b. Check analog outputs using a milliampere meter at zero, 50, and 100 percent output.
 - c. Check digital inputs using a jumper wire.
 - d. Check digital outputs using an ohmmeter to test for contact making or breaking.
 - e. Check resistance temperature inputs at zero, 50, and 100 percent of span using a precision-resistant source.
6. Flow: Set differential pressure flow transmitters for zero and 100 percent values with three-point calibration accomplished at 100, 50, and 90 percent of span.
7. Gas: Calibrate gas transmitters at zero, 50, and 100 percent of span.
8. Humidity: Calibrate relative humidity transmitters at zero, 50, and 100 percent of span.
9. Pressure: Calibrate pressure transmitters at zero, 50, and 100 percent of span.
10. Temperature: Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistant source.
11. Dampers: Stroke and adjust control dampers following the recommended procedure from manufacturer, such that damper is 100 percent open and closed.
12. Replace out of tolerance instruments failing the test.
13. Provide diagnostic and test instruments for calibration and adjustment.

2.32 SMOKE DETECTORS

- A. System, Duct Smoke Detectors: For connection to conventional fire-alarm system. Coordinate requirements with Section 284621.13 "Conventional Fire Alarm System."
1. Operating at 24-V dc, nominal.
 2. Detectors shall be two-wire type.
 3. Base Mounting: Detector and associated electronic components shall be mounted in a twist-lock module that connects to a fixed base. Provide terminals in the fixed base for connection to building wiring.
 4. Self-Restoring: Detectors do not require resetting or readjustment after actuation to restore them to normal operation.
 5. Integral Visual-Indicating Light: LED type, indicating detector has operated and power-on status.
 6. Provide multiple levels of detection sensitivity for each sensor, with alarm-verification feature.
 7. Duct Smoke Detectors: Photoelectric type complying with UL 268A.
 - a. Remote indication and test station. Operating key switch initiates an alarm test.
 - b. Enclosure: NEMA 250, Type 4X; NRTL listed for use with the supplied detector for smoke detection in HVAC systems.
 - c. Sampling Tubes: Design and dimensions as recommended by manufacturer for specific size, air velocity, and installation conditions where applied.
 - d. Relay Fan Shutdown: Rated to interrupt fan motor-control circuit.
- B. Nonsystem, Single-Station Duct Smoke Detectors:
1. Nonsystem smoke detectors shall be listed as compatible with fire-alarm equipment installed or shall have a contact closure interface listed for the connected load.
 2. Nonsystem smoke detectors shall meet the monitoring for integrity requirements in NFPA 72.
 3. Comply with UL 268A; operating at 120 V ac.
 4. Base Mounting: Detector and associated electronic components shall be mounted in a twist-lock module that connects to a fixed base. The fixed base shall be designed for mounting directly to mounting brackets air-handling unit. Provide terminals in the fixed base for connection to building wiring.
 - a. Enclosure: NEMA 250, Type 4X; listed for use with the supplied detector.

5. Sampling Tubes: Design and dimensions as recommended by manufacturer for specific size, air velocity, and installation conditions where applied.
 6. Relay Fan Shutdown: Rated to interrupt fan motor-control circuit.
- C. Air-Handling Unit Factory Assembly:
1. Furnish and install smoke detectors inside air-handling units to comply with governing building codes.
 2. Install smoke detectors in accordance with smoke detector manufacturer's written installation instructions.
 - a. Sampling tubes shall extend the full width of airstream.
 - b. Sampling tubes greater than 36 inches long shall be supported on both ends.
 3. Install smoke detectors within air-handling units in a location that is easily accessible for inspection, repair, and replacement of smoke detector, and in a location that does not hinder access to other internal components.
- D. Air-Handling Unit Factory Testing: Functionally test smoke detectors to ensure proper operation in accordance with smoke detector manufacturer's written instructions.
- E. Air-Handling Unit Factory Installation of Addressable Smoke Detectors Furnished by Building Fire-Alarm System Supplier:
1. Where addressable duct smoke detectors are indicated to be installed within air-handling unit casing, air-handling unit manufacturer shall install duct smoke detector components supplied by building fire-alarm system supplier.
 2. Mount duct smoke detector sampling housing on exterior of air-handling unit casing. Locate on accessible side and coordinate with installers before installation.
 3. Seal air-handling unit casing penetrations.
 4. Install duct smoke detector components in accordance with written instructions furnished by supplier.
 - a. Sampling tubes shall extend the full width of airstream.
 - b. Sampling tubes greater than 36 inches long shall be supported on both ends.
 5. Photograph installation and transmit photos to fire-alarm system Installer before air-handling unit shipment to ensure proper installation. Fire-alarm system Installer shall review photos and provide written acceptance of installation to air-handling unit manufacturer before air-handling unit shipment.
 - a. Document date of photos and approval for record purposes.

- b. Make corrective measures required by fire-alarm system Installer as required for acceptance.
- 6. Coordinate work schedule of air-handling unit manufacturer and fire-alarm system supplier to meet requirements of Project schedule.
- 7. See Section 284621.11 "Addressable Fire-Alarm Systems" for additional requirements.

2.33 HARDWARE

A. Screws:

- 1. For Galvanized-Steel Materials: Self-tapping, hex-head, zinc-plate steel or 300 series stainless steel screws with a neoprene gasket encapsulated by a zinc-plate steel or 300 series stainless steel washer.
- 2. For Aluminum and Stainless Steel Materials: Self-tapping, hex-head, 300 series stainless steel screws with a neoprene gasket encapsulated by a 300 series stainless steel washer.
- 3. Provide protective covers on exposed screws to prevent personnel injury.

B. Bolts, Nuts, and Washers:

- 1. For Joining Galvanized and Painted Carbon-Steel Materials: Hex-head, high-strength, galvanized steel or 300 series stainless steel.
- 2. For Joining Aluminum and Stainless Steel Materials: Hex-head, high-strength, 300 series stainless steel.
- 3. Use washers and lock washers at each bolted connection.
- 4. Select bolt size and spacing sufficient for load and application.

2.34 WELDING

- A. Welding Filler Metals: Comply with AWS welding codes for welding materials appropriate for thickness and chemical analysis of material being welded.
 - 1. Use welding materials with corrosion properties equal to material being welded.
- B. Use welders that are certified to weld at least twice the thickness of the material to be welded. Certification shall be within three months of work being performed.
- C. Welds shall be continuous, full-penetration welds unless otherwise indicated. Intermittent welds, stitch welds and tack welds are permitted only in specific applications indicated.
- D. Use welders and welding procedures complying with the following:

1. Piping Systems: Section IX of the ASME Boiler and Pressure Vessel Code and Section V of ASME B31.1.
2. Structural Aluminum: AWS D1.2/D1.2M.
3. Structural Carbon Steel: AWS D1.1/D1.1M.
4. Structural Stainless Steel: AWS D1.6/D1.6M.
5. Sheetmetal: AWS D9.1/D9.1M.

2.35 PAINTING

A. General:

1. Painted OEM components do not require additional coating other than touch-up to damaged areas. Match the touchup coating to surrounding undamaged surfaces.
2. Finish miscellaneous surfaces to match continuous surfaces.
3. Protect mill galvanized surfaces that are exposed to view, such as raw steel cuts and damage by welding, with multiple coats of matching galvanized paint.
4. Protect mill galvanized surfaces that are concealed, such as raw steel cuts and damage by welding, with multiple coats of zinc-rich paint or matching galvanized paint.
5. Touch up or entirely repaint surface finishes, damaged during shipment and installation, to the original condition, using original materials and methods.

B. Preparation:

1. Submit proposed manufacturer's written preparation and application instructions for information.
2. If paint manufacturer's recommended preparation requirements differ from those indicated, use the more stringent requirements.
3. Structural carbon steel to be painted shall be deburred, ground smooth, cleaned, and blasted in accordance with SSPC-SP 6/NACE No. 3 or SSPC-SP 10/NACE No. 5.
4. Before applying a primer and a finish coat, remove oil and grease from surfaces to be coated using clean rags soaked in thinner in accordance with SSPC-SP 1.
5. Treat surfaces to be painted to ensure that paint adheres.

C. Primer:

1. Rust-inhibiting type, with a minimum dry film thickness of 1 mil(s) per coat.

2. Apply at least two coats of primer to unfinished carbon-steel surfaces and at least one coat of primer to other surfaces.
3. Use primer that is compatible with substrate and finish coat.

D. Finish Coat:

1. Finish coat painting system shall be alkyd-enamel.
2. Use dry film thickness recommended by paint manufacturer for each coat. Total dry film thickness of all finish coats not less than 3 mils.
3. Painted Surfaces Minimum Properties:
 - a. Salt Spray ASTM B117: 5 percent salt solution fog at 95 deg F for 1000 hours with no deterioration.
 - b. Adhesion, ASTM D3359: When the coating is cut into 0.0625-inch squares and 3M No. 600 tape is suddenly removed, there is no loss of adhesion.
 - c. Acid Resistance ASTM D3260: 15-minute exposure to 10 percent hydrochloric acid at room temperature with no effect.
 - d. Alkali Resistance ASTM D1647: 15-minute exposure to 10 percent sodium hydroxide at room temperature with no effect.
 - e. Humidity Resistance ASTM D2247: 850-hour exposure to 100 deg F and at least 95 percent relative humidity with no effect.
 - f. Pencil Hardness ASTM D3363: A hardness of 1H.
4. Finish coat color shall be selected by Architect and not be limited to manufacturer's standard offering.
 - a. Submit a written request for color selection and indicate in the request the date color selection must be returned without impacting schedule.

E. Application: Paint the following surfaces with primer and finish coat indicated:

1. Unfinished carbon-steel surfaces.
2. Exposed mill galvanized-steel surfaces of air-handling unit casing exterior.
3. Exposed aluminum surfaces of air-handling unit casing exterior.
4. Exposed stainless steel surfaces of air-handling unit casing exterior.

2.36 CLEANLINESS REQUIREMENTS

A. General:

1. Provide equipment that has been manufactured, shipped, stored, and installed maintaining highest degree of cleanliness possible.
2. Owner Cleanliness Inspection: Air-handling unit(s) cleanliness is subject to Owner cleanliness inspection before packaging for shipment.

B. During Manufacturing:

1. Clean materials to be free of mill grease, oxidation, dirt, dust, and other impurities before manufacturing and assembly.
2. Protect casing materials from contamination during manufacturing and assembly.
3. Use sealing materials that do not outgas.
4. Provide OEM components and equipment from their respective manufacturers free of grease, oxidation, and dirt. Store OEM components and equipment indoors. Cover and protect OEM components and equipment to maintain cleanliness. Follow OEM instructions for equipment storage.

C. After Manufacturing:

1. Before shipment, after unit is completely assembled, clean unit inside and out.
 - a. Vacuum entire inside to remove dirt, dust, and debris using HEPA-filtered vacuum equipment.
 - b. Purge hard to reach surfaces with dry, oil-free, compressed or bottled nitrogen.
 - c. Wipe down all surfaces, inside and out, with a residue-free cleaning agent.
2. Protect unit to maintain cleanliness.

D. Shipping:

1. Protect interior and exterior of air-handling unit from exposure to weather dirt, dust, and debris during shipment and rigging.
2. Cover openings with puncture-resistant durable coverings to ensure that cleanliness is maintained inside unit while providing an air- and watertight seal.

E. On-Site Storage:

1. If air-handling unit is to be stored before installation, Installer shall work closely with air-handling unit manufacturer for air-handling unit manufacturer to provide adequate protection at the factory to ensure that cleanliness for both unit interior and unit exterior is maintained. This protection shall remain in place until unit startup is performed.

2. For extended periods of storage, provide a means to rotate fan and motor assemblies on a periodic basis (as recommended in writing by manufacturer) without compromising unit cleanliness.

2.37 ACCESSORIES

A. Tool Kit:

1. Manufacturer shall assemble a tool kit specially designed for use in servicing air-handling units furnished.
2. Include only special tools required to service air-handling unit components not readily available for purchase by Owner service personnel in performing routine maintenance.
3. Place tools in a lockable case with hinged cover.
4. Mark case cover with large and permanent text to indicate special purpose of tool kit, such as "Air-Handling Unit Tool Kit." Text size shall be at least 1 inch high.
5. Provide a list of each tool furnished and permanently attach the list to underside of case cover. Text size shall be at least 1 inch high.

2.38 SOURCE QUALITY CONTROL

A. AHRI Compliance:

1. AHRI 260 (I-P): Air-handling unit sound ratings shall be in accordance with AHRI 260 (I-P), "Sound Rating of Ducted Air Moving and Conditioning Equipment."
2. AHRI 410: Air-handling unit coils shall be rated in accordance with AHRI 410 and shall be listed by AHRI and labeled in accordance with AHRI.
3. AHRI 1060 (I-P) Certification: Air-handling units that include fixed plate heat exchangers and heat pipe heat exchangers shall be rated in accordance with AHRI 1060 (I-P) and shall be listed by AHRI and labeled in accordance with AHRI.

B. AMCA Compliance:

1. AMCA 201: Air-handling unit manufacturer shall evaluate fan's performance within the air-handling unit in accordance with AMCA 201, "Fans and Systems" and account for conditions within the air-handling unit that could be detrimental to fan's performance by adjusting the fan performance indicated on Drawings.
2. AMCA 205 Certification: Air-handling unit fan's fan efficiency grade (FEG) shall be rated in accordance with AMCA 205, "Energy Efficiency Classifications for Fans" and shall bear the AMCA-certified fan efficiency grade seal.

3. AMCA 210 Certification: Air-handling unit fan's air performance shall be rated in accordance with AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating" and shall bear the AMCA-certified air ratings seal.
4. AMCA 300: Air-handling unit fan's sound performance shall be rated in accordance with AMCA 300, "Reverberant Room Method for Sound Testing of Fans."
5. AMCA 301 Certification: Air-handling unit fans sound performance shall be rated in accordance with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data" and shall bear the AMCA-certified sound ratings seal.
6. AMCA 500-D: Air-handling unit damper's performance shall be rated in accordance with AMCA 500-D, "Laboratory Methods of Testing Dampers for Rating" and shall bear the AMCA-certified air ratings seal.

C. NFPA Compliance:

1. NFPA 70: Electrical components, devices, and accessories shall be listed and labeled by a qualified testing agency, and marked for intended location and application.
2. NFPA 90A: Design, fabrication, and installation of air-handling units and components shall comply with NFPA 90A.

D. UL Compliance:

1. UL 1598 Certification: Air-handling unit UVGI shall be NRTL listed and labeled in accordance with UL 1598, "Luminaires."
2. UL 1995 Certification: Where indicated, air-handling unit components shall be NRTL listed and labeled in accordance with UL 1995, "Standard for Safety Heating and Cooling Equipment."

2.39 SOURCE QUALITY CONTROL - INDEPENDENT LABORATORY TESTING

A. General:

1. Project-specific testing by an independent laboratory is not required if air-handling unit manufacturer has written independent laboratory test results of past tests performed on same casing construction proposed for use on this Project.
2. If Project-specific testing is required, testing shall be performed in ample time to include test reports with submittals and before manufacturing of air-handling units. Include sufficient lead time for unit delivery, installation, and testing required by construction schedule.

B. Casing Structural Deflection Test:

1. Include service of an independent testing laboratory to verify casing structural deflection requirements indicated.

- a. In lieu of independent laboratory testing, manufacturer may perform factory deflection testing of proposed construction to prove compliance if witnessed by Architect and Owner. Manufacturer shall bear cost of labor and travel expenses to witness testing.
 2. Test casing construction to performance criteria indicated.
 3. Test casing construction proposed for use on Project. Include, at a minimum, particulars such as metal materials and thickness, internal support and reinforcing, and insulation material and thickness.
 4. Test largest full-size casing panel proposed for use on Project.
 5. Test proposed construction of walls, floor, and roof. Include a separate test for each unique casing construction proposed.
 6. Submit test reports for each test to show compliance with performance indicated.
- C. Casing Airborne Sound Transmission Test:
1. Include services of an independent testing laboratory to test proposed casing construction for sound transmission. Include a separate test for each unique casing construction proposed.
 2. Conduct tests in accordance with ASTM E90.
 3. Determine sound transmission class by using ASTM E413.
 4. Test proposed construction of walls and roof.
 5. Test proposed construction of floor assembly only if air-handling unit is not installed on a concrete housekeeping pad or building structural floor.
 6. Submit test reports for each test to show compliance with performance indicated.
- D. Casing Sound Absorption Test:
1. Include services of an independent testing laboratory to verify casing sound absorption coefficients for perforated casing panels. Provide a separate test for each unique casing construction proposed.
 2. Conduct tests in accordance with ASTM C423 and ASTM E795.
 3. Test proposed construction of walls and roof.
 4. Submit test reports to show compliance with performance indicated.

2.40 SOURCE QUALITY CONTROL - AIR-HANDLING UNIT FACTORY TESTS

- A. Witness of Testing: Allow Architect, Commissioning Agent, Construction Manager and Owner access to place where air-handling units are being tested for witness testing.
 - 1. Submit written notification at least 30 days in advance of testing.
 - 2. Schedule testing at mutually agreeable dates and times.
- B. Witness Testing Travel Expenses:
 - 1. Include in bid the cost of travel expenses to witness factory testing. Total cost for travel expenses shall be clearly indicated separately in bid.
 - 2. Expenses shall include roundtrip class airfare, out-of-town hotel accommodations, out-of-town meals (breakfast, lunch, and dinner), out-of-town ground transportation and parking, and all associated taxes and fees.
 - 3. Exclude other incidental expenses not indicated.
 - 4. Include travel expenses for one representative(s) with origin of.
- C. Casing Leakage Test:
 - 1. Perform a leak test for each assembled air-handling unit.
 - 2. Follow testing procedures in accordance with ASHRAE 111.
 - 3. Perform leak test before shipping first air-handling unit.
 - 4. Test results shall indicate that units comply with leakage requirements indicated. Make changes to noncompliant air-handling units and retest until units comply with requirements.
 - 5. Prepare test reports in accordance with ASHRAE 111.
 - 6. Submit test reports indicating test location, documentation of test equipment used, test procedures, test results, test date and time, and full names of personnel performing tests and witnesses. If multiple tests are required to achieve compliance for a single air-handling unit, report shall include test date and time, test results, and full names of personnel performing tests and witnesses of each test with a detailed description and photographs of interim corrective measures made before each retest.
- D. Casing Structural Deflection Test:
 - 1. Perform a structural deflection test for each assembled air-handling unit.
 - 2. Pressurize and load air-handling units to the performance criteria indicated for structural deflection. Test air-handling unit floors, walls and roofs.

3. Test results shall indicate that units comply with deflection requirements indicated. Make changes to noncompliant air-handling units and retest until units comply with requirements.
4. Submit test reports indicating test location, documentation of test equipment used, test procedures, test results, test date and time, and full names of personnel performing tests and witnesses. If multiple tests are required to achieve compliance for a single air-handling unit, report shall include test date and time, test results, and full names of personnel performing tests and witnesses of each test with a detailed description and photographs of interim corrective measures made before each retest.

E. Functional Run Test:

1. Run test each unit before shipment.
2. Test and balance fans to comply with vibration requirements indicated.
3. Energize each electrical device to ensure it is operational.
 - a. Take meter readings for volts, amperes, and kVAr on each phase leg of each motor.
 - b. Take meter readings for volts, amperes, and kVAr on each single-phase power connection to field power.
4. Exercise each damper to ensure proper operation.
5. Exercise each access door to ensure proper fit.
6. Exercise each valve to ensure proper operation.
7. Submit a written report for each unit tested. Written report shall include, at a minimum, full name of each person witnessing test, detailed list of each unit component tested, condition observed, and corrective action required. Each line item shall have full name of the person doing the checkout and date and time the checkout was performed.

F. Fan Vibration Test:

1. Perform a fan vibration test for each assembled air-handling unit.
2. Energize each fan within the air-handling unit after air-handling unit final assembly and perform a vibration analysis with fan operating at design speed and at all speeds throughout the range from design to minimum speed.
3. Three vibration measurements shall be taken for each bearing in horizontal, vertical, and axial directions. Vibration measurements shall be recorded and consist of vibration amplitude verses frequency with filter-in.
4. Fan bearing measurement points shall be marked or scribed on bearings for permanent record.

5. Test results shall indicate that units comply with vibration requirements indicated. Make changes to noncompliant air-handling units and retest until units comply with requirements.
6. Submit test reports indicating test location, documentation of test equipment used, test procedures, test results, test date and time, and full names of personnel performing tests and witnesses. If multiple tests are required to achieve compliance for a single air-handling unit, report shall include test date and time, test results, and full names of personnel performing tests and witnesses of each test with a detailed description and photographs of interim corrective measures made before each retest.

G. Acoustical Performance Test:

1. Perform an acoustical performance test for each assembled air-handling unit.
2. Air-handling unit acoustic performance shall be verified by factory test in accordance with AHRI 260 (I-P) or AHRI 261 (SI).
3. Air-handling unit supply-air discharge, return-air inlet, and casing radiated sound components shall be measured with air-handling unit operating at design conditions.
4. Testing Location: Perform testing in a location complying with AHRI 220, "Reverberation Room Qualification and Testing Procedures for Determining Sound Power of HVAC Equipment."
 - a. Test location shall be broadband qualified in accordance with AHRI 220 Section 5.1 and discrete frequency qualified in accordance with Section 5.2.
5. Operating conditions used in acoustic testing shall be verified by test in accordance with AMCA 210.
6. Test results shall indicate that units comply with acoustical requirements indicated. Make changes to noncompliant air-handling units and retest until units comply with requirements.
7. Submit test reports indicating test location, documentation of test equipment used, test procedures, test results, test date and time, and full names of personnel performing tests and witnesses. If multiple tests are required to achieve compliance for a single air-handling unit, report shall include test date and time, test results, and full names of personnel performing tests and witnesses of each test with a detailed description and photographs of interim corrective measures made before each retest.

H. Airflow Capacity Performance Test:

1. Perform an airflow capacity performance test for each assembled air-handling unit.
2. Operating conditions shall be verified by test in accordance with AMCA 210.

3. Test results shall indicate that units comply with design airflow requirements indicated. Make changes to noncompliant air-handling units and retest until units comply with requirements.
 4. Submit test reports indicating test location, documentation of test equipment used, test procedures, test results, test date and time, and full names of personnel performing tests and witnesses. If multiple tests are required to achieve compliance for a single air-handling unit, report shall include test date and time, test results, and full names of personnel performing tests and witnesses of each test with a detailed description and photographs of interim corrective measures made before each retest.
- I. Hydronic Piping Systems Testing: Pressure test factory-assembled piping systems with compressed air or water at a pressure to comply with governing codes and ASME B31.9, but not less than design pressure indicated.
1. Test results shall indicate that piping systems are without leaks. Make changes to noncompliant piping systems and retest until units comply with requirements.
 2. Submit test reports indicating test location, documentation of test equipment used, test procedures, test results, test date and time, and full names of personnel performing tests and witnesses. If multiple tests are required to achieve compliance for a single air-handling unit, report shall include test date and time, test results, and full names of personnel performing tests and witnesses of each test with a detailed description and photographs of interim corrective measures made before each retest.

2.41 SOURCE QUALITY CONTROL - OEM COMPONENT FACTORY TESTS

A. Air Blender Testing:

1. Owner-witnessed performance test to demonstrate compliance with performance requirements indicated.

B. Coil Testing:

1. Hydronic Coils: Factory tested with air while coil is completely submerged underwater to design pressure indicated, but not less than 300-psig internal pressure.
2. Coils to display a tag with inspector's identification as proof of testing.

C. Fan Vibration Testing:

1. Perform a fan vibration test for each fan.
2. Energize each fan after final assembly and perform a vibration analysis with fan operating at design speed and at all speeds throughout the range from design to minimum speed.

3. Three vibration measurements shall be taken for each bearing in the, vertical, and axial directions. Vibration measurements shall be recorded and consist of vibration amplitude verses frequency with filter-in.
4. Fan bearing measurement points shall be marked or scribed on bearings for permanent record.
5. Test results shall indicate units comply with vibration requirements indicated. Make changes to noncompliant fans and retest until fans comply with requirements.
6. Submit test reports indicating test location, documentation of test equipment used, test procedures, test results, test date and time, and full names of personnel performing tests and witnesses. If multiple tests are required to achieve compliance for a single fan, report shall include test date and time, test results, and full names of personnel performing tests and witnesses of each test with a detailed description and photographs of interim corrective measures made before each retest.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine air-handling units before installation. Reject units with physical damage, and air-handling unit components that are wet, moisture damaged, or mold damaged.
- C. Examine roughing-in for the following before installation of air-handling units:
 1. Structural substrate mounting and anchorage to verify actual sizes, types, and locations.
 2. Piping systems to verify actual sizes, types, and locations of connections.
 3. Ductwork and plenums to verify actual sizes, types, and locations of connections.
 4. Electrical services and controls to verify actual sizes, types, and locations of connections.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Equipment Mounting: Install air-handling units at locations indicated on Drawings. Unless, otherwise indicated on Drawings, install air-handling units on concrete equipment bases.
 1. Install air-handling units on curbs following air-handling unit manufacturer's written procedures.

- a. Install gaskets before setting air-handling units on curbs.
 - b. Secure air-handling units to curbs using stainless steel fasteners.
 - c. Install curb and fasten to structure.
 - d. Coordinate curb requirements, attachment, and location before installation.
- B. Roof Openings:
1. Provide exact size and location of roof openings to trade installing structural framing and roof structure.
 2. Supervise framing of openings to ensure coordinated installation with air-handling units.
- C. Equipment Clearances and Access:
1. Arrange installation of air-handling units to provide access space around air-handling units for service and maintenance and for removal and replacement of internal components.
 2. Provide clearance and access required by governing codes and NFPA 70.
 3. At a minimum, comply with requirements indicated on Drawings and air-handling unit manufacturer's written instructions.

3.3 PROTECTION DURING CONSTRUCTION

- A. Exterior Covers: Cover air-handling units during construction with sealed covers to protect air-handling unit casing and externally mounted components from physical damage, dirt, dust and debris, paint splatter, and any other construction materials.
1. Minor physical damage, as determined by Owner, shall be repaired by air-handling unit factory service personnel to factory-finished condition.
 2. Replace air-handling units with damage that in any way compromises the performance indicated.
- B. Internal Access: Keep access doors locked to maximum extent possible and restrict access to only authorized personnel.
1. Open access doors only during periods authorized work inside air-handling units is required.
 2. Coordinate and monitor work inside air-handling units on a shift basis. Lock access doors once work is complete or at the end of each shift.
 3. Immediately report unauthorized access and any observed damage to Owner.

3.4 DUCT CONNECTIONS

- A. Connect ducts and plenums to air-handling unit connections. Comply with requirements in Section 233113 "Metal Ducts."
- B. Connect ducts and plenums to air-handling unit connections with flexible connections. Comply with requirements in Section 233300 "Air Duct Accessories."
- C. Provide duct transitions required to make field connections to air-handling units.
- D. Arrange ducts and plenums to provide unobstructed access to inside of air-handling units.

3.5 PIPING CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to air-handling unit, provide unobstructed access to inside of air-handling units for service and maintenance.
- C. Connect piping to air-handling units with flexible connectors.
- D. Drain Pan Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping."
 - 1. Make connections to air-handling unit connections with flanges or unions.
 - 2. Extend drain piping from each air-handling unit connection to nearest equipment or floor drain and arrange piping to maintain clear service aisle paths free of potential tripping hazards.
 - 3. Construct traps near air-handling unit connections to seal airflow from escaping within air-handling unit. Locate traps in a serviceable location that is away from access doors.
 - 4. Install threaded cleanouts at changes in direction.
 - 5. Secure drain piping to structure.
- E. Air-Handling Unit Floor Drains: Do not require installation of permanent drain piping.
- F. Air-Handling Unit Floor Drain Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping."
 - 1. Make connections to air-handling unit connections with flanges or unions.
 - 2. Extend drain piping from each air-handling unit connection to nearest equipment or floor drain and arrange piping to maintain clear service aisle paths free of potential tripping hazards.

3. Construct traps near air-handling unit connections to seal airflow from escaping within air-handling unit. Locate traps in a serviceable location that is away from access doors.
 4. Install threaded cleanouts at changes in direction.
 5. Secure drain piping to structure.
- G. Chilled-and Hot-Water Coil Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties."
1. Comply with requirements indicated on Drawings.
 2. Make connections to coils with a flange or union.
 3. Connect to each coil inlet with shutoff valve, test plug, pressure gauge and thermometer.
 4. Connect to each coil outlet with balancing valve, test plug, pressure gauge thermometer flow meter and shutoff valve.
 5. Connect each coil drain connection with a drain valve, which is full size of drain connection.
 6. Connect each coil vent connection with automatic or manual vent, which is full size of vent connection.

3.6 ELECTRICAL CONNECTIONS

- A. Install field power to each air-handling unit electrical power connection. Coordinate with air-handling unit manufacturer and installers.
- B. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- C. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."
- D. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.
- E. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.
 1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."

3.7 CONTROL CONNECTIONS

- A. Install control and electrical power wiring to field-mounted control devices.

- B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."
- C. Install nameplate for each control connection, indicating field control panel designation and I/O control designation feeding connection.
 - 1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."

3.8 STARTUP SERVICE

- A. Engage an air-handling unit factory-authorized service representative to perform startup service.
 - 1. Complete installation and startup checks in accordance with manufacturer's written instructions.
 - 2. Verify that shipping, blocking, and bracing are removed.
 - 3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, controls, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
 - 4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
 - 5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
 - 6. Verify that face-and-bypass dampers provide full face flow.
 - 7. Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.
 - 8. Comb coil fins for parallel orientation.
 - 9. Verify that proper thermal-overload protection is installed for electric heaters.
 - 10. Install new, clean filters.
 - 11. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.
- B. Starting procedures for air-handling units include the following:
 - 1. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm. Replace fan and motor pulleys as required to achieve design conditions.
 - 2. Measure and record motor electrical values for voltage and amperage.

3. Manually operate dampers from fully closed to fully open position and record fan performance.

3.9 ADJUSTING

- A. Adjust damper linkages for proper damper operation.
- A. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.
- B. Before turning equipment over to Owner for use, adjust air-handling unit components that require further adjustment for proper operation. Consult air-handling unit manufacturer for instruction.
- C. Occupancy Adjustments: When requested within 12 months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.
- D. Seasonal Adjustments: Make seasonal visits during warranty period to inspect and review operation of equipment. Make necessary adjustments for components observed to require adjustments for proper operation. Prepare and submit a report to Owner documenting each visit, observations, and any adjustments made.

3.10 CLEANING

- A. Cleaning Schedule: After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems, and after completing startup service, and immediately before Owner use, clean air-handling units to remove foreign material and construction dirt and dust.
- B. Unit Interior: Clean air-handling units internally to factory clean condition. Remove foreign material and construction debris, dirt, and dust.
 1. Vacuum clean with HEPA-filtered vacuum and then wipe down with cleaning solution.
 2. Clean casing floors, roofs, wall surfaces, access doors, and panels.
 3. Clean all internal components, such as, coils, dampers, filter frames, fans, and motors.
 4. Clean light fixtures and control devices.
- C. Unit Exterior: Clean external surfaces of air-handling units to factory clean condition. Remove foreign material and construction debris, dirt and dust. Vacuum clean with HEPA-filtered vacuum and then wipe down all surfaces with cleaning solution.
- D. Cleaning Materials: Use cleaning materials and products recommended in writing by air-handling unit manufacturer.

- E. Acceptance: Following unit cleaning submit a written request for review and Owner acceptance.

3.11 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory service representative to test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform the following tests and inspections with the assistance of a factory-authorized service representative.
 - 1. After field piping connections are complete, test hydronic coils and connections for leaks.
 - 2. Charge refrigerant coils with refrigerant and test for leaks.
 - 3. Field-Assembly Supervision: Instruct Installer and supervise field installation of first air-handling unit(s) shipped in multiple pieces for field assembly.
 - 4. Roof-Mounted Field-Installation Supervision: Instruct Installer and supervise field installation of first roof-mounted air-handling unit(s).
 - 5. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 6. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- D. Field Casing Leakage Test:
 - 1. Perform leak testing of air-handling units that include field assembly of multiple sections. Air-handling units that are shipped and installed as a single piece do not require field testing.
 - 2. Leak test one air-handling unit(s) of each unique size and arrangement randomly selected by Commissioning Agent.
 - 3. Follow procedures complying with ASHRAE 111.
 - 4. Assembled air-handling units shall satisfy leakage criteria indicated. Modify air-handling units that fail to satisfy criteria and retest. For every air-handling unit that fails test, another air-handling unit shall be tested until all air-handling units tested pass leakage criteria on first attempt.
 - 5. Submit a test report for each test indicating test equipment, procedures, results, date and time, and full name of personnel performing tests and witnesses.
 - 6. Test report shall be in accordance with ASHRAE 111.

7. Witness Testing:
 - a. Provide written notification at least 30 business days in advance of testing.
 - b. Testing shall be conducted in presence of testing and balancing agent.
 - c. Other parties such as Architect, Commissioning Agent, and Owner shall be invited to witness testing with attendance being optional.

E. Field Fan Vibration Test:

1. Perform fan vibration testing for every one out of 10 air-handling unit fans randomly selected by Architect.
2. Test after air-handling unit installation is complete.
3. Three vibration readings shall be taken for each bearing in horizontal, vertical, and axial directions. Record each reading including vibration amplitude verses frequency.
4. Modify fans that fail to satisfy performance criteria and retest. For every fan that fails test, another fan shall be tested until all fans tested pass criteria on first attempt.
5. Submit a report for each fan tested indicating air-handling unit designation, fan designation, test equipment, procedures, results, date and time, and full name of personnel performing tests and witnesses.
6. Witness Testing:
 - a. Provide written notification at least 30 business days in advance of testing.
 - b. Testing shall be conducted in presence of testing and balancing agent.
 - c. Other parties such as Commissioning Agent, Architect, and Owner shall be invited to witness testing with attendance being optional.

F. Air-handling unit or components will be considered defective if unit or components do not pass tests and inspections.

G. Prepare test and inspection reports.

3.12 OPERATION DURING CONSTRUCTION

A. Operation of air-handling units for temporary cooling, heating, and ventilation is not allowed without Owner authorization.

1. Submit written request for Owner approval by signature with detailed description of operating procedures to be followed including, but not limited to, the following:
 - a. Description of construction activities while units are operating.

- b. Operation:
 - 1) Beginning and ending calendar dates.
 - 2) List each day during week.
 - 3) List start and stop time and hours for each day.
 - c. Startup procedures and shut-down procedures.
 - d. Provisions for routine monitoring of unit operation.
 - e. Provisions to prevent and protect against damage to equipment due to adverse operation such as, low temperature, high temperature, over pressure, fire, smoke, electrical over- and undervoltage and current and electrical fault.
 - f. Provisions and safeguards for filtration to keep inside of units from getting dirty.
 - g. Record keeping.
- 2. If approved by Owner, units used for temporary cooling, heating, and ventilation during and before interior finish work is complete shall include an unconditional complete unit labor and parts warranty to extend at least two years after the warranty indicated expires.
 - 3. Interior and exterior of air-handling units shall be cleaned to a factory-cleaned condition and clean condition must be accepted by Owner.
- B. Filtration During Temporary Use:
- 1. Protect air-handling system ducts (exhaust air, outdoor air, and return air) with temporary filters installed and supported to prevent filter media from collapse and bypass of unfiltered air. Temporary media shall be installed at each inlet and shall have a published filtration efficiency of MERV 8 in accordance with ASHRAE 52.2.
 - 2. Protect air-handling units with open inlets that are not ducted with temporary filters installed and supported to prevent filter media from collapse and by-pass of unfiltered air. Temporary media shall be installed at each inlet and shall have a published filtration efficiency of MERV 8 in accordance with ASHRAE 52.2.
 - 3. Do not operate air-handling units until both temporary and scheduled permanent air-handling unit particulate filters are in place. Temporary filters must be installed upstream of permanent filters while units are operating.
 - 4. Replace temporary and permanent filters used during construction when dirty. After end of temporary use, replace permanent filters with new, clean filters before beginning testing, adjusting and balancing.
- C. Comply with SMACNA 008, "IAQ Guidelines for Occupied Buildings under Construction," for procedures to protect HVAC system.

3.13 DEMONSTRATION

- A. Engage air-handling unit manufacturer employed training instructor or factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain air-handling units.
- B. Training shall include, but not be limited to, procedures and schedules related to performance, safety, startup and shut down, troubleshooting, servicing, preventive maintenance, and how to obtain replacement parts.
 - 1. Access Doors: Adjustment, gasket removal and replacement, handle removal and replacement, and spare parts.
 - 2. Access Panels: Removal and replacement, adjustment, gasket removal and replacement, and spare parts.
 - 3. Air Blenders: Cleaning, operation, removal, and replacement.
 - 4. Coils: Cleaning, combing fins, draining, venting, removal, and replacement.
 - 5. Controls: Calibration, cleaning, operation, service, removal and replacement, and spare parts.
 - 6. Damper Assemblies: Cleaning, operation, service, removal and replacement, and spare parts.
 - 7. Drain Pans: Cleaning, removal, and replacement.
 - 8. Fan and Motor Assemblies: Cleaning, operation, removal and replacement, service, and spare parts.
 - 9. Filters: Operation, removal and replacement, frame gasket removal and replacement, clip removal and replacement, and spare parts.
 - 10. Fixed Plate heat Exchangers: Cleaning, removal, and replacement.
 - 11. Lights, Receptacles and Switches: Cleaning, operation, service, removal and replacement, and spare parts.
- C. Instructor:
 - 1. Instructor shall be factory trained and certified by air-handling unit manufacturer with current training on equipment installed.
 - 2. Instructor's credentials shall be submitted for review by Architect before scheduling training.
 - 3. Instructor(s) primary job responsibility shall be Owner training.
 - 4. Instructor(s) shall have not less than three years of training experience with air-handling unit manufacturer and past training experience on at least three projects of comparable size and complexity.

- D. Schedule and Duration:
1. Schedule training with Owner at least 20 business days before first training session.
 2. Training shall occur before Owner occupancy.
 3. Training shall be held at mutually agreed date and time during normal business hours.
 4. Each training day shall not exceed eight hours of training. Daily training schedule shall allow time for a one-hour lunch period and 15-minute break after every two hours of training.
 5. Perform not less than eight hours of training.
- E. Location: Owner to provide a suitable on-site location to host classroom training.
- F. Training Attendees: Assume three people.
- G. Training Attendance Records: For record purposes, document training attendees at start of each new training session. Record date, time, brief description of training covered during the session, attendee's name, signature, phone number, and e-mail address. Submit scanned copy of sign-in sheet to Owner for each training session.
- H. Training Format: Individual training modules to include classroom training followed by hands-on field demonstration and training.
- I. Training Materials: Provide training materials in electronic format to each attendee.
1. Include instructional videos showing general operation and maintenance that are coordinated with operation and maintenance manuals.
- J. Training Video Recording: Video record each classroom training session and submit an electronic copy to Owner before requesting Owner acceptance of training.
- K. Written Acceptance: Obtain Owner written acceptance that training is complete and requirements indicated have been satisfied.

END OF SECTION 23 73 43.19