SECTION 230513 - COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

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 general requirements for single-phase and polyphase, general-purpose, horizontal, small and medium, squirrel-cage induction motors for use on ac power systems up to 600 V and installed at equipment manufacturer's factory or shipped separately by equipment manufacturer for field installation.

1.3 COORDINATION

A. Coordinate features of motors, installed units, and accessory devices to be compatible with the following:

1. Motor controllers.
2. Torque, speed, and horsepower requirements of the load.
3. Ratings and characteristics of supply circuit and required control sequence.
4. Ambient and environmental conditions of installation location.

PART 2 - PRODUCTS

2.1 GENERAL MOTOR REQUIREMENTS

A. Comply with NEMA MG 1 unless otherwise indicated.

B. Comply with IEEE 841 for severe-duty motors.

2.2 MOTOR CHARACTERISTICS

A. Duty: Continuous duty at ambient temperature of 40 deg C and at altitude of 3300 feet above sea level.

B. 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.

2.3 POLYPHASE MOTORS

A. Description: NEMA MG 1, Design B, medium induction motor.

B. Efficiency: Energy efficient, as defined in NEMA MG 1.

C. Service Factor: 1.15.

D. Multispeed Motors: Variable torque.

1. For motors with 2:1 speed ratio, consequent pole, single winding.
2. For motors with other than 2:1 speed ratio, separate winding for each speed.

E. Multispeed Motors: Separate winding for each speed.

F. Rotor: Random-wound, squirrel cage.

G. Bearings: Regreasable, shielded, antifriction ball bearings suitable for radial and thrust loading.

H. Temperature Rise: Match insulation rating.

I. Insulation: Class F.

J. Code Letter Designation:

1. Motors 15 HP and Larger: NEMA starting Code F or Code G.
2. Motors Smaller than 15 HP: Manufacturer's standard starting characteristic.

K. Enclosure Material: Cast iron for motor frame sizes 7.5HP and larger; rolled steel for motor frame sizes smaller than 7.5HP.

2.4 POLYPHASE MOTORS WITH ADDITIONAL REQUIREMENTS

A. Motors Used with Reduced-Voltage and Multispeed Controllers: Match wiring connection requirements for controller with required motor leads. Provide terminals in motor terminal box, suited to control method.

B. Motors Used with Variable Frequency Controllers: Ratings, characteristics, and features coordinated with and approved by controller manufacturer.

1. Windings: Copper magnet wire with moisture-resistant insulation varnish, designed and tested to resist transient spikes, high frequencies, and short time rise pulses produced by pulse-width modulated inverters.
2. Energy- and Premium-Efficient Motors: Class B temperature rise; Class F insulation.
3. Inverter-Duty Motors: Class F temperature rise; Class H insulation.
4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.

C. Source Quality Control for Field-Installed Motors: Perform the following tests on each motor according to NEMA MG 1:
1. Measure winding resistance.
2. Read no-load current and speed at rated voltage and frequency.
3. Measure locked rotor current at rated frequency.
4. Perform high-potential test.

D. Source Quality Control for Field-Installed Motors: Perform the following tests on each motor according to NEMA MG 1:
1. Measure winding resistance.

2. Read no-load current and speed at rated voltage and frequency.
3. Measure locked rotor current at rated frequency.
4. Perform high-potential test.

E. Severe-Duty Motors: Comply with IEEE 841, with 1.15 minimum service factor.

2.5 SINGLE-PHASE MOTORS

A. Motors larger than 1/20 hp shall be one of the following, to suit starting torque and requirements of specific motor application:

1. Permanent-split capacitor.
2. Split phase.
3. Capacitor start, inductor run.
4. Capacitor start, capacitor run.

B. Multispeed Motors: Variable-torque, permanent-split-capacitor type.

C. Bearings: Prelubricated, antifriction ball bearings or sleeve bearings suitable for radial and thrust loading.

D. Motors 1/20 HP and Smaller: Shaded-pole type.

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

PART 3 - EXECUTION (Not Applicable)

END OF SECTION 230513

SECTION 230548 - MECHANICAL SOUND AND VIBRATION CONTROL AND SEISMIC RESTRAINTS

PART 1 - GENERAL

1.1 DESCRIPTION

A. Vibration isolation for all rotating equipment, inertia bases, and equipment support frames.

B. Vibration isolation for piping and ductwork, including resilient attachments.

C. Supervision and inspection of installed vibration isolation hardware.

D. The contractor is responsible for selecting, engineering, and incorporating all bracing, anchorage and seismic restraints. Such restraints shall not reduce the vibration isolation capabilities of the system.

1.2 QUALITY ASSURANCE

A. Design Criteria:

1. Vibration Isolation: Provide isolation to avoid excessive noise or vibration in the building due to the operation of machinery or equipment, or due to interconnected piping, ductwork or conduit.

B. Testing Laboratory:

1. Testing Laboratory will test expansion bolts as specified in Section 055000.

C. Reference Standards:

1. SMACNA - Sheet Metal and Air Conditioning Contractors National Association. "Guidelines for Seismic Restraints of Mechanical Systems and Plumbing Piping Systems"

2. Codes and Standards for Noise Control:

a. ADC 1062R-4 Air Diffusion Council: Certification Rating and Test Manual

b. ANSI S1.13 American National Standards Institute: Measurement of Sound Pressure Levels

c. ARI 575 American Refrigeration Institute: Measurement of Sound in Equipment Rooms

d. ARI 443 American Refrigeration Institute: Standard of Sound Rating of Fan Coil Air Conditioners

e. ASHRAE 36-72 American Society of Heating, Refrigeration and Air Conditioning Engineers: Determination of Ventilating Equipment Sound Power.

f. AMCA 300 Air Moving and Control Association: Determination of Fan Sound Power Levels

g. ASTM E477 American Society for Testing and Materials: Test of Duct Lining and Silencer Performance

h. ASTM C423 American Society for Testing and Materials: Method for Measuring Sound Absorption

i. ASTM E90 American Society of Testing and Materials: Method for Measuring Sound Transmission Loss

j. ASTM E413 American Society of Testing and Materials: Determination of Sound Transmission Class

k. SMACNA Sheet Metal and Air Conditioning Contractors National Association

D. Acoustical Testing/Quality Assurance:

1. The contractor shall cooperate with regard to sound tests (ARI 575, ANSI S1.13) which may be conducted by the Owner or his representative to verify that noise criteria are met.

2. The contractor shall notify the Architect of any changes which will affect the acoustical performance.

3. All vibration isolation apparatus shall be by one manufacturer who has supplied vibration isolation equipment for at least 5 years.

1.3 DESIGN RESPONSIBILITY

A. Design support and anchorage systems in accordance with procedures indicated herein and in Section 055000.

1.4 SUBMITTALS

A. Submit product data for all vibration isolation components

B. Flexible Pipe Connectors: Indicate maximum temperature and pressure rating, face-to-face length, live length, hose wall thickness, hose convolutions per foot and per assembly, fundamental frequency of assembly, braid structure, and total number of wires in braid.

C. Indicate inertia base on shop drawings.

D. Submit, in drawing plan form, exact location and weight at each support point for floor mounted and suspended equipment and piping in mechanical rooms and fan rooms. Drawing shall include HVAC, and plumbing supports.

E. For each isolator, submit calculations to substantiate the size; quantity, location and connection to structure; complete manufacturer's description; actual loading at each isolator for floor mounted and suspended equipment and piping in mechanical and fan rooms, static deflection, spring outside diameters; and free, operating and solid heights of coils.

F. Submit vibration isolation for all equipment in one package, not as part of equipment submittals. All isolators to be of one manufacturer.

G. Submit record drawings that reflect actual conditions.

1.5 OPERATION AND MAINTENANCE DATA

A. Submit under provision of General Conditions and Division 1 as applicable.

B. Maintenance Data: Include adjustment instructions.

C. Submit manufacturer's installation instructions.

1.6 CERTIFICATES

A. Submit manufacturer's certificate that isolators are properly installed and properly adjusted to meet or exceed indicated requirements.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Acceptable Manufacturers:

a. Mason Industries, Inc

b. Kinetics Noise Control

c. Vibration Mountings and Controls

B. General

1. Isolators shall be selected by the supplier, even if sizing is shown. Size vibration isolators on single piece of equipment for equal static deflections based on actual static and dynamic weight distribution per point of support furnished by equipment manufacturer. Dynamic loads include those due to wind, fluid flow, thrust and rotations inertial. Select each isolator independently for the load distribution on the equipment base, duct or pipe support.

2. In determining weight of equipment, include concrete inertia bases, grout filled pump bases, etc., where relevant.

3. All static deflections are nominal. Actual installed deflections shall be +15 percent of the specified value. Where static deflections are not specified, provide minimum 2 inch deflection for rotating and reciprocating equipment.

4. Use as few isolators on equipment as practical. For example, 4 isolators on small equipment and inertia bases.

5. Vibration isolators shall have either known height without a load or other markings so that after adjustment, when fully loaded, the deflection can be verified.

6. Incorporate a resilient neoprene element of 1/4-inch minimum thickness on spring hangers to prevent solid contact between the spring and isolator housing.

7. Install thrust restraints on fans over 3 inches wg static pressure with the same deflection as isolators supporting the fan.

8. All spring isolators laterally stable with leveling bolts. Spring isolators minimum additional "travel" to full compression of half the rated deflection. The ratio of lateral to vertical stiffness shall be 0.9 minimum and 1.5 maximum.

9. Provide all floor-mounted spring isolators with mounting base plates that provide for bolting to the floor and incorporate 1/2-inch thick neoprene bearing pads.

10. Provide EPDM or equal elastomeric elements in place of neoprene on all vibration isolators installed outdoors.

11. Provide neoprene material with anti-ozone and anti-oxidant additives.

12. Supply all miscellaneous steel to make support compatible with equipment.

13. Mount motors on rigid base common with equipment or supported from equipment frame.

14. Snubbers shall not limit vibration isolation capability during normal operation. Where steel limit stops are used, provide 3/4-inch thick neoprene to prevent metal-to-metal impact.

15. Vibration isolation manufacturer's representative shall supervise and inspect all installed isolation hardware and generate punchlist for the Construction Manager, along with corrective measures required. Submit inspection report.

C. Description

1. Isolator types: Type of mounting and supporting base and minimum static deflection, as scheduled and required. Mason model numbers used.

2. Base mounts:

a. **Type SLR**: restrained mountings with removable steel spacers.

b. **Type NP**: Neoprene pad. Waffle, ribbed, or other forms. Typically 3/4-inch thick. Durometers of 40 to 50. Static deflections from 0.125 inch. Provide steel load distribution plates. Size of pad to be specified by isolator supplier based on load per point. Provide grommetted bolt when anchoring. Mason "Super" W and WM.

c. **Type NM**: Neoprene mounts. Molded one-piece assemblies with skid resistant base plates and mounting holes. Double deflection type with static deflection range from 0.3 to 0.5 inch. Coat metal surfaces with neoprene to prevent corrosion. Provide friction pad. Mason ND.

d. **Type USM**: Unhoused spring mounts. Single or multiple bare steel springs, baseplates with neoprene pad. Height saving mounting brackets where applicable, height adjustment bolts. Static deflection range from 1.0 to 5.0 inches nominal. Mason SLF.

e. **Type SSM**: Seismic spring mounts. Single spring, leveling device, maximum 1/4-inch travel. Spring diameters no less than 0.8 of compressed height of spring at rated load. Minimum additional travel to solid equal to 50 percent of rated deflection. Spring inspection ports. Static deflection range from 1.0 to 5.0 inches nominal. Withstand 1.0G acceleration in all directions. Mason SSLR.

3. Hangers:

a. **Type NH:** Neoprene hangers. Molded neoprene units in a steel hanger frame. Double deflection types with static deflection range from 0.3 to 0.5 inch. Designed to preclude contact of hanger rods with frame (30 degrees misalignment). Insert neoprene bushing where rod passes through housing. Mason HD.

b. **Type SH:** Hanger containing spring in series with deflected neoprene element, load transfer. Same as Type NH with yoke assembly and indicator for load transfer seat spring

in neoprene cup with washer to distribute load evenly to cup and to prevent spring-to-casing contact. Mason ~~PC~~ 30N.

4. Seismic Snubbers:

   a. **Type SS**: All-directional seismic snubber. Mason Z-1225, or equal.

5. Risers:

   a. **Type RC**: Vertical riser piping support/suspension. . Single point of support desired. Multiple points of support acceptable, but must be engineered, complete with detailed installation and adjustment instructions by supplier.

   b. **Type DS**: Vertical duct risers in shafts.

   c. **Type RG**: Provide all-directional, resiliently supported vertical riser piping support/suspension from structure. Single point of support desired. Multiple points of support acceptable, but must be engineered, complete with detailed installation and adjustment instructions by supplier. Resilient anchors to preclude direct contact of piping with structure, yet provide a neutral point for expansion/contraction or piping. Neoprene element to be no less than 0.50" thick. Mason ADA or VSG.

6. Resilient attachments:

   a. **Type RA-1**: 3/4-inch nominal thickness resilient pipe sleeve between pipe and clamp or hanger.

      1) Operating temperature at or below 80 degrees F, except in plenums: Armstrong Armaflex, Manville Aerotube or approved equal.

      2) Operating temperature above 80 degrees F or in plenums: preformed glass fiber pipe insulation not exceeding 6 pcf.

   b. **Type RA-2**: Manufactured insulated hanger for uninsulated pipe: Superstrut P/A-716 Cush-A-Clamp, Unistrut, B-line or approved equal.

   c. **Type RA-3**: Manufacturer resilient attachment for water pipes
   1 inch and less diameter: Technical Specialties Acousto-Plumb System (orange and blue).

7. Other Supports:

   a. **Type T**: Trapeze. Supporting sling of steel member with vibration isolation mount or hangers at each end. Used to distribute load or to conserve space.

   b. **Type S:** Stanchion support. A supporting arm or system for equipment or piping between the isolator and load.

   c. Type "cable" seismic restraints shall be constructed of 7 x 19 strand galvanized aircraft cable. Cable assembly shall come compete with two "U" bolt clamps per end. Allowed loads shall contain a safety factor of three when worse-case loading applied to one cable. Cable shall be installed with 1/4-inch slack to prevent the transmission of vibration to the structure.

8. Bases:

a. **Type SF**: Structural steel integral frame of wide flange (W) or junior beam (M) members. Rigid fabrication to preclude deflections or frame distortion under dynamic load. Motor mounts, base plate mounts, stanchion support for piping or as shown on Drawings for equipment, pumps, fans, etc. Brackets to prevent drop of frame more than 3/8-inch. Thickness: minimum 8 percent longest dimension. Mason WFSL.

b. **Type B**: Brackets to equipment. Height saving brackets attached directly to equipment where rigidity of same does not require supplemental frame. Drop protection as for Type SF. Mason.

c. **Type IB**: Inertia base frame. Welded steel frame with rebar reinforcement and height saving brackets. Provision for air decoupling holes on large units. Unit delivered ready for assembly. Preset equipment mount attachment bolts or other hold down methods for equipment involved. Space between bottom of base and floor to be at least 2 inches. Minimum weight equal to one to two times weight of equipment or as noted. Thickness minimum 8 percent largest dimension. Mason KSL.

9. Concrete Inertia Bases

a. Pumps (and other highly unbalanced equipment such as slow speed horizontal and vertical air compressors) shall be mounted on isolated concrete inertia bases. Vibration isolator manufacturer shall furnish rectangular structural beam or channel concrete forms for floating foundations. Bases for pumps shall be large enough to provide support for suction and discharge base ells. The base depth need not exceed 12" unless specifically recommended by the base manufacturer for mass or rigidity. In general, base depth shall be a minimum of 1/12th of the longest dimension of the base, but not less than 6". Forms shall include minimum concrete reinforcement consisting of half-inch bars or angles welded in place on 6" centers running both ways in a layer 1-1/2" above the bottom, or additional steel members to hold anchor-bolt sleeves when the anchor bolts fall in concrete locations. Height saving brackets shall be employed in all mounting locations to maintain a 1" clearance below the base. Bases shall be type K as manufactured by Mason Industries, Inc.

10. Flexible Connections

a. Pipework flexible connections shall be manufactured of multiple plies of nylon tire cord fabric and neoprene both molded and cured in hydraulic rubber presses. No steel wire or rings shall be used as pressure reinforcement. Straight connectors shall have two spheres. Connectors up to and including 1-1/2" diameter may have threaded ends. Connectors 2" and larger shall be manufactured with floating galvanized flanges recessed to lock the connector's raised face neoprene flanges. Hoses shall be installed on the equipment side of the shut valves.

b. Connectors shall be rated a minimum of 150 psi at 220ºF.

c. Elbows shall be Mason-Flex type MFNEC, straight connectors Mason-Flex type MFTFU or MFTNC, and control cable assemblies type ACC, all as manufactured by Mason Industries, Inc.

d. Where system pressure and temperature exclude the use of rubber flexible connections, use flexible metallic hose. Flexible metallic hose shall have stainless steel braid and carbon steel fittings. Sizes 3" and larger shall be flanged. Smaller sizes shall have male nipples. Lengths shall be as tabulated:

Male Nipples		Flanged	
1/2 x 9	1-1/2 x 13	3 x 14	10 x 26
3/4 x 10	2 x 14	4 x 14	12 x 28
1 x 11	2-1/2" x 18	5 x 19	14 x 30
1-1/4 x 12		6 x 20	16 x 32
		8 x 22	

D. Electrical Connections to Resiliently Mounted Equipment

1. Make electrical connections to equipment which is supported or suspended by vibration isolators with long lengths of flexible steel conduit (no less than 24”), depending on environment. Locate these flexible connections so as to prevent rigid connections between the resiliently mounted equipment and the building structure.

E. Services Penetrations (Mechanical, Electrical, Plumbing) of acoustical partitions:

1. Penetrations - Ductwork: Where ductwork penetrates acoustical partitions, create an acoustic seal around the ducts. The gap between the duct and the surrounding partition shall not exceed 1/2 inch. Pack the gap with fiberglass and cover the entire joint with an 18 gauge (1.3mm) metal angle or 5/8 inch gypsum board cover plate. Fully bed the angle or cover plate in acoustical sealant.

2. Penetrations - Pipework: Where pipework penetrates acoustical partitions, create an acoustic seal around the pipes. Insert a flanged pipe sleeve and seal the pipe sleeve into the partition with acoustic sealant. The gap between the pipe and the pipe sleeve shall not exceed 1/2 inch. Pack the gap with fiberglass and cover the entire joint with an 18 gauge metal flange or 5/8 inch gypsum board cover plate. Fully bed the flange or cover plate in mastic.

3. Electrical Box Sealant: Backs of electrical boxes, light fittings etc., in acoustically rated constructions shall be sealed airtight by sheet caulking. Caulking shall be pliable putty-like pads 1/4 inch thick. Manufacturer Harry Lowry and Associates Sun Valley California. (Alternate manufacturer Nelson Electric).

4. Refer to the architectural drawings for locations of acoustical partitions.

F. Expansion Bolts: As specified in Section 055000.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General:

1. Install vibration isolation equipment in full accordance with the manufacturer's instructions.

2. Suspend the vibration isolators supporting piping ductwork and equipment from structural members.

3. Provide a minimum of 1 inch clearance between the building structure and vibration isolated supports, ducts, pipes, and equipment.

4. Provide 2 inch minimum clearance between the top of the housekeeping pad or floor and the underside of concrete inertial pads and/or steel equipment support frames.

5. Fasten all vibration isolators to the structure, not to floor diaphragms or lightweight components. Use bolts where holes are provided in the mounting flanges; otherwise, adhere using structural adhesive. Where mounting flanges are steel, use neoprene grommets and washers under anchor bolts. Where vibrating elements are to be fastened to structural elements provide connection details for review by Architect.

6. Do not use vibration isolation components to straighten or connect misaligned sections of piping or ductwork.

7. Align spring isolation hanger rods to clear the hanger box under all operating conditions.

8. Any bracing or supports for mechanical ductwork, piping, and equipment shall not bridge or reduce the effectiveness of vibration isolators.

9. Level vibration isolated equipment under rated design operating conditions while maintaining the isolation criteria. Isolators shall be plumb and aligned to preclude misalignment or undesired contact during operation.

B. Vibration Isolation Schedule:

Equipment	Deflection	Isolator Class
Air handling unit fans (internal isolation)	2.0"	USM
Air handling units (typical external isolation)	0.125”	NP
Boiler	0.75”	SLR
Chillers	0.75”	SLR
Cooling Towers	2.5”	SLR
Fans	2.0"	SH or USM
Base-mounted pumps and compressors, 5 hp and larger (provide inertia base)	2.0”	IB
Base-mounted pumps and compressors less than 5 hp	0.25"	NM
Other small pumps and motors (incl. inline pumps)	0.25	NM
Wall and exhaust fans less than ¼ hp	0.25”	NH or NM
All process and passive equipment attached to pump systems	0.25”	NM, SF
All Level B and Penthouse piping	Same as attached equipment	
(but not less than the first 50-ft from rotating and reciprocating equipment)		
Piping Risers		RG
Transformers	0.25”	NM

C. Piping and Ductwork:

1. All piping within Level B and the mechanical Penthouse, but not less than 50-ft from all rotating and reciprocating equipment shall be vibration isolated. Isolation devices shall be equivalent to that scheduled for the associated equipment.

2. All piping within the building, larger than 2” shall be vibration isolated from the structure using neoprene mounts or hangers, type NH / NM.

3. All piping less than 2” shall be vibration isolated using a resilient attachment, type RA-3.

4. Use trapezes for vertical support to horizontal piping only. Brace trapeze with an OSHPD pre-approved bracing system, or provide calculations demonstrating compliance with regulatory requirements.

5. No electrical conduit, fixture, ceiling suspension wires or other elements of the building construction attached to or abutted against the duct and piping systems.

6. Where ducts or piping penetrate walls, ceilings and floors of the occupied spaces, or ceiling void partitions or acoustically rated elements whether shown on the drawings or not, acoustically seal the penetration. See detail specified herein.

7. Contain rough-in of piping within stud wall cavities no less than 1/4-inch from the plane of the studs and 1 inch from gypsum board or other wall sheathing.

8. Install flexible connections at all connections to vibration isolated equipment, rotating, reciprocating and other vibrating equipment, and all pumps, whether isolated or not and at all air handlers whether internally isolated or not.

9. Vibration isolate all pipes except vents, gas and fire protection lines. Do not allow piping, plumbing or vent stacks to contact gypsum board.

10. Do not suspend plumbing or piping from ducts, conduits or related supports.

11. Provide flexible connectors in inlet and discharge piping systems for pumps having concrete inertial bases and where indicated on the Drawings.

12. Sheet metal band supports are not permitted on ducts suspended on vibration isolators. Use threaded rods, or other indicated support.

13. Do not suspend ducts from piping, plumbing, conduits or related supports.

14. Incorporate flexible connections in ductwork adjacent to all air moving units.

15. When equipment is in full operational condition, adjust the mounts to ensure that the equipment is free floating, level and stable.

16. All equipment mounted on anti vibration mounts shall be connected to the adjacent ductwork or pipework system via a flexible connection positioned to avoid a direct connection between equipment and mounting surface.

17. Flanged equipment shall be directly connected to neoprene elbows in the size range 2-1/2" through 12" if the piping makes a 90º turn at the equipment. All straight through connections shall be made with twin-spheres properly pre-extended as recommended by the manufacturer to prevent additional elongation under pressure, 12" and larger sizes operating above 100 psi shall employ control cables with end fittings isolated by means of 1/2" thick bridge bearing neoprene washer bushings designed for maximum of 1000 psi.

END OF SECTION 230548

SECTION 230553 - IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Equipment labels.
2. Warning signs and labels.
3. Pipe labels.
4. Duct labels.
5. Stencils.
6. Valve tags.
7. Warning tags.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

B. Samples: For color, letter style, and graphic representation required for each identification material and device.

C. Equipment Label Schedule: Include a listing of all equipment to be labeled with the proposed content for each label.

D. Valve numbering scheme.

E. Valve Schedules: For each piping system to include in maintenance manuals.

1.4 COORDINATION

A. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.

B. Coordinate installation of identifying devices with locations of access panels and doors.

C. Install identifying devices before installing acoustical ceilings and similar concealment.

PART 2 - PRODUCTS

2.1 EQUIPMENT LABELS

A. Plastic Labels for Equipment:

1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/16 inch or 1/8 inch thick, and having predrilled holes for attachment hardware.
2. Letter Color: Black.
3. Background Color: White.
4. Maximum Temperature: Able to withstand temperatures up to 160 deg F.
5. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
6. Minimum Letter Size: 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
7. Fasteners: Stainless-steel rivets or self-tapping screws.
8. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

B. Label Content: Include equipment's Drawing designation or unique equipment number, Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Specification Section number and title where equipment is specified.

C. Equipment Label Schedule: For each item of equipment to be labeled, on 8-1/2-by-11-inch (A4) bond paper. Tabulate equipment identification number and identify Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Specification Section number and title where equipment is specified. Equipment schedule shall be included in operation and maintenance data.

2.2 WARNING SIGNS AND LABELS

A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/16 inch or 1/8 inch thick, and having predrilled holes for attachment hardware.

B. Letter Color: White.

C. Background Color: Red.

D. Maximum Temperature: Able to withstand temperatures up to 160 deg F.

E. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.

F. Minimum Letter Size: 1/2 inch (13 mm) for viewing distances up to 72 inches (1830 mm), and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

G. Fasteners: Stainless-steel rivets or self-tapping screws.

H. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

I. Label Content: Include caution and warning information, plus emergency notification instructions.

2.3 PIPE LABELS (NOT USED)

2.4 DUCT LABELS

A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/16 inch (1.6 mm)> thick, and having predrilled holes for attachment hardware.

B. Letter Color: Black.

C. Background Color: Yellow.

D. Maximum Temperature: Able to withstand temperatures up to 160 deg F.

E. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.

F. Minimum Letter Size: 1/2 inch for viewing distances up to 72 inches and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

G. Fasteners: Stainless-steel rivets or self-tapping screws.

H. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

I. Duct Label Contents: Include identification of duct service using same designations or abbreviations as used on Drawings, duct size, and an arrow indicating flow direction.

1. Flow-Direction Arrows: Integral with duct system service lettering to accommodate both directions or as separate unit on each duct label to indicate flow direction.
2. Lettering Size: At least 1-1/2 inches high.

2.5 VALVE TAGS (NOT USED)

2.6 WARNING TAGS

A. Warning Tags: Preprinted or partially preprinted, accident-prevention tags, of plasticized card stock with matte finish suitable for writing.

1. Size: Approximately 4 by 7 inches
2. Fasteners: Brass grommet and wire.
3. Nomenclature: Large-size primary caption such as "DANGER," "CAUTION," or "DO NOT OPERATE."
4. Color: Yellow background with black lettering.

PART 3 - EXECUTION

3.1 PREPARATION

A. Clean piping and equipment surfaces of substances that could impair bond of identification devices, including dirt, oil, grease, release agents, and incompatible primers, paints, and encapsulants.

3.2 EQUIPMENT LABEL INSTALLATION

A. Install or permanently fasten labels on each major item of mechanical equipment.

B. Locate equipment labels where accessible and visible.

3.3 PIPE LABEL INSTALLATION (NOT USED)

3.4 DUCT LABEL INSTALLATION

A. Install self-adhesive duct labels with permanent adhesive on air ducts in the following color codes:

1. Blue: For cold-air supply ducts.
2. Yellow: For hot-air supply ducts.
3. Green: For exhaust-, outside-, relief-, return-, and mixed-air ducts.
4. ASME A13.1 Colors and Designs: For hazardous material exhaust.

B. Locate labels near points where ducts enter into concealed spaces and at maximum intervals of 50 feet (15 m) in each space where ducts are exposed or concealed by removable ceiling system.

3.5 VALVE-TAG INSTALLATION (NOT USED)

3.6 WARNING-TAG INSTALLATION

A. Write required message on, and attach warning tags to, equipment and other items where required.

END OF SECTION 230553

SECTION 230593 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

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. Provide all labor, materials, tools and equipment, man-lifts, incidentals and services to carry out the work of this section. This Section includes TAB to produce design objectives for the following:

1. Balancing Air Systems:

    a. Constant-volume air systems.
    b. Variable-air-volume systems.
    c. Multizone systems.

2. Balancing Hydronic Piping Systems:
    a. Variable-flow hydronic systems.
    b. Domestic water system (where required)
3. HVAC equipment.
4. Space pressurization testing and adjusting.
5. Vibration measuring.
6. Sound level measuring.
7. Indoor-air quality measuring.
8. Verifying that automatic control devices are functioning properly.
9. Reporting results of activities and procedures specified in this Section

B. The testing, adjusting and balancing contractor will cooperate and support the commissioning agent as required by the client’s campus standards.

1.3 DEFINITIONS

A. AABC: Associated Air Balance Council.

B. NEBB: National Environmental Balancing Bureau.

C. TAB: Testing, adjusting, and balancing.

D. TABB: Testing, Adjusting, and Balancing Bureau.

E. TAB Specialist: An entity engaged to perform TAB Work.

1.4 ACTION SUBMITTALS

A. LEED Submittals:

1. Air-Balance Report for Prerequisite IEQ 1: Documentation of work performed for ASHRAE 62.1, Section 7.2.2 - "Air Balancing."
2. TAB Report for Prerequisite EA 2: Documentation of work performed for ASHRAE/IESNA 90.1, Section 6.7.2.3 - "System Balancing."

1.5 INFORMATIONAL SUBMITTALS

A. Qualification Data: Within 30 days of Contractor's Notice to Proceed, submit documentation that the TAB contractor and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.

B. Contract Documents Examination Report: Within 45 days of Contractor's Notice to Proceed, submit the Contract Documents review report as specified in Part 3.

C. Strategies and Procedures Plan: Within 90 days of Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures as specified in "Preparation" Article.

D. Certified TAB reports.

E. Sample report forms.

F. Instrument calibration reports, to include the following:

1. Instrument type and make.
2. Serial number.
3. Application.
4. Dates of use.
5. Dates of calibration.

1.6 QUALITY ASSURANCE

A. TAB Contractor Qualifications: Engage a TAB entity certified by AABC, NEBB or TABB.

1. TAB Field Supervisor: Employee of the TAB contractor and certified by AABC, NEBB or TABB.
2. TAB Technician: Employee of the TAB contractor and who is certified by AABC NEBB or TABB as a TAB technician.

B. TAB Conference: Meet with Architect, Owner, Construction Manager and Commissioning Authority on approval of the TAB strategies and procedures plan to develop a mutual understanding of the details. Require the participation of the TAB field supervisor and technicians. Provide seven days' advance notice of scheduled meeting time and location.

1. Agenda Items:

a. The Contract Documents examination report.
b. The TAB plan.
c. Coordination and cooperation of trades and subcontractors.
d. Coordination of documentation and communication flow.

C. Certify TAB field data reports and perform the following:

1. Review field data reports to validate accuracy of data and to prepare certified TAB reports.
2. Certify that the TAB team complied with the approved TAB plan and the procedures specified and referenced in this Specification.

D. TAB Report Forms: Use standard TAB contractor's forms approved by Architect and Commissioning Authority.

E. Instrumentation Type, Quantity, Accuracy, and Calibration: As described in ASHRAE 111, Section 5, "Instrumentation."

F. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 7.2.2 - "Air Balancing."

G. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.7.2.3 - "System Balancing."

1.7 PROJECT CONDITIONS

A. Full Owner Occupancy: Owner will occupy the site and existing building during entire TAB period. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

B. Partial Owner Occupancy: Owner may occupy completed areas of building before Substantial Completion. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

1.8 COORDINATION

A. Notice: Provide seven days' advance notice for each test. Include scheduled test dates and times.

B. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 TAB SPECIALISTS

A. Subject to compliance with requirements, engage one of the following:

1. EL Barrett Company, Inc., 1147 Hancock Street, Suite 201, Quincy, MA 02169, 617-770-9990

2. J. F. Coffey Associates, Inc., 61 Willard St., Quincy, MA 02169, 617-769-9901

3.2 EXAMINATION

A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems' designs that may preclude proper TAB of systems and equipment.

B. Examine systems for installed balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers. Verify that locations of these balancing devices are accessible.

C. Examine the approved submittals for HVAC systems and equipment.

D. Examine design data including HVAC system descriptions, statements of design assumptions for environmental conditions and systems' output, and statements of philosophies and assumptions about HVAC system and equipment controls.

E. Examine ceiling plenums and underfloor air plenums used for supply, return, or relief air to verify that they meet the leakage class of connected ducts as specified in Section 233113 "Metal Ducts" and are properly separated from adjacent areas. Verify that penetrations in plenum walls are sealed and fire-stopped if required.

F. Examine equipment performance data including fan and pump curves.

1. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
2. Calculate system-effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.

G. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.

H. Examine test reports specified in individual system and equipment Sections.

I. Examine HVAC equipment and filters and verify that bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.

J. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.

K. Examine strainers. Verify that startup screens are replaced by permanent screens with indicated perforations.

L. Examine three-way valves for proper installation for their intended function of diverting or mixing fluid flows.

M. Examine heat-transfer coils for correct piping connections and for clean and straight fins.

N. Examine system pumps to ensure absence of entrained air in the suction piping.

O. Examine operating safety interlocks and controls on HVAC equipment.

P. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.3 PREPARATION

A. Prepare a TAB plan that includes strategies and step-by-step procedures.

B. Complete system-readiness checks and prepare reports. Verify the following:

1. Permanent electrical-power wiring is complete.
2. Hydronic systems are filled, clean, and free of air.
3. Automatic temperature-control systems are operational.
4. Equipment and duct access doors are securely closed.
5. Balance, smoke, and fire dampers are open.
6. Isolating and balancing valves are open and control valves are operational.
7. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.
8. Windows and doors can be closed so indicated conditions for system operations can be met.

3.4 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in AABC's "National Standards for Total System Balance", NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems" and in this Section.

1. Comply with requirements in ASHRAE 62.1, Section 7.2.2 - "Air Balancing."

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures.

1. After testing and balancing, patch probe holes in ducts with same material and thickness as used to construct ducts.
2. After testing and balancing, install test ports and duct access doors that comply with requirements in Section 233300 "Air Duct Accessories."
3. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Section 230700 “HVAC Insulation”.

C. Mark equipment and balancing devices, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.

D. Take and report testing and balancing measurements in inch-pound (IP) units.

3.5 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.

B. Prepare schematic diagrams of systems' "as-built" duct layouts.

C. For variable-air-volume systems, develop a plan to simulate diversity.

D. Determine the best locations in main and branch ducts for accurate duct-airflow measurements.

E. Check airflow patterns from the outdoor-air louvers and dampers and the return- and exhaust-air dampers through the supply-fan discharge and mixing dampers.

F. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.

G. Verify that motor starters are equipped with properly sized thermal protection.

H. Check dampers for proper position to achieve desired airflow path.

I. Check for airflow blockages.

J. Check condensate drains for proper connections and functioning.

K. Check for proper sealing of air-handling-unit components.

L. Verify that air duct system is sealed as specified in Section 233113 "Metal Ducts."

3.6 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

1. Measure total airflow.

    a. Where sufficient space in ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow.

2. Measure fan static pressures as follows to determine actual static pressure:

    a. Measure outlet static pressure as far downstream from the fan as practical and upstream from restrictions in ducts such as elbows and transitions.
    b. Measure static pressure directly at the fan outlet or through the flexible connection.
    c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from the flexible connection, and downstream from duct restrictions.
    d. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.

3. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and -treating equipment.

    a. Report the cleanliness status of filters and the time static pressures are measured.

4. Measure static pressures entering and leaving other devices, such as sound traps, heat-recovery equipment, and air washers, under final balanced conditions.
5. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.
6. Obtain approval from Architect for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.

7. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows within specified tolerances.

1. Measure airflow of submain and branch ducts.

a. Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.

2. Measure static pressure at a point downstream from the balancing damper, and adjust volume dampers until the proper static pressure is achieved.
3. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.

C. Measure air outlets and inlets without making adjustments.

1. Measure terminal outlets using a direct-reading hood or outlet manufacturer's written instructions and calculating factors.

D. Adjust air outlets and inlets for each space to indicated airflows within specified tolerances of indicated values. Make adjustments using branch volume dampers rather than extractors and the dampers at air terminals.

1. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.
2. Adjust patterns of adjustable outlets for proper distribution without drafts.

3.7 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

A. Compensating for Diversity: When the total airflow of all terminal units is more than the indicated airflow of the fan, place a selected number of terminal units at a minimum set-point airflow with the remainder at maximum-airflow condition until the total airflow of the terminal units equals the indicated airflow of the fan. Select the reduced-airflow terminal units so they are distributed evenly among the branch ducts.

B. Pressure-Independent, Variable-Air-Volume Systems: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Set outdoor-air dampers at minimum, and set return- and exhaust-air dampers at a position that simulates full-cooling load.
2. Select the terminal unit that is most critical to the supply-fan airflow and static pressure. Measure static pressure. Adjust system static pressure so the entering static pressure for the critical terminal unit is not less than the sum of the terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
3. Measure total system airflow. Adjust to within indicated airflow.
4. Set terminal units at maximum airflow and adjust controller or regulator to deliver the designed maximum airflow. Use terminal-unit manufacturer's written instructions to make this adjustment.

When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.

5. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow the same as described for constant-volume air systems.

    a. If air outlets are out of balance at minimum airflow, report the condition but leave outlets balanced for maximum airflow.

6. Remeasure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.

    a. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.

7. Measure static pressure at the most critical terminal unit and adjust the static-pressure controller at the main supply-air sensing station to ensure that adequate static pressure is maintained at the most critical unit.
8. Record final fan-performance data.

C. Pressure-Dependent, Variable-Air-Volume Systems without Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Balance variable-air-volume systems the same as described for constant-volume air systems.
2. Set terminal units and supply fan at full-airflow condition.
3. Adjust inlet dampers of each terminal unit to indicated airflow and verify operation of the static-pressure controller. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.
4. Readjust fan airflow for final maximum readings.
5. Measure operating static pressure at the sensor that controls the supply fan if one is installed, and verify operation of the static-pressure controller.
6. Set supply fan at minimum airflow if minimum airflow is indicated. Measure static pressure to verify that it is being maintained by the controller.
7. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow the same as described for constant-volume air systems.

    a. If air outlets are out of balance at minimum airflow, report the condition but leave the outlets balanced for maximum airflow.

8. Measure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.

    a. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.

D. Pressure-Dependent, Variable-Air-Volume Systems with Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Set system at maximum indicated airflow by setting the required number of terminal units at minimum airflow. Select the reduced-airflow terminal units so they are distributed evenly among the branch ducts.
2. Adjust supply fan to maximum indicated airflow with the variable-airflow controller set at maximum airflow.
3. Set terminal units at full-airflow condition.

4. Adjust terminal units starting at the supply-fan end of the system and continuing progressively to the end of the system. Adjust inlet dampers of each terminal unit to indicated airflow. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.
5. Adjust terminal units for minimum airflow.
6. Measure static pressure at the sensor.
7. Measure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.

3.8 PROCEDURES FOR MULTIZONE SYSTEMS

A. Set unit at maximum airflow through the cooling coil.

B. Adjust each zone's balancing damper to achieve indicated airflow within the zone.

3.9 PROCEDURES FOR INDUCTION-UNIT SYSTEMS

A. Balance primary-air risers by measuring static pressure at the nozzles of the top and bottom units of each riser to determine which risers must be throttled. Adjust risers to indicated airflow within specified tolerances.

B. Adjust each induction unit.

3.10 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

A. Prepare test reports with pertinent design data, and number in sequence starting at pump to end of system. Check the sum of branch-circuit flows against the approved pump flow rate. Correct variations that exceed plus or minus 5 percent.

B. Prepare schematic diagrams of systems' "as-built" piping layouts.

C. Prepare hydronic systems for testing and balancing according to the following, in addition to the general preparation procedures specified above:

1. Open all manual valves for maximum flow.
2. Check liquid level in expansion tank.
3. Check makeup water-station pressure gage for adequate pressure for highest vent.
4. Check flow-control valves for specified sequence of operation, and set at indicated flow.
5. Set differential-pressure control valves at the specified differential pressure. Do not set at fully closed position when pump is positive-displacement type unless several terminal valves are kept open.
6. Set system controls so automatic valves are wide open to heat exchangers.
7. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.
8. Check air vents for a forceful liquid flow exiting from vents when manually operated.

3.11 PROCEDURES FOR CONSTANT-FLOW HYDRONIC SYSTEMS

A. Measure water flow at pumps. Use the following procedures except for positive-displacement pumps:

1. Verify impeller size by operating the pump with the discharge valve closed. Read pressure differential across the pump. Convert pressure to head and correct for differences in gage heights. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.

    a. If impeller sizes must be adjusted to achieve pump performance, obtain approval from Architect and comply with requirements in Section 232123 "Hydronic Pumps."

2. Check system resistance. With all valves open, read pressure differential across the pump and mark pump manufacturer's head-capacity curve. Adjust pump discharge valve until indicated water flow is achieved.

    a. Monitor motor performance during procedures and do not operate motors in overload conditions.

3. Verify pump-motor brake horsepower. Calculate the intended brake horsepower for the system based on pump manufacturer's performance data. Compare calculated brake horsepower with nameplate data on the pump motor. Report conditions where actual amperage exceeds motor nameplate amperage.
4. Report flow rates that are not within plus or minus 10 percent of design.

B. Measure flow at all automatic flow control valves to verify that valves are functioning as designed.

C. Measure flow at all pressure-independent characterized control valves, with valves in fully open position, to verify that valves are functioning as designed.

D. Set calibrated balancing valves, if installed, at calculated presettings.

E. Measure flow at all stations and adjust, where necessary, to obtain first balance.

1. System components that have Cv rating or an accurately cataloged flow-pressure-drop relationship may be used as a flow-indicating device.

F. Measure flow at main balancing station and set main balancing device to achieve flow that is 5 percent greater than indicated flow.

G. Adjust balancing stations to within specified tolerances of indicated flow rate as follows:

1. Determine the balancing station with the highest percentage over indicated flow.
2. Adjust each station in turn, beginning with the station with the highest percentage over indicated flow and proceeding to the station with the lowest percentage over indicated flow.
3. Record settings and mark balancing devices.

H. Measure pump flow rate and make final measurements of pump amperage, voltage, rpm, pump heads, and systems' pressures and temperatures including outdoor-air temperature.

I. Measure the differential-pressure-control-valve settings existing at the conclusion of balancing.

J. Check settings and operation of each safety valve. Record settings.

3.12 PROCEDURES FOR VARIABLE-FLOW HYDRONIC SYSTEMS

A. Balance systems with automatic two- and three-way control valves by setting systems at maximum flow through heat-exchange terminals and proceed as specified above for hydronic systems.

3.13 PROCEDURES FOR PRIMARY-SECONDARY HYDRONIC SYSTEMS

A. Balance the primary circuit flow first and then balance the secondary circuits.

3.14 PROCEDURES FOR HEAT EXCHANGERS

A. Measure water flow through all circuits.

B. Adjust water flow to within specified tolerances.

C. Measure inlet and outlet water temperatures.

D. Measure inlet steam pressure.

E. Check settings and operation of safety and relief valves. Record settings.

3.15 PROCEDURES FOR MOTORS

A. Motors, 1/2 HP and Larger: Test at final balanced conditions and record the following data:

1. Manufacturer's name, model number, and serial number.
2. Motor horsepower rating.
3. Motor rpm.
4. Efficiency rating.
5. Nameplate and measured voltage, each phase.
6. Nameplate and measured amperage, each phase.
7. Starter thermal-protection-element rating.

B. Motors Driven by Variable-Frequency Controllers: Test for proper operation at speeds varying from minimum to maximum. Test the manual bypass of the controller to prove proper operation. Record observations including name of controller manufacturer, model number, serial number, and nameplate data.

3.16 PROCEDURES FOR CHILLERS

A. Balance water flow through each evaporator and condenser to within specified tolerances of indicated flow with all pumps operating. With only one chiller operating in a multiple chiller installation, do not exceed the flow for the maximum tube velocity recommended by the chiller manufacturer. Measure and record the following data with each chiller operating at design conditions:

1. Evaporator-water entering and leaving temperatures, pressure drop, and water flow.
2. For water-cooled chillers, condenser-water entering and leaving temperatures, pressure drop, and water flow.
3. Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.

4. Power factor if factory-installed instrumentation is furnished for measuring kilowatts.
5. Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatts.
6. Capacity: Calculate in tons of cooling.
7. For air-cooled chillers, verify condenser-fan rotation and record fan and motor data including number of fans and entering- and leaving-air temperatures.

3.17 PROCEDURES FOR COOLING TOWERS

A. Shut off makeup water for the duration of the test, and verify that makeup and blowdown systems are fully operational after tests and before leaving the equipment. Perform the following tests and record the results:

1. Measure condenser-water flow to each cell of the cooling tower.
2. Measure entering- and leaving-water temperatures.
3. Measure wet- and dry-bulb temperatures of entering air.
4. Measure wet- and dry-bulb temperatures of leaving air.
5. Measure condenser-water flow rate recirculating through the cooling tower.
6. Measure cooling-tower spray pump discharge pressure.
7. Adjust water level and feed rate of makeup water system.
8. Measure flow through bypass.

3.18 PROCEDURES FOR BOILERS

A. Hydronic Boilers: Measure and record entering- and leaving-water temperatures and water flow.

B. Steam Boilers: Measure and record entering-water temperature and flow and leaving-steam pressure, temperature, and flow.

3.19 PROCEDURES FOR HEAT-TRANSFER COILS

A. Measure, adjust, and record the following data for each water coil:

1. Entering- and leaving-water temperature.
2. Water flow rate.
3. Water pressure drop.
4. Dry-bulb temperature of entering and leaving air.
5. Wet-bulb temperature of entering and leaving air for cooling coils.
6. Airflow.
7. Air pressure drop.

B. Measure, adjust, and record the following data for each electric heating coil:

1. Nameplate data.
2. Airflow.
3. Entering- and leaving-air temperature at full load.
4. Voltage and amperage input of each phase at full load and at each incremental stage.
5. Calculated kilowatt at full load.
6. Fuse or circuit-breaker rating for overload protection.

C. Measure, adjust, and record the following data for each steam coil:

1. Dry-bulb temperature of entering and leaving air.
2. Airflow.
3. Air pressure drop.
4. Inlet steam pressure.

D. Measure, adjust, and record the following data for each refrigerant coil:

1. Dry-bulb temperature of entering and leaving air.
2. Wet-bulb temperature of entering and leaving air.
3. Airflow.
4. Air pressure drop.
5. Refrigerant suction pressure and temperature.

3.20 TOLERANCES

A. Set HVAC system's air flow rates and water flow rates within the following tolerances:

1. Supply, Return, and Exhaust Fans and Equipment with Fans: Plus or minus 5 percent.
2. Air Outlets and Inlets: Plus or minus 5 percent.
3. Heating-Water Flow Rate: Plus or minus 5 percent.
4. Cooling-Water Flow Rate: Plus or minus 5 percent.

3.21 REPORTING

A. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for systems' balancing devices. Recommend changes and additions to systems' balancing devices to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.

B. Status Reports: Prepare weekly progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

3.22 FINAL REPORT

A. General: Prepare a certified written report; tabulate and divide the report into separate sections for tested systems and balanced systems.

1. Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.
2. Include a list of instruments used for procedures, along with proof of calibration.

B. Final Report Contents: In addition to certified field-report data, include the following:

1. Pump curves.
2. Fan curves.
3. Manufacturers' test data.
4. Field test reports prepared by system and equipment installers.

5. Other information relative to equipment performance; do not include Shop Drawings and product data.

C. General Report Data: In addition to form titles and entries, include the following data:

1. Title page.
2. Name and address of the TAB contractor.
3. Project name.
4. Project location.
5. Architect's name and address.
6. Engineer's name and address.
7. Contractor's name and address.
8. Report date.
9. Signature of TAB supervisor who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
11. Summary of contents including the following:

    a. Indicated versus final performance.
    b. Notable characteristics of systems.
    c. Description of system operation sequence if it varies from the Contract Documents.

12. Nomenclature sheets for each item of equipment.
13. Data for terminal units, including manufacturer's name, type, size, and fittings.
14. Notes to explain why certain final data in the body of reports vary from indicated values.
15. Test conditions for fans and pump performance forms including the following:

    a. Settings for outdoor-, return-, and exhaust-air dampers.
    b. Conditions of filters.
    c. Cooling coil, wet- and dry-bulb conditions.
    d. Face and bypass damper settings at coils.
    e. Fan drive settings including settings and percentage of maximum pitch diameter.
    f. Inlet vane settings for variable-air-volume systems.
    g. Settings for supply-air, static-pressure controller.
    h. Other system operating conditions that affect performance.

D. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:

1. Quantities of outdoor, supply, return, and exhaust airflows.
2. Water and steam flow rates.
3. Duct, outlet, and inlet sizes.
4. Pipe and valve sizes and locations.
5. Terminal units.
6. Balancing stations.
7. Position of balancing devices.

E. Air-Handling-Unit Test Reports: For air-handling units with coils, include the following:

1. Unit Data:

    a. Unit identification.
    b. Location.
    c. Make and type.
    d. Model number and unit size.

e. Manufacturer's serial number.
f. Unit arrangement and class.
g. Discharge arrangement.
h. Sheave make, size in inches, and bore.
i. Center-to-center dimensions of sheave, and amount of adjustments in inches.
j. Number, make, and size of belts.
k. Number, type, and size of filters.

2. Motor Data:

a. Motor make, and frame type and size.
b. Horsepower and rpm.
c. Volts, phase, and hertz.
d. Full-load amperage and service factor.
e. Sheave make, size in inches, and bore.
f. Center-to-center dimensions of sheave, and amount of adjustments in inches.

3. Test Data (Indicated and Actual Values):

a. Total air flow rate in cfm.
b. Total system static pressure in inches wg.
c. Fan rpm.
d. Discharge static pressure in inches wg.
e. Filter static-pressure differential in inches wg.
f. Preheat-coil static-pressure differential in inches wg.
g. Cooling-coil static-pressure differential in inches wg.
h. Heating-coil static-pressure differential in inches wg.
i. Outdoor airflow in cfm.
j. Return airflow in cfm.
k. Outdoor-air damper position.
l. Return-air damper position.
m. Vortex damper position.

F. Apparatus-Coil Test Reports:

1. Coil Data:

a. System identification.
b. Location.
c. Coil type.
d. Number of rows.
e. Fin spacing in fins per inch o.c.
f. Make and model number.
g. Face area in sq. ft..
h. Tube size in NPS.
i. Tube and fin materials.
j. Circuiting arrangement.

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm.
b. Average face velocity in fpm.
c. Air pressure drop in inches wg.
d. Outdoor-air, wet- and dry-bulb temperatures in deg F.
e. Return-air, wet- and dry-bulb temperatures in deg F.

f. Entering-air, wet- and dry-bulb temperatures in deg F.
g. Leaving-air, wet- and dry-bulb temperatures in deg F.
h. Water flow rate in gpm.
i. Water pressure differential in feet of head or psig.
j. Entering-water temperature in deg F.
k. Leaving-water temperature in deg F.
l. Refrigerant expansion valve and refrigerant types.
m. Refrigerant suction pressure in psig.
n. Refrigerant suction temperature in deg F.
o. Inlet steam pressure in psig.

G. Gas- and Oil-Fired Heat Apparatus Test Reports: In addition to manufacturer's factory startup equipment reports, include the following:

1. Unit Data:

a. System identification.
b. Location.
c. Make and type.
d. Model number and unit size.
e. Manufacturer's serial number.
f. Fuel type in input data.
g. Output capacity in Btu/h.
h. Ignition type.
i. Burner-control types.
j. Motor horsepower and rpm.
k. Motor volts, phase, and hertz.
l. Motor full-load amperage and service factor.
m. Sheave make, size in inches, and bore.
n. Center-to-center dimensions of sheave, and amount of adjustments in inches.

2. Test Data (Indicated and Actual Values):

a. Total air flow rate in cfm.
b. Entering-air temperature in deg F.
c. Leaving-air temperature in deg F.
d. Air temperature differential in deg F.
e. Entering-air static pressure in inches wg.
f. Leaving-air static pressure in inches wg.
g. Air static-pressure differential in inches wg.
h. Low-fire fuel input in Btu/h.
i. High-fire fuel input in Btu/h.
j. Manifold pressure in psig.
k. High-temperature-limit setting in deg F.
l. Operating set point in Btu/h.
m. Motor voltage at each connection.
n. Motor amperage for each phase.
o. Heating value of fuel in Btu/h.

H. Electric-Coil Test Reports: For electric furnaces, duct coils, and electric coils installed in central-station air-handling units, include the following:

1. Unit Data:

a. System identification.

b. Location.
c. Coil identification.
d. Capacity in Btu/h.
e. Number of stages.
f. Connected volts, phase, and hertz.
g. Rated amperage.
h. Air flow rate in cfm.
i. Face area in sq. ft..
j. Minimum face velocity in fpm.

2. Test Data (Indicated and Actual Values):

a. Heat output in Btu/h.
b. Air flow rate in cfm.
c. Air velocity in fpm.
d. Entering-air temperature in deg F.
e. Leaving-air temperature in deg F.
f. Voltage at each connection.
g. Amperage for each phase.

I. Fan Test Reports: For supply, return, and exhaust fans, include the following:

1. Fan Data:

a. System identification.
b. Location.
c. Make and type.
d. Model number and size.
e. Manufacturer's serial number.
f. Arrangement and class.
g. Sheave make, size in inches, and bore.
h. Center-to-center dimensions of sheave, and amount of adjustments in inches.

2. Motor Data:

a. Motor make, and frame type and size.
b. Horsepower and rpm.
c. Volts, phase, and hertz.
d. Full-load amperage and service factor.
e. Sheave make, size in inches, and bore.
f. Center-to-center dimensions of sheave, and amount of adjustments in inches.
g. Number, make, and size of belts.

3. Test Data (Indicated and Actual Values):

a. Total airflow rate in cfm.
b. Total system static pressure in inches wg.
c. Fan rpm.
d. Discharge static pressure in inches wg.
e. Suction static pressure in inches wg.

J. Round, Flat-Oval, and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:

1. Report Data:

a. System and air-handling-unit number.
b. Location and zone.
c. Traverse air temperature in deg F.
d. Duct static pressure in inches wg.
e. Duct size in inches.
f. Duct area in sq. ft..
g. Indicated air flow rate in cfm.
h. Indicated velocity in fpm.
i. Actual air flow rate in cfm.
j. Actual average velocity in fpm.
k. Barometric pressure in psig.

K. Air-Terminal-Device Reports:

1. Unit Data:

a. System and air-handling unit identification.
b. Location and zone.
c. Apparatus used for test.
d. Area served.
e. Make.
f. Number from system diagram.
g. Type and model number.
h. Size.
i. Effective area in sq. ft..

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm.
b. Air velocity in fpm.
c. Preliminary air flow rate as needed in cfm.
d. Preliminary velocity as needed in fpm.
e. Final air flow rate in cfm.
f. Final velocity in fpm.
g. Space temperature in deg F.

L. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:

1. Unit Data:

a. System and air-handling-unit identification.
b. Location and zone.
c. Room or riser served.
d. Coil make and size.
e. Flowmeter type.

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm.
b. Entering-water temperature in deg F.
c. Leaving-water temperature in deg F.
d. Water pressure drop in feet of head or psig.
e. Entering-air temperature in deg F.
f. Leaving-air temperature in deg F.

M. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves and include the following:

1. Unit Data:

a. Unit identification.
b. Location.
c. Service.
d. Make and size.
e. Model number and serial number.
f. Water flow rate in gpm.
g. Water pressure differential in feet of head or psig.
h. Required net positive suction head in feet of head or psig.
i. Pump rpm.
j. Impeller diameter in inches.
k. Motor make and frame size.
l. Motor horsepower and rpm.
m. Voltage at each connection.
n. Amperage for each phase.
o. Full-load amperage and service factor.
p. Seal type.

2. Test Data (Indicated and Actual Values):

a. Static head in feet of head or psig.
b. Pump shutoff pressure in feet of head or psig.
c. Actual impeller size in inches.
d. Full-open flow rate in gpm.
e. Full-open pressure in feet of head or psig.
f. Final discharge pressure in feet of head or psig.
g. Final suction pressure in feet of head or psig.
h. Final total pressure in feet of head or psig.
i. Final water flow rate in gpm.
j. Voltage at each connection.
k. Amperage for each phase.

N. Instrument Calibration Reports:

1. Report Data:

a. Instrument type and make.
b. Serial number.
c. Application.
d. Dates of use.
e. Dates of calibration.

3.23 INSPECTIONS

A. Initial Inspection:

1. After testing and balancing are complete, operate each system and randomly check measurements to verify that the system is operating according to the final test and balance readings documented in the final report.
2. Check the following for each system:

a. Measure airflow of at least 10 percent of air outlets.
b. Measure water flow of at least 5 percent of terminals.
c. Measure room temperature at each thermostat/temperature sensor. Compare the reading to the set point.
d. Verify that balancing devices are marked with final balance position.
e. Note deviations from the Contract Documents in the final report.

B. Final Inspection:

1. After initial inspection is complete and documentation by random checks verifies that testing and balancing are complete and accurately documented in the final report, request that a final inspection be made by Architect.
2. The TAB contractor's test and balance engineer shall conduct the inspection in the presence of Commissioning Authority.
3. Commissioning Authority shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.
4. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."
5. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.

C. TAB Work will be considered defective if it does not pass final inspections. If TAB Work fails, proceed as follows:

1. Recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection.
2. If the second final inspection also fails, Owner may contract the services of another TAB contractor to complete TAB Work according to the Contract Documents and deduct the cost of the services from the original TAB contractor's final payment.

D. Prepare test and inspection reports.

3.24 ADDITIONAL TESTS

A. Within 90 days of completing TAB, perform additional TAB to verify that balanced conditions are being maintained throughout and to correct unusual conditions.

B. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.

END OF SECTION 230593

SECTION 237313-13 - CUSTOM INDOOR CENTRAL-STATION 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.

B. Contractor shall provide in writing schedule of delivery for all units.

C. Refurbished units shall be as scheduled.

D. Contractor shall provide alternate pricing and associated completion schedule for refurbished equipment as noted under contract documents.
   1. Contractor shall provide confirmation that unit meets the following performance requirements:
      a. Air flow
      b. Coil performance
      c. Design Pressure (external)
      d. Sound performance
      e. Structural Integrity
      f. Leakage Testing in compliance with SMACNA
      g. Structural Deflection at 150% of design total static pressure.
   2. Refurbished equipment shall include, but not limited to, all components of a fully operational air handler, which includes fan, motors, drives, coils, filters, support racks, fan bases, and associated accessories, piping and associated accessories as part of unit, wall insulation, interior and exterior lining, unit bases, discharge openings bell mouths, Supply air, return air and outside air dampers.
   3. Refer to design drawings for additional notes on refurbishment requirements.
   4. All refurbished air handling units shall comply with this section of the specifications.
   5. All unit components noted heirn shall comply with these specification requirements.

1.2 SUMMARY

A. Section Includes:
   1. Variable-air-volume, single-zone air-handling units.

1.3 PERFORMANCE REQUIREMENTS

A. Delegated Design: Design vibration isolation and seismic-restraint details, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

B. Structural Performance: Casing panels shall be self-supporting and capable of withstanding 150 percent of internal static pressures indicated, without panel joints exceeding a deflection of L/200 where "L" is the unsupported span length within completed casings.

C. Seismic Performance: Air-handling units shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

1.4 ACTION SUBMITTALS

A. Product Data: For each air-handling unit indicated.

1. Unit dimensions and weight.
2. Cabinet material, metal thickness, finishes, insulation, and accessories.
3. Fans:

    a. Certified fan-performance curves with system operating conditions indicated. Fan curves shall indicate (as a minimum) air volume, total static pressure, fan speed, and brake horsepower.
    b. Certified fan-sound power ratings including all system effects, components and accessories.
    c. Fan construction and accessories.
    d. Motor ratings, electrical characteristics, and motor accessories.

4. Certified coil-performance ratings with system operating conditions indicated. Include details of coil support in a coil bank, including all secondary drain pans.
5. Dampers, including housings, linkages, and operators.
6. Filters with performance characteristics.
7. Unit accessories including (but not limited to): filter gauges, access doors & windows, latches, including sizes and elevations, lights, GFI outlets, drain pans, and vibration isolation.
8. Sound power levels by octave band for air handling units at scheduled design conditions. Provide sound power levels for discharge, inlet and cabinet sound paths in accordance with AMCA 300 (or ASHRAE 68) and AMCA 301.
9. Clearly define any exception made to the Plans and Specification. Contractor is responsible for any expenses that occur do to exceptions made.
10. Shipping and operating weight of unit and/or sections.
11. Component equipment data as detailed in component specification section.
12. Details of coil support in a coil bank, including elevated and secondary drain pans.
13. Method for providing and sealing of field openings.
14. Drain pan details.
15. Operating and Maintenance Data.
16. Unit construction details for all units including unit cross section, base, double wall construction, method of joining panels, floor and roof construction, method of sealing piping/ controls openings in casing, non-through-metal fastening

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

1. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
2. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Mechanical-room layout and relationships between components and adjacent structural and mechanical elements.
2. Support location, type, and weight.
3. Field measurements.

B. Source quality-control reports.
1. Field or Contractor Certified representative shall provide written confirmation of unit equipment installation is in accordance with manufacturer requirements for coils, fans, VFDs and silencers.
2. Contractor representative shall confirm performance is in accordance with contract documents.

C. Field quality-control reports.
1. Shall be provided for each equipment at each stage of refurbishment and after installation completeness prior to acceptance.

1.6 CLOSEOUT SUBMITTALS

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

1.7 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. Filters: Three set(s) for each air-handling unit.
2. Gaskets: Two set(s) for each access door.
3. Fan Belts: Two set(s) for each air-handling unit fan.
4. Fans: One fan array motor of each size for emergency replacement..

1.8 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, 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. Provide testing to verify specified criteria are met. Testing shall be as required in this section and shall include air flow, total static pressure and sound. Sound testing shall be performed in the field. representatives.

D. Provide testing for (3) the following units per Engineer Direction:
   1. AHU-B1, B7, B8, B9 and B-12.
   2. Unit tests shall verify specified criteria are met, including a blank copy of the testing report is to be include with the submittal.

E. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

F. Uniform Mechanical Code

G. Comply with NFPA 70.

H. ANSI/ABMA 9 - Load Ratings and Fatigue Life for Ball Bearings.

I. ANSI/ABMA 11 - Load Ratings and Fatigue Life for Roller Bearings.

J. SMACNA - HVAC Duct Construction Standards.

K. ARI Compliance: All coils shall be certified in accordance with ARI Standard 410.

L. ANSI/UL 900 - Test Performance of Air Filter Units.

M. ASTM E 84-05 - Standard Test Method for Surface Burning Characteristics of Building Materials

N. ASTM C916 - Standard Specification for Adhesives for Duct Thermal Insulation

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

P. Sound power levels shall be in accordance with AMCA 301 - Method for Publishing Sound Ratings for Air Moving Devices.

Q. Sound power levels shall be in accordance with ASHRAE 68 - Laboratory Method of Testing In-Duct Sound Power Measurement Procedure for Fans.

1.9 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.

C. Coordinate locations of floor drains with existing locations and new/existing equipment.

1.10 WARRANTY

A. The manufacturer shall provide the parts warranty for equipment manufactured and all vendor supplied components. The said warranty shall cover replacement of all defective parts for a period of 18 months

from equipment start up. If startup is more than 30 days prior to owner hand over, than warranty period shall be 18 months from date of hand over.

1.11 DELIVERY, STORAGE, AND HANDLING

A. Deliver products to site under provisions of 016000 (product requirements). Unit parts not shipped fully assembled shall have tags and airflow arrows on each section to indicate location and orientation in direction of airflow. Unit parts shall be field assembled under supervision of manufacturer representative in the field.

B. Store and protect products under provisions of 016000 (product requirements).

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

D. All unit parts shall be itemized on the packing slip and be suitably secured in the unit or on a separate pallet.

E. No storage of units parts shall be permitted outside. Contractor shall be responsible for storage and protection of all unit equipment.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

A. Provide sectionalized custom indoor air handling units of the type, capacity, and arrangement as specified and as shown on the drawings. The custom fabricated air handling unit shall be designed to be field pre-fabricated', based on modular sections comprised of double-wall panels and base sections with all equipment components field installed.

B. For specified unit, a full set of layout and panel field fabrication drawings with step by step installation instructions shall be provided prior to unit component delivery. All necessary tags and decals to aid in the service and/or indicating cautions areas will be provided. Electrical wiring diagrams and maintenance manuals shall be supplied with each unit.

C. The Unit Manufacturer is responsible for and shall warrant the proper operation and performance of this unit and all modular sections/components for pressure requirements, leak tightness, thermal, structural, and non-condensation requirements of the unit's casing.

D. The Unit Manufacturer shall be responsible and warrant the structural integrity of the unit to ensure no distortion of the unit's infrastructure during trucking, rigging, and installation. The Unit Manufacturer shall provide design provisions for any special requirements such as structural columns, beams, bracing, etc. being installed throughout the unit.

E. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

2.2 PERFORMANCE REQUIREMENTS

A. The construction specifications below detail the minimum requirements. contractor must adhere to the following requirements while still meeting or exceeding the sound and performance data listed in the schedules and the dimensions shown in the unit details.

B. Thermal Performance: Provide housing with insulation "U" value less than 0.052 BTU/Hr/S.F./ºF.

C. The air handling unit shall be constructed to operate up to 8.0" W.C. static pressure without affecting integrity of the panels and joints.

D. The cabinet construction type and materials shall have been previously manufactured and tested for structural performance and the test data shall be used to calculate the support spacing, material gauge and other details of the construction of the specific unit for this project. The overall casing shall be designed and constructed to meet the following requirements:
   1. The maximum panel deflection shall be 1/200th of the longest panel span at 150 percent of design operating pressure.
   2. The unit shall have maximum leakage rate of 1 percent of scheduled design airflow capacity at 1.5 times design static pressure or fan shutoff, whichever is greater.

E. Strength Requirements:
   1. Base floor of the new unit shall be designed for a minimum live load of 100 Lbs./S.F., and shall be supported with adequate stiffening members to prevent sagging, pulsating, and oil canning.

2.3 UNIT CASINGS

A. All units listed below shall be minimum 4-inch-thick wall construction with 3-pcf high density polyisocyanurate or polyurethane foam insulation, or equivalent fiberglass insulation required to meet the specified U-value. All other units shall be provided with min 2 inch thick wall construction with 3-pcf high density polyisocyanurate or polyurethane foam insulation, or equivalent fiberglass insulation required to meet the specified U-value.

B. Under 50°F supply air temperature and design conditions on the exterior of the unit of 81°F dry bulb and 73°F wet bulb, condensation shall not form on the casing exterior. The AHU manufacturer shall provide tested casing thermal performance for the scheduled supply air temperature plotted on a psychrometric chart. If tested casing thermal data is not available, AHU manufacturer shall provide, in writing to the Engineer and Owner, a guarantee against condensation forming on the unit exterior at the stated design conditions above. The guarantee shall note that the AHU manufacturer will cover all expenses associated with modifying units in the field should external condensate form on them.All panels shall be double wall construction, with solid galvanized exterior liner and solid interior liner. Perforated liner shall be provided downstream of fan section.

C. Interior liner shall be 16 gauge interior or minimum 0.0635 inch thick. The liner shall be installed over top of the panel flanges and each liner seam shall be sealed with a lap joint, sealant, and thermal break gasket. Panel shall have continuous tight seal at the interior and exterior skins completely encapsulating the insulation. Perforated liner shall be provided where currently provided in existing units at unit intake and fan discharge sections.

D. Where exterior panels require replacement or repair, the exterior walls and roof panel shall be constructed of 20 gauge or 0.0516 painted galvanized steel. Panel shall have continuous tight seal at the interior and exterior skins completely encapsulating the insulation.

E. All permanently joined flanged panel surfaces shall be sealed with an individual strip of 1/8" X 3/8" Tremco tape sealer, or similar, during assembly to produce an airtight unit or shall be fully welded. Usage of caulk as the primary panel sealant is not acceptable.

F. The minimum panel thickness shall be at least 4" thick with 3-pcf high density polyisocyanurate or polyurethane foam insulation, or equivalent required to meet the specified U-value. If spray foam insulation is used the manufacturer shall provide thermal imaging for each units, under operating conditions, demonstrating that the insulation coverage is consistent across each panel.

G. Casing system shall be guaranteed to assure the owner that system capacity, performance, and cleanliness standards specified are not compromised. Leakage to be guaranteed at no more than 1% of the design volume at 1-1/2 times the design operating pressure or 30 CFM, whichever is greater.

H. Panel system shall incorporate an integral thermal break barrier with an R value equal or better than 4 per inch an integral thermal break system IN ALL AIR HANDLER SECTIONS such that there is no through metal path between the interior and exterior surface of the unit casing at all locations. Criteria to evaluate requirement for thermal break system shall be based upon scheduled unit performance and ambient conditions anticipated around the units.

I. Any equipment flashing, internal partitions or other attachments to the casing shall be made in such a way as to ensure a permanent leak-tight connection. Attachments that are bolted, screwed, or welded to or through the casing skin creating air bypass, air leakage or rust propagation areas are not acceptable.

J. All ductwork penetrations through unit enclosure shall be provided with framed openings of size indicated on drawing.

K. All piping and conduit penetrations shall be provided with sleeves sealed watertight to unit casing; pipe penetrations through the unit casings shall be properly sealed prior to leaving the field. Penetrations created by any form of cutting through panels, compromising panel integrity, will not be acceptable.

L. Existing removable access panels shall be provided of same size. Access panels shall be of the same construction as panels described above. Removable access panels shall be designed and constructed such that removal and replacement may be accomplished without disturbing adjacent panels. Airtight integrity must be maintained.

M. Structural Base Refurbishment
1. Unit floor shall be minimum 12 gauge or 0.1082-inch-thick fully welded aluminum. Floor seams shall be continuously welded providing a completely flat unit floor. Units with screwed sheet metal floors or formed metal floor pans joined by standing seams are not acceptable. The base floor shall be designed for a minimum live load of 100 pounds per square foot throughout the unit.
2. A perimeter collar shall be provided to ensure the unit is internally watertight. The collar shall be welded to the unit floor and extend up the outside of the inner liner of the wall panel by 1½ inches. This collar, together with the fully welded floor, shall guarantee no water leakage into the floor insulation.
3. Existing floor drain locations shall be matched and shall be provided with a minimum 1¼" capped floor drain connections on the side of the unit per existing unit.
4. The base shall be insulated with at least 3" thick 3 lb injected foam insulation and sheeted with a 22ga galvanized steel liner.

N. ACCESS DOORS
1. Access doors shall be double wall construction matching unit casing with a solid liner. Access doors shall have same thermal break construction standards as unit casing.
2. Doors shall be designed, gasketed, hinged, and latched to provide airtight closure based on design static pressure and air leakage requirements. All doors shall open against pressure.

3. The access doors shall be guaranteed tight closing by the means of continuous gasket seals around the entire periphery of the door or panel. Gasket material shall be UV-resistant, closed cell neoprene; gaskets shall be attached by adhesive and not be mechanically held in place.
4. A double pane tempered glass window (min. 80 sq. in.) shall be provided in each door. Window material and assembly shall be capable of withstanding total developed pressure of unit, and not allow condensation to form.
5. Latches will be positive action, creating an air-tight seal between door and unit. Each access door shall have a least two (2) non-corrosive handles operable from either side. Door handles shall be cast aluminum Vent-Lok adjustable or approved equal. Door handles shall include self-locking nuts and stainless steel hardware and operate together via linking mechanism. Striker plates shall be non-metallic high impact nylon to lock latch in place.
6. Provide a static pressure probe port with cap plug for ease of pressure readings across various internal components up and down stream of each component. Provide minimum 1" diameter test ports with screwed caps on casing upstream and downstream of all coils and filters for pressure and temperature measurement.

7. Service Light: 100-W or equivalent LED vapor proof fixture with switched junction box located outside adjacent to door.

    a. Locations: Each section accessed with door.

    b. Provide additional light within Fan section

2.4 FAN, DRIVE, AND MOTOR SECTION

A. Provide fans, motors and drives of number, size and capacity as required for air handling system indicated on drawings and as stated in these specifications. Motor horsepower and inlet velocity shall not be exceeded. Unit shall be provided with a single point electrical connection. If not provide as a single point connection, then vendor shall bare all cost for multiple field connections.

B. Wheel shall be in accordance with the standard sizes adopted by AMCA for non-overloading fans. Wheel shall be of the high efficient, non-overloading, airfoil type only. Aluminum airfoil blades shall be die-formed, double-surface type blades continuously welded to a hub plate and wheel cone. Fan wheel shall have tapered, smooth flowing wheel cone. Inlet shall be suitably braced to prevent vibration.

C. Fan and Drive Assemblies (applicable only to belt driven fans): Statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower.
    1. Thrust restraints shall be provided on all fans with 100 lbs of thrust or more.

    2. Shafts: Designed for continuous operation at maximum-rated fan speed and motor horsepower, and with field-adjustable alignment.

        a. Shaft shall be AISI C-1045 hot rolled steel, turned, ground and polished. The shaft's first critical speed shall be at least 125% (Class I and II) of the fan's maximum operating speed. Ship with a protective coating of lubricating oil.
        b. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

D. Fan performance shall be based on tests run in an AMCA registered laboratory according to AMCA Standard 210. Fans shall be selected to provide the airflow and pressure specified. Wheel diameter shall not be less than scheduled and bhp shall not be more than scheduled.

E. The fan motor and fan assembly (for belt driven fans) shall be mounted on a common base to allow consistent belt tension with no relative motion between the fan and motor shafts. The entire assembly shall be spring isolated from the unit base. The fan discharge shall be connected to the cabinet through a flexible connection.

F. Provide L10-200,000h bearings with extended grease lines - manufactured of copper; extended to access door side of unit. Not required for direct drive fans.

G. Fan wheels shall be non-overloading, airfoil type. Impellers shall be statically and dynamically balanced to a level of G6.3 (per ANSI 2-19) or better. Hubs shall be straight bored, keyed and set screwed to the shaft. Shafts are to be solid steel sized for first critical speed of at least 1.25 times the maximum speed for the class for class I and II fans and 1.42 times the maximum speed for class for class III and IV fans.

H. Fan shall be cleaned, prime coated and provided with two coats of enamel final coat.

I. Once installed in the unit each fan shall be test run, at the field prior to shipping, at their operating speed or at the maximum RPM for the particular fan's construction class prior to shipment. The fans are to be balanced and records maintained of the readings in the axial, vertical, and horizontal direction on each of the fan's bearings. Final peak velocity measurements shall not exceed 0.1 in/sec. Refer to AMCA 204-96 Vibration Levels Standard, Cat. VB-3.

J. Fan inlets shall be supplied without collars that could obstruct flow into fan.

K. Where more than one fan is provided each shall be provided with inlet isolation, back draft, dampers to prevent backflow in the unit, in the event of individual fan failure.

L. An inlet screen shall be provided on fans without inlet isolation dampers.

M. Fans shall be provided with an expanded metal screen completely enclosing the wheel area.

N. Fan sections shall be provided with a painted structural steel I-beam for mounting trolley to assist in motor removal. Trolley assembly by others. Beam to be of same material as unit interior.

O. Parallel plenum fans shall be counter rotating to avoid parallel fan system effect.

P. Fan diameters scheduled are the minimum acceptable, and fan speeds scheduled are the maximum acceptable.

Q. Submit AMCA certified sound power data for each fan. Data shall be referenced as sound power level to the 10-12 watts in eight octave bands, 63Hz-8000Hz. Sound power levels shall be obtained from tests made in accordance with AMCA Standard 300.

R. The fan shall be installed with a flexible connection between fan and fan wall. Flex connection material shall be flame retardant fabric suitable for intended use meeting the requirements of NFPA 90A.

S. All features, as outlined above shall be provided in order to reduce fan system maintenance downtime and minimize equipment service.

T. Motor: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

U. Provide motor overload panel per NEC requirements and in accordance with manufacturer recommended installations.

1. Enclosure Type: Totally enclosed, fan cooled.
2. NEMA Premium (TM) efficient motors as defined in NEMA MG 1.
3. Motor shall be capable of operating with VFD without undue noise, vibration, or deterioration of reliability and life. Motor operation with a VFD shall not adversely affect operation, useful life, nor void the motor warranty.
4. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
5. Controllers, Electrical Devices, and Wiring: Comply with requirements per Division 26 drawings and Specifications and shall be submitted for approval by engineer of record.

V. Variable Frequency Controllers will include harmonic distortion feedback protection:
   1. Swinging DC Line Choke (equivalent to 5% input line reactor)
   2. Integral RFI/EMI filtering to meet EMC EN61800-3 for First Environment
   3. VFD User interface, integral to VFD, will include:
      a. 30 Character multi-lingual alphanumeric display
      b. Parameter set-up and operating data
      c. Display data includes:
         1) output frequency (Hz)
         2) speed (RPM)
         3) motor current
         4) calculated % motor torque
         5) calculated motor power (kW)
         6) DC bus voltage
         7) output voltage
         8) heat sink temperature
         9) elapsed time meter (re-settable)
         10) kWh (re-settable)
         11) input / output terminal monitor
         12) PID actual value (feedback) & error
         13) fault text
         14) warning text
         15) scalable process variable display
   4. VFD protection circuits will include:
      a. over current
      b. ground fault
      c. over voltage
      d. under voltage
      e. over temperature
      f. input power loss of phase
      g. loss of reference/feedback
      h. adjustable current limit regulator
   5. VFD will be UL 508C approved for electronic motor overload (12t).
   6. VFD will include high input transient protection and surge suppression:
      a. 4 MOVs ahead of diode bridge
      b. 120 Joule rated 1600V diode module
      c. Compliant with UL 1449 / ANSI 61.4
   7. VFD communication features include:
      a. Two programmable analog inputs
      b. Six programmable digital inputs
      c. Two programmable analog outputs
      d. Three programmable digital relay outputs
      e. Modbus RTU Communications protocol
      f. Adjustable filters on analog inputs and outputs
      g. Input speed signals, including 4-20 mA and 0-10 VDC
      h. Acceleration/Deceleration contacts (floating point control)

i. Auto restart (customer selectable and adjustable)
j. Start/Stop options will include 2 wire (dry contact closure), 3 wire (momentary contacts), application of input power, and application of reference signal (PID sleep/wake-up)
k. Integrated control interface for Siemens FLN, and or BACnet MS/TP

8. VFD will have the following functions:
   a. Premagnetization on start
   b. DC braking/hold at stop
   c. Ramp or coast to stop
   d. Seven preset speeds
   e. Three critical frequency lockout bands

2.5 COIL SECTION

A. General Requirements for Coil Section:

1. Comply with ARI 410.
2. Fabricate coil section to allow removal and replacement of coil for maintenance and to allow in-place access for service and maintenance of coil(s).
3. Coils shall not act as structural component of unit.

B. Coils

1. Provide coils as specified and scheduled on drawings. Refer to schedules for maximum coil face velocity, maximum air and water side pressure drops. Refer to schedules for maximum coil velocities.
2. Coils shall be provided with 5/8 inch O.D. copper tubes 0.025 inch nominal wall thickness, 0.035 inch tube bends with 0.008" thick aluminum, smooth, plate fins. Headers shall be heavy seamless copper tubing, silver-brazed to tubes, with vents, drains, and serpentine, continuous tube design with circuiting as required to meet scheduled pressure requirements. Coil connections shall be of threaded steel pipe, with male pipe threads, silver-brazed to the headers. Supply and return coil connections shall extend through unit casing.
3. Chilled water coil casing shall be constructed from 16 gauge, 304 stainless steel.
4. Heating coil frames shall be 16ga galvanized. All coils shall be safed off with stainless steel panel to a panel seam or a frame joint so that no air bypass can occur. Coils safed to inner liners are not acceptable.
5. Coils shall be drainable and be designed to operate at 250 PSIG design working pressure and up to 300ºF and shall be tested with 350 PSIG compressed air under water. Circuiting shall not exceed water velocity of 6 FPS and shall not exceed maximum design pressure.
6. At design conditions, there shall be no moisture carryover. If required to prevent moisture carryover, provide aluminum or stainless steel moisture eliminators on downstream side.
7. All drain connections shall be extended to outside of unit casing. Mechanical Contractor shall furnish and install manual ball valves for manual vents and drain connections as required. All drain piping shall be copper Type DWV, with soldered connections.
8. Coils will be circuited for counter flow of air and water. Water velocities will not exceed water pressure drop head of 10ft. All coils will have same end connections regardless of the number of rows deep.
9. All coils shall be removable from one side, and all coil connections shall be on the same side as the coil pull side. Split coils shall have end connections on, and be removable from, one side of the air handling unit.
10. Provide type 304 stainless steel safe-off panels between coils and casing walls to prevent air bypass; the assembly shall be airtight.
11. All bolts and fasteners required to be removed when replacing a coil shall be type 304 stainless steel.

12. Provide removable access panels in unit casing as shown on Bid Drawings for coil removal. Provide coil support racks designed for upstream or downstream removal if side removal is not possible.
13. Provide condensate drain pain in cooling coil section; refer to Drain Pan Section for further requirements. Condensate pans shall be designed and manufactured to incorporate future eliminators without any field modification.
14. All supply and return connections shall extend through the unit casing and be sealed by the AHU Manufacturer. AHU casing penetration shall be fully sealed out outer casing and inner liner such that no insulation is exposed. Cover open ended pipe with air/water tight end caps during shipping (plastic sheet covers will not be acceptable).
15. For any pipe supports required, use flexible pipe couplings ring supports (aluminum) for all pipe supports. All pipe supports within unit shall be aluminum Behringer heavy series vibration reduction clamps and stainless steel hex head bolts and polypropylene bushings directly bolted to the unit support system.

C. Condensate Drain Pans:

1. Fabricated with one percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and from humidifiers and to direct water toward drain connection.

    a. Length (min 36 inches): Extend drain pan downstream from leaving face to comply with ASHRAE 62.1.
    b. Depth: A minimum of 2 inches deep.
2. Double-wall, 18 gauge 304 stainless-steel sheet with space between walls filled with foam insulation and moisture-tight seal. Pan shall be welded to structural base. Insulation performance shall not be diminished by the sloping of the drain pan. Provide additional base height for increased insulation to meet the performance specified.
3. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on one end of pan.

    a. Minimum Connection Size: NPS 1.

4. Connections shall be on the same side as the access.
5. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.
6. All drain pans shall have a removable 304 stainless steel grating that sits flush to the unit floor for safe access to the section.

2.6 AIR FILTRATION SECTION

A. General Requirements for Air Filtration Section:

1. Comply with NFPA 90A.
2. Provide minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
3. Provide filter holding frames arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lifted out from access plenum.

B. Disposable Panel Filters:

1. Field-fabricated, viscous-coated, flat-panel type.
2. Thickness: 2 inches.
3. Dust-Holding Capacity: 170g.
4. Initial Resistance: 0.15 inches wg.

5. Recommended Final Resistance: 1.15 inches wg. or as per selected manufacturer requirements.
6. Arrestance (ASHRAE 52.1): 90.
7. Merv (ASHRAE 52.2): 8.
8. Media: Cotton synthetic blend formed into a uniform radial pleat.
9. Frame: Galvanized steel, with metal grid on outlet side, steel rod grid on inlet side, hinged, and with pull and retaining handles. All filter holding frames must be caulked in between them to minimize bypass air through the frames.

C. Filter Gage:

1. Provide filter gauge across each filter section with display flush to exterior of unit.

2. 3-1/2-inch- diameter, diaphragm-actuated dial in metal case.
3. Vent valves.
4. Black figures on white background.
5. Front recalibration adjustment.
6. 2 percent of full-scale accuracy.
7. Range: 0- to 2.0-inch wg.
8. Accessories: Static-pressure tips with integral compression fittings, 1/4-inch aluminum tubing, and 2- or 3-way vent valves.

2.7 DAMPERS

A. General Requirements for Dampers: Leakage rate, according to AMCA 500, "Laboratory Methods for Testing Dampers for Rating," shall not exceed 3cfm/sqft 1-inch wg pressure differential, AMCA licensed as a Class 1A damper.

B. Provide dampers for intake, discharge and outside air unit openings. Supply air and Return air dampers shall be provided with end switches.

A. Electronic Damper Actuators: Provide actuators with analog 0-10Vdc, 2-10Vdc, 4-20ma. Actuators shall travel full stroke in less than 90 seconds. Actuators shall be designed for a minimum of 60,000 cycles at full torques and be UL873 listed. Actuators shall have current limiting motor protection. Damper actuators shall have internal damper position mechanism for damper open-close feedback indication to BAS. Manufacturers: Siemens, Honeywell.
1. Actuators on all dampers related to smoke control systems must travel full stroke in less than 30 seconds.

B. End Switches: Provide mechanically activated damper position switch where indicated. Device shall be cam or whisker type. Actuator manufacturer’s integrated end switch may also be used as long as proof positions are adjustable to match actual damper blade position

C. Aluminum Airfoil Dampers

1. Aluminum airfoil frames and blades shall be a minimum of 12 gauge extruded aluminum. Blades to be 6” wide single air foil design.

2. Frames shall be extruded aluminum channel with grooved inserts for vinyl seals. Standard frames 2” x 4” x 5/8” on linkage side, 1” x 4” x 1” on the other sides.

3. Pivot rods shall be 7/16” hexagon extruded aluminum interlocking into blade section. Bearings to be double sealed type with a Celcon inner bearing on a rod within a Polycarbonate outer bearing inserted into frame so that the outer bearing cannot rotate.

4. Bearing shall be designed so that there is no metal-to-metal or metal-to-bearing riding surfaces. Interconnecting linkage shall have a separate Celcon bearing to eliminate friction in linkage.

5. Blade linage hardware is to be installed in frame out of airstream. All hardware to be on non-corrosive reinforced material or cadmium plated steel.
6. Damper seals shall be designed for minimum air leakage by means of overlapping seals.

7. Damper blades shall be maximum 40" long per section.

8. Dampers greater than 2 sections wide shall be provided with a jackshaft.

2.8 ELECTRICAL

A. Provide an interlocking mechanism on the fan section access door to de-energize the fan when the door is opened. The de-energizing switch is compliance with CAL-OSHA, ETL and the mechanical protection requirements of UL 1995. Provide a caution label on the door alerting the fact that opening the door will cause fan shutdown.

B. Wire each motor to a junction box mounted on the unit exterior.

C. Provide fifty percent of fan motors with field-wired to a VFD with integral disconnect, with a total of two fully wired, integral VFDs. The VFD shall be provided by the AHU manufacturer.

D. All VFDs shall be per building base manufacturer, coordinate with construction manager for preferred VFD vendors.

E. Service Light: 100-W (or LED equivalent) equivalent CFL vapor-proof fixture with guard.
1. Locations: Each access section.
2. One-60 minute timer switch to control all service lights at the most accessible end of the unit in a NEMA 1 enclosure.
3. Lights shall be constructed of safety glass.
4. Lights and conduit shall be suitable for wet locations and vaportight.

F. Conduit shall be appropriately sized EMT with a 3 ft. section of flex conduit at the motor to provide a vibration loop. EMT conduit used up to 100 HP, TEK wire used on 100 HP and up, when single point wiring is required.

G. Field wiring of Lights, VFDs, Combination Starters/Disconnects, and Fan Disconnect Switches
1. VFDs, Fan disconnect switches shall be wired per NEC, UL, and NFPA 90 A requirements. Units with VFDs shall have a binary start-stop signal and an analog speed signal wired from the direct digital controller to the VFD.
2. All power wiring for voltages greater than 24V shall be contained in an enclosed, metal, power-wiring raceway or EMT. When a power-wiring raceway is used, access panels shall be provided in the raceway at each shipping split to enable access to the wiring during installation. Flexible conduit connections shall be vapor tight. All junction boxes shall be gasketed.
3. The AHU shall provide a single-point power connection for all motors, VFDs, fan disconnect switches, control end devices, and unit controller on each AHU. The AHU Manufacturer shall also provide a separate 115V power connection for lights and GFCI convenience outlet.
4. Field Commissioning of VFDs and Combination Starter/Disconnects
   a. After mounting and wiring of VFDs, on the AHUs, trained field personnel shall ensure proper operation of each VFD, through a thorough field test. Testing shall include a Hypot test of unit wiring to ensure that no weaknesses exist in wiring or motor.

5. Field wired for a single point electrical connection for all field connection as all components shall be field wired.

H. Low voltage conduits and junction boxes shall be field installed with internal (i.e. section to section) through-wall penetrations to limit the number of field openings through the casing thermal/vapor barrier.

2.9 CONTROLS

A. Field-install airflow measurement stations for each fan and for outdoor airflow. Provide a digital display on outside of unit, with outputs for Controls Contractor to connect to.
1. Acceptable Air Flow Stations shall be:
a. Air Monitor Corporation or Approved Equal.

B. Provide terminal contacts and other wiring termination points for field-connection by Controls Contractor.

2.10 SOURCE QUALITY CONTROL

A. Fan Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Fans shall bear AMCA-certified sound ratings seal.

B. Fan Performance Rating: Field test fan performance for airflow, pressure, power, air density, rotation speed, and efficiency. Rate performance according to AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating."

C. Water Coils: Factory tested to 300 psig according to ARI 410 and ASHRAE 33.

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 casing insulation materials and filter media before air-handling unit installation. Reject insulation materials and filter media that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for hydronic, and condensate drainage piping systems and electrical services to verify actual locations of connections before installation.

D. Proceed with installation only after unsatisfield conditions have been corrected.

3.2 INSTALLATION

1. Comply with requirements for vibration isolation control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."

B. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing, with new, clean filters.

C. Install filter-gage, static-pressure taps upstream and downstream of filters. Mount filter gages on outside of filter housing or filter plenum in accessible position.

3.3 CONNECTIONS

A. Comply with requirements for piping specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to air-handling unit to allow service and maintenance.

C. Connect piping to air-handling units mounted on vibration isolators with flexible connectors.

D. Connect condensate drain pans using NPS 1 , ASTM B 88, Type L copper tubing. Extend to nearest equipment or floor drain. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

3.4 ELECTRICAL

A. Refer to Division 26 Specification sections for electrical installation requirements

3.5 FIELD QUALITY CONTROL

A. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a field-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

B. Tests and Inspections:

1. Leak Test: After installation, fill water coils with water, and test coils and connections for leaks.
2. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

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

D. Prepare test and inspection reports.

3.6 STARTUP SERVICE

A. Mechanical Contractor to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.

4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with field-recommended lubricants.
6. Verify that zone dampers fully open and close for each zone.
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. Install new, clean filters.
10. 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.
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.

3.7 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.

3.8 CLEANING

A. After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems and after completing startup service, clean air-handling units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new, clean filters.

3.9 DEMONSTRATION

A. Engage a field-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain air-handling units.

END OF SECTION 237313