ADDENDUM 3

Oklahoma City Airport Trust

Oklahoma City, Oklahoma

Air Navigation Facility 1 Mechanical Renovation
Mike Monroney Aeronautical Center
Project No. OCAT WRWA 2432

APPROVAL RECOMMENDED:

Director of Airports

APPROVED by the Oklahoma City Airport Trust and signed by the Chairman this _____ day of _____, 20_____.

ATTEST:

Trust Secretary

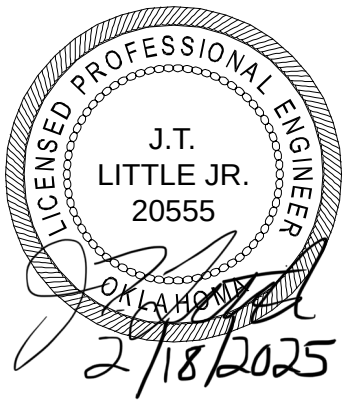
OKLAHOMA CITY AIRPORT TRUST

Chairman

REVIEWED for form and legality.

Assistant Municipal Counselor/
Attorney for the Trust

OKLAHOMA CERTIFICATE
OF AUTHORIZATION
ARCHITECTURE: # 00199
EXP. 06/30/2025



OKLAHOMA CERTIFICATE
OF AUTHORIZATION
P.E: # 1072
EXP. 06/30/26

ADDENDUM 3

FEBRUARY 18, 2025

OKLAHOMA CITY AIRPORT TRUST **OCAT WRWA 2432** **AIR NAVIGATION FACILITY 1** **MECHANICAL RENOVATION** **MIKE MONRONEY AERONAUTICAL CENTER**	**FRANKFURT-SHORT-BRUZA ASSOCIATES, P.C.** **5801 BROADWAY EXTENSION SUITE 500** **OKLAHOMA CITY, OKLAHOMA, 73118**

Items in this addendum take precedence over the original bid documents. Items not specifically revised remain in effect.

SPECIFICATIONS

ITEM 3-1 Section OCAT 00005 SPECIFICATION SIGNATURE PAGE: Page 3 is reissued to add the Addendum 3 specifications.

ITEM 3-2 Section OCAT 00010 TABLE OF CONTENTS is reissued to add the Addendum 3 specifications.

ITEM 3-3 Section 024119 SELECTIVE DEMOLITION is reissued to add information on the existing roofing warranty and requirements for roofing contractors top perform work on the roof.

ITEM 3-4 Section 232123 HYDRONIC PUMPS. Add Paragraph 2.2.A.7, adding Wilo Pumps to the list of approved manufacturers.

ITEM 3-5 Section 236416 CENTRIFUGAL WATER CHILLERS is revised to add Paragraph 2.3.A.4, adding York/JCI to the list of approved manufacturers.

ITEM 3-6 Section 237313.19 INDOOR, CUSTOM AIR-HANDLING UNITS is revised to add Paragraph 2.3.A.1 for approved manufacturers:

ITEM 3-7 Section 237343.19 OUTDOOR, CUSTOM AIR-HANDLING UNITS is revised to modify Paragraph 2.4.A for approved manufacturers.

ITEM 3-8 Section 260573.13 - SHORT-CIRCUIT STUDIES is added to the project.

ITEM 3-9 Section 260573.16 - COORDINATION STUDIES is added to the project.

ITEM 3-10 Section 260573.19 - ARC-FLASH HAZARD ANALYSIS is added to the project.

QUESTIONS AND ANSWERS (previously responded to on Electronic Bidding website)

ITEM 3-11 Question 1
Will there be any temporary construction fence and or construction gates required on this project? (Submitted: Jan 27, 2025 7:59:14 AM CST)

Answer
See OCAT 00660 LEGAL RELATION AND RESPONSIBILITY TO THE PUBLIC for contractor's responsibility for the safekeeping of the worksite and materials. (Answered: Feb 6, 2025 9:56:18 AM CST)

ITEM 3-12 Question 2
Does a specific roofing contractor need to be used? (Submitted: Feb 6, 2025 2:42:28 PM CST)

Answer
See Project Manual Section 024119 - Selective Demolition 1.10 and forthcoming Addenda No 3

for clarification. (Answered: Feb 7, 2025 3:39:43 PM CST)

ITEM 3-13 Question 3
What is existing type of roofing membrane? (Submitted: Feb 6, 2025 2:42:53 PM CST)

Answer
See Project Manual Section 024119 - Selective Demolition 1.10. The existing roof system is a Skia Sarnafil G410 (PVC), 60-mil, fully adhered system. The Sika Sarnafil Warranty Serial Number is 0000007316-069713.2. (Answered: Feb 7, 2025 3:39:43 PM CST)

ITEM 3-14 Question 4
Do existing indoor AHU, chiller, pump equipment pads need to be demolished and replaced? Or, can they be extended as needed? (Submitted: Feb 6, 2025 3:12:33 PM CST)

Answer
Existing equipment pads may be modified and reused. (Answered: Feb 13, 2025 2:51:41 PM CST)

ITEM 3-15 Question 5
Does the Lightning protection need to be re certified after it is removed from the existing equipment and reinstalled on the new roof top equipment? (Submitted: Feb 7, 2025 3:14:37 PM CST)

Answer
The existing lightning protection system does not have a Underwriter's Laboratory (UL) Master Label Certificate. Contractor shall provide a UL Letter of Findings for the lightning protection scope under this project. (Answered: Feb 13, 2025 2:51:41 PM CST)

ITEM 3-16 Question 6
Will an updated arc flash/coordination study be required on the modified/added electrical equipment? (Submitted: Feb 7, 2025 3:15:54 PM CST)

Answer
Yes. Reference the added specifications included with Addendum 3. (Answered: Feb 13, 2025 2:51:41 PM CST)

END OF ADDENDUM 3

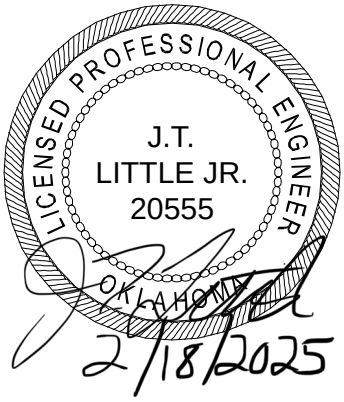
ENGINEERING SPECIFICATION RESPONSIBILITY	
FRANKFURT-SHORT-BRUZA ASSOCIATES, P.C OKLAHOMA CERTIFICATION OF AUTHORITY NO. 1072 Expiration Date: JUNE 30, 2026	
I hereby certify that the applicable portions of this project plans and specifications were prepared by me or under my responsible control and that I am a duly Licensed Engineer under the laws of the State of Oklahoma.	
Seal and Signature	**Responsible For**
 J.T. LITTLE, P.E. DIRECTOR OF ELECTRICAL ENGINEERING	SECTION 260519 LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES SECTION 260523 CONTROL-VOLTAGE ELECTRICAL POWER CABLES SECTION 260526 GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS SECTION 260529 HANGERS AND SUPPORTS FOR ELECTRICAL SYSTEMS SECTION 260533.13 CONDUITS FOR ELECTRICAL SYSTEM SECTION 260533.16 BOXES AND COVERS FOR ELECTRICAL SYSTEMS SECTION 260553 IDENTIFICATION FOR ELECTRICAL SYSTEMS **SECTION 260573.13 SHORT-CIRCUIT STUDIES** **SECTION 260573.16 COORDINATION STUDIES** **SECTION 260573.19 ARC-FLASH HAZARD ANALYSIS** SECTION 262416 PANELBOARDS SECTION 262726 WIRING DEVICES SECTION 262816 ENCLOSED SWITCHES AND CIRCUIT BREAKERS SECTION 262913.03 MANUAL AND MAGNETIC MOTOR CONTROLLERS SECTION 262923 VARIABLE-FREQUENCY MOTOR CONTROLLERS

TABLE OF CONTENTS

DIVISION 00 — PROCUREMENT AND CONTRACTING REQUIREMENTS

SECTION 024119 - SELECTIVE DEMOLITION

PART 1 - GENERAL

1.1 SUMMARY

A. The Work of this Section Includes:

1. Demolition and removal of selected portions of exterior or interior of building or structure and site elements.
2. Removal and salvage of existing items for delivery to Owner and removal of existing items for reinstallation.

B. Related Requirements:

1. Section 013516 "Alteration Project Procedures" for general protection and work procedures for alteration projects.

1.2 DEFINITIONS

A. Remove: Detach items from existing construction and legally dispose of off-site unless indicated to be removed and salvaged or removed and reinstalled.

B. Remove and Salvage: Detach items from existing construction, in a manner to prevent damage, and deliver to Owner as indicated.

C. Remove and Reinstall: Detach items from existing construction, in a manner to prevent damage; prepare for reuse; and reinstall where indicated.

D. Existing to Remain: Existing items of construction that are not to be removed.

1.3 MATERIALS OWNERSHIP

A. Unless otherwise indicated, demolition waste becomes property of Contractor.

B. Historic items, relics, antiques, and similar objects including, but not limited to, cornerstones and their contents, commemorative plaques and tablets, and other items of interest or value to Owner that may be uncovered during demolition remain the property of Owner.

1. Carefully salvage in a manner to prevent damage and promptly return to Owner.

1.4 COORDINATION

A. Arrange selective demolition schedule so as not to interfere with Owner's operations.

1.5 PREINSTALLATION MEETINGS

A. Predemolition Conference: Conduct conference at Project site.

1. Inspect and discuss condition of construction to be selectively demolished.
2. Review structural load limitations of existing structure.
3. Review and finalize selective demolition schedule and verify availability of demolition personnel, equipment, and facilities needed to make progress and avoid delays.
4. Review requirements of work performed by other trades that rely on substrates exposed by selective demolition operations.
5. Review areas where existing construction is to remain and requires protection.
6. Review and finalize protection requirements.
7. Review procedures for noise control and dust control.
8. Review storage, protection, and accounting for items to be removed for salvage or reinstallation.

1.6 INFORMATIONAL SUBMITTALS

A. Qualification Statements: For refrigerant recovery technician.

B. Engineering Survey: Submit engineering survey of condition of building.

C. Survey of Existing Conditions: Submit survey.

D. Proposed Protection Measures: Submit report, including Drawings, that indicates the measures proposed for protecting individuals and property. Indicate proposed locations and construction of barriers.

E. Schedule of Selective Demolition Activities: Indicate the following:

1. Detailed sequence of selective demolition and removal work, with starting and ending dates for each activity. Ensure Owner's on-site operations are uninterrupted.
2. Temporary interruption of utility services. Indicate how long utility services will be interrupted.
3. Coordination for shutoff, capping, and continuation of utility services.
4. Use of elevator and stairs.
5. Coordination of Owner's continuing occupancy of portions of existing building and of Owner's partial occupancy of completed Work.

F. Statement of Refrigerant Recovery: Signed by refrigerant recovery technician responsible for recovering refrigerant, stating that all refrigerant that was present was recovered and that recovery was performed in accordance with EPA regulations. Include name and address of technician and date refrigerant was recovered.

G. Warranties: Documentation indicating that existing warranties are still in effect after completion of selective demolition.

1.7 CLOSEOUT SUBMITTALS

A. Inventory: Submit a list of items that have been removed and salvaged.

1.8 QUALITY ASSURANCE

A. Refrigerant Recovery Technician Qualifications: Universal certified by an EPA-approved certification program.

1.9 FIELD CONDITIONS

A. Owner will occupy portions of building immediately adjacent to selective demolition area. Conduct selective demolition so Owner's operations will not be disrupted.

B. Conditions existing at time of inspection for bidding purpose will be maintained by Owner as far as practical.

C. Notify Architect of discrepancies between existing conditions and Drawings before proceeding with selective demolition.

D. Hazardous Materials:

1. It is not expected that hazardous materials will be encountered in the Work.

a. If materials suspected of containing hazardous materials are encountered, do not disturb; immediately notify Architect and Owner. Hazardous materials will be removed by Owner under a separate contract.

E. On-site sale of removed items or materials is not permitted.

1.10 WARRANTY

A. Existing Warranties: Remove, replace, patch, and repair materials and surfaces cut or damaged during selective demolition, by methods and with materials and using approved contractors so as not to void existing warranties. Notify warrantor before proceeding. Existing warranties include the following:

~~1. Existing roof system is under warranty by Sika Sarnafil. Warranty Serial No. 0000007316-069713.2.~~

1. The existing roof system is a Sika Sarnafil G410 (PVC), 60-mil, fully adhered system and is covered by a Manufacturer's Roof System Warranty. The Sika Sarnafil Warranty Serial Number is 0000007316-069713.2.

2. The Roofing Contractor performing modifications to the roof system must be a Sika Sarnafil Authorized Roofing Applicator. Contractor shall obtain written authorization from Sika Sarnafil and submit this to the Owner and A/E for approval before any roofing work begins. For project closeout, Contractor shall submit documentation from Sika Sarnafil that the roof work has been accepted and that the warranty remains in effect.

B. Notify warrantor on completion of selective demolition, and obtain documentation verifying that existing system has been inspected and warranty remains in effect. Submit documentation at Project closeout.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Regulatory Requirements: Comply with governing EPA notification regulations before beginning selective demolition. Comply with hauling and disposal regulations of authorities having jurisdiction.

B. Standards: Comply with ANSI/ASSP A10.6 and NFPA 241.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Verify that utilities have been disconnected and capped before starting selective demolition operations.

B. Review Project Record Documents of existing construction or other existing condition and hazardous material information provided by Owner. Owner does not guarantee that existing conditions are same as those indicated in Project Record Documents.

C. Steel Tendons: Locate tensioned steel tendons and include recommendations for de-tensioning.

D. Verify that hazardous materials have been remediated before proceeding with building demolition operations.

E. Survey of Existing Conditions: Record existing conditions by use of preconstruction photographs or video and measured drawings. Comply with Section 013233 "Photographic Documentation."

1. Inventory and record the condition of items to be removed for salvage or reinstallation. Photograph or video conditions that might be misconstrued as damage caused by removal.
2. Photograph or video existing conditions of adjoining construction including finish surfaces, that might be misconstrued as damage caused by selective demolition operations or removal of items for salvage or reinstallation.

3.2 PREPARATION

A. Temporary Shoring: Design, provide, and maintain shoring, bracing, and structural supports as required to preserve stability and prevent movement, settlement, or collapse of construction and finishes to remain, and to prevent unexpected or uncontrolled movement or collapse of construction being demolished.

1. Strengthen or add new supports when required during progress of selective demolition.

B. Temporary Protection: Provide temporary barricades and other protection required to prevent injury to people and damage to adjacent buildings and facilities to remain.

1. Provide protection to ensure safe passage of people around selective demolition area and to and from occupied portions of building.
2. Provide temporary weather protection, during interval between selective demolition of existing construction on exterior surfaces and new construction, to prevent water leakage and damage to structure and interior areas.
3. Protect walls, ceilings, floors, and other existing finish work that are to remain or that are exposed during selective demolition operations.
4. Cover and protect furniture, furnishings, and equipment that have not been removed.
5. Comply with requirements for temporary enclosures, dust control, heating, and cooling specified in Section 015000 "Temporary Facilities and Controls."

C. Existing Items to Remain: Protect construction indicated to remain against damage and soiling during selective demolition. When permitted by Architect, items may be removed to a suitable, protected storage location and cleaned and reinstalled in their original locations after selective demolition operations are complete.

D. Refrigerant: Before starting demolition, remove refrigerant from mechanical equipment in accordance with 40 CFR 82 and regulations of authorities having jurisdiction.

3.3 UTILITY SERVICES AND BUILDING SYSTEMS

A. Existing Services/Systems to Remain: Maintain utilities and building systems and equipment to remain and protect against damage during selective demolition operations.

1. Maintain fire-protection facilities in service during selective demolition operations.

B. Existing Services/Systems to Be Removed, Relocated, or Abandoned: Locate, identify, disconnect, and seal or cap off utilities and building systems serving areas to be selectively demolished.

1. Owner will arrange to shut off indicated utilities when requested by Contractor.
2. Arrange to shut off utilities with utility companies.
3. If disconnection of utilities and building systems will affect adjacent occupied parts of the building, provide temporary services/systems that bypass area of selective demolition and that maintain continuity of services/systems to those parts of the building.
4. Demolish and remove existing building systems, equipment, and components indicated on Drawings to be removed.

    a. Piping to Be Removed: Remove portion of piping indicated to be removed and cap or plug remaining piping with same or compatible piping material.
    b. Ducts to Be Removed: Remove portion of ducts indicated to be removed and plug remaining ducts with same or compatible ductwork material.
    c. Equipment to Be Removed: Disconnect and cap services and remove equipment and components.

5. Abandon existing building systems, equipment, and components indicated on Drawings to be abandoned in place.

    a. Piping to Be Abandoned in Place: Drain piping and cap or plug piping with same or compatible piping material and leave in place.
    b. Ducts to Be Abandoned in Place: Cap or plug ducts with same or compatible ductwork material and leave in place.

6. Remove and reinstall/salvage existing building systems, equipment, and components indicated on drawings to be removed and reinstalled or removed and salvaged:

    a. Equipment to Be Removed and Reinstalled: Disconnect and cap services and remove, clean, and store equipment and components; when appropriate, reinstall, reconnect, and make equipment operational.
    b. Equipment to Be Removed and Salvaged: Disconnect and cap services and remove equipment and components and deliver to Owner.

3.4 SALVAGE/REINSTALL

A. Removed and Salvaged Items:

1. Clean salvaged items.
2. Pack or crate items after cleaning. Identify contents of containers with label indicating elements, date of removal, quantity, and location where removed.
3. Store items in a secure area until delivery to Owner.
4. Transport items to Owner's storage area on-site .
5. Protect items from damage during transport and storage.

B. Removed and Reinstalled Items:

1. Clean and repair items to functional condition adequate for intended reuse.
2. Pack or crate items after cleaning and repairing. Identify contents of containers.
3. Protect items from damage during transport and storage.
4. Reinstall items in locations indicated. Comply with installation requirements for new materials and equipment. Provide connections, supports, and miscellaneous materials necessary to make item functional for use indicated.

3.5 SELECTIVE DEMOLITION, GENERAL

A. General: Demolish and remove existing construction only to extent required by new construction and as indicated. Use methods required to complete the Work within limitations of governing regulations and as follows:

1. Proceed with selective demolition systematically, from higher to lower level. Complete selective demolition operations above each floor or tier before disturbing supporting members on the next lower level.

2. Neatly cut openings and holes plumb, square, and true to dimensions required. Use cutting methods least likely to damage construction to remain or adjoining construction. Use hand tools or small power tools designed for sawing or grinding, not hammering and chopping. Temporarily cover openings to remain.
3. Cut or drill from the exposed or finished side into concealed surfaces to avoid marring existing finished surfaces.
4. Do not use cutting torches until work area is cleared of flammable materials. At concealed spaces, such as duct and pipe interiors, verify condition and contents of hidden space before starting flame-cutting operations. Maintain portable fire-suppression devices during flame-cutting operations.
5. Maintain fire watch during and for at least two hours after flame-cutting operations.
6. Maintain adequate ventilation when using cutting torches.
7. Remove decayed, vermin-infested, or otherwise dangerous or unsuitable materials and promptly dispose of off-site.
8. Remove structural framing members and lower to ground by method suitable to avoid free fall and to prevent ground impact or dust generation.
9. Locate selective demolition equipment and remove debris and materials so as not to impose excessive loads on supporting walls, floors, or framing.

B. Site Access and Temporary Controls: Conduct selective demolition and debris-removal operations to ensure minimum interference with roads, streets, walks, walkways, and other adjacent occupied and used facilities.

1. Do not close or obstruct streets, walks, walkways, or other adjacent occupied or used facilities without permission from Owner and authorities having jurisdiction. Provide alternate routes around closed or obstructed trafficways if required by authorities having jurisdiction.
2. Use water mist and other suitable methods to limit spread of dust and dirt. Comply with governing environmental-protection regulations. Do not use water when it may damage adjacent construction or create hazardous or objectionable conditions, such as ice, flooding, and pollution.

3.6 SELECTIVE DEMOLITION PROCEDURES FOR SPECIFIC MATERIALS

A. Concrete:

1. Demolish in small sections. Using power-driven saw, cut concrete to a depth of at least 3/4 inch at junctures with construction to remain. Dislodge concrete from reinforcement at perimeter of areas being demolished, cut reinforcement, and then remove remainder of concrete. Neatly trim openings to dimensions indicated.
2. Demolish in sections. Cut concrete full depth at junctures with construction to remain and at regular intervals using power-driven saw, and then remove concrete between saw cuts.

B. Masonry: Demolish in small sections. Cut masonry at junctures with construction to remain, using power-driven saw, and then remove masonry between saw cuts.

C. Concrete Slabs-on-Grade: Saw-cut perimeter of area to be demolished, and then break up and remove.

D. Resilient Floor Coverings: Remove floor coverings and adhesive in accordance with recommendations in RFCI's "Recommended Work Practices for the Removal of Resilient Floor Coverings." Do not use methods requiring solvent-based adhesive strippers.

3.7 DISPOSAL OF DEMOLISHED MATERIALS

A. Remove demolition waste materials from Project site.

1. Do not allow demolished materials to accumulate on-site.
2. Remove and transport debris in a manner that will prevent spillage on adjacent surfaces and areas.
3. Remove debris from elevated portions of building by chute, hoist, or other device that will convey debris to grade level in a controlled descent.

B. Burning: Do not burn demolished materials.

3.8 CLEANING

A. Clean adjacent structures and improvements of dust, dirt, and debris caused by selective demolition operations. Return adjacent areas to condition existing before selective demolition operations began.

END OF SECTION

SECTION 232123 - HYDRONIC PUMPS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Separately coupled, base-mounted, end-suction centrifugal pumps.

1.2 DEFINITIONS

A. ECM: Electronically commutated motor.

B. EPDM: Ethylene propylene diene monomer.

C. EPR: Ethylene propylene rubber.

D. FKM: Fluoroelastomer polymer.

E. HI: Hydraulic Institute.

F. NBR: Nitrile rubber or Buna-N.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of pump.

1. Include certified performance curves and rated capacities, operating characteristics, furnished specialties, final impeller dimensions, and accessories for each type of product indicated.
2. Indicate pump's operating point on curves.

B. Shop Drawings: For each pump.

1. Show pump layout and connections.
2. Include setting drawings with templates for installing foundation and anchor bolts and other anchorages.
3. Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Plans, or BIM model, drawn to scale, showing the items described in this Section, and coordinated with all building trades.

B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For pumps to include in emergency, operation, and maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Mechanical Seals: One mechanical seal(s) for each pump.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

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.

2.2 SEPARATELY COUPLED, BASE-MOUNTED, END-SUCTION CENTRIFUGAL PUMPS

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

1. Armstrong Fluid Technology.
2. Aurora Pump; Pentair Ltd.
3. ITT Corporation.
4. PACO Pumps; Grundfos Pumps Corporation, USA.
5. Peerless Pump Company.
6. Taco Comfort Solutions.
7. **Wilo**

B. Source Limitations: Obtain pumps from single source from single manufacturer.

C. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, end-suction pump with flexible shaft coupling as defined in HI 1.1-1.2 and HI 1.3; designed for base mounting, with pump and motor shafts horizontal.

D. Pump Construction:

1. Casing: Radially split, cast iron, with replaceable bronze wear rings, threaded gauge tappings at inlet and outlet, drain plug at bottom and air vent at top of volute, and flanged connections. Provide integral mount on volute to support the casing, and provide attached piping to allow removal and replacement of impeller without disconnecting piping or requiring realignment of pump and motor shaft.
2. Impeller: ASTM B584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For pumps that are not frequency-drive controlled, trim impeller to match specified performance.

3. Pump Shaft: Type 304 stainless steel.
4. Seal, Mechanical Type: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless steel spring, and EPDM bellows and gasket.
5. Pump Bearings: Grease-lubricated ball bearings in cast-iron housing with grease fittings.

E. Shaft Coupling: Molded-rubber insert and interlocking spider capable of absorbing vibration. Couplings shall be drop-out type to allow disassembly and removal without removing pump shaft or motor.

F. Coupling Guard: Dual rated; ANSI B15.1, Section 8; OSHA 1910.219 approved; steel; removable; attached to mounting frame.

G. Mounting Frame: Welded-steel frame and cross members, factory fabricated from ASTM A36/A36M channels and angles. Fabricate to mount pump casing, coupling guard, and motor.

H. Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230500 "Common Work Results for HVAC."

1. Enclosure: Totally enclosed, fan cooled.
2. NEMA Premium Efficient motors as defined in NEMA MG 1.
3. 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.
4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
5. Variable-speed motor.

2.3 PUMP SPECIALTY FITTINGS

A. Suction Diffuser:

1. Angle pattern.
2. 175-psig pressure rating, cast-iron body and end cap, pump-inlet fitting.
3. Bronze 16-mesh wire startup and Type 304 stainless steel permanent strainers with 3/16-inch.
4. Drain plug.
5. Factory-fabricated support.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine equipment foundations and anchor-bolt locations for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for piping systems to verify actual locations of piping connections before pump installation.

C. Examine foundations and inertia bases for suitable conditions where pumps will be installed.

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

3.2 PUMP INSTALLATION

A. Comply with HI 1.4.

B. Install pumps to provide access for periodic maintenance including removing motors, impellers, couplings, and accessories.

C. Independently support pumps and piping so weight of piping is not supported by pumps and weight of pumps is not supported by piping.

D. Equipment Mounting:

1. Install base-mounted pumps on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."
2. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

3.3 ALIGNMENT

A. Perform alignment service. When required by manufacturer to maintain warranty coverage, engage a factory-authorized service representative to perform it.

B. Comply with requirements in HI standards for alignment of pump and motor shaft. Add shims to the motor feet and bolt motor to base frame. Do not use grout between motor feet and base frame.

C. Comply with pump and coupling manufacturers' written instructions.

D. After alignment is correct, tighten foundation bolts evenly but not too firmly. Completely fill baseplate with nonshrink, nonmetallic grout while metal blocks and shims or wedges are in place. After grout has cured, fully tighten foundation bolts.

3.4 PIPING CONNECTIONS

A. Where installing piping adjacent to pump, allow space for service and maintenance.

B. Connect piping to pumps. Install valves that are same size as piping connected to pumps.

C. Install suction and discharge pipe sizes equal to or greater than diameter of pump nozzles.

D. Install check, shutoff, and throttling valves on discharge side of pumps.

E. Install Y-type strainer, suction diffuser and shutoff valve on suction side of pumps.

1. Use startup strainer for initial system startup. Install permanent strainer element before turnover of system to Owner.

F. Install flexible connectors on suction and discharge sides of base-mounted pumps between pump casing and valves.

G. Install pressure gauges on pump suction and discharge or at integral pressure-gauge tapping, or install single gauge with multiple-input selector valve.

3.5 ELECTRICAL CONNECTIONS

A. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

B. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."

C. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.

D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.

1. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.6 CONTROL CONNECTIONS

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

B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."

3.7 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks in accordance with manufacturer's written instructions.
2. Check piping connections for tightness.
3. Clean strainers on suction piping. Use startup strainer for initial startup.
4. Perform the following startup checks for each pump before starting:

    a. Verify bearing lubrication.
    b. Verify that pump is free to rotate by hand and that pump for handling hot liquid is free to rotate with pump hot and cold. If pump is bound or drags, do not operate until cause of trouble is determined and corrected.
    c. Verify that pump is rotating in correct direction.

5. Prime pump by opening suction valves and closing drains, and prepare pump for operation.
6. Start motor.

7. Open discharge valve slowly.

3.8 FIELD QUALITY CONTROL

A. Testing Agency: Owner will engage a qualified testing agency to perform tests and inspections.

B. Hydronic pumps will be considered defective if they do not pass tests and inspections.

C. Prepare test and inspection reports.

3.9 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps.

END OF SECTION

SECTION 236416 - CENTRIFUGAL WATER CHILLERS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Centrifugal water chillers.

1.2 DEFINITIONS

A. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input, using consistent units for any given set of rating conditions.

B. DDC: Direct digital control.

C. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.

D. IPLV: Integrated part-load value. A single-number part-load efficiency figure of merit for a single chiller calculated according to the method defined by AHRI 550/590 and referenced to AHRI standard rating conditions.

E. kVAR: Kilovolt-ampere reactive.

F. NPLV: Nonstandard part-load value. A single-number part-load efficiency figure of merit for a single chiller calculated according to the method defined by AHRI 550/590 and intended for operating conditions other than the AHRI standard rating conditions.

G. SCCR: Short-circuit current rating.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.
2. Performance at AHRI standard conditions and at conditions indicated.
3. Performance at AHRI standard unloading conditions.
4. Minimum evaporator flow rate.
5. Minimum condenser flow rate.
6. Refrigerant capacity of chiller.
7. Oil capacity of chiller.
8. Fluid capacity of evaporator, condenser.
9. Characteristics of safety relief valves.
10. Minimum entering condenser-fluid temperature.

11. Performance at varying capacities with constant design condenser-fluid temperature. Repeat performance at varying capacities for different condenser-fluid temperatures from design to minimum in 5 deg F increments.
12. Force and moment capacity of each piping connection.

B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, load distribution, required clearances, method of field assembly, components, and location and size of each field connection.
2. Wiring Diagrams: For power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Plans and elevations, or Building Information Model (BIM), drawn to scale, showing the items described in this Section and coordinated with all building trades.

B. Source Quality-Control Certifications: For chillers.

C. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For each chiller to include in emergency, operation, and maintenance manuals.

B. Instructional Videos: Including those that are pre-recorded and those that are recorded during training.

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Tool Kit:

1. A tool kit specially designed by chiller manufacturer for use in servicing chiller(s) furnished.
2. Special tools required to service chiller components not readily available to Owner service personnel in performing routine maintenance.
3. Lockable case with hinged cover, marked with large and permanent text to indicate the special purpose of tool kit, such as "Chiller Tool Kit." Text size must be at least 1 inch high.
4. A list of each tool furnished. Permanently attach the list to underside of case cover. Text size must be at least 1/2 inch high.

B. Touch-up Paint: 32-oz. container of paint used for finish coat. Label outside of container with detailed description of paint to allow for procurement of a matching paint in the future.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Ship chillers from the factory fully charged with refrigerant.

B. Ship each chiller with a full charge of refrigerant. Charge each chiller with nitrogen if refrigerant is shipped in containers separate from chiller.

C. Ship each oil-lubricated chiller with a full charge of oil.

1. Ship oil factory installed in chiller.

D. Package chiller for export shipping in totally enclosed bagging.

1.8 WARRANTY

A. Manufacturer Warranty: Manufacturer and Installer agree to repair or replace chillers that fail in materials or workmanship within specified warranty period.

B. Special Warranty: Manufacturer and Installer agree to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:

a. Complete chiller, including refrigerant and oil charge.
b. Complete compressor and drive assembly, including refrigerant and oil charge.
c. Refrigerant and oil charge.

1) Loss of refrigerant charge for any reason due to manufacturer product defect and product installation.

d. Parts and labor.

2. Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 SOURCE LIMITATIONS

A. Obtain centrifugal chillers from single manufacturer.

2.2 PERFORMANCE REQUIREMENTS

A. Condenser-Fluid Temperature Performance:

1. Startup Condenser-Fluid Temperature: Chiller is to be capable of starting with an entering condenser-fluid temperature of 55 deg F and providing stable operation until the system temperature is elevated to the minimum operating entering condenser-fluid temperature.

2. Minimum Operating Condenser-Fluid Temperature: Chiller is to be capable of continuous operation over the entire capacity range indicated with an entering condenser-fluid temperature of 60 deg F.
3. Make factory modifications to standard chiller design if necessary to comply with performance indicated.

B. Site Altitude: Chiller is to be suitable for altitude at which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.

C. ASHRAE Compliance:

1. ASHRAE 15 for safety code for mechanical refrigeration.
2. ASHRAE 147 for refrigerant leaks, recovery, and handling and storage requirements.
3. ASHRAE/IES 90.1.

D. ASME Compliance: Fabricate and label chillers to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, as applicable to chiller design. For chillers charged with R-134a, R-513A, or R-1234ze(E) refrigerant, include an ASME U-stamp and nameplate certifying compliance.

E. 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.

F. Comply with requirements of Underwriters Laboratories, and include label by a qualified testing agency showing compliance.

G. Operation Following Loss of Normal Power:

1. Equipment, associated factory- and field-installed controls, and associated electrical equipment and power supply connected to backup power system are to automatically return equipment and associated controls to the operating state occurring immediately before loss of normal power without need for manual intervention by an operator when power is restored either through a backup power source, or through normal power if restored before backup power is brought online.
2. Refer to Drawings for equipment served by back-up power systems.
3. Provide means and methods required to satisfy requirement, even if not explicitly indicated.

2.3 CENTRIFUGAL WATER CHILLERS

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

1. Carrier Global Corporation.
2. Daikin Applied.
3. Trane.
4. **York/JCI**

B. Description: Factory-assembled and -tested chiller complete with compressor, compressor motor, compressor motor controller, lubrication system evaporator, condenser, heat-reclaim condenser as indicated, controls, interconnecting unit piping and wiring, and indicated accessories.

1. Multi-Piece Assembly: Disassemble chiller into major assemblies as required by the installation after factory testing and before packaging for shipment.
2. Dual-Compressor Chillers: For chillers with dual compressors, provide each compressor with a dedicated motor and motor controller, and provide for continued operation when either compressor-drive assembly fails.

C. Fabricate chiller mounting base with reinforcement strong enough to resist chiller movement during a seismic event when chiller is anchored to field support structure.

D. Compressor-Drive Assembly: Single-stage or multistage, variable- or dynamic-displacement, centrifugal-type compressor driven by an electric motor.

1. Oil-Free Technology:

a. Where indicated, compressors must have oil-free technology using a permanent magnet synchronous motor, magnetic bearings, integral variable-frequency controller, and digital electronic controls.

1) Magnetic Bearings or Roller Element Bearings:

a) Levitated shaft position is to be actively controlled and monitored by an X-, Y-, and Z-axis digital position sensor.
b) Compressor assembly is to be capable of coming to a controlled, safe stop without damage during a power failure by diverting stored power to the magnetic bearing control system.

2) Integrate monitoring and controls associated with magnetic bearings into chiller controls, including following:

a) Operating Information: Positions, currents, temperatures, rotor elongation, and speed.
b) Warning Messages: Vibration.
c) Safety Shutdown: Internal fault, high bearing temperature or current, startup failure, speed signal fault, overspeed fault, communication error, rotor elongation, oscillator fault, rotor contraction, unauthorized rotation, and high and low voltage.
d) Cycling Shutdown: Position, low-frequency displacement, vibration, speed signal fault, startup failure, serial communications fault.

2. Compressor:

a. Casing: Cast iron, precision ground.
b. Impeller: High-strength cast-aluminum or cast-aluminum alloy on carbon- or alloy-steel shaft.

3. Drive: Direct-drive, hermetic design, using an electric motor as the driver.

a. Seals: Seal drive assembly to prevent refrigerant leakage.

4. Compressor Motor:

    a. Continuous-duty, squirrel-cage, induction-type, two-pole motor with energy efficiency required to suit chiller energy efficiency indicated.
    b. Factory mounted, aligned, and balanced as part of compressor assembly before shipping.
    c. Motor is to be of sufficient capacity to drive compressor throughout entire operating range without overload and with sufficient capacity to start and accelerate compressor without damage.

5. Vibration Balance: Balance chiller compressor and drive assembly to provide a precision balance that is free of noticeable vibration over the entire operating range.

    a. Overspeed Test: At least 20 percent above design operating speed.
    b. Vibration Limits: Velocities not to exceed 0.15 inch/s and 0.8 mil peak to peak on all axes.

6. Service: Easily accessible for inspection and service.

    a. Compressor's internal components are to be accessible without having to remove compressor-drive assembly from chiller.
    b. Provide lifting lugs or eyebolts attached to casing.

7. Economizers: For multistage chillers, provide interstage economizers.
8. Capacity Control: Modulating, variable-inlet, guide-vane assembly combined with hot-gas bypass, if necessary, to achieve performance indicated.

    a. Maintain stable operation that is free of surge, cavitation, and vibration throughout range of operation. Configure to achieve most energy-efficient operation possible.
    b. Operating Range: From 100 to 10 percent of design capacity.
    c. Condenser-Fluid Unloading Requirements over Operating Range: Constant-design of entering condenser-fluid temperature.
    d. Chillers with variable-frequency controllers must modulate compressor speed with variable-inlet, guide-vane control to achieve optimum energy efficiency.
    e. Avoid use of hot-gas bypass if other options are available to achieve performance indicated. Apply hot-gas bypass according to ASHRAE/IES 90.1 and governing codes.

9. Oil Lubrication System: Consisting of pump, filtration, heater, cooler, factory-wired power connection, and controls.

    a. Bearings, gears, and other rotating surfaces are to be lubricated at all operating, startup, coast down, and standby conditions, including power failure.
    b. Manufacturer's standard method to remove refrigerant from oil.
    c. Oil filter to be the easily replaceable cartridge type, minimum 0.5-micron efficiency, with means of positive isolation while servicing.
    d. Refrigerant- or water-cooled oil cooler.
    e. Factory-installed and pressure-tested piping with isolation valves and accessories.
    f. Oil compatible with refrigerant and chiller components.

g. Positive visual indication of oil level.

E. Refrigeration:

1. Refrigerant:

a. Type: R-514A; ASHRAE 34, Class B1.
b. Compatibility: Chiller parts exposed to refrigerants are to be fully compatible with refrigerants, and pressure components are to be rated for refrigerant pressures.

2. Refrigerant Flow Control: Manufacturer's standard refrigerant flow-control device satisfying performance requirements indicated.
3. Pressure Relief Device:

a. Comply with requirements in ASHRAE 15, ASHRAE 147, and applicable portions of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.
b. Select and configure pressure relief devices to protect against corrosion and inadvertent release of refrigerant.
c. Where dual pressure relief devices are installed in series, provide a sensor with indicator between devices to indicate refrigerant release past first device.
d. For Chillers Using R-514A or R-1233zd(E): Manufacturer's standard offering complying with ASHRAE 15 and ASHRAE 147.

4. Refrigeration Transfer: Provide service valves and other factory-installed accessories required to facilitate transfer of refrigerant from chiller to a remote refrigerant storage and recycling system. Comply with requirements in ASHRAE 15 and ASHRAE 147.
5. Refrigerant Isolation for Chillers Using R-134a, R-513A, or R-1234ze(E):

a. Factory install positive shutoff, manual isolation valves in the compressor discharge line to the condenser and the refrigerant liquid line leaving the condenser to allow for isolation and storage of full refrigerant charge in the chiller condenser shell.
b. Suction side of compressor from evaporator is to have an isolation valve to allow for isolation and storage of full refrigerant charge in the chiller evaporator shell.

6. Purge System:

a. For chillers operating at subatmospheric pressures using R-514A or R-1233zd(E) refrigerant, factory install an automatic purge system for collection and return of refrigerant and lubricating oil and for removal of noncondensables, including, but not limited to, water, water vapor, and noncondensable gases.
b. System is to be of thermal purge design, refrigerant or air cooled, and equipped with a carbon filter that includes an automatic regeneration cycle.
c. Factory wire to chiller's main power supply and system complete with controls, piping, and refrigerant valves to isolate the purge system from the chiller.
d. Construct components of noncorrodible materials.
e. Controls are to interface with chiller control panel to indicate modes of operation, set points, data reports, diagnostics, and alarms.
f. Efficiency of not more than 0.02 lb of refrigerant per pound of air when rated according to AHRI 580.
g. Operation independent of chiller according to ASHRAE 147.

7. Positive-Pressure System:

    a. For chillers operating at subatmospheric pressures using R-514A refrigerant, factory install an automatic positive-pressure system.
    b. During nonoperational periods, positive-pressure system is to automatically maintain a positive pressure for atmosphere in the refrigerant-pressure vessel of not less than 0.5 psig adjustable up to a pressure that remains within the vessel design pressure limits.
    c. Provide factory-wired system including controller, electric heat, pressure transmitter, or switch.

F. Evaporator:

1. Description: Shell-and-tube design, with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from condenser.
2. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
3. Designed to prevent liquid refrigerant carryover from entering compressor.
4. Evaporator must have sight glass or other form of positive visual verification of liquid-refrigerant level.
5. Tubes:

    a. Individually replaceable from either end and without damage to tube sheets and other tubes.
    b. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
    c. Material: Copper.
    d. Nominal OD: Manufacturer's choice.
    e. Minimum Wall Thickness: Manufacturer's choice.
    f. External Finish: Manufacturer's standard.
    g. Internal Finish: Enhanced.

6. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes, with positive seal between fluid in tubes and refrigerant in shell.
7. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear, but not more than 4 feet apart.
8. Water Box:

    a. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
    b. Marine type for water box with piping connections; standard type for water box without piping connections.
    c. Provide water boxes and marine water-box covers with lifting lugs or eyebolts.
    d. Hinged or davited marine water-box covers.
    e. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange .
    f. Thermistor or RTD temperature sensor factory installed in each nozzle.
    g. Fit each water box with 1-inch drain connection at low point and vent connection at high point, each with threaded plug.

9. Flow Sensor: Thermal dispersion type, factory calibrated for Project-specific application.

G. Condenser:

1. Description: Shell-and-tube design, with water in tubes and refrigerant surrounding tubes within shell. Shell is to be separate from evaporator.
2. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
3. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.
4. Condenser is to have sight glass or other form of positive visual verification of refrigerant charge and condition.
5. Tubes:

    a. Individually replaceable from either end and without damage to tube sheets and other tubes.
    b. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
    c. Material: Copper.
    d. Nominal OD: Manufacturer's choice.
    e. Minimum Wall Thickness: Manufacturer's choice.
    f. External Finish: Manufacturer's standard.
    g. Internal Finish: Enhanced.

6. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes, with positive seal between fluid in tubes and refrigerant in shell.
7. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear, but not more than 4 feet apart.
8. Water Box:

    a. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
    b. Marine type for water box with piping connections. Standard type for water box without piping connections.
    c. Water boxes and marine water-box covers are to have lifting lugs or eyebolts.
    d. Hinged or davited marine water-box covers.
    e. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange .
    f. Thermistor or RTD temperature sensor factory installed in each nozzle.
    g. Fit each water box with 1-inch drain connection at low point and vent connection at high point, each with threaded plug.

9. Flow Sensor: Thermal dispersion type, factory calibrated for Project-specific application.

H. Insulation:

1. Closed-cell, flexible elastomeric thermal insulation complying with ASTM C534, Type I for tubular materials and Type II for sheet materials.

    a. Thickness: 3/4 inch.

2. Adhesive: As recommended by insulation manufacturer.

3. Factory-applied insulation over all cold surfaces of chiller capable of forming condensation. Components include, but are not limited to, evaporator shell and end tube sheets, evaporator water boxes including nozzles, refrigerant suction pipe from evaporator to compressor, cold surfaces of compressor, refrigerant-cooled motor, and auxiliary piping.

    a. Apply adhesive to 100 percent of insulation contact surface.
    b. Before insulating steel surfaces, prepare surfaces for paint, and prime and paint as indicated for other painted components. Do not insulate unpainted steel surfaces.
    c. Seal seams and joints to provide a vapor barrier.
    d. After adhesive has fully cured, paint exposed surfaces of insulation to match other painted parts.
    e. Manufacturer has option to factory or field insulate chiller components installed in multiple pieces to reduce potential for damage during installation.
    f. Manufacturer has option to factory or field insulate water boxes and nozzles to reduce potential for damage during installation.

4. Field-Applied Insulation:

    a. Components that are not factory insulated are to be field insulated to comply with requirements indicated.
    b. Manufacturer must be responsible for chiller insulation whether factory or field installed, to ensure manufacturer is the single point of responsibility for chillers.
    c. Manufacturer factory-authorized service representative is to instruct and supervise installation of field-applied insulation.
    d. After field-applied insulation is complete, paint insulation to match factory-applied finish.

I. Electrical:

1. Factory installed and wired, and functionally tested at factory before shipment.
2. Single-point, field-power connection to fused disconnect switch. Minimum SCCR according to UL 508 is to be as required by electrical power distribution system, but not less than 100,000A.

    a. Branch power circuit to each motor, electric heater, dedicated electrical load, and control, with circuit breaker having SCCR to match main disconnecting means.

        1) NEMA KS 1, heavy-duty fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.

    b. NEMA ICS 2-rated motor controller for auxiliary motors, hand-off-auto switch, and overcurrent protection for each motor. Provide variable-frequency controller for each variable-speed motor furnished.
    c. Control-circuit transformer with primary and secondary side fuses.

3. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
4. Factory-installed wiring located outside of enclosures is to be installed in metal raceway. Provide terminal connections with not more than a 24-inch length of liquid tight conduit.

5. Factory install and wire capacitor bank for the purpose of power factor correction to 0.95 at full load.

    a. If capacitors are mounted in a dedicated enclosure, use same NEMA enclosure type as that for motor controller. Provide enclosure with service entrance knockouts and bushings for conduit.
    b. Capacitors are to be of non-PCB dielectric fluid, metallized electrode design, with low loss with low-temperature rise. Indicate kVAR ratings and do not exceed the maximum limitations set by NFPA 70. Provide individual cells as required.
    c. Provide each cell with current-limiting replaceable fuses and carbon-film discharge resistors to reduce residual voltage to less than 50 V within one minute after de-energizing.
    d. Provide a ground terminal and a terminal block or individual connectors for phase connection.

J. Motor Controller:

1. Enclosure: Factory installed, unit mounted, NEMA 250, Type 4X, with hinged full-front access door.
2. Control Circuit: Obtained from integral control power transformer with a control power transformer of enough capacity to operate connected control devices.
3. Size overload relay in accordance with UL 1995 or provide as integral component of chiller control microprocessor.
4. Across-the-Line Controller: NEMA ICS 2, Class A, full voltage, nonreversing; include isolation switch and current-limiting fuses.

5. Accessories: Factory install devices in controller enclosure unless otherwise indicated.

    a. Push-Button Stations, Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.
    b. Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.
    c. Control Relays: Time-delay relays.
    d. Elapsed-Time Meters: Numerical readout in hours on face of enclosure.
    e. Number-of-Starts Counter: Numerical readout on face of enclosure.
    f. Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems and with the following features:

        1) Selectable, digital display of the following:

            a) Phase Currents, Each Phase: Plus or minus 1 percent.
            b) Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
            c) Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
            d) Three-Phase Real Power: Plus or minus 2 percent.
            e) Three-Phase Reactive Power: Plus or minus 2 percent.
            f) Power Factor: Plus or minus 2 percent.
            g) Frequency: Plus or minus 0.5 percent.
            h) Integrated Demand with Demand Interval Selectable from Five to 60 Minutes: Plus or minus 2 percent.

i) Accumulated energy, in megawatt hours, plus or minus 2 percent; stored values unaffected by power outages for up to 72 hours.

2) Mounting: Display and control unit flush or semirecessed in instrument compartment door.

g. Phase-Failure, Phase-Reversal, Undervoltage Relays: Solid-state sensing circuit with adjustable undervoltage setting and isolated output contacts for hardwired connection.

h. Power Protection: Chiller must shut down within six cycles of power interruption.

K. Variable-Frequency Controller:

1. Motor controller is to be factory mounted and wired on the chiller to provide a single-point, field-power termination to the chiller and its auxiliaries.
2. Description: NEMA ICS 2; listed and labeled according to UL 508 as a complete unit and arranged to provide variable speed by adjusting output voltage and frequency.
3. Enclosure: Unit mounted, NEMA 250, Type 4x, with hinged full-front access door with lock and key.
4. Integral Disconnecting Means: Door-interlocked, NEMA AB 1, instantaneous-trip circuit breaker with lockable handle. Minimum SCCR according to UL 508 is to be as required by electrical power distribution system, but not less than 100,000 A.
5. Technology: Pulse width modulated (PWM) output with insulated gate bipolar transistors; suitable for variable torque loads.
6. Controller is to consist of a rectifier converter section, a digital/analog driver regulator section, and an inverter output section.

a. Rectifier Section: Full-wave diode bridge that changes fixed-voltage, fixed-frequency, ac line power to a fixed dc voltage. Silicon controller rectifiers, current source inverters, and paralleling of devices are unacceptable. Rectifier is to be insensitive to phase rotation of the ac line.

b. Regulator: Full digital control of frequency and voltage.

c. Inverter Section: Change fixed dc voltage to variable-frequency, variable ac voltage for application to a squirrel-cage motor. Inverter is to produce a sine-coded, PWM output waveform and conduct no RFI back to the input power supply.

7. Output Rating: Three phase, with voltage proportional to frequency throughout voltage range.
8. Operating Requirements:

a. Input AC Voltage Tolerance: 460-V ac, plus 10 percent or 506 V maximum.

b. Input frequency tolerance of 60 Hz, plus or minus 2 Hz.

c. Capable of driving full load, without derating, under the following conditions:

1) Ambient Temperature: Zero to 50 deg C.
2) Relative Humidity: Up to 90 percent (noncondensing).
3) Altitude: Up to 3300 feet.

d. Minimum Efficiency: 96 percent at 60 Hz, full load.

e. Minimum Displacement Primary-Side Power Factor: 95 percent without harmonic filter; 98 percent with harmonic filter.
f. Overload Capability: 1.05 times the full-load current for seven seconds.
g. Starting Torque: As required by compressor-drive assembly.
h. Speed Regulation: Plus or minus 1 percent.
i. Isolated control interface to allow controller to follow control signal over a 10:1 speed range.
j. To avoid equipment resonant vibrations, provide critical speed lockout circuitry to allow bands of operating frequency at which controller is to not operate continuously.
k. Capable of being restarted into a motor coasting in either the forward or reverse direction without tripping.

9. Internal Adjustability Capabilities: Integral to controller or through chiller control panel.

a. Minimum Output Frequency: 6 Hz.
b. Maximum Output Frequency: 60 Hz.
c. Acceleration: Two seconds to a minimum of 60 seconds.
d. Deceleration: Two seconds to a minimum of 60 seconds.
e. Current Limit: 30 percent to a minimum of 100 percent of maximum rating.

10. Self-Protection and Reliability Features: Subjecting the controller to any of the following conditions must not result in component failure or the need for replacement:

a. Overtemperature.
b. Short circuit at controller output.
c. Ground fault at controller output. Variable-frequency controller is to be able to start a grounded motor.
d. Open circuit at controller output.
e. Input undervoltage.
f. Input overvoltage.
g. Loss of input phase.
h. Reverse phase.
i. AC line switching transients.
j. Instantaneous overload, line to line or line to ground.
k. Sustained overload exceeding 100 percent of controller-rated current.
l. Starting a rotating motor.

11. Motor Protection: Controller is to protect motor against overvoltage and undervoltage, phase loss, reverse phase, overcurrent, overtemperature, and ground fault.
12. Automatic Reset and Restart:

a. Capable of three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction.
b. Controller is to be capable of automatic restart on phase-loss and overvoltage and undervoltage trips.

13. Visual Indication: On face of controller enclosure or chiller control enclosure. indicating the following conditions:

a. Power on.

b. Run.
c. Overvoltage.
d. Line fault.
e. Overcurrent.
f. External fault.
g. Motor speed (percent).
h. Fault or alarm status (code).
i. DC-link voltage.
j. Motor output voltage.
k. Input kilovolt amperes.
l. Total power factor.
m. Input kilowatts.
n. Input kilowatt-hours.
o. Three-phase input voltage.
p. Three-phase output voltage.
q. Three-phase input current.
r. Three-phase output current.
s. Three-phase input voltage THD.
t. Three-phase input current THD.
u. Output frequency (Hertz).
v. Elapsed operating time (hours).
w. Diagnostic and service parameters.

14. Operator Interface: At controller or chiller control panel; with start-stop and auto-manual selector with manual-speed-control potentiometer.
15. Control Signal Interface:

a. Electric Input Signal Interface: A minimum of two analog inputs (0 to 10 V or 0/4-20 mA) and six programmable digital inputs.
b. Manufacturer has option to incorporate control signal interface into chiller control panel.

L. Accessory Control Relays:

1. Control Relays: Auxiliary and adjustable time-delay relays.
2. Devices are to be factory installed in controller enclosure unless otherwise indicated.

M. Chiller Capacity Control Interface: Equip chiller with adaptive control logic to automatically adjust the compressor motor speed and the compressor pre-rotation inlet vane position independently to achieve maximum part-load efficiency in response to sensor inputs that are integral to the chiller controls.

N. Finish:

1. Paint chiller, using manufacturer's standard procedures, except comply with the following minimum requirements:

a. Provide at least one coat of primer with a total dry film thickness of at least 2 mils.
b. Provide at least two coats of epoxy finish with a total dry film thickness of at least 4 mils.
c. Paint surfaces that are to be insulated before applying the insulation.

d. Paint installed insulation to match adjacent uninsulated surfaces.
e. Color of finish coat is to be manufacturer's standard.

O. Accessories:

1. Flow Switches:

a. Chiller manufacturer is to furnish a switch for each evaporator and condenser and verify field-mounting location before installation.
b. Paddle Flow Switches:

1) Vane operated to actuate a double-pole, double-throw switch, with one pole field wired to the chiller control panel and the other pole field wired to the DDC system for HVAC.
2) Contacts: Platinum alloy, silver alloy, or gold-plated switch contacts with a rating of 10 A at 120-V ac.
3) Pressure rating equal to pressure rating of heat exchanger.
4) Construct body and wetted parts of Type 316 stainless steel.
5) House switch in a NEMA 250, Type 4 enclosure constructed of die-cast aluminum.
6) Vane length to suit installation.

c. Pressure-Differential Switches:

1) Construction: Wetted parts of body and trim constructed of Type 316 stainless steel.
2) Performance: Switch is to withstand, without damage, the full-pressure rating of the heat exchanger applied to either port and exhibit zero set-point shift due to variation in working pressure.
3) Set Point: Screw type, field adjustable.
4) Electrical Connections: Internally mounted screw-type terminal blocks.
5) Switch Enclosure: NEMA 250, Type 4.
6) Switch Action: Double-pole, double-throw switch, with one pole field wired to the chiller control panel and the other pole field wired to the DDC system for HVAC.

2. Vibration Isolation:

a. Chiller manufacturer is to furnish vibration isolation for each chiller.
b. Neoprene Pad:

1) Two layers of 0.375-inch- thick, ribbed- or waffle-pattern neoprene pads separated by a 16-gauge, stainless steel plate.
2) Fabricate pads from 40- to 50 -durometer neoprene.
3) Provide stainless steel square bearing plate to load the pad uniformly between 20 and 40 psig with a 0.12- to 0.16-inch deflection.

c. Spring Isolator:

1) Stable in operation and designed for not less than 30 percent reserve deflection beyond actual operating conditions.

2) Design isolators so that the Kx/Ky ratio will be 1.0 or more for stability.
3) Provide PVC or neoprene-coated springs and hot-dip, galvanized-steel components. Provide aluminum components that are etched and painted. Provide nuts, bolts, and washers that are zinc electroplated.
4) Isolators are to be adjustable and with an open spring, having one or more coil springs attached to a top compression plate and a baseplate.
5) An elastomeric pad with a minimum thickness of 0.25 inch is to be bonded to the baseplate.
6) Spring assembly is to be removable and fit within a welded-steel enclosure consisting of a top plate and rigid lower housing, which serves as a blocking device during installation.
7) Isolated restraining bolts are to not be engaged during normal operation and are to connect the top plate and lower housing to prevent the isolated equipment from rising when drained of fluid.
8) Select isolators for a nominal 1-inch deflection.
9) Integrate seismic restraints in applications that require seismic requirements.

2.4 SOURCE QUALITY CONTROL

A. AHRI Certification: Certify chiller in accordance with "Water-Cooled Chiller Certification Program."

B. Perform functional run tests of chillers before shipping.

C. Factory Performance Testing:

1. Factory performance test chillers, before shipping, in accordance with AHRI 550/590.
2. Test the following conditions:

    a. Design conditions indicated.
    b. Reduction in capacity from design to minimum load in steps of 25 with condenser fluid at design conditions.
    c. Reduction in capacity from design to minimum load in steps of 25 with varying entering condenser-fluid temperature from design to minimum conditions in 5 deg F increments.
    d. At four point(s) of varying part-load performance to be selected by Owner at time of test.

3. Allow Owner access to place where chillers are being tested. Notify Owner in writing at least 30 days in advance of testing.
4. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

D. Factory Sound Testing:

1. For chillers located indoors, rate sound power level in accordance with AHRI 575.
2. Factory sound test chillers, before shipping, in accordance with AHRI 575.
3. Test the following conditions:

    a. Design conditions indicated.

b. Chiller operating at calculated worst-case sound condition.
c. At two point(s) of varying part-load performance to be selected by Owner at time of test.

4. Allow Owner access to place where chillers are being tested. Notify Owner in writing at least 30 days in advance of testing.
5. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

E. Factory test and inspect evaporator and condenser according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Pressure test fluid side of heat exchangers, including water boxes, to 1.5 times the rated pressure. Pressure proof test refrigerant side of heat exchangers to a minimum of 45 psig. Vacuum and pressure test for leaks.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine chillers before installation. Reject chillers that are damaged.

B. Examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, control and electrical connections to verify actual locations, sizes, and other conditions affecting chiller performance, maintenance, and operations before equipment installation.

1. Chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and control and electrical connections.

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

3.2 INSTALLATION OF CENTRIFUGAL WATER CHILLERS

A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.

B. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.

C. Install chillers on support structure indicated.

D. Equipment Mounting:

1. Install chillers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."
2. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

E. Maintain manufacturer's recommended clearances for service and maintenance.

F. Maintain clearances required by governing code.

G. Chiller manufacturer's factory-trained service personnel are to charge chiller with refrigerant and fill with oil if not factory installed.

H. Install separate devices furnished by manufacturer and not factory installed.

1. Chillers shipped in multiple major assemblies are to be field assembled by chiller manufacturer's factory-trained service personnel.

3.3 INSTALLATION OF PACKAGED REFRIGERANT-RECOVERY UNIT

A. Install field electric power as required for unit furnished. Install power connections at multiple locations as recommended by chiller manufacturer for unit to service chillers indicated. Install receptacle(s) furnished with unit.

B. Install field water source as required for unit furnished. Install connections at multiple locations as recommended by chiller manufacturer for unit to service chillers indicated. Terminate connections with valves.

C. Install quick-connect adapters furnished with unit.

D. Functionally test unit for proper operations with field connections to power and water, as applicable.

3.4 PIPING CONNECTIONS

A. Comply with requirements for piping specified in Section 232113 "Hydronic Piping," Section 232116 Hydronic Piping Specialties," and Section 232300 "Refrigerant Piping." Drawings indicate general arrangement of piping, fittings, and specialties.

B. Where installing piping adjacent to chillers, allow space for service and maintenance.

C. Evaporator-Fluid Connections:

1. Connect to evaporator inlet with shutoff valve, strainer, thermometer, and plugged tee with pressure gauge.
2. Connect to evaporator outlet with shutoff valve, balancing valve, thermometer, plugged tee with shutoff valve and pressure gauge, and drain connection with valve.
3. Make connections to chiller with a flange.

D. Condenser-Fluid Connections:

1. Connect to condenser inlet with shutoff valve, strainer, thermometer, and plugged tee with pressure gauge.
2. Connect to condenser outlet with shutoff valve, balancing valve, thermometer, plugged tee with shutoff valve and pressure gauge, and drain connection with valve.
3. Make connections to chiller with a flange.

E. For chillers equipped with a purge system, extend purge vent piping to the outdoors. Comply with ASHRAE 15 and ASHRAE 147.

F. Connect each chiller water box vent connection with an automatic vent, which is full size of vent connection.

3.5 ELECTRICAL POWER CONNECTIONS

A. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

B. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

C. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection. Nameplate is to be laminated phenolic layers of black with engraved white letters at least 1/2 inch high. Locate nameplate where easily visible.

3.6 CONTROLS CONNECTIONS

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

B. Connect control wiring between chillers and other equipment to interlock operation as required to provide a complete and functioning system.

C. Connect control wiring between chiller control interface and DDC control system for remote monitoring and control of chillers. Comply with requirements in Drawings

D. Install nameplate on face of chiller control panel indicating the control equipment designation serving chiller and the I/O point designation for each control connection. Nameplate is to be laminated phenolic layers of black with engraved white letters at least 0.5 inch high.

3.7 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that refrigerant charge is sufficient and chiller has been leak tested.
3. Verify that pumps are installed and functional.
4. Verify that thermometers and gauges are installed.
5. Operate chiller for run-in period.
6. Check bearing lubrication and oil levels.
7. Verify that refrigerant pressure relief device is vented outside.
8. Verify proper motor rotation.
9. Verify static deflection of vibration isolators, including deflection during chiller startup and shutdown.
10. Verify and record performance of fluid flow and low-temperature interlocks for evaporator and condenser.
11. Verify and record performance of chiller protection devices.
12. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.

B. Inspect field-assembled components, equipment installation, piping, controls and electrical connections for proper assembly, installation, and connection.

C. Visually inspect chiller for damage before starting. Repair or replace damaged components, including insulation. Do not start chiller until damage that is detrimental to operation has been corrected.

D. Prepare test and inspection startup reports.

3.8 WARRANTY PERIOD TESTING

A. Within one month(s) of warranty period expiration, perform testing, analysis, and reporting indicated for each chiller.

B. Oil Analysis:

1. Take oil sample and solicit services of a third-party testing agency, specializing in such analysis, to perform oil analysis.
2. Submit analysis results and recommendations to Owner.

C. Refrigerant Analysis:

1. Take refrigerant sample and solicit services of a third-party testing agency, specializing in such analysis, to perform refrigerant analysis.
2. Submit analysis results and recommendations to Owner.

D. Site Access and Scheduling:

1. Contact Owner to schedule testing at least 30 days in advance of testing.
2. Make mutually agreeable schedule adjustments to accommodate Owner's request for testing.
3. Review, with Owner, requirements for visitors in advance of testing.
4. Comply with Owner requirements for visitors while on-site.

3.9 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain chillers. Video record the training sessions and provide electronic copy to Owner.

1. Instructor must be factory trained and certified.
2. Provide not less than eight hours of training.
3. Provide not less than 16 hours of training spread across consecutive days, not to exceed eight hours per day.
4. Train personnel in operation and maintenance and to obtain maximum efficiency in plant operation.
5. Provide instructional videos showing general operation and maintenance that are coordinated with operation and maintenance manuals.
6. Obtain Owner sign-off that training is complete.

7. Owner training is to be held at Project site.

END OF SECTION

SECTION 237313.19 - INDOOR, CUSTOM AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Indoor, custom air-handling units.

1.2 ACTION SUBMITTALS

A. Product Data:

1. For each indoor, custom air-handling unit.

a. Product information organized to show compliance with each performance requirement of "Performance Requirements" Article.
b. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
c. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
d. Include unit dimensions and weight.
e. Include cabinet material, metal thickness, finishes, insulation, and accessories.
f. Fans:

1) Include certified fan-performance curves with system operating conditions indicated. For fans operating at variable speeds include curves in 10 percent speed increments starting at design speed down to minimum speed.
2) Include fan-sound power ratings in all eight octave bands. Include inlet or outlet sound power levels to coincide with sound requirements indicated on Drawings.
3) Include fan construction and accessories. Submit sufficient information to show product compliance with requirements indicated.
4) Include dimensions and weight.
5) Include motor ratings, electrical characteristics, and motor accessories.

g. Vibration isolation product data with performance ratings. Uniquely identify and include information for each different isolator type and indicate for each air-handling unit where each isolator type is being used.
h. Include certified coil-performance ratings with system operating conditions indicated. Product data to include dimensions, dry and operating weight, volume of fluid contained, materials of construction, and performance ratings with system operating conditions indicated.
i. Casing insulation product data and performance ratings.
j. Access door and access panel product data and performance ratings.
k. Paint product data and performance ratings.

l. Electrical product data and performance ratings.
m. Metal grating product data and performance ratings.
n. Dampers product data, including housings, linkages, and operators with performance ratings.
o. Filters product data with performance characteristics.

B. Shop Drawings: For each type and configuration of indoor, custom air-handling unit.

1. Prepared by manufacturer's factory employees with review and sign-off by those individuals responsible for manufacturing the air-handling units.
2. Include plans, elevations, sections, and mounting details.
3. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, methods of field assembly, components, and location and size of each field connection.
4. Detail fabrication and assembly of indoor, custom air-handling units, as well as procedures and diagrams.
5. Indicate details of construction with materials description including applicable specified standards and material grades in sufficient detail for reviewers to evaluate point by point compliance with requirements indicated for each air-handling unit.
6. Use actual dimensions of internal equipment in preparing Shop Drawings. Identify mechanical equipment shown on Shop Drawings with equipment designations on Drawings.
7. Thickness and finish of all casing materials with cross references indicated where each is used. Uniquely identify and include information for each different casing construction.
8. Details for each unique casing joint and reinforcing. Indicate wall joints, wall to floor joints, wall to roof joints, floor joints, and roof joints.
9. Assembly details of base and casing for units consisting of multiple sections requiring field assembly.
10. Sizes and dimensioned locations of field connections for ductwork, piping, electrical, and controls.
11. Base and casing penetration and sealing details for factory-installed conduit.
12. Base and casing penetration and sealing details for factory-installed piping including coils.
13. Details of casing connections to field-installed ductwork.
14. Size, shape, and layout of base members including localized support of internal components.
15. Base materials, thickness, finishes, lifting provisions, and mounting requirements. Uniquely identify and include information for each different base construction. Clearly indicate for each air-handling unit.
16. Recommended points of field attachment with dimensioned locations.
17. Size and location of each access door, including clearing opening size, with door swing indicated.
18. Size and location of each access panel with service equipment superimposed to show relationship of panel to internal equipment.
19. Drain pans and associated piping, with sizes and locations dimensioned, including relationship to internal equipment.
20. Coil framework and support including enlarged details showing framework attachment to air-handling unit base, coil attachment to framework, and means for individual coil removal.
21. Mounting details of all internal components, such as fans, filters, and dampers.
22. Location of receptacles, service lights, and switches.

23. Location of motor controllers and disconnect switches.
24. Size and location of junction boxes used for interface with field electrical power.
25. Point-to-point electrical power wiring diagrams including wire size, conduit size, motor controllers sizes, switch types and ratings, receptacle types and ratings, service light fixture types, and ratings.
26. Point-to-point control wiring diagrams including cable types and sizes, conduit sizes, and connected control devices.
27. Control panel drawings drawn to scale showing detailed internal layout.
28. Indicate code, operating, and maintenance clearances drawn to scale using dashed lines.
29. Indicate weights of internal components, weight of each separately shipped section, and air-handling unit total weight.

1.3 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans, sections, and other details, or BIM model, drawn to scale, showing the items described in this Section and coordinated with all building trades.

B. Source quality-control reports.

C. Startup service reports.

D. Field quality-control reports.

E. Sample Warranty: For manufacturer's warranty.

1.4 CLOSEOUT SUBMITTALS

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

1.5 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Panel Filters: One set(s) for each air-handling unit.
2. Access Door Gaskets: One set(s) for each access door.
3. Fan Belts: set(s) for each fan with belt-drive assembly.

B. Tool Kit: Manufacturer to provide a tool kit including special tools required for air-handling unit service. See "Accessories" Article for additional requirements.

1.6 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided.

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

1.7 FACTORY VISITS FOR PRODUCT INSPECTION

A. While units are being manufactured, and during factory normal working hours, allow escorted access to manufacturing facility for Owner to verify product compliance with requirements indicated.

1. As many as 4 persons shall visit factory for product inspection.

B. Manufacturer shall provide Owner with written notice at least 30 business days before units go into assembly.

C. Inspection visits shall be scheduled with manufacturer at least 10 business days before visit.

D. Personnel making visits for purposes of product inspection shall comply with manufacturer requirements for visitors.

1.8 DELIVERY, STORAGE, HANDLING

A. Deliver air-handling units with factory-installed shipping skids and lifting lugs; pack small components in factory-fabricated protective containers. Cover units with heat-shrinkable plastic sheeting suitable for shipping from point of manufacture to Project.

B. Handle air-handling units carefully to avoid damage to components, casing, and finish. Do not install damaged components; replace and return damaged components to air-handling unit manufacturer.

C. Store air-handling units in a clean dry place and protect them from weather and construction activities.

D. Keep air-handling units fully covered and protected during construction. Remove dirt and debris and clean units to a factory-cleaned condition.

E. Comply with manufacturer's written rigging and installation instructions for unloading air-handling units and moving them to their final locations.

1.9 WARRANTY

A. Warranty: Manufacturer agrees to repair or replace components of air-handling units that fails in materials or workmanship within specified warranty period.

1. Warranty Period: Two year(s) from date of Substantial Completion.

B. Extended warranties include, but are not limited to, the following:

1. Complete Air-Handling Unit: Two years from date of Substantial Completion for entire air-handling unit and longer where indicated for individual components.
2. Air-Handling Unit Casing: 25 years from date of Substantial Completion.
3. Motors: Two years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and application.

B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handing units and components.

C. ASHRAE 62.1 Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

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

E. Casing Structural Performance:

1. Floor: Capable of withstanding positive/negative 8 inches wg of internal static pressure, without exceeding a deflection of L/300 of span.
2. Walls and Roof: Capable of withstanding positive/negative 8 inches wg of internal static pressure, without exceeding a midpoint deflection of L/200 of span.

F. Casing Leakage Performance, ASHRAE 111: Class 3 leakage or better at plus or minus 8 inches wg.

G. Casing Thermal Performance:

1. Surface Condensation: Air-handling manufacturer shall evaluate potential for condensation and design and manufacture entire unit casing to prevent condensation at most extreme operating conditions encountered.
2. Thermal Break: Incorporate a thermal break at each through metal path to prevent condensation from occurring on interior and exterior of casing.
3. U-Value: Overall U-value or equivalent R-value of casing shall not exceed governing codes and ASHRAE/IES 90.1, while considering the effects of metal-to-metal contact and thermal bridging in calculations.

H. Air Tunnel Aerodynamic Performance: Position air-handling unit internal components and transition between internal components to maintain uniform airflow; minimize sound levels and energy consumption. Use methods indicated and other means to ensure compliance.

1. Use turning vanes if necessary to direct the air path.

a. Design, manufacture, and install vanes in accordance with applicable requirements in ASHRAE and SMACNA guidelines, handbooks, and standards.
b. Install vanes firmly in place so that no vane movement occurs at worst-case airflow capacity possible.

2. Use fan inlet and discharge transitions and other devices to maximize system regain and minimize airborne sound levels.

3. Center system components such as coils, fans, and filters, vertically and horizontally, in airstream.
4. Maintain spacing between components such that airflow patterns to adjacent components are as uniform as possible and that component "dead spots" or "jetted areas" are avoided.
5. Design and install internal structural supports, piping, and conduit that do not block airflow and impede performance of coils, fans, filters, and other unit components, and service space clearances.

I. Durability Performance: Design and manufacture air-handling units with underlying requirement to provide a highly durable piece of equipment.

1. Unit Life Expectancy: 25 years.
2. Supporting Documentation: Submit documentation showing proposed products to consider and include design features, components, and materials to satisfy requirement.

J. Safety:

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

K. Serviceability:

1. Mounting Location: Install internal components in readily accessible locations to facilitate ease of service and replacement.
2. Service Access:

    a. Internal components shall be serviceable through access sections with doors indicated on Drawings.
    b. Internal components shall be removable and replaceable through access doors or panels.
    c. Review requirements for access doors and panels indicated and recommend additional access doors and panels if required for uninhabited service, removal, and replacement of components.

3. Tripping Hazards: Floors in accessible sections of air-handling unit shall be free of standing seams, reinforcing, supports, or section splits located in the walking path that is capable of causing a tripping hazard. Locate section splits immediately adjacent to internal walls.

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

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

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

2.2 CAPACITIES AND CHARACTERISTICS

A. See equipment schedules on Drawings.

2.3 SOURCE LIMITATIONS

A. Source all indoor and outdoor custom air-handling units from same manufacturer.

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include the following:

a. Temtrol
b. ClimateCraft

B. Like components furnished with air-handling units shall be from same manufacturer.

2.4 INDOOR, CUSTOM AIR-HANDLING UNITS

A. Unit Arrangement and Configuration:

1. Arrangement: Project-specific arrangement and configuration of air-handling units as indicated on Drawings. Do not deviate from requirements indicated.
2. Mounting Requirements: Units mounted on concrete housekeeping pads.
3. Knock-Down Unit Construction: Physical limitations of existing building(s) require a specialized installation consisting of field assembly of air-handling unit kit of parts shipped on pallets or in containers. Before preparing Shop Drawings, air-handling unit manufacturer shall review with Installer the on-site path of travel, physical size of each opening, weight limits, and methods for erection and installation.

B. Air-Handling Unit Base:

1. Performance:

a. Air-handling unit manufacturer shall design and assemble air-handing unit casing and internal components for attachment and support by air-handling unit structural base.
b. Design air-handling units to be lifted from only the air-handling unit structural base and not the casing.
c. Support air-handling units from only the perimeter base unless otherwise indicated on Drawings.
d. Air-handling unit manufacturer to size and locate intermediate structural base supports as required to comply with structural performance indicated for air-handling unit floors.

e. Level base before factory assembly of air-handling unit casing and internal components to ensure proper fit and alignment.

2. Structural Member Size:

a. Air-handling unit manufacturer shall select size of base members and construction of base to withstand the rigors of loading, unloading, shipping, and rigging without damage to air-handling unit components or misalignment of factory-assembled components.
b. Depth and weight of structural members shall be selected by air-handling unit manufacturer to comply with performance requirements indicated.
c. Depth of perimeter base members is not less than 8 inches deep.

3. Structural Member Spacing: Positioned as required to comply with requirements indicated, but not to exceed 24 inches.
4. Welding Filler Metals: Comply with AWS welding codes for welding materials appropriate for thickness and chemical analysis of material being welded.

a. Use welding materials with corrosion properties equal to material being welded.

5. Welding Procedures:

a. Structural Welding Codes: AWS D1.1/D1.1M for carbon steel.
b. Join structural members to one another using continuous welds.
c. After welding and fabrication, deburr and grind exposed welds to provide smooth surfaces free of sharp edges.

6. Penetrations through Base Perimeter: Seal weld pipe, tubing, and conduit penetrations through base perimeter members to provide a watertight assembly.
7. Section Joints: Air-handling units consisting of multiple sections for field assembly shall be joined with structural joining plates.

a. Joining plate material type to match base.
b. Joining plate of thickness required to join sections without resulting in a permanent deflection, minimum 1/2 inch thick.
c. Continuously weld joining plates to each mating end of base.
d. Joining plates shall not extend beyond outer edge of adjoining base.
e. Plates to include at least three equally spaced holes for field connection using factory-furnished threaded hardware of a nominal diameter of at least 1/2 inch.

8. Lifting Provisions: Air-handling unit manufacturer to design and install lifting lugs of size and location required to comply with performance requirements indicated. Lifting lugs extending beyond the base shall be easily removable in the field after unit is installed.

C. Unit Casings:

1. Casing Assembly:

a. Appearance:

1) Exposed exterior surfaces of casing shall have a neat and finished appearance free of standing seams, exposed reinforcing, and other casing protrusions more than 0.25 inch beyond the exterior skin surface.
2) Interior surfaces of casing shall have a neat and finished appearance free of standing seams, exposed reinforcing, and other casing protrusions more than 0.25 inch beyond the skin surface.

b. Dissimilar Metals: Isolate dissimilar metals that are in contact to prevent galvanic action and corrosion.
c. Framing and Supports: Interconnect and support individual casing wall and roof panels using either formed panel construction or framed construction with structural support members. For framed casing construction, materials used to construct casing of structural support members shall be as follows:

1) Casings with Aluminum Outer and Inner Skins: Aluminum extrusions in accordance with ASTM B211, Alloy 6063 T6.
2) Casings with Galvanized-Steel Outer and Inner Skins: Galvanized steel.
3) Casings with Galvanized-Steel Outer Skin and Aluminum or Stainless Steel Inner Skins: Stainless steel.
4) Casings with Stainless Steel Outer and Inner Skins: Stainless steel.

d. Seals: Seal interior and exterior joints and seams to make casing air- and watertight. Trim factory-applied sealant flush with adjacent surface.
e. Double-Wall Casings: Consisting of insulation sandwiched between an outer and inner metal wall. Use double-wall casings to construct air-handling units unless septum casings are required.
f. Septum Casings: Triple-wall construction consisting of a solid metal inner wall sandwiched between insulation layers that are covered with metal walls. Use septum casings for applications having performance requirements that are not achievable with double-wall casings.
g. Wall and Roof Penetrations: Seal voids around conduit, piping, and tubing penetrations.

1) Conduit, Pipe, and Tube Sizes and Smaller: NPS 3.

a) Seal void through casing with a nonhardening vapor-barrier caulk covered by an escutcheon on both interior and exterior sides of casing. Back caulk using formed insulation within a sheet metal sleeve.
b) Seal void using a friction fit neoprene or EPDM sheet material attached to casing using a bed of adhesive.
c) Cover penetration and sealing sheet material with metal escutcheon matching adjacent casing material.
d) Larger Conduit, Pipe, and Tube Sizes: Seal annular void using an adjustable compression-type sealing sleeve.

h. Floor Penetrations: Route conduit, pipe, and tube within a floor-mounted pipe sleeve.

1) Sleeve:

a) Fabricate sleeve of aluminum, galvanized-steel, or stainless steel pipe.
b) Extend top of sleeve above adjacent floor surface to prevent standing water on floor from entering annular space of sleeve.
c) Seal sleeve to top of floor for an air- and watertight seal.
d) Seal annular void of sleeve using an adjustable compression seal ornonhardening packing material.

i. Floor Openings with Metal Grating:

1) Factory install walk-on safety gratings over any floor opening large enough to create a safety hazard for operators including, but not be limited to, supply-, return-, and exhaust-air openings.
2) Bar Grating:

a) Materials: Use stainless steel grating for stainless steel floors.
b) Air-handling unit manufacturer shall select depth and thickness of grating bars to limit deflection to 1/360 of span when subjected to a dynamic load of not less than 500 lb.
c) Industry-standard welded grating with bars at least 1-1/2 inches deep by at least 3/16 inch thick with nominal 1-3/16-inch main bar spacing and 4-inch cross bar spacing.
d) Source: Product manufacturer specializing in metal gratings.
e) Grating bearing surface shall extend beyond clear opening in floor at least 2 inches.

3) Mounting Frame:

a) Mount grating in a continuous structural angle or bar frame so no ends of grating bars are exposed. Top of frame to be flush with top of grating.
b) Secure grating to frame with threaded hardware, so grating does not move when walked on but can be easily removed from top to gain access behind grating.
c) Continuously weld mounting frame to air-handling unit floor.
d) Fasten mounting frame to air-handling unit floor with hardware and seal attachment air- and watertight.
e) For applications with automatic dampers installed at floor openings, elevate height of mounting frame and grating to enclose entire damper assembly including jackshaft so walk-on surface of grating is above damper assembly.

j. Waterproof Floors: Continuously weld floor joints, seams, and penetrations to completely seal floor. Roll all edges of floor up at least 1 inch to create a shallow tub capable of holding standing water.
k. Duct Connections - Direct to Casing: Frame and reinforce unit casing around perimeter of unit duct openings to accommodate direct attachment of field-installed ductwork. Coordinate requirements with Installer to accommodate field connection.
l. Duct Connections - Elevated Off Casing:

1) Terminate with angle flange face elevated 3 inches from exterior surface of casing.
2) Flange Thickness: 0.25 inch.
3) Flange face with holes located not more than 4 inches o.c., starting at corners, and sized for 0.375-inch- diameter, field-installed hardware.
4) Size flange face to mate to full face of duct flange.

a) Clear inside dimension of unit connection to match clear inside dimension of duct.
b) For connections to acoustically lined ducts, increase unit flange face to accommodate thickness of liner so end of duct liner is concealed by air-handling unit flange.

2. Materials for Outer Skin of Casing Walls and Roofs:

a. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating; minimum (nominal) 16 gauge thick.
b. Application: See Drawings for application of different materials indicated.

3. Materials for Inner Skin of Casing Walls and Roofs:

a. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating, minimum (nominal) 18 gauge thick.
b. Application: See Drawings for application of different materials indicated.

4. Materials for Floor Walking Surface:

a. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating; minimum (nominal) 12 gauge thick.
b. Aluminum Diamond Treadplate: ASTM B632/B632M, Alloy 6061 T6; mill finish; minimum (nominal) 0.125 inch thick.
c. Application: See drawings for application of different materials indicated.

5. Materials for Underside of Floor Insulation:

a. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating, minimum (nominal) 16 gauge thick.
b. Application: See Drawings for application of different materials indicated.

6. Materials for Internal Walls:

a. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating; minimum (nominal) 16 gauge thick.
b. Application: See Drawings for application of different materials indicated.

7. Surfaces in Contact with Airstream:

a. Comply with ASHRAE 62.1 and NFPA 90A.

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

a. Materials Not Exposed to Airstream: injected or sprayed polyurethane foam insulation with a minimum nominal density of 2 lb/cu. ft..
b. R-Value: Minimum R-10.
c. Thickness: Minimum 2 inches.
d. Insulation shall completely fill the casing cavity so no voids exist.

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

a. Materials Exposed to Airstream: Glass or mineral-fiber board insulation with a minimum density of 2 lb/cu. ft..
b. R-Value: Minimum R-10.
c. Thickness: Minimum 2 inches.
d. Insulation shall completely fill the casing cavity so no voids exist.

10. Insulation for Casing Floors:

a. Materials: injected or sprayed polyurethane foam insulation with a minimum nominal density of 2 lb/cu. ft..
b. R-Value: Minimum R-10.
c. Thickness: Minimum 2 inches.
d. Insulation shall completely fill the casing cavity so no voids exist.

11. Access Doors:

a. Application: Install access doors in air-handling units at locations indicated on Drawings.
b. Adjustment: Design doors for field adjustment capable of maintaining specified leakage rate.
c. Mounting Height: Install bottom of door frame within 2 inches of air-handling unit floor walking surface.
d. Performance: Leakage as required to satisfy overall unit leakage performance indicated, but not more than 1.0 cfm per door when tested at 10 inch wg.
e. Fabrication: Formed and reinforced, constructed of same materials and thicknesses as casing.
f. Swing: Arrange doors to be opened against pressure unless otherwise indicated on Drawings.
g. Frame: Extruded aluminum with thermal break with welded mitered corners.
h. Handles:

1) Secure door closed using not less than two roller-style latches with handles located at quarter points along door height.
2) If three latches with handles are included, install one at midpoint of door height and equally space others.
3) Air-handling unit manufacturer has option to use a multipoint latching mechanism that is operable from a single door handle located at midpoint of door height, but secures door to frame at top, bottom, and handle location.
4) Include door handles on outside and inside of door to allow operator access to open and close door from outside and inside of unit.
5) Field adjustable to accommodate changes to fit and gasket compression.
6) Durable product capable of withstanding repeated opening and closing of door while operating under design pressure without damage.

i. Hinges: Minimum of two hinges or full-length, concealed, stainless steel piano hinge.

j. Gasket:

1) Design: Specially formed with an internal air chamber specifically designed to seal on two surfaces without taking a permanent set.
2) Dual Gaskets: Primary and secondary gasket.
3) Location: Install gaskets around entire perimeter of doors or frames.
4) Material: EPDM, neoprene, or santoprene.
5) Protection: Seat gasket in a protective metal ribbed chamber integral to door or door frame to protect gasket from damage by operator incidental contact.
6) Service: Field replaceable.
7) Adhesive-backed tape-type gaskets adhered to a single flat surface are unacceptable.

k. Size of Door Frame Clear Opening: Large enough to allow for unobstructed access for inspection and maintenance of air-handling unit's internal components.

1) Width: At least 18 inches clear inside of door frame.
2) Height: Full clear height of unit casing up to a maximum height of 72 inches clear inside of door frame.
3) Door sizes indicated on Drawings.

l. Safety Latches and Stops:

1) Safety Latches: Install safety latch with retainers on outward swing doors that do not open against pressure to allow restricted travel for purpose of pressure relief and so that doors do not open uncontrollably due to inside pressure.
2) Stops: Install cushioned door stops on inward swinging doors where necessary to limit door travel that could potentially damage the door or internal components.

m. Tie-Backs: Install tie-backs with retainers on outward-swinging access doors to hold doors in an open position during service.

n. Locks: Include each access door with an integral key lock. Pad locks are unacceptable.

1) Incorporate key lock into door handle where feature is available.
2) A common key shall be used to lock and unlock access doors of each air-handling unit(s).
3) Include two keys for each air-handling unit.
4) Lock access doors at factory to ensure that unauthorized access is in place before air-handling unit packaging and shipment.

o. Windows:

1) Construction: Fabricate windows with frame mounted in access doors of double-glazed safety glass with an airspace between panes and interior and exterior seals.

2) Condensation Control: Install desiccant material in airspace between panes if necessary to prevent condensation from forming on glazing.
3) Clear Viewing Size: Minimum 8 inches, square or round.
4) Mounting Location: Center window in door width. For doors up to 60 inches high, locate top of window 6 inches below top of door. For taller doors, locate center of windows at optimal viewing height, approximately 60 inches above floor adjacent to unit.
5) Application: Install windows in all access doors.

p. Nameplates:

1) On each access door, include a nameplate defining the access to service within. Nameplates shall be included for, but not be limited to, the following:

a) Dampers.
b) Filters.
c) Cooling coils.
d) Heating coils.
e) Supply fans.
f) Return fans.

2) Air-handling unit designation.
3) Where door access is to multiple components, list all components accessed. For example: Filter/Cooling Coil.
4) For each door that does not open against static pressure, include a warning sign stating: "DANGER: DOOR UNDER PRESSURE. DO NOT OPEN WITH FAN ON."
5) Lettering Size and Style: At least 1-inch- high, block style.
6) Material: Lettering engraved in black plastic on a white plastic back. Engraving shall penetrate through black plastic so lettering reads white.
7) Attachment: Attach nameplates to door using high-strength bonding cement and stainless steel screws.
8) Mounting Location:

a) For access doors with windows, locate nameplate directly above window frame and center in door width.
b) Align nameplates of all doors for uniform placement.

12. Access Panels:

a. Performance: Leakage as required to satisfy overall unit leakage performance indicated.
b. Fabrication: Formed and reinforced panels of same material and thickness as casing.
c. Fasteners: Adjustable, reusable type for multiple operations without degradation due to reuse.
d. Arrangement: Panels removable from exterior side of casing.
e. Gasket: EPDM, neoprene, or santoprene similar to access doors, applied around entire perimeter of panels or frames.
f. Location and Size:

1) Coils: Oversized access panel to allow removal and replacement without impacting adjacent casing.
2) Electric Heaters: Oversized access panel to allow removal and replacement without impacting adjacent casing.
3) Fans: Oversized access panel to allow removal and replacement of entire fan assembly including base without impacting adjacent casing.

g. Nameplates:

1) On each access panel, include a nameplate defining the access to service within. Nameplates shall be included for, but not be limited to, the following:

a) Cooling coils.
b) Heating coils.
c) Supply fans.
d) Return fans.

D. Internal Structural Supports:

1. General:

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

2. Structural Member Size and Spacing:

a. Size: Air-handling unit manufacturer shall select size of members and construction to do the following:

1) Withstand the rigors of loading, unloading, shipping, and rigging without damage to air-handling unit components or misalignment of factory-assembled casing and components.
2) Comply with performance requirements indicated.

b. Spacing: Positioned as required to comply with requirements.

3. Materials: Structural aluminum, ASTM B209, Alloy 6061 T6 .

a. Structural Supports: Angle shapes selected by air-handling unit manufacturer for application.
b. Hoist Beams for Internal Components (Spanning Full Width of Unit): I or W beam shapes.

4. Carbon Steel Finish, Mill Galvanized: Mill galvanized carbon steel with weld damaged areas cleaned, prepared and painted with galvanized paint after fabrication.

5. Carbon Steel Finish: Carbon steel bases shall be shot-blasted, cleaned, prepared and painted after fabrication.

E. Centrifugal Fan Arrays:

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

    a. Air-handling unit manufacturer shall account for, and include in, submitted fan selections any static pressure drops associated with unit, and system effect due to fan operating in the air-handling unit.

        1) Add additional static pressure to fan scheduled total static pressure.
        2) If fan motor horsepower is increased, notify Architect.

    b. Fans shall have sharply rising pressure characteristics at operating point and stable in operation. Fan horsepower characteristics shall be self-limiting and non-loading.
    c. Fan speed, brake horsepower, and sound power levels indicated are maximum acceptable.
    d. Scheduled motor horsepower, airflow rate, and static pressure are minimum acceptable. Motor horsepower shall be capable of handling maximum horsepower of fan at scheduled speed.
    e. As a minimum, fans shall have AMCA class indicated on Drawings.

        1) Fan operating limits shall be in accordance with AMCA 99 for AMCA class indicated.
        2) If AMCA class is not indicated, use AMCA 99 as basis for determining AMCA class.
        3) AMCA class selected shall be capable of accommodating a plus 10 percent increase to fan static pressure indicated on Drawings.

    f. Motor starting torque shall exceed fan speed-torque requirements.
    g. Airflow Profile:

        1) Fan arrangement within fan array shall produce a uniform airflow and velocity profile across air-handling unit air tunnel when measured 12 inches upstream of fan inlet and 48 inches downstream of fan inlet.

3. Vibration Balance:

    a. Each fan/motor assembly shall be factory balanced to AMCA 204, BV-5, Balance Quality Grade G1.0 or better through entire operating speed range from minimum speed to maximum speed. If minimum speed is not indicated on Drawings, assume minimum speed to be 10 percent of design speed.
    b. Identify and record each speed and speed range within the fan operating range that could cause potential vibration problems.
    c. Submit test reports as an informational submittal for Project record.

4. Vibration Isolation: Install vibration isolation on each fan/motor assembly in the fan array, except vibration isolation may be omitted on fans/motor assemblies balanced to AMCA 204, BV-5, with a maximum residual imbalance of 0.22-in./s peak, filter in.
5. Operation and Service Requirements:

    a. Remaining fans in array shall continue to operate with one or multiple failed fans.
    b. Each fan/motor assembly of fan array shall be capable of lock-out/tag-out procedure without interrupting operation of other fans in the array.
    c. Each fan/motor assembly shall be controlled through a variable-frequency controller, except for fans with electronically commutated (EC) motors having integral motor controls.

        1) Include a dedicated variable-frequency controller for each fan/motor assembly in the fan array.
        2) If fan array is served from a single variable-frequency controller, include a redundant variable-frequency controller with automatic switchover in event of primary variable-frequency controller failure.

    d. A single mechanical, electrical, and control device failure shall not result in a fan array available capacity of less than 33 percent of air-handling unit total scheduled airflow capacity.
    e. Fan wheel/motor assembly shall pass through the air-handling unit access door servicing fans. Entire individual fan assembly shall pass through the door to the room where air-handling unit is located.
    f. Design and incorporate features to permit safe, rapid, and economical maintenance.

6. Airflow Measurement, Local Indication, and Remote Monitoring:

    a. Each fan within fan array shall include airflow measurement indication in cfm.
    b. Include airflow totalization of all operating fans in fan array.
    c. Airflow measurement instrumentation shall not restrict or deflect air travel through fan and shall not impact fan air and sound performance.
    d. Include digital display of individual fan airflow and total fan array airflow on face of fan control panel.
    e. Include a 4- to 20-mA output signal for remote monitoring of total fan array airflow.

7. Fan Array Local Control:

    a. Include fan control panel with operator interface to control fan array locally through the fan control panel and to switch to control of fan array through a remote-control source.
    b. Local control shall include on/off operation and speed adjustment for entire fan array and each individual fan/motor in fan array.

8. Fan Array Remote Control:

    a. Include fan control panel with control interface for remote control.
    b. Fan array on/off operation shall be remotely controlled through a single hardwired digital output signal.

c. Fan array speed shall be remotely controlled through a single hardwired analog (4- to 20-mA) output signal.

9. Fan Base, Stackable Fan Units:

   a. Mount fan/motor on galvanized-steel base.
   b. Include base and vibration isolators in accordance with requirements indicated.
   c. Weld structural members to form a rigid base.
   d. Size and design the base construction to withstand the rigors of shipping and rigging.
   e. Include the base with lifting lugs or holes.

10. Fan Frame:

   a. Construct frame of galvanized steel.
   b. Reinforce and brace frame to prevent excessive deflection and pulsation.
   c. Include stiffeners to form a rigid frame that is free of structural resonance and vibration.

11. Fan Panel:

   a. Construct fan panel of galvanized steel .
   b. Reinforce and brace fan panel to prevent excessive deflection and pulsation.
   c. Include stiffeners to form a rigid panel that is free of structural resonance and vibration.

12. Fan Inlet Cone:

   a. Include a precision-spun or die-formed, matched inlet and wheel cone to ensure streamlined airflow into the wheel and full loading of fan blades.
   b. Inlet cone shall be a smooth hyperbolic shape.
   c. Inlet cone shall be a single piece, constructed of aluminum or powder-coated steel.
   d. Fasten inlet cone to fan panel using bolts, nuts, and washers to provide a positive and secure attachment that can be field removable.

13. Fan Wheel:

   a. Fan blades shall be a true hollow airfoil shape, welded to backplate and wheel cone.
   b. Construct blades of aluminum, reinforced for AMCA fan class.
   c. Design blades to provide smooth airflow over all surfaces of blade.
   d. Construct fan hubs of aluminum with integral bracing for extra strength and stiffness.

      1) Castings shall be sound and free of shrink holes, blow holes, cracks, scale, blisters, or other similar injurious defects.
      2) Clean surfaces of castings by blasting, pickling, or any other standard method.
      3) Mold-parting fins and remains of gates and risers shall be chipped, filed, and ground flush.

4) Design hubs to maintain a high resistance to fatigue and low relative wheel imbalance.

e. Hubs shall be keyed and setscrewed to motor shaft for positive attachment.
f. Construct wheel backplates of aluminum.
g. Select entire rotating assembly so first critical speed is at least 30 percent greater than fan design speed and at least 20 percent greater than maximum speed in AMCA fan class.

14. Fan Drive:

a. Direct drive, arrangement 4 in accordance with AMCA 99.
b. Adjust wheel width and diameter to match motor speed while providing performance scheduled.
c. Fasten fan wheel directly to motor shaft using a key in motor shaft and setscrew.
d. Construct motor base and pedestal supports of galvanized steel .
e. Fan Speed Limitation:

1) Fan speed at design conditions indicated shall not exceed speed on motor nameplate.
2) Do not select fans to operate at motor speeds greater than motor nameplate.

15. Fan Motors: See "Fan Motors" Article for ac motors.
16. Fan Motors, Electronically Commutated (EC):

a. Description: EC, variable-speed, dc, programmable brushless motor.
b. Features:

1) Integral controller/inverter operates wound stator and senses rotor position to electronically commutate the stator.
2) Controller shall control motor speed either through manual adjustment locally at fan array control panel or through a remote 0- to 10-V-dc control signal.
3) Motor Mounting: Coordinate with driven equipment; suitable for mounting with motor shaft in either horizontal or vertical position.

c. Performance:

1) Altitude: Suitable for operation at site altitude.
2) Electrical Characteristics: Suitable for operation with field power source. Coordinate with electrical Installer.
3) Energy Efficiency: Complying with governing energy codes; 80 percent or higher maintained throughout entire operating range.
4) Power Factor: 0.9 or higher at full load.
5) Service Factor: 1.0 or higher.
6) Speed Control: Variable, zero to 100 percent.

a) Synchronous speed rotation with no slip losses.
b) Gradual ramp-up to set point upon receiving a start signal.
c) Soft speed change ramps.
d) Able to overcome reverse rotation without impact.

e) Control airflow within 5 percent of set point regardless of static pressure.

d. Temperature: Suitable for operation in ambient temperature range encountered.
e. Thermal Protection:

1) Automatically breaks electrical power to motor when temperature exceeds a safe value.
2) Automatically resets and restores power when temperature returns to normal range.

f. Bearings: Sealed and permanently lubricated ball bearings.
g. Enclosure: ODP or TEFC.
h. Insulation: Class B or Class F.
i. Rotor: Permanent magnet with near zero rotor losses that operates independent of motor current.
j. Materials and Construction:

1) Enclosure and Frame: Aluminum, painted steel, or stainless steel.
2) End Brackets: Cast aluminum.
3) Shaft: Steel or stainless steel.
4) Motor Leads: Pin or screw terminals.
5) Nameplates: Manufacturer's standard.
6) Paint: Manufacturer's standard.

17. Fan Enclosure:

a. Include each fan in fan array with integral single-wall enclosure constructed of solid galvanized-steel sheet.
b. Enclosure shall not increase fan array length beyond size indicated on Drawings.
c. Enclosure shall not add static pressure loss.
d. Enclosure shall provide a physical separation between operating adjacent fans to prevent negative performance.

18. Backdraft Damper:

a. Include each fan in the fan array with a backdraft damper at the fan inlet to prevent air circulation through a fan that is not operating.
b. Open backdraft damper when fan is operating and close when fan is not operating.
c. Design backdraft damper assembly to operate with little to no static pressure loss with fan operating throughout entire operating range from design to minimum airflow.

1) Add damper pressure loss to fan scheduled total static pressure.
2) If pressure loss requires a change field electrical power, air-handling unit manufacturer shall be responsible for associated cost of change.

d. Fasten backdraft damper assembly to fan panel or enclosure using hardware designed for easy removal by maintenance personnel.
e. Dampers shall not create measurable additional noise above the sound level of fan.
f. Dampers shall not vibrate or rattle.

g. Construct dampers of extruded aluminum, stainless steel, or powder-coated steel.

19. Protective Screens:

    a. Include easily removable safety screens where fan inlet and outlet are exposed to maintenance personnel, including walk-in air-handling unit plenums.

        1) Safety screens are not required on fan inlets and outlets with backdraft dampers.

    b. Expanded-metal or wire screens, fastened to a flat bar perimeter frame.
    c. Screens shall comply with OSHA requirements.
    d. Screens and frame shall be constructed of aluminum, stainless steel, or powder-coated steel.
    e. Fasten screens to fan using removable and reusable hardware designed for easy removal by maintenance personnel.

20. Hardware: Hex-head, high-strength 300 series stainless steel.
21. Nameplates:

    a. Construct nameplates and rotation arrows of aluminum or 300 series stainless steel.
    b. Securely fasten nameplate and rotation arrow to fan housing using pins or sheet metal screws.
    c. Locate nameplates in a highly visible location on motor side of fan.
    d. Provide the Following Information on Nameplate: Engrave.

        1) Manufacturer, address, phone number, and website address.
        2) Manufacturer model number.
        3) Serial number.
        4) Manufacturing date.
        5) Fan size.
        6) Fan schedule equipment designation (may be listed on a separate nameplate if there is insufficient space).
        7) Design airflow.
        8) Design static pressure.
        9) Design fan speed.
        10) AMCA fan class.

22. Air-Handling Unit Factory Assembly:

    a. Internal Access: Include each fan with internal access from downstream sides as indicated on Drawings.
    b. Removal and Replacement: Each fan wheel and motor shall be independently removable and replaceable through a removable access door installed in air-handling unit casing.
    c. Stackable Fan Arrays: Construct frame work from aluminum, galvanized steel, or stainless steel.
    d. Panel-Mounted Fan Array Supports:

        1) Construct a freestanding and self-supporting structural framework to support each fan individually from and independent of adjacent fans.

2) Construct frame work from aluminum, galvanized steel, or stainless steel.

F. Fan Motors:

1. Source Limitations: Obtain motors from single source from single manufacturer.
2. Standard: Comply with NEMA MG 1 unless more stringent requirements are indicated.
3. Description: NEMA MG 1, Design B, as required to comply with capacity and torque characteristics; medium-induction motor.

a. Performance:

1) 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) Efficiency: NEMA Premium Efficiency rating complying with NEMA MG 1.
3) Motor Horsepower: Minimum size as indicated on Drawings. Motor shall operate fan under all conditions indicated without exceeding motor nameplate and without use of motor service factor.
4) Inverter-Duty Rating: Comply with minimum requirements of Class F or Class H insulation, suitable for "inverter-duty" or "drive-duty" applications in accordance with NEMA MG 1. Motor operation through a variable-frequency controller shall not adversely affect the motor performance, operation, useful life, and warranty.
5) Service Factor: 1.15.
6) Temperature Rise: Match insulation rating.

4. Enclosure Type: See Drawings for motor enclosure type.
5. Shaft Grounding System:

a. Shaft grounding system to protect bearings from induced voltage.
b. Shaft grounding system shall have low drag (less than 0.05 percent of motor horsepower), and shall operate for a minimum of three years without periodic maintenance or adjustments.
c. Mounting: External or internal to motor enclosure.

6. Frame:

a. Frames with integrally cast feet unless other requirements of driven equipment require a different arrangement.
b. Frame, front and back end brackets, and front and back end bearing intercaps constructed of cast iron, ASTM A48/A48M, Class 25 or better.

7. Rotor:

a. Fabricate rotor frame from die-cast aluminum, copper, or associated alloys.
b. Key rotors to motor shaft.
c. Rotating assembly shall be dynamically balanced to within limits defined in NEMA MG 1.

d. Motors shall have the entire rotating assembly between bearing inner caps coated with a corrosion-resistant coating.

8. Stator:

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

9. Shaft:

a. Solid shaft fabricated of Type 304 stainless steel, accurately turned, ground and polished, and inspected for accuracy.
b. End of shaft with drilled hole for use in field measurements.

10. Bearings:

a. Grease-lubricated ball or roller bearings.
b. ABMA 11 L-10 motor bearing life of 100,000 hours.
c. Bearing Lubrication:

1) Factory lubricate motor bearings using a premium moisture-resistant polyurea thickened grease with rust inhibitors suitable for extreme operating temperatures encountered.
2) Coordinate special requirements that may impact lubrication and include appropriate lubrication.

d. Grease Fittings:

1) Equip each bearing housing with an easily accessible grease inlet.
2) Fit grease inlets with a grease fitting and protective fitting cap.
3) Equip inlets with an automatic grease relief fitting to prevent excessive greasing.
4) Equip each bearing housing with grease drain and threaded plug.

11. Conduit Box:

a. Material same as frame.
b. For motor frames 365T and below, furnish conduit boxes sized with internal volumes in accordance with NEMA MG 1.
c. For motor frames larger than 365T, furnish conduit boxes one size larger than NEMA MG 1.
d. Coordinate the location and mounting of conduit box with driven equipment manufacturer.
e. Factory mount conduit box on motor.

12. Grounding: NRTL-listed clamp-type grounding lug mounted in conduit box.
13. Motor Leads:

a. Non-wicking type, Class F temperature rating or better, and permanently numbered over entire length for identification.

b. Lead terminals shall be manufacturer's standard.

14. Condensate Drains:

a. Motor with drain holes at the lowest point for drainage of condensate.
b. Each drain hole with a threaded removable plug.

15. TEFC Motor Fans: Corrosion-resistant construction, non-sparking, metallic or non-metallic, bi-directional, and keyed to shaft.

a. Motor Fan Cover: Steel.

16. Hardware: Hex-head, high-strength, zinc-plated carbon steel or stainless steel.
17. Lifting Eyebolts: Eyebolt threaded into frame receptacle and design to prevent moisture and other foreign material from entering motor cavity when eyebolt is removed.
18. Nameplates:

a. Construct nameplates of aluminum or stainless steel and attach to motor frame with aluminum, stainless steel, or brass drive pins.
b. Engrave or stamp data on the nameplate.
c. At a minimum, include nameplate data in accordance with NEMA MG 1. Also include ABMA bearing designation for the drive and opposite end bearing.

19. Paint: Successfully pass 1000 -hour salt spray test for corrosion in accordance with ASTM B117.

G. Vibration Isolation:

1. General:

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

2. Spring Isolators:

a. Performance:

1) Deflection: Minimum deflection indicated on Drawings. Use a greater deflection if required to maintain an isolator efficiency of at least 98 percent under all operating conditions encountered. Calculate isolator efficiency using actual support conditions considering the rigidity of structure.
2) Laterally stable freestanding open-spring mounting.
3) Spring diameter not less than 0.8 of compressed spring height at rated load and in the installed and operating condition.
4) Reserve travel to solid shall be equal to a minimum of 50 percent of rated deflection and in no case less than 25 percent of rated deflection in an installed and operating condition.
5) Ratio of horizontal stiffness to vertical stiffness equal to approximately one.
6) Design and install so that ends of springs remain parallel.
7) Select springs that are non-resonant with equipment related frequencies and natural frequencies of support structure.

8) Springs shall not take a permanent set when compressed to coil bind.
9) Seismic restraints to limit motion under seismic forces to 1/4 inch.

b. Construction:

1) Coat springs with PVC or neoprene. Color-code springs to allow positive identification after installation.
2) Construct baseplates, spring retainers, and other components of galvanized carbon steel. Etch and paint aluminum components.
3) Use nuts, bolts, and washers and other associated hardware constructed of stainless steel.
4) Isolators with integral leveling bolts.
5) Baseplates with holes and isolation grommets for bolting.
6) Bond nominal 1/4-inch- thick, neoprene friction pad to baseplate.

3. Elastomeric Grommets:

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

4. Flexible Connections:

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

5. Air-Handling Unit Factory Assembly:

a. Use precompression-type height-saving brackets with isolators having 2-1/2-inch deflection or greater, to limit exposed bolt length.
b. Install spring isolators plumb and adjust isolators that are not plumb under operating conditions to make plumb.
c. Adjust isolators to prevent stress transfer to equipment.
d. Verify that installed isolators and mounting systems permit equipment motion in all directions.
e. Restraint fans with isolated thrust resistors to limit displacement to 1/4 inch. Design for maximum lateral thrust the fan can develop.
f. Adjust or include additional resilient restraints to flexibly limit fan lateral motion to 1/4 inch during startup and operation of equipment.
g. Anchor restraints to fixed supports having a stiffness greater than the thrust encountered.
h. Include at least 2-inch operating clearance between fan bases and walking surface of air-handling unit floor. Before startup, clean out foreign matter between bases and equipment to prevent short circuit.
i. Flexible Connections:

1) Install flexible connections at connections to fans.

2) Install flexible connections in accordance with SMACNA standards and manufacturer's written instructions.
3) Make fabric joints on the flat run, not the corners, with overlap to provide an area sufficient to make a positive seal.
4) Apply adhesive between the fabric layers.
5) Attach connections using screws or bolts.
6) Reinforce fabric if required to keep fabric from collapsing and impacting airflow into fan.

H. Hydronic Coils:
1. Sourcing Option: In lieu of sourcing hydronic coils from a specialty coil manufacturer, air-handling unit manufacturer has option to furnish in-house hydronic coils that achieve equal or better performance while complying with other requirements indicated.
2. General: Provide air-handling units with hydronic coils where indicated on Drawings.
3. Description: Plate fin coils constructed of staggered tubes mechanically expanded into continuous collars that are die formed into plate fins.
4. Design and Performance:

a. Capacities, face area, and number of rows indicated on Drawings are minimum acceptable.
b. Air pressure drop, water pressure drop, fin spacing, and face velocity indicated on Drawings are the maximum acceptable.
c. Coils shall be counterflow design, air to fluid. Fluid supply shall enter air leaving side of coil and exit air entering side.
d. Design coils to be drainable.

1) Coils shall have all circuits drainable when coils are installed in horizontal position and level.
2) Coil supply and return header shall be furnished with a drain connection at lowest point on header.

e. Design coils to be self-venting.

1) Supply connection near bottom of supply header.
2) Return connection near top of return header.
3) Furnish coil return and supply header with a vent connection at highest point on header.

f. Coils supply and return piping connections on same end of coil.
g. Coils shall be rated for system operating pressures and temperatures encountered by installation, but not less than 200 psig.
h. Coil selection criteria, unless otherwise indicated on Drawings, are as follows:

1) Face Velocity: Maximum of 500 fpm.
2) Fluid Tube Velocity (at Design Flow Rate):

a) Maximum: 6 fps.
b) Minimum: 3 fps.

3) Fluid Header Velocity: Maximum of 6 fps.
4) Fin Height: Maximum of 48 inches.

5) Fin Spacing: Maximum of 12 fins per inch.

i. Cooling coils shall have no moisture carryover at design conditions. Install moisture eliminators on discharge face of coil if it is necessary to eliminate moisture carryover.

5. Casing and Tube Sheets:

a. Depth: Extend coil casing and tube sheets a minimum of 1/2 inch beyond face of fins on both entering and leaving sides.
b. Casing and Tube Sheet Materials:

1) Cooling Coils: Stainless steel, ASTM A240/A240M or ASTM A480/A480M, Type 304L, No. 2D finish.
2) Heating Coils:

a) Stainless steel, ASTM A240/A240M or ASTM A480/A480M, Type 304L, No. 2D finish.
b) Galvanized steel, ASTM A653/A653M, G90 coating.

c. Top and Bottom Casings:

1) Flange face minimum of 1-1/2 inches; double flange edge for rigidity and ease of removal with secondary flange face minimum of 1/2 inch.
2) Thickness:

a) Coils with Fin Length of up to 72 Inches: Minimum of 16 gauge thick.
b) Coils with Fin Length Exceeding 72 Inches: Minimum of 14 gauge thick.

d. End Tube Sheets:

1) Tube sheet holes rolled to prevent chaffing of tubes during thermal expansion and contraction.
2) Flange face minimum of 1-1/2 inches.
3) Thickness: Minimum of 16 gauge thick.

e. Intermediate Tube Sheets:

1) Tube sheet holes rolled to prevent chaffing of tubes during thermal expansion and contraction.
2) Space intermediate tube sheets a maximum of 48 inches o.c. and locate to provide equal spacing between tube sheet across coil tube length.
3) Flange face minimum of 1/2 inch.
4) Thickness: Minimum of 16 gauge thick.

f. Holes: Include number, size, and location of holes in casing and end tube sheets required for coil installation.

6. Fins:

a. Materials:

1) Aluminum: 0.0075 inch thick.

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

7. Headers:

a. Construct header of seamless copper, ASTM B75/B75M drawn temper of diameter and wall thickness based on coil size, flow rate, design pressure, design temperature, and circuiting.
b. Tube-to Header Connections: Tube-to-header holes shall intrude inward so landed surface area is three times the core tube thickness, to provide enhanced header to tube joint integrity. Tubes shall evenly extend within the ID of the header no more than 0.12 inch.
c. Header Top and Bottom Caps: End caps shall be die-formed and installed on the ID of header such that the landed surface area is three times the header wall thickness.
d. Drains: Include low point of supply and return header with a NPS 1/2 drain connection. Extend copper or carbon steel pipe through air-handling unit casing and terminate end with male national pipe thread (MNPT). Pipe shall be threaded on both ends to facilitate easy field removal and replacement.
e. Vents: Include high point of supply and return header with a NPS 1/2 vent connection. Extend copper or carbon steel pipe through air-handling unit casing and terminate end with MNPT. Pipe shall be threaded on both ends to facilitate easy field removal and replacement.
f. Supply and Return Connections:

1) Terminate ends with MNPT.
2) Connections to header shall be either copper tube with brazed ASME B16.18 threaded male adapters or carbon steel pipe with machine-threaded MNPT connections. Pipe shall extend through air-handling unit casing and be threaded on both ends to facilitate easy field removal and replacement.
3) Connections NPS 2-1/2 and larger shall have a bronze ASME 16.24 threaded flanges attached to threaded connections to provide for a flanged field connection. Select flange class, Class 150 or Class 300, for system pressure and temperature encountered.

g. Protect openings of supply, return, vent, and drain connections with a threaded cap to prevent entry of dirt into the coil.

8. Tubes:

a. Material: Copper, ASTM B75/B75M annealed temper or ASTM B280 drawn temper; .
b. Tube Nominal Diameter: 1/2 or 5/8 inch before expanding, selected to provide performance indicated.

c. Tube Nominal Wall Thickness: As required by performance, minimum of 0.025 inch thick.

9. Tube Return Bends: 180-degree bends brazed to tubes; material, wall thickness, and nominal diameter to match tubes.

    a. Tube Return Bend Nominal Wall Thickness: As required by performance, minimum of 0.025 inch thick.

10. Brazing: High-temperature brazing alloy with not less than 5 percent silver when brazing like non-ferrous materials together and more than 30 percent silver when brazing ferrous to non-ferrous materials.
11. Hardware: Use hex-head bolts, nuts, and washers constructed of Type 304 stainless steel.
12. Nameplate: Aluminum or stainless steel nameplate with brass or stainless steel chain for each coil, with the following data engraved or embossed:

    a. Manufacturer name, address, telephone number, and website address.
    b. Manufacturer model number.
    c. Serial number.
    d. Manufacturing date.
    e. Coil identification (indicated on Drawings).
    f. Coil fin length.
    g. Coil fin height.
    h. Coil weight with fluid/without fluid.
    i. Coil casing material and thickness.
    j. Coil fin material and thickness.
    k. Coil tube material and thickness.
    l. Coil header material and thickness.

13. Cleaning: Residual manufacturing oils and solid contaminants shall be removed internally and externally by completely submersing the coil in an environmentally acceptable degreasing solution that is chemically compatible with the coil material.
14. Air-Handling Unit Factory Assembly:

    a. Coil Connections: Extend each coil connection through casing access panel and terminate connections, approximately 4 inches beyond exterior face of access panel, and seal each penetration as indicated. Casing access panels shall be removed and reinstalled with coils installed inside air-handling units.
    b. Internal Access: Include each coil with internal access from downstream and upstream sides as indicated on Drawings.
    c. Removal and Replacement: Each coil shall be independently removable and replaceable through a removable access panel installed in air-handling unit casing.
    d. Supports for Coils:

        1) Construct a freestanding and self-supporting structural framework to support each coil individually from and independent of adjacent coils.
        2) Construct framework for cooling coils, from aluminum or stainless steel structural shapes.
        3) Construct frame work for heating coils from aluminum, galvanized steel,or stainless steel structural shapes.

I. Drain Pans:

1. General:

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

2. Intermediate Drain Pans:

a. Where multiple individual horizontally mounted coils are vertically stacked to make a coil bank, install intermediate drain pans under each stacked coil in the coil bank.
b. Material: Type 304L stainless steel ASTM A240/A240M or ASTM A480/A480M, a minimum of 16 gauge thick.
c. Minimum Depth: 1.0 inch.
d. Drain Pan Connection:

1) Stainless steel threaded coupling welded to underside of drain pan at lowest point.
2) Minimum Nominal Connection Size: NPS 1.

e. Drain Pipe:

1) Air-handling unit manufacturer to connect full-size drain pipe to each drain pan connection. Option to use one of following pipe materials:

a) Copper tube with a bronze threaded male adapter, brazed or solder to end.
b) Aluminum pipe with threaded MNPT ends.
c) Stainless steel pipe with threaded MNPT ends.

2) Extend drain pipe to top of drain pan immediately below.
3) Include a removable stainless steel support to secure bottom of drain pipe from drain pan below to prevent lateral movement.
4) In applications where multiple drain pans are stacked, align stacked drains pan connections and pipes for clear vertical flow.

3. Bottom Drain Pans:

a. Mounting Location, Recessed in Floor: Air-handling unit manufacturer has option to recess bottom drain pan into the floor or install drain pan above air-handling unit floor walking surface.
b. Mounting Location, Above Floor: Bottom drain pan shall be installed above air-handling unit floor walking surface. Do not recess drain pan into unit base.
c. Grating: Install removable stainless steel grating on top of drain pan.

d. Material: Type 304L stainless steel ASTM A240/A240M or ASTM A480/A480M, a minimum of 16 gauge thick.
e. Minimum Depth: 1.5 inches.
f. Drain Pan Connection:

1) Stainless steel threaded half-coupling welded to lowest point of drain pan.
2) Location: One end.
3) Minimum Nominal Connection Size: NPS 1.

g. Drain Pipe:

1) Air-handling unit manufacturer to connect full size drain pipe to each drain pan connection. Option to use one of following pipe materials:

a) Copper tube with threaded male adapter, brazed or soldered to ends.

2) Extend drain pipe and terminate 3 inches beyond exterior face of casing.

J. Pleated Panel Filters:
1. Source Limitations: Obtain filters from single source from single manufacturer.
2. Description: Factory-fabricated, self-supported, extended-surface, pleated, panel-type, disposable air filters.
3. Performance:

a. Filtration Efficiency, ASHRAE 52.2 MERV Rating: See Drawings.
b. Energy Cost Index: Five star rating.
c. Initial Air Pressure Drop: With face velocity of 500 fpm, clean filter pressure drop shall not exceed the following:

1) MERV 13:

a) Depth 2 Inches: 0.30 inch wg.

d. Manufacturer-Recommended Final Air Pressure Drop: 1.0 inch wg.
e. Pressure Differential without Failure: 2 inches wg.
f. Temperature Rating: 200 deg F.

4. Certification:

a. AHRI: Tolerances in accordance with AHRI 850 (I-P) and AHRI 851 (SI).
b. ASHRAE: Tested and rated in accordance with ASHRAE 52.2.
c. UL: UL 900 listed.

5. Size:

a. Nominal size of individual filters indicated on Drawings:
b. Nominal Filter Size:

1) Face: 24 by 24 inches.
2) Depth: 2 inches.

c. Actual Filter Size: Suitable for installation in an industry-standard filter holding frame.

6. Filter Media Surface Area: Each filter shall contain the following minimum media surface area for a filter with a nominal 24-by-24-inch face:

a. Depth 2 Inches: 17.3 sq. ft..

7. Construction:

a. Media: Glass or synthetic blend of fibers arranged in a series of pleats attached to and supported by a corrosion-resistant welded-wire grid.
b. Filter Media Casing: High wet strength (28-point) beverage board that is bonded around the periphery to eliminate air bypass.

1) Diagonal support members across upstream and downstream filter face constructed of same material as casing shall ensure pleat spacing and stability.

c. Adhesive: Fire-retardant bonding adhesive where bonding media to casing.

K. ASHRAE-Rated Filter Holding Frames:

1. Filter Holding Frames for ASHRAE-Rated Filters:

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

2. Air-Handling Unit Factory Installation:

a. Air-handling unit manufacturer shall furnish filters and provide filter holding frames, retaining clips, and filter support structures.
b. Furnish filter quantity, size, type, and performance indicated on Drawings.
c. Install filter frames in a flat vertical position for horizontal airflow.
d. Install holding frames in accordance with manufacturer's written instructions and to prevent passage of unfiltered air. Include additional gaskets as necessary.
e. Secure individual holding frames together to build a multiple filter bank.
f. Construct aluminum support structure to hold frames and filters.

1) Design support structure for maximum system operating pressures encountered equal to fan shutoff pressure.
2) Design and fabricate support structure to limit deflection across filter bank to 1/360 of the span when subjected to a 200-lb lateral force applied at any point on the filter holding frame assembly.

L. Filter Gauges:

1. Provide a gauge to indicate pressure differential between entering and leaving side of each filter bank. Panel filter bank separate from cartridge filter bank.

    a. Where multiple filters share a common frame, include a separate gauge for each filter bank.
    b. Include a metal spacer constructed of same material as filter frame for one of the filters installed in filter bank to accommodate pressure differential measure across both upstream and downstream filters.

2. Gauge shall have a nominal 4-inch- diameter face.
3. Select range of gauge to be approximately twice the dirty filter pressure drop.
4. Provide each gauge with vent valves to allow for re-zeroing the gauge without removing tubing connections.
5. Include static pressure sensors on entering and leaving side of each filter bank.
6. Air-Handling Unit Factory Assembly:

    a. Mount each filter gauge on exterior surface of unit casing near associated filter sections.
    b. Mount center of gauges 60 inches above bottom of air-handling unit structural base.
    c. Connect static pressure sensors to filter gauges using aluminum tubing and compression type fittings.
    d. Support tubing at intervals not greater than 60 inches o.c.

M. Automatic Dampers:

1. General: Provide air-handling units with automatic dampers where indicated on Drawings.

    a. Unless otherwise indicated, use parallel-blade configuration for two-position control, for equipment isolation service, and when mixing two airstreams. For other applications, use opposed-blade configuration.
    b. Factory assemble multiple damper sections to provide a single damper assembly of size required by application.
    c. Damper actuator shall be factory installed by damper manufacturer as integral part of damper assembly. Coordinate actuator location and mounting requirements with damper manufacturer.

2. Rectangular Dampers with Aluminum Blades:

    a. Source Limitations: Obtain dampers from single source from single manufacturer.
    b. Performance:

1) Leakage: AMCA 511, Class 1A. Leakage shall not exceed 3 cfm/sq. ft. against 1-inch wg differential static pressure.
2) Pressure Drop: 0.05 inch wg at 1500 fpm across a 24-by-24-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
3) Velocity: Up to 4000 fpm.
4) Temperature: Minus 40 to plus 185 deg F.
5) Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.
6) Damper shall have AMCA seal for both air leakage and air performance.

c. Construction:

1) Frame:

a) Material: ASTM B211, Alloy 6063 T5 extruded-aluminum profiles, 0.07 inch thick.
b) Hat-shaped channel with integral flange(s). Flange mating face shall be a minimum of 1 inch.
c) Width not less than 5 inches.

2) Blades:

a) Hollow, airfoil, extruded aluminum.
b) Parallel- or opposed-blade configuration as required by application.
c) Material: ASTM B211, Alloy 6063 T5 aluminum, 0.07 inch thick.
d) Width not to exceed 6 inches.
e) Length as required by close-off pressure, not to exceed 48 inches.

3) Seals:

a) Blades: Replaceable, mechanically attached extruded silicone, vinyl, or plastic composite.
b) Jambs: Stainless steel, compression type.

4) Axles: 0.5-inch- diameter, stainless steel, mechanically attached to blades.
5) Bearings:

a) Molded synthetic or stainless steel sleeve mounted in frame.
b) Where blade axles are installed in vertical position, include thrust bearings.

6) Linkage:

a) Concealed in frame.
b) Constructed of aluminum and stainless steel.
c) Hardware: Stainless steel.

d. Airflow Measurement: Where indicated, include damper assembly with integral airflow monitoring.

1) Source Limitations: Obtain damper applications from single source from single manufacturer.
2) Performance:

a) Zero- to 10-V dc or 4- to 20-mA scaled output signal for remote monitoring of actual airflow.
b) Accuracy shall be within 5 percent of actual flow rate between the range of minimum and design airflow. For applications with a large variation in range between the minimum and design airflow, configure damper sections and flow measurement assembly as required to comply with stated accuracy over the entire modulating range.
c) Include a straightening device as part of flow measurement assembly to achieve the specified accuracy with configuration indicated.
d) Suitable for operation in untreated and unfiltered air.
e) Include temperature and altitude compensation and correction to maintain accuracy over temperature range encountered at site altitude.
f) Include automatic zeroing feature.

e. Airflow Control: Where indicated, provide damper assembly with integral airflow measurement and control.

1) Source Limitations: Obtain damper assembly from single source from single manufacturer.
2) Performance:

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

3. Damper Actuators:

a. General:

1) Actuators shall operate related damper(s) with sufficient reserve power to provide smooth modulating action or two-position action and proper speed of response at velocity and pressure conditions to which damper is subjected.
2) Actuators shall produce sufficient power and torque to close off against the maximum system pressures encountered. Actuators shall be sized to close off against the fan shutoff pressure as a minimum requirement.
3) Total damper area operated by an actuator shall not exceed 80 percent of manufacturer's maximum area rating.
4) Include one actuator for each damper assembly where possible. Multiple actuators required to drive a single damper assembly shall operate in unison.
5) Avoid use of excessively oversized actuators, which could overdrive and cause linkage failure when the damper blade has reached either its full open or closed position.
6) Use jackshafts and shaft couplings in lieu of blade-to-blade linkages when driving axially aligned damper sections.
7) Include mounting hardware and linkages for connecting actuator to damper.
8) Select actuators to fail in desired position in the event of a power failure.
9) Actuator Fail Positions: See Drawings.

b. Type: Motor operated, with or without gears, electric and electronic.
c. Voltage:

1) 24 V.
2) Actuator shall deliver torque required for continuous uniform movement of controlled device from limit to limit when operated at rated voltage.
3) Actuator shall function properly within a range of 85 to 120 percent of nameplate voltage.

d. Construction:

1) Less Than 100 W: Fiber or reinforced nylon gears with steel shaft, copper alloy or nylon bearings, and pressed steel enclosures.
2) 100 up to 400 W: Gears ground steel, oil immersed, shaft-hardened steel running in bronze, copper alloy, or ball bearings. Operator and gear trains shall be totally enclosed in dustproof cast-iron, cast-steel, or cast-aluminum housing.
3) Greater Than 400 W: Totally enclosed reversible induction motors with auxiliary hand crank and permanently lubricated bearings.

e. Field Adjustment:

1) Spring return actuators shall be easily switchable from fail open to fail closed in the field without replacement.
2) Provide gear-type actuators with an external manual adjustment mechanism to allow manual positioning of the damper when actuator is not powered.

f. Two-Position Actuators: Single direction, spring return, or reversing type.
g. Modulating Actuators:

1) Capable of stopping at all points across full range, and starting in either direction from any point in range.
2) Control Input Signal:

    a) Proportional: Actuator drives proportional to input signal and modulates throughout its angle of rotation. Suitable for 2- to 10-V dc and 4- to 20-mA signals.
    b) Pulse-Width Modulation (PWM): Actuator drives to a specified position in accordance with a pulse duration (length) of signal from a dry-contact closure, triac sink, or source controller.

3) Programmable Multifunction:

    a) Control programmable multifunction input, position feedback, and running time shall be factory or field programmable.
    b) Diagnostic programmable multifunction feedback of hunting or oscillation, mechanical overload, mechanical travel, and mechanical load limit.
    c) Programmable multifunction service data, including at a minimum, number of hours powered, and number of hours in motion.

h. Position Feedback:

1) Where indicated, equip two-position actuators with limits switches or other positive means of a position indication signal for remote monitoring of open and close position.
2) Where indicated, equip modulating actuators with a position feedback through current or voltage signal for remote monitoring.
3) Include a position indicator and graduated scale on each actuator indicating open and closed travel limits.

i. Fail-Safe:

1) Where indicated, provide actuator to fail to an end position.
2) Internal spring return mechanism to drive-controlled device to an end position (open or close) on loss of power.
3) Batteries, capacitors, and other non-mechanical forms of fail-safe operation are acceptable only where uniquely indicated.

j. Integral Overload Protection:

1) Provide against overload throughout the entire operating range in both directions.
2) Electronic overload, digital rotation sensing circuitry, mechanical end switches, or magnetic clutches are acceptable methods of protection.

k. Damper Attachment:

1) Unless otherwise required for damper interface, provide actuator designed to be directly coupled to damper shaft without need for connecting linkages.

2) Attach actuator to damper drive shaft in a way that ensures maximum transfer of power and torque without slippage.
3) Bolt and set screw method of attachment is acceptable only if included with at least two points of attachment.

l. Temperature and Humidity:

1) Temperature: Suitable for operating temperature range encountered by application with minimum operating temperature range of minus 20 to plus 120 deg F.
2) Humidity: Suitable for humidity range encountered by application; minimum operating range shall be from 5 to 95 percent relative humidity, noncondensing.

m. Enclosure:

1) Suitable for ambient conditions encountered by application.
2) Provide actuator enclosure with a heater and controller where required by application.

n. Stroke Time: Select operating speed to be compatible with equipment and system operation.

1) Operate damper from fully closed to fully open within 60 seconds.
2) Operate damper from fully open to fully closed within 60 seconds.
3) Move damper to failed position within 15 seconds.
4) Actuators operating in smoke-control systems shall comply with governing code and NFPA requirements.

o. Sound:

1) Spring Return: 62 dBA.
2) Non-Spring Return: 45 dBA.

N. Manual Balancing Dampers:

1. General: Air-handling unit manufacturer shall furnish and factory install manual balancing dampers inside air-handling units where indicated on Drawings.
2. Rectangular Manual Balancing Dampers with Aluminum Airfoil Blades:

a. Source Limitations: Obtain dampers from single source from single manufacturer.
b. Performance:

1) Leakage: AMCA 511, Class 1A. Leakage shall not exceed 3 cfm/sq. ft. against 1-inch wg differential static pressure.
2) Pressure Drop: 0.05 inch wg at 1500 fpm across a 24-by-24-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
3) Velocity: Up to 6000 fpm.
4) Temperature: Minus 40 to plus 185 deg F.
5) Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.

6) Damper shall have AMCA seal for both air leakage and air performance.

c. Construction:

1) Frame:

a) Material: ASTM B211, Alloy 6063 T5 extruded-aluminum profiles, 0.07 inch thick.
b) Hat-shaped channel with integral flange(s). Flange mating face shall be a minimum of 1 inch.
c) Width not less than 5 inches.

2) Blades:

a) Hollow, airfoil, extruded aluminum.
b) Parallel- or opposed-blade configuration as required by application.
c) Material: ASTM B211, Alloy 6063 T5 aluminum, 0.07 inch thick.
d) Width not to exceed 6 inches.
e) Length as required by close-off pressure, not to exceed 48 inches.

3) Seals:

a) Blades: Replaceable, mechanically attached extruded silicone, vinyl, or plastic composite.
b) Jambs: Stainless steel, compression type.

4) Axles: 0.5-inch- diameter stainless steel, mechanically attached to blades.
5) Bearings:

a) Molded synthetic or stainless steel sleeve mounted in frame.
b) Where blade axles are installed in vertical position, include thrust bearings.

6) Linkage:

a) Concealed in frame.
b) Constructed of aluminum and stainless steel.
c) Hardware: Stainless steel.

7) Locking Regulator:

a) Aluminum or stainless steel standoff with locking regulator mounted to frame in an accessible location for manual adjustment of damper blades.

O. Smoke Dampers:

1. General: Air-handling unit manufacturer shall furnish and factory install smoke dampers inside air-handling units where indicated on Drawings.
2. Rectangular Smoke Dampers with Aluminum Blades:

a. Source Limitations: Obtain dampers from single source from single manufacturer.

b. General: Air-handling unit manufacturer shall furnish and factory install smoke dampers inside air-handling units where indicated on Drawings.
c. Performance:

1) Leakage: In accordance with UL 555S, Class 1.
2) Pressure Drop: 0.05 inch wg at 1500 fpm across a 24-by-24-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
3) Velocity: Up to 4000 fpm.
4) Temperature: 250 deg F.
5) Pressure Rating: 8.0 inches wg.

d. Certification: NRTL listed and labeled in accordance with UL 555S, Class 1.
e. Construction:

1) Frame:

a) Material: ASTM B211, Alloy 6063 T5 extruded-aluminum profiles, 0.07 inch thick.
b) Hat-shaped channel with integral flange(s). Flange mating face shall be a minimum of 1 inch.
c) Width not less than 5 inches.

2) Blades:

a) Hollow, extruded airfoil shape.
b) Material: ASTM B211, Alloy 6063 T5 aluminum, 0.07 inch thick.
c) Width not to exceed 6 inches.
d) Length as required by close-off pressure, not to exceed 48 inches.

3) Seals:

a) Blades: Replaceable, mechanically attached extruded silicone.
b) Jambs: Stainless steel, compression type.

4) Axles: 0.5-inch- diameter stainless steel, mechanically attached to blades.
5) Bearings:

a) Molded synthetic or stainless steel sleeve mounted in frame.
b) Where blade axles are installed in vertical position, include thrust bearings.

6) Linkage:

a) Concealed in frame.
b) Constructed of aluminum and stainless steel.
c) Hardware: Stainless steel.

P. Air Blenders:

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

2. Description: Static air mixing devices fabricated in assemblies consisting of multidirectional vanes that are designed to reduce stratification of multiple mixed airstreams and improve uniformity of the air tunnel velocity profile located downstream of air mixer.
3. Performance:

    a. Certification: Documented performance verified by tests performed by an independent agency .
    b. Mixing: Uniform mixed airstream within 6 deg F of the theoretical average temperature of two or more airstreams.
    c. Indicated on Drawings.

4. Construction:

    a. Configuration: Indicated on Drawings.
    b. Material: Aluminum .
    c. Thickness: 0.080 inch.
    d. Attachment: Integral mounting flange for attachment to mounting substrate.
    e. Welding: Stitch or continuous welds. Filler metals matched to welded materials.
    f. Hardware: Stainless steel.
    g. OEM Factory Assembly: Single-piece assembly for sizes through 96 inches. For larger sizes, air mixers shall be fabricated in two pieces, bolted together to ensure proper fit and alignment and then disassembled for shipment.
    h. Finish: Anodized.

5. Air-Handling Unit Factory Assembly:

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

Q. Smoke Detectors:

1. System, Duct Smoke Detectors: For connection to conventional fire-alarm system. Coordinate requirements with Section 284621.13 "Conventional Fire-Alarm System."

    a. Operating at 24 V dc, nominal.
    b. Detectors shall be two-wire type.
    c. Base Mounting: Detector and associated electronic components shall be mounted in a twist-lock module that connects to a fixed base. Provide terminals in the fixed base for connection to building wiring.
    d. Self-Restoring: Detectors do not require resetting or readjustment after actuation to restore them to normal operation.
    e. Integral Visual-Indicating Light: LED type, indicating detector has operated and power-on status.

R. Hardware:

1. Screws:

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

2. Bolts, Nuts, and Washers:

    a. For Joining Galvanized and Painted Carbon Steel Materials: Hex-head, high-strength, 300 series stainless steel.
    b. For Joining Aluminum and Stainless Steel Materials: Hex-head, high-strength, 300 series stainless steel.
    c. Use washers and lock washers at each bolted connection.
    d. Select bolt size and spacing sufficient for load and application.

S. Welding:

1. Welding Filler Metals: Comply with AWS welding codes for welding materials appropriate for thickness and chemical analysis of material being welded.

    a. Use welding materials with corrosion properties equal to material being welded.

2. Use welders that are certified to weld at least twice the thickness of the material to be welded. Certification shall be within three months of work being performed.
3. Welds shall be continuous, full-penetration welds unless otherwise indicated. Intermittent welds, stitch welds, and tack welds are permitted only in specific applications indicated.
4. Use welders and welding procedures complying with the following:

    a. Piping Systems: Section IX of the ASME Boiler and Pressure Vessel Code and Section V of ASME B31.1.
    b. Structural Aluminum: AWS D1.2/D1.2M.
    c. Structural Carbon Steel: AWS D1.1/D1.1M.
    d. Structural Stainless Steel: AWS D1.6/D1.6M.
    e. Sheetmetal: AWS D9.1/D9.1M.

T. Painting:

1. General:

    a. Painted OEM components do not require additional coating other than touchup to damaged areas. Match the touchup coating to surrounding undamaged surfaces.
    b. Finish miscellaneous surfaces to match continuous surfaces.
    c. Protect mill galvanized surfaces that are exposed to view, such as raw steel cuts and damage by welding, with multiple coats of matching galvanized paint.

d. Protect mill galvanized surfaces that are concealed, such as raw steel cuts and damage by welding, with multiple coats of zinc-rich paint or matching galvanized paint.
e. Touch up or entirely repaint surface finishes, damaged during shipment and installation, to the original condition, using original materials and methods.

2. Preparation:

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

3. Primer:

a. Rust-inhibiting type, with a minimum dry film thickness of 2 mil(s) per coat.
b. Apply at least two coats of primer to unfinished carbon steel surfaces and at least one coat of primer to other surfaces.
c. Use primer that is compatible with substrate and finish coat.

4. Finish Coat:

a. Finish coat painting system shall be epoxy .
b. Use dry film thickness recommended by paint manufacturer for each coat. Total dry film thickness of all finish coats not less than 3 mils.
c. Painted Surfaces Minimum Properties:

1) Salt Spray ASTM B117: 5 percent salt solution fog at 95 deg F for 2000 hours with no deterioration.
2) Adhesion ASTM D3359: When the coating is cut into 0.0625-inch squares and 3M No. 600 tape is suddenly removed, there is no loss of adhesion.
3) Acid Resistance ASTM D3260: 15-minute exposure to 10 percent hydrochloric acid at room temperature with no effect.
4) Alkali Resistance ASTM D1647: 15-minute exposure to 10 percent sodium hydroxide at room temperature with no effect.
5) Humidity Resistance ASTM D2247: 850-hour exposure to 100 deg F and at least 95 percent relative humidity with no effect.
6) Pencil Hardness ASTM D3363: A hardness of 1H.

d. Finish coat color shall be selected by Architect and not be limited to manufacturer's standard offering.

1) Submit a written request for color selection and indicate in the request the date color selection must be returned without impacting schedule.

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

a. Unfinished carbon steel surfaces.
b. Exposed mill galvanized-steel surfaces of air-handling unit casing exterior.
c. Exposed aluminum surfaces of air-handling unit casing exterior.
d. Exposed stainless steel surfaces of air-handling unit casing exterior.

U. Cleanliness Requirements:

1. General:

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

2. During Manufacturing:

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

3. After Manufacturing:

a. Before shipment, after unit is completely assembled, clean unit inside and out.

1) Vacuum entire inside to remove dirt, dust, and debris using HEPA-filtered vacuum equipment.
2) Purge hard to reach surfaces with dry, oil-free, compressed or bottled nitrogen.
3) Wipe down all surfaces, inside and out, with a residue-free cleaning agent.

b. Protect unit to maintain cleanliness.

4. Shipping:

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

5. On-Site Storage:

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

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

V. Accessories:

1. Tool Kit:

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

2.5 SOURCE QUALITY CONTROL

A. AHRI Compliance:

1. AHRI 260 (I-P): Air-handling unit sound ratings shall be in accordance with AHRI 260 (I-P), "Sound Rating of Ducted Air Moving and Conditioning Equipment."
2. AHRI 410: Air-handling unit coils shall be rated in accordance with AHRI 410 and shall be listed by AHRI and labeled in accordance with AHRI.

B. AMCA Compliance:

1. AMCA 201: Air-handling unit manufacturer shall evaluate fan's performance within the air-handling unit in accordance with AMCA 201, "Fans and Systems" and account for conditions within the air-handling unit that could be detrimental to fan's performance by adjusting the fan performance indicated on Drawings.
2. AMCA 205 Certification: Air-handling unit fan's fan efficiency grade (FEG) shall be rated in accordance with AMCA 205, "Energy Efficiency Classifications for Fans" and shall bear the AMCA-certified FEG seal.
3. AMCA 210 Certification: Air-handling unit fan's air performance shall be rated in accordance with AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating" and shall bear the AMCA-certified air ratings seal.
4. AMCA 301 Certification: Air-handling unit fan's sound performance shall be rated in accordance with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data" and shall bear the AMCA-certified sound ratings seal.
5. AMCA 500-D: Air-handling unit damper's performance shall be rated in accordance with AMCA 500-D, "Laboratory Methods of Testing Dampers for Rating" and shall bear the AMCA-certified air ratings seal.

C. NFPA Compliance:

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

D. UL Compliance:

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

2.6 SOURCE QUALITY CONTROL - INDEPENDENT LABORATORY TESTING

A. General:

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

B. Casing Structural Deflection Test:

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

    a. In lieu of independent laboratory testing, manufacturer may perform factory deflection testing of proposed construction to prove compliance if witnessed by Architect and Owner. Manufacturer shall bear cost of labor and travel expenses to witness testing.

2. Test casing construction to performance criteria indicated.
3. Test casing construction proposed for use on Project. Include, at a minimum, particulars such as metal materials and thickness, internal support and reinforcing, and insulation material and thickness.
4. Test largest full-size casing panel proposed for use on Project.
5. Test proposed construction of walls, floor, and roof. Include a separate test for each unique casing construction proposed.
6. Submit test reports for each test to show compliance with performance indicated.

C. Casing Airborne Sound Transmission Test:

1. Include services of an independent testing laboratory to test proposed casing construction for sound transmission. Include a separate test for each unique casing construction proposed.
2. Conduct tests in accordance with ASTM E90.
3. Determine sound transmission class by using ASTM E413.
4. Test proposed construction of walls and roof.

5. Test proposed construction of floor assembly only if air-handling unit is not installed on a concrete housekeeping pad or building structural floor.
6. Submit test reports for each test to show compliance with performance indicated.

D. Casing Sound Absorption Test:

1. Include services of an independent testing laboratory to verify casing sound absorption coefficients for perforated casing panels. Provide a separate test for each unique casing construction proposed.
2. Conduct tests in accordance with ASTM C423 and ASTM E795.
3. Test proposed construction of walls and roof.
4. Submit test reports to show compliance with performance indicated.

2.7 SOURCE QUALITY CONTROL - AIR-HANDLING UNIT FACTORY TESTS

A. Witness of Testing: Allow Architect and Owner access to place where air-handling units are being tested for witness testing.

1. Submit written notification at least 30 days in advance of testing.
2. Schedule testing at mutually agreeable dates and times.

B. Witness Testing Travel Expenses:

1. Include in bid, the cost of travel expenses to witness factory testing. Total cost for travel expenses shall be clearly indicated separately in bid.
2. Exclude other incidental expenses not indicated.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine air-handling units before installation. Reject units with physical damage, and air-handling unit components that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for the following before installation of air-handling units:

1. Structural substrate mounting and anchorage to verify actual sizes, types, and locations.
2. Piping systems to verify actual sizes, types, and locations of connections.
3. Ductwork and plenums to verify actual sizes, types, and locations of connections.
4. Electrical services and controls to verify actual sizes, types, and locations of connections.

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

3.2 INSTALLATION OF INDOOR, CUSTOM AIR-HANDLING UNITS

A. Equipment Mounting: Install air-handling units at locations indicated on Drawings. Unless, otherwise indicated on Drawings, install air-handling units on concrete equipment bases.

1. Units Mounted on Concrete Bases:

    a. Install air-handling units on cast-in-place concrete equipment bases. Coordinate sizes and locations of concrete bases with actual equipment provided. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."
    b. Level air-handling unit bases using aluminum or stainless steel shims compatible with air-handling unit base material.
    c. Fill voids between air-handling unit bases and concrete bases using high-strength non-shrink grout.
    d. Continuously seal between concrete bases and perimeter of air-handling unit bases with nonhardening sealant.

2. Units Mounted to Structural-Steel Supports: Level unit air-handling bases using aluminum or stainless steel shims compatible with air-handling unit base material. Continuously seal between structural supports and air-handling unit bases with nonhardening sealant.
3. Units Mounted Directly to Finished Floors: Level air-handling unit bases using aluminum or stainless steel shims compatible with air-handling unit base material. Continuously seal between floor and perimeter of air-handling unit bases with nonhardening sealant.
4. Suspended Units: Suspend and laterally brace air-handling units from building structure by attaching to only air-handling unit bases at manufacturer-designated locations.
5. Comply with requirements for seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."

B. Equipment Clearances and Access:

1. Arrange installation of air-handling units to provide access space around air-handling units for service and maintenance and for removal and replacement of internal components.
2. Provide clearance and access required by governing codes and NFPA 70.
3. At a minimum, comply with requirements indicated on Drawings and air-handling unit manufacturer's written instructions.

3.3 PROTECTION DURING CONSTRUCTION

A. Exterior Covers: Cover air-handling units during construction with sealed covers to protect air-handling unit casing and externally mounted components from physical damage, dirt, dust and debris, paint splatter, and any other construction materials.

1. Minor physical damage, as determined by Owner, shall be repaired by air-handling unit factory service personnel to factory-finished condition.
2. Replace air-handling units with damage that in any way compromises the performance indicated.

B. Internal Access: Keep access doors locked to maximum extent possible and restrict access to only authorized personnel.

1. Open access doors only during periods authorized work inside air-handling units is required.
2. Coordinate and monitor work inside air-handling units on a shift basis. Lock access doors once work is complete or at the end of each shift.
3. Immediately report unauthorized access and any observed damage to Owner.

3.4 DUCT CONNECTIONS

A. Connect ducts and plenums to air-handling unit connections. Comply with requirements in Section 233113 "Metal Ducts."

B. Connect ducts and plenums to air-handling unit connections with flexible connections. Comply with requirements in Section 233300 "Air Duct Accessories."

C. Provide duct transitions required to make field connections to air-handling units.

D. Arrange ducts and plenums to provide unobstructed access to inside of air-handling units.

3.5 PIPING CONNECTIONS

A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Where installing piping adjacent to air-handling unit, provide unobstructed access to inside of air-handling units for service and maintenance.

C. Connect piping to air-handling units with flexible connectors.

D. Drain Pan Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping."

1. Make connections to air-handling unit connections with flanges or unions.
2. Extend dedicated drain piping from each air-handling unit connection to nearest equipment or floor drain and arrange piping to maintain clear service aisle paths free of potential tripping hazards.
3. Construct traps near air-handling unit connections to seal airflow from escaping within air-handling unit. Locate traps in a serviceable location that is away from access doors.
4. Install threaded cleanouts at changes in direction.
5. Secure drain piping to structure.

E. Chilled-Water Coil Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties."

1. Comply with requirements indicated on Drawings.
2. Make connections to coils with a union.
3. Connect to each coil inlet with shutoff valve, test plug, pressure gauge andthermometer.
4. Connect to each coil outlet with balancing valve, test plug, pressure gaugeflow meter and shutoff valve.

5. Connect each coil drain connection with a drain valve, which is full size of drain connection. Connect drain pipe to drain valve with union, and extend drain pipe to terminate over floor drain.
6. Connect each coil vent connection with manual vent, which is full size of vent connection.

F. Hot-Water Coil Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties."

1. Comply with requirements indicated on Drawings.
2. Make connections to coils with a union.
3. Connect to each coil inlet with shutoff valve, test plug, pressure gauge andthermometer.
4. Connect to each coil outlet with balancing valve, test plug, pressure gaugeflow meter and shutoff valve.
5. Connect each coil drain connection with a drain valve, which is full size of drain connection. Connect drain pipe to drain valve with union, and extend drain pipe to terminate over floor drain.
6. Connect each coil vent connection with manual vent, which is full size of vent connection.

3.6 ELECTRICAL CONNECTIONS

A. Install field power to each air-handling unit electrical power connection. Coordinate with air-handling unit manufacturer and installers.

B. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

C. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."

D. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.

E. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.

1. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.7 CONTROL CONNECTIONS

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

B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."

C. Install nameplate for each control connection, indicating field control panel designation and I/O control designation feeding connection.

3.8 STARTUP SERVICE

A. Engage an air-handling unit factory-authorized service representative to perform startup service.

1. Complete installation and startup checks in accordance with manufacturer's written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, controls, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
6. Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.
7. Comb coil fins for parallel orientation.
8. Verify that proper thermal-overload protection is installed for electric heaters.
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. Replace fan and motor pulleys as required to achieve design conditions.
2. Measure and record motor electrical values for voltage and amperage.
3. Manually operate dampers from fully closed to fully open position and record fan performance.

3.9 ADJUSTING

A. Adjust damper linkages for proper damper operation.

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

C. Before turning equipment over to Owner for use, adjust air-handling unit components that require further adjustment for proper operation. Consult air-handling unit manufacturer for instruction.

D. Occupancy Adjustments: When requested within 12 months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

E. Seasonal Adjustments: Make seasonal visits during warranty period to inspect and review operation of equipment. Make necessary adjustments for components observed to require adjustments for proper operation. Prepare and submit a report to Owner documenting each visit, observations, and any adjustments made.

3.10 CLEANING

A. Cleaning Schedule: After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems, and after completing startup service, and immediately before Owner use, clean air-handling units to remove foreign material and construction dirt and dust.

B. Unit Interior: Clean air-handling units internally to factory clean condition. Remove foreign material and construction debris, dirt, and dust.

1. Vacuum clean with HEPA-filtered vacuum and then wipe down with cleaning solution.
2. Clean casing floors, roofs, wall surfaces, access doors, and panels.
3. Clean all internal components, such as, coils, dampers, filter frames, fans, and motors.
4. Clean light fixtures and control devices.

C. Unit Exterior: Clean external surfaces of air-handling units to factory clean condition. Remove foreign material and construction debris, dirt, and dust. Vacuum clean with HEPA-filtered vacuum and then wipe down all surfaces with cleaning solution.

D. Cleaning Materials: Use cleaning materials and products recommended in writing by air-handling unit manufacturer.

E. Acceptance: Following unit cleaning, submit a written request for review and Owner acceptance. Acceptance for cleaning of air-handling units must pass a white glove test.

3.11 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory service representative to test and inspect components, assemblies, and equipment installations, including connections.

C. Tests and Inspections: Perform the following tests and inspections with the assistance of a factory-authorized service representative:

1. After field piping connections are complete, test hydronic coils and connections for leaks.
2. Charge refrigerant coils with refrigerant and test for leaks.
3. Field-Assembly Supervision: Instruct Installer and supervise field installation of first air-handling unit(s) shipped in multiple pieces for field assembly.
4. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. Field Casing Leakage Test:

1. Perform leak testing of air-handling units that include field assembly of multiple sections. Air-handling units that are shipped and installed as a single piece do not require field testing.
2. Follow procedures complying with ASHRAE 111.

3. Assembled air-handling units shall satisfy leakage criteria indicated. Modify air-handling units that fail to satisfy criteria and retest. For every air-handling unit that fails test, another air-handling unit shall be tested until all air-handling units tested pass leakage criteria on first attempt.
4. Submit a test report for each test indicating test equipment, procedures, results, date and time, and full name of personnel performing tests and witnesses.
5. Test report shall be in accordance with ASHRAE 111.
6. Witness Testing:

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

E. Field Fan Vibration Test:

1. Perform fan vibration testing for every one out of 10 air-handling unit fans randomly selected by Owner.
2. Test after air-handling unit installation is complete.
3. Three vibration readings shall be taken for each bearing in horizontal, vertical, and axial directions. Record each reading including vibration amplitude verses frequency.
4. Modify fans that fail to satisfy performance criteria and retest. For every fan that fails test, another fan shall be tested until all fans tested pass criteria on first attempt.
5. Submit a report for each fan tested indicating air-handling unit designation, fan designation, test equipment, procedures, results, date and time, and full name of personnel performing tests and witnesses.
6. Witness Testing:

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

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

G. Prepare test and inspection reports.

3.12 OPERATION DURING CONSTRUCTION

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

1. Submit written request for Owner approval by signature with detailed description of operating procedures to be followed including, but not limited to, the following:

    a. Description of construction activities while units are operating.
    b. Operation:

        1) Beginning and ending calendar dates.

2) List each day during week.
3) List start and stop time and hours for each day.

c. Startup procedures and shut-down procedures.
d. Provisions for routine monitoring of unit operation.
e. Provisions to prevent and protect against damage to equipment due to adverse operation such as, low temperature, high temperature, over pressure, fire, smoke, electrical over- and undervoltage, and current and electrical fault.
f. Provisions and safeguards for filtration to keep inside of units from getting dirty.
g. Record keeping.

2. If approved by Owner, units used for temporary cooling, heating, and ventilation during and before interior finish work is complete shall include an unconditional complete unit labor and parts warranty to extend at least two years after the warranty indicated expires.
3. Interior and exterior of air-handling units shall be cleaned to a factory-cleaned condition and clean condition must be accepted by Owner.

B. Filtration during Temporary Use:

1. Protect air-handling system ducts (exhaust air, outdoor air, and return air) with temporary filters installed and supported to prevent filter media from collapse and bypass of unfiltered air. Temporary media shall be installed at each inlet and shall have a published filtration efficiency of MERV 13 in accordance with ASHRAE 52.2.
2. Protect air-handling units with open inlets that are not ducted with temporary filters installed and supported to prevent filter media from collapse and bypass of unfiltered air. Temporary media shall be installed at each inlet and shall have a published filtration efficiency of MERV 13 in accordance with ASHRAE 52.2.
3. Do not operate air-handling units until both temporary and scheduled permanent air-handling unit particulate filters are in place. Temporary filters must be installed upstream of permanent filters while units are operating.
4. Replace temporary and permanent filters used during construction when dirty. After end of temporary use, replace permanent filters with new, clean filters before beginning testing, adjusting, and balancing.

C. Comply with SMACNA 008, "IAQ Guidelines for Occupied Buildings under Construction," for procedures to protect HVAC system.

3.13 DEMONSTRATION

A. Engage air-handling unit manufacturer employed training instructor or factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain air-handling units.

B. Training shall include, but not be limited to, procedures and schedules related to performance, safety, startup and shut down, troubleshooting, servicing, preventive maintenance, and how to obtain replacement parts.

1. Access Doors: Adjustment, gasket removal and replacement, handle removal and replacement, and spare parts.

2. Access Panels: Removal and replacement, adjustment, gasket removal and replacement, and spare parts.
3. Air Blenders: Cleaning, operation, removal, and replacement.
4. Coils: Cleaning, combing fins, draining, venting, removal, and replacement.
5. Controls: Calibration, cleaning, operation, service, removal and replacement, and spare parts.
6. Damper Assemblies: Cleaning, operation, service, removal and replacement, and spare parts.
7. Drain Pans: Cleaning, removal, and replacement.
8. Fan and Motor Assemblies: Cleaning, operation, removal and replacement, service, and spare parts.
9. Filters: Operation, removal and replacement, frame gasket removal and replacement, clip removal and replacement, and spare parts.
10. Lights, Receptacles, and Switches: Cleaning, operation, service, removal and replacement, and spare parts.

C. Instructor:

1. Instructor shall be factory trained and certified by air-handling unit manufacturer with current training on equipment installed.
2. Instructor's credentials shall be submitted for review by Owner before scheduling training.
3. Instructor(s) primary job responsibility shall be Owner training.
4. Instructor(s) shall have not less than three years of training experience with air-handling unit manufacturer and past training experience on at least three projects of comparable size and complexity.

D. Schedule and Duration:

1. Schedule training with Owner at least 20 business days before first training session.
2. Training shall occur before Owner occupancy.
3. Training shall be held at mutually agreed date and time during normal business hours.
4. Each training day shall not exceed eight hours of training. Daily training schedule shall allow time for a one -hour lunch period and 15 -minute break after every two hours of training.
5. Perform not less than 16 hours of training.

E. Location: Owner to provide a suitable on-site location to host classroom training.

F. Training Attendees: Assume three people.

G. Training Attendance Records: For record purposes, document training attendees at start of each new training session. Record date, time, brief description of training covered during the session, attendee's name, signature, phone number, and e-mail address. Submit scanned copy of sign-in sheet to Owner for each training session.

H. Training Format: Individual training modules to include classroom training followed by hands-on field demonstration and training.

I. Training Materials: Provide training materials in electronic format to each attendee.

1. Include instructional videos showing general operation and maintenance that are coordinated with operation and maintenance manuals.

J. Training Video Recording: Video record each classroom training session and submit an electronic copy to Owner before requesting Owner acceptance of training.

K. Written Acceptance: Obtain Owner written acceptance that training is complete and requirements indicated have been satisfied.

END OF SECTION

SECTION 237343.19 - OUTDOOR, CUSTOM AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Outdoor, custom air-handling units.

1.2 ACTION SUBMITTALS

A. Product Data: For each outdoor, custom air-handling unit.

1. Product information organized to show compliance with each performance requirement of "Performance Requirements" article.
2. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
3. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
4. Include unit dimensions and weight.
5. Include cabinet material, metal thickness, finishes, insulation, and accessories.
6. Fans:

    a. Include certified fan-performance curves with system operating conditions indicated. For fans operating at variable speeds include curves in 10 percent speed increments starting at design speed down to minimum speed.
    b. Include fan-sound power ratings in all eight octave bands. Include inlet or outlet sound power levels to coincide with sound requirements indicated on Drawings.
    c. Include fan construction and accessories. Submit sufficient information to show product compliance with requirements indicated.
    d. Include dimensions and weight.
    e. Include motor ratings, electrical characteristics, and motor accessories.

7. Vibration isolation product data with performance ratings. Uniquely identify and include information for each different isolator type and indicate for each air-handling unit where each isolator type is being used.
8. Include certified coil-performance ratings with system operating conditions indicated. Product data to include: dimensions, dry and operating weight, volume of fluid contained, materials of construction, and performance ratings with system operating conditions indicated.
9. Casing insulation product data and performance ratings.
10. Access door and access panel product data and performance ratings.
11. Roofing product data and performance ratings.
12. Louver product data and performance ratings.
13. Paint product data and performance ratings.
14. Electrical product data and performance ratings.

15. Metal grating product data and performance ratings.
16. Dampers product data, including housings, linkages, and operators with performance ratings.
17. Filters product data with performance characteristics.
18. Air blender product data with dimensions, weights, materials of construction, performance ratings, and installation requirements.
19. Hydronic pipe, valves, fittings, vents, strainers, and hydronic accessories product data.
20. Pipe insulation and jacket product data.
21. Roof curbs product data.

B. Shop Drawings: For each type and configuration of indoor, custom air-handling unit.

1. Prepared by manufacturer's factory employees with review and sign-off by those individuals responsible for manufacturing the air-handling units.
2. Include plans, elevations, sections, and attachment details. For air-handling units consisting of multiple levels, create drawings for each level showing interrelationship of levels superimposed.
3. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, methods of field assembly, components, and location and size of each field connection.
4. Detail fabrication and assembly of indoor, custom air-handling units, as well as procedures and diagrams.
5. Indicate details of construction with materials description including applicable specified standards and material grades in sufficient detail for reviewers to evaluate point by point compliance with requirements indicated for each air-handling unit.
6. Use actual dimensions of internal equipment in preparing Shop Drawings. Identify mechanical equipment shown on Shop Drawings with equipment designations on Drawings.
7. Thickness and finish of all casing materials with cross references indicated where each is used. Uniquely identify and include information for each different casing construction.
8. Details for each unique casing joint and reinforcing. Indicate wall joints, wall to floor joints, wall to roof joints, floor joints, and roof joints.
9. Roofing details.
10. Assembly details of base and casing for units consisting of multiple sections requiring field assembly.
11. Sizes and dimensioned locations of field connections for ductwork, piping, electrical, and controls.
12. Base and casing penetration and sealing details for factory-installed conduit.
13. Base and casing penetration and sealing details for factory-installed piping including coils.
14. Details of casing connections to field-installed ductwork.
15. Size, shape and layout of base members including localized support of internal components.
16. Base materials, thickness, finishes, lifting provisions, and mounting requirements. Uniquely identify and include information for each different base construction. Clearly indicate for each air-handling unit.
17. Recommended points of field attachment with dimensioned locations.
18. Size and location of each access door, including clearing opening size, with door swing indicated.
19. Size and location of each access panel with service equipment superimposed to show relationship of panel to internal equipment.

20. Drain pans and associated piping, with sizes and locations dimensioned, including relationship to internal equipment.
21. Floor drains and associated piping, with sizes and locations dimensioned, including relation to internal equipment.
22. Coil framework and support including enlarged details showing framework attachment to air-handling unit base, coil attachment to framework, and means for individual coil removal.
23. Mounting details of all internal components, such as fans, filters, and dampers.
24. Hoist rails layout for internal equipment showing size of members, attachments to structure, and serviced equipment superimposed to indicate relationships.
25. Size and location of catwalks, handrails, ladders, and safety cages including construction details and details of attachment to air-handling unit base.
26. Location of receptacles, service lights, and switches.
27. Location of motor controllers and disconnect switches.
28. Size and location of junction boxes used for interface with field electrical power.
29. Point-to-point electrical power wiring diagrams including wire size, conduit size, motor controllers sizes, switch types and ratings, receptacle types and ratings, service light fixture types and ratings.
30. Point-to-point control wiring diagrams including cable types and sizes, conduit sizes, and connected control devices.
31. Point-to-point control tubing diagrams including tubing types and sizes, conduit sizes, and connection controls devices.
32. Control panel drawings drawn to scale showing detailed internal layout.
33. Plans, sections and isometric reviews of hydronic piping systems showing pipe, fittings, flanges, unions, valves, vents, strainers, accessories, specialties and insulation.
34. Indicate code, operating, and maintenance clearances drawn to scale using dashed lines.
35. Indicate weights of internal components, weight of each separately shipped section, and air-handling unit total weight.

C. Comparison Schedule:

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

1.3 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans, sections, and other details, or BIM model, drawn to scale, showing the items described in this Section and coordinated with all building trades.

B. Source quality-control reports.

C. Startup service reports.

D. Field quality-control reports.

1.4 CLOSEOUT SUBMITTALS

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

1.5 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Panel Filters: One set(s) for each air-handling unit.
2. Access Door Gaskets: One set(s) for each access door.
3. Fan Belts: One set(s) for each fan with belt-drive assembly.

B. Tool Kit: Manufacturer to provide a tool kit including special tools required for air-handling unit service. See "Accessories" Article for additional requirements.

1.6 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided.

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

1.7 FACTORY VISITS FOR PRODUCT INSPECTION

A. While units are being manufactured, and during factory normal working hours, allow escorted access to manufacturing facility for Owner to verify product compliance with requirements indicated.

B. Manufacturer shall provide Owner with written notice at least 30 business days before units go into assembly.

C. Inspection visits shall be scheduled with manufacturer at least 10 business days before visit.

D. Personnel making visits for purposes of product inspection shall comply with manufacturer requirements for visitors.

1.8 DELIVERY, STORAGE, HANDLING

A. Deliver air-handling units with factory-installed shipping skids and lifting lugs; pack small components in factory-fabricated protective containers. Cover units with heat-shrinkable plastic sheeting suitable for shipping from point of manufacture to Project.

B. Handle air-handling units carefully to avoid damage to components, casing, and finish. Do not install damaged components; replace and return damaged components to air-handling unit manufacturer.

C. Store air-handling units in a clean dry place and protect them from weather and construction activities.

D. Keep air-handling units fully covered and protected during construction. Remove dirt and debris and clean units to a factory-cleaned condition.

E. Comply with manufacturer's written rigging and installation instructions for unloading air-handling units and moving them to their final locations.

F. For air-handling units equipped with key locks on access doors, keep doors locked during construction.

1. If access is required within air-handling units, only open the doors to sections that require access and lock doors at the end of each work shift.
2. Protect inside of air-handling units from damage and keep inside of units as clean as the factory-cleaned condition.
3. Report observed abuse to Ownerfor immediate corrective action.

1.9 WARRANTY

A. Warranty: Manufacturer agrees to repair or replace components of air-handling units that fails in materials or workmanship within specified warranty period.

1. Warranty Period: Two year(s) from date of Substantial Completion.

B. Extended warranties include, but are not limited to, the following:

1. Complete Air-Handling Unit: Two years from date of Substantial Completion for entire air-handling unit and longer where indicated for individual components.
2. Air-Handling Unit Casing: 25 years from date of Substantial Completion.
3. Air-Handling Unit Roofing: 25 years from date of Substantial Completion.
4. Motors: Five years from date of Substantial Completion

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and application.

B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handing units and components.

C. ASHRAE 62.1 Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

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

E. Casing Structural Performance:

1. Floor: Capable of withstanding positive/negative 8 inches wg of internal static pressure, without exceeding a deflection of L/300 of span.
2. Walls and Roof: Capable of withstanding positive/negative 8 inches wg of internal static pressure, without exceeding a midpoint deflection of L/200 of span.

F. Casing Leakage Performance, ASHRAE 111: Class 3 leakage or better at plus or minus 8 inches wg.

G. Casing Thermal Performance:

1. Surface Condensation: Air-handling manufacturer shall evaluate potential for condensation and design and manufacture entire unit casing to prevent condensation at most extreme operating conditions encountered.
2. Thermal Break: Incorporate a thermal break at each through metal path to prevent condensation from occurring on interior and exterior of casing.
3. U-Value: Overall U-value or equivalent R-value of casing shall not exceed governing codes and ASHRAE/IES 90.1 while considering the effects of metal-to-metal contact and thermal bridging in calculations.

H. Air Tunnel Aerodynamic Performance: Position air-handling unit internal components and transition between internal components to maintain uniform airflow; minimize sound levels and energy consumption. Use methods indicated and other means to ensure compliance.

1. Use turning vanes if necessary to direct the air path.

    a. Design, manufacture, and install vanes in accordance with applicable requirements in ASHRAE and SMACNA guidelines, handbooks, and standards.
    b. Install vanes firmly in place so that no vane movement occurs at worst-case airflow capacity possible.

2. Use fan inlet and discharge transitions and other devices to maximize system regain and minimize airborne sound levels.
3. Center system components such as coils, fans, and filters, vertically and horizontally, in the airstream.
4. Maintain spacing between components such that airflow patterns to adjacent components are as uniform as possible and that component "dead spots" or "jetted areas" are avoided.
5. Design and install internal structural supports, piping, and conduit that do not block airflow and impede performance of coils, fans, filters, and other unit components, and service space clearances.

I. Durability Performance: Design and manufacture air-handling units with underlying requirement to provide a highly durable piece of equipment.

1. Unit Life Expectancy: 25 years.
2. Supporting Documentation: Submit documentation showing proposed products to consider and include design features, components, and materials to satisfy requirement.

J. Extreme Operating Conditions:

1. Corrosive Environments: Air-handling unit manufacturer shall evaluate the quality and potential corrosiveness of air passing through air-handling units and propose additional protective finishes and better-quality materials of a heavier thickness if required to comply with requirements indicated.

    a. Unless otherwise indicated, air-handling units for HVAC applications may use up to 100 percent of outdoor air or a mix of outdoor air with return air from habitable areas served.

2. Humidity and Temperatures: Materials and components of air-handling units shall be suitable for use in low and high humidity and temperature extremes when operating under normal and abnormal conditions without permanent degradation or loss in material performance.

K. Outdoor Environment:

1. Air-handling units specially designed to withstand effects of wind, rain, ice, snow, seismic, air quality, sun, and other influences associated with outdoor installations.
2. Comply with requirements of air-handling unit and governing codes.

L. Safety:

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

M. Serviceability:

1. Hoisting Provisions: Fans and motors weighing more than 200 lb shall have full-length hoist rails mounted over the equipment to facilitate service, removal, and replacement.
2. Mounting Location: Install internal components in readily accessible locations to facilitate ease of service and replacement.
3. Service Access:

    a. Internal components shall be serviceable through access sections with doors indicated on Drawings.
    b. Internal components shall be removable and replaceable through access doors or panels.
    c. Review requirements for access doors and panels indicated and recommend additional access doors and panels if required for uninhabited service, removal, and replacement of components.

4. Tripping Hazards: Floors in accessible sections of air-handling unit shall be free of standing seams, reinforcing, supports, or section splits located in the walking path that is capable of causing a tripping hazard. Locate section splits immediately adjacent to internal walls.

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

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

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

2.2 CAPACITIES AND CHARACTERISTICS

A. See equipment schedules on Drawings.

2.3 SOURCE LIMITATIONS

A. Source all outdoor and indoor custom air-handling units from same manufacturer.

B. Like components furnished with air-handling units shall be from same manufacturer.

C. Air-handling units shall be manufactured in United States.

2.4 OUTDOOR, CUSTOM AIR-HANDLING UNITS

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

~~1. Air Enterprises, LLC.~~
~~2. Buffalo Air Handling.~~
3. Climate Craft.
~~4. Engineered Air.~~
~~5. Environmental Air Systems.~~
~~6. Haakon Industries.~~
~~7. HUNTAIR; A Nortek Air Solutions Company.~~
8. Temtrol; A Nortek Air Solutions Company.
~~9. Trane; An Ingersoll Rand Company.~~

B. Unit Arrangement and Configuration:

1. Arrangement: Project-specific arrangement and configuration of air-handling units indicated on Drawings. Do not deviate from requirements indicated without submitting a formal request clearly describing each deviation and reason for each deviation, and only after receiving Architect's written acceptance.
2. Mounting Requirements: Indicated on Drawings.

3. Multiple Sections: Each air-handling unit shall consist of multiple sections for field assembly to comply with requirements indicated on Drawings.

C. Air-Handling Unit Base:

1. Performance:

   a. Air-handling unit manufacturer shall design and assemble air-handing unit casing and internal components for attachment and support by air-handling unit structural base.
   b. Design air-handling units to be lifted from only the air-handling unit structural base and not the casing.
   c. Support air-handling units from only the perimeter base unless otherwise indicated on Drawings.
   d. Air-handling unit manufacturer to size and locate intermediate structural base supports as required to comply with structural performance indicated for air-handling unit floors.
   e. Level base before factory assembly of air-handling unit casing and internal components to ensure proper fit and alignment.

2. Structural Member Size:

   a. Air-handling unit manufacturer shall select size of base members and construction of base to withstand the rigors of loading, unloading, shipping, and rigging without damage to air-handling unit components or misalignment of factory-assembled components.
   b. Depth and weight of structural members shall be selected by air-handling unit manufacturer to comply with performance requirements indicated.
   c. Depth of perimeter base members is not less than 8 inches deep.

3. Structural Member Spacing: Positioned as required to comply with requirements indicated, but not to exceed 24 inches.
4. Welding Procedures:

   a. Structural Welding Codes: AWS D1.1/D1.1M for carbon steel.
   b. Join structural members to one another using continuous welds.
   c. After welding and fabrication, deburr and grind exposed welds to provide smooth surfaces free of sharp edges.

5. Penetrations through Base Perimeter: Seal weld pipe, tubing, and conduit penetrations through base perimeter members to provide a watertight assembly.
6. Section Joints: Air-handling units consisting of multiple sections for field assembly shall be joined with structural joining plates.

   a. Joining plate material type to match base.
   b. Joining plate of thickness required to join sections without resulting in a permanent deflection, minimum 1/2 inch thick.
   c. Continuously weld joining plates to each mating end of base.
   d. Joining plates shall not extend beyond outer edge of adjoining base.
   e. Plates to include at least three equally spaced holes for field connection using factory-furnished threaded hardware of a nominal diameter of at least 1/2 inch.

7. Lifting Provisions: Air-handling unit manufacturer to design and install lifting lugs of size and location required to comply with performance requirements indicated. Lifting lugs extending beyond the base shall be easily removable in the field after unit is installed.
8. Curb Cap:

    a. For air-handling units installed on a continuous perimeter curb, provide air-handling unit base with a continuous structural angle counterflashing.
    b. Angle shall extend down vertical face of curb to completely cover wood nailer.
    c. Coordinate inside dimension of angle counterflashing with curb dimension and roofing. Provide adequate clearance between angle counterflashing and roofing over curb.

D. Unit Casings:

1. Casing Assembly:

    a. Appearance:

        1) Exposed exterior surfaces of casing shall have a neat and finished appearance free of standing seams, exposed reinforcing, and other casing protrusions more than 0.25 inch beyond the exterior skin surface.
        2) Interior surfaces of casing shall have a neat and finished appearance free of standing seams, exposed reinforcing, and other casing protrusions more than 0.25 inch beyond the skin surface.

    b. Dissimilar Metals: Isolate dissimilar metals that are in contact to prevent galvanic action and corrosion.
    c. Framing and Supports: Interconnect and support individual casing wall and roof panels using either formed panel construction or framed construction with structural support members. For framed casing construction, materials used to construct casing of structural support members shall be as follows:

        1) Casings with Aluminum Outer and Inner Skins: Aluminum extrusions in accordance with ASTM B211 Alloy 6063 T6.
        2) Casings with Galvanized-Steel Outer and Inner Skins: Galvanized steel.
        3) Casings with Galvanized-Steel Outer Skin and Aluminum or Stainless Steel Inner Skins: Stainless steel.
        4) Casings with Stainless Steel Outer and Inner Skins: Stainless steel.

    d. Seals: Seal interior and exterior joints and seams to make casing air- and watertight. Trim factory-applied sealant flush with adjacent surface.
    e. Double-Wall Casings: Consisting of insulation sandwiched between an outer and inner metal wall. Use double-wall casings to construct air-handling units unless septum casings are required.
    f. Septum Casings: Triple-wall construction consisting of a solid metal inner wall sandwiched between insulation layers that are covered with metal walls. Use septum casings for applications having performance requirements that are not achievable with double-wall casings.
    g. Wall and Roof Penetrations: Seal voids around conduit, piping, and tubing penetrations.

1) Conduit, Pipe, and Tube: Sizes NPS 3 and smaller:

a) Seal void through casing with a nonhardening vapor-barrier caulk covered by an escutcheon on both interior and exterior sides of casing. Back caulk using formed insulation within a sheet metal sleeve.
b) Seal void using a friction fit neoprene or EPDM sheet material attached to casing using a bed of adhesive.
c) Cover penetration and sealing sheet material with metal escutcheon matching adjacent casing material.

2) Larger Conduit, Pipe, and Tube Sizes: Seal annular void using an adjustable compression-type sealing sleeve.

h. Floors: Route conduit, pipe, and tube within a floor-mounted pipe sleeve.

1) Sleeve:

a) Fabricate sleeve of aluminum, galvanized-steel, or stainless steel pipe.
b) Extend top of sleeve above adjacent floor surface to prevent standing water on floor from entering annular space of sleeve.
c) Seal weld sleeve to top of floor for an air- and watertight seal.
d) Seal annular void of sleeve using an adjustable compression seal .

i. Floor Openings with Metal Grating:

1) Factory install walk-on safety gratings over any floor opening large enough to create a safety hazard for operators including, but not be limited to, supply-, return-, and exhaust-air openings.
2) Bar Grating:

a) Materials: Use stainless steel grating for aluminum stainless steel grating for stainless steel hot-dip galvanized-steel grating for galvanized-steel painted steel grating for painted steel floors.
b) Air-handling unit manufacturer shall select depth and thickness of grating bars to limit deflection to 1/360 of span when subjected to a dynamic load of not less than 500 lb.
c) Industry-standard welded grating with bars at least 1-1/2 inches deep by at least 3/16 inch thick with nominal 1-3/16-inch main bar spacing and 4-inch cross bar spacing.
d) Source: Product manufacturer specializing in metal gratings.
e) Grating bearing surface shall extend beyond clear opening in floor at least 2 inches.

3) Mounting Frame:

a) Mount grating in a continuous structural angle or bar frame so no ends of grating bars are exposed. Top of frame to be flush with top of grating.

b) Secure grating to frame with threaded hardware so grating does not move when walked on but can be easily removed from top to gain access behind grating.
c) Continuously weld mounting frame to air-handling unit floor.
d) For applications with automatic dampers installed at floor openings, elevate height of mounting frame and grating to enclose entire damper assembly including jackshaft so walk-on surface of grating is above damper assembly.

j. Waterproof Floors: Continuously weld floor joints, seams, and penetrations to completely seal floor. Roll all edges of floor up at least 1 inch to create a shallow tub capable of holding standing water.
k. Duct Connections - Direct to Casing: Frame and reinforce unit casing around perimeter of unit duct openings to accommodate direct attachment of field-installed ductwork. Coordinate requirements with Installer to accommodate field connection.

2. Materials for Outer Skin of Casing Walls and Roofs:

a. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating; minimum (nominal) 16 gauge thick.

3. Materials for Inner Skin of Casing Walls and Roofs:

a. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating, minimum (nominal) 18 gauge thick.

4. Materials for Floor Walking Surface:

a. Aluminum Diamond Treadplate: ASTM B632/B632M, Alloy 6061 T6; mill finish; minimum (nominal) 0.125 inch thick.

5. Materials for Internal Walls:

a. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating; minimum (nominal) 16 gauge thick.

6. Surfaces in Contact with Airstream:

a. Comply with ASHRAE 62.1 and NFPA 90A.
b. Glass or mineral-fiber insulation installed behind perforated metal shall be encapsulated to prevent insulation fibers from entering the airstream by using a polymer sheet material.

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

a. Materials Not Exposed to Airstream: Injected or sprayed polyurethane foam insulation with a minimum nominal density of 3 lb/cu. ft..
b. R-Value: Minimum R-10.
c. Insulation shall completely fill the casing cavity so no voids exist.

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

    a. Materials Exposed to Airstream: Glass or mineral-fiber board insulation with a minimum density of 3 lb/cu. ft..
    b. R-Value: Minimum R-10.
    c. Insulation shall completely fill the casing cavity so no voids exist.

9. Insulation for Casing Floors:

    a. Materials: Injected or sprayed polyurethane foam insulation with a minimum nominal density of 3 lb/cu. ft..
    b. R-Value: Minimum R-10.
    c. Insulation shall completely fill the casing cavity so no voids exist.

10. Access Doors:

    a. Application: Install access doors in air-handling units at locations indicated on Drawings.
    b. Adjustment: Design doors for field adjustment capable of maintaining specified leakage rate.
    c. Mounting Height: Install bottom of door frame within 2 inches of air-handling unit floor walking surface. Where internal conditions require access doors to be mounted higher above air-handling unit floor, include permanent retractable stairs inside and outside of air-handling unit to limit stair risers to 6 inches.
    d. Performance: Leakage as required to satisfy overall unit leakage performance indicated, but not more than 1.0 cfm per door when tested at 10 inches wg.
    e. Fabrication: Formed and reinforced, constructed of same materials and thicknesses as casing. Where doors are installed in casing walls with perforated interior, install doors with solid interior.
    f. Swing: Arrange doors to be opened against pressure, unless otherwise indicated on Drawings.
    g. Frame: Extruded aluminum with thermal break with welded mitered corners.
    h. Handles:

        1) Secure door closed using not less than two roller-style latches with handles located at quarter points along door height.
        2) If three latches with handles are included, install one at midpoint of door height and equally space others.
        3) Air-handling unit manufacturer has option to use a multipoint latching mechanism that is operable from a single door handle located at midpoint of door height, but secures door to frame at top, bottom, and handle location.
        4) Include door handles on outside and inside of door to allow operator access to open and close door from outside and inside of unit.
        5) Field adjustable to accommodate changes to fit and gasket compression.
        6) Durable product capable of withstanding repeated opening and closing of door while operating under design pressure without damage.

    i. Hinges: Minimum of two hinges.
    j. Gasket:

1) Design: Specially formed with an internal air chamber specifically designed to seal on two surfaces without taking a permanent set.
2) Dual Gaskets: Primary and secondary gasket.
3) Location: Install gaskets around entire perimeter of doors or frames.
4) Material: EPDM, neoprene, or santoprene.
5) Protection: Seat gasket in a protective metal ribbed chamber integral to door or door frame to protect gasket from damage by operator incidental contact.
6) Service: Field replaceable.
7) Adhesive-backed tape-type gaskets adhered to a single flat surface are unacceptable.

k. Size of Door Frame Clear Opening: Large enough to allow for unobstructed access for inspection and maintenance of air-handling unit's internal components.

1) Width: At least 24 inches clear inside of door frame.
2) Height: Full clear height of unit casing up to a maximum height of 72 inches clear inside of door frame.
3) Door sizes indicated on Drawings.

l. Safety Latches and Stops:

1) Safety Latches: Install safety latch with retainers on outward swing doors that do not open against pressure to allow restricted travel for purpose of pressure relief and so that doors do not open uncontrollably due to inside pressure.
2) Stops: Install cushioned door stops on inward swinging doors where necessary to limit door travel that could potentially damage the door or internal components.

m. Tie-Backs: Install tie-backs with retainers on outward-swinging access doors to hold doors in an open position during service.

n. Locks: Include each access door with an integral key lock. Pad locks are unacceptable.

1) Incorporate key lock into door handle where feature is available.
2) A common key shall be used to lock and unlock access doors of all air-handling unit(s).
3) Include two keys for each air-handling unit.
4) Lock access doors at factory to ensure that unauthorized access is in place before air-handling unit packaging and shipment.

o. Windows:

1) Construction: Fabricate windows with frame mounted in access doors of double-glazed safety glass with an airspace between panes and interior and exterior seals.
2) Condensation Control: Install desiccant material in airspace between panes if necessary to prevent condensation from forming on glazing.
3) Clear Viewing Size: Minimum 6 inches, square or round.

4) Mounting Location: Center window in door width. For doors up to 60 inches high, locate top of window 6 inches below top of door. For taller doors, locate center of windows at optimal viewing height, approximately 60 inches above floor adjacent to unit.
5) Application: Install windows in all access doors .

p. Nameplates:

1) On each access door, include a nameplate defining the access to service within. Nameplates shall be included for, but not be limited to, the following:

a) Dampers.
b) Filters.
c) Cooling coils.
d) Heating coils.
e) Supply fans.
f) Return fans.
g) Air-handling unit designation.
h) Where door access is to multiple components, list all components accessed. For example: Filter/Cooling Coil.
i) For each door that does not open against static pressure, include a warning sign stating: "DANGER: DOOR UNDER PRESSURE. DO NOT OPEN WITH FAN ON."

2) Lettering Size and Style: At least 1-inch- high, block style.
3) Material: Lettering engraved in black plastic on a white plastic back. Engraving shall penetrate through black plastic so lettering reads white.
4) Attachment: Attach nameplates to door using high-strength bonding cement and stainless steel screws.
5) Mounting Location:

a) For access doors without windows, locate top of nameplate 6 inches from top of door and center in door width.
b) For access doors with windows, locate nameplate directly below window frame and center in door width.
c) Align nameplates of all doors for uniform placement.

11. Access Panels:

a. Performance: Leakage as required to satisfy overall unit leakage performance indicated.
b. Fabrication: Formed and reinforced panels of same material and thickness as casing.
c. Fasteners: Adjustable, reusable type for multiple operations without degradation due to reuse. Do not use screws capable of stripping.
d. Arrangement: Panels removable from exterior side of casing.
e. Gasket: EPDM, neoprene, or santoprene similar to access doors, applied around entire perimeter of panels or frames.
f. Location and Size:

1) Coils: Oversized access panel to allow removal and replacement without impacting adjacent casing.
2) Electric Heaters: Oversized access panel to allow removal and replacement without impacting adjacent casing.
3) Fans: Oversized access panel to allow removal and replacement of entire fan assembly including base without impacting adjacent casing.

12. Standing-Seam Metal Roof: Construct air-handling unit roof casing with standing seams designed for waterproof roofing applications.

a. Construct air-handling unit roof using same materials and finish as walls.
b. Slope roof away from primary access side of unit at not less than 1 percent.
c. For air-handling units shipped in multiple sections, include standing-seam joiners at each split with adhesive, hardware, and cover strips for field joining by Installer.

13. Piping Enclosures:

a. Description: Integral accessible enclosure(s) to house field-installed piping from below and connecting to hydronic and steam coils and steam humidifiers.
b. Size: Adequate clearance for field installation of piping, valves, accessories, and associated insulation.

1) Maintain at least 6 inches of clearance between inside of enclosure and face of pipe insulation at most restricted point.

c. Construction:

1) Base, Walls, and Roof: Match air-handling unit.
2) Floor: Not required, open to below.
3) Access Doors:

a) Size for full front access to piping, valves, and accessories installed within enclosure.
b) Double-door applications with removable center mullions for unrestricted access.

d. Electrical: Factory install and wire service light with switch for each enclosure.

E. Wall Louvers:

1. Wall Louvers, Drainable Blade:

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

1) Greenheck Fan Corporation.
2) Pottorff.
3) Ruskin; Air Distribution Technologies, Inc.; Johnson Controls, Inc.

b. Source Limitations: Obtain louvers from single source from single manufacturer.

c. Performance:

1) Air Pressure Drop, Design: Less than 0.1 inch wg at airflow indicated on Drawings.
2) Air Pressure Drop, Rating: Less than 0.1 inch wg at free area intake face velocity of 700 fpm.
3) Face Velocity: If louver size is not indicated on Drawings, size louver for 500-fpm velocity across louver free area.
4) Free Area: 54 percent or more for a 48-by-48-inch representative sample.
5) AMCA 500-L: Beginning point of water penetration at 870 fpm.

d. Features:

1) Depth: 4 inches.
2) Frame: 0.080 inch thick, ASTM B211, Grade 6063, T5 temper, extruded-aluminum alloy.
3) Blades: 0.080 inch thick, ASTM B211, Grade 6063, T5 temper, extruded-aluminum alloy; stationary in horizontal position, drainable.
4) Stationary vertically positioned blades.
5) Bird Screen: 0.5-by-0.040-inch expanded flattened aluminum attached to back of louver.
6) Finish: Match exterior casing.

e. Air-Handling Unit Factory Assembly:

1) Install louver face flush with exterior of casing and seal to provide a weathertight installation.
2) Secure louver in casing and include additional bracing if required to handle loading of extreme outdoor environmental performance indicated.

f. Application: Factory install louvers in air-handling casing at locations indicated on Drawings.

F. Internal Structural Supports:

1. General:

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

2. Structural Member Size and Spacing:

a. Size: Air-handling unit manufacturer shall select size of members and construction to do the following:

1) Withstand the rigors of loading, unloading, shipping and rigging without damage to air-handling unit components or misalignment of factory-assembled casing and components.
2) Comply with performance requirements indicated.

b. Spacing: Positioned as required to comply with requirements.

3. Materials: Structural aluminum, ASTM B209, Alloy 6061 T6 .

a. Structural Supports: Angle or tube shapes selected by air-handling unit manufacturer for application.
b. Hoist Beams for Internal Components (Spanning Full Width of Unit): I or W beam shapes.

G. Factory-Manufactured Roof Curbs:

1. General:

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

2. Size:

a. Size curb to provide continuous support of unit base and to fit within footprint of unit perimeter base.
b. Height:

1) See Drawings.

3. Materials:

a. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating; minimum (nominal) 12 gauge thick. Treat welded areas to protect against corrosion with a zinc-rich coating.

4. Insulation:

a. Insulate curb to provide thermal performance equal to unit casing.
b. Completely encapsulate insulation within metal curb.

5. Gaskets:

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

H. Centrifugal Fan Arrays:

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

    a. ebm-papst Inc.
    b. Greenheck Fan Corporation.
    c. Lau Fan.
    d. Loren Cook Company.
    e. Rosenberg USA, Inc.
    f. Twin City Fan & Blower.
    g. ZIEHL-ABEGG Inc.

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

    a. Air-handling unit manufacturer shall account for, and include in, submitted fan selections any static pressure drops associated with unit, and system effect due to fan operating in the air-handling unit.

        1) Add additional static pressure to fan scheduled total static pressure.
        2) If fan motor horsepower is increased, notify Architect.

    b. Fans shall have sharply rising pressure characteristics at operating point and stable in operation. Fan horsepower characteristics shall be self-limiting and non-loading.
    c. Fan speed, brake horsepower, and sound power levels indicated are maximum acceptable.
    d. Scheduled motor horsepower, airflow rate, and static pressure are minimum acceptable. Motor horsepower shall be capable of handling maximum horsepower of fan at scheduled speed.
    e. At a minimum, fans shall have AMCA class indicated on Drawings.

        1) Fan operating limits shall be in accordance with AMCA 99 for AMCA class indicated.
        2) If AMCA class is not indicated, use AMCA 99 as basis for determining AMCA class.

3) AMCA class selected shall be capable of accommodating a plus 10 percent increase to fan static pressure indicated on Drawings.

f. Motor starting torque shall exceed fan speed-torque requirements.
g. Airflow Profile:

1) Fan arrangement within fan array shall produce a uniform airflow and velocity profile across air-handling unit air tunnel when measured 12 inches upstream of fan inlet and 48 inches downstream of fan inlet.

4. Vibration Balance:

a. Each fan/motor assembly shall be factory balanced to AMCA 204, BV-5, Balance Quality Grade G1.0 or better through entire operating speed range from minimum speed to maximum speed. If minimum speed is not indicated on Drawings, assume minimum speed to be 10 percent of design speed.
b. Identify and record each speed and speed range within the fan operating range that could cause potential vibration problems.
c. Submit test reports as an informational submittal for Project record.

5. Vibration Isolation: Install vibration isolation on each fan/motor assembly in the fan array, except vibration isolation may be omitted on fans/motor assemblies balanced to AMCA 204, BV-5, with a maximum residual imbalance of 0.22-in./s peak, filter in.
6. Operation and Service Requirements:

a. Remaining fans in array shall continue to operate with one or multiple failed fans.
b. Each fan/motor assembly of fan array shall be capable of lock-out/tag-out procedure without interrupting operation of other fans in the array.
c. Each fan/motor assembly shall be controlled through a variable-frequency controller, except for fans with electronically commutated (EC) motors having integral motor controls.

1) Include a dedicated variable-frequency controller for each fan/motor assembly in the fan array.
2) If fan array is served from a single variable-frequency controller, include a redundant variable-frequency controller with automatic switchover in event of primary variable-frequency controller failure.

d. A single mechanical, electrical, and control device failure shall not result in a fan array available capacity of less than 33 percent of air-handling unit total scheduled airflow capacity.
e. Fan wheel/motor assembly shall pass through the air-handling unit access door servicing fans. Entire individual fan assembly shall pass through the door to the room where air-handling unit is located.
f. Design and incorporate features to permit safe, rapid, and economical maintenance.

7. Airflow Measurement, Local Indication, and Remote Monitoring:

a. Each fan within fan array shall include airflow measurement indication in cfm.
b. Include airflow totalization of all operating fans in fan array.

c. Airflow measurement instrumentation shall not restrict or deflect air travel through fan and shall not impact fan air and sound performance.
d. Include digital display of individual fan airflow and total fan array airflow on face of fan control panel.
e. Include a 4- to 20-mAoutput signal for remote monitoring of total fan array airflow.

8. Fan Array Local Control:

a. Include fan control panel with operator interface to control fan array locally through the fan control panel and to switch to control of fan array through a remote-control source.
b. Local control shall include on/off operation and speed adjustment for entire fan array and each individual fan/motor in fan array.

9. Fan Array Remote Control:

a. Include fan control panel with control interface for remote control.
b. Fan array on/off operation shall be remotely controlled through a single hardwired digital output signal.
c. Fan array speed shall be remotely controlled through a single hardwired analog (4- to 20-mA) output signal.

10. Fan Base, Stackable Fan Units:

a. Mount fan/motor on aluminum base.
b. Include base and vibration isolators in accordance with requirements indicated.
c. Weld structural members to form a rigid base.
d. Size and design the base construction to withstand the rigors of shipping and rigging.
e. Include the base with lifting lugs or holes.

11. Fan Frame:

a. Construct frame of aluminum.
b. Reinforce and brace frame to prevent excessive deflection and pulsation.
c. Include stiffeners to form a rigid frame that is free of structural resonance and vibration.

12. Fan Panel:

a. Construct fan panel of continuously welded aluminum .
b. Reinforce and brace fan panel to prevent excessive deflection and pulsation.
c. Include stiffeners to form a rigid panel that is free of structural resonance and vibration.

13. Fan Inlet Cone:

a. Include a precision-spun or die-formed, matched inlet and wheel cone to ensure streamlined airflow into the wheel and full loading of fan blades.
b. Inlet cone shall be a smooth hyperbolic shape.

c. Inlet cone shall be a single piece, constructed of aluminum or powder-coated steel.
d. Fasten inlet cone to fan panel using bolts, nuts, and washers to provide a positive and secure attachment that can be field removable.

14. Fan Wheel:

a. Fan blades shall be a true hollow airfoil shape, welded to backplate and wheel cone.
b. Construct blades of aluminum, reinforced for AMCA fan class.
c. Design blades to provide smooth airflow over all surfaces of blade.
d. Construct fan hubs of aluminum with integral bracing for extra strength and stiffness.

1) Castings shall be sound and free of shrink holes, blow holes, cracks, scale, blisters, or other similar injurious defects.
2) Clean surfaces of castings by blasting, pickling, or any other standard method.
3) Mold-parting fins and remains of gates and risers shall be chipped, filed, and ground flush.
4) Design hubs to maintain a high resistance to fatigue and low relative wheel imbalance.

e. Hubs shall be keyed and setscrewed to motor shaft for positive attachment.
f. Construct wheel backplates of aluminum.
g. Select entire rotating assembly so first critical speed is at least 30 percent greater than fan design speed and at least 20 percent greater than maximum speed in AMCA fan class.

15. Fan Drive:

a. Direct drive, arrangement 4 in accordance with AMCA 99.
b. Adjust wheel width and diameter to match motor speed while providing performance scheduled.
c. Fasten fan wheel directly to motor shaft using a key in motor shaft and setscrew.
d. Construct motor base and pedestal supports of galvanized steel orpowder-coated steel.
e. Fan Speed Limitation:

1) Fan speed at design conditions indicated shall not exceed speed on motor nameplate.
2) Do not select fans to operate at motor speeds greater than motor nameplate.

16. Fan Motors: See "Fan Motors" Article for ac motors.

17. Fan Enclosure:

a. Include each fan in fan array with integral single-wall enclosure constructed of solid aluminum sheet.
b. Enclosure shall not increase fan array length beyond size indicated on Drawings.
c. Enclosure shall not add static pressure loss.

d. Enclosure shall provide a physical separation between operating adjacent fans to prevent negative performance.

18. Backdraft Damper:

    a. Include each fan in the fan array with a backdraft damper at the fan inlet to prevent air circulation through a fan that is not operating.
    b. Open backdraft damper when fan is operating and close when fan is not operating.
    c. Design backdraft damper assembly to operate with little to no static pressure loss with fan operating throughout entire operating range from design to minimum airflow.

        1) Add damper pressure loss shall to fan scheduled total static pressure.
        2) If pressure loss requires a change field electrical power, air-handling unit manufacturer shall be responsible for associated cost of change.

    d. Fasten backdraft damper assembly to fan panel or enclosure using hardware designed for easy removal by maintenance personnel.
    e. Dampers shall not create measurable additional noise above the sound level of fan.
    f. Dampers shall not vibrate or rattle.
    g. Construct dampers of extruded aluminum, stainless steel, or powder-coated steel.

19. Hardware: Hex-head, high-strength carbon steel with corrosion-resistant coating .
20. Nameplates:

    a. Construct nameplates and rotation arrows of aluminum or 300 series stainless steel.
    b. Securely fasten nameplate and rotation arrow to fan housing using pins or sheet metal screws.
    c. Locate nameplates in a highly visible location on motor side of fan.
    d. Provide the following information on nameplate: Engraved .

        1) Manufacturer, address, phone number, and website address.
        2) Manufacturer model number.
        3) Serial number.
        4) Manufacturing date.
        5) Fan size.
        6) Fan schedule equipment designation (may be listed on a separate nameplate if there is insufficient space).
        7) Design airflow.
        8) Design static pressure.
        9) Design fan speed.
        10) AMCA fan class.

21. Air-Handling Unit Factory Assembly:

    a. Internal Access: Include each fan with internal access from downstream sides as indicated on Drawings.
    b. Removal and Replacement: Each fan wheel and motor shall be independently removable and replaceable through a removable access door installed in air-handling unit casing.
    c. Stackable Fan Arrays: Construct frame work from aluminum or stainless steel.

d. Panel-Mounted Fan Array Supports:

1) Construct a freestanding and self-supporting structural framework to support each fan individually from and independent of adjacent fans.

I. Fan Motors:

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

a. Baldor Electric Company.
b. Emerson Electric Company.
c. Regal Beloit (Genteq).
d. Siemens Industry, Inc., Building Technologies Division.
e. Toshiba International Corporation.
f. US Motors; Nidec Motor Corporation; Nidec Corporation.

2. Source Limitations: Obtain motors from single source from single manufacturer.
3. Standard: Comply with NEMA MG 1 unless more stringent requirements are indicated.
4. Description: NEMA MG 1, Design B, as required to comply with capacity and torque characteristics; medium-induction motor.

a. Performance:

1) 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) Efficiency: NEMA Premium Efficiency rating complying with NEMA MG 1.
3) Motor Horsepower: Minimum size as indicated on Drawings. Motor shall operate fan under all conditions indicated without exceeding motor nameplate and without use of motor service factor.
4) Inverter-Duty Rating: Comply with minimum requirements of Class F or Class H insulation, suitable for "inverter-duty" or "drive-duty" applications in accordance with NEMA MG 1. Motor operation through a variable-frequency controller shall not adversely affect the motor performance, operation, useful life, and warranty.
5) Service Factor: 1.15.
6) Temperature Rise: Match insulation rating.

5. Enclosure Type: See Drawings for motor enclosure type.
6. Shaft Grounding System:

a. Shaft grounding system to protect bearings from induced voltage.
b. Shaft grounding system shall have low drag (less than 0.05 percent of motor horsepower), and shall operate for a minimum of three years without periodic maintenance or adjustments.
c. Mounting: External or internal to motor enclosure.

7. Frame:

    a. Frames with integrally cast feet unless other requirements of driven equipment require a different arrangement.
    b. Frame, front and back end brackets, and front and back end bearing intercaps constructed of cast iron, ASTM A48/A48M, Class 25 or better.

8. Rotor:

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

9. Stator:

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

10. Shaft:

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

11. Bearings:

    a. Grease-lubricated ball or roller bearings.
    b. ABMA 11 L-10 motor bearing life of 100,000 hours.
    c. Bearing Lubrication:

        1) Factory lubricate motor bearings using a premium moisture-resistant polyurea thickened grease with rust inhibitors suitable for extreme operating temperatures encountered.
        2) Coordinate special requirements that may impact lubrication and include appropriate lubrication.

12. Grease Fittings:

    a. Equip each bearing housing with an easily accessible grease inlet.
    b. Fit grease inlets with a grease fitting and protective fitting cap.
    c. Equip inlets with an automatic grease relief fitting to prevent excessive greasing.
    d. Equip each bearing housing with grease drain and threaded plug.

13. Conduit Box:

    a. Material same as frame.

b. For motor frames 365T and below, furnish conduit boxes sized with internal volumes in accordance with NEMA MG 1.
c. For motor frames larger than 365T, furnish conduit boxes one size larger than NEMA MG 1.
d. Coordinate the location and mounting of conduit box with driven equipment manufacturer.
e. Factory mount conduit box on motor.

14. Grounding: NRTL-listed clamp-type grounding lug mounted in conduit box.
15. Motor Leads:

a. Non-wicking type, Class F temperature rating or better and permanently numbered over entire length for identification.
b. Lead terminals shall be manufacturer's standard.

16. Condensate Drains:

a. Motor with drain holes at the lowest point for drainage of condensate.
b. Each drain hole with a threaded removable plug.

17. Hardware: Hex-head, high-strength, zinc-plated carbon steel or stainless steel.
18. Lifting Eyebolts: Eyebolt threaded into frame receptacle and design to prevent moisture and other foreign material from entering motor cavity when eyebolt is removed.
19. Nameplates:

a. Construct nameplates of aluminum or stainless steel and attach to motor frame with aluminum, stainless steel, or brass drive pins.
b. Engrave or stamp data on the nameplate.
c. At a minimum, include nameplate data in accordance with NEMA MG 1. Also include ABMA bearing designation for the drive and opposite end bearing.

J. Vibration Isolation:

1. General:

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

2. Spring Isolators:

a. Performance:

1) Deflection: Minimum deflection indicated on Drawings. Use a greater deflection if required to maintain an isolator efficiency of at least 98 percent under all operating conditions encountered. Calculate isolator efficiency using actual support conditions considering the rigidity of structure.
2) Laterally stable freestanding open-spring mounting.
3) Spring diameter not less than 0.8 of compressed spring height at rated load and in the installed and operating condition.

4) Reserve travel to solid shall be equal to a minimum of 50 percent of rated deflection and in no case less than 25 percent of rated deflection in an installed and operating condition.
5) Ratio of horizontal stiffness to vertical stiffness equal to approximately one.
6) Design and install so that ends of springs remain parallel.
7) Select springs that are non-resonant with equipment related frequencies and natural frequencies of support structure.
8) Springs shall not take a permanent set when compressed to coil bind.
9) Seismic restraints to limit motion under seismic forces to 1/4 inch.

b. Construction:

1) Coat springs with PVC or neoprene. Color-code springs to allow positive identification after installation.
2) Construct baseplates, spring retainers, and other components of aluminumor stainless steel. Etch and paint aluminum components.
3) Use nuts, bolts, and washers and other associated hardware constructed of stainless steel.
4) Isolators with integral leveling bolts.
5) Baseplates with holes and isolation grommets for bolting.
6) Bond nominal 1/4-inch- thick, neoprene friction pad to baseplate.

3. Thrust Restraints:

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

4. Elastomeric Grommets:

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

5. Flexible Connections:

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

6. Air-Handling Unit Factory Assembly:

a. Use precompression -type height-saving brackets with isolators having 2-1/2 inch deflection or greater, to limit exposed bolt length.
b. Install spring isolators plumb and adjust isolators that are not plumb under operating conditions to make plumb.

c. Adjust isolators to prevent stress transfer to equipment.
d. Verify that installed isolators and mounting systems permit equipment motion in all directions.
e. Restraint fans with isolated thrust resistors to limit displacement to 1/4 inch. Design for the maximum lateral thrust the fan can develop.
f. Adjust or include additional resilient restraints to flexibly limit fan lateral motion to 1/4 inch during startup and operation of equipment.
g. Anchor restraints to fixed supports having a stiffness greater than the thrust encountered.
h. Include at least 2-inch operating clearance between fan bases and walking surface of air-handling unit floor. Before startup, clean out foreign matter between bases and equipment to prevent short circuit.
i. Flexible Connections:

1) Install flexible connections at connections to fans.
2) Install flexible connections in accordance with SMACNA standards and manufacturer's written instructions.
3) Make fabric joints on the flat run, not the corners, with overlap to provide an area sufficient to make a positive seal.
4) Apply adhesive between fabric layers.
5) Attach connections using screws or bolts.
6) Reinforce fabric if required to keep fabric from collapsing and impacting airflow into fan.

K. Hydronic Coils:

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

a. Aerofin.
b. Coilmaster Corporation.
c. Modine Manufacturing Company.
d. Super Radiator Coils.

2. Sourcing Option: In lieu of sourcing hydronic coils from a specialty coil manufacturer, air-handling unit manufacturer has option to furnish in-house hydronic coils that achieve equal or better performance while complying with other requirements indicated.
3. General: Provide air-handling units with hydronic coils where indicated on Drawings.
4. Description: Plate fin coils constructed of staggered tubes mechanically expanded into continuous collars that are die formed into plate fins.
5. Design and Performance:

a. Capacities, face area, and number of rows indicated on Drawings are minimum acceptable.
b. Air pressure drop, water pressure drop, fin spacing, and face velocity indicated on Drawings are the maximum acceptable.
c. Coils shall be counterflow design, air to fluid. Fluid supply shall enter air leaving side of coil and exit air entering side.
d. Design coils to be drainable.

1) Coils shall have all circuits drainable when coils are installed in horizontal position and level.
2) Coil supply and return header shall be furnished with a drain connection at lowest point on header.

e. Design coils to be self-venting.

1) Supply connection near bottom of supply header.
2) Return connection near top of return header.
3) Furnish coil return and supply header with a vent connection at highest point on header.

f. Coils supply and return piping connections on same end of coil.
g. Coils shall be rated for system operating pressures and temperatures encountered by installation, but not less than 200 psig.
h. Coil selection criteria, unless otherwise indicated on Drawings, are as follows:

1) Face Velocity: Maximum of 500 fpm.
2) Fluid Tube Velocity (at Design Flow Rate):

a) Maximum: 6 fps.
b) Minimum: 3 fps.

3) Fluid Header Velocity: Maximum of 6 fps.

a) Fin Height: Maximum of 48 inches.
b) Fin Spacing: Maximum of 12 fins per inch.

i. Cooling coils shall have no moisture carryover at design conditions. Install moisture eliminators on discharge face of coil if it is necessary to eliminate moisture carryover.

6. Casing and Tube Sheets:

a. Depth: Extend coil casing and tube sheets a minimum of 1/2 inch beyond face of fins on both entering and leaving side.
b. Casing and Tube Sheet Materials:

1) Cooling Coils: Stainless steel, ASTM A240/A240M or ASTM A480/A480M, Type 304L, No. 2D finish.
2) Heating Coils:

a) Stainless steel, ASTM A240/A240M or ASTM A480/A480M, Type 304L, No. 2D finish.

c. Top and Bottom Casings:

1) Flange face minimum of 1-1/2 inches; double flange edge for rigidity and ease of removal with secondary flange face minimum of 1/2 inch.
2) Thickness:

a) Coils with Fin Length of up to 72 Inches: Minimum of 16 gauge thick.
b) Coils with Fin Length Exceeding 72 Inches: Minimum of 14 gauge thick.

d. End Tube Sheets:

1) Tube sheet holes rolled to prevent chaffing of tubes during thermal expansion and contraction.
2) Flange face minimum of 1-1/2 inches.
3) Thickness: Minimum of 14 gauge thick.

e. Intermediate Tube Sheets:

1) Tube sheet holes rolled to prevent chaffing of tubes during thermal expansion and contraction.
2) Space intermediate tube sheets a maximum of 48 inches o.c. and locate to provide equal spacing between tube sheet across coil tube length.
3) Flange face minimum of 1/2 inch.
4) Thickness: Minimum of 16 gauge thick.

f. Holes: Include number, size, and location of holes in casing and end tube sheets required for coil installation.

7. Fins:

a. Materials:

1) Aluminum: 0.0075 inch thick.

b. Collars: Full collars for accurate fin spacing and maximum tube contact while leaving no surface of tube exposed.
c. Fin Configuration: Flat face fins without ripples.

8. Headers:

a. Construct header of seamless copper, ASTM B75/B75M drawn temper of diameter and wall thickness based on coil size, flow rate, design pressure, design temperature, and circuiting.
b. Tube-to Header Connections: Tube-to-header holes shall intrude inward so landed surface area is three times the core tube thickness, to provide enhanced header to tube joint integrity. Tubes shall evenly extend within the ID of the header no more than 0.12 inch.
c. Header Top and Bottom Caps: End caps shall be die-formed and installed on the ID of header such that the landed surface area is three times the header wall thickness.
d. Drains: Include low point of supply and return header with a NPS 1/2 drain connection. Extend copper or carbon steel pipe through air-handling unit casing and terminate end with male national pipe threads (MNPT). Pipe shall be threaded on both ends to facilitate easy field removal and replacement.

e. Vents: Include high point of supply and return header with a NPS 1/2 vent connection. Extend copper or carbon steel pipe through air-handling unit casing and terminate end with MNPT. Pipe shall be threaded on both ends to facilitate easy field removal and replacement.
f. Supply and Return Connections:

1) Terminate ends with MNPT.
2) Connections to header shall be either copper tube with brazed ASME B16.18 threaded male adapters or carbon steel pipe with machine-threaded MNPT connections. Pipe shall extend through air-handling unit casing and be threaded on both ends to facilitate easy field removal and replacement.
3) Connections NPS 2-1/2 and larger shall have a bronze ASME 16.24 threaded flanges attached to threaded connections to provide for a flanged field connection. Select flange class, Class 150 or Class 300, for system pressure and temperature encountered.

g. Protect openings of supply, return, vent, and drain connections with a threaded cap to prevent entry of dirt into the coil.

9. Tubes:

a. Material: Copper, ASTM B75/B75M annealed temper or ASTM B280 drawn temper; .
b. Tube Nominal Diameter: 1/2 or 5/8 inch before expanding, selected to provide performance indicated.
c. Tube Nominal Wall Thickness: As required by performance, minimum of 0.025 inch thick.

10. Tube Return Bends: 180-degree bends brazed to tubes; material, wall thickness, and nominal diameter to match tubes.

a. Tube Return Bend Nominal Wall Thickness: As required by performance, minimum of 0.025 inch thick.

11. Brazing: High-temperature brazing alloy with not less than 5 percent silver when brazing like non-ferrous materials together and more than 30 percent silver when brazing ferrous to non-ferrous materials.
12. Hardware: Use hex-head bolts, nuts, and washers constructed of Type 304 stainless steel.
13. Nameplate: Aluminum or stainless steel nameplate with brass or stainless steel chain for each coil, with the following data engraved or embossed:

a. Manufacturer name, address, telephone number, and website address.
b. Manufacturer model number.
c. Serial number.
d. Manufacturing date.
e. Coil identification (indicated on Drawings).
f. Coil fin length.
g. Coil fin height.
h. Coil weight with fluid/without fluid.
i. Coil casing material and thickness.
j. Coil fin material and thickness.

k. Coil tube material and thickness.
l. Coil header material and thickness.

14. Cleaning: Residual manufacturing oils and solid contaminants shall be removed internally and externally by completely submersing the coil in an environmentally acceptable degreasing solution that is chemically compatible with the coil material.
15. Air-Handling Unit Factory Assembly:

a. Coil Connections: Extend each coil connection through casing access panel and terminate connections, approximately 4 inches beyond exterior face of access panel, and seal each penetration as indicated. Casing access panels shall be removed and reinstalled with coils installed inside air-handling units.
b. Internal Access: Include each coil with internal access from downstream andupstream sides as indicated on Drawings.
c. Removal and Replacement: Each coil shall be independently removable and replaceable through a removable access panel installed in air-handling unit casing.
d. Supports for Coils:

1) Construct a freestanding and self-supporting structural framework to support each coil individually from and independent of adjacent coils.
2) Construct framework for cooling coils, from aluminum or stainless steel structural shapes.
3) Construct frame work for heating coils from aluminum, galvanized steel,or stainless steel structural shapes.

L. Drain Pans:

1. General:

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

2. Bottom Drain Pans:

a. Mounting Location, Recessed in Floor: Air-handling unit manufacturer has option to recess bottom drain pan into the floor or install drain pan above air-handling unit floor walking surface.
b. Grating: Install removable stainless steel grating on top of drain pan.
c. Material: Type 304L stainless steel ASTM A240/A240M or ASTM A480/A480M, a minimum of 16 gauge thick.
d. Minimum Depth: 1.5 inches.
e. Extend drain pan beyond air leaving face of coil casing at least 12 inches.

1) Where moisture eliminators are required to prevent moisture carryover, extend drain pan beyond leaving face of moisture eliminator in lieu of the leaving face of coil.

f. Drain Pan Connection:

1) Stainless steel threaded half-coupling welded to lowest point of drain pan.
2) Location: See Drawings.
3) Minimum Nominal Connection Size: NPS 1.

g. Drain Pipe:

1) Air-handling unit manufacturer to connect full size drain pipe to each drain pan connection. Option to use one of following pipe materials:

a) Copper tube with threaded male adapter, brazed or soldered to ends.

M. Pleated Panel Filters:

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

a. AAF International.
b. Camfil Farr Inc.
c. Flanders Corporation.
d. Koch Filter Corporation.

2. Source Limitations: Obtain filters from single source from single manufacturer.
3. Description: Factory-fabricated, self-supported, extended-surface, pleated, panel-type, disposable air filters.
4. Performance:

a. Filtration Efficiency, ASHRAE 52.2 MERV Rating: See Drawings.
b. Energy Cost Index: Five star rating.
c. Initial Air Pressure Drop: With face velocity of 500 fpm, clean filter pressure drop shall not exceed the following:

1) Depth 2 Inches: 0.30 inch wg.
2) Depth 4 Inches: 0.27 inch wg.

d. Manufacturer-Recommended Final Air Pressure Drop: 1.0 inch wg.
e. Pressure Differential without Failure: 2 inches wg.
f. Temperature Rating: 200 deg F.

5. Certification:

a. AHRI: Tolerances in accordance with AHRI 850 (I-P) and AHRI 851 (SI).
b. ASHRAE: Tested and rated in accordance with ASHRAE 52.2.
c. UL: UL 900 listed.

6. Size:

    a. Nominal Filter Size:

        1) Face: 24 by 24 inches.
        2) Depth: 2 inches.

    b. Actual Filter Size: Suitable for installation in an industry-standard filter holding frame.

7. Filter Media Surface Area: Each filter shall contain the following minimum media surface area for a filter with a nominal 24-by-24-inch face:

    a. Depth 2 Inches: 17.3 sq. ft..

8. Construction:

    a. Media: Glass or synthetic blend of fibers arranged in a series of pleats attached to and supported by a corrosion-resistant welded-wire grid.
    b. Filter Media Casing: High wet strength (28-point) beverage board that is bonded around the periphery to eliminate air bypass.

        1) Diagonal support members across upstream and downstream filter face constructed of same material as casing shall ensure pleat spacing and stability.

    c. Adhesive: Fire-retardant bonding adhesive where bonding media to casing.

N. ASHRAE-Rated Filter Holding Frames:

1. Filter Holding Frames for ASHRAE-Rated Filters:

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

2. Air-Handling Unit Factory Installation:

    a. Air-handling unit manufacturer shall furnish filters and provide filter holding frames, retaining clips, and filter support structures.
    b. Furnish filter quantity, size, type, and performance indicated on Drawings.

c. Install filter frames in a flat vertical position for horizontal airflow.
d. Install holding frames in accordance with manufacturer's written instructions and to prevent passage of unfiltered air. Include additional gaskets as necessary.
e. Secure individual holding frames together to build a multiple filter bank.
f. Construct galvanized-steel or stainless steel support structure to hold frames and filters.

1) Design support structure for maximum system operating pressures encountered equal to fan shutoff pressure.
2) Design and fabricate support structure to limit deflection across filter bank to 1/360 of the span when subjected to a 200-lb lateral force applied at any point on the filter holding frame assembly.

O. Filter Gauges:

1. Provide a gauge to indicate pressure differential between entering and leaving side of each filter bank. Panel filter bank separate from cartridge filter bank.

a. Where multiple filters share a common frame, include a separate gauge for each filter bank.
b. Include a metal spacer constructed of same material as filter frame for one of the filters installed in filter bank to accommodate pressure differential measure across both upstream and downstream filters.

2. Gauge shall have a nominal 4-inch- diameter face.
3. Select range of gauge to be approximately twice the dirty filter pressure drop.
4. Provide each gauge with vent valves to allow for re-zeroing the gauge without removing tubing connections.
5. Include static pressure sensors on entering and leaving side of each filter bank.
6. Air-Handling Unit Factory Assembly:

a. Mount each filter gauge on exterior surface of unit casing near associated filter sections.
b. Mount center of gauges 60 inches above bottom of air-handling unit structural base.
c. Connect static pressure sensors to filter gauges using stainless steel tubing and compression type fittings.
d. Support tubing at intervals not greater than 60 inches o.c.

P. Automatic Dampers:

1. General: Provide air-handling units with automatic dampers where indicated on Drawings.

a. Unless otherwise indicated, use parallel-blade configuration for two-position control, for equipment isolation service, and when mixing two airstreams. For other applications, use opposed-blade configuration.
b. Factory assemble multiple damper sections to provide a single damper assembly of size required by application.

c. Damper actuator shall be factory installed by damper manufacturer as integral part of damper assembly. Coordinate actuator location and mounting requirements with damper manufacturer.

2. Rectangular Dampers with Aluminum Blades:

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

1) American Warming and Ventilating (AWV); Mestek, Inc.
2) Greenheck Fan Corporation.
3) Ruskin; Air Distribution Technologies, Inc.; Johnson Controls, Inc.
4) TAMCO (T. A. Morrison & Co. Inc.).

b. Source Limitations: Obtain dampers from single source from single manufacturer.
c. Performance:

1) Leakage: AMCA 511, Class 1A. Leakage shall not exceed 3 cfm/sq. ft. against 1-inch wg differential static pressure.
2) Pressure Drop: 0.05 inch wg at 1500 fpm across a 24-by-24-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
3) Velocity: Up to 4000 fpm.
4) Temperature: Minus 40 to plus 185 deg F.
5) Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.
6) Damper shall have AMCA seal for both air leakage and air performance.

d. Construction:

1) Frame:

a) Material: ASTM B211, Alloy 6063 T5 extruded-aluminum profiles, 0.07 inch thick.
b) Hat-shaped channel with integral flange(s). Flange mating face shall be a minimum of 1 inch.
c) Width not less than 5 inches.

2) Blades:

a) Hollow, airfoil, extruded aluminum.
b) Parallel- or opposed-blade configuration as required by application.
c) Material: ASTM B211, Alloy 6063 T5 aluminum, 0.07 inch thick.
d) Width not to exceed 6 inches.
e) Length as required by close-off pressure, not to exceed 48 inches.

3) Seals:

a) Blades: Replaceable, mechanically attached extruded silicone, vinyl, or plastic composite.
b) Jambs: Stainless steel, compression type.

4) Axles: 0.5-inch- diameter, stainless steel, mechanically attached to blades.
5) Bearings:

a) Molded synthetic or stainless steel sleeve mounted in frame.
b) Where blade axles are installed in vertical position, include thrust bearings.

6) Linkage:

a) Concealed in frame.
b) Constructed of aluminum and stainless steel.
c) Hardware: Stainless steel.

3. Damper Actuators:

a. General:

1) Actuators shall operate related damper(s) with sufficient reserve power to provide smooth modulating action or two-position action and proper speed of response at velocity and pressure conditions to which damper is subjected.
2) Actuators shall produce sufficient power and torque to close off against the maximum system pressures encountered. Actuators shall be sized to close off against the fan shutoff pressure as a minimum requirement.
3) Total damper area operated by an actuator shall not exceed 80 percent of manufacturer's maximum area rating.
4) Include one actuator for each damper assembly where possible. Multiple actuators required to drive a single damper assembly shall operate in unison.
5) Avoid use of excessively oversized actuators, which could overdrive and cause linkage failure when the damper blade has reached either its full open or closed position.
6) Use jackshafts and shaft couplings in lieu of blade-to-blade linkages when driving axially aligned damper sections.
7) Include mounting hardware and linkages for connecting actuator to damper.
8) Select actuators to fail in desired position in the event of a power failure.
9) Actuator Fail Positions: As indicated below:

a) Exhaust Air: Close.
b) Outdoor Air: Close.
c) Supply Air: Open.
d) Return Air: Open.

b. Type: Motor operated, with or without gears, electric and electronic.
c. Voltage:

1) Voltage selection is delegated to professional designing control system.
2) Actuator shall deliver torque required for continuous uniform movement of controlled device from limit to limit when operated at rated voltage.
3) Actuator shall function properly within a range of 85 to 120 percent of nameplate voltage.

d. Construction:

1) Less Than 100 W: Fiber or reinforced nylon gears with steel shaft, copper alloy or nylon bearings, and pressed steel enclosures.
2) 100 up to 400 W: Gears ground steel, oil immersed, shaft-hardened steel running in bronze, copper alloy, or ball bearings. Operator and gear trains shall be totally enclosed in dustproof cast-iron, cast-steel, or cast-aluminum housing.
3) Greater Than 400 W: Totally enclosed reversible induction motors with auxiliary hand crank and permanently lubricated bearings.

e. Field Adjustment:

1) Spring return actuators shall be easily switchable from fail open to fail closed in the field without replacement.
2) Provide gear-type actuators with an external manual adjustment mechanism to allow manual positioning of the damper when actuator is not powered.

f. Two-Position Actuators: Single direction, spring return, or reversing type.
g. Modulating Actuators:

1) Capable of stopping at all points across full range, and starting in either direction from any point in range.
2) Control Input Signal:

a) Proportional: Actuator drives proportional to input signal and modulates throughout its angle of rotation. Suitable for 0- to 10-V dc and 4- to 20-mA signals.
b) Pulse-Width Modulation (PWM): Actuator drives to a specified position in accordance with a pulse duration (length) of signal from a dry-contact closure, triac sink, or source controller.
c) Programmable Multifunction:
d) Control input, position feedback, and running time shall be factory or field programmable.
e) Diagnostic feedback of hunting or oscillation, mechanical overload, mechanical travel, and mechanical load limit.
f) Service data, including at a minimum, number of hours powered, and number of hours in motion.

h. Position Feedback:

1) Equip two-position actuators with limits switches or other positive means of a position indication signal for remote monitoring of open and close position.
2) Include a position indicator and graduated scale on each actuator indicating open and closed travel limits.

i. Fail-Safe:

1) Where indicated, provide actuator to fail to an end position.

2) Internal spring return mechanism to drive-controlled device to an end position (open or close) on loss of power.
3) Batteries, capacitors, and other non-mechanical forms of fail-safe operation are acceptable only where uniquely indicated.

j. Integral Overload Protection:

1) Provide against overload throughout the entire operating range in both directions.
2) Electronic overload, digital rotation sensing circuitry, mechanical end switches, or magnetic clutches are acceptable methods of protection.

k. Damper Attachment:

1) Unless otherwise required for damper interface, provide actuator designed to be directly coupled to damper shaft without need for connecting linkages.
2) Attach actuator to damper drive shaft in a way that ensures maximum transfer of power and torque without slippage.
3) Bolt and setscrew method of attachment is acceptable only if included with at least two points of attachment.

l. Temperature and Humidity:

1) Temperature: Suitable for operating temperature range encountered by application with minimum operating temperature range of minus 20 to plus 120 deg F.
2) Humidity: Suitable for humidity range encountered by application; minimum operating range shall be from 5 to 95 percent relative humidity, noncondensing.

m. Enclosure:

1) Suitable for ambient conditions encountered by application.
2) Provide actuator enclosure with a heater and controller where required by application.
3) NEMA 250, Type 2 for all applications except exterior applications.
4) NEMA 250, Type 4 or Type 4X for exterior applications.

n. Stroke Time: Select operating speed to be compatible with equipment and system operation.

1) Operate damper from fully closed to fully open within 60 seconds.
2) Actuators operating in smoke-control systems shall comply with governing code and NFPA requirements.

o. Sound:

1) Spring Return: 62 dBA.
2) Non-Spring Return: 45 dBA.

Q. Manual Balancing Dampers:

1. General: Air-handling unit manufacturer shall furnish and factory install manual balancing dampers inside air-handling units where indicated on Drawings.
2. Rectangular Manual Balancing Dampers with Aluminum Airfoil Blades:

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

        1) Greenheck Fan Corporation.
        2) Ruskin; Air Distribution Technologies, Inc.; Johnson Controls, Inc.
        3) TAMCO (T. A. Morrison & Co. Inc.).

    b. Source Limitations: Obtain dampers from single source from single manufacturer.
    c. Performance:

        1) Leakage: AMCA 511, Class 1A. Leakage shall not exceed 3 cfm/sq. ft. against 1-inch wg differential static pressure.
        2) Pressure Drop: 0.05 inch wg at 1500 fpm across a 24-by-24-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
        3) Velocity: Up to 6000 fpm.
        4) Temperature: Minus 40 to plus 185 deg F.
        5) Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.
        6) Damper shall have AMCA seal for both air leakage and air performance.

    d. Construction:

        1) Frame:

            a) Material: ASTM B211, Alloy 6063 T5 extruded-aluminum profiles, 0.07 inch thick.
            b) Hat-shaped channel with integral flange(s). Flange mating face shall be a minimum of 1 inch.
            c) Width not less than 5 inches.

        2) Blades:

            a) Hollow, airfoil, extruded aluminum.
            b) Parallel- or opposed-blade configuration as required by application.
            c) Material: ASTM B211, Alloy 6063 T5 aluminum, 0.07 inch thick.
            d) Width not to exceed 6 inches.
            e) Length as required by close-off pressure, not to exceed 48 inches.

        3) Seals:

            a) Blades: Replaceable, mechanically attached extruded silicone, vinyl, or plastic composite.
            b) Jambs: Stainless steel, compression type.

        4) Axles: 0.5-inch- diameter stainless steel, mechanically attached to blades.
        5) Bearings:

a) Molded synthetic or stainless steel sleeve mounted in frame.
b) Where blade axles are installed in vertical position, include thrust bearings.

6) Linkage:

a) Concealed in frame.
b) Constructed of aluminum and stainless steel.
c) Hardware: Stainless steel.

7) Locking Regulator:

a) Aluminum or stainless steel standoff with locking regulator mounted to frame in an accessible location for manual adjustment of damper blades.

8) Additional Corrosion Protection for Corrosive Environments:

a) Provide anodized finish for aluminum surfaces in contact with airstream. Anodized finish shall be a minimum of 0.0007 inch thick.
b) Axles, damper linkage, and hardware shall be constructed of Type 316L stainless steel.

R. Drains:

1. Floor Drains:

a. Drain Body: Fabricate floor drain body of NPS 4 or larger aluminum or stainless pipe and weld a plate of same material to the bottom. Option to fabricate an aluminum or stainless steel rectangular box drain at least 4 by 4 inches of material at least 0.1 inch thick.
b. Drain Connection: Weld a nominal NPS 2 half coupling in side of drain body located within 1 inch from bottom.
c. Drain Cover: Perforated plate, at least 0.1 inch thick, or grating, fabricated from aluminum or stainless steel. Drain cover shall be supported and secured in place by drain body, but not fastened to drain body with fasteners.
d. Fluid Seal: Weld floor drain body to air-handling unit floor for a watertight installation.
e. Mounting: Recess floor drain body into structural base. Top of floor drain to be slightly recessed below air-handling unit finished floor for unobstructed gravity flow from floor into drain.
f. Application:

1) Install floor drains in air-handling unit floors at locations indicated on Drawings.
2) Install floor drains in air-handling unit floors of all sections.
3) Install floor drains in air-handling unit floors of coil sections and associated access sections.

2. Field Power Junction Box: Factory-install junction box with internal wire terminal block mounted on air-handling unit casing exterior for interface of factory power wiring with field power wiring.
3. Interior Service Light Fixtures:

    a. LED Luminaires:

        1) Suitable for wet locations and operation in cold- and hot-temperature extremes encountered; dust and moisture resistant.
        2) High-impact, UV-stabilized fiberglass housing and acrylic lens.
        3) Light Color: 4000 K.
        4) Light Output: 3000 lumens.
        5) Driver: 1 percent dimming.

    b. Application:

        1) Provide one service light fixture in each accessible section of air-handling units.

4. Toggle Switches for Service Light Fixtures:

    a. Single-Pole Switches, 120/277 V, 20 A: Comply with UL 20 and FS W-S-896.
    b. Toggle Switch Box and Cover: Mount toggle switch in a metal outlet box with stainless steel cover. Weatherproof where exposed to outdoors.
    c. Application:

        1) Factory install switching configuration (single, three way, or four way) required to operate a single service light fixture or group of service light fixtures from any access door that opens to respective service light fixtures.
        2) Factory install a single service light switch to switch all service light fixtures from a single location.

5. Receptacles:

    a. Isolated-Ground Duplex Receptacles, 125 V, 20 A:

        1) Description: Straight blade; equipment grounding contacts shall be connected only to green grounding screw terminal of the device and with inherent electrical isolation from mounting strap. Isolation shall be integral to receptacle construction and not dependent on removable parts. Two pole, three wire, and self-grounding.
        2) Configuration: NEMA WD 6, Configuration 5-20R.
        3) Standards: Comply with UL 498 and FS W-C-596.

    b. Duplex GFCI Receptacles, 125 V, 20 A:

        1) Description: Integral GFCI with "Test" and "Reset" buttons and LED indicator light. Two pole, three wire, and self-grounding.
        2) Configuration: NEMA WD 6, Configuration 5-20R.
        3) Type: Non-feed through.
        4) Standards: Comply with UL 498, UL 943 Class A, and FS W-C-596.

c. Receptacle Box and Cover: Mount receptacle in a metal outlet box with cast-aluminum cover. Weatherproof where exposed to outdoors.
d. Applications: Factory install a receptacle in a convenient and field-accessible location on air-handling unit exterior of casing near access doors accessing fans.

S. Factory-Assembled Controls:

1. General:

a. Air-handling unit manufacturer shall furnish and factory install control instruments, control power circuit, control transformers, power supplies, wiring, tubing, raceways, and control panels.
b. Provide for a single-point field connection to 120 -V electrical power for all factory-installed controls. Terminate power connection with a toggle switch mounted in control panel.
c. Control panel shall serve as field tie-in point for all electric damper actuators, and control instruments located within air-handling unit. Controls for control dampers, control valves and instruments installed in ductwork and piping are not included as part of air-handling unit factory-installed controls.
d. Control instruments shall be installed in accordance with manufacturer's written instructions.
e. Control panel shall house flow, moisture, pressure and temperature transmitters, transformers, dc voltage power supplies, and wiring terminal strip.
f. Carbon dioxide transmitters shall be mounted on air-handling unit casing exterior with sensor port exposed to the airstream.

2. Pitot Tube Airflow Stations:

a. Fan Inlet Airflow Sensor (Piezometer Ring):

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

a) ebm-papst Inc.
b) Greenheck Fan Corporation.
c) Twin City Fan & Blower.

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

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

3. Thermal Airflow Measurement Stations:

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

1) Air Monitor; an ONICON Brand.
2) Ebtron, Inc.

b. Source Limitations: Obtain stations from single source from single manufacturer.
c. Description: Airflow station shall consist of one or more sensor probes and a remotely mounted microprocessor-based transmitter.
d. Performance:

1) Capable of independently processing up to 16 independently wired sensor assemblies.
2) Airflow rate of each sensor assembly shall be equally weighted and averaged by transmitter prior to output.
3) Temperature of each sensor assembly shall be velocity weighted and averaged by transmitter prior to output unless temperature sensor has an accuracy of 0.1 deg F.
4) Listed and labeled by an NRTL as successfully tested as an assembly in accordance with UL 873 or UL 60730.
5) Components shall be interconnected by exposed NRTL-listed plenum-rated cable or non-plenum-rated cable placed in conduit.
6) Each flow station shall be factory calibrated at a minimum of six airflow rates and three temperatures to standards that are traceable to NIST.
7) Individual Sensor Airflow Accuracy: Within 3 percent of reading over the entire operating airflow range.
8) Thermal Airflow Station Assembly Airflow Accuracy: Within 3 percent of reading over the entire operating airflow range.

a) Devices whose accuracy is combined accuracy of transmitter and sensor probes must demonstrate that total accuracy meets performance requirements throughout the measurement range.

9) Temperature Accuracy: Within 0.2 deg F over entire operating range of minus 20 to plus 140 deg F.
10) Sensor Ambient Operating Temperature Range: Minus 20 to plus 160 deg F.
11) Transmitter Ambient Operating Temperature Range: Minus 20 to plus 120 deg F.
12) Sensor and Transmitter Ambient Operating Humidity Range: Zero to 99 percent, noncondensing.
13) Instrument shall compensate for changes in air temperature and density throughout calibrated velocity range for seasonal extremes at Project location.
14) Pressure Drop: 0.05 inch wg at 2000 fpm across a 24-by-24-inch area.

15) Instruments mounted in throat or face of fan inlet cone shall not negatively influence fan performance by reducing flow more than 2 percent of Project design flow or negatively impact fan-generated sound. Losses in performance shall be documented with submittal data, and adjustments to compensate for performance impact shall be made to fan to deliver Project design airflow indicated.

e. Sensor Assemblies:

1) Each sensor probe shall contain two individually wired, hermetically sealed bead-in-glass thermistors.
2) Mount thermistors in sensor using a marine-grade, waterproof material.
3) Thermistor leads shall be protected and not exposed to environment.
4) Each sensor assembly shall independently determine airflow rate and temperature at each measurement point.
5) Each sensor probe shall have an integral cable for connection to remotely mounted transmitter.
6) Sensor Probe Material: Gold anodized, extruded Alloy 6063 aluminum tube or Type 304 stainless steel.
7) Probe Assembly Mounting Brackets Material: Type 304 stainless steel.

f. Transmitter:

1) Integral digital display capable of simultaneously displaying total airflow and average temperature, individual airflow, and temperature readings of each independent sensor assembly.
2) Capable of field configuration and diagnostics using an onboard push-button interface and digital display.

a) Include an integral power switch to operate on 24-V ac (isolation not required) and include the following:
b) Integral protection from transients and power surges.
c) Circuitry to ensure reset after power disruption, transients, and brownouts.
d) Integral transformer to convert field power source to operating voltage required by instrument.

g. Remote Signal Interface:

1) Linear Analog Signals for Airflow and Temperature: Fuse protected and isolated, field selectable,.

4. Flow Transmitters for Pitot Tube Sensors:

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

1) Air Monitor; an ONICON Brand.

b. Source Limitations: Obtain sensors from single source from single manufacturer.

c. Receives total and static pressure signals from a flow element, amplify, extract the square root, and scale the signal to produce a 4- to 20-mA dc output signal linear to airflow.
d. Housed in NEMA 250, Type 1 enclosure.
e. Assembly constructed so that shock, vibration, and pressures surges of up to 1 psig will neither harm transmitter nor affect its accuracy.
f. Provide transmitter with an automatic zeroing circuit capable of automatically readjusting transmitter zero at predetermined time intervals. Automatic zeroing circuit shall re-zero transmitter to within 0.1 percent of true zero.
g. Performance:

1) Range: At least 20 percent below minimum airflow and 20 percent greater than design airflow.
2) Calibrated Span: Field adjustable, minus 40 percent of the range.
3) Accuracy: Within 0.10 percent of natural span.
4) Repeatability: Within 0.15 percent of calibrated span.
5) Linearity: Within 0.2 percent of calibrated span.
6) Hysteresis and Deadband (Combined): Less than 0.2 percent of calibrated span.

h. Equip transmitter with an integral digital LED or LCD for continuous indication of airflow.
i. Install in control panel.

T. Hardware:

1. Screws:

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

2. Bolts, Nuts, and Washers:

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

U. Welding:

1. Welding Filler Metals: Comply with AWS welding codes for welding materials appropriate for thickness and chemical analysis of material being welded.

a. Use welding materials with corrosion properties equal to material being welded.

2. Use welders that are certified to weld at least twice the thickness of the material to be welded. Certification shall be within three months of work being performed.
3. Welds shall be continuous, full-penetration welds unless otherwise indicated. Intermittent welds, stitch welds and tack welds are permitted only in specific applications indicated.
4. Use welders and welding procedures complying with the following:

    a. Piping Systems: Section IX of the ASME Boiler and Pressure Vessel Code and Section V of ASME B31.1.
    b. Structural Aluminum: AWS D1.2/D1.2M.
    c. Structural Carbon Steel: AWS D1.1/D1.1M.
    d. Structural Stainless Steel: AWS D1.6/D1.6M.
    e. Sheetmetal: AWS D9.1/D9.1M.

V. Painting:

1. General:

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

2. Preparation:

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

3. Primer:

    a. Rust-inhibiting type, with a minimum dry film thickness of 2 mil(s) per coat.
    b. Apply at least two coats of primer to unfinished carbon steel surfaces and at least one coat of primer to other surfaces.
    c. Use primer that is compatible with substrate and finish coat.

4. Finish Coat:

    a. Finish coat painting system shall be epoxy.

b. Use dry film thickness recommended by paint manufacturer for each coat. Total dry film thickness of all finish coats not less than 5 mils.
c. Painted Surfaces Minimum Properties:

1) Salt Spray ASTM B117: 5 percent salt solution fog at 95 deg F for 2000 hours with no deterioration.
2) Adhesion, ASTM D3359: When the coating is cut into 0.0625-inch squares and 3M No. 600 tape is suddenly removed, there is no loss of adhesion.
3) Acid Resistance ASTM D3260: 15-minute exposure to 10 percent hydrochloric acid at room temperature with no effect.
4) Alkali Resistance ASTM D1647: 15-minute exposure to 10 percent sodium hydroxide at room temperature with no effect.
5) Humidity Resistance ASTM D2247: 850-hour exposure to 100 deg F and at least 95 percent relative humidity with no effect.
6) Pencil Hardness ASTM D3363: A hardness of 1H.

d. Finish coat color shall be selected by Architect and not be limited to manufacturer's standard offering.

1) Submit a written request for color selection and indicate in the request the date color selection must be returned without impacting schedule.

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

a. Unfinished carbon steel surfaces.
b. Exposed mill galvanized-steel surfaces of air-handling unit casing exterior.
c. Exposed aluminum surfaces of air-handling unit casing exterior.
d. Exposed stainless steel surfaces of air-handling unit casing exterior.

W. Accessories:

1. Tool Kit:

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

2.5 SOURCE QUALITY CONTROL

A. AHRI Compliance:

1. AHRI 260 (I-P): Air-handling unit sound ratings shall be in accordance with AHRI 260 (I-P), "Sound Rating of Ducted Air Moving and Conditioning Equipment."

2. AHRI 261 (SI): Air-handling unit sound ratings shall be in accordance with AHRI 261 (SI), "Sound Rating of Ducted Air Moving and Conditioning Equipment."
3. AHRI 410: Air-handling unit coils shall be rated in accordance with AHRI 410 and shall be listed by AHRI and labeled in accordance with AHRI.

B. AMCA Compliance:

1. AMCA 201: Air-handling unit manufacturer shall evaluate fan's performance within the air-handling unit in accordance with AMCA 201, "Fans and Systems" and account for conditions within the air-handling unit that could be detrimental to fan's performance by adjusting the fan performance indicated on Drawings.
2. AMCA 205 Certification: Air-handling unit fan's fan efficiency grade (FEG) shall be rated in accordance with AMCA 205, "Energy Efficiency Classifications for Fans" and shall bear the AMCA-certified fan efficiency grade seal.
3. AMCA 210 Certification: Air-handling unit fan's air performance shall be rated in accordance with AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating" and shall bear the AMCA-certified air ratings seal.
4. AMCA 300: Air-handling unit fan's sound performance shall be rated in accordance with AMCA 300, "Reverberant Room Method for Sound Testing of Fans."
5. AMCA 301 Certification: Air-handling unit fans sound performance shall be rated in accordance with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data" and shall bear the AMCA-certified sound ratings seal.
6. AMCA 500-D: Air-handling unit damper's performance shall be rated in accordance with AMCA 500-D, "Laboratory Methods of Testing Dampers for Rating" and shall bear the AMCA-certified air ratings seal.

C. NFPA Compliance:

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

D. UL Compliance:

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

2.6 SOURCE QUALITY CONTROL - INDEPENDENT LABORATORY TESTING

A. General:

1. Project-specific testing by an independent laboratory is not required if air-handling unit manufacturer has written independent laboratory test results of past tests performed on same casing construction proposed for use on this Project.

2. If Project-specific testing is required, testing shall be performed in ample time to include test reports with submittals and before manufacturing of air-handling units. Include sufficient lead time for unit delivery, installation, and testing required by construction schedule.

B. Casing Structural Deflection Test:

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

    a. In lieu of independent laboratory testing, manufacturer may perform factory deflection testing of proposed construction to prove compliance if witnessed by Owner. Manufacturer shall bear cost of labor and travel expenses to witness testing.

2. Test casing construction to performance criteria indicated.
3. Test casing construction proposed for use on Project. Include, at a minimum, particulars such as metal materials and thickness, internal support and reinforcing, and insulation material and thickness.
4. Test largest full-size casing panel proposed for use on Project.
5. Test proposed construction of walls, floor, and roof. Include a separate test for each unique casing construction proposed.
6. Submit test reports for each test to show compliance with performance indicated.

C. Casing Airborne Sound Transmission Test:

1. Include services of an independent testing laboratory to test proposed casing construction for sound transmission. Include a separate test for each unique casing construction proposed.
2. Conduct tests in accordance with ASTM E90.
3. Determine sound transmission class by using ASTM E413.
4. Test proposed construction of walls and roof.
5. Test proposed construction of floor assembly only if air-handling unit is not installed on a concrete housekeeping pad or building structural floor.
6. Submit test reports for each test to show compliance with performance indicated.

2.7 SOURCE QUALITY CONTROL - AIR-HANDLING UNIT FACTORY TESTS

A. Witness of Testing: Allow Architect and Owner access to place where air-handling units are being tested for witness testing.

1. Submit written notification at least 30 days in advance of testing.
2. Schedule testing at mutually agreeable dates and times.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine air-handling units before installation. Reject units with physical damage, and air-handling unit components that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for the following before installation of air-handling units:

1. Structural substrate mounting and anchorage to verify actual sizes, types, and locations.
2. Piping systems to verify actual sizes, types, and locations of connections.
3. Ductwork and plenums to verify actual sizes, types, and locations of connections.
4. Electrical services and controls to verify actual sizes, types, and locations of connections.

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

3.2 INSTALLATION OF OUTDOOR, CUSTOM AIR-HANDLING UNITS

A. Equipment Mounting: Install air-handling units at locations indicated on Drawings. Unless, otherwise indicated on Drawings, install air-handling units on concrete equipment bases.

1. Units Mounted on Concrete Bases:

a. Install air-handling units on cast-in-place concrete equipment bases. Coordinate sizes and locations of concrete bases with actual equipment provided. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."
b. Level air-handling unit bases using aluminum or stainless steel shims compatible with air-handling unit base material.
c. Fill voids between air-handling unit bases and concrete bases using high-strength non-shrink grout.
d. Continuously seal between concrete bases and perimeter of air-handling unit bases with nonhardening sealant.

2. Units Mounted to Structural-Steel Supports: Level unit air-handling bases using aluminum or stainless steel shims compatible with air-handling unit base material. Continuously seal between structural supports and air-handling unit bases with nonhardening sealant.
3. Units Mounted Directly to Finished Floors: Level air-handling unit bases using aluminum or stainless steel shims compatible with air-handling unit base material. Continuously seal between floor and perimeter of air-handling unit bases with nonhardening sealant.
4. Suspended Units: Suspend and laterally brace air-handling units from building structure by attaching to only air-handling unit bases at manufacturer-designated locations.
5. Install air-handling units on curbs following air-handling unit manufacturer's written procedures.

a. Install gaskets before setting air-handling units on curbs.
b. Secure air-handling units to curbs using stainless steel fasteners.
c. Install curb and fasten to structure.
d. Coordinate curb requirements, attachment, and location before installation.

B. Roof Openings:

1. Provide exact size and location of roof openings to trade installing structural framing and roof structure.
2. Supervise framing of openings to ensure coordinated installation with air-handling units.

C. Equipment Clearances and Access:

1. Arrange installation of air-handling units to provide access space around air-handling units for service and maintenance and for removal and replacement of internal components.
2. Provide clearance and access required by governing codes and NFPA 70.
3. At a minimum, comply with requirements indicated on Drawings and air-handling unit manufacturer's written instructions.

3.3 PROTECTION DURING CONSTRUCTION

A. Exterior Covers: Cover air-handling units during construction with sealed covers to protect air-handling unit casing and externally mounted components from physical damage, dirt, dust and debris, paint splatter, and any other construction materials.

1. Minor physical damage, as determined by Owner, shall be repaired by air-handling unit factory service personnel to factory-finished condition.
2. Replace air-handling units with damage that in any way compromises the performance indicated.

B. Internal Access: Keep access doors locked to maximum extent possible and restrict access to only authorized personnel.

1. Open access doors only during periods authorized work inside air-handling units is required.
2. Coordinate and monitor work inside air-handling units on a shift basis. Lock access doors once work is complete or at the end of each shift.
3. Immediately report unauthorized access and any observed damage to Owner.

3.4 DUCT CONNECTIONS

A. Connect ducts and plenums to air-handling unit connections. Comply with requirements in Section 233113 "Metal Ducts."

B. Connect ducts and plenums to air-handling unit connections with flexible connections. Comply with requirements in Section 233300 "Air Duct Accessories."

C. Provide duct transitions required to make field connections to air-handling units.

D. Arrange ducts and plenums to provide unobstructed access to inside of air-handling units.

3.5 PIPING CONNECTIONS

A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Where installing piping adjacent to air-handling unit, provide unobstructed access to inside of air-handling units for service and maintenance.

C. Connect piping to air-handling units with flexible connectors.

D. Drain Pan Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping."

1. Make connections to air-handling unit connections with flanges or unions.
2. Extend dedicated drain piping from each air-handling unit connection to nearest equipment or floor drain and arrange piping to maintain clear service aisle paths free of potential tripping hazards.
3. Construct traps near air-handling unit connections to seal airflow from escaping within air-handling unit. Locate traps in a serviceable location that is away from access doors.
4. Install threaded cleanouts at changes in direction.
5. Secure drain piping to structure.

E. Air-Handling Unit Floor Drains: Do not require installation of permanent drain piping.

F. Air-Handling Unit Floor Drain Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping."

1. Make connections to air-handling unit connections with flanges or unions.
2. Extend dedicated drain piping from each air-handling unit connection to nearest equipment or floor drain and arrange piping to maintain clear service aisle paths free of potential tripping hazards.
3. Construct traps near air-handling unit connections to seal airflow from escaping within air-handling unit. Locate traps in a serviceable location that is away from access doors.
4. Install threaded cleanouts at changes in direction.
5. Secure drain piping to structure.

G. Chilled-Water Coil Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties."

1. Comply with requirements indicated on Drawings.
2. Make connections to coils with a union.
3. Connect to each coil inlet with shutoff valve, test plug, pressure gauge andthermometer.
4. Connect to each coil outlet with balancing valve, test plug, pressure gaugethermometer and shutoff valve.
5. Connect each coil drain connection with a drain valve, which is full size of drain connection. Connect drain pipe to drain valve with union, and extend drain pipe to terminate over floor drain.
6. Connect each coil vent connection with manual vent, which is full size of vent connection.

H. Hot-Water Coil Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties."

1. Comply with requirements indicated on Drawings.
2. Make connections to coils with a union.
3. Connect to each coil inlet with shutoff valve, test plug, pressure gauge andthermometer.
4. Connect to each coil outlet with balancing valve, test plug, pressure gaugeand shutoff valve.
5. Connect each coil drain connection with a drain valve, which is full size of drain connection. Connect drain pipe to drain valve with union, and extend drain pipe to terminate over floor drain.
6. Connect each coil vent connection with manual vent, which is full size of vent connection.

3.6 ELECTRICAL CONNECTIONS

A. Install field power to each air-handling unit electrical power connection. Coordinate with air-handling unit manufacturer and installers.

B. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

C. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."

D. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.

E. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.

1. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.7 CONTROL CONNECTIONS

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

B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."

C. Install nameplate for each control connection, indicating field control panel designation and I/O control designation feeding connection.

1. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.8 STARTUP SERVICE

A. Engage an air-handling unit factory-authorized service representative to perform startup service.

1. Complete installation and startup checks in accordance with manufacturer's written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, controls, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
6. Verify that face-and-bypass dampers provide full face flow.
7. Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.
8. Comb coil fins for parallel orientation.
9. Verify that proper thermal-overload protection is installed for electric heaters.
10. Install new, clean filters.
11. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.

B. Starting procedures for air-handling units include the following:

1. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm.
2. Measure and record motor electrical values for voltage and amperage.
3. Manually operate dampers from fully closed to fully open position and record fan performance.

3.9 ADJUSTING

A. Adjust damper linkages for proper damper operation.

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

C. Before turning equipment over to Owner for use, adjust air-handling unit components that require further adjustment for proper operation. Consult air-handling unit manufacturer for instruction.

D. Occupancy Adjustments: When requested within 12 months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

E. Seasonal Adjustments: Make seasonal visits during warranty period to inspect and review operation of equipment. Make necessary adjustments for components observed to require adjustments for proper operation. Prepare and submit a report to Owner documenting each visit, observations, and any adjustments made.

3.10 CLEANING

A. Cleaning Schedule: After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems, and after completing startup service, and immediately before Owner use, clean air-handling units to remove foreign material and construction dirt and dust.

B. Unit Interior: Clean air-handling units internally to factory clean condition. Remove foreign material and construction debris, dirt, and dust.

1. Vacuum clean with HEPA-filtered vacuum and then wipe down with cleaning solution.
2. Clean casing floors, roofs, wall surfaces, access doors, and panels.
3. Clean all internal components, such as coils, dampers, filter frames, fans, and motors.
4. Clean light fixtures and control devices.

C. Unit Exterior: Clean external surfaces of air-handling units to factory clean condition. Remove foreign material and construction debris, dirt and dust. Vacuum clean with HEPA-filtered vacuum and then wipe down all surfaces with cleaning solution.

D. Cleaning Materials: Use cleaning materials and products recommended in writing by air-handling unit manufacturer.

E. Acceptance: Following unit cleaning submit a written request for review and Owner acceptance. Acceptance for cleaning of air-handling units must pass a white glove test.

3.11 FIELD QUALITY CONTROL

A. Testing Agency: Owner will engage a qualified testing agency to perform tests and inspections.

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

C. Prepare test and inspection reports.

3.12 OPERATION DURING CONSTRUCTION

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

1. Submit written request for Owner approval by signature with detailed description of operating procedures to be followed including, but not limited to, the following:

a. Description of construction activities while units are operating.
b. Operation:

1) Beginning and ending calendar dates.
2) List each day during week.
3) List start and stop time and hours for each day.

c. Startup procedures and shut-down procedures.

d. Provisions for routine monitoring of unit operation.
e. Provisions to prevent and protect against damage to equipment due to adverse operation such as, low temperature, high temperature, over pressure, fire, smoke, electrical over- and undervoltage and current and electrical fault.
f. Provisions and safeguards for filtration to keep inside of units from getting dirty.
g. Record keeping.

2. If approved by Owner, units used for temporary cooling, heating, and ventilation during and before interior finish work is complete shall include an unconditional complete unit labor and parts warranty to extend at least two years after the warranty indicated expires.
3. Interior and exterior of air-handling units shall be cleaned to a factory-cleaned condition and clean condition must be accepted by Owner.

B. Filtration During Temporary Use:

1. Protect air-handling system ducts (exhaust air, outdoor air, and return air) with temporary filters installed and supported to prevent filter media from collapse and bypass of unfiltered air. Temporary media shall be installed at each inlet and shall have a published filtration efficiency of MERV 13 in accordance with ASHRAE 52.2.
2. Protect air-handling units with open inlets that are not ducted with temporary filters installed and supported to prevent filter media from collapse and by-pass of unfiltered air. Temporary media shall be installed at each inlet and shall have a published filtration efficiency of MERV 13 in accordance with ASHRAE 52.2.
3. Do not operate air-handling units until both temporary and scheduled permanent air-handling unit particulate filters are in place. Temporary filters must be installed upstream of permanent filters while units are operating.
4. Replace temporary and permanent filters used during construction when dirty. After end of temporary use, replace permanent filters with new, clean filters before beginning testing, adjusting and balancing.

C. Comply with SMACNA 008, "IAQ Guidelines for Occupied Buildings under Construction," for procedures to protect HVAC system.

3.13 DEMONSTRATION

A. Training shall include, but not be limited to, procedures and schedules related to performance, safety, startup and shut down, troubleshooting, servicing, preventive maintenance, and how to obtain replacement parts.

1. Access Doors: Adjustment, gasket removal and replacement, handle removal and replacement, and spare parts.
2. Air Blenders: Cleaning, operation, removal, and replacement.
3. Coils: Cleaning, combing fins, draining, venting, removal, and replacement.
4. Controls: Calibration, cleaning, operation, service, removal and replacement, and spare parts.
5. Damper Assemblies: Cleaning, operation, service, removal and replacement, and spare parts.
6. Drain Pans: Cleaning, removal, and replacement.
7. Fan and Motor Assemblies: Cleaning, operation, removal and replacement, service, and spare parts.

8. Filters: Operation, removal and replacement, frame gasket removal and replacement, clip removal and replacement, and spare parts.
9. Lights, Receptacles and Switches: Cleaning, operation, service, removal and replacement, and spare parts.

B. Location: Owner to provide a suitable on-site location to host classroom training.

C. Training Attendees: Assume three people.

D. Training Attendance Records: For record purposes, document training attendees at start of each new training session. Record date, time, brief description of training covered during the session, attendee's name, signature, phone number, and e-mail address. Submit scanned copy of sign-in sheet to Owner for each training session.

E. Training Format: Individual training modules to include classroom training followed by hands-on field demonstration and training.

F. Training Materials: Provide training materials in electronic format to each attendee.

1. Include instructional videos showing general operation and maintenance that are coordinated with operation and maintenance manuals.

G. Training Video Recording: Video record each classroom training session and submit an electronic copy to Owner before requesting Owner acceptance of training.

H. Written Acceptance: Obtain Owner written acceptance that training is complete and requirements indicated have been satisfied.

END OF SECTION

SECTION 260573.13 - SHORT-CIRCUIT STUDIES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Computer-based, fault-current study to determine minimum interrupting capacity of circuit protective devices.

B. Related Requirements:

1. Section 260573.16 "Coordination Studies" for overcurrent protective device coordination studies.
2. Section 260573.19 "Arc-Flash Hazard Analysis" for arc-flash studies.

1.2 DEFINITIONS

A. Existing to Remain: Existing items of construction that are not to be removed and that are not otherwise indicated to be removed and salvaged, or removed and reinstalled. Existing to remain items must remain functional throughout construction period.

B. One-Line Diagram: A diagram that shows, by means of single lines and graphic symbols, the course of an electric circuit or system of circuits and the component devices or parts used therein.

C. Protective Device: A device that senses when an abnormal current flow exists and then removes the affected portion of the circuit from the system.

D. SCCR: Short-circuit current rating.

E. Service: The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served.

F. Single-Line Diagram: See "One-Line Diagram".

1.3 ACTION SUBMITTALS

A. Product Data:

1. For power system analysis software to be used for studies.

B. Short-Circuit Study Report:

1. Submit the following after approval of system protective devices submittals. Submittals must be in digital form.

a. Short-circuit study input data, including completed computer program input data sheets.
b. Submit study report for action prior to receiving final approval of distribution equipment submittals. If formal completion of studies will cause delay in equipment manufacturing, obtain approval from Architect for preliminary submittal of sufficient study data to ensure that selection of devices and associated characteristics is satisfactory.
c. Revised one-line diagram, reflecting field investigation results and results of short-circuit study.

1.4 QUALITY ASSURANCE

A. Study must be performed using commercially developed and distributed software designed specifically for power system analysis.

B. Software algorithms must comply with requirements of standards and guides specified in this Section.

PART 2 - PRODUCTS

2.1 POWER SYSTEM ANALYSIS SOFTWARE

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. SKM Systems Analysis, Inc.

B. Comply with IEEE 399 and IEEE 551.

C. Analytical features of power systems analysis software program must have capability to calculate "mandatory," "very desirable," and "desirable" features as listed in IEEE 399.

D. Computer software program must be capable of plotting and diagramming time-current-characteristic curves as part of its output.

E. Computer program must be designed to perform short-circuit studies or have function, component, or add-on module designed to perform short-circuit studies.

F. Computer program must be developed under supervision of licensed professional engineer who holds IEEE Computer Society's Certified Software Development Professional certification.

2.2 SHORT-CIRCUIT STUDY REPORT CONTENTS

A. Executive summary of study findings.

B. Study descriptions, purpose, basis, and scope. Include case descriptions, definition of terms, and guide for interpretation of results.

C. One-line diagram of modeled power system, showing the following:

1. Protective device designations and ampere ratings.
2. Conductor types, sizes, and lengths.
3. Transformer kVA and voltage ratings.
4. Motor and generator designations and kVA ratings.
5. Switchgear, switchboard, motor-control center, and panelboard designations and ratings.
6. Derating factors and environmental conditions.
7. Any revisions to electrical equipment required by study.

D. Comments and recommendations for system improvements or revisions in written document, separate from one-line diagram.

E. Protective Device Evaluation:

1. Evaluate equipment and protective devices and compare to available short-circuit currents. Verify that equipment withstand ratings exceed available short-circuit current at equipment installation locations.
2. Tabulations of circuit breaker, fuse, and other protective device ratings versus calculated short-circuit duties.
3. For 600 V overcurrent protective devices, ensure that interrupting ratings are equal to or higher than calculated 1/2-cycle symmetrical fault current.
4. For devices and equipment rated for asymmetrical fault current, apply multiplication factors listed in standards to 1/2-cycle symmetrical fault current.
5. Verify adequacy of phase conductors at maximum three-phase bolted fault currents; verify adequacy of equipment grounding conductors and grounding electrode conductors at maximum ground-fault currents. Ensure that short-circuit withstand ratings are equal to or higher than calculated 1/2-cycle symmetrical fault current.

F. Short-Circuit Study Input Data:

1. One-line diagram of system being studied.
2. Power sources available.
3. Manufacturer, model, and interrupting rating of protective devices.
4. Conductors.
5. Transformer data.

G. Short-Circuit Study Output Reports:

1. Low-Voltage Fault Report: Three-phase and unbalanced fault calculations, showing the following for each overcurrent device location:

    a. Voltage.
    b. Calculated fault-current magnitude and angle.
    c. Fault-point X/R ratio.
    d. Equivalent impedance.

2. Interrupting Duty Report: Three-phase and unbalanced fault calculations, showing the following for each overcurrent device location:

    a. Voltage.

b. Calculated symmetrical fault-current magnitude and angle.
c. Fault-point X/R ratio.
d. No AC Decrement (NACD) ratio.
e. Equivalent impedance.
f. Multiplying factors for 2-, 3-, 5-, and 8-cycle circuit breakers rated on symmetrical basis.
g. Multiplying factors for 2-, 3-, 5-, and 8-cycle circuit breakers rated on total basis.

PART 3 - EXECUTION

3.1 POWER SYSTEM DATA

A. Obtain data necessary for conduct of study.

1. Verify completeness of data supplied on one-line diagram. Call discrepancies to Architect's attention.
2. For equipment included as Work of this Project, use characteristics submitted under provisions of action submittals and information submittals for this Project.
3. For equipment that is existing to remain, obtain required electrical distribution system data by field investigation and surveys, conducted by qualified technicians and engineers in accordance with NFPA 70E.

B. Gather and tabulate required input data to support short-circuit study. Comply with requirements in Section 017839 "Project Record Documents" for recording circuit protective device characteristics. Record data on Record Document copy of one-line diagram. Comply with recommendations in IEEE 551 as to amount of detail that is required to be acquired in field. Field data gathering must be by, or under supervision of, qualified electrical professional engineer. Data include, but are not limited to, the following:

1. Product Data for Project's overcurrent protective devices involved in overcurrent protective device coordination studies. Use equipment designation tags that are consistent with electrical distribution system diagrams, overcurrent protective device submittals, input and output data, and recommended device settings.
2. Obtain electrical power utility impedance at service.
3. Power sources and ties.
4. For transformers, include kVA, primary and secondary voltages, connection type, impedance, X/R ratio, taps measured in percent, and phase shift.
5. For reactors, provide manufacturer and model designation, voltage rating, and impedance.
6. For circuit breakers and fuses, provide manufacturer and model designation. List type of breaker, type of trip, SCCR, current rating, and breaker settings.
7. Generator short-circuit current contribution data, including short-circuit reactance, rated kVA, rated voltage, and X/R ratio.
8. Busway manufacturer and model designation, current rating, impedance, lengths, and conductor material.
9. Motor horsepower and NEMA MG 1 code letter designation.
10. Conductor sizes, lengths, number, conductor material and conduit material (magnetic or nonmagnetic).
11. Derating factors.

3.2 SHORT-CIRCUIT STUDY

A. Perform study following general study procedures contained in IEEE 399.

B. Calculate short-circuit currents according to IEEE 551.

C. Base study on device characteristics supplied by device manufacturer.

D. Extent of electrical power system to be studied is indicated on Drawings.

E. Begin short-circuit current analysis at service, extending down to system overcurrent protective devices as follows:

1. To normal system low-voltage load buses where fault current is 5 kA or less.

F. Study electrical distribution system from normal and alternate power sources throughout electrical distribution system for Project. Study cases of system-switching configurations and alternate operations that could result in maximum fault conditions.

G. Include ac fault-current decay from induction motors, synchronous motors, and asynchronous generators and apply to low- and medium-voltage, three-phase ac systems. Also account for fault-current dc decrement to address asymmetrical requirements of interrupting equipment.

H. Calculate short-circuit momentary and interrupting duties for three-phase bolted fault and single line-to-ground fault at each equipment indicated on one-line diagram.

1. For grounded systems, provide bolted line-to-ground fault-current study for areas as defined for three-phase bolted fault short-circuit study.

I. Include in report identification of protective device applied outside its capacity.

END OF SECTION 260573.13

SECTION 260573.16 - COORDINATION STUDIES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Computer-based, overcurrent protective device coordination studies to determine overcurrent protective devices and to determine overcurrent protective device settings for selective tripping.

a. Study results must be used to determine coordination of series-rated devices.

B. Related Requirements:

1. Section 260573.13 "Short-Circuit Studies" for fault-current studies.
2. Section 260573.19 "Arc-Flash Hazard Analysis" for arc-flash studies.

1.2 DEFINITIONS

A. Existing to Remain: Existing items of construction that are not to be removed and that are not otherwise indicated to be removed, removed and salvaged, or removed and reinstalled. Existing to remain items must remain functional throughout construction period.

B. One-Line Diagram: A diagram that shows, by means of single lines and graphic symbols, the course of electric circuit or system of circuits and the component devices or parts used therein.

C. Protective Device: A device that senses when abnormal current flow exists and then removes the affected portion of the circuit from the system.

D. SCCR: Short-circuit current rating.

E. Service: The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served.

F. Single-Line Diagram: See "One-Line Diagram."

1.3 ACTION SUBMITTALS

A. Product Data:

1. For power system analysis software to be used for studies.

B. Coordination Study Report:

1. Submit the following after approval of system protective devices submittals. Submittals must be in digital form.

    a. Coordination-study input data, including completed computer program input data sheets.
    b. Study and equipment evaluation reports.
    c. Submit study report for action prior to receiving final approval of distribution equipment submittals. If formal completion of studies will cause delay in equipment manufacturing, obtain approval from Architect for preliminary submittal of sufficient study data to ensure that selection of devices and associated characteristics is satisfactory.
    d. Revised one-line diagram, reflecting field investigation results and results of coordination study.

1.4 INFORMATIONAL SUBMITTALS

A. Product Certificates: For overcurrent protective device coordination study software, certifying compliance with IEEE 399.

1.5 QUALITY ASSURANCE

A. Studies must be performed using commercially developed and distributed software designed specifically for power system analysis.

B. Software algorithms must comply with requirements of standards and guides specified in this Section.

C. Manual calculations are unacceptable.

1.6 REGULATORY AGENCY APPROVALS

A. Submittals for coordination study require action by Architect prior to submitting for approval by authorities having jurisdiction.

PART 2 - PRODUCTS

2.1 POWER SYSTEM ANALYSIS SOFTWARE

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    1. SKM Systems Analysis, Inc.

B. Comply with IEEE 242 and IEEE 399.

C. Analytical features of device coordination study computer software program must have capability to calculate "mandatory," "very desirable," and "desirable" features as listed in IEEE 399.

D. Computer software program must be capable of plotting and diagramming time-current-characteristic curves as part of its output. Computer software program must report device settings and ratings of overcurrent protective devices and must demonstrate selective coordination by computer-generated, time-current coordination plots.

1. Optional Features:

a. Arcing faults.
b. Simultaneous faults.
c. Explicit negative sequence.
d. Mutual coupling in zero sequence.

E. Computer program must be designed to perform coordination studies or have function, component, or add-on module designed to perform coordination studies.

F. Computer program must be developed under supervision of licensed professional engineer who holds IEEE Computer Society's Certified Software Development Professional certification.

2.2 COORDINATION STUDY REPORT CONTENTS

A. Executive summary of study findings.

B. Study descriptions, purpose, basis, and scope. Include case descriptions, definition of terms, and guide for interpretation of results.

C. One-line diagram of modeled power system, showing the following:

1. Protective device designations and ampere ratings.
2. Conductor types, sizes, and lengths.
3. Transformer kVA and voltage ratings.
4. Motor and generator designations and kVA ratings.
5. Switchgear, switchboard, motor-control center, and panelboard designations.
6. Revisions to electrical equipment required by study.
7. Study Input Data: As described in "Power System Data" Article.

a. Short-Circuit Study Output: As specified in "Short-Circuit Study Output Reports" Paragraph in "Short-Circuit Study Report Contents" Article in Section 260573.13 "Short-Circuit Studies."

D. Protective Device Coordination Study:

1. Report recommended settings of protective devices, ready to be applied in field. Use manufacturer's data sheets for recording recommended setting of overcurrent protective devices when available.

a. Circuit Breakers:

1) Adjustable pickups and time delays (long time, short time, and ground).
2) Adjustable time-current characteristic.
3) Adjustable instantaneous pickup.
4) Recommendations on improved trip systems, if applicable.

E. Time-Current Coordination Curves: Determine settings of overcurrent protective devices to achieve selective coordination. Graphically illustrate that adequate time separation exists between devices installed in series, including power utility company's upstream devices. Prepare separate sets of curves for switching schemes and for emergency periods where power source is local generation. Show the following information:

1. Device tag and title, one-line diagram with legend identifying portion of system covered.
2. Terminate device characteristic curves at point reflecting maximum symmetrical or asymmetrical fault current to which device is exposed.
3. Identify device associated with each curve by manufacturer type, function, and, if applicable, tap, time delay, and instantaneous settings recommended.
4. Plot the following listed characteristic curves, as applicable:

    a. Power utility's overcurrent protective device.
    b. Medium-voltage equipment overcurrent relays.
    c. Medium- and low-voltage fuses including manufacturer's minimum melt, total clearing, tolerance, and damage bands.
    d. Low-voltage equipment circuit-breaker trip devices, including manufacturer's tolerance bands.
    e. Transformer full-load current, magnetizing inrush current, and ANSI through-fault protection curves.
    f. Cables and conductors damage curves.
    g. Ground-fault protective devices.
    h. Motor-starting characteristics and motor damage points.
    i. Generator short-circuit decrement curve and generator damage point.
    j. Largest feeder circuit breaker in each motor-control center and panelboard.

5. Maintain selectivity for tripping currents caused by overloads.
6. Maintain maximum achievable selectivity for tripping currents caused by overloads on series-rated devices.
7. Provide adequate time margins between device characteristics such that selective operation is achieved.
8. Comments and recommendations for system improvements.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine Project overcurrent protective device submittals for compliance with electrical distribution system coordination requirements and other conditions affecting performance of the Work. Devices to be coordinated are indicated on Drawings.

1. Proceed with coordination study only after relevant equipment submittals have been assembled. Overcurrent protective devices that have not been submitted and approved prior to coordination study may not be used in study.

3.2 POWER SYSTEM DATA

A. Obtain data necessary for conduct of overcurrent protective device study.

1. Verify completeness of data supplied in one-line diagram on Drawings. Call discrepancies to Architect's attention.
2. For equipment included as Work of this Project, use characteristics submitted under provisions of action submittals and information submittals for this Project.
3. For equipment that is existing to remain, obtain required electrical distribution system data by field investigation and surveys, conducted by qualified technicians and engineers. Qualifications of technicians and engineers must be in accordance with NFPA 70E.

B. Gather and tabulate required input data to support coordination study. List below is guide. Comply with recommendations in IEEE 551 for amount of detail required to be acquired in field. Field data gathering must be by, or under supervision of, qualified electrical professional engineer. Data include, but are not limited to, the following:

1. Product Data for overcurrent protective devices specified in other Sections and involved in overcurrent protective device coordination studies. Use equipment designation tags that are consistent with electrical distribution system diagrams, overcurrent protective device submittals, input and output data, and recommended device settings.
2. Electrical power utility impedance at service.
3. Power sources and ties.
4. Short-circuit current at each system bus (three phase and line to ground).
5. Full-load current of loads.
6. Voltage level at each bus.
7. For transformers, include kVA, primary and secondary voltages, connection type, impedance, X/R ratio, taps measured in percent, and phase shift.
8. For reactors, provide manufacturer and model designation, voltage rating, and impedance.
9. For circuit breakers and fuses, provide manufacturer and model designation. List type of breaker, type of trip and available range of settings, SCCR, current rating, and breaker settings.
10. Generator short-circuit current contribution data, including short-circuit reactance, rated kVA, rated voltage, and X/R ratio.
11. For relays, provide manufacturer and model designation, current transformer ratios, potential transformer ratios, and relay settings.
12. Maximum demands from service meters.
13. Busway manufacturer and model designation, current rating, impedance, lengths, size, and conductor material.
14. Motor horsepower and NEMA MG 1 code letter designation.
15. Low-voltage cable sizes, lengths, number, conductor material, and conduit material (magnetic or nonmagnetic).
16. Medium-voltage cable sizes, lengths, conductor material, cable construction, metallic shield performance parameters, and conduit material (magnetic or nonmagnetic).

17. Data sheets to supplement electrical distribution system one-line diagram, cross-referenced with tag numbers on diagram, showing the following:

    a. Special load considerations, including starting inrush currents and frequent starting and stopping.
    b. Transformer characteristics, including primary protective device, magnetic inrush current, and overload capability.
    c. Motor full-load current, locked rotor current, service factor, starting time, type of start, and thermal-damage curve.
    d. Generator thermal-damage curve.
    e. Ratings, types, and settings of utility company's overcurrent protective devices.
    f. Special overcurrent protective device settings or types stipulated by utility company.
    g. Time-current-characteristic curves of devices indicated to be coordinated.
    h. Manufacturer, frame size, interrupting rating in amperes root mean square (rms) symmetrical, ampere or current sensor rating, long-time adjustment range, short-time adjustment range, and instantaneous adjustment range for circuit breakers.
    i. Manufacturer and type, ampere-tap adjustment range, time-delay adjustment range, instantaneous attachment adjustment range, and current transformer ratio for overcurrent relays.
    j. Switchgear, switchboards, motor-control centers, and panelboards ampacity, and SCCR in amperes rms symmetrical.
    k. Identify series-rated interrupting devices for condition where available fault current is greater than interrupting rating of downstream equipment. Obtain device data details to allow verification that series application of these devices complies with NFPA 70 and UL 489 requirements.

3.3 COORDINATION STUDY

A. Comply with IEEE 242 for calculating short-circuit currents and determining coordination time intervals.

B. Comply with IEEE 399 for general study procedures.

C. Base study on device characteristics supplied by device manufacturer.

D. Extent of electrical power system to be studied is indicated on Drawings.

E. Begin analysis at service, extending down to system overcurrent protective devices as follows:

    1. To normal system low-voltage load buses where fault current is 5 kA or less.

F. Study electrical distribution system from normal and alternate power sources throughout electrical distribution system for Project. Study cases of system-switching configurations and alternate operations that could result in maximum fault conditions.

G. Transformer Primary Overcurrent Protective Devices:

    1. Device must not operate in response to the following:

a. Inrush current when first energized.
b. Self-cooled, full-load current or forced-air-cooled, full-load current, whichever is specified for that transformer.
c. Permissible transformer overloads according to IEEE C57.96 if required by unusual loading or emergency conditions.

2. Device settings must protect transformers according to IEEE C57.12.00, for fault currents.

H. Motor Protection:

1. Select protection for low-voltage motors according to IEEE 242 and NFPA 70.
2. Select protection for motors served at voltages more than 600 V according to IEEE 620.

I. Conductor Protection: Protect cables against damage from fault currents according to ICEA P-32-382, ICEA P-45-482, and protection recommendations in IEEE 242. Demonstrate that equipment withstands maximum short-circuit current for time equivalent to tripping time of primary relay protection or total clearing time of fuse. To determine temperatures that damage insulation, use curves from cable manufacturers or from listed standards indicating conductor size and short-circuit current.

J. Generator Protection: Select protection according to manufacturer's instructions and to IEEE 242.

K. Include ac fault-current decay from induction motors, synchronous motors, and asynchronous generators and apply to low- and medium-voltage, three-phase ac systems. Also account for fault-current dc decrement, to address asymmetrical requirements of interrupting equipment.

L. Calculate short-circuit momentary and interrupting duties for three-phase bolted fault and single line-to-ground fault at each equipment indicated on one-line diagram.

1. For grounded systems, provide bolted line-to-ground fault-current study for areas as defined for three-phase bolted fault short-circuit study.

M. Protective Device Evaluation:

1. Evaluate equipment and protective devices and compare to short-circuit ratings.
2. Adequacy of switchgear, motor-control centers, and panelboard bus bars to withstand short-circuit stresses.
3. Application of series-rated devices must be recertified, complying with requirements in NFPA 70.
4. Include in report identification of protective device applied outside its capacity.

3.4 FIELD ADJUSTING

A. Adjust relay and protective device settings according to recommended settings provided by coordination study. Field adjustments must be completed by engineering service division of equipment manufacturer under "Startup and Acceptance Testing" contract portion.

B. Make minor modifications to equipment as required to accomplish compliance with short-circuit and protective device coordination studies.

END OF SECTION 260573.16

SECTION 260573.19 - ARC-FLASH HAZARD ANALYSIS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Computer-based, arc-flash study to determine arc-flash hazard distance and incident energy to which personnel could be exposed during work on or near electrical equipment.

B. Related Requirements:

1. Section 260573.13 "Short-Circuit Studies" for fault-current studies.
2. Section 260573.16 "Coordination Studies" for overcurrent protective device coordination studies.

1.2 DEFINITIONS

A. Existing to Remain: Existing items of construction that are not to be removed and that are not otherwise indicated to be removed, removed and salvaged, or removed and reinstalled.

B. One-Line Diagram: A diagram that shows, by means of single lines and graphic symbols, the course of an electric circuit or system of circuits and the component devices or parts used therein.

C. Protective Device: A device that senses when an abnormal current flow exists and then removes the affected portion from the system.

D. p.u.: Per unit. The reference unit, established as a calculating convenience, for expressing all power system electrical parameters on a common reference base.

E. SCCR: Short-circuit current rating.

F. Service: The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served.

G. Single-Line Diagram: See "One-Line Diagram".

1.3 ACTION SUBMITTALS

A. Product Data:

1. For power system analysis software to be used for studies.

B. Study Submittals:

1. Submit the following after approval of system protective devices submittals. Submittals must be in digital form:

    a. Arc-flash study input data, including completed computer program input data sheets.
    b. Submit study report for action prior to receiving final approval of distribution equipment submittals. If formal completion of studies will cause delay in equipment manufacturing, obtain approval from Architect for preliminary submittal of sufficient study data to ensure that selection of devices and associated characteristics is satisfactory.
    c. Revised one-line diagram, reflecting field investigation results and results of arc-flash study.

1.4 INFORMATIONAL SUBMITTALS

A. Product Certificates: For arc-flash hazard analysis software, certifying compliance with IEEE 1584 and NFPA 70E.

1.5 QUALITY ASSURANCE

A. Study must be performed using commercially developed and distributed software designed specifically for power system analysis.

B. Software algorithms must comply with requirements of standards and guides specified in this Section.

C. Manual calculations are unacceptable.

PART 2 - PRODUCTS

2.1 COMPUTER SOFTWARE

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. SKM Systems Analysis, Inc.

B. Comply with IEEE 1584 and NFPA 70E.

C. Analytical features of device coordination study computer software program must have capability to calculate "mandatory," "very desirable," and "desirable" features as listed in IEEE 399.

D. Computer program must be designed to perform arc-flash analysis or have function, component, or add-on module designed to perform arc-flash analysis.

E. Computer program must be developed under supervision of licensed professional engineer who holds IEEE Computer Society's Certified Software Development Professional certification.

2.2 ARC-FLASH STUDY REPORT CONTENT

A. Executive summary of study findings.

B. Study descriptions, purpose, basis, and scope. Include case descriptions, definition of terms, and guide for interpretation of results.

C. One-line diagram, showing the following:

1. Protective device designations and ampere ratings.
2. Conductor types, sizes, and lengths.
3. Transformer kVA and voltage ratings, including derating factors and environmental conditions.
4. Motor and generator designations and kVA ratings.
5. Switchgear, switchboard, motor-control center, panelboard designations, and ratings.

D. Study Input Data: As described in "Power System Data" Article.

E. Short-Circuit Study Output Data: As specified in "Short-Circuit Study Output Reports" Paragraph in "Short-Circuit Study Report Contents" Article in Section 260573.13 "Short-Circuit Studies."

F. Protective Device Coordination Study Report Contents: As specified in "Coordination Study Report Contents" Article in Section 260573.16 "Coordination Studies."

G. Arc-Flash Study Output Reports:

1. Interrupting Duty Report: Three-phase and unbalanced fault calculations, showing the following for each equipment location included in report:

a. Voltage.
b. Calculated symmetrical fault-current magnitude and angle.
c. Fault-point X/R ratio.
d. No AC Decrement (NACD) ratio.
e. Equivalent impedance.
f. Multiplying factors for 2-, 3-, 5-, and 8-cycle circuit breakers rated on symmetrical basis.
g. Multiplying factors for 2-, 3-, 5-, and 8-cycle circuit breakers rated on total basis.

H. Incident Energy and Flash Protection Boundary Calculations:

1. Arcing fault magnitude.
2. Protective device clearing time.
3. Duration of arc.
4. Arc-flash boundary.
5. Restricted approach boundary.
6. Limited approach boundary.
7. Working distance.
8. Incident energy.
9. Hazard risk category.
10. Recommendations for arc-flash energy reduction.

I. Fault study input data, case descriptions, and fault-current calculations including definition of terms and guide for interpretation of computer printout.

2.3 ARC-FLASH WARNING LABELS

A. Comply with requirements in Section 260553 "Identification for Electrical Systems" for self-adhesive equipment labels. Produce 3.5 by 5 inch self-adhesive equipment label for each work location included in analysis.

B. Label must have orange header with wording, "WARNING, ARC-FLASH HAZARD," and must include the following information taken directly from arc-flash hazard analysis:

1. Location designation.
2. Nominal voltage.
3. Protection boundaries.
    a. Arc-flash boundary.
    b. Restricted approach boundary.
    c. Limited approach boundary.
4. Arc flash PPE category.
5. Required minimum arc rating of PPE in Cal/cm squared.
6. Available incident energy.
7. Working distance.
8. Engineering report number, revision number, and issue date.

C. Labels must be machine printed, with no field-applied markings.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine Project overcurrent protective device submittals. Proceed with arc-flash study only after relevant equipment submittals have been assembled. Overcurrent protective devices that have not been submitted and approved prior to arc-flash study may not be used in study.

3.2 ARC-FLASH HAZARD ANALYSIS

A. Comply with NFPA 70E and its Annex D for hazard analysis study.

B. Preparatory Studies: Perform Short-Circuit and Protective Device Coordination studies prior to starting Arc-Flash Hazard Analysis.

1. Short-Circuit Study Output: As specified in "Short-Circuit Study Output Reports" Paragraph in "Short-Circuit Study Report Contents" Article in Section 260573.13 "Short-Circuit Studies."
2. Coordination Study Report Contents: As specified in "Coordination Study Report Contents" Article in Section 260573.16 "Coordination Studies."

C. Calculate maximum and minimum contributions of fault-current size.

1. Maximum calculation must assume maximum contribution from utility and must assume motors to be operating under full-load conditions.
2. Calculate arc-flash energy at 85 percent of maximum short-circuit current in accordance with IEEE 1584 recommendations.
3. Calculate arc-flash energy at 38 percent of maximum short-circuit current in accordance with NFPA 70E recommendations.
4. Calculate arc-flash energy with utility contribution at minimum and assume no motor contribution.

D. Calculate arc-flash protection boundary and incident energy at locations in electrical distribution system where personnel could perform work on energized parts.

E. Include medium- and low-voltage equipment locations, except equipment fed from transformers smaller than 75 kVA.

F. Calculate limited, restricted, and prohibited approach boundaries for each location.

G. Incident energy calculations must consider accumulation of energy over time when performing arc-flash calculations on buses with multiple sources. Iterative calculations must take into account changing current contributions, as sources are interrupted or decremented with time. Fault contribution from motors and generators must be decremented as follows:

1. Fault contribution from induction motors must not be considered beyond three to five cycles.
2. Fault contribution from synchronous motors and generators must be decayed to match actual decrement of each as closely as possible (for example, contributions from permanent magnet generators will typically decay from 10 p.u. to 3 p.u. after 10 cycles).

H. Arc-flash energy must generally be reported for maximum of line or load side of circuit breaker. However, arc-flash computation must be performed and reported for both line and load side of circuit breaker as follows:

1. When circuit breaker is in separate enclosure.
2. When line terminals of circuit breaker are separate from work location.

I. Base arc-flash calculations on actual overcurrent protective device clearing time. Cap maximum clearing time at two seconds based on IEEE 1584, Section B.1.2.

3.3 POWER SYSTEM DATA

A. Obtain data necessary for conduct of arc-flash hazard analysis.

1. For new equipment, use characteristics from approved submittals under provisions of action submittals and information submittals for this Project.
2. For existing equipment, whether or not relocated, obtain required electrical distribution system data by field investigation and surveys conducted by qualified technicians and engineers.

B. Electrical Survey Data: Gather and tabulate the following input data to support study. Comply with recommendations in IEEE 1584 and NFPA 70E as to amount of detail that is required to be acquired in field. Field data gathering must be under direct supervision and control of engineer in charge of performing study, and must be by, or under supervision of, qualified electrical professional engineer. Data include, but are not limited to, the following:

1. Product Data for overcurrent protective devices specified in other Sections and involved in overcurrent protective device coordination studies. Use equipment designation tags that are consistent with electrical distribution system diagrams, overcurrent protective device submittals, input and output data, and recommended device settings.
2. Obtain electrical power utility impedance or available short circuit current at service.
3. Power sources and ties.
4. Short-circuit current at each system bus (three phase and line to ground).
5. Full-load current of loads.
6. Voltage level at each bus.
7. For transformers, include kVA, primary and secondary voltages, connection type, impedance, X/R ratio, taps measured in percent, and phase shift.
8. For reactors, provide manufacturer and model designation, voltage rating and impedance.
9. For circuit breakers and fuses, provide manufacturer and model designation. List type of breaker, type of trip and available range of settings, SCCR, current rating, and breaker settings.
10. Generator short-circuit current contribution data, including short-circuit reactance, rated kVA, rated voltage, and X/R ratio.
11. Busway manufacturer and model designation, current rating, impedance, lengths, size, and conductor material.
12. Motor horsepower and NEMA MG 1 code letter designation.
13. Low-voltage conductor sizes, lengths, number, conductor material and conduit material (magnetic or nonmagnetic).

3.4 LABELING

A. Apply one arc-flash label on front cover of each section of equipment for each equipment included in study. Base arc-flash label data on highest values calculated at each location.

B. Each piece of equipment listed below must have arc-flash label applied to it:

1. Panelboards.
2. Low voltage transformers.
3. Automatic Transfer Switch.

C. Note on record Drawings location of equipment where personnel could be exposed to arc-flash hazard during their work.

1. Indicate arc-flash energy.
2. Indicate protection level required.

3.5 APPLICATION OF WARNING LABELS

A. Install arc-flash warning labels under direct supervision and control of qualified electrical professional engineer.

END OF SECTION