PROJECT MANUAL
INCLUDING CONSTRUCTION SPECIFICATIONS

for

BP-S00195
TERMINAL C, PHASE 1X – AIRSIDE CONCOURSE

CONTRACT DOCUMENTS

Volume 5 OF 7
(Division 23)

ORLANDO INTERNATIONAL AIRPORT

Orlando, Florida 32827

GREATER ORLANDO AVIATION AUTHORITY

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SECTION 23 00 10 - BASIC HVAC REQUIREMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Mechanical systems, equipment, devices and accessories shall be installed, finished, tested and adjusted for continuous and proper operation. Any apparatus, material or device not shown on the Drawings but mentioned in these Specifications, or vice versa, or any incidental accessories necessary to make the project complete and operational in all respects, shall be provided. Include all materials, equipment, supervision, operation, methods and labor for the fabrication, installation, start-up and tests necessary for complete and properly functioning systems.

1.3 QUALITY ASSURANCE

A. Code Compliance: Comply with all rules, laws, statutes, regulations, building codes, and the amendments of local, state and federal governments by the authorities having jurisdiction.

B. ADA: Comply with the requirements of the Americans with Disabilities Act (ADA).

C. HANDICAP ACCESS: Comply with Chapter 553, Part II, Florida Statutes, "ACCESSIBILITY BY HANDICAP PERSONS"; and the accessibility requirements manual from the Florida Board of Building Codes and Standards, Department of Community Affairs, latest Revisions.

D. NFPA: Comply with the National Fire Codes compiled by the National Fire Protection Association.

E. Florida Building Code: Conform in strict compliance to the current editions of Florida Building Code; Florida Mechanical Code; Florida Energy Efficiency Code, Florida Plumbing Code; Florida Fuel Gas Code; and the amendments to these codes which are enforced by the local authority having lawful jurisdiction.

1.4 DRAWINGS AND SPECIFICATIONS

A. Equipment Placement: The drawings are diagrammatic, intended to show general arrangement, capacity and location of various components, equipment and devices. Reasonable changes in locations ordered by the Engineer prior to the installation may be made at no additional cost.

B. Drawing Scale: Due to the small scale of the drawings, and to unforeseen job conditions, all required offsets, transitions and fittings may not be shown but shall be provided at no additional cost.

1.5 DEFINITIONS

A. Concealed: When standing inside a finished room, insulated or non-insulated piping or ductwork not visible after installation, such as inside a chase or above a ceiling.

B. Exposed: When standing inside a finished room, insulated piping or ductwork is visible after installation, such as inside an equipment room or an air handling unit room.

C. Protected: The surface of insulated or non-insulated piping or ductwork on the exterior of the building but protected from direct exposure to the weather by an overhang, eave, in an unconditioned parking garage or building crawl space.

D. Unprotected: The surface of insulated on non-insulated piping or ductwork on the exterior of the building and exposed to the weather.

1.6 SUBMITTALS

A. Shop Drawings: Shop drawings include piping system layouts, ductwork layouts, fabrication and installation drawings of supports and anchorage for mechanical materials and equipment, and coordination drawings. Shop drawings also include proposed equipment layouts, drawn to scale, indicating that proposed equipment will fit into allotted space, including service access, connections, etc.

1. Piping Systems: See Specification 232113 HYDRONIC PIPING. Submit shop drawings for piping systems drawn at a minimum scale of 3/8 inch per foot (1/4 inch per foot for mechanical rooms or congested areas) to verify clearances and equipment locations. Show required maintenance and operational clearances. Include the following:

a. Architectural and structural backgrounds with room names and numbers, including but not limited to plans, sections, elevations and details.
b. Fabrication and erection dimensions.
c. Arrangements and sectional views.
d. Details, including complete information for making connections to equipment.
e. Descriptive names of equipment.
f. Modifications and options to standard equipment required by Contract Documents.

2. Ductwork: See Specification 233113 METAL DUCTS. Submit shop drawings for duct systems at a minimum scale of 3/8 inch per foot (1/4 inch per foot for mechanical rooms or congested areas) to verify clearances and equipment locations. Show required maintenance and operational clearances. Include the following:

a. Architectural and structural backgrounds with room names and numbers, etc., including but not limited to plans, sections, elevations, details, etc.
b. Fabrication and erection dimensions.
c. Arrangements and sectional views.
d. Details, including complete information for making connections to equipment.
e. Materials and finishes.

f. Descriptive names of equipment.
g. Modifications and options to standard equipment required by Contract Documents.

3. Coordination Drawings: Submit coordination drawings including detailed drawings showing locations and positions of all Architectural, structural, electrical and mechanical elements. Drawings shall be minimum ¼ inch per foot for each mechanical equipment room, mechanical riser, or chase. All other areas shall be a minimum 1/8 inch per foot.

B. Sustainable Design Documentation Submittals: Refer to section 01 81 13.14 “Sustainable Design Requirements – LEED V4 BD+C”.
   1. Product Data: Documentation for Leadership Extraction Practices in the following:
      a. Leadership Extraction Practices for Recycled Content
   2. Product Data: Documentation for Low Emitting Materials
      a. Low Emitting Materials for Paints and Coatings
      b. Low Emitting Materials for Adhesives and Sealants
   3. Product Certificates: Provide the following:
      a. Environmental Product Declarations (EPD’s)
      b. Corporate Sustainability Reporting (CSR’s)

C. Product Data: Product data includes the manufacturer's printed literature.

D. Performance Data: Provide performance data, wiring and control diagrams.

E. Installation Instructions: Installation instructions include detailed information, from the manufacturer, indicating specific installation requirements, instructions, and recommendations. Generic installation instructions are not acceptable. Instructions shall be the same as those included with the product when it is shipped from the factory.

F. Written Operating Instructions: Operating instructions shall be the manufacturer's written operating instructions for the specified product. If the instructions cover more than one model or type of product they shall be clearly marked to identify the instructions that cover the product delivered to the project.

G. Maintenance Instructions: Maintenance instructions shall be the manufacturer's printed instructions and parts lists for the equipment furnished. If the instructions cover more than one model or type of equipment they shall be marked to identify the instructions for the furnished product.

H.

1.7 INSTRUCTION TO THE OWNER

A. General: Instructions to the Owner shall be accomplished by representatives of the manufacturers involved. Allow time for complete coverage of all operating procedures. Provide field training in the design, operation and maintenance of the equipment and troubleshooting procedures. Explain the identification system, operational diagrams, emergency and alarm provisions, sequencing requirements, seasonal provisions, security, safety, efficiency and similar provisions of the systems. On the date of substantial completion, turn over the prime responsibility for operation of the mechanical equipment and systems to the Owner's operating personnel.

B. Training Period: Training period shall encompass a minimum of 12 hours of hands-on instructions with a maximum period of 4 hours per day. All training sessions will be recorded via video and turned over to GOAA for future reference. Refer to Sections 01 91 13 – General Commissioning Requirements and 23 08 00 – Commissioning of HVAC Systems

C. Scheduling: Submit any remaining required items for checking at least one week before final inspection of the work. When submittal items are found acceptable, notify the Owner, in writing, that an "Instruction Conference" may proceed. Conference will be scheduled by the Owner. After the conference, copies of a memo certifying that the "Instruction Conference" and "Completed Demonstration" have been made will be signed by the Owner and the instructors, and one copy will be inserted in each submittal binder.

1.8 LIMITED COMMISSIONING RESPONSIBILITIES

A. See Specification Section 230800-Commissioning of HVAC Systems.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Specified Products: Manufacturer's names and product model numbers indicated on the drawings and in these specifications establish the type, style, quality, performance, and sound rating of the desired product. Listing of other manufacturers indicates that their equivalent products would be acceptable if they meet the specification requirements, the specific use and installation shown on the drawings, including space and clearance requirements, and the energy consumption and efficiency of the specified product.

B. Space Requirements: All manufactured products furnished on this project must have the required space and service areas indicated in the manufacturer's printed literature or shown on their approved shop drawings. When the manufacturer does not indicate the space required for servicing the equipment, the space shown on the drawings or as required by the Engineer must be provided.

2.2 MATERIAL AND EQUIPMENT

A. General: Material and equipment used shall be produced by manufacturers regularly engaged in the production of similar items, and with a history of satisfactory use as judged by the Engineer.

B. Specified Equipment: Equipment shall be the capacity and types indicated. Equipment and material furnished shall be the manufacturer's standard item of production unless specified or required to be modified to suit job conditions. Sizes, material, finish, dimensions and the capacities for the specified application shall be published in catalogs for national distribution. Ratings and capacities shall be certified by a recognized rating bureau. Products shall be complete with accessories, trim, finish, safety guards and other devices and details needed for a complete installation and for the intended use and effect.

C. Aompatibility: Material and equipment of one and the same kind, type or classification and used for identical or similar purposes shall be made by the same manufacturer. Where more than one choice is available, select the options which are compatible with other products already selected. Compatibility is a basic general requirement of product selection.

PART 3 - EXECUTION

3.1 WORKMANSHIP

A. General: Personnel who install materials and equipment shall be qualified by training and experience to perform their assigned tasks.

B. Performance: Material and equipment installations not in compliance with the Contract Documents, or installed with substandard workmanship in the opinion of the Engineer, shall be removed and reinstalled.

3.2 CLEANING AND PROTECTION

A. General: Refer to Division 01 and to SMACNA IAQ Guidelines for Occupied Buildings Under Construction, 2007.

B. Housekeeping: Keep interiors of duct and pipe systems clean and free from dirt, rubbish and foreign matter. Close open ends of piping and ductwork at all times throughout the installation. Install 30% efficient filter media over each return air grille and open return duct opening; change media regularly during construction when dirty to keep duct interiors clean. Prevent dust, debris and foreign material from entering the piping and ductwork.

C. Equipment Protection: Protect fan motors, switches, equipment, fixtures, and other items from dirt, rubbish and foreign matter. Do not operate air handling equipment if the building is not clean or if dust can enter the coils or the fan housings.

D. Equipment Cleaning: Thoroughly clean equipment and entire piping systems internally upon completion of installation and immediately prior to Submittal Completion. Open dirt pockets and strainers, blow down each piping system and clean strainer screens of accumulated debris. Remove accumulated dirt, scale, oil and foreign substances. Thoroughly wipe clean internal surfaces of ductwork and air handling units prior substantial completion. Refer to Section 15060, Pipe and Fittings, for detailed requirements for piping systems' flushing and cleaning.

E. Filter Replacement: Provide filtersfor the protection of the air moving equipment and ductwork continuously throughout the construction phase. Filters shall have a minimum efficiency rating of MERV 8 in accordance with specification section 01 35 46. Provide a new set of clean filters matching the efficiency and performance as specified for the final installation for the test and balance of the air side equipment.

F. Protection of Finished Installation: Where installation is required in areas previously finished by other trades, protect the area from marring, soiling or other damage.

3.3 CORRECTION OF WORK

A. General: At no additional cost to the Owner, rectify discrepancies between the actual installation and Contract Documents when in the opinion of the Testing and Balancing Agency (T&B Agency) or the Engineer the discrepancies will affect system balance and performance.

B. Shop drawing deviations need to be highlighted and noted on the submittal.

C. Drive Changes: Include the cost of all pulley, belt, and drive changes, as well as balancing dampers, valves and fittings, and access panels to achieve proper system balance recommended by the T&B Agency.

3.4 COORDINATION AND ASSISTANCE

A. General: Provide all labor, equipment, tools and material required to operate the equipment and systems necessary for the testing and balancing of the systems and for the adjustment, calibration and repair of all electric or pneumatic automated control devices and components. These services shall be available on each working day during the period of final testing and balancing.

B. Drawings and Specifications: Provide to the T&B Agency a complete set of project record drawings and specifications and an approved copy of all HVAC shop drawings and equipment submittals. The T&B Agency shall be informed of all changes made to the system during construction, including applicable change orders.

C. Coordination: Coordinate the work of all trades and equipment suppliers to complete the modifications recommended by the T&B Agency and accepted by the Engineer. T&B shall cut or drill holes for the insertion of air measuring devices as directed for test purposes; repair to as-new condition, inserting plastic caps or covers to prevent air leakage. Repair or replace insulation and re-establish the integrity of the vapor retardant.

3.5 PREPARATIONS FOR PERFORMANCE VERIFICATION

A. See Specification Section 230593 TESTING, ADJUSTING, AND BALANCING

B. Verification: Prior to commencement of balancing by the T&B Agency, verify the following in writing:

1. Air filters have been replaced and are clean.
2. Linkages between dampers and their actuators are secure, non-overloading and non-binding.
3. Ductwork specialties are in their normal operating positions.
4. Fans are operating at the correct rotation and specified RPM.
5. Ductwork has been pressure tested and accepted.
6. Strainers have been removed, cleaned and replaced, and that temporary construction strainers have been removed.
7. Compression or expansion tanks have been inspected, are not air-bound or water-logged and are pre-charged, and that the piping systems have been completely vented and filled with water.
8. Air vents at coils and high points of the piping systems have been inspected and installed and operating freely.

9. Automatic valves, hand valves, and balancing valves have been placed in a fixed open position for full flow through all devices.
10. Linkages between valves and their actuators are secure, non-overloading and non-binding.
11. Pressures for hydronic reducing valves have been set.
12. Operating temperatures have been set for chillers and regulating valves.
13. Pumps are operating at the correct rotation and specified horsepower.
14. Piping has been pressure tested and accepted and piping systems have been cleaned, flushed, sterilized and refilled with chemicals and prescribed treated water and vented.
15. Operating safety features (such as thermal overloads, firestats, freezestats, smoke detectors and relief valves), are installed and fully functional.
16. Equipment has been lubricated and can be operated without damage.
17. Systems are operational and complete.
18. No latent residual work remains to be completed.

3.6 LIMITED COMMISSIONING EXECUTION REQUIREMENTS

A. TESTING PREPARATION

1. Certify that HVAC&R systems, subsystems, and equipment have been installed, calibrated, and started and are operating according to the Contract Documents.
2. Certify that HVAC&R instrumentation and control systems have been completed and calibrated, that they are operating according to the Contract Documents, and that pretest set points have been recorded.
3. Certify that testing, adjusting, and balancing procedures have been completed and that testing, adjusting, and balancing reports have been submitted, discrepancies corrected, and corrective work approved.
4. Set systems, subsystems, and equipment into operating mode to be tested (e.g., normal shutdown, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).
5. Inspect and verify the position of each device and interlock identified on checklists.
6. Check safety cutouts, alarms, and interlocks with smoke control and life-safety systems during each mode of operation.
7. Testing Instrumentation: Install measuring instruments and logging devices to record test data as directed by the OAR/Engineer of Record.

B. TESTING AND BALANCING VERIFICATION

1. Prior to performance of testing and balancing Work, provide copies of reports, sample forms, checklists, and certificates to the OAR/Engineer of Record.
2. Notify the OAR/Engineer of Record at least 10 days in advance of testing and balancing Work, and provide access for the OAR/Engineer of Record to witness testing and balancing Work.
3. The test and balance contractor shall provide an ultrasonic flow meter for test and balance verification of water systems. Mechanical subcontractor shall install pete’s plug and balancing valves where they are needed but not shown on plans.
4. Provide technicians, instrumentation, and tools to verify testing and balancing of HVAC&R systems at the direction of the OAR/Engineer of Record.

a. The OAR/Engineer of Record will notify testing and balancing subcontractor, 10 days in advance of the date of field verification. Notice will not include data points to be verified.

b. The testing and balancing subcontractor shall use the same instruments (by model and serial number) that were used when original data were collected.

c. Failure of an item includes, other than sound, a deviation of more than 10 percent. Failure of more than 10 percent of selected items shall result in rejection of final testing, adjusting, and balancing report. For sound pressure readings, a deviation of 3 dB shall result in rejection of final testing. Variations in background noise must be considered.

d. Remedy the deficiency and notify the OAR/Engineer of Record so verification of failed portions can be performed.

C. GENERAL TESTING REQUIREMENTS

1. Provide technicians, instrumentation, and tools to perform commissioning test at the direction of the OAR/Engineer of Record.
2. Scope of HVAC&R testing shall include entire HVAC&R installation, from central equipment for heat generation and refrigeration through distribution systems to each conditioned space. Testing shall include measuring capacities and effectiveness of operational and control functions.
3. Test all operating modes, interlocks, control responses, and responses to abnormal or emergency conditions, and verify proper response of building automation system controllers and sensors.
4. The OAR/Engineer of Record along with the HVAC&R Subcontractor, testing and balancing Subcontractor, and HVAC&R Instrumentation and Control Subcontractor shall prepare detailed testing plans, procedures, and checklists for HVAC&R systems, subsystems, and equipment.
5. Tests will be performed using design conditions whenever possible.
6. Simulated conditions may need to be imposed using an artificial load when it is not practical to test under design conditions. Before simulating conditions, calibrate testing instruments. Provide equipment to simulate loads. Set simulated conditions as directed by the OAR/Engineer of Record and document simulated conditions and methods of simulation. After tests, return settings to normal operating conditions.
7. The OAR/Engineer of Record may direct that set points be altered when simulating conditions is not practical.
8. The OAR/Engineer of Record may direct that sensor values be altered with a signal generator when design or simulating conditions and altering set points are not practical.
9. If tests cannot be completed because of a deficiency outside the scope of the HVAC&R system, document the deficiency and report it to the Owner. After deficiencies are resolved, reschedule tests.
10. If the testing plan indicates specific seasonal testing, complete appropriate initial performance tests and documentation and schedule seasonal tests.

D. HVAC&R SYSTEMS, SUBSYSTEMS, AND EQUIPMENT TESTING PROCEDURES

1. HVAC&R Instrumentation and Control System Testing: Field testing plans and testing requirements are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls." Assist the OAR/Engineer of Record with preparation of testing plans.

2. Pipe system cleaning, flushing, hydrostatic tests, and chemical treatment requirements are specified in Division 23 piping Sections. HVAC&R Subcontractor shall prepare a pipe system cleaning, flushing, and hydrostatic testing plan. Provide cleaning, flushing, testing, and treating plan and final reports to the OAR/Engineer of Record. Plan shall include the following:
3. Sequence of testing and testing procedures for each section of pipe to be tested, identified by pipe zone or sector identification marker. Markers shall be keyed to Drawings for each pipe sector, showing the physical location of each designated pipe test section. Drawings keyed to pipe zones or sectors shall be formatted to allow each section of piping to be physically located and identified when referred to in pipe system cleaning, flushing, hydrostatic testing, and chemical treatment plan.

    a. Description of equipment for flushing operations.
    b. Minimum flushing water velocity.
    c. Tracking checklist for managing and ensuring that all pipe sections have been cleaned, flushed, hydrostatically tested, and chemically treated.

4. HVAC&R Distribution System Testing: Provide technicians, instrumentation, tools, and equipment to test performance of air, steam, and hydronic distribution systems; special exhaust; and other distribution systems, including HVAC&R terminal equipment and unitary equipment.

E. NON-CONFORMANCE

1. The OAR/Engineer of Record will record the results of the Performance Tests. All deficiencies, non-conformance issues, or test failures will be noted and reported to the Contractors in a deficiency list or in a punch-list format.
2. Corrections of minor deficiencies identified may be made during the tests at the discretion of the OAR/Engineer of Record. In such cases the deficiency and resolution will be documented on the procedure form.
3. Every effort will be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures. However, the OAR/Engineer of Record will not be pressured into overlooking deficient work or loosening acceptance criteria to satisfy scheduling or cost issues, unless there is an overriding reason to do so at the request of the Owners Representative.
4. Re-testing:

    a. If a Performance Test fails, corrections shall be made to the deficient equipment or systems by the Contractors. The systems will be re-tested until they pass the Tests.
    b. The time/cost for the OAR/Engineer of Record to perform any re-testing required because of improper set up of the systems by the contractors or failed performance tests will be back-charged to the Contractor (who may choose to recover costs from the party responsible for executing faulty equipment start-up/checkout and associated checklists). This includes instances where a specific item was overlooked in the equipment start-up and checkout procedures, reported to have been successfully completed, but determined during Performance testing to be faulty.

c. Any required re-testing by any contractor, sub-contractor, or vendor shall not be considered a justified reason for a claim of delay or for a time extension by the Contractor.

F. DEFICIENCIES AND RETESTING

1. The OAR/Engineer of Record documents the results of each test. (Corrections of minor installation or sequence of operation deficiencies are made during tests at the discretion of OAR/Engineer of Record.)
2. Deficiencies/non-conformance issues not corrected during testing are reported to the Contractors for corrective action. Upon completion, a request is made by the Contractors to OAR/Engineer of Record for retest.

3.7 PROTECTION OF MATERIALS AND EQUIPMENT

A. Requirements: Do not install or store fiberglass insulation or any equipment within the building until it has been "dried in". If dry space is unavailable and the insulation and equipment must be installed or stored before the building is "dried in" and completely enclosed, provide polyethylene film cover for protection. Protection must be continuously maintained until the building has been “dried in”. Any insulation or equipment that becomes wet shall be removed and replaced.

B. Replacement of Damaged Stored Material and Equipment: Any material and equipment that has been wet or otherwise damaged prior to, or after, installation shall be replaced with new material regardless of the condition of the material and equipment at the time of installation.

C. Repair or replacement of Damaged Installed Material and Equipment: After installation correct or repair dents, scratches and other visible blemishes. At the direction of Engineer replace or repair to "as new" condition equipment which has been wet or damaged during construction. Evidence of moisture damage includes, but is not limited to, corrosion (including “white rust” on galvanized surfaces), biological growth or odors.

3.8 COORDINATION OF SERVICES

A. Interruption of existing services: Provide shutoff valves at points of interconnection to minimize downtime.

3.9 LAYOUT OF EXISTING EQUIPMENT

A. The existing installation and all layouts are shown for reference only. Unforeseen conditions probably exist and existing and new work may not be field located exactly as shown on the drawings. Verify existing conditions in the field and notify the Engineer of any deviations required to install the work as shown. Coordinate new work with existing equipment, including removing, relocating, rerouting, extending with new materials, and reinstall existing piping, ductwork, conduits, wiring, tubing, supports and other equipment. The Engineer shall make the final decision on all deviations or modifications required by the existing conditions.

3.10 OWNERSHIP OF REMOVED EQUIPMENT

A. Construction materials and items of mechanical and electrical equipment which are removed and not reused shall be removed from the jobsite unless indicated as to be retained for the Owner. Include rigging, removal and hauling cost, as well as any salvage value, in the contract.

3.11 INTERRUPTION OF EXISTING BUILDING SERVICES

A. Interruptions to existing services shall be scheduled with the owner and shall not be made without the prior written consent of the owner's representative and proper coordination with other trades. Pre-work shall be performed to make the shutdown period as brief as possible.

END OF SECTION 23 00 10

SECTION 23 05 00 - COMMON WORK RESULTS FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements, Supplementary Conditions, Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

B. Basic Requirements: Provisions of Section 23 00 10, Basic HVAC Requirements are part of this Section.

C. Commissioning Requirements: Provisions of Sections 01 91 13 – General Commissioning Requirements, 01 91 15 – Facility Exterior Enclosure Commissioning are part of this Section.

1.2 SUMMARY

A. This Section includes and applies to all work included in Division 23.

B. Work in this Section includes providing labor, materials, equipment, services necessary, fabrication, installation and testing for fully operational and safe systems including all necessary materials, appurtenances and features whether specified or shown in the contract documents or not, in conformity with all applicable codes and authorities having jurisdiction for the following:

1. Mechanical work covered by all sections within Division 23 of the specifications, including, but not limited to:

   a. Heating, ventilating and air conditioning systems and equipment and accessories.
   b. Piping materials and installation instructions common to most piping systems.
   c. Equipment installation requirements common to equipment sections.
   d. Motors and controllers, including variable frequency drives.
   e. Control systems.
   f. Testing and balancing.
   g. Cleaning of piping systems.
   h. Cleaning of ductwork, casings, plenums, etc.
   i. Transition fittings.
   j. Dielectric fittings.
   k. Mechanical sleeve seals.
   l. Escutcheons.
   m. Grout.
   n. Equipment installation requirements common to equipment sections.

o. Painting and finishing.
p. Concrete bases.
q. Supports and anchorages.
r. Commissioning.
s. Access Doors and Frames.
t. Vibration and Sound Control.

C. Provide cutting and patching, for the Mechanical Work.

D. Provide piping from plumbing terminations, 10 feet from equipment, for water, gas, compressed air and as indicated.

E. Provide drainage from noted equipment to floor drains, roof drains, sink, or funnel drains.

F. Provide piping connections to equipment, as required, for kitchens and as indicated.

G. Division 23 Contractors shall be responsible to carry out the commissioning requirements as specified in Section 230800 Commissioning of HVAC.

H. It is the responsibility of each individual trade to provide access doors and frames of the appropriate size and locations to allow access to their respective equipment, valves, dampers, pull boxes, etc.

1.3 DEFINITIONS

A. "Piping": pipe, tube, fittings, flanges, valves, controls, strainers, hangers, supports, unions, traps, drains, insulation, and related items.

B. "Wiring": raceway, fittings, wire, boxes and related items.

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

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

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

F. Concealed, Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings, in chases, in enclosures, in trenches or in crawl spaces.

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

H. "Indicated," "Shown" or "Noted": as indicated, shown or noted on drawings or specifications.

I. "Motor Controllers": manual or magnetic starters (with or without switches), individual pushbuttons or hand-off-automatic (HOA) switches controlling the operation of motors.

J. "Control" or "Actuating Devices": automatic sensing and switching devices such as thermostats, pressure, float, electro-pneumatic switches and electrodes controlling operation of equipment.

1.4 ABBREVIATIONS

A. The following are industry abbreviations for plastic materials.

1. CPVC: Chlorinated polyvinyl chloride plastic.
2. PE: Polyethylene plastic.
3. PVC: Polyvinyl chloride plastic.

B. The following are industry abbreviations for rubber materials:

1. EPDM: Ethylene-propylene-diene terpolymer rubber.
2. NBR: Acrylonitrile-butadiene rubber.

C. Following is a list of abbreviations and symbols that are used in the specifications:

Word or Symbol	**Abbreviation or Symbol Used in Specifications**
ϕ	phase
air conditioning unit	ACU
alternating current	AC
ampere	amp
brake horsepower (bhp)	BHP
British thermal units	Btu
Celsius	C
Cubic feet per hour	CFH
cubic feet per minute	cfm
cubic feet per second	cfs
degree	°
direct current	DC
emergency power system	EPS
etcetera (etc.)	etc.
Fahrenheit	F
feet	ft.
feet per minute	fpm
gallon	gal.
gallons per minute	gpm
hertz	Hz

Word or Symbol	Abbreviation or Symbol Used in Specifications
horsepower	hp
inches	in.
kilovolt	kV
kilowatt	kW
KVA	kVA
length	length
manufacturer	Mfr.
minute	minute
number	No.
ounce	oz.
percent	%
plus and minus	±
pound or pounds	lb. or lbs.
pounds per square inch (psi)	psi
power factor	pf
psig	psig
PVC	PVC
revolutions per minute (rpm)	rpm
square foot or square feet	sq. ft.
times	times (unless used in an equation, then use x)
uninterruptible power supply (UPS)	UPS
Variable Frequency Drive	VFD
volt	V
water gauge	w.g.
width	width
wire-gauge	awg

1.5 UTILITY CONNECTIONS

A. Arrange for and pay utility costs for work of this Division.

B. Included:
1. Connection to utility company mains.
2. Connection to on-site piping mains.
3. Payment of service charges.
4. Provisions for temporary utilities.
5. Others as required.

1.6 JOB CONDITIONS

A. Examine all drawings and specifications in a manner to be fully cognizant of all work required under this Division.

B. Adjoining work of other Divisions shall be examined for interferences and conditions affecting this Division.

C. Examine site related work and surfaces before starting work of any Section.

1. Report to Architect, in writing, conditions which will prevent proper provision of this work.
2. Beginning work of any Section without reporting unsuitable conditions to Architect constitutes acceptance of conditions by Contractor.
3. Perform any required removal, repair or replacement of this work caused by unsuitable conditions at no additional cost to Owner.

D. Connections to existing work.

1. Verification of existing:

a. Before submitting bid, become thoroughly familiar with actual existing conditions and systems at the building, and of the existing installations to which connections must be made, including any necessary alterations, and existing building engineering practices and requirements. The intent of the work is shown on the drawings and described herein, and no consideration will be granted by reason of lack of familiarity on the part of the contractor with actual physical conditions, requirements, and practices at the site.

2. Install new work and connect to existing work with minimum interference to existing facilities.
3. Temporary shutdowns of existing services:

a. At no additional charges.
b. At times not to interfere with normal operation of existing facilities.
c. Only with written consent of Owner.

4. Maintain continuous operation of existing facilities as required with necessary temporary connections between new and existing work.
5. Restore existing disturbed work to original condition.

E. Removal and relocation of existing work.

1. Disconnect, remove or relocate material, equipment, plumbing fixtures, piping and other work noted and required by removal or changes in existing construction.
2. Where existing pipes, conduits and/or ducts which are to remain prevent installation of new work as indicated, relocate, or arrange for relocation, of existing pipes, conduits and/or ducts.
3. Provide new material and equipment required for relocated equipment.
4. Plug or cap active piping or ductwork behind or below finish.
5. Do not leave long dead-end branches. Cap or plug as close as possible to active line.
6. Remove unused piping, ductwork and material.
7. Dispose of removed fixtures and equipment as directed.
8. Turn over removed fixtures and equipment to Owner as directed.

F. Special Traffic Requirements:

1. Maintain emergency and service entrances useable to pedestrian, truck, and ambulance traffic at all times.
2. Where trenches are cut, provide adequate bridging for above mentioned traffic.

1.7 CLEARANCE FROM ELECTRICAL EQUIPMENT

A. Piping or ductwork:

1. Prohibited in:

a. Electric rooms and closets.
b. Telephone rooms and closets.
c. Elevator machine rooms.
d. Electric switchboard room.
e. IDF and MDF Rooms

2. Prohibited above an area within 5 ft. of:

a. Transformers.
b. Motor control centers.
c. Standby power plant.
d. Bus ducts.

1.8 SUBMITTALS

A. Product Data: Product data includes the manufacturer's printed literature. ALL equipment, material, product and performance data shall be CLEARLY marked to specifically identify the item(s) being submitted for inclusion in this project. Non-pertinent data shall be deleted or marked through. Any and all deviations from the requirements of the Contract Documents shall be specifically listed, and clearly shown in the submittal. Any deviations not specifically disclosed in the submittal shall be solely at the risk of the Contractor, and shall be subject to discovery at any time. Any undisclosed deviations shall be corrected by the Contractor to comply with the requirements of the Contract Documents at no additional cost to the Owner, regardless of the acceptance of the submittal by the Architect/Engineer.

B. Submit the following items as hereinafter specified:

1. Names and qualifications of test and balance agencies.
2. Layout Drawings.
3. Coordinated Drawings.
4. As-built Record Drawings (Submitted to Owner).
5. Record Files (Submitted to Owner).
6. Operating and Maintenance Manuals.
7. Welding certificates.
8. Equipment and material submittals as required by sections within this division.

C. Sustainable Design Documentation Submittals: Refer to section 01 81 13.14 “Sustainable Design Requirements – LEED V4 BD+C”.
   1. Product Data: Documentation for Leadership Extraction Practices in the following:
      a. Leadership Extraction Practices for Recycled Content
   2. Product Data: Documentation for Low Emitting Materials
      a. Low Emitting Materials for Paints and Coatings
      b. Low Emitting Materials for Adhesives and Sealants
   3. Product Certificates: Provide the following:
      a. Environmental Product Declarations (EPD’s)
      b. Corporate Sustainability Reporting (CSR’s)

D. Items shall comply with the requirements as hereinafter specified.

E. Submit shop drawings, product data, samples and certificates of compliance required by contract documents.

   1. See Division 1, Submittals for reference of minimum requirements, if not stated hereinbelow.

F. Schedule of submittals, as agreed to by the Engineer, will set the basis of the minimum required submittals. Submittals shall be provided by the Contractor promptly and in accordance with the Schedule of submittals and in such sequence as to cause no delay in work or in work of any other divisions.

G. Resubmission Requirements:

   1. In addition to Division 1 requirements, make any corrections or change in Submittals required. Resubmit for review until no exceptions are taken or a resubmission is not required.
   2. Shop Drawings and Product Data:

      a. Revise initial drawings or data, and resubmit as specified for initial submittal.
      b. Indicate any changes which have been made other than those requested.

   3. Samples: Submit new samples as required for initial submittal.
   4. Clearly identify resubmittal by original submittal date, number and revision number and indicate all changes from previous submittal.
   5. If more than two submissions are required (initial submittal and one resubmittal) based on rejection or lack of compliance by submittal, then the Contractor shall:

      a. Arrange for additional reviews by the Design Engineers.
      b. Pay all costs for such additional reviews.

H. Corrections or comments made on the shop drawings during review do not relieve the Contractor from compliance with requirements of the drawings and specifications. Shop drawing checking by the Engineer is only for review of general conformance with the design concept of the project and general compliance with the information given in the contract documents. The Contractor is responsible for:

1. Confirming and correlating all quantities and dimensions.
2. Selecting fabrication processes and techniques of construction.
3. Coordinating their work with that of all other trades.
4. Performing their work in a safe and satisfactory manner.

I. Substitutions:
   1. See Division 1, Substitution Procedures.

J. Layout (Shop) Drawings:

   1. Submit Layout Drawings indicating work within mechanical rooms, areas containing boilers, chillers, cooling towers, air handlers or pumps, areas containing acoustically lined ductwork, food service areas and for any areas. See Division 1 specification sections for additional requirements on layout drawings.
   2. Layout Drawings for mechanical rooms shall be at a scale of 1/4"=1’-0”.
   3. Prepare 3-D models for all mechanical rooms, boiler room and chiller room.
   4. Prepare layout shop drawings for all areas.
   5. From the layout drawings, prepare and submit Coordinated Drawings as herein specified below.

K. Coordinated Drawings:

   1. This Contractor shall prepare coordinated drawings which shall show work of all trades including, but not limited to:
      a. Items noted in the Supplemental General conditions.
      b. Coordinated Ductwork with penetrations at floors, walls, ceiling and roof.
      c. Piping, including:

         1) HVAC, plumbing and fire protection.
         2) Minor Piping such as drains, air vents, condensate piping, etc.
         3) Sleeves and penetrations.
         4) Expansion devices, anchors, guides and hangers.

      d. Mechanical Equipment.
      e. Supports and suspension devices.
      f. Ductwork/Piping high points and low points.
      g. Electrical Equipment.
      h. Main Electrical conduits and bus ducts.
      i. Equipment support and suspension devices including hangers, supports and bracing.
      j. Structural and architectural constraints including:

         1) Beams, braces, trusses, flanges, constraints, walls, openings ratings, doors, wall types, glazing.

      k. Show location of:
         1) Valves.
         2) Chemical Treatment.
         3) Piping specialties.
         4) Dampers.

5) Access doors.
6) Control and electrical panels.
7) Disconnect switches
8) Others as required.

2. Drawings shall indicate coordination with work in other Divisions which must be incorporated in mechanical spaces, including, but not limited to:

a. Irrigation equipment and piping.
b. Elevator equipment.
c. Cable trays not furnished under Division 26.
d. Computer equipment.
e. Others as required.

3. Provide sections and elevations for all mechanical rooms, mechanical areas, areas with routed duct mains, areas with routed piping mains, and areas adjacent to the existing structure.
4. Preparation of drawings:

a. Prepare reproducible CADD drawings.
b. Provide 3D model for the engineer's review (Revit, Navisworks, BIM 360 Glue)
c. Submit to other trades for review of space allocated to all trades.
d. Revise drawings to compensate for requirements of conditions created by other trades.

5. Final prepared drawings shall show that other trades affected have made reviews and signed, by each trade, at completion of coordination.
6. Coordinated shop drawings shall be for all areas.
7. Contractor is to assure that each trade has coordinated work with other trades, prior to submittal.

L. As-built (Record) Drawings:

Provide after installation is complete. Final signoff and Owner acceptance will not occur prior to submission of As-built drawings to Owner.
1. Indicate as-built conditions and all revisions that occurred subsequent to "Coordinated Drawings" submittal, fully illustrating all revisions made by all trades in the course of work.
2. Dimension physical locations of ductwork, and piping with reference elevations and distances above finished floors, below beams, from wall faces, underground (invert elevations) and from column lines.
3. Exact location, type and function of concealed valves, dampers, controllers, piping, air vents, piping drains and isolators.
4. Indicate all equipment sizes and capacities and tag numbers.
5. Provide drawing on reproducible mylar, CADD.
6. Provide 3D model for the engineer's review (Revit, Navisworks, BIM 360 Glue)
7. These drawings shall be for as-built record purposes for the Owner's use and are not considered shop drawings.

M. Record Files:
1. Provide 5 (five) electronic file copies of the As-built CADD drawings in the media (CDROM, Disks, Tape, etc.) of Owner's choice.
2. Provide 3D model (Revit, Navisworks, BIM 360 Glue) in the owner's choice.
3. Include electronic copy of file naming convention, layering standards, drawing index and file descriptions.
4. Electronic files shall be modifiable and shall include all associated referenced background files.

N. Operating Instructions, Maintenance Manuals and Parts Lists:
1. Before requesting acceptance of work, submit one set for review by Architect.
2. After review, furnish five printed and bound sets.
3. Include:
a. Manufacturer's name, model number, service manual, spare-parts list, and descriptive literature for all components, cross referenced and numbered on Record Drawings as required.
b. Maintenance instructions.
c. Listing of possible breakdown and repairs.
d. Instruction for starting, operation and programming.
e. Detailed and simplified one line, color coded flow and wiring diagram.
f. Field test report, including:
g. Instrument set points.
h. Normal operating valves.
i. Name, address and phone number of contractors equipment suppliers and service agencies.
j. Assemble manufacturer's equipment manuals in chronological order, following the specification alpha-numeric system, in heavy duty 3-ring binders clearly titled on the spine and front cover with appropriate index dividers.

O. Quantity of Submittals Required:
1. Layout (Shop) Drawings and Coordinated Drawings:
a. Submit two prints and an electronic copy. Coordinate with project manager.
b. Upon review, the electronic copy will be annotated and returned. Prints will be retained by the Engineer.
c. Copies of these prints and the electronic copy will serve as record copies for Architect.
2. Product Data (brochures):
a. Submit two copies of product data and an electronic copy. Coordinate with project manager.
b. Upon review, the electronic copy will be annotated and returned.
c. If comments are required, they will be returned with each copy.
d. One copy will be retained by the Engineer.

1.9 RELATED WORK AND REQUIREMENTS

A. Requirements of General Conditions and Division No.1 apply to all work in this division.

B. Carefully check the documents of each section with those of other sections and Divisions. Ascertain the requirements of any interfacing materials or equipment being furnished and/or installed by those sections and Divisions, and provide the proper installation and/or required interface.

C. As a minimum requirement and condition, the Contractor shall provide REVIT generated drawings (for the purpose of Layout Drawings, Coordinated Drawings, As-built Drawings and Record Drawings) with a proven layering standard. Deviation from this requirement shall be:

1. At the sole discretion of the Engineer.
2. Submitted as a substitution within the specified time frame.

D. Related work specified elsewhere:

1. Providing temporary heat.
2. Providing finish painting.
3.
4. Access doors.
5. Trench covers and frames.
6. Providing chimney cleanout door and thimble.
7. Cutting and patching, except as noted in "AIA Document A201" and "Supplementary Conditions for Mechanical and Electrical Work.
8. Excavating and backfilling under building.
9. Excavating and backfilling.
10. Louvers in doors.
11. Undercut doors.
12. Wall louvers and screens.
13. Plenums other than sheet metal.
14. Flashing.
15. Shaft gratings.
16. Equipment platforms.
17. Pipe heat tracing system.

1.10 QUALITY ASSURANCE

A. All equipment and accessories to be the product of a manufacturer regularly engaged in its manufacture.

B. Supply all equipment and accessories new and free from defects.

C. Supply all equipment and accessories in compliance with the applicable standards and with all applicable national, state and local codes.

D. All items of a given type shall be the products of the same manufacturer.

E. Steel Support Welding: Qualify processes and operators according to AWS D1.1, "Structural Welding Code--Steel."

F. Steel Pipe Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."

1. Comply with provisions in ASME B31 Series, "Code for Pressure Piping."
2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

G. Electrical Characteristics for HVAC Equipment: Equipment of higher electrical characteristics may be furnished provided such proposed equipment is approved in writing and connecting electrical services, circuit breakers, and conduit sizes are appropriately modified. If minimum energy ratings or efficiencies are specified, equipment shall comply with requirements. All costs of any required changes, including redesign requirements, shall be the responsibility of the contractor.

1.11 REFERENCE STANDARDS

A. Published codes, specifications, standards, tests or recommended methods of trade, industry or governmental organizations apply to work in this Division where cited below:

1. AABC: Associated Air Balance Council.
2. ADC: Air Diffuser Council.
3. AMCA: Air Moving and Conditioning Association.
4. ANSI: American National Standards Institute.
5. ARI: Air-Conditioning and Refrigeration Institute.
6. ASHRAE: American Society of Heating, Refrigerating and Air Conditioning Engineers.
7. ASME: American Society of Mechanical Engineers.
8. ASSE: American Society of Sanitary Engineers.
9. ASTM: American Society for Testing and Materials.
10. AWS: American Welding Standards.
11. FM: Factory Mutual.
12. Local Utility Authorities.
13. National, State and Local Codes of all authorities having jurisdiction.
14. NEMA: National Electrical Manufacturer's Association.
15. NFPA: National Fire Protection Association.
16. OSHA: Occupational Safety and Health Act.
17. PDI: Plumbing and Drainage Institute.
18. State Energy Code having jurisdiction
19. FBC: Florida Building Code.
20. UL: Underwriters' Laboratories, Inc.
21. FMC: Florida Mechanical Code.
22. FPC: Florida Plumbing Code.

B. In addition to complying with all other legal requirements, comply with current provisions of governing codes and regulations in effect during progress of the Work, and with the following:

1. Drawings and specification requirements shall govern where they exceed Code and Regulation requirements.

2. Where requirements between governing Codes and Regulations vary, the more restrictive provisions shall apply.
3. Nothing contained in Contract Documents shall be construed as authority or permission to disregard or violate legal requirements. The Contractor shall immediately draw the attention of the Architect to any such conflicts noted in the Contract Documents.

1.12 COORDINATION

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

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

C. Coordinate requirements for access panels and doors for HVAC items requiring access that are concealed behind finished surfaces.

1.13 SPECIAL TOOLS

A. Furnish to Owner at completion of work:

1. One set of any special tools required to operate, adjust, dismantle or repair equipment furnished under any section of this Division.
2. "Special tools": those not normally found in possession of mechanics or maintenance personnel.
3. One pressure grease gun for each type of grease required.

    a. With adapters to fit all lubricating fittings on equipment.
    b. Include lubricant for lubricated plug valves.

4. Tag each item and cross reference in Maintenance Manual.
5. Turn over to Owner's representative or temporarily secure to unit at Architect's instruction.

1.14 DELIVERY, STORAGE, AND HANDLING

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

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

C. Check dimensions of access route through the site from delivery point to final location. Where necessary, ship in crated sections of size to permit passing through available space. Dismantle and/or reassemble, reprovision and retest equipment too large to pass through available access route to final location in one piece.

D. Ship equipment in original packages, to prevent damaging or entrance of foreign matter.

E. Handle and ship in accordance with manufacturer's recommendations.

F. Provide protective coverings during construction.

G. Replace at no expense to Owner, equipment or material damaged during storage or handling, as directed by Architect.

H. Tag all items with weatherproof tag, identifying equipment by name and purchase order number.

I. Include packing and shipping lists.

J. Special requirements as specified in individual sections.

1.15 PROTECTION OF MATERIALS

A. Protect from damage, water, dust, etc., material, equipment and apparatus provided under this Division, both in storage and installed, until Notice of Completion has been filed.

B. Provide temporary storage facilities for material and equipment.

C. Arrange with Owner for storage facilities for materials and equipment.

D. Material, equipment or apparatus damaged because of improper storage or protection will be rejected.

1. Remove from site and provide new, duplicate, material equipment or apparatus in replacement of that rejected.

E. Cover motors and other moving machinery to protect from dirt and water during construction.

F. Protect premises and work of other Divisions from damage arising out of installation of work of this Division.

1. Repair or replace, as directed by Architect, materials and parts of premises which become damaged as result of installation of work of this Division.
2. Remove replaced parts from premises.

1.16 REVIEW OF CONSTRUCTION

A. Work may be reviewed at any time by representatives of Architect.

B. Advise Architect in writing that work is ready for review at following times:
   1. Prior to backfilling buried work.
   2. Prior to concealment of work in walls and above ceilings.
   3. When all requirements of Contract have been completed.

C. Neither backfill nor conceal work without Architect's consent.

1.17 SCHEDULE OF WORK

A. Arrange work to conform to schedule of construction established or required to comply with Contract Documents.

B. In scheduling, anticipate means of installing equipment through available openings in structure.

C. All equipment and materials shall be protected from damages, exposure to moisture and weather from the time of delivery to job site until date of substantial completion.

D. Confirm in writing to Architect, within 30 days of signing of contract, anticipated number of days required to perform test, balance, and acceptance testing of mechanical systems:

   1. This phase must occur after completion of mechanical systems, including all control calibration and adjustment, and requires substantial completion of the building, including closure, ceilings, lighting, partitioning, etc.
   2. Submit for approval at this time, names and qualifications of test and balancing agencies to be used.

1.18 NOISE REDUCTION

A. Cooperate in reducing objectionable noise or vibration caused by mechanical systems.

   1. To extent of adjustments to specified and installed equipment and appurtenances.

B. Correct noise problems caused by failure to install work in accordance with Contract Documents. Include labor and materials required as result of such failure.

1.19 PERMITS, LICENSES, AND INSPECTIONS

A. Permits and Licenses:

   1. Secure required permits and licenses including payments of all charges and fees.

B. Inspections:

   1. Obtain certificates of final inspection approval from authorities having jurisdiction, and submit to Architect before acceptance of the Work.

2. Obtain inspections during the Work as required to allow timely progress of these and other trades.

1.20 GUARANTEE

A. Guarantee all materials, equipment, apparatus and workmanship to be free of defective materials and faulty workmanship for period of one year from date of filing of Notice of Completion, unless extended guarantee periods are specified in individual sections.

B. Furnish guarantee covering all work in accordance with general requirements of the Contract.

C. Provide new materials, equipment, apparatus and labor to replace that determined by Architect to be defective or faulty.

D. This guarantee also applies to services such as Instructions, Adjusting, Testing, Noise, Balancing, etc.

E. Equipment manufacturers shall include extended warranty to give full coverage during warranty period, unless longer period is specified.

1.21 PRELIMINARY OPERATION

A. Any portion of the system or equipment shall be placed in operation at the request of the Owner prior to the final completion and acceptance of the work. Such operation shall be under the direct supervision of the Contractor.

B. Preliminary operation thereof shall not be construed as acceptance of any part of the Work.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. In other Division 23 Sections where articles and subparagraphs introduce lists, the following requirements apply for product selection:

1. Contractor's Options:

a. For products specified only by reference standard, select product meeting that standard, by any manufacturer.
b. For products specified by naming several products or manufacturers, select any one of products and manufacturers named which complies with Specifications.
c. For products specified by naming one product or manufacturer, use that product or manufacturer only.

d. Wherever catalog numbers and specific brands or trade names are used, they are used to establish standards of quality, utility and appearance required.

B. Submission of equipment of manufacturers' other than those specified shall detail equality and difference, item by item.

2.2 GROUT

A. Description: ASTM C 1107, Grade B, nonshrink and nonmetallic, dry hydraulic-cement grout.

1. Characteristics: Post-hardening, volume-adjusting, nonstaining, noncorrosive, nongaseous, and recommended for interior and exterior applications.
2. Design Mix: 5000-psi, 28-day compressive strength.
3. Packaging: Premixed and factory packaged.

2.3 ACCESS DOORS

A. Size for proper access, adjusting and maintenance:

1. 12 in. x 12 in. minimum for valves, trap primers, shock absorbers, etc.
2. 24 in. x 24 in. for man access to concealed fans, coils, etc., unless indicated otherwise.

B. Supply as required by work in this Division.

C. Turn over for setting under trade installing surface on which panels are installed. Direct location and setting, after review by architect.

D. Manufacturers:

1. Access doors:
   a. See Division 8

E. Locate and set after review.

F. Doors, except as noted, flush type with:

1. No. 13 USSG steel door and trim.
2. No. 16 USSG steel frame.
3. Metal wings for keying into construction.
4. Concealed hinges.
5. Stainless steel cam lock, screwdriver operated.
6. Similar to Karp Type DSC-214.
7. Where door cannot swing open:

   a. Lift off type.

b. With safety wire or chain.
c. Similar to Karp Type DSC-212.

G. Doors, in acoustic tile ceilings:

1. No. 13 USSG steel frame.
2. No. 16 USSG steel pan-type door suitable for receiving tile thickness.
3. Factory white finish.
4. Stainless steel cam locks:

   a. Screwdriver operated.
   b. Finish flush with tile.
   c. Minimum 2 per door.

5. Hinges: not visible when door is closed.
6. Tile filler: under General construction Work.
7. Similar to Karp Type DSC-210.

H. Doors recessed in plaster ceilings:

1. With recess to receive plaster.
2. Plaster fill: under General Construction Work.
3. Similar to Karp DSC-210-PL.

I. Doors in fire-rated construction:

1. Insulated door panel and frame.

   a. Frame: 16 gauge steel.
   b. Panel: 20 gauge steel.
   c. 2 in. thick fire rated insulation.

2. Conform to requirements of regulating agencies.
3. Rating: UL 1 1/2 hour "B" label, 250°F rating.
4. Continuous hinge with stainless steel pin.
5. Automatic panel closer.
6. Interior latch release.
7. Finish:
   a. Stainless steel.
   b. With stainless steel trim for frame.
   c. No. 4 satin finish.

8. Lock:

   a. Self-latching.
   b. Direct action knurled knob.
   c. Flush screwdriver operated.
   d. Key-operated cylinder lock with two keys.
   e. Knurled knob and mortise cylinder. Cylinder replaceable with cylinder for master keying system.

f. Similar to Karp Type KRP-150 FR.

J. Doors: Shop-painted 1 coat zinc chromate primer.

2.4 ACCESS TILE IDENTIFICATION

A. Buttons, tabs, and markers: to identify location of concealed work.

B. Submit for review.

2.5 PAINTING

A. See Division 9, Painting

PART 3 - EXECUTION

3.1 PIPING SYSTEMS - COMMON REQUIREMENTS

A. Install piping according to the following requirements and Division 23 Sections specifying piping systems.

B. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

C. Install piping in concealed locations, unless otherwise indicated and except in equipment rooms and service areas.

D. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

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

F. Install piping to permit valve servicing.

G. Install piping at indicated slopes.

H. Install piping free of sags and bends.

I. Install fittings for changes in direction and branch connections.

J. Install piping to allow application of insulation.

K. Select system components with pressure rating equal to or greater than system operating pressure.

L. Install escutcheons for penetrations of walls, ceilings, and floors according to the following:

1. New Piping:

a. Piping with Fitting or Sleeve Protruding from Wall: One-piece, deep-pattern type.
b. Chrome-Plated Piping: One-piece, cast-brass type with polished chrome-plated finish.
c. Insulated Piping: One-piece, stamped-steel type with spring clips.
d. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, cast-brass type with polished chrome-plated finish.
e. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, stamped-steel type.
f. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece or split-casting, cast-brass type with polished chrome-plated finish.
g. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece, stamped-steel type or split-plate, stamped-steel type with concealed hinge and set screw.
h. Bare Piping in Unfinished Service Spaces: One-piece, cast-brass type with polished chrome-plated finish.
i. Bare Piping in Unfinished Service Spaces: One-piece, stamped-steel type concealed or exposed-rivet hinge and set screw or spring clips.
j. Bare Piping in Equipment Rooms: One-piece, cast-brass type.
k. Bare Piping in Equipment Rooms: One-piece, stamped-steel type with set screw or spring clips.
l. Bare Piping at Floor Penetrations in Equipment Rooms: One-piece, floor-plate type.

M. Sleeves are not required for core-drilled holes.

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

O. Install sleeves for pipes passing through concrete and masonry walls and concrete floor and roof slabs.

P. Install sleeves for pipes passing through concrete and masonry walls, gypsum-board partitions, and concrete floor and roof slabs.

1. Cut sleeves to length for mounting flush with both surfaces.

a. Exception: Extend sleeves installed in floors of mechanical equipment areas or other wet areas 2 inches above finished floor level. Extend cast-iron sleeve fittings below floor slab as required to secure clamping ring if ring is specified.

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

3. Install sleeves that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation. Use the following sleeve materials:

    a. Steel Pipe Sleeves: For pipes smaller than NPS 6.
    b. Steel Sheet Sleeves: For pipes NPS 6 and larger, penetrating gypsum-board partitions.
    c. Stack Sleeve Fittings: For pipes penetrating floors with membrane waterproofing. Secure flashing between clamping flanges. Install section of cast-iron soil pipe to extend sleeve to 2 inches above finished floor level. Refer to Division 07 Section "Sheet Metal Flashing and Trim" for flashing.

        1) Seal space outside of sleeve fittings with grout.

4. Except for underground wall penetrations, seal annular space between sleeve and pipe or pipe insulation, using joint sealants appropriate for size, depth, and location of joint. Refer to Division 07 Section "Joint Sealants" for materials and installation.

Q. Aboveground, Exterior-Wall Pipe Penetrations: Seal penetrations using sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve for installing mechanical sleeve seals.

1. Install steel pipe for sleeves smaller than 6 inches in diameter.
2. Install cast-iron "wall pipes" for sleeves 6 inches and larger in diameter.
3. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

R. Underground, Exterior-Wall Pipe Penetrations: Install cast-iron "wall pipes" for sleeves. Seal pipe penetrations using mechanical sleeve seals. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve for installing mechanical sleeve seals.

1. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

S. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Refer to Division 07 Section "Penetration Firestopping" for materials.

T. Verify final equipment locations for roughing-in.

U. Refer to equipment specifications in other Sections of these Specifications for roughing-in requirements.

3.2 PIPING JOINT CONSTRUCTION

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

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

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

D. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.

E. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8.

F. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

G. Welded Joints: Construct joints according to AWS D10.12, using qualified processes and welding operators according to Part 1 "Quality Assurance" Article.

H. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

I. Grooved Joints: Grooved joint piping systems shall be installed in accordance with the manufacturer's guidelines and recommendations. All grooved couplings, fittings, valves and specialties shall be supplied by a single manufacturer. Grooving tools shall be supplied by the same manufacturer as the grooved components. The gasket style and elastomeric material (grade) shall be verified as suitable for the intended service as specified. Gaskets shall be supplied by the grooved coupling manufacturer. Grooved end shall be clean and free from indentations, projections and roll marks in the area from pipe end to groove for proper gasket sealing. A factory trained field representative shall provide on-site training to contractor's field personnel in the installation of grooved piping products. Factory trained representative shall periodically review the product installation. Contractor shall remove and replace any improperly installed products.

3.3 PIPING CONNECTIONS

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

1. Install unions, in piping NPS 2 and smaller, adjacent to each valve and at final connection to each piece of equipment.
2. Install flanges or grooved-joint couplings in piping NPS 2-1/2 and larger, adjacent to flanged or-grooved-ended valves and at final connection to each piece of equipment.
3. Dry Piping Systems: Install dielectric unions and flanges to connect piping materials of dissimilar metals.
4. Wet Piping Systems: Install dielectric coupling and nipple fittings to connect piping materials of dissimilar metals.

3.4 EQUIPMENT INSTALLATION - COMMON REQUIREMENTS

A. Install equipment to allow maximum possible headroom unless specific mounting heights are indicated.

B. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, unless otherwise indicated.

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

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

E. Access to Valves and Equipment.

1. Access shall be possible where valves, expansion joints, fire dampers, motors, filters, control devices, and any other equipment requiring access for servicing, repairs, or maintenance are located in walls, chases, and/or above ceilings.
2. Definition of Accessible:

   a. Valves and dampers may be operated.
   b. Control devices may be adjusted.
   c. Fire dampers may be reset.
   d. Equipment access panels may be opened.
   e. Normal maintenance work such as replacement of filters, lubrication of bearings, etc., may be performed readily within arm's reach of access opening.
   f. It shall not be necessary to crawl through furred ceiling space to perform such operations.

3. Group concealed valves, expansion joints, controls, dampers and equipment requiring service access, so as to be freely accessible through access doors and to minimize the number of access doors required.
4. Relocate piping equipment and accessories as required, at no extra cost to afford proper maintenance access.
5. For access into ductwork see Section 233300: Air Duct Accessories.
6. Coordinate location of access panels with applicable trades installing walls or ceiling.

a. Coordinate panel locations with lights and other architectural features.
b. Submit proposed panel locations to Architect for review.

7. Access doors or panels will be installed by the trade furnishing surface on which panels are installed.
8. Arrange for location and marking of removable tiles in splined ceilings where access panels are not installed.

3.5 PAINTING

A. All paint and coatings used within the waterproofing membrane must comply with the Low Emitting Pai9nt and Coatings testing criteria. Refer to Sections 01 35 46 and 01 81 13.14 for requirements.

B. Painting of exposed roof-top equipment.

C. Finish painting under Division 09 Sections “Interior Panting” and “Exterior Painting.”.

1. Colors coordinated by Mechanical Contractor as directed by Architect.

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

E. Painting under this Division:

1. Interior of ductwork as far back as visible from outside: flat black.
2. Uncoated hangers, supports, rods and inserts: dip in zinc chromate primer.
3. Factory prime coat for following except as noted.

a. Pumps.
b. Fans.
c. Motors.
d. Equipment.
e. Air outlets.

4. Marred surfaces of prime coated equipment and piping: spot prime coat to match adjacent coat.
5. Shop prime coat for following, except as noted:

a. Structural frames.
b. Platforms.
c. Ladders.
d. Railings.
e. Tanks.

F. General:

1. Labor, materials and equipment necessary for field painting.
2. Protect flooring and equipment with drip cloths.

3. Paint and materials stored in location where directed.
4. Oily rags and waste removed from building every night.
5. Furnish each space containing stored painting materials with approved 2½ gallon fire extinguisher.
6. Wire brush and clean off all oil, dirt and grease areas to be painted before paint is applied.
7. Mixing:

    a. Mixed and strained as required by manufacturer.
    b. Use thinners only in accordance with manufacturer's recommendation.
    c. Follow printed instructions on paint containers. If none are available, instructions shall be obtained in writing from manufacturer.

8. Workmanship:

    a. No painting or finishing shall be done with:

        1) Dust laden air.
        2) Unsuitable weather conditions.
        3) Space temperature below 60°F.

    b. Pipes being painted: containing no heat and to remain cold until paint is dried.
    c. Paint spread: uniform and proper film thickness showing no runs, sags, crawls or other defects.
    d. Finished surfaces shall be uniform in sheen, color, and texture.
    e. All coats to be thoroughly dry before succeeding coats are applied, minimum 24 hrs. between coats.
    f. Priming undercoat: slightly different color for inspection purposes.

9. Exposed, uninsulated, ungalvanized sheet metal other than stainless steel and aluminum: Two coats of aluminum paint or alkyd paint color as directed.
10. Exposed, uninsulated, galvanized sheet metal in finished space including mechanical equipment rooms:

    a. One coat galvanized iron primer.
    b. Two coats alkyd oil paint, color as directed.

11. Exposed, insulated piping and equipment covering:

    a. One coat primer sealer.
    b. Two coats alkyd oil paint, color as directed.

12. Finned tube radiation: One coat factory or field applied coat of heat resisting paint.
13. Paint following with two coats alkyd oil paint, color as directed:

    a. Exposed steel and metal work not furnished with factory-painted finish.
    b. Structural steel supports for piping ductwork and equipment.
    c. Exposed, uninsulated piping.

14. Exposed, uninsulated aluminum sheet metal in finished space:

    a. One coat zinc chromate primer.

15. No paint on exposed, uninsulated stainless steel sheet metal in finished space.

G. Finish painting:

1. Consisting of two finished coats of high gloss medium or long alkyd paint over prime coat.
2. Submit color shade for approval.
3. Piping continuously painted in all exposed areas.
4. Color coding per Section 230553: Mechanical Identification for HVAC piping and equipment

H. Interior of ductwork as far back as visible from outside: flat black.

I. Uncoated hangers, supports, rods and inserts: dip in zinc chromate primer.

J. Factory finish:

1. Steel air outlets in acoustical tile ceilings: baked white enamel.
2. Aluminum air outlets: anodized.
3. Exposed fan coil units: baked enamel.
4. Unit ventilators and unit heaters: baked enamel.

K. Factory prime coat, except as noted:

1. Pumps.
2. Fans.
3. Motors.
4. Equipment.
5. Registers.
6. Diffusers.
7. Grilles.

L. Marred surfaces of prime coated equipment and piping: spot prime coat to match adjacent coat.

M. Shop prime coat for following except as noted:

1. Structural frames.
2. Platforms.
3. Ladders.
4. Railings.
5. Tanks.

3.6 CONCRETE WORK

A. On concrete floors, install equipment on concrete housekeeping pads:

1. Pads 4 in. high unless otherwise noted.
2. Extend 6 in. minimum beyond equipment base, all sides.
3. Concrete work, including forming and reinforcing, under Division 03
   a. Coordinate size and location with General Contractor.
   b. Furnish and locate anchors and anchor bolts.

4. Curbs for field erected plenums similar.

B. Miscellaneous Concrete Items:
   1. Concrete work, including forming and reinforcing, under Division 03.
   2. Concrete for:

      a. Anchor and thrust blocks.
      b. Underground tank hold down slabs.
      c. Pipe trenches.

   3. Refer to details on drawings.

C. Provide foundations for:

   1. Pumps.
   2. Fans.
   3. Air handling units and floor mounted plenums
   4. Refrigeration equipment.
   5. Floor mounted control panels.
   6. Motors.
   7. As noted.

3.7 CONCRETE BASES

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

   1. Construct concrete bases of dimensions indicated, but not less than 4 inches larger in both directions than supported unit.
   2. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of the base.
   3. Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.
   4. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   5. Install anchor bolts to elevations required for proper attachment to supported equipment.
   6. Install anchor bolts according to anchor-bolt manufacturer's written instructions.
   7. Use 3000-psi, 28-day compressive-strength concrete and reinforcement as specified in Division 03 Section "Cast-in-Place Concrete."

3.8 ERECTION OF METAL SUPPORTS AND ANCHORAGES

A. Refer to Division 05 Section "Metal Fabrications" for structural steel.

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

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

3.9 GROUTING

A. See requirements in Divisions 3 and 4.

3.10 EXCAVATION AND BACKFILL

A. Excavate, backfill and restore surfaces inside building.

B. Excavate, backfill and restore surfaces inside and outside building.

C. Excavate, backfill and restore surfaces to 5 ft. outside building.

D. Excavation:

1. In accordance with requirements of Division 2.
2. Minimum depth, unless otherwise indicated:

    a. Metallic pipe: 24 in.
    b. Non-metallic pipe: 30 in.
    c. Below frost line.

3. If rock encountered:

    a. Excavate to 6 in. below bottom of piping.
    b. Refill with well tamped sand and gravel.

4. Bank excavated materials adjacent to trench as directed.
5. Bank supports:

    a. Sheet-piling, shoring or otherwise properly supported.

6. Install and maintain barricades, signs and lights.
7. Keep excavation free of water with attended pumping equipment.
8. No extra compensation:

    a. For quicksand, hardpan, or other material encountered in excavating.
    b. Except rock on unit price basis.

9. Remove bog or other swampy conditions encountered in excavating to 1 ft. below bottom of piping.

    a. Backfill with well tamped sand, finely crushed stone or gravel.

E. Installation of Underground Piping:

1. On solid undisturbed ground.

    a. Provide firm bed of sand for pipes with any form of protective covering.

2. On concrete or brick piers or cradles:

    a. Unsuitable ground, as directed.
    b. Trench crossings.
    c. Crossing excavation adjacent to building wall or foundations.

3. Bottom of trenches:

    a. Tamped hard.
    b. Graded for required pitch.
    c. Shaped to give uniform support to lower third of full length of pipe.
    d. Recesses excavated for bells and joints.

4. Support and protect piping so it remains in place without settling or damage during and from backfilling.

    a. Replace damaged pipe.

5. Under building:

    a. Temporarily support from below during installation and construction.
    b. Encase in concrete as detailed on Drawings.
    c. Permanently support with U rod hangers.

        1) Ends bent over reinforcing bars in construction above.
        2) Rod materials:

            a) Everdur 651 Alloy.
            b) Double-dipped galvanized steel.

        3) Minimum diameter of rods for following pipe sizes:

Up to 2 in.	3/8 in.
2 ½ to 4 in.	½ in.
5 and 6 in.	5/8 in.
8 and 10 in.	¾ in.
12 to 16 in.	7/8 in.

4) Paint hangers with heavy coat of bitumen solution paint.Paint shall comply with the Low-Emitting Paint and Coatings criteria. Refer to Division 9.

F. Backfilling:

1. Immediately after piping installed, inspected, tested and accepted:
2. Remove sheet piling and bracing.
3. Backfill around piping with special care to solidly fill voids without damage to piping.
4. Backfill material.
   a. Clean loam, clay, sand, gravel or lightweight aggregate:

      1) Sand only up to 6 in. above top of piping with any form of protective covering.
      2) Remainder to be excavated earth free from frozen materials, lumps of clay, rocks, cinders, slag, ashes, organic materials, building or other debris, or refuse.

   b. Install granular pipe insulation around pipe as specified in Section 230700: Piping Insulation.

5. Backfill:

   a. Up to 2 ft. above pipe, hand fill in 4 in. layers.
   b. Remainder, fill in 6 in. layers.
   c. Tamp and puddle each layer before placing next layer.
   d. No stones larger than 2 in. diameter allowed in fill up to 2 ft. above piping.
   e. No stones larger than 4 in. diameter allowed in fill above.
   f. Backfill in manner to prevent future settlement, in accordance with Division 2.
   g. Backfill to required compaction; per ASTM D-1557-587:
      1) 95% under building slabs.
      2) 90% outside of building.

G. Restore existing surfaces disturbed or damaged by excavation and backfilling, including, but not limited to:

1. Turf.
2. Plants.
3. Concrete walks.
4. Asphaltic paving.
5. All other surface improvements.

H. Dispose of acceptable surplus excavation on site as directed.

I. Remove surplus and unsuitable excavated materials from site as directed.

3.11 CUTTING AND PATCHING

A. All carpentry, cutting and patching to be done under trades doing that work.

B. Provide all carpentry, cutting and patching required for proper installation of material and equipment specified in this Division.

C. Do not cut or drill structural members without consent of Architect.

3.12 CUTTING THROUGH CELLULAR FLOORING

A. Cut openings for reception of work:

1. In accordance with manufacturer's recommendations and approval.
2. Not to interrupt continuity of electrical raceways.

3.13 WATER PROOFING

A. Under General Construction Work.

B. Where any work pierces waterproofing, installation shall be subject to review.

1. Provide all necessary sleeves, caulking, flashing and flashing fittings required to make openings absolutely watertight.

C. Flashing:

1. 6 lb. lead.
2. 16 oz. lead coated copper.
3. No.22 USSG aluminum.
4. Fittings for piping through roof:

a. Galvanized cast iron bottom recess roof type.
b. Similar to Josam No. 26440 or No. 26450.

D. Provide weather protection canopies, hoods or enclosures over out-of-door equipment which could be damaged by exposure to weather.

1. This requirement applies to:

a. Damper operators.
b. Damper bearings.
c. Controls.
d. Instruments.

2. See other sections in this Division for application of this requirement to motors, drives, ducts, and fans, etc.
3. Identify items under such covers if entirely enclosed.

3.14 CLEANING AND ADJUSTING

A. Brush and clean work prior to concealing, painting and acceptance. Perform in stages if directed.

B. Painted or exposed work soiled or damaged: clean and repair to match adjoining work before final acceptance.

C. Remove debris from inside and outside of materials and equipment.

D. Flush out piping after installation.

E. Clean piping systems as described in Division 23, Section Hydronic Piping.

F. Adjust valves and automatic control devices.

G. Traps, wastes and supplies: unobstructed.

3.15 FIELD QUALITY CONTROL

A. Tests:

1. Perform as specified in individual sections, and as required by authorities having jurisdiction.
2. Duration as noted.

B. Provide required labor, material, equipment, and connections.

C. Furnish written report and certification that tests have been satisfactorily completed.

D. Repair or replace defective work, as directed.

E. Pay for restoring or replacing damaged work due to tests, as directed.

F. Pay for restoring or replacing damaged work of others, due to tests, as directed.

3.16 TRAINING

A. Provide training by qualified manufacturers' representatives for equipment as specified in this Division.

B. Training to include:

1. Site-specific training. System operations, system maintenance, emergency processes (if any), warranty procedures and process, as well as what type of recording deliverable preferred. Refer to additional information included in 01 19 13 and 01 32 33.
2. Minimum hours as specified in each Section.

3. Training materials (minimum six sets).
4. Video recordings (2 copies on USB keys) of each training session upon completion.

C. Each training session to be scheduled with Owner at least 30 days in advance.

3.17 COMMISSIONING

A. Division 23 Contractors shall be responsible to carry out the commissioning requirements specified in the commissioning sections, and all other sections related to commissioning. Provide all necessary labor, materials, and coordination required for successful completion of the commissioning requirements. Refer to Specification Sections 01 91 13 General Commissioning Requirements.

3.18 ACCESS DOORS AND FRAMES

A. Provide access doors and frames of the appropriate size and locations to allow access to mechanical equipment, valves, dampers, etc. All locations are to be field verified with the Architect prior to installation.

3.19 INSTALLATION OF HVAC EQUIPMENT SUPPLIED BY OTHER DIVISIONS

A. Division 23 Contractors shall be responsible to provide all necessary labor, materials, and coordination required for successful installation of equipment provided by other divisions but vital for successful operation of HVAC equipment. Equipment and materials vital for successful operation of HVAC equipment include but are not limited to the follow:

1. Control Dampers
2. Control Valves
3. Thermowells
4. Pipe Taps
5. Water Sensors and Switches

B. Prior to performing testing and balancing work, provide copies of reports, sample forms checklists, and certificates to the OAR/ Engineer of Record.

END OF SECTION 23 05 00

SECTION 23 05 13 - COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

B. Basic Requirements: Provisions of Section 230010, BASIC HVAC REQUIREMENTS are part of this Section

1.2 SUMMARY

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

1.3 COORDINATION

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

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

PART 2 - PRODUCTS

2.1 GENERAL MOTOR REQUIREMENTS

A. Comply with requirements in this Section except when stricter requirements are specified in HVAC equipment schedules or Sections.

B. Comply with NEMA MG 1 unless otherwise indicated.

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

2.2 ELECTRIC MOTOR MANUFACTURERS:

A. Manufacturers:

1. General Electric Inc.
2. Westinghouse Electric
3. Baldor Electric Company

2.3 MOTOR CHARACTERISTICS

A. Duty: Provide motors for continuous duty conditions in which they will be required to perform; i.e., general purpose, splashproof, explosion proof, standard load, high torque, or any other special type as required by the equipment motor manufacturer's recommendations. Unless otherwise indicated or required, motors shall be open drip-proof type. Continuous duty at ambient temperature of 95 deg F and at altitude of 3300 feet above sea level.

B. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.

C. Unless otherwise indicated or required, motors shall be open drip-proof type.

D. Motors installed outdoors shall be totally enclosed fan cooled (TEFC) type.

E. Motor enclosures shall be of the type recommended by the equipment manufacturer for the specific application.

F. All motors shall be furnished for starting in accordance with the electric utility company's requirements and shall be compatible with the motor starter and driven load. Motors shall not exceed full-rated nameplate load when operated at any point along the driven equipment's characteristic performance curve. The motor service factor shall not be used to justify exceeding nameplate amperage.

G. Unless otherwise indicated, motors 1/3 horsepower and less shall be single phase. Motors 1/2 horsepower and larger shall be 3 phase, squirrel-cage induction type.

H. Sound power levels for motors shall be no greater than the guidelines recommended by NEMA MG 1-2007

I. Verify the circuit voltage and phase being furnished to the motor. All motors shall be 1800 rpm unless noted otherwise. Motors shall operate with electrical input voltage variations of plus or minus 1 percent of nameplate rating or frequency variations of plus or minus 5 percent of nameplate rating.

2.4 POLYPHASE MOTORS

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

B. Efficiency: Energy efficient, as defined in NEMA MG 1, including applications of premium efficiency motors.

C. Service Factor: 1.15.

D. Multispeed Motors: Variable torque.

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

E. Multispeed Motors: Separate winding for each speed.

F. Rotor: Random-wound, squirrel cage.

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

H. Temperature Rise: Match insulation rating.

I. Insulation: Class F.

J. Code Letter Designation:

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

K. Enclosure Material: Cast iron for motor frame sizes 324T and larger; rolled steel for motor frame sizes smaller than 324T.

2.5 POLYPHASE MOTORS WITH ADDITIONAL REQUIREMENTS

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

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

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

4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.
5. Shaft Grounding System:
   a. Motors 5 hp and greater shall have a single shaft grounding system to protect the bearings from capacitive discharge through the bearings. A shaft grounding system equal to that manufactured by Shaft Grounding Systems, Inc., CR Series, or approved equivalent shall be used.
   b. The shaft grounding system shall reduce the shaft to frame voltage below 3 volts (as measured with 50 MHZ Fluke 97 oscilloscope), have low drag, be field installable with hand held tools, sealed to be resistant to weather and contaminants and require no periodic adjustments or maintenance for a normal running life of five to ten years at speed up to 1800 rpm. The grounding brush element must be changeable without shutting down or using special tools. Experience has shown that brush life may often be as long as ten years.

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

2.6 ELECTRICALLY COMMUTATED (EC) MOTORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. ebm-papst
2. Rosenberg
3. Ziehl-Abegg
4. Approved Equal

B. Factory mounted, line-fed variable speed EC external-rotor motor with maintenance-free ball bearings and permanent lubrication.

C. Type: As indicated or selected by manufacturer from one of the following, to suit starting torque and other requirements of specific motor application.
1. Permanent-split capacitor.
2. Split-phase start, capacitor run.
3. Capacitor start, capacitor run.
4. Motors shall be permanently lubricated with heavy duty ball bearings to match the fan load and pre-wired to the specific voltage and phase.
5. Motors shall include integrated electronic control board to convert AC power supplied to the fan to DC power to operate the motor with direct micro- processing control signaling for fan speed control, soft starting capabilities and integrated current limitations.
6. Motor shall be speed controllable down to 20% of full speed (80% turndown).

D. Motor shall be a minimum of 85% efficient at all speeds

E. Wide voltage input:
1. Single phase: 200-277V, 50/60 Hz respectively
2. Three phase: 380-480V, 50/60 Hz respectively

F. Robust mechanical design with IP 55 type of protection and insulation class "F".

G. Die-cast aluminum closed and compact design with integrated electronics.

H. Shaded-Pole Motors: Do not use, unless motors are smaller than 0.05 kW.

I. Technical Features:
1. Continuous operation
2. PFC (passive)
3. Integrated PID controller
4. Control input 0-10VDC or 4-20 mA
5. Input for sensor 0-10V or 4-20 mA
6. Slave output 0-10V max. 5 mA
7. 7. Output 20VDC (±25 % / -10%) max. 50 mA
8. Output 10VDC (+3 %) max. 10 mA
9. RS485 MODBUS
10. Motor current limitation
11. Short-circuit protection
12. Alarm relay with zero-potential change-over contacts (250VAC/2A,cos ϕ = 1)
13. Line undervoltage / phase failure detection
14. Over-temperature protected electronics / motor
15. Locked-rotor protection, soft start
16. Digital inputs for day/night switch, enabling, cooling / heating
17. EMC:
    a. Interference emission acc.to EN 61000-6-3
    b. Interference immunity acc.to EN 61000-6-2
    c. Harmonics acc.to EN 61000-3-2/3
18. Leakage current: < 3,5 mA acc.to EN 61800-5-1
19. Connection leads: Via terminal box
20. Protection class: I (acc.to EN 61800-5-1)
21. Approvals: UL

2.7 SINGLE-PHASE MOTORS

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

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

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

C. Single phase motors for hard starting applications including outdoor installations shall be capacitor start/induction run or capacitor start/capacitor run type designed for the application. Motors for fans and pumps located indoor may be split phase with permanently lubricated sealed ball bearings and shall be selected for quiet operation.

Motors 1/8 horsepower and below may be shaded pole type with permanently sealed bearings.

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

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

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

2.8 POWER FACTOR

A. All equipment furnished utilizing a combined electrical load of greater than 1000 watts shall have a power factor of not less than 0.90 under rated load conditions.

1. Where motors are not available with a minimum 0.90 power factor, provide motor mounted power factor correction capacitor to improve power factor to at least 0.90 under rated load condition.

2.9 MOTOR STARTERS

A. Compliance: Motor starters included as an integral part of a factory pre-wired control panel shall be provided by the manufacturer of the equipment it serves and shall comply with the requirements of Division 26.

B. Overload Protection: Unless otherwise indicated, all 3 phase motor starters shall be provided with thermal overload relays on each phase sized in accordance with the actual nameplate full load ampere rating. Single phase motors shall be furnished with built-in thermal protection.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install material and equipment in accordance with details shown on the drawings, submittals drawings and manufacturer's instructions.

3.2 SCHEDULED HORSEPOWER

A. Nominal Size: The horsepower scheduled or specified are those nominal sizes estimated to be required by the equipment when operating at specified duties and efficiencies. In the case of pumps and fans, these motors shall be non-overloading at any point of the performance curve.

B. Minimum Size: Motor horsepower shall not be reduced from the scheduled size regardless of the requirements of the selected or submitted equipment.

C. Increased Size: If the actual motor horsepower for the equipment furnished is larger than the scheduled size indicated, the proper size feeder, breaker, starter, etc. shall be provided at no additional cost to the Owner. Change in motor size shall be identified and brought up to the engineer's attention as part of the submittal.

D. Vibration: Motor vibration in any direction as measured at the bearing housings, when tested in accordance with NEMA Standard MG 1, shall be within the following table:

1. TABLE - VIBRATION LIMITS

UNFILTERED VIBRATION LIMITS

Speed, rpm	Rotational Frequency, Hz	Velocity, in/s peak (mm/s)
3600	60	0.15 (3.8)
1800	30	0.15 (3.8)
1200	20	0.15 (3.8)
900	15	0.12 (3.0)
720	12	0.09 (2.3)
600	10	0.08 (2.0)

2. If balance weights are added to the rotor, they shall be permanently secured by welding or riveting. Machine nuts, bolts and screws are prohibited.

3.3 WIRING

A. Power: All power wiring including safety disconnect switches, motor starters, over-current protection, connection to equipment, etc. shall be installed according to the requirements of Division 26, ELECTRICAL.

B. Interlock: Unless otherwise noted, all interlock wiring, such as remote line voltage thermostats, fan speed controllers, etc. shall be installed by the supplier of that equipment. Interlock wiring shall be installed according to the requirements of Division 26, ELECTRICAL.

C. Control: All control wiring exposed in mechanical equipment rooms, fan rooms, return air plenums, etc. shall be in conduit. Low voltage control wiring may be installed without conduit in return air plenums provided the cable is plenum rated and installed in an approved raceway system. Control wiring freely run in concealed plenums is not acceptable for any applications on this project.

3.4 WEATHER PROTECTION

A. Wiring: All electrical wiring exposed to the weather or in damp locations shall be enclosed in weatherproof fittings as required in Division 26, ELECTRICAL.

B. Enclosures: Enclosures for electrical equipment shall be NEMA 3R unless indicated otherwise.

END OF SECTION 23 05 13

SECTION 23 05 14 - VARIABLE FREQUENCY MOTOR CONTROLLERS & MAGNETIC MOTOR CONTROLLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 DESCRIPTION

A. This specification is to cover a complete Variable Frequency motor Drive (VFD) consisting of a pulse width modulated (PWM) inverter designed for use with a standard NEMA Design B induction motor.

B. The drive manufacturer shall supply the drive and all necessary options, specified. The manufacturer shall have been engaged in the production of this type of equipment for a minimum of ten years. All VFDs installed on this project shall be from the same manufacturer.

C. Magnetic motor controller for constant speed fans and pumps matching the electrical and horsepower requirements as indicated on drawings and equipment schedules.

1.3 SUMMARY

A. Related Sections

1. Section 237313 – Modular Air-Handling Units
2. Section 233423 - HVAC Power Ventilators
3. Section 232123 - Hydronic Pumps
4. Section 230900 – Instrumentation and Control For HVAC

B. Section includes separately enclosed, pre-assembled, combination VFCs and motor controllers, rated 600 V and less, for speed control of three-phase, squirrel-cage induction motors.

C. Refer to Division 26 for additional electrical requirements for the specifications and installation of equipment specified in this section.

1.4 REFERENCES

A. Institute of Electrical and Electronics Engineers

1. IEEE C62.41 – Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.

B. National Electrical Manufacturers Association

1. NEMA 250 – Enclosures for Electrical Equipment (1000 Volts Maximum).

2. NEMA FU 1 – Low Voltage Cartridge Fuses.
3. NEMA ICS 7 – Industrial Control and Systems: Adjustable Speed Drives.
4. NEMA ICS 7.1 – Safety Standards for Construction and Guide for Selection, Installation, and Operation of Adjustable Speed Drive Systems.

C. International Electrical Testing Association

1. NETA ATS – Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems.

1.5 SUBMITTALS

A. Shop Drawings: Indicate front and side views of enclosures with overall dimensions and weights shown; conduit entrance locations and requirements; and nameplate legends.

B. Product Data: For each type and rating of VFC or magnetic motor controller indicated. Include the following features:

1. Performance
2. Electrical Ratings
3. Operating Characteristics
4. Dimensioned outline drawing
5. Schematic diagram
6. Component list
7. Power and control connection diagram(s).
8. Bacnet Interface Controller (BACnet MSTP)

9. Compliance to IEEE 519 – harmonic analysis for particular jobsite including total harmonic voltage distortion and total harmonic current distortion (TDD).

a. The VFD manufacturer shall provide calculations; specific to this installation, showing total harmonic voltage distortion is less than 5%. If Distortion is more than 5%, then an external Harmonic Mitigation Filter shall be provided by the Manufacturer. Testing shall be performed and certified in accordance with IEEE per Manufacturer or an independent certified Electrical Testing Laboratory specialized in these tests. Input filters shall be sized and provided as required by the VFD manufacturer to ensure compliance with IEEE standard 519. All VFD's shall include a minimum of 5% impedance reactors.

C. Test Reports: Indicate field test and inspection procedures and test results.

D. Manufacturer's Field Reports: Indicate start-up inspection findings.

E. Harmonic Analysis Study and Report: Comply with IEEE 399 and NETA Acceptance Testing Specification; indentify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze possible operating scenarios, including recommendations for VFC input filtering to limit TDD and THD (V) at each VFC to specified levels. Testing shall be performed and certified in accordance with IEEE per Manufacturer or an independent certified Electrical Testing Laboratory specialized in these tests.

F. Provide list of all "read only" integration points, functions and alarms available at the BMS via BACnet MSTP integration.

1.6 CLOSEOUT SUBMITTALS

A. Section 01 - Execution and closeout requirements.

B. Provide final equipment submittal information with all noted corrections incorporated.

C. Field quality-control reports

D. Operation and Maintenance Data: Submit instructions complying with NEMA ICS 7.1. Include procedures for starting and operating controllers, and describe operating limits possibly resulting in hazardous or unsafe conditions. Include routine preventive maintenance schedule.

1. Manufacturer's written instructions for testing and adjusting thermal-magnetic circuit breaker and MCP trip setting.
2. Manufacturer's written instructions for setting field-adjustable overload relays.
3. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.
4. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.

E. Load Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed and arrange to demonstrate that switch settings for motor-running overload protection suit actual motor to be protected.

1.7 QUALITY ASSURANCE

A. Refer to calculation and additional testing requirements located within Division 26 and Part 3 of this Section.

B. 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.

C. QUALITY ASSURANCE

1. Referenced Standards:

a. Institute of Electrical and Electronic Engineers (IEEE)

1) Standard 519-1992, IEEE Guide for Harmonic Content and Control.

b. Underwriters laboratories

1) UL508C

c. National Electrical Manufacturer's Association (NEMA)

1) ICS 7.0, AC Adjustable Speed Drives

d. IEC 16800 Parts 1 and 2

e. National Electric Code (NEC)

1) NEC 430.120, Adjustable-Speed Drive Systems

2. Qualifications:

a. VFDs and magnetic motor controllers shall be UL listed as a complete assembly.
b. VFD's that require the customer to supply external fuses for the VFD to be UL listed are not acceptable. VFDs with red label UL stickers, requiring additional branch circuit protection are not acceptable. The base VFD shall be UL listed for 100 KAIC without the need for input fuses.

1.8 DELIVERY, STORAGE AND HANDLING

A. Section 01 – Product Requirements: Product storage and handling requirements.

B. Store in clean, dry space. Maintain factory wrapping and provide additional plastic cover to protect units from dirt, water, construction debris, and traffic.

C. Handle in accordance with manufacturer's written instructions. Lift only with lugs provided. Handle carefully to avoid damage to components, enclosure, and finish.

1.9 PROJECT CONDITIONS

A. Environmental Limitations: Rate equipment for continuous operation, capable of driving full load without derating, under the following conditions:

1. Ambient Temperature: Not less than 14 deg. F. and not exceeding 104 deg. F.
2. Ambient Storage Temperature: Not less than minus 4 deg. F. and not exceeding 140 deg. F.
3. Humidity: Less than 95 percent (noncondensing).
4. Altitude: Not Exceeding 1000 feet.

B. Conform to NEMA ICS 7 service conditions during and after installation of variable frequency controllers.

1.10 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace VFCs and motor controllers that fail in materials or workmanship within the specified warranty period.

B. Furnish five year manufacturer warranty for variable frequency controller, starting from the date of Substantial Completion

1.11 TRAINING

A. Contractor shall provide 16 hours of training to facility staff divided into 4 sessions.

B. Training shall be video taped by a licensed videographer. One DVD copy shall be provided to the owner and one DVD copy shall be provided to the commissioning agent for issuance into the commissioning report.

1.12 MAINTENANCE SERVICE

A. Section 01 – Execution and Closeout Requirements: Maintenance service.

B. Furnish service and maintenance of variable frequency controller for one year from Date of Substantial Completion.

PART 2 - PRODUCTS

2.1 VARIABLE FREQUENCY CONTROLLER

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. ABB.
2. Danfoss Inc.; Danfoss Drives Division (Labeled Drives Manufactured by Danfoss Inc. also Permitted)
3. Siemens Energy & Automation, Inc.
4. Square D; a brand of Schneider Electric.
5. Yaskawa Electric America, Inc; Drives Division

2.2 VARIABLE FREQUENCY CONTROLLER

A. The VFD package as specified herein shall be enclosed in a UL Listed Type enclosure, exceeding NEMA enclosure design criteria (enclosures with only NEMA ratings are not acceptable), completely assembled and tested by the manufacturer in an ISO9001 facility. The VFD tolerated voltage window shall allow the VFD to operate from a line of +30% nominal, and -35% nominal voltage as a minimum.

1. Environmental operating conditions: VFDs shall be capable of continuous operation at 0 to 500 C (32 to 1220 F) ambient temperature as per VFD manufacturers documented/submittal data or VFD must be oversized to meet these temperature requirements. Not acceptable are VFD's that can only operate at 40° C intermittently (average during a 24 hour period) and therefore must be oversized. Altitude 0 to 3300 feet above sea level, less than 95% humidity, non-condensing. All circuit boards shall have conformal coating.

B. All VFDs shall have the following standard features:

1. All VFDs shall have the same customer interface, including digital display, and keypad, regardless of horsepower rating. The keypad shall be removable, capable of remote mounting and allow for uploading and downloading of parameter settings as an aid for start-up of multiple VFDs.
2. VFDs shall be capable to operate with a minimum power factor of 0.95

3. The keypad shall include Hand-Off-Auto selections and manual speed control. The drive shall incorporate "bumpless transfer" of speed reference when switching between "Hand" and "Auto" modes. There shall be fault reset and "Help" buttons on the keypad. The Help button shall include "on-line" assistance for programming and troubleshooting.
4. There shall be a built-in time clock in the VFD keypad. The clock shall have a battery backup with 10 years minimum life span. The clock shall be used to date and time stamp faults and record operating parameters at the time of fault. If the battery fails, the VFD shall automatically revert to hours of operation since initial power up. Capacitor back-up is not acceptable. The clock shall also be programmable to control start/stop functions, constant speeds, PID parameter sets and output Form-C relays. The VFD shall have a digital input that allows an override to the time clock (when in the off mode) for a programmable time frame. There shall be four (4) separate, independent timer functions that have both weekday and weekend settings.
5. The VFD's shall utilize pre-programmed application macro's specifically designed to facilitate start-up. The Application Macros shall provide one command to reprogram all parameters and customer interfaces for a particular application to reduce programming time. The VFD shall have two user macros to allow the end-user to create and save custom settings.
6. The VFD shall have cooling fans that are designed for easy replacement. The fans shall be designed for replacement without requiring removing the VFD from the wall or removal of circuit boards. The VFD cooling fans shall operate only when required. To extend the fan and bearing operating life, the VFD shall cycle the cooling fans on and off as required.
7. The VFD shall be capable of starting into a coasting load (forward or reverse) up to full speed and accelerate or decelerate to set point without tripping or component damage (flying start).
8. The VFD shall have the ability to automatically restart after an over-current, over-voltage, under-voltage, or loss of input signal protective trip. The number of restart attempts, trial time, and time between attempts shall be programmable.
9. The overload rating of the drive shall be 110% of its normal duty current rating for 1 minute every 10 minutes, 130% overload for 2 seconds. The minimum FLA rating shall meet or exceed the values in the NEC/UL table 430.250 for 4-pole motors.
10. The VFD shall have internal 5% impedance reactors to reduce the harmonics to the power line and to add protection from AC line transients. The 5% impedance may be from dual (positive and negative DC bus) reactors, or 5% AC line reactors. VFD's with only one DC reactor shall add an AC line reactor.
11. The input current rating of the VFD shall be no more than 3% greater than the output current rating. VFD's with higher input current ratings require the upstream wiring, protection devices, and source transformers to be oversized per NEC 430.120. Input and output current ratings must be shown on the VFD nameplate.
12. The VFD shall include a coordinated AC transient surge protection system consisting of 4-120 joule rated MOV's (phase to phase and phase to ground), a capacitor clamp, and 5% impedance reactors.
13. The VFD shall provide a programmable loss-of-load (broken belt / broken coupling) Form-C relay output. The drive shall be programmable to signal the loss-of-load condition via a keypad warning, Form-C relay output, and / or over the serial communications bus. The loss-of-load condition sensing algorithm

shall include a programmable time delay that will allow for motor acceleration from zero speed without signaling a false loss-of-load condition.

14. The VFD shall have user programmable underload and overload curve functions to allow user defined indications of broken belt or mechanical failure / jam condition causing motor overload
15. The VFD shall include multiple "two zone" PID algorithms that allow the VFD to maintain PID control from two separate feedback signals (4-20mA, 0-10V, and / or serial communications). The two zone control PID algorithm will control motor speed based on a minimum, maximum, or average of the two feedback signals. All of the VFD PID controllers shall include the ability for "two zone" control.
16. If the input reference (4-20mA or 2-10V) is lost, the VFD shall give the user the option of either (1) stopping and displaying a fault, (2) running at a programmable preset speed, (3) hold the VFD speed based on the last good reference received, or (4) cause a warning to be issued, as selected by the user. The drive shall be programmable to signal this condition via a keypad warning, Form-C relay output and / or over the serial communication bus.
17. The VFD shall have programmable "Sleep" and "Wake up" functions to allow the drive to be started and stopped from the level of a process feedback signal.

C. All VFDs to have the following adjustments:

1. Three (3) programmable critical frequency lockout ranges to prevent the VFD from operating the load continuously at an unstable speed. The lockout range must be fully adjustable, from 0 to full speed.
2. Two (2) PID Set point controllers shall be standard in the drive, allowing pressure or flow signals to be connected to the VFD, using the microprocessor in the VFD for the closed-loop control. The VFD shall have 250 ma of 24 VDC auxiliary power and be capable of loop powering a transmitter supplied by others. The PID set point shall be adjustable from the VFD keypad, analog inputs, or over the communications bus. There shall be two independent parameter sets for the PID controller and the capability to switch between the parameter sets via a digital input, serial communications or from the keypad. The independent parameter sets are typically used for night setback, switching between summer and winter set points, etc.
3. There shall be an independent, second PID loop that can utilize the second analog input and modulate one of the analog outputs to maintain the set point of an independent process (ie. valves, dampers, etc.). All set points, process variables, etc. to be accessible from the serial communication network.
4. Two (2) programmable analog inputs shall accept current or voltage signals.
5. Two (2) programmable analog outputs (0-20ma or 4-20 ma). The outputs may be programmed to output proportional to Frequency, Motor Speed, Output Voltage, Output Current, Motor Torque, Motor Power (kW), DC Bus voltage, Active Reference, Active Feedback, and other data.
6. Six (6) programmable digital inputs for maximum flexibility in interfacing with external devices. All digital inputs shall be programmable to initiate upon an application or removal of 24VDC or 24VAC.
7. Three (3) programmable, digital Form-C relay outputs. The relay outputs shall include programmable on and off delay times and adjustable hysteresis. The relays shall be rated for maximum switching current 8 amps at 24 VDC and 0.4 A at 250 VAC; Maximum voltage 300 VDC and 250 VAC; continuous current rating

of 2 amps RMS. Outputs shall be true Form-C type contacts; open collector outputs are not acceptable.

8. Run permissive circuit - There shall be a run permissive circuit for damper or valve control. Regardless of the source of a run command (keypad, input contact closure, time-clock control, or serial communications), the VFD shall provide a dry contact closure that will signal the damper to open (VFD motor does not operate). When the damper is fully open, a normally open dry contact (end-switch) shall close. The closed end-switch is wired to a VFD digital input and allows VFD motor operation. Two separate safety interlock inputs shall be provided. When either safety is opened, the motor shall be commanded to coast to stop and the damper shall be commanded to close. The keypad shall display "start enable 1 (or 2) missing". The safety input status shall also be transmitted over the serial communications bus.
9. The VFD control shall include a programmable time delay for VFD start and a keypad indication that this time delay is active. A Form C relay output provides a contact closure to signal the VAV boxes open. This will allow VAV boxes to be driven open before the motor operates. The time delay shall be field programmable from 0 – 120 seconds. Start delay shall be active regardless of the start command source (keypad command, input contact closure, time-clock control, or serial communications), and when switching from drive to bypass.
10. Seven (7) programmable preset speeds.
11. Two independently adjustable accel and decel ramps with 1 – 1800 seconds adjustable time ramps.
12. The VFD shall include a motor flux optimization circuit that will automatically reduce applied motor voltage to the motor to optimize energy consumption and reduce audible motor noise. The VFD shall have selectable software for optimization of motor noise, energy consumption, and motor speed control.
13. The VFD shall include a carrier frequency control circuit that reduces the carrier frequency based on actual VFD temperature that allows higher carrier frequency settings without derating the VFD.
14. The VFD shall include password protection against parameter changes.

D. The Keypad shall include a backlit LCD display. The display shall be in complete English words for programming and fault diagnostics (alpha-numeric codes are not acceptable). All VFD faults shall be displayed in English words. The keypad shall include a minimum of 14 assistants including:

1. Start-up assistant

2. Parameter assistants

    a. PID assistant
    b. Reference assistant
    c. I/O assistant
    d. Serial communications assistant
    e. Option module assistant
    f. Panel display assistant
    g. Low noise set-up assistant

3. Maintenance assistant
4. Troubleshooting assistant
5. Drive optimizer assistants

E. All applicable operating values shall be capable of being displayed in engineering (user) units. A minimum of three operating values from the list below shall be capable of being displayed at all times. The display shall be in complete English words (alpha-numeric codes are not acceptable):

1. Output Frequency
2. Motor Speed (RPM, %, or Engineering units)
3. Motor Current
4. Motor Torque
5. Motor Power (kW)
6. DC Bus Voltage
7. Output Voltage

F. Serial Communications

1. The VFD shall have an EIA-485 port as standard. The standard protocols shall be ASHRAE 135 - BACnet. Each individual drive shall have the protocol in the base VFD. The use of third party gateways and multiplexers is not acceptable. All protocols shall be “certified” BTL Listed for BACnet. Use of non-certified protocols is not allowed.

2. The BACnet connection shall be an EIA-485, MS/TP interface operating at 76.8 Kbps. The connection shall be tested by the BACnet Testing Labs (BTL) and be BTL Listed. The BACnet interface shall conform to the BACnet standard device type of an Applications Specific Controller (B-ASC). The interface shall support all BIBBs defined by the BACnet standard profile for a B-ASC including, but not limited to:

   a. Data Sharing – Read Property – B.
   b. Data Sharing – Write Property – B.
   c. Device Management – Dynamic Device Binding (Who-Is; I-Am).
   d. Device Management – Dynamic Object Binding (Who-Has; I-Have).
   e. Device Management – Communication Control – B.

3. If additional hardware is required to obtain the BACnet interface, the VFD manufacturer shall supply one BACnet gateway per drive. Multiple VFDs sharing one gateway shall not be acceptable.
4. Serial communication capabilities shall include, but not be limited to; run-stop control, speed set adjustment, proportional/integral/derivative PID control adjustments, current limit, accel/decel time adjustments, and lock and unlock the keypad. The drive shall have the capability of allowing the DDC to monitor feedback such as process variable feedback, output speed / frequency, current (in amps), % torque, power (kW), kilowatt hours (resettable), operating hours (resettable), and drive temperature. The DDC shall also be capable of monitoring the VFD relay output status, digital input status, and all analog input and analog output values. All diagnostic warning and fault information shall be

transmitted over the serial communications bus. Remote VFD fault reset shall be possible.

5. Serial communication in bypass shall include, but not be limited to; bypass run-stop control, the ability to force the unit to bypass, and the ability to lock and unlock the keypad. The bypass shall have the capability of allowing the DDC to monitor feedback such as, current (in amps), kilowatt hours (resettable), operating hours (resettable), and bypass logic board temperature. The DDC shall also be capable of monitoring the bypass relay output status, and all digital input status. All bypass diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote bypass fault reset shall be possible.
6. The VFD / bypass shall allow the DDC to control the drive and bypass digital and analog outputs via the serial interface. This control shall be independent of any VFD function. The analog outputs may be used for modulating chilled water valves or cooling tower bypass valves. The drive and bypass' digital (Form-C relay) outputs may be used to actuate a damper, open a valve or control any other device that requires a maintained contact for operation. In addition, all of the drive and bypass' digital inputs shall be capable of being monitored by the DDC system. This allows for remote monitoring of which (of up to 4) safeties are open.
7. The VFD shall include an independent PID loop for customer use. The independent PID loop would be used for chilled water value control. Both the VFD PID control loop and the independent PID control loop shall continue functioning even if the serial communications connection is lost. As default, the VFD shall keep the last good set point command and last good DO & AO commands in memory in the event the serial communications connection is lost and continue controlling the process.

G. EMI / RFI filters. All VFD's shall include EMI/RFI filters. The onboard filters shall allow the VFD assembly to be CE Marked and the VFD shall meet product standard EN 61800-3 for the First Environment restricted level with up to 100 feet of motor cable. No Exceptions. Certified test reports shall be provided with the submittals confirming compliance to EN 61800-3, First Environment.

H. All VFD's through 25HP at 480 V shall be protected from input and output power mis-wiring. The VFD shall sense this condition and display an alarm on the keypad. The VFD shall not sustain damage from this power mis-wiring condition.

I. ADDITIONAL FEATURES – Optional features to be furnished and mounted by the drive manufacturer. All optional features shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508 label.

1. Fieldbus adapters - BACnet IP, shall be provided by adding of an optional card.

J. BYPASS CONTROLLER

1. A complete factory wired and tested bypass system consisting of a door interlocked, padlockable circuit breaker, output contactor, bypass contactor, and fast acting VFD input fuses are required. UL Listed motor overload protection shall be provided in both drive and bypass modes.

2. Bypasses for motor loads equivalent to 100 hp and lower shall be a full voltage non-reversing (FVNR) starter. Bypasses for motor loads equivalent to 125 hp and greater shall feature a reduced voltage non-reversing (RVNR) starter design.
3. The bypass enclosure door and VFD enclosure must be mechanically interlocked such that the disconnecting device must be in the "Off" position before either enclosure may be accessed.
4. The VFD and bypass package shall have a UL listed short circuit current rating (SCCR) of 100,000 amps and this rating shall be indicated on the UL data label.
5. Drive Isolation Fuses - To ensure maximum possible bypass operation, fast acting fuses, exclusive to the VFD, shall be provided to allow the VFD to disconnect from the line prior to clearing upstream branch circuit protection. This maintains bypass operation capability in the event of a VFD failure. Bypass designs which have no such fuses, or that incorporate fuses common to both the VFD and the bypass, will not be accepted.
6. The system (VFD and Bypass) tolerated voltage window shall allow the system to operate from a line of +30%, -35% nominal voltage range. The system shall incorporate circuitry that will allow the drive or bypass contactor to remain "sealed in" over this voltage tolerance at a minimum.
7. The bypass shall maintain positive contactor control through the voltage tolerance window of nominal voltage +30%, -35%. This feature is designed to avoid contactor coil failure during brown out / low line conditions and allow for input single phase operation when in the VFD mode. Designs that will not allow input single phase operation in the VFD mode are not acceptable.
8. Motor protection from single phase power conditions - the bypass system must be able to detect a single phase input power condition while running in bypass, disengage the motor in a controlled fashion, and give a single phase input power indication. Bypass systems not incorporating single phase protection in bypass mode are not acceptable.
9. The bypass system shall NOT depend on the VFD for bypass operation. The bypass system shall be designed for stand alone operation and shall be completely functional in both Hand and Automatic modes even if the VFD has been removed from the system for repair / replacement. Serial communications shall remain functional even with the VFD removed.
10. Serial communications – the bypass shall be capable of being monitored and controlled via serial communications. Communication shall be through BACnet IP.
11. Serial communication capabilities shall include, but not be limited to; bypass run-stop control; the ability to force the unit to bypass; and the ability to lock and unlock the keypad. The bypass shall have the capability of allowing the DDC to monitor feedback such as, current (in amps), kilowatt hours (resettable), operating hours (resettable), and bypass logic board temperature. The DDC shall also be capable of monitoring the bypass relay output status, and all digital input status. All bypass diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote bypass fault reset shall be possible. The following additional status indications and settings shall be transmitted over the serial communications bus and / or via a Form-C relay output – keypad "Hand" or "Auto" selected, bypass selected, and broken belt indication. The DDC system shall also be able to monitor if the motor is running in the VFD mode or bypass mode over serial communications. A minimum of 50 field serial communications points shall be capable of being monitored in the bypass mode.

12. The bypass serial communications shall allow control of the bypass' digital outputs via the serial interface. This control shall be independent of any bypass function or operating state. The bypass' digital (relay) outputs may be used to actuate a damper, open a valve or control any other device that requires a maintained contact for operation. In addition, all of the bypass' digital inputs shall be capable of being monitored by the DDC system.
13. There shall be an adjustable motor current sensing circuit for the bypass and VFD modes to provide proof of flow (broken belt) indication. The condition shall be indicated on the keypad display, transmitted over the building automation protocol and / or via a Form-C relay output contact closure. The broken belt indication shall be programmable to be a system (drive and bypass) indication. The broken belt condition sensing algorithm shall be programmable to cause only a warning or a fault and / or system shutdown.
14. The digital inputs for the system shall accept 24VAC or 24VDC. The bypass shall incorporate an internally sourced power supply and not require an external control power source. The bypass power board shall supply 250 ma of 24 VDC for use by others to power external devices.
15. There shall be a run permissive circuit for damper or valve control. Regardless of the source of a run command (keypad command, time-clock control, digital input, or serial communications) the bypass shall provide a dry contact closure that will signal the damper to open (motor does not operate). When the damper is fully open, a normally open dry contact (end-switch) shall close. The closed end-switch is wired to a bypass system input and allows motor operation. Up to four separate safety interlock inputs shall be provided. When any safety is opened, the motor shall be commanded to coast to stop, and the damper shall be commanded to close. This feature will also operate in Fireman's override / smoke control mode.
16. The bypass control shall monitor the status of the VFD and bypass contactors and indicate when there is a welded contactor contact or open contactor coil. This failed contactor condition shall be indicated on the bypass LCD display, programmed to fire a Form-C relay output, and / or over the serial communications protocol.
17. The bypass control shall include a programmable time delay for bypass start and keypad indication that this time delay is in process. A Form C relay output provides a contact closure to signal the VAV boxes open. This will allow VAV boxes to be driven open before the motor operates at full speed in the bypass mode. The time delay shall be field programmable from 0 – 120 seconds.

18. There shall be a keypad adjustment to select manual or automatic transfer bypass. The user shall be able to select via keypad programming which drive faults will result in an automatic transfer to the bypass mode and which faults require a manual transfer to bypass. The user may select whether the system shall automatically transfer from drive to bypass mode on the following drive fault conditions:

    a. Over current
    b. Over voltage
    c. Under voltage
    d. Loss of analog input

19. The following operators shall be provided:

a. Bypass Hand-Off-Auto
b. Drive mode selector
c. Bypass mode selector
d. Bypass fault reset

20. The bypass shall include a two line, 20 character LCD display. The display shall allow the user to access and view:

a. Energy savings – in US dollars
b. Bypass motor amps
c. Bypass input voltage– average and individual phase voltage
d. Bypass power (kW)
e. Bypass faults and fault logs
f. Bypass warnings
g. Bypass operating time (resettable)
h. Bypass energy (kilowatt hours – resettable)
i. I/O status
j. Parameter settings / programming
k. Printed circuit board temperature

21. The following indicating lights (LED type) or keypad display indications shall be provided. A test mode or push to test feature shall be provided.

a. Power-on (Ready)
b. Run enable
c. Drive mode selected
d. Bypass mode selected
e. Drive running
f. Bypass running
g. Drive fault
h. Bypass fault
i. Bypass H-O-A mode
j. Automatic transfer to bypass selected
k. Safety open
l. Damper opening
m. Damper end-switch made

22. The Bypass controller shall have six programmable digital inputs, and five programmable Form-C relay outputs. This I/O allows for a total System (VFD and Bypass) I/O count of 24 points as standard. The bypass I/O shall be available to the BAS / DDC system even with the VFD removed.

1. The on-board Form-C relay outputs in the bypass shall programmable for any of the following indications.

a. System started
b. System running
c. Bypass override enabled
d. Drive fault
e. Bypass fault

f. Bypass H-O-A position
g. Motor proof-of-flow (broken belt)
h. Overload
i. Bypass selected
j. Bypass run
k. System started (damper opening)
l. Bypass alarm
m. Over temperature

23. The bypass shall provide a separate terminal strip for connection of freeze, fire, smoke contacts, and external start command. All external safety interlocks shall remain fully functional whether the system is in VFD or Bypass mode. The remote start/stop contact shall operate in VFD and bypass modes. The terminal strip shall allow for independent connection of up to four (4) unique safety inputs.
24. Class 10, 20, or 30 (programmable) electronic motor overload protection shall be included.

K. Enclosures:

1. Provide the VFD and bypass panels with the appropriate NEMA rated enclosure for the following applications:

    a. Indoors: NEMA 1.
    b. Indoors (mechanical rooms): NEMA 12.
    c. Outdoors (Protected by overhang): NEMA 3R enclosure.
    d. Outdoors (exposed to windblown dust or water): NEMA 4.

2. Provide appropriate ventilation of VFD cabinetry to maintain ambient temperature rating of the drive based upon application. On outdoor installations appropriate ventilation shall be powered ventilation fan(s) and external 12”x12”x1”paper filter arranged so as to not allow paper filter to be exposed to rain.

2.3 MAGNETIC MOTOR CONTROLLERS

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. Eaton.
2. Siemens Energy & Automation, Inc.
3. Square D; a brand of Schneider Electric.
4. ABB.

B. The magnetic motor controllers shall be enclosed full voltage, non-combination, non-reversing starter with control power transformer. The controller shall be enclosed in a UL Listed Type enclosure, exceeding NEMA enclosure design criteria (enclosures with only NEMA ratings are not acceptable), completely assembled and tested by the manufacturer.

C. Standard: Comply with NEMA ICS 2, general purpose, Class A.

D. For on-board control power, obtain from line circuit or from integral CPT. The CPT shall have capacity to operate integral devices and remotely located pilot, indicating, and control devices.

E. Thermal Overload Relays:
1. Inverse-time-current characteristic.
2. Class 10 tripping characteristic.
3. Heaters in each phase shall be matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
4. Ambient compensated.
5. Automatic resetting.

F. Provide factory mounted communication module for connection to the building management system (BMS). Coordinate with equipment schedule and control drawings for required control and monitoring points.

G. Provide the magnetic motor controller panels with the appropriate NEMA rated enclosure for the following applications:

1. Indoors: NEMA 1.
2. Indoors (mechanical rooms): NEMA 12.
3. Outdoors (Protected by overhang): NEMA 3R enclosure.
4. Outdoors (exposed to windblown dust or water): NEMA 4.

H. Accessories
1. Provide 3-position, HAND-OFF-AUTO, selector switch for local on/off and remote operation.
2. Provide indication lights to indicate if the motor is running, stop and overload trip.

2.4 SOURCE QUALITY CONTROL

A. Shop, inspect and perform standard productions tests for each controller.

B. Make completed controllers available for inspection at manufacturer’s factory prior to packaging for shipment. Notify the Owner at least seven days before inspection is allowed.

C. Allow witnessing of factory inspections and tests at manufacturer’s test facility. Notify the Owner at least seven days before inspections and tests are scheduled.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Section 01300 – Administrative Requirements: Coordination and project conditions.

B. Verify that building environment can be maintained within the service and ambient temperature and humidity ratings required by the VFD and motor controller manufacturer

3.2 INSTALLATION

A. Installation shall be the responsibility of the mechanical contractor. The contractor shall install the drive and motor controller in accordance with the recommendations of the manufacturer as outlined in the installation manual.

B. Power wiring shall be completed by the electrical contractor, to NEC code 430.122 wiring requirements based on the controller input current.

C. Caution: VFDs supplied without internal reactors have substantially higher input current ratings, which may require larger input power wiring and branch circuit protection. The contractor shall complete all wiring in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.

D. Install in accordance with NEMA ICS 7.1.

E. Verify that mounting surface for controllers are ready to receive work. Mount controllers on the wall or at supports in locations identified on the drawings.

F. Tighten accessible connections and mechanical fasteners after placing controller.

G. Install fuses in fusible switches.

H. Select and install overload heater elements in motor controllers to match installed motor characteristics.

I. Install engraved plastic nameplates in accordance with Section 23 05 53.

J. Neatly type label inside controller door identifying motor served, nameplate horsepower, full load amperes, code letter, service factor, and voltage/phase rating. Place label in clear plastic holder.

K. Ground and bond controller in accordance with Section 26 05 26.

L. Controls installer shall provide all wiring and conduit associated with the control signals into and out of the controllers to the DDC EMS and as required for any motor control interlocks.

3.3 FIELD QUALITY CONTROL

A. Inspect and test in accordance with NETA ATS, except Section 4.

B. Perform inspections and tests listed in NETA ATS, Section 7.16 and NEMA ICS 7.1.

C. Perform power quality analysis per warranty requirements.

3.4 MANUFACTURER'S FIELD SERVICES

A. VFD Start-up: Provide certified factory start-up for each drive by a factory authorized service center representative. A certified start-up form shall be filled out for each drive with a copy provided to the Owner, and a copy kept on file at the manufacturer. The following VFD start-up services are to be provided as a minimum:

1. Service center technician shall be responsible for verifying correct installation, power and control wiring connections, starting-up the drive, and checking out for proper operation.
2. Service center technician shall also provide all final adjustments to meet the specified performance requirements.

3.5 DEMONSTRATION AND TRAINING

A. Provide 16 hours of instruction to be conducted at the project site with manufacturer's representative. The training shall be conducted at 4 hour maximums. Contractor to also provide two sets of VFD operation manuals for use at the training session and then provide to the Owner after completion of the session.

3.6 VARIABLE FREQUENCY DRIVE START-UP SERVICE

A. Provide start-up commissioning of variable frequency drive and optional circuits by factory certified service technician experienced in start-up and repair services. Commissioning personnel shall be the same personnel that will provide factory service and warranty repairs at site. Sales personnel and other agents who are not factory certified technicians for drive field repair not acceptable.

B. Include checking for verification of proper operation and installation and interface wiring to building automation system. Include as a minimum:

1. Verify contractor wire terminations to VFD or motor controller optional circuitry.
2. Verify proper operation and reliability of VFD and motor controller, motor being driven and building automation system.
3. Provide up to one hour of Owner/operator training on operation and service diagnostics during commissioning.

4. Measure to verify proper operation on:

a. Motor voltage and frequency. Verify proper motor operation.
b. Control input for proper building automation system interface and control calibration.
c. Calibration check for:
d. Minimum speed.
e. Maximum speed.
f. Acceleration and deceleration rates.
g. Adjust as necessary.

C. Configure VSD for automatic restart after a power failure or after an external fault is cleared.

3.7 COMMISSIONING

A. Refer to Commissioning Specifications, Section 01 81 10, for related commissioning requirements.

B. Contractor shall provide all necessary support to the commissioning team to implement commissioning plan as outlined in Section 01 81 10.

END OF SECTION 23 05 14

SECTION 23 05 16 - EXPANSION FITTINGS AND LOOPS FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. Section Includes:
1. Expansion compensators.
2. Flexible-hose expansion joints.
3. Grooved-end expansion joints.
4. Pipe bends and loops.
5. Alignment guides and anchors.

1.3 ABBREVIATIONS

A. BR: Butyl rubber.

B. Buna-N: Nitrile rubber.

C. CR: Chlorosulfonated polyethylene synthetic rubber.

D. CSM: Chlorosulfonyl-polyethylene rubber.

E. EPDM: Ethylene-propylene-diene terpolymer rubber.

F. NR: Natural rubber.

G. PTFE: Polytetrafluoroethylene plastic.

1.4 PERFORMANCE REQUIREMENTS

A. Compatibility: Products shall be suitable for piping system fluids, materials, working pressures, and temperatures.

B. Capability: Products shall absorb 200 percent of maximum axial movement between anchors.

C. Expansion Calculations:

1. Installation Temperature: 50 deg F.
2. Use above data unless otherwise noted.

1.5 DELIVERY, STORAGE AND HANDLING

A. Accept expansion fittings and connectors on site in factory packing with shipping bars and positioning devices intact. Inspect for damage.

1.6 SUBMITTALS

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

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

1. Contractor to provided design of expansion compensation within piping systems to meet project design and temperature parameters. Design shall include each anchor, alignment guide and performance requirements with analysis data signed and sealed by the qualified registered professional engineer responsible for their preparation.
2. Design Calculations: Calculate requirements for thermal expansion of piping systems and for selecting and designing expansion joints, loops, and bends.
3. Anchor Details: Detail fabrication of each anchor indicated. Show dimensions and methods of assembly and attachment to building structure.
4. Alignment Guide Details: Detail field assembly and attachment to building structure.
5. Schedule: Indicate type, manufacturer's number, size, material, temperature and pressure rating, end connections, and location for each expansion joint.

C. Welding certificates.

D. Product Certificates: For each type of pipe expansion joint, signed by product manufacturer.

E. Maintenance Data: For pipe expansion joints to include in maintenance manuals. Include adjustment instructions.

1.7 QUALITY ASSURANCE

A. Design expansion compensation system under direct supervision of a professional engineer experience in design of this work and license in the State of Florida.

B. Welding Qualifications: Qualify procedures and personnel according to the following:

1. Steel Shapes and Plates: AWS D1.1, "Structural Welding Code - Steel."

2. Welding to Piping: ASME Boiler and Pressure Vessel Code: Section IX.

PART 2 - PRODUCTS

2.1 EXPANSION JOINTS

A. Expansion Compensators: Double-ply corrugated steel, stainless-steel, or copper-alloy bellows in a housing with internal guides, antitorque device, and removable end clip for positioning.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Adsco Manufacturing, LLC.
b. Flexicraft Industries.
c. Flex-Pression, Ltd.
d. Flex-Weld, Inc.
e. Hyspan Precision Products, Inc.
f. Metraflex, Inc.
g. Senior Flexonics, Inc.; Pathway Division.
h. Unaflex Inc.

2. Minimum Pressure Rating: 150 psig, unless otherwise indicated.
3. Configuration for Copper Piping: Two-ply phosphor-bronze or stainless-steel bellows and bronze or stainless-steel shroud.
4. Configuration for Steel Piping: Two-ply stainless-steel bellows and carbon-steel shroud.
5. End Connections for Copper Tubing NPS 2 and Smaller: Solder joint or threaded.
6. End Connections for Copper Tubing NPS 2-1/2 to NPS 4: Solder joint or threaded.
7. End Connections for Steel Pipe NPS 2 and Smaller: Threaded.
8. End Connections for Steel Pipe NPS 2-1/2 to NPS 4: Flanged or Weld.

B. Flexible-Hose Expansion Joints: Manufactured assembly with two flexible-metal-hose legs joined by long-radius, 180-degree return bend or center section of flexible hose; with inlet and outlet elbow fittings, corrugated-metal inner hoses, and braided outer sheaths.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Flex-Hose Co., Inc.
b. Flexicraft Industries.
c. Flex-Pression, Ltd.
d. Metraflex, Inc.

2. Flexible-Hose Expansion Joints for Copper Piping: Copper-alloy fittings with solder-joint end connections.

    a. NPS 2 and Smaller: Bronze hoses and single-braid bronze sheaths with 450 psig at 70 deg F and 340 psig at 450 deg F ratings.
    b. NPS 2-1/2 to NPS 4: Stainless-steel hoses and single-braid, stainless-steel sheaths with 300 psig at 70 deg F and 225 psig at 450 deg F ratings.

3. Flexible-Hose Expansion Joints for Copper Piping: Copper-alloy fittings with solder-joint end connections.

    a. NPS 2 and Smaller: Bronze hoses and double-braid bronze sheaths with 700 psig at 70 deg F and 500 psig at 450 deg F ratings.
    b. NPS 2-1/2 to NPS 4: Stainless-steel hoses and double-braid, stainless-steel sheaths with 420 psig at 70 deg F and 315 psig at 450 deg F ratings.

4. Flexible-Hose Expansion Joints for Steel Piping: Carbon-steel fittings with threaded end connections for NPS 2 and smaller and flanged or weld end connections for NPS 2-1/2 and larger.

    a. NPS 2 and Smaller: Stainless-steel hoses and single-braid, stainless-steel sheaths with 450 psig at 70 deg F and 325 psig at 600 deg F ratings.
    b. NPS 2-1/2 to NPS 6: Stainless-steel hoses and single-braid, stainless-steel sheaths with 200 psig at 70 deg F and 145 psig at 600 deg F ratings.
    c. NPS 8 to NPS 12: Stainless-steel hoses and single-braid, stainless-steel sheaths with 125 psig at 70 deg F and 90 psig at 600 deg F ratings.

C. Grooved-End Expansion Joints:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Victaulic

    b. Owner-approved substitution

2. Description:

    a. Factory-assembled expansion joint made of several grooved-end pipe nipples, couplings, and grooved joints. Movement capability dependent on number and style of couplings/nipples used. Pressure rating dependent on size and style of flexible couplings used.

    b. Packless, gasketed, slip-type expansion joint with grooved ends. Provides up to 3” of axial movement. Rated to 350 psi.

2.2 ALIGNMENT GUIDES

A. Description: Steel, factory fabricated, with bolted two-section outer cylinder and base for alignment of piping and two-section guiding spider for bolting to pipe. Guides to be capable of serving as seismic braces if required. See Section 230548 “Vibration and Seismic Controls for HVAC Piping and Equipment.”

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Adsco Manufacturing, LLC.
b. Advanced Thermal Systems, Inc.
c. Flex-Hose Co., Inc.
d. Flexicraft Industries.
e. Flex-Weld, Inc.
f. Hyspan Precision Products, Inc.
g. Metraflex, Inc.
h. Piping Technology & Products, Inc.
i. Senior Flexonics, Inc.; Pathway Division.

2.3 MATERIALS FOR ANCHORS

A. Steel Shapes and Plates: ASTM A 36/A 36M.

B. Bolts and Nuts: ASME B18.10 or ASTM A 183, steel, hex head.

C. Washers: ASTM F 844, steel, plain, flat washers.

D. Mechanical Fasteners: Insert-wedge-type stud with expansion plug anchor for use in hardened portland cement concrete, and tension and shear capacities appropriate for application.

1. Stud: Threaded, zinc-coated carbon steel.
2. Expansion Plug: Zinc-coated steel.
3. Washer and Nut: Zinc-coated steel.

E. Chemical Fasteners: Insert-type-stud bonding system anchor for use with hardened portland cement concrete, and tension and shear capacities appropriate for application.

1. Bonding Material: ASTM C 881, Type IV, Grade 3, 2-component epoxy resin suitable for surface temperature of hardened concrete where fastener is to be installed.
2. Stud: ASTM A 307, zinc-coated carbon steel with continuous thread on stud, unless otherwise indicated.
3. Washer and Nut: Zinc-coated steel.

F. Concrete: Portland cement mix, 3000 psi minimum. Comply with requirements in Division 03 Section "Cast-in-Place Concrete" for formwork, reinforcement, and concrete.

G. Grout: ASTM C 1107, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink, nonmetallic grout; suitable for interior and exterior applications.

1. Properties: Nonstaining, noncorrosive, and nongaseous.
2. Design Mix: 5000-psi, 28-day compressive strength.

PART 3 - EXECUTION

3.1 PROVISIONS FOR EXPANSION

A. Install piping to permit free expansion and contraction without damaging piping or construction.

B. Provide offsets, expansion loops, anchors, guides and supports to permit expansion, within stress limits of ANSI B31.1 “Power Piping for temperature ranges specified.

C. Where pipe loops or changes in direction of piping cannot be employed to absorb expansion and contraction, provide mechanical expansion joints.

D. Flexible pipe connections and expansion joints suitable to connect the adjoining piping:

1. As specified for pipe units.
2. Use line sized units.

E. Rigidly anchor pipe to building structure.

F. Provide pipe guides so that movement takes place along axis of pipe only.

G. Use swing or swivel joints for connections as specified in other Sections for piping.

H. Branch connections to terminal heat transfer units shall have strain on when cold, off when hot.

I. Make riser offsets in manner to avoid pocket forming due to expansion.

J. Loops, bends, offsets:

1. As indicated.
2. If additional required, because of job required relocation of piping and equipment, design as follows.

   a. Use spring type loop, U-bend, offset U-bend, L-bend, or Z-bend.
   b. Join bends only by welding.
   c. Submit design details for approval before fabrication.

3. Loops with ball type joints may be used in lieu of rigid elbows.

   a. Submit design details for approval before fabrication.

b. Base expansion calculations on temperatures listed under performance requirements. Submit calculations with details before fabrication.

3.2 EXPANSION-JOINT INSTALLATION

A. Install manufactured, nonmetallic expansion joints according to FSA's "Technical Handbook: Non-Metallic Expansion Joints and Flexible Pipe Connectors" and the manufacturer’s published installation instructions.

B. Install expansion joints of sizes matching size of piping in which they are installed.

C. Install alignment guides to allow expansion and to avoid end-loading and torsional stress.

D. Where expansion joints are in concealed locations, provide access doors of size to permit inspection, servicing and replacement, as approved.

E. Install grooved-joint expansion joints to grooved-end steel piping. Grooved end expansion joints shall be installed in accordance with the manufacturer's guidelines and recommendations. The gasket style and elastomeric material (grade) shall be verified as suitable for the intended service as specified. Gaskets shall be supplied by the grooved coupling manufacturer. Grooved end shall be clean and free from indentations, projections and roll marks in the area from pipe end to groove for proper gasket sealing. A direct employee of the manufacturer, factory trained field representative shall provide on-site training to contractor's field personnel in the installation of grooved piping products. A distributor representative is not qualified for this site service on behalf of the manufacturer. Factory trained representative shall periodically review the product installation. Contractor shall remove and replace any improperly installed products without additional charges

3.3 PIPE BEND AND LOOP INSTALLATION

A. Install pipe bends and loops cold-sprung in tension or compression as required to partly absorb tension or compression produced during anticipated change in temperature.

B. Attach pipe bends and loops to anchors.

1. Steel Anchors: Attach by welding. Comply with ASME B31.9 and ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
2. Concrete Anchors: Attach by fasteners. Follow fastener manufacturer's written instructions.

C. On grooved installations, Use eight (8) flexible style couplings, (4)-90° elbows, and (3) grooved end pipe spools to provide expansion loops in water systems to 250°F in accordance with the latest manufacturer’s recommendations for expansion compensation. Rigid couplings shall not be used on loop corners

3.4 SWING CONNECTIONS

A. Connect risers and branch connections to mains with at least five pipe fittings, including tee in main.

B. Connect risers and branch connections to terminal units with at least four pipe fittings, including tee in riser.

C. Connect mains and branch connections to terminal units with at least four pipe fittings, including tee in main.

3.5 ALIGNMENT-GUIDE INSTALLATION

A. Install guides on piping adjoining pipe expansion fittings and loops.

B. Attach guides to pipe and secure to building structure.

C. Locate and secure guides to maintain alignment with center line of pipe and preclude binding of spider in guide housing.

3.6 ANCHOR INSTALLATION

A. Install anchors at locations to prevent stresses from exceeding those permitted by ASME B31.9 and to prevent transfer of loading and stresses to connected equipment.

B. Fabricate and install steel anchors by welding steel shapes, plates, and bars to piping and to structure. Comply with ASME B31.9 and AWS D1.1.

C. Construct concrete anchors of poured-in-place concrete of dimensions indicated and include embedded fasteners.

D. Install pipe anchors according to expansion-joint manufacturer's written instructions if expansion joints or compensators are indicated.

E. Use grout to form flat bearing surfaces for expansion fittings, guides, and anchors installed on or in concrete.

F. Submit details of anchoring methods for approval before installation.

3.7 FLEXIBLE CONNECTORS

A. Install flexible pipe connectors on pipes connected to equipment supported by vibration isolation.

B. Install flexible connectors at right angles to displacement.

C. Install one end immediately adjacent to isolated equipment and anchor other end.

D. Construct spool pieces to exact size for future insertion of flexible connectors.

E. Seismic and other building separations which allow differential movement.

1. Packless Type Expansion Joints as specified hereinbefore.

   a. Suitable for pressure and service.
   b. Single or dual unit as required.
   c. Limit stops.
   d. Not to exceed lateral limits of joints.

2. Factory Assembled Seismic Joints.

   a. Two flexible metal hoses at right angles to each other:

      1) Inner corrugated hose: Stainless steel or bronze.
      2) Outer stainless steel or bronze braid.
      3) Suitable for service temperature and pressure.
      4) End connections to suit piping system.

   b. Movement permitted in three planes.
   c. Minimum movement required.

3. Ball joints as specified hereinbefore. Arranged to provide seismic movement without exceeding angular limits.

F. Supports and Guides:

1. As detailed on Drawings.
2. Describe method of supports and guides.

END OF SECTION 23 05 16

SECTION 23 05 17 - SLEEVES AND SLEEVE SEALS FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Sleeves.
2. Grout.

1.3 ACTION SUBMITTALS

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

1. Sleeves.

2. Sleeve layout plan for all penetrations through the post tensioned concrete structure. Plans shall be submitted for approval no later than 8 weeks prior to forming the PT concrete.
3. Grout.

PART 2 - PRODUCTS

2.1 SLEEVES

A. Galvanized-Steel-Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, zinc coated, with plain ends.

2.2 GROUT

A. See requirements outlined in Division 3 and 4

B. Standard: ASTM C 1107/C 1107M, Grade B, post-hardening and volume-adjusting, dry, hydraulic-cement grout.

C. Characteristics: Nonshrink; recommended for interior and exterior applications.

D. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.

E. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION

3.1 SLEEVE INSTALLATION

A. Install sleeves for piping passing through penetrations in floors, partitions, roofs, and walls.

B. Install sleeves in concrete floors, concrete roof slabs, and concrete walls as new slabs and walls are constructed.

1. Permanent sleeves are not required for holes in slabs formed by molded-PE or -PP sleeves.

2. Cut sleeves to length for mounting flush with both surfaces.

    a. Exception: Extend sleeves installed in floors of mechanical equipment areas or other wet areas 2 inches above finished floor level.

3. Using grout, seal the space outside of sleeves in slabs and walls without sleeve-seal system.

C. Install sleeves for pipes passing through interior partitions.

1. Cut sleeves to length for mounting flush with both surfaces.
2. Install sleeves that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.
3. Seal annular space between sleeve and piping or piping insulation; use joint sealants appropriate for size, depth, and location of joint. Comply with requirements for sealants specified in Section 07 "Joint Sealants."

D. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with requirements for firestopping specified in Section 07 "Penetration Firestopping."

3.2 SLEEVE AND SLEEVE-SEAL SCHEDULE

A. Use sleeves and sleeve seals for the following piping-penetration applications:

1. Exterior Concrete Walls above Grade:

    a. Piping Smaller Than NPS 6: Galvanized-steel wall sleeves.
    b. Piping NPS 6 and Larger: Galvanized-steel wall sleeves.

2. Concrete Slabs above Grade:

    a. Piping Smaller Than NPS 6: Galvanized-steel wall sleeves.
    b. Piping NPS 6 and Larger: Galvanized-steel wall sleeves.

3. Interior Partitions:

   a. Piping Smaller Than NPS 6: Galvanized-steel wall sleeves.
   b. Piping NPS 6 and Larger: Galvanized-steel wall sleeves.

END OF SECTION 23 05 17

SECTION 23 05 18 - CONTROL WIRING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Basic Requirements: Provisions of Section 23 00 10, Basic HVAC Requirements are part of this Section.

C. Section 230900, Instrumentation and Controls for HVAC

C. Refer to Division 26 for electrical wiring requirements.

1.2 WORK INCLUDED

A. BMS Control System Wiring.

B. Thermostat and Aquastat Wiring for Unit Heaters.

C. Interlock Wiring for Refrigeration Equipment.

D. Fire Pump and Jockey Pump Interlock Wiring.

E. Fire Suppression System Interlock Wiring.

F. Plumbing Systems Interlock Wiring.

G. Water Treatment Equipment Interlock Wiring.

H. Interior & Exterior Lighting Control Wiring

1.3 DEFINITIONS

A. Control Wiring: All wiring, high or low voltage other than power wiring, required for the proper operation of the mechanical systems.

B. Power Wiring: All line voltage wiring to the mechanical equipment. Line voltage which also serves as a control circuit, such as a line voltage thermostat, or involves interlocking with a damper, shall be considered control wiring.

1.4 QUALITY ASSURANCE

A. All work will be in accordance with the requirements of the National Electrical Code.

1.5 SUBMITTALS

A. Submittals are not required.

PART 2 – PRODUCTS

2.1 MATERIALS

A. All material used in the completion of the wiring under this section will comply with the requirements of Division 26 Electrical and Section 23 09 13 – Instrumentation and Control Devices for HVAC.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Cooperate completely with the contractor for Division 26.

B. Provide all conduit, wire and accessories necessary to complete the control wiring as specified under WORK INCLUDED.

C. Because of variations in requirements from manufacturer to manufacturer, all details may not be included in the Contract Documents. This sub-contractor must obtain approved coordinated wiring diagrams before proceeding with the control wiring.

D. All control wiring shall be properly installed in an approved raceway system or when allowed, run exposed in concealed spaces. All control wiring run in exposed areas shall be in an approved raceway unless otherwise noted.

E. Control wire run exposed shall be neatly bundled and routed parallel and/or perpendicular to building structure or equipment casing. Routing of wire shall be so that it does not interfere, chafe or obstruct service or maintenance of the equipment served.

F. Exposed control wire shall be properly secured and/or supported within equipment encloses. Cable shall be secured on no greater than 18" centers.

G. All openings made for the passing of control wire shall be properly bushed to prevent chafing. Hole size shall be suitable for the quantity of wires or tubing passing through while allowing for ease of pulling and future expansion. Oversized holes beyond these requirements are not allowed.

H. Holes made within air handling equipment which may allow the transfer or bypassing of air shall be properly sealed after wire is pulled. Expanding foam sealant and proper backing material will be acceptable. Seal shall be suitable for maximum unit operating pressures. Sealant shall be in accordance with the requirements of Division 7 sections.

I. Attachments of control devices, raceway and cable supports shall be made with proper attachments. Self-drilling screws which result in exposed end will not be acceptable. Bolts and nuts shall be used with bolt head exposed to view. All fasteners located where exposed to weather or moisture shall be stainless steel or cadmium plated.

J. Any opening, holes or cuts in equipment enclosures or building structure not used shall be neatly sealed. On equipment, the seal or patch shall be of similar material sealed and painted to match.

K. The BMS Contractor shall clean all unused or scrap material from the equipment enclosure.

L. All control wire shall be identified by proper cable identification methods. Verify how cables shall be labeled with the Owner's Representative prior to the start of work. All termination shall be labeled and labels clearly visible.

M. All control devices, cabinets, equipment and raceways shall be labeled. Verify how the hardware shall be labeled with the Owner's Representative prior to the start of work.

N. Splices in control wire are not allowed unless the length of run is too great to allow for a continuous run. When splices become necessary, they shall be solder connected with heat shrink tubing. When raceway is used, all splices shall be in junction boxes.

O. Control devices (i.e., flow switches), connected to cold equipment where the possibility of condensation may occur shall be vaporproof type. The connecting conduit shall be properly sealed with spray type foam after the wires are pulled through. If this is not possible, a weatherproof junction box shall be close mounted to the device to allow for proper moisture sealing. Conduit connections shall be sealed with a silicon type caulk/sealant.

P. All control devices or wiring located exposed to weather or moisture shall be in an approved raceway system. This system shall be properly supported and sealed to prohibit moisture convection or transfer. Provide flexible conduit similar to seal tight for connection to all equipment. EMT and set screw fittings are not acceptable. All exterior raceway shall be IMC (Intermediate Metallic Conduit) rigid galvanized conduit or better with threaded fittings.

Q. Where a disconnect switch is mounted between an adjustable frequency drive and the motor, the disconnect must have a late make, early break auxiliary contact. This contact shall be wired into the AFD control circuit so that the control circuit is disconnected before the power circuit it broken.

R. BMS Contractor to fully review the electrical drawings for interlock wiring required for exterior and interior lighting control. BMS contractor to coordinate with the electrical contractor all relays, contactors, programming and wiring required.

END OF SECTION 23 05 18

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SECTION 23 05 19 - METERS AND GAGES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. Section Includes:

1. Thermometers.
2. Thermowells.
3. Gages.
4. Gage attachments.
5. Test plugs.
6. Test-plug kits.
7. Flowmeters.
8. Thermal-energy meters.

1.3 DEFINITIONS

A. CR: Chlorosulfonated polyethylene synthetic rubber.

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

1.4 SUBMITTALS

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

B. Shop Drawings: Schedule for thermometers, gages, flowmeters and thermal-energy meters indicating manufacturer's number, scale range, and location for each.

C. Product Certificates: For each type of thermometer, gages, flowmeters and thermal-energy meter, signed by product manufacturer.

D. Wiring Diagrams: For power, signal, and control wiring.

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

1.5 QUALITY ASSURANCE

A. Comply with applicable portions of American Society of Mechanical Engineers (ASME) and Instrument Society of America (ISA) standards pertaining to construction an installation of meters and gauges.

B. Design Criteria: The drawings indicate types, sizes, capacities, ranges, profiles, connections, and dimensional requirements of meters and gauges and are based on the specific manufacturer types and models indicated.

1.6 EXTRA MATERIALS

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

1. Provide six spare pressure gauges for use with valved pressure gauge outlets.
2. Provide six spare thermometers for use with pressure-temperature test stations.

PART 2 - PRODUCTS

2.1 METAL-CASE, LIQUID-IN-GLASS THERMOMETERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Trerice, H. O. Co.
2. Weiss Instruments, Inc.
3. Winters Instruments – U.S.
4. Weksler Glass Thermometer Corp.

B. Standard: ASME B40.200.

C. Case: Cast aluminum 9 inches nominal size unless otherwise indicated.

D. Tube: Red reading organic-liquid filled glass, with magnifying lens.

E. Tube Background: Satin-faced, nonreflective aluminum with permanently etched scale markings in deg. F.

F. Window: Glass or plastic.

G. Connector: Adjustable type, 180 degrees in vertical plane, 360 degrees in horizontal plane, with locking device.

H. Stem: Stainless steel and of stem length to suit installation pipe size.

1. Below NPS 4: 3 1/2 inch stem, elbow mounted.
2. NPS 4 – NPS 8: 3 1/2 inch stem.
3. NPS 10 – NPS 14: 6 inch stem.
4. NPS 16 – NPS 20: 9 inch stem.
5. NPS 24: 12 inch stem.
6. Over NPS 24: Stem length equal to 50% pipe diameter.

I. Design for Thermowell Installation: Bare stem.

J. Accuracy: Plus or minus 1 percent of range or plus or minus 1 scale division to maximum of 1.5 percent of range.

2.2 DIRECT-MOUNTING, VAPOR-ACTUATED DIAL THERMOMETERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Trerice, H. O. Co.
2. Weiss Instruments, Inc.
3. Winters Instruments – U.S.

B. Case: Dry type, cast aluminum, 4-1/2-inch diameter.

C. Element: Bourdon tube or other type of pressure element. Brass, bronze bushed, recalibrator type.

D. Movement: Mechanical, connecting element and pointer.

E. Dial: Satin-faced, nonreflective aluminum with permanently etched scale markings.

F. Pointer: Red metal.

G. Window: Glass or plastic.

H. Ring: Chrome plated metal.

I. Connector: Adjustable type, 180 degrees in vertical plane, 360 degrees in horizontal plane, with locking device.

J. Thermal System: Liquid-filled bulb in copper-plated steel, aluminum, or brass stem for thermowell installation and of length to suit installation pipe size:

1. Below NPS 4: 3 1/2 inch stem, elbow mounted.
2. NPS 4 – NPS 8: 3 1/2 inch stem.
3. NPS 10 – NPS 14: 6 inch stem.
4. NPS 16 – NPS 20: 9 inch stem.
5. NPS 24: 12 inch stem.
6. Over NPS 24: Stem length equal to 50% pipe diameter.

K. Accuracy: Plus or minus 1 percent of range or plus or minus 1 scale division to maximum of 1.5 percent of range.

2.3 REMOTE-MOUNTING, VAPOR-ACTUATED DIAL THERMOMETERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Trerice, H. O. Co.
2. Weiss Instruments, Inc.
3. Winters Instruments – U.S.

B. Case: Dry type, cast aluminum, 4-1/2-inch diameter with holes for panel mounting.

C. Element: Bourdon tube or other type of pressure element. Brass, bronze brushed, recalibrator type.

D. Movement: Mechanical, connecting element and pointer.

E. Dial: Satin-faced, nonreflective aluminum with permanently etched scale markings.

F. Pointer: Red metal.

G. Window: Glass or plastic.

H. Ring: Black aluminum.

I. Connector: Bottom or Back union type. Connecting tubing shall be double braided bronze armor over copper capillary.

J. Thermal System: Liquid-filled bulb in copper-plated steel, aluminum, or brass stem for thermowell installation and of length to suit installation pipe size:

1. Below NPS 4: 3 1/2 inch stem, elbow mounted.
2. NPS 4 – NPS 8: 3 1/2 inch stem.
3. NPS 10 – NPS 14: 6 inch stem.
4. NPS 16 – NPS 20: 9 inch stem.
5. NPS 24: 12 inch stem.
6. Over NPS 24: Stem length equal to 50% pipe diameter.

K. Accuracy: Plus or minus 1 percent of range or plus or minus 1 scale division to maximum of 1.5 percent of range.

L. For use in locations where temperature sensing bulb is located more than 5 feet.

2.4 THERMOWELLS

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

B. Standard: ASME B40.200.

C. Description: Pressure-tight, socket-type metal fitting made for insertion into piping and of type, diameter, and length required to hold thermometer. Provide with separable brass socket connection, cap and chain.

D. Material for Use with Copper Tubing: CNR or CUNI.

E. Material for Use with Steel Piping: CRES.

F. Type: Stepped shank unless straight or tapered shank is indicated.

G. External Threads: NPS 1/2, NPS 3/4, or NPS 1, ASME B1.20.1 pipe threads.

H. Internal Threads: 1/2, 3/4, and 1 inch, with ASME B1.1 screw threads.

I. Bore: Diameter required to match thermometer bulb or stem.

J. Insertion Length: Length required to match thermometer bulb or stem.

K. Lagging Extension: Include on thermowells for insulated piping and tubing.

L. Bushings: For converting size of thermowell's internal screw thread to size of thermometer connection.

M. Heat-Transfer Medium: Mixture of graphite and glycerin.

2.5 PRESSURE GAGES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Trerice, H. O. Co.
2. Weiss Instruments, Inc.
3. Winters Instruments – U.S.

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

1. Case: Liquid-filled type, cast aluminum 4-1/2-inch nominal diameter.
2. Pressure-Element Assembly: Bourdon tube, unless otherwise indicated.
3. Pressure Connection: Brass, NPS 1/4, bottom-outlet type unless back-outlet type is indicated.
4. Movement: Mechanical, stainless steel, with link to pressure element and connection to pointer.
5. Dial: Satin-faced, nonreflective aluminum with permanently etched scale markings graduated in psi.
6. Pointer: Dark-colored metal.

7. Window: Glass.
8. Ring: Brass.
9. Accuracy: Grade A, plus or minus 1 percent of middle half of scale range.
10. Vacuum-Pressure Range: 30-in. Hg of vacuum to 15 psig of pressure.
11. Range for Fluids under Pressure: Two times operating pressure.

C. Remote-Mounting, Dial-Type Pressure Gages: ASME B40.100, indicating-dial type.

1. Case: Dry type, cast aluminum 4-1/2-inch diameter with holes for panel mounting.
2. Pressure-Element Assembly: Bourdon tube, unless otherwise indicated.
3. Pressure Connection: Brass, NPS 1/4, bottom-outlet type unless back-outlet type is indicated.
4. Movement: Mechanical, stainless steel, with link to pressure element and connection to pointer.
5. Dial: Satin-faced, nonreflective aluminum with permanently etched scale markings.
6. Pointer: Dark-color metal.
7. Window: Glass.
8. Ring: Brass.
9. Accuracy: Grade A, plus or minus 1 percent of middle half of scale range.
10. Vacuum-Pressure Range: 30-in. Hg of vacuum to 15 psig of pressure.
11. Range for Fluids under Pressure: Two times operating pressure.
12. For use with sensing lines up to 25 feet in length.

D. Pressure-Gage Fittings:

1. Valves: NPS 1/4 or NPS 1/2 as applicable, ASME B1.20.1 pipe threads, brass or stainless-steel needle type.
2. Snubbers: ASME B40.100, brass, with NPS 1/4 or NPS 1/2, ASME B1.20.1 pipe threads, and piston-type surge-dampening device suitable for system fluid and working pressure. Include extension for use on insulated piping.

2.6 TEST PLUGS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Flow Design, Inc.
2. Peterson Equipment Co., Inc.
3. Trerice, H. O. Co.
4. Watts Industries, Inc.; Water Products Div.

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

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

D. Core Inserts: Chlorosulfonated polyethylene synthetic and EPDM self-sealing rubber valves.

E. Test Kit: Furnish four test kits containing one pressure gage and adaptor, two thermometers, and carrying case. Pressure gage, adapter probes, and thermometer sensing elements shall be of diameter to fit test plugs and of length to project into piping.

1. Pressure Gage: Small bourdon-tube insertion type with 2- to 3-inch- diameter dial and probe. Dial range shall be 0 to 200 psig.
2. Low-Range Thermometer: Small bimetallic insertion type with 1- to 2-inch-diameter dial and tapered-end sensing element. Dial ranges shall be 25 to 125 deg F.
3. Carrying case shall have formed instrument padding.

2.7 WAFER-ORIFICE FLOWMETERS

A. Manufacturers: Subject to compliance with requirements:

1. ABB, Inc.; ABB Instrumentation.
2. Armstrong Pumps, Inc.
3. Badger Meter, Inc.; Industrial Div.
4. Bell & Gossett; ITT Industries.
5. Meriam Instruments Div.; Scott Fetzer Co.

B. Description: Differential-pressure-design orifice insert for installation between pipe flanges; with calibrated flow-measuring element, separate flowmeter, hoses or tubing, valves, fittings, and conversion chart compatible with flow-measuring element, flowmeter, and system fluid.

C. Construction: Cast-iron body, brass valves with integral check valves and caps, and calibrated nameplate.

D. Pressure Rating: 300 psig (2070 kPa).

E. Temperature Rating: 250 deg F (121 deg C).

F. Range: Flow range of flow-measuring element and flowmeter shall cover operating range of equipment or system served.

G. Permanent Indicators: Suitable for wall or bracket mounting, calibrated for connected flowmeter element, and having 6-inch- (150-mm-) diameter, or equivalent, dial with fittings and copper tubing for connecting to flowmeter element.

1. Scale: Gallons per minute (Liters per second).
2. Accuracy: Plus or minus 1 percent between 20 and 80 percent of range.

H. Portable Indicators: Differential-pressure type calibrated for connected flowmeter element and having two 12-foot (3.7-m) hoses in carrying case.

1. Scale: Gallons per minute (Liters per second).
2. Accuracy: Plus or minus 2 percent between 20 and 80 percent of range.

I. Operating Instructions: Include complete instructions with each flowmeter.

2.8 VENTURI FLOWMETERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Armstrong Pumps, Inc.
2. Badger Meter, Inc.; Industrial Div.
3. Bailey-Fischer & Porter Co.
4. Flow Design, Inc.
5. Gerand Engineering Co.
6. Hyspan Precision Products, Inc.
7. Leeds & Northrup.
8. McCrometer, Inc.
9. Preso Meters Corporation.
10. Victaulic Co. of America.

B. Description: Differential-pressure design for installation in piping; with calibrated flow-measuring element, separate flowmeter, hoses or tubing, valves, fittings, and conversion chart compatible with flow-measuring element, flowmeter, and system fluid.

C. Construction: Bronze, brass, or factory-primed steel, as noted below; with brass fittings and attached tag with flow conversion data.

1. NPS 1/2 (DN 15) through NPS 2 (DN 50): Bronze or brass.
2. NPS 2 1/2 (DN 65) through NPS 8 (DN 200): Factory primed cast steel.
3. NPS 10 (DN 250) and larger: Factory primed fabricated steel.

D. Pressure Rating: 250 psig (1725 kPa).

E. Temperature Rating: 250 deg F (121 deg C).

F. End Connections for NPS 2 (DN 50) and Smaller: Threaded.

G. End Connections for NPS 2-1/2 (DN 65) and Larger: Flanged.

H. Range: Flow range of flow-measuring element and flowmeter shall cover operating range of equipment or system served.

I. Permanent Indicators: Suitable for wall or bracket mounting, calibrated for connected flowmeter element, and having 6-inch- (150-mm-) diameter, or equivalent, dial with fittings and copper tubing for connecting to flowmeter element.

1. Scale: Gallons per minute (Liters per second).
2. Accuracy: Plus or minus 1 percent between 20 and 80 percent of range.

J. Portable Indicators: Differential-pressure type calibrated for connected flowmeter element and having two 12-foot (3.7-m) hoses in carrying case.

1. Scale: Gallons per minute (Liters per second).
2. Accuracy: Plus or minus 2 percent between 20 and 80 percent of range.

K. Operating Instructions: Include complete instructions with each flowmeter.

2.9 TURBINE FLOWMETERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Badger Meter, Inc.; Industrial Div.
2. Bailey-Fischer & Porter Co.
3. Data Industrial Corp.
4. Engineering Measurements Company.
5. ERDCO Engineering Corp.
6. Fischer, George Inc.
7. Hoffer Flow Controls, Inc.
8. ISTEC Corporation.
9. Midwest Instruments & Controls Corp.
10. ONICON Incorporated.
11. SeaMetrics Inc.
12. Sponsler Company, Inc.
13. Thermo Measurement Ltd.
14. Venture Measurement.

B. Description: Insertion type for inserting turbine into piping and measuring flow directly in gallons per minute (liters per second).

C. Construction: Bronze or stainless-steel body; with plastic turbine or impeller and integral direct-reading scale.

D. Pressure Rating: 150 psig (1035 kPa) minimum.

E. Temperature Rating: 180 deg F (82 deg C) minimum.

F. Display: Visual instantaneous rate of flow, with register to indicate total volume in gallons (liters).

G. Accuracy: Plus or minus 2-1/2 percent.

2.10 VORTEX-SHEDDING FLOWMETERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Bailey-Fischer & Porter Co.
2. Engineering Measurements Company.
3. ISTEC Corporation.
4. MCO/Eastech, Inc.
5. Schlumberger Limited; Measurement Div.
6. Venture Measurement.

B. Description: Inline type for installing between pipe flanges and measuring flow directly in gallons per minute (liters per second).

C. Construction: Stainless-steel body; with integral transmitter and direct-reading scale.

D. Pressure Rating: 1000 psig (6900 kPa) minimum.

E. Temperature Rating: 500 deg F (260 deg C) minimum.

F. Display: Visual instantaneous rate of flow, with register to indicate total volume in gallons (liters).

G. Integral Transformer: For low-voltage power operation.

H. Accuracy: Plus or minus 7/10 percent for liquids and 1-1/4 percent for gases.

2.11 PITOT-TUBE FLOWMETERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Dieterich Standard Inc.
2. Meriam Instruments Div.; Scott Fetzer Co.
3. Preso Meters Corporation.
4. Taco, Inc.
5. Veris Industries.

B. Description: Insertion-type, differential-pressure design for inserting probe into piping and measuring flow directly in gallons per minute (liters per second).

C. Construction: Stainless-steel probe of length to span inside of pipe; with integral transmitter and direct-reading scale.

D. Pressure Rating: 150 psig (1035 kPa) minimum.

E. Temperature Rating: 250 deg F (121 deg C) minimum.

F. Display: Visual instantaneous rate of flow, with register to indicate total volume in gallons (liters).

G. Integral Transformer: For low-voltage power connection.

H. Accuracy: Plus or minus 1 percent for liquids and gases.

2.12 FLOW INDICATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Brooks Instrument Div.; Emerson Electric Co.
2. Dwyer Instruments, Inc.
3. Ernst Gage Co.
4. Eugene Ernst Products Co.
5. McCrometer, Inc.
6. OPW Engineered Systems; Dover Corp.
7. Penberthy, Inc.

B. Description: Instrument for installation in piping systems for visual verification of flow.

C. Construction: Bronze or stainless-steel body; with sight glass and plastic pelton-wheel indicator, and threaded or flanged ends.

D. Pressure Rating: 125 psig (860 kPa).

E. Temperature Rating: 200 deg F (93 deg C).

F. End Connections for NPS 2 (DN 50) and Smaller: Threaded.

G. End Connections for NPS 2-1/2 (DN 65) and Larger: Flanged.

2.13 INSERTION-TURBINE, THERMAL-ENERGY METER SYSTEMS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Data Industrial Corp.
2. ONICON Incorporated.
3. Thermo Measurement Ltd.

B. Description: Flow sensor, strainer, two temperature sensors, transmitter, meter, and connecting wiring.

C. Flow Sensor: Insertion-type turbine or paddle-wheel element with corrosion-resistant-metal body and transmitter.

1. Pressure Rating: 125 psig (860 kPa).
2. Temperature Range: 40 to 250 deg F (5 to 121 deg C).

D. Meter: Solid-state integrating type with integral battery pack.

1. Data Output: Six-digit electromechanical counter with readout in kilowatts per hour or British thermal units (joules).
2. Accuracy: Plus or minus 1 percent.
3. Battery Pack: Five-year lithium battery.

E. Strainer: Full size of main line piping.

2.14 INLINE-TURBINE, THERMAL-ENERGY METER SYSTEMS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Engineering Measurements Company.
2. Hoffer Flow Controls, Inc.
3. ISTEC Corporation.
4. Thermo Measurement Ltd.
5. Venture Measurement.

B. Description: Flow sensor, strainer, two temperature sensors, transmitter, meter, and connecting wiring.

C. Flow Sensor: Turbine-type water meter with corrosion-resistant-metal body and transmitter.

1. Pressure Rating: 150-psig (1035-kPa) minimum working-pressure rating.
2. Temperature Range: 40 to 250 deg F (5 to 121 deg C).

D. Meter: Solid-state integrating type with integral battery pack.

1. Data Output: Six-digit electromechanical counter with readout in kilowatts per hour or British thermal units (joules).
2. Accuracy: Plus or minus 1 percent.
3. Battery Pack: Five-year lithium battery.

E. Strainer: Full size of main line piping.

2.15 ULTRASONIC, THERMAL-ENERGY METER SYSTEMS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Controlotron Corporation.
2. Engineering Measurements Company.
3. Mesa Laboratories, Inc.; Nusonics Div.

B. Description: Flow sensor, two temperature sensors, transmitter, meter, and connecting wiring.

C. Flow Sensor: Strap-on or integral ultrasonic type with transmitter.

D. Meter: Solid-state integrating type with integral battery pack.

1. Data Output: Six-digit electromechanical counter with readout in kilowatts per hour or British thermal units (joules).
2. Accuracy: Plus or minus 1 percent.
3. Battery Pack: Five-year lithium battery.

E. Strainer: Full size of main line piping.

2.16 DIFFERENTIAL PRESSURE INDICATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. ITT Barton.
2. Meriam Instrument Co.
3. Rosemount Engineering Co.

B. Description: Pressure sensor, two pressure sensors, meter and connecting tubing.

C. Die cast aluminum, 6 inch (152 mm) diameter.

D. Pressure Connections: Brass, NPS 1/4 (DN 8), bottom outlet type, unless otherwise indicated.

E. Pressure-Element Assemblies: Stainless steel bellows and torque tube; self-draining.

F. Movement: Jeweled rotary type with zero and range adjustment screws.

G. Manifold: Stainless steel with carbon steel tubing.

H. Scale: Uniform, calibrated in psig (kPa).

I. Accuracy: 1/2 of 1 percent of full scale range.

J. Pressure Rating: 500 psig (3450 kPa).

PART 3 - EXECUTION

3.1 THERMOMETER APPLICATIONS

A. Install liquid-in-glass thermometers in the following locations:

1. Inlet and outlet of each hydronic zone.

2. Inlet and outlet of each hydronic coil in air-handling units and built-up central systems.
3. Chilled water lines at exit of equipment rooms.
4. Other locations as noted on drawings.

B. Install direct-mounting, vapor-actuated dial thermometers in the following locations:

1. Inlet and outlet of each hydronic zone.
2. Inlet and outlet of each hydronic coil in air-handling units and built-up central systems.
3. Chilled water lines at exit of equipment rooms.
4. Other locations as noted on drawings.

C. Install remote-mounting, vapor-actuated dial thermometers in the following locations:

1. Inlet and outlet of each hydronic zone.
2. Inlet and outlet of each hydronic coil in air-handling units and built-up central systems.
3. Chilled water lines at exit of equipment rooms.
4. Outside air, return air and mixed air ducts.
5. Other locations as noted on drawings.

D. Install bimetallic-actuated dial thermometers in the following locations:

1. Inlet and outlet of each hydronic zone.
2. Inlet and outlet of each hydronic coil in air-handling units and built-up central systems.
3. Chilled water lines at exit of equipment rooms.
4. Other locations as noted on drawings.

E. Install liquid-filled-case-type, vapor-actuated dial thermometers at suction and discharge of each pump.

F. Provide the following temperature ranges for thermometers:

1. Chilled Water: 0 to 100 deg F, with 2-degree scale divisions.
2. Air Ducts: Minus 40 to plus 110 deg F, with 2-degree scale.

3.2 GAGE APPLICATIONS

A. Install liquid-filled-case-type pressure gages at suction and discharge of each pump, between shut-off valve and pump. Provide compound type gauge if subject to negative pressure.

B. Install pressure gauges at other locations as noted on the drawings.

C. Pressure gauge ranges shall be selected so that normal system operating pressures occur at the center portion of the scale range.

3.3 INSTALLATIONS

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

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

C. Install thermowells with socket extending one-third of diameter of pipe and in vertical position in piping tees where thermometers are indicated.

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

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

F. Install remote-mounting pressure gages on panel.

G. Install needle-valve and snubber fitting in piping for each pressure gage for fluids.

H. Install test plugs in tees in piping.

I. Install flow indicators, in accessible positions for easy viewing, in piping systems.

J. Assemble and install connections, tubing, and accessories between flow-measuring elements and flowmeters as prescribed by manufacturer's written instructions.

K. Install flowmeter elements in accessible positions in piping systems.

L. Install differential-pressure-type flowmeter elements with at least minimum straight lengths of pipe upstream and downstream from element as prescribed by manufacturer's written instructions.

M. Install wafer-orifice flowmeter elements between pipe flanges.

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

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

P. Install flowmeters at discharge of hydronic system pumps and at inlet of hydronic air coils.

Q. Assemble components and install thermal-energy meters.

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

S. Install pressure-temperature test stations adjacent to each bulb for controllers, remote temperature indication and recording thermometers, and at other points where noted on drawings.

T. Install valved outlets for pressure gauges at cooling water supply and return for coil assemblies, for other equipment not noted to receive permanent pressure gauges, and at other points where noted on drawings.

3.4 CONNECTIONS

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

B. Connect flowmeter-system elements to meters.

C. Connect flowmeter transmitters to meters.

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

3.5 ADJUSTING

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

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

END OF SECTION 23 05 19

SECTION 23 05 23 - GENERAL – DUTY VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Basic Requirements: Provisions of Section 23 00 10 - Basic HVAC Requirements are part of this Section.

C. Division 22 plumbing piping Sections for specialty valves applicable to those Sections only.

D. Division 22 Section "Identification for Plumbing Piping and Equipment" for valve tags and schedules.

1.2 SUMMARY

A. General: Provide valves, cocks and specialties which are required for piping systems specified in other sections of these specifications.

B. Section Includes:

1. Bronze ball valves.
2. Iron, grooved-end ball valves.
3. Iron, single-flange butterfly valves.
4. Iron, grooved-end butterfly valves.
5. High-performance butterfly valves
6. Bronze swing check valves.
7. Iron swing check valves.
8. Iron, grooved-end swing-check valves.
9. Chainwheels.
10. Flow Balancing Valves

C. Related Sections:

1. Section 23 05 53 Identification for HVAC Piping and Equipment for valve tags and schedules.

1.3 ABBREVIATIONS

A. EPDM: Ethylene propylene copolymer rubber.

B. NBR: Acrylonitrile-butadiene, Buna-N, or nitrile rubber.

C. NRS: Nonrising stem.

D. OS&Y: Outside screw and yoke.

E. RS: Rising stem.

F. SWP: Steam working pressure.

1.4 APPLICABLE STANDARDS

A. General: All equipment, material, accessories, methods of construction and reinforcement, finish quality, workmanship and installation shall be in compliance with Section 230010.

B. Pressure and Temperature Rating: Valves shall have a pressure and temperature rating equal to or exceeding the piping in which they are installed, except that valves shall be designed for a minimum steam working pressure (SWP) of 125 psi; water-oil-gas (WOG) pressure of 200 psi.

1.5 ACTION SUBMITTALS

A. Product Data: For each type of valve indicated. Manufacturer’s data indicating body material, valve design, design pressure and temperature ratings and classification, end connection details, seat materials, trim materials, dimensions, required clearances, and installation instructions.

B. General: Include the following data:

1. Manufacturers Literature:

   a. Dimensional outline drawing of each valve listed in this section including sizes available and pressure limitations.
   b. Outline drawing of each calibrated balancing and flow measuring valve including flow and pressure limitations.
   c. Outline drawing of each safety and pressure relief valve including discharge capacity and pressure limitations.

2. Installation Instructions: Manufacturer's printed installation instructions for all valves including copies shipped with the valves.

1.6 QUALITY ASSURANCE

A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.

B. To assure uniformity and compatibility, all grooved end valves and adjoining couplings shall be the products of a single manufacturer

C. ASME Compliance:

1. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
2. ASME B31.1 for power piping valves.
3. ASME B31.9 for building services piping valves.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Prepare valves for shipping as follows:

1. Protect internal parts against rust and corrosion.
2. Protect threads, flange faces, grooves, and weld ends.
3. Set ball valves open to minimize exposure of functional surfaces.
4. Set butterfly valves closed or slightly open.
5. Block check valves in either closed or open position.

B. Use the following precautions during storage:

1. Maintain valve end protection.
2. Store valves indoors and maintain at higher than ambient dew point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.

C. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use handwheels or stems as lifting or rigging points.

1.8 BASIC VALVE REQUIREMENTS

A. General: Valves and cocks may not be indicated in every instance on the drawings, but whether or not shown, all valves, cocks and check valves necessary for the proper operation of the system shall be furnished and installed. Valves shall have rising stems except in locations where space is limited; in these locations non-rising stem valves of equivalent material and pressure class will be accepted. Valves shall have the manufacturer's name or trademark, recommended service pressure, and size indicated by raised letters cast on the valve body.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR VALVES

A. Refer to specific sections in Part 3 for applications of valves.

B. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.

C. Bronze valves shall be made with dezincification-resistant materials. Bronze valves made with copper alloy (brass) containing more than 15 percent zinc are not permitted.

D. Valve Pressure and Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.

E. Valve Sizes: Same as upstream piping unless otherwise indicated.

F. Valve Actuator Types:

1. Gear Actuator: For quarter-turn valves NPS 8 and larger.
2. Handwheel: For valves other than quarter-turn types.
3. Handlever: For quarter-turn valves NPS 6 and smaller.
4. Chainwheel: Device for attachment to valve handwheel, stem, or other actuator; of size and with chain for mounting height, as indicated in the "Valve Installation" Article.

G. Valves in Insulated Piping: With 2-inch stem extensions and the following features:

1. Ball Valves: With extended operating handle of non-thermal-conductive material, and protective sleeve that allows operation of valve without breaking the vapor seal or disturbing insulation. Memory stops that are fully adjustable after insulation is applied.
2. Butterfly Valves: With extended neck.

H. Valve-End Connections:

1. Flanged: With flanges according to ASME B16.1 for iron valves.
2. Grooved: With grooves according to AWWA C606.

I. Valve Bypass and Drain Connections: MSS SP-45.

2.2 BRONZE BALL VALVES

A. Two-Piece, Full-Port, Brass or Stainless Steel Ball Valves with Brass Trim:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Crane Co.; Crane Valve Group; Crane Valves.
    b. Milwaukee Valve Company.
    c. NIBCO INC.
    d. Flow-Tek

2. Description:

    a. Standard: MSS SP-110.
    b. SWP Rating: 150 psig.
    c. CWP Rating: 600 psig.
    d. Body Design: Two piece.
    e. Body Material: Bronze, Stainless Steel
    f. Ends: Threaded.
    g. Seats: PTFE or TFE.
    h. Blowout-proof stem
    i. Stem: Bronze, Stainless Steel
    j. Stem Seals: Double O-ring
    k. Ball: Chrome-plated brass or Stainless Steel
    l. Port: Full.

2.3 IRON, GROOVED – END BALL VALVES

A. Two-Piece, Full-Port, Brass Ball Valves with Brass Trim:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Victaulic
    b. Owner-approved substitution

2. Description:

    a. SWP Rating: 800 psi.
    b. Body Design: Two piece, Standard Port.
    c. Body Material: Ductile Iron conforming to ASTM A-536, painted black enamel.
    d. Ends: Ductile Iron conforming to ASTM A-536, painted black enamel.
    e. Seats: TFE.
    f. Stem: Micro-finished Steel.
    g. Ball: Micro-finished Nickel-Plated Carbon Steel.
    h. Port: Standard.

2.4 IRON BALL VALVES

A. Class 125, Iron/Carbon Steel Ball Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. American Valve, Inc.
   b. Conbraco Industries, Inc.; Apollo Valves.
   c. Kitz Corporation.
   d. Flow-Tek F 15

2. Description:

   a. Standard: MSS SP-72.
   b. CWP Rating: 200 psig (1380 kPa).
   c. Body Design: Split body.
   d. Body Material: ASTM A 126, gray iron, carbon steel
   e. Ends: Flanged.
   f. Seats: PTFE or TFE.
   g. Stem: Stainless steel.
   h. Ball: Stainless steel.
   i. Port: Full.

2.5 IRON, SINGLE – FLANGE BUTTERFLY VALVES

A. 150 CWP, Iron, Single-Flange Butterfly Valves with EPDM Seat and Aluminum-Bronze Disc:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Bray Controls; a division of Bray International.
   b. Crane Co.; Crane Valve Group; Stockham Division.
   c. Milwaukee Valve Company.
   d. NIBCO INC.

2. Description:

   a. Standard: MSS SP-67, Type I.
   b. CWP Rating: 150 psig.
   c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
   d. Body Material: ASTM A 126, cast iron or ASTM A 536, ductile iron.
   e. Seat: EPDM.
   f. Stem: One- or two-piece stainless steel.

g. Disc: stainless steel.

2.6 IRON, GROOVED – END BUTTERFLY VALVES

A. 300 CWP, Iron, Grooved-End Butterfly Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    a. Victaulic Company.
    b. Owner-approved substitution

2. Description:

    a. Standard: MSS SP-67, Type I.
    b. CWP Rating: 300 psig.
    c. Body Material: Coated, ductile iron.
    d. Stem: Two-piece stainless steel.
    e. Disc: stainless steel or ductile-iron; offset
    f. Seal: EPDM rated continuous-duty to 250F for 12” and smaller and 230F for 14” and larger.

2.7 HIGH-PERFORMANCE BUTTERFLY VALVES

A. Class 150, Single-Flange, High-Performance Butterfly Valves

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Bray Controls

    b. Milwaukee Valve Company

    c. NIBCO INC

    d. Stockham; Crane Energy Flow Solutions

    e. Tyco Valves & Controls

2. Description:

    a. Standard: MSS SP-68. API-609

    b. CWP Rating: 285 psig at 100 deg F

    c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange

d. Body Material: Carbon steel, ductile iron, or stainless steel

e. Seat: Reinforced PTFE or metal

f. Stem: Stainless steel; offset from seat plane. Stem to be blow-out proof

g. Disc: 316 stainless steel

h. Service: Bidirectional

2.8 BRONZE SWING CHECK VALVES

A. Class 125, Bronze Swing Check Valves with Bronze Disc:

1. Manufacturers: Subject to compliance with requiremengvb-p0[=p-[ts, provide products by one of the following:

   a. Crane Co.; Crane Valve Group; Stockham Division.
   b. Milwaukee Valve Company.
   c. NIBCO INC.
   d. Powell Valves.

2. Description:

   a. Standard: MSS SP-80, Type 3.
   b. CWP Rating: 200 psig (1380 kPa).
   c. Body Design: Horizontal flow.
   d. Body Material: ASTM B 62, bronze.
   e. Ends: Threaded.
   f. Disc: Bronze.

B. Class 150, Bronze Swing Check Valves with Bronze Disc:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Crane Co.; Crane Valve Group; Stockham Division.
   b. Milwaukee Valve Company.
   c. NIBCO INC.

2. Description:

   a. Standard: MSS SP-80, Type 3.
   b. CWP Rating: 300 psig (2070 kPa).
   c. Body Design: Horizontal flow.
   d. Body Material: ASTM B 62, bronze.

e. Ends: Threaded.
f. Disc: Bronze.

2.9 BRONZE LIFT CHECK VALVES

A. Class 125 Lift Check Valves with Bronze Disc:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Stockham; Crane Energy Flow Solutions

b. Milwaukee Valve Company

c. NIBCO INC

B. Description:

1. Standard: MSS SP-80, Type 1

2. CWP Rating: 200 psig

3. Body Design: Vertical

4. Body Material: ASTM B 61 or ASTM B 62, bronze

5. Ends: Threaded

6. Disc: Bronze

2.10 IRON SWING CHECK VALVES

A. Class 125, Iron Swing Check Valves with Metal Seats:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Crane Co.; Crane Valve Group; Stockham Division.
b. Milwaukee Valve Company.
c. NIBCO INC.
d. Powell Valves.

2. Description:

a. Standard: MSS SP-71, Type I.
b. NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 200 psig (1380 kPa).

c. NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 150 psig (1035 kPa).
d. Body Design: Clear or full waterway.
e. Body Material: ASTM A 126, gray iron with bolted bonnet.
f. Ends: Flanged.
g. Trim: Bronze.
h. Gasket: Asbestos free.

B. Class 250, Iron Swing Check Valves with Metal Seats:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Crane Co.; Crane Valve Group; Stockham Division.
b. Milwaukee Valve Company.
c. NIBCO INC.

2. Description:

a. Standard: MSS SP-71, Type I.
b. NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 500 psig (3450 kPa).
c. NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 300 psig (2070 kPa).
d. Body Design: Clear or full waterway.
e. Body Material: ASTM A 126, gray iron with bolted bonnet.
f. Ends: Flanged.
g. Trim: Bronze.
h. Gasket: Asbestos free.

2.11 IRON, GROOVED -END SWING CHECK VALVES

A. 300 CWP, Iron, Grooved-End Swing Check Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
a. Victaulic Company.
b. Owner-approved substitution

2. Description:

a. CWP Rating 12” and smaller: 300 psig (2070 kPa).

b. CWP Rating 14” and larger: 230 psig (1586 kPa)
c. Body Material: ASTM A 536 or ASTM A 395, ductile iron.
d. Seal: EPDM.
e. Disc: Spring operated, ductile iron or stainless steel.

2.12 IRON, CENTER-GUIDED CHECK VALVES

A. Class 125, Iron, Compact-Wafer, Center-Guided Check Valves with Metal Seat

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    a. Anvil International; a subsidiary of Mueller Water Products, Inc
    b. Milwaukee Valve Company
    c. NIBCO INC

2. Description:
    a. Standard: MSS SP-125
    b. NPS 2-1/2 to NPS 12, CWP Rating: 200
    c. NPS 14 to NPS 24, CWP Rating: 150 psig
    d. Body Material: ASTM A 126, gray iron
    e. Style: Compact wafer
    f. Seat: Bronze

2.13 IRON SWING CHECK VALVES WITH CLOSURE CONTROL

A. Class 125, Iron Swing Check Valves with Lever- and Weight-Closure Control

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. NIBCO INC

b. Milwaukee Valve Company

c. Stockham; Crane Energy Flow Solutions

2. Description:

a. Standard: MSS SP-71, Type I

b. NPS 2-1/2 to NPS 12, CWP Rating: 200 psig

c. NPS 14 to NPS 24, CWP Rating: 150 psi

d. Body Design: Clear or full waterway

e. Body Material: ASTM A 126, gray iron with bolted bonnet

f. Ends: Flanged

g. Trim: Bronze

h. Gasket: Asbestos free

i. Closure Control: Factory-installed, exterior lever and weight

2.14 FLOW BALANCING VALVES

A. Automatic Flow Control Valve: Provide automatic flow control valves with variable openings which respond to pressure, factory set to control the water flow over an operating pressure differential at least 10 times the minimum required for full flow conditions. Valves shall be tamper proof when installed, and shall have body pressure tappings with a set of pressure and temperature test ports. Valves shall have flanged or grooved ends or a union either integral or directly adjacent to permit replacement of the control element. The automatic flow controls shall be selected for the project by the manufacturer to provide flow rates matching the equipment requirements, including any increased or decreased flow rates that are indicated.

1. Body: Brass or ferrous metal.
2. Piston and Spring Assembly: Stainless steel, tamper proof, self-cleaning, and removable.
3. Combination Assemblies: Include bronze or brass-alloy ball valve.
4. Identification Tag: Marked with zone identification, valve number, and flow rate.
5. Size: Same as pipe in which installed.
6. Performance: Maintain constant flow, plus or minus 5 percent over system pressure fluctuations.
7. Minimum CWP Rating: 175 psig.
8. Maximum Operating Temperature: 200 deg F.
9. Minimum Differential operating pressure: 5-60 psid (35-414 KpA).

B. Manufacturer:

1. Autoflow, Inc.
2. Griswold
3. IMI Flow Design
4. Victaulic

C. Calibration Meter: Provide one portable differential pressure gauge calibration meter kit of same manufacturer as valves. Kit shall be housed in a hand-carrying case and shall contain all devices required, including pressure gauges, 5 foot meter hoses with disconnect ends, positive shutoff valves, operating instructions, and flow versus pressure drop curves, to enable testing and balancing of each size and type of balancing valve installed.

2.15 Combination Balancing and Shut-off valve:

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Tour & Anderson.
2. Armstrong Pumps, Inc.
3. Bell & Gossett; a Xylem brand.

B. Description:
1. Body: "Y" pattern, modified, equal percentage globe style. Brass up to 2 inch; ductile iron for 2-1/2 inch and larger.
2. Bronze trim.
3. Precision flow measurement.
4. Precision flow balancing.
5. Positive drip tight shut-off.
6. Two (2) 1/2 inch NPT metering ports with nordel check valves and gasketed caps located on both sides of the valve seat.
7. Two (2) additional 1/4 inch NPT connections with brass plugs on opposite side of the metering ports for use as drain connections.
8. Drain connections and metering ports are to be interchangeable.
9. Handwheel with hidden memory feature.
10. Minimum CWP Rating: 175 psig or 300 psig.
11. Maximum Operating Temperature: 200 deg F or 250 deg F.

2.16 CHAINWHEELS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Babbitt Steam Specialty Co.
2. Roto Hammer Industries.
3. Trumbull Industries.

B. Description: Valve actuation assembly with sprocket rim, brackets, and chain.

1. Brackets: Type, number, size, and fasteners required to mount actuator on valve.
2. Attachment: For connection to butterfly valve stems.
3. Sprocket Rim with Chain Guides: Ductile or cast iron, of type and size required for valve.
4. Chain: Hot-dip, galvanized steel, of size required to fit sprocket rim.
5. Provide safety cable system for each chain wheel. Safety cable system shall consist of cable, clips, and eyebolts made from Type 316 stainless steel

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.

B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.

C. Examine threads on valve and mating pipe for form and cleanliness.

D. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.

E. Examine grooved ends for conditions that might cause leakage. Ends should be free from indentations or projections in the area from valve end to groove

F. Do not attempt to repair defective valves; replace with new valves.

3.2 VALVE INSTALLATION

A. Install valves with unions, grooved-joint couplings or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.

B. Locate valves for easy access and provide separate support where necessary.

C. Install valves in horizontal piping with stem at or above center of pipe.

D. Install valves in position to allow full stem movement.

E. Install chainwheels on operators for butterfly valves NPS 4 and larger and more than 96 inches above floor. Extend chains to 60 inches above finished floor.

F. Install isolation/shutoff valve at all main risers and main branch takeoffs, to permit isolation of piping sections for drainage.

G. Install isolation/shutoff valves on each inlet and outlet of each piece of equipment to which water is piped to allow isolation, venting and drainage. Provide a flange, union, or groove between the valve and the equipment to permit disconnection, removal and service.

H. Install check valves for proper direction of flow and as follows:

1. Swing Check Valves: In horizontal position with hinge pin level.
2. Y-pattern horizontal swing check valves shall be used in vertical lines.
3. Horizontal swing check valves shall be used with ball valves;
4. Wafer check valves shall be used with butterfly valves.

3.3 ADJUSTING

A. Adjust or replace valve packing after piping systems have been tested and put into service but before final adjusting and balancing. Replace valves if persistent leaking occurs.

3.4 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

A. If valve applications are not indicated, use the following:

1. Shutoff Service: Ball, or High Performance butterfly valves.
2. Butterfly Valve Dead-End Service: High Performance Single-flange (lug) type.
3. Throttling Service: Ball or High Performance Butterfly valves.

B. If valves with specified SWP classes or CWP ratings are not available, the same types of valves with higher SWP classes or CWP ratings may be substituted.

C. Select valves, except wafer types, with the following end connections:

1. For Copper Tubing, NPS 2 and Smaller: Threaded ends except where solder-joint valve-end option is indicated in valve schedules below.
2. For Copper Tubing, NPS 2-1/2 to NPS 4: Flanged ends except where threaded valve-end option is indicated in valve schedules below.
3. For Copper Tubing, NPS 5 and Larger: Flanged ends.
4. For Steel Piping, NPS 2 and Smaller: Threaded ends.
5. For Steel Piping, NPS 2-1/2 to NPS 4: Flanged ends except where threaded valve-end option is indicated in valve schedules below.
6. For Steel Piping, NPS 5 and Larger: Flanged ends.
7. For Grooved-End Copper Tubing and Steel Piping except Steam and Steam Condensate Piping: Valve ends may be grooved.

3.5 CHILLED - WATER VALVE SCHEDULE

A. Pipe NPS 2 and Smaller above-grade:

1. Bronze Valves: May be provided with solder-joint ends instead of threaded ends.
2. Ball Valves: Two piece, standard port, bronze with bronze trim.
3. Bronze Swing Check Valves: Class 125, bronze disc.

B. Pipe NPS 2-1/2 and Larger above-grade:

1. Steel Ball Valves, NPS 2-1/2 to NPS 10 (DN 65 to DN 250): Class 150.
2. Steel, Single-Flange High Performance Butterfly Valves, NPS 2-1/2 and Larger: Class 150, Reinforced PTFE, stainless steel disc and stem
3. Steel, High PerformanceButterfly Valves, NPS 2-1/2 to NPS 24: Class 150.
4. Iron Swing Check Valves: Class 150, metal seats.
5. Iron, Grooved-End Check Valves, NPS 3 to NPS 12: 300 CWP.
6. Iron, Grooved-End Check Valves, NPS 14 to NPS 24: 230 CWP

3.6 FLOW BALANCING VALVES

A. Location: Provide flow balancing valves where indicated. The exact location shall be determined using field measurements relating to the specific piping arrangement and the manufacturer's recommendations.

B. Manufacturer' Recommendation: Install in accordance with manufacturer's recommendations including valve orientation and increases or decreases in pipe size at points of installation, together with minimum recommended lengths of straight pipe before and after points of installation.

C. Calibration Meter: At the conclusion of the system test and balance and prior to final completion the meter shall be turned over to, and shall become the property of, the Owner.

3.7 DRAIN VALVES

A. Location: Install drain valves at the base of all water piping risers (both supply and return) and at all low points in the piping system. Drain valves shall be fitted with schedule 80 hose connection end with cap unless otherwise indicated.

3.8 CONDENSER -WATER VALVE SCHEDULE

A. Pipe NPS 2-1/2 and Larger below and above-grade - exterior:

   1. Iron, Single-Flange Butterfly Valves, 200 CWP, EPDM seat, stainless steel disc and stem.

   2. Iron, Grooved-End Butterfly Valves, 300 CWP, EPDM seat, ductile-iron disc and stainless steel stem (above-grade)

B. Pipe NPS 2-1/2 and Larger above-grade - interior:

   1. Iron, Single-Flange Butterfly Valves, 200 CWP, EPDM seat, stainless steel disc and stem.

   2. Iron, Grooved-End Butterfly Valves, 300 CWP, EPDM seat, ductile-iron disc and stainless steel stem.

END OF SECTION 23 05 23

SECTION 23 05 29 - HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes the following hangers and supports for HVAC system piping and equipment:

1. Steel pipe hangers and supports.
2. Trapeze pipe hangers.
3. Metal framing systems.
4. Thermal-hanger shield inserts.
5. Fastener systems.
6. Pipe stands.
7. Equipment supports.

B. Related Sections include the following:

1. Division 05 Section "Metal Fabrications" for structural-steel shapes and plates for trapeze hangers for pipe and equipment supports.
2. Division 21 Section "Water-Based Fire-Suppression Systems" for pipe hangers for fire-protection piping.
3. Division 23 Section "Expansion Fittings and Loops for HVAC Piping" for pipe guides and anchors.
4. Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment" for vibration isolation devices.
5. Division 23 Section(s) "Metal Ducts" for duct hangers and supports.

1.3 DEFINITIONS

A. MSS: Manufacturers Standardization Society for The Valve and Fittings Industry Inc.

B. Terminology: As defined in MSS SP-90, "Guidelines on Terminology for Pipe Hangers and Supports."

1.4 PERFORMANCE REQUIREMENTS

A. Design supports for multiple pipes, including pipe stands, capable of supporting combined weight of supported systems, system contents, and test water.

B. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.

C. Design hangers and supports for piping and equipment.

D. Where thermal movement in pipe line occurs, hanger assembly shall support pipe line in all operating conditions.

1.5 SUBMITTALS

A. Product Data: Manufacturer’s catalog data, including load ratings, dimensions and installation instructions, for the following:

1. Steel pipe hangers and supports.
2. Fiberglass pipe hangers.
3. Thermal-hanger shield inserts.
4. Powder-actuated fastener systems.

B. Submit schedule indicating type of hanger to be used by system and pipe size. Include rod size for each hanger size.

C. Product data, along with installation operation and maintenance instructions, shall be included in the operation and maintenance manuals.

D. Shop Drawings: Show fabrication and installation details and include calculations for the following:

1. Trapeze pipe hangers. Include Product Data for components.
2. Metal framing systems. Include Product Data for components.
3. Pipe stands. Include Product Data for components.
4. Equipment supports.

E. Welding certificates.

1.6 QUALITY ASSURANCE

A. Welding: Qualify procedures and personnel according to the following:

1. AWS D1.1, "Structural Welding Code--Steel."
2. AWS D1.2, "Structural Welding Code--Aluminum."
3. AWS D1.3, "Structural Welding Code--Sheet Steel."

4. AWS D1.4, "Structural Welding Code--Reinforcing Steel."
5. ASME Boiler and Pressure Vessel Code: Section IX.

B. Codes and Standards: Provide pipe hangers and supports conforming to the following:

1. American Society of Mechanical Engineering:

a.	B31.1	Power Piping.
b.	B31.2	Fuel Gas Piping.
c.	B31.5	Refrigerating Piping and Heat Transfer Components.
d.	B31.9	Building Services Piping.

2. American Society for Testing and Materials (ASTM):

a.	A36	Standard Specification for Carbon Structural Steel.
b.	A123	Standard Specification for Zinc (Hot Dip Galvanized) Coatings on Iron and Steel Products.
c.	A307	Standard Specification for Carbon Steel Bolts and Studs, 60000 PSI Tensile Strength.
d.	A575	Standard Specification for Steel Bars, Carbon, Merchant Quality, M-Grades.
e.	D695	Compressive Properties of Rigid Plastics.
f.	D790	Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.
g.	F708	Standard Practice for Design and Installation of Rigid Pipe.

3. Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. (MSS):

a.	SP58	Pipe Hangers and Supports - Materials, Design And Manufacture.
b.	SP69	Pipe Hangers And Supports – Selection And Application.
c.	SP89	Pipe Hangers And Supports – Fabrication And Installation Practices.
d.	SP90	Guidelines on Terminology for Pipe Hangers and Supports.

C. Steel angles, channels and plate shall be in accordance with ASTM A36, red primed or hot dipped galvanized for interior applications, and hot galvanized for exterior applications.

D. Bolts, including nuts and washers, used for fabricating steel members shall be in accordance with ASTM A325 and shall be stainless steel or plated for corrosion protection. Plain steel components are unacceptable.

E. Welding of steel members shall be in accordance with AWS D1.1.

F. Duct hangers and supports shall be in accordance with SMACNA HVAC Duct Construction Standards – Metal and Flexible as applicable.

G. Steel supports for ducts, pipe anchors, pipe guides, and piping supported from below shall be fabricated in accordance with AISC Specification for the Design, Fabrication and Erection of Structural Steel for buildings. The contractor shall include the cost of the services of a Professional Structural Engineer to design or review the system and sign and seal the drawings.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Manufacturers: Subject to compliance with requirements, provide products by one of the manufacturers specified.

2.2 STEEL PIPE HANGERS AND SUPPORTS

A. Description: MSS SP-58, Types 1 through 58, factory-fabricated components. Refer to Part 3 "Hanger and Support Applications" Article for where to use specific hanger and support types.

B. Manufacturers:

1. AAA Technology & Specialties Co., Inc.
2. Bergen-Power Pipe Supports.
3. B-Line Systems, Inc.; a division of Cooper Industries.
4. Carpenter & Paterson, Inc.
5. Empire Industries, Inc.
6. ERICO/Michigan Hanger Co.
7. Globe Pipe Hanger Products, Inc.
8. Grinnell Corp.
9. GS Metals Corp.
10. National Pipe Hanger Corporation.
11. PHD Manufacturing, Inc.
12. PHS Industries, Inc.
13. Piping Technology & Products, Inc.
14. Tolco Inc.
15. Anvil International, Inc.

C. Galvanized, Metallic Coatings: Pregalvanized or hot dipped.

D. Nonmetallic Coatings: Plastic coating, jacket, or liner.

E. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion for support of bearing surface of piping.

2.3 TRAPEZE PIPE HANGERS

A. Description: MSS SP-69, Type 59, shop- or field-fabricated pipe-support assembly made from structural-steel shapes with MSS SP-58 hanger rods, nuts, saddles, and U-bolts.

2.4 METAL FRAMING SYSTEMS

A. Description: MFMA-3, shop- or field-fabricated pipe-support assembly made of steel channels and other components.

B. Manufacturers:

1. B-Line Systems, Inc.; a division of Cooper Industries.
2. ERICO/Michigan Hanger Co.; ERISTRUT Div.
3. GS Metals Corp.
4. Power-Strut Div.; Tyco International, Ltd.
5. Thomas & Betts Corporation.
6. Tolco Inc.
7. Unistrut Corp.; Tyco International, Ltd.

C. Coatings: Manufacturer's standard finish, unless bare metal surfaces are indicated.

D. Nonmetallic Coatings: Plastic coating, jacket, or liner.

2.5 THERMAL-HANGER SHIELD INSERTS

A. Description: 100-psig- minimum, compressive-strength insulation insert encased in sheet metal shield.

B. Manufacturers:

1. Carpenter & Paterson, Inc.
2. ERICO/Michigan Hanger Co.
3. PHS Industries, Inc.
4. Pipe Shields, Inc.
5. Rilco Manufacturing Company, Inc.
6. Value Engineered Products, Inc.

C. Insulation-Insert Material for Cold Piping: ASTM C 552, Type II cellular glass with vapor barrier.

D. For Trapeze or Clamped Systems: Insert and shield shall cover entire circumference of pipe.

E. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.

F. Insert Length: Extend 2 inches beyond sheet metal shield for piping operating below ambient air temperature.

2.6 FASTENER SYSTEMS

A. Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

1. Manufacturers:

   a. Hilti, Inc.
   b. ITW Ramset/Red Head.
   c. Masterset Fastening Systems, Inc.
   d. MKT Fastening, LLC.
   e. Powers Fasteners.

B. Mechanical-Expansion Anchors: Insert-wedge-type zinc-coated steel, for use in hardened portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

1. Manufacturers:

   a. B-Line Systems, Inc.; a division of Cooper Industries.
   b. Empire Industries, Inc.
   c. Hilti, Inc.
   d. ITW Ramset/Red Head.
   e. MKT Fastening, LLC.
   f. Powers Fasteners.

2.7 PIPE STAND FABRICATION

A. Pipe Stands, General: Shop or field-fabricated assemblies made of manufactured corrosion-resistant components to support roof-mounted piping.

B. Compact Pipe Stand: One-piece plastic unit with integral-rod-roller, pipe clamps, or V-shaped cradle to support pipe, for roof installation without membrane penetration.

1. Manufacturers:

   a. ERICO/Michigan Hanger Co.

b. MIRO Industries.
c. Owner approved substitution.

C. Low-Type, Single-Pipe Stand: One-piece plastic or stainless-steel base unit with plastic roller, for roof installation without membrane penetration.

1. Manufacturers:

   a. MIRO Industries.
   b. Owner approved substitution.

D. High-Type, Single-Pipe Stand: Assembly of base, vertical and horizontal members, and pipe support, for roof installation without membrane penetration.

1. Manufacturers:

   a. ERICO/Michigan Hanger Co.
   b. MIRO Industries.
   c. Portable Pipe Hangers.

2. Base: Plastic or Stainless steel.
3. Vertical Members: Two or more cadmium-plated-steel or stainless-steel, continuous-thread rods.
4. Horizontal Member: Cadmium-plated-steel or stainless-steel rod with plastic or stainless-steel, roller-type pipe support.

E. High-Type, Multiple-Pipe Stand: Assembly of bases, vertical and horizontal members, and pipe supports, for roof installation without membrane penetration.

1. Manufacturers:

   a. Portable Pipe Hangers.
   b. Owner approved substitution.

2. Bases: One or more plastic.
3. Vertical Members: Two or more protective-coated-steel channels.
4. Horizontal Member: Protective-coated-steel channel.
5. Pipe Supports: Galvanized-steel, clevis-type pipe hangers.

F. Curb-Mounting-Type Pipe Stands: Shop- or field-fabricated pipe support made from structural-steel shape, continuous-thread rods, and rollers for mounting on permanent stationary roof curb.

2.8 EQUIPMENT SUPPORTS

A. Description: Welded, shop- or field-fabricated equipment support made from structural-steel shapes.

2.9 MISCELLANEOUS MATERIALS

A. Structural Steel: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

B. Grout: ASTM C 1107, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink and nonmetallic grout; suitable for interior and exterior applications.

1. Properties: Nonstaining, noncorrosive, and nongaseous.
2. Design Mix: 5000-psi, 28-day compressive strength.

C. Hanger Rods: ASTM A 575, hot rolled Steel, ANSI B1.1 threads, continuously threaded, with electro-galvanized finish.

D. Steel Pipe Columns: ASTM A 53, Schedule 40, black steel.

E. Bolts and Nuts: ASTM A 307, Grade A, regular hexagon-head type.

PART 3 - EXECUTION

3.1 HANGER AND SUPPORT INSTALLATION

A. Steel Pipe Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from building structure.

B. Metal Trapeze Pipe Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Arrange for grouping of parallel runs of horizontal piping and support together on field-fabricated trapeze pipe hangers.

1. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified above for individual pipe hangers.
2. Field fabricate from ASTM A 36/A 36M, steel shapes selected for loads being supported. Weld steel according to AWS D1.1.

C. Metal Framing System Installation: Arrange for grouping of parallel runs of piping and support together on field-assembled metal framing systems.

D. Thermal-Hanger Shield Installation: Install in pipe hanger or shield for insulated piping.

E. Fastener System Installation:

1. Install powder-actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches thick in concrete after concrete is placed and completely cured.

Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.
2. Install mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.

F. Pipe Stand Installation:

1. Pipe Stand Types except Curb-Mounting Type: Assemble components and mount on smooth roof surface. Do not penetrate roof membrane.
2. Curb-Mounting-Type Pipe Stands: Assemble components or fabricate pipe stand and mount on permanent, stationary roof curb. Refer to Division 07 Section "Roof Accessories" for curbs.

G. Install hangers and supports complete with necessary inserts, bolts, rods, nuts, washers, and other accessories.

H. Equipment Support Installation: Fabricate from welded-structural-steel shapes.

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

J. Install lateral bracing with pipe hangers and supports to prevent swaying.

K. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, NPS 2-1/2 and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.

L. Load Distribution: Install hangers and supports so piping live and dead loads and stresses from movement will not be transmitted to connected equipment.

M. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and so maximum pipe deflections allowed by ASME B31.1 (for power piping) and ASME B31.9 (for building services piping) are not exceeded.

N. Insulated Piping: Comply with the following:

1. Attach clamps and spacers to piping.

   a. Piping Operating above Ambient Air Temperature: Clamp may project through insulation.
   b. Piping Operating below Ambient Air Temperature: Use thermal-hanger shield insert with clamp sized to match OD of insert.
   c. Do not exceed pipe stress limits according to ASME B31.1 for power piping and ASME B31.9 for building services piping.

2. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.

    a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.

3. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.

    a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.

4. Shield Dimensions for Pipe: Not less than the following:

    a. NPS 1/4 to NPS 3-1/2: 12 inches long and 0.048 inch thick.
    b. NPS 4: 12 inches long and 0.06 inch thick.
    c. NPS 5 and NPS 6: 18 inches long and 0.06 inch thick.
    d. NPS 8 to NPS 14: 24 inches long and 0.075 inch thick.
    e. NPS 16 and larger: 24 inches long and 0.105 inch thick.

5. Pipes NPS 8 and Larger: Include cellular glass or reinforced calcium-silicate insulation.
6. Inserts of length at least as long as protective shield.
7. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

O. Outdoor Piping: Pipe hangers, supports and hardware including screws, bolts, nuts, and washers, located outdoors shall be hot-dip galvanized after fabrication in accordance with ASTM A123.

P. Miscellaneous Steel: Provide miscellaneous framing, steel members, beams, brackets, etc. for support of work in Division, unless specifically included in other Divisions.

3.2 EQUIPMENT SUPPORTS

A. Fabricate structural-steel stands to suspend equipment from structure overhead or to support equipment above floor.

B. Grouting: Place grout under supports for equipment and make smooth bearing surface.

C. Provide lateral bracing, to prevent swaying, for equipment supports.

3.3 METAL FABRICATIONS

A. Cut, drill, and fit miscellaneous metal fabrications for trapeze pipe hangers and equipment supports.

B. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.

C. Field Welding: Comply with AWS D1.1M procedures for shielded metal arc welding, appearance and quality of welds, and methods used in correcting welding work, and with the following:

1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
2. Obtain fusion without undercut or overlap.
3. Remove welding flux immediately.
4. Finish welds at exposed connections so no roughness shows after finishing and contours of welded surfaces match adjacent contours.

3.4 ADJUSTING

A. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.

B. Trim excess length of continuous-thread hanger and support rods to 1/2 inch maximum to 3 visible threads minimum.

3.5 PAINTING

A. Touch Up: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.

1. Apply paint by brush or spray to provide minimum dry film thickness of 2.0 mils.

B. Touch Up: Cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal are specified in Division 09 Painting Sections.

C. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

3.6 HANGER AND SUPPORT SCHEDULE

A. Specific hanger and support requirements are specified in Sections specifying piping systems and equipment.

B. Comply with MSS SP-69 for pipe hanger selections and applications that are not specified in piping system Sections.

C. Use hangers and supports with galvanized, metallic coatings for piping and equipment that will not have field-applied finish.

D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.

E. Use carbon-steel pipe hangers and supports, metal trapeze pipe hangers and metal framing systems and attachments for general service applications.

F. Use copper-plated pipe hangers and copper or stainless-steel attachments for copper piping and tubing.

G. Use padded hangers for piping that is subject to scratching.

H. Use thermal-hanger shield inserts for insulated piping and tubing.

I. Horizontal-Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of noninsulated or insulated stationary pipes, NPS 1/2 to NPS 30.
2. Carbon- or Alloy-Steel, Double-Bolt Pipe Clamps (MSS Type 3): For suspension of pipes, NPS 3/4 to NPS 36, requiring clamp flexibility and up to 4 inches of insulation.
3. Steel Pipe Clamps (MSS Type 4): For suspension of cold and hot pipes, NPS 1/2 to NPS 24, if little or no insulation is required.
4. Pipe Hangers (MSS Type 5): For suspension of pipes, NPS 1/2 to NPS 4, to allow off-center closure for hanger installation before pipe erection.
5. Adjustable, Swivel Split- or Solid-Ring Hangers (MSS Type 6): For suspension of noninsulated stationary pipes, NPS 3/4 to NPS 8.
6. Adjustable, Steel Band Hangers (MSS Type 7): For suspension of noninsulated stationary pipes, NPS 1/2 to NPS 8.
7. Adjustable Band Hangers (MSS Type 9): For suspension of noninsulated stationary pipes, NPS 1/2 to NPS 8.
8. Adjustable, Swivel-Ring Band Hangers (MSS Type 10): For suspension of noninsulated stationary pipes, NPS 1/2 to NPS 8.
9. Split Pipe-Ring with or without Turnbuckle-Adjustment Hangers (MSS Type 11): For suspension of noninsulated stationary pipes, NPS 3/8 to NPS 8.
10. Extension Hinged or Two-Bolt Split Pipe Clamps (MSS Type 12): For suspension of noninsulated stationary pipes, NPS 3/8 to NPS 3.
11. U-Bolts (MSS Type 24): For support of heavy pipes, NPS 1/2 to NPS 30.
12. Clips (MSS Type 26): For support of insulated pipes not subject to expansion or contraction.
13. Pipe Saddle Supports (MSS Type 36): For support of pipes, NPS 4 to NPS 36, with steel pipe base stanchion support and cast-iron floor flange.
14. Pipe Stanchion Saddles (MSS Type 37): For support of pipes, NPS 4 to NPS 36, with steel pipe base stanchion support and cast-iron floor flange or carbon-steel plate and with U-bolt to retain pipe.

15. Adjustable, Pipe Saddle Supports (MSS Type 38): For stanchion-type support for pipes, NPS 2-1/2 to NPS 36, if vertical adjustment is required, with steel pipe base stanchion support and cast-iron floor flange.
16. Single Pipe Rolls (MSS Type 41): For suspension of pipes, NPS 1 to NPS 30, from 2 rods if longitudinal movement caused by expansion and contraction might occur.
17. Adjustable Roller Hangers (MSS Type 43): For suspension of pipes, NPS 2-1/2 to NPS 24, from single rod if horizontal movement caused by expansion and contraction might occur.
18. Complete Pipe Rolls (MSS Type 44): For support of pipes, NPS 2 to NPS 42, if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is not necessary.
19. Pipe Roll and Plate Units (MSS Type 45): For support of pipes, NPS 2 to NPS 24, if small horizontal movement caused by expansion and contraction might occur and vertical adjustment is not necessary.
20. Adjustable Pipe Roll and Base Units (MSS Type 46): For support of pipes, NPS 2 to NPS 30, if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.

J. Vertical-Piping Clamps: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers, NPS 3/4 to NPS 24.
2. Carbon- or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers, NPS 3/4 to NPS 24, if longer ends are required for riser clamps.

K. Hanger-Rod Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches for heavy loads.
2. Steel Clevises (MSS Type 14): For 120 to 450 deg F piping installations.
3. Swivel Turnbuckles (MSS Type 15): For use with MSS Type 11, split pipe rings.
4. Malleable-Iron Sockets (MSS Type 16): For attaching hanger rods to various types of building attachments.
5. Steel Weldless Eye Nuts (MSS Type 17): For 120 to 450 deg F piping installations.

L. Building Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel or Malleable Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
2. Top-Beam C-Clamps (MSS Type 19): For use under roof installations with bar-joist construction to attach to top flange of structural shape.
3. Side-Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.
4. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.

5. Welded Beam Attachments (MSS Type 22): For attaching to bottom of beams if loads are considerable and rod sizes are large.
6. C-Clamps (MSS Type 23): For structural shapes.
7. Top-Beam Clamps (MSS Type 25): For top of beams if hanger rod is required tangent to flange edge.
8. Side-Beam Clamps (MSS Type 27): For bottom of steel I-beams.
9. Steel-Beam Clamps with Eye Nuts (MSS Type 28): For attaching to bottom of steel I-beams for heavy loads.
10. Linked-Steel Clamps with Eye Nuts (MSS Type 29): For attaching to bottom of steel I-beams for heavy loads, with link extensions.
11. Malleable Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.
12. Welded-Steel Brackets: For support of pipes from below, or for suspending from above by using clip and rod. Use one of the following for indicated loads:

    a. Light (MSS Type 31): 750 lb.
    b. Medium (MSS Type 32): 1500 lb.
    c. Heavy (MSS Type 33): 3000 lb.

13. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
14. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.
15. Horizontal Travelers (MSS Type 58): For supporting piping systems subject to linear horizontal movement where headroom is limited.

M. Saddles and Shields: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.
2. Protection Shields (MSS Type 40): Of length recommended in writing by manufacturer to prevent crushing insulation.
3. Thermal-Hanger Shield Inserts: For supporting insulated pipe.

N. Spring Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Restraint-Control Devices (MSS Type 47): Where indicated to control piping movement.
2. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches.
3. Spring-Cushion Roll Hangers (MSS Type 49): For equipping Type 41 roll hanger with springs.
4. Spring Sway Braces (MSS Type 50): To retard sway, shock, vibration, or thermal expansion in piping systems.
5. Variable-Spring Hangers (MSS Type 51): Preset to indicated load and limit variability factor to 25 percent to absorb expansion and contraction of piping system from hanger.

6. Variable-Spring Base Supports (MSS Type 52): Preset to indicated load and limit variability factor to 25 percent to absorb expansion and contraction of piping system from base support.
7. Variable-Spring Trapeze Hangers (MSS Type 53): Preset to indicated load and limit variability factor to 25 percent to absorb expansion and contraction of piping system from trapeze support.
8. Constant Supports: For critical piping stress and if necessary to avoid transfer of stress from one support to another support, critical terminal, or connected equipment. Include auxiliary stops for erection, hydrostatic test, and load-adjustment capability. These supports include the following types:

   a. Horizontal (MSS Type 54): Mounted horizontally.
   b. Vertical (MSS Type 55): Mounted vertically.
   c. Trapeze (MSS Type 56): Two vertical-type supports and one trapeze member.

O. Comply with MSS SP-69 for trapeze pipe hanger selections and applications that are not specified in piping system Sections.

P. Comply with MFMA-103 for metal framing system selections and applications that are not specified in piping system Sections.

Q. Use mechanical-expansion anchors instead of building attachments where required in concrete construction.

R. Supports of wire rope, wood, chain, strap perforated bar or any other makeshift device shall not be permitted.

END OF SECTION 23 05 29

SECTION 23 05 48 - VIBRATION CONTROLS FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes the following:

1. Isolation pads.
2. Isolation mounts.
3. Restrained elastomeric isolation mounts.
4. Freestanding and restrained spring isolators.
5. Housed spring mounts.
6. Elastomeric hangers.
7. Spring hangers.
8. Spring hangers with vertical-limit stops.
9. Pipe riser resilient supports.
10. Resilient pipe guides.
11. Freestanding and restrained air-mounting system.
12. Restrained vibration isolation roof-curb rails.
13. Restraining braces and cables.
14. Steel and inertia, vibration isolation equipment bases.
15. Braided Flexible pipe connectors.
16. Neoprene Flexible Pipe Connectors.
17. Grooved-joint Flexible Pipe Connectors

1.3 DEFINITIONS

A. IBC: International Building Code.

B. ICC-ES: ICC-Evaluation Service.

C. ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

D. Life Safety and Hazardous Components - All systems involved with fire protection including sprinkler piping, fire pumps, jockey pumps, fire pump control panels, service water supply piping, water tanks, fire dampers and smoke exhaust systems and mechanical, electrical, plumbing or fire protection systems that support the operation of or are connected to emergency power equipment including all lighting, generators, transfer switches and transformers. Hazardous components include any pipe, vessel, duct or piece of equipment that contains flammable or toxic material.

E. Component – a part or element of an architectural, mechanical, electrical or structural system.

F. Positive Attachment – a cast in place anchor, a drill in wedge anchor, a chemical anchor, a double sided beam clamp loaded perpendicular to the beam or a welded or bolted connection to the structure.

G. Special Inspection – inspection of the materials, installation, fabrication or placement of components and anchorage.

1.4 PERFORMANCE REQUIREMENTS

A. Wind-Restraint Loading:

1. Values as specified from Project structural engineer and applicable code.

B. Seismic-Restraint Loading:

1. Values as specified from Project structural engineer and applicable code.

1.5 SUBMITTALS

A. Product Data: For the following:

1. Include rated load, rated deflection, and overload capacity for each vibration isolation device.
2. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of seismic-restraint component used.

    a. Tabulate types and sizes of seismic restraints, complete with report numbers and rated strength in tension and shear as evaluated by an agency acceptable to authorities having jurisdiction.
    b. Annotate to indicate application of each product submitted and compliance with requirements.

3. Interlocking Snubbers: Include ratings for horizontal, vertical, and combined loads.
4. Catalog cuts and data sheets on specific vibration isolators and restraints to be utilized showing compliance with specifications.
5. An itemized list showing the items of equipment or piping to be isolated, the isolator type and model number selected, isolator loading and deflection, and reference to specific drawings showing base and construction where applicable.
6. restraint calculations and structural or civil engineers stamp verifying design and calculations for seismic restraining system used.

7. Drawings showing equipment base construction for each piece of equipment, including dimensions, structural member sizes and support point locations.
8. Drawing showing methods of suspension, support guides for piping.
9. Drawings showing methods for isolation of pipes piercing walls and slabs.
10. Concrete and steel details for bases including anchor bolt locations.
11. Number and location of restraints and anchors for each piece of equipment.
12. Specific details of restraints including anchor bolts for mounting and maximum loading at each location, for each piece of equipment and or pipe.

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

1. Design Calculations: Calculate static and dynamic loading due to equipment weight and operation, seismic and wind forces required to select vibration isolators, and wind restraints, and for designing vibration isolation bases.

    a. Coordinate design calculations with wind load calculations required for equipment mounted outdoors. Comply with requirements in other Division 23 Sections for equipment mounted outdoors.

2. Riser Supports: Include riser diagrams and calculations showing anticipated expansion and contraction at each support point, initial and final loads on building structure, spring deflection changes,. Include certification that riser system has been examined for excessive stress and that none will exist.
3. Vibration Isolation Base Details: Detail overall dimensions, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, base weights, equipment static loads, power transmission, component misalignment, and cantilever loads.
4. Wind Restraint Details:

    a. Design Analysis: To support selection and arrangement of wind restraints. Include calculations of combined tensile and shear loads.
    b. Details: Indicate fabrication and arrangement. Detail attachments of restraints to the restrained items and to the structure. Show attachment locations, methods, and spacings. Identify components, list their strengths, and indicate directions and values of forces transmitted to the structure during seismic events. Indicate association with vibration isolation devices.
    c. Coordinate vibration isolation details with wind-restraint details required for equipment mounted outdoors. Comply with requirements in other Division 23 Sections for equipment mounted outdoors.
    d. Preapproval and Evaluation Documentation: By an agency acceptable to authorities having jurisdiction, showing maximum ratings of restraint items and the basis for approval (tests or calculations).

C. Coordination Drawings: Show coordination of seismic bracing for HVAC piping and equipment with other systems and equipment in the vicinity, including other supports and seismic restraints.

D. Welding certificates.

E. Qualification Data: For professional engineer and testing agency.

F. Air-Mounting System Performance Certification: Include natural frequency, load, and damping test data performed by an independent agency.

G. Field quality-control test reports.

H. Operation and Maintenance Data: For air-mounting systems to include in operation and maintenance manuals.

1.6 QUALITY ASSURANCE

A. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.

B. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

C. Restraint devices shall have horizontal and vertical load testing and analysis and shall bear anchorage preapproval OPA number from OSHPD, preapproval by ICC-ES, or preapproval by another agency acceptable to authorities having jurisdiction, showing maximum restraint ratings. Ratings based on independent testing are preferred to ratings based on calculations. If preapproved ratings are not available, submittals based on independent testing are preferred. Calculations (including combining shear and tensile loads) to support -restraint designs must be signed and sealed by a qualified professional engineer.

D. It is the objective of this Specification to provide the necessary design for the seismic restraint and control of excessive noise and vibration in the buildings due to the operation of machinery or equipment, and/or due to interconnected piping. The installation of all vibration isolation units, and associated hangers and bases, shall be under the direct supervision of the vibration isolation manufacturer’s representatives.

1. All vibration isolators shall have either known undeflected heights or calibration markings so that, after adjustment when carrying their load, the deflection under load can be verified, thus determining that the load is within the proper range of the device and that the correct degree of vibration isolation ins being provided according to the design.
2. All isolators shall operate in the linear portion of their load versus deflection curve. Load versus deflection curves shall be furnished by the manufacturer, and must be linear over a deflection range of not less than 50 percent above the design deflection.

3. The theoretical vertical natural frequency for each support point, based upon load per isolator and isolator stiffness, shall not differ from the design objectives for the equipment as whole by more than plus or minus 10 percent.
4. All neoprene mountings shall have a shore hardness of 30 to 60 plus or minus 5, after minimum aging of 20 days or corresponding oven aging.

1.7 MANUFACTURER RESPONSIBILITIES

A. Manufacturer of vibration isolation control equipment shall have the following responsibilities:

1. Determine vibration isolation restraint sizes and locations.
2. Provide piping and equipment isolation systems restraints as scheduled or specified.
3. Guarantee specified isolation system deflection.
4. Provide installation instructions, drawings and field supervision to assure proper installation and performance.
5. Purchased and/or fabricated equipment must be designed to safely accept external forces of one-half "G" load in any direction for all rigidly and resiliently supported equipment and piping without failure and permanent displacement of the equipment. Life safety equipment including, but not limited to, fire pumps, sprinkler piping, and machinery must be capable of safely accepting external forces up to one "G" load in any direction without permanent displacement of the supported equipment. Substitution of "Internally Isolated" mechanical equipment in lieu of the specified isolation of this Section must be approved for individual equipment units and is acceptable only if above accelerations are certified in writing by equipment manufacturer and stamped by a licensed civil or structural engineer.

1.8 CONTRACTOR RESPONSIBILITIES

A. The Contractor performing the work on equipment in the section shall have the following responsibilities.

1. Identify the components that are part of the Quality Assurance Plan.
2. All electrical components for standby or emergency power systems.
3. All flammable, combustible and highly toxic piping and their associated mechanical systems.
4. All ductwork containing hazardous materials.
5. All equipment using combustible or toxic energy sources.
6. Identify all Special inspection and Testing.
7. List control procedures within the contractor's organization including methods and frequency of reporting and their distribution.
8. List personnel and their qualifications exercising control over the seismic aspects of the project.
9. Purchased and/or fabricated equipment must be designed to safely accept external forces of one "G" load in any direction for all rigidly and resiliently

supported life safety or hazardous equipment components, piping and ductwork without failure and permanent displacement of the equipment.

PART 2 - PRODUCTS

2.1 VIBRATION ISOLATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Amber/Booth Company, Inc.
2. Kinetics Noise Control.
3. Mason Industries.
4. Vibration Eliminator Co., Inc.
5. Vibration Mountings & Controls, Inc.
6. Victaulic

B. Vibration Isolator Types:

1. Type A: Spring isolators shall incorporate the following:

   a. Minimum diameter of 0.8 of the loaded operating height.
   b. Corrosion resistance where exposed to corrosive environment with:

      1) Springs cadmium plated or electro-galvanized.
      2) Hardware cadmium plated.
      3) All other metal parts hot-dip galvanized.

   c. Reserve deflection (from loaded to solid height) of 50 percent of rated deflection.
   d. Minimum 1/4 inch thick neoprene acoustical base pad on underside, unless designated otherwise.
   e. Designed and installed so that ends of springs remain parallel and all springs installed with adjustment bolts.
   f. Non-resonant with equipment forcing frequencies or support structure natural frequencies.
   g. Spring isolators to be Mason Type SLF, or as approved.
   h. This isolator must be accompanied by seismic isolator Type II.

2. Type B: Spring isolators shall be same as Type A, except:

   a. Provide built-in vertical limit stops with minimum 1/4 inch clearance under normal operation.
   b. Tapped holes in top plate for bolting to equipment when subject to wind load.
   c. Capable of supporting equipment at a fixed elevation during equipment erection. Installed and operating heights shall be identical.
   d. Adjustable and removable spring pack with separate neoprene pad isolation.

e. Housing shall be designed to accept 1 G of acceleration.
f. Mason Type SLR, or as approved.

3. Type C: Spring hanger rod isolators shall incorporate the following:

a. Spring element seated on a steel washer within a neoprene cup incorporating a rod isolation bushing.
b. Steel retainer box encasing the spring and neoprene cup.
c. Mason Type HS, or as approved.

4. Type E: Elastomer hanger rod isolators shall be incorporate the following:

a. Molded unit type neoprene element with projecting bushing lining rod clearance hole.
b. Neoprene element shall be minimum 1-3/4 inch thick.
c. Steel retainer box encasing neoprene mounting.
d. Clearance between mounting hanger rod and neoprene bushing shall be minimum of 1/8 inch.
e. Mason Type HD, or as approved.

5. Type F: Combination spring/elastomer hanger rod isolators to incorporate the following:

a. Spring and neoprene isolator elements in a steel box retainer. Neoprene of double deflection type. Single deflection is unacceptable. Spring seated in a neoprene cup with extended rod bushing.
b. Characteristics of spring and neoprene as describe in Type A and Type E isolators.
c. Mason Type 30N, or as approved.

6. Type G: Pad type elastomer mountings to incorporate the following:

a. 0.750 inch minimum thickness.
b. 50 psi maximum loading.
c. Ribbed or waffled design.
d. 0.10 inch deflection per pad thickness.
e. 1/16 inch galvanized steel plate between multiple layers or pad thickness.
f. Suitable bearing plate to distribute load.
g. Mason Type Super W, or as approved.

7. Type H: Pad type elastomer mountings to incorporate the following:

a. Laminate canvas duck and neoprene.
b. Maximum loading 1000 psi.
c. Suitable bearing plate to distribute load.
d. Minimum thickness, 1/2 inch.
e. Mason Type HL, or as approved.

8. Type J: Rail type spring isolators:

a. Rail type spring isolators shall provide steel members of sufficient strength to prevent flexure with equipment operation.
b. Mason Type ICS, or equal.

9. Type K: Pipe anchors:

a. Vibration isolator manufacturer shall provide an all directional acoustical pipe anchor, consisting of a telescopic arrangement of two sizes of steel tubing separated by a minimum half inch thickness of heavy duty neoprene and duck or neoprene isolation material.
b. Vertical restraints shall be provided by similar material arranged to prevent vertical travel in either direction.
c. Allowable loads on the isolation material shall not exceed 500 psi and the design shall be balanced for equal resistance in any direction.
d. Mason Type ADA, or as approved.

2.2 AIR-MOUNTING SYSTEMS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Kinetics Noise Control.
2. Mason Industries.
3. Vibration Eliminator Co., Inc.

B. Air Mounts: Freestanding, single or multiple, compressed-air bellows.

1. Assembly: Upper and lower steel sections connected by a replaceable, flexible, nylon-reinforced neoprene bellows.
2. Maximum Natural Frequency: 3 Hz.
3. Operating Pressure Range: 25 to 100 psig (172 to 690 kPa).
4. Burst Pressure: At least three times manufacturer's published maximum operating pressure.
5. Leveling Valves: Minimum of 3 required to maintain leveling within plus or minus 1/8 inch (3 mm).

C. Restrained Air Mounts: Housed compressed-air bellows.

1. Assembly: Upper and lower steel sections connected by a replaceable, flexible, nylon-reinforced neoprene bellows and spring, with angle-iron frame having vertical-limit stops and channel-section top with leveling adjustment and attachment screws.
2. Maximum Natural Frequency: 3 Hz.
3. Operating Pressure Range: 25 to 100 psig (172 to 690 kPa).
4. Burst Pressure: At least three times manufacturer's published maximum operating pressure.
5. Leveling Valves: Minimum of 3 required to maintain leveling within plus or minus 1/8 inch (3 mm).

2.3 VIBRATION ISOLATION EQUIPMENT BASES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Amber/Booth Company, Inc.
2. Kinetics Noise Control.
3. Mason Industries.
4. Vibration Eliminator Co., Inc.
5. Vibration Mountings & Controls, Inc.

B. Type B-1: Integral Structural Steel Base

1. Reinforced, as required, to prevent base flexure at start-up and misalignment of drive and driven units. Centrifugal fan bases complete with motor slide rails. Drilled for drive and driven unit mounting template.
2. Mason Type M, WF, or as approved.

C. Type B-2: Concrete Inertia Base

1. Concrete inertia bases shall be formed in a structural steel perimeter base, reinforced as required to prevent flexure, misalignment of drive and driven unit or stress transferal into equipment. The base shall be complete with motor slide rails, pump base elbow supports, and complete with height saving brackets, reinforcing, equipment bolting provisions and isolators.
2. Minimum thickness of the inertia base shall be according to the following tabulation:

Motor Size (hp)	Minimum Thickness (in)
5-15	6
20-50	8
60-75	10
100-250	12
300-500	18

3. Mason Type K, BMK, or as approved.

D. Type B-3: Curb Mounted Base

1. Curb mounted rooftop equipment shall be mounted on spring isolation curbs that directly sit on roof construction and are flashed and incorporated into roof's membrane waterproofing system.
2. All spring locations shall have removable waterproof covers to allow for spring adjustment and/or removal.
3. All spring mounts shall be as Isolator Type B.
4. Curb and spring mounting shall be capable of withstanding 110mph wind and 1.0 g seismic loads for life safety or hazardous components.

5. Curbs shall be Mason Type CMAB or RSC (depending on deflection required), or approved equal.

E. Type B-4: Vaneaxial Fan Built-Up Casing Floating Base

1. The vaneaxial fan casing, coils, filter assembly and inlet/discharge silencers shall be erected on top of a poured-in-place, reinforced concrete floating floor supported on Mason Industries Type EAFM 2" high mounting system, or as approved.
2. The mountings shall be oriented in the floating floor base for the weight and weight distribution of the supported equipment (casing, coils, filter, silencers) on the floating floor.
3. The plywood form shall be Type AC exterior grade, 2", thick. Isolation mounts shall be 2", thick and shall be selected and oriented to provide deflections not exceeding 0.3" or 10 Hz frequency.
4. The fans shall be resiliently spring supported, and as described elsewhere, from concrete piers erected from the structural slab and isolated from the floating floor.
5. The design and installation of the vaneaxial fan built-up casing floating floor and fan isolation shall be coordinated with the vibration control vendor such that there will be no short circuit of the floating built-up casing base and the building structure.

2.4 FLEXIBLE CONNECTORS

A. Elastomer Type FC-1:

1. Manufactured of nylon tire cord and EPDM both molded and cured with hydraulic presses.
2. Straight connectors shall have two spheres reinforced with a molded-in external ductile iron ring between spheres.
3. Elbow shall be long radius reducing type.
4. Rated 250 psi at 170 degrees F dropping in a straight line to 170 psi at 250 degrees F for sizes 1-1/2 inch to 12 inch elbows. Elbows shall be rated no less than 90 percent of straight connections.
5. Sizes 10 inches to 12 inches to employ control cables with neoprene end fittings isolated from anchor plates by means of 1/2 inch bridge bearing neoprene bushings.
6. Minimum safety factor, 4 to 1 at maximum pressure ratings.
7. Submittals shall include test reports.
8. Mason Type MFTNC Superflex.

B. Flexible Stainless Hose, Type FC-2:

1. Braided flexible metal hose.
2. 2 inch pipe size and smaller with male nipple fittings.
3. 2-1/2 inch and larger pipe size with fixed steel flanges.
4. Suitable for operating pressure with 4 to 1 minimum safety factor.
5. Length as required or shown on drawings.
6. Mason Type BSS, or as approved.

Flexible Couplings, Type FC-3:

7. Flexible style grooved-joint couplings
8. 2 inch pipe size and larger
9. Suitable for vibration attenuation at major equipment connections
10. Victaulic Styles 77, 177 or W77

2.5 FACTORY FINISHES

A. Finish: Manufacturer's standard prime-coat finish ready for field painting.

B. Finish: Manufacturer's standard paint applied to factory-assembled and -tested equipment before shipping.

1. Powder coating on springs and housings.
2. All hardware shall be galvanized. Hot-dip galvanize metal components for exterior use.
3. Baked enamel or powder coat for metal components on isolators for interior use.
4. Color-code or otherwise mark vibration isolation and seismic- and wind-control devices to indicate capacity range.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and equipment to receive vibration isolation and seismic- and wind-control devices for compliance with requirements for installation tolerances and other conditions affecting performance.

B. Examine roughing-in of reinforcement and cast-in-place anchors to verify actual locations before installation.

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

3.2 APPLICATIONS

A. Multiple Pipe Supports: Secure pipes to trapeze member with clamps approved for application by an agency acceptable to authorities having jurisdiction.

B. Hanger Rod Stiffeners: Install hanger rod stiffeners where indicated or scheduled on Drawings to receive them and where required to prevent buckling of hanger rods due to seismic forces.

C. Strength of Support -Restraint Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static loads within specified loading limits.

3.3 VIBRATION-CONTROL -RESTRAINT DEVICE INSTALLATION

A. Comply with requirements in Division 07 Section "Roof Accessories" for installation of roof curbs, equipment supports, and roof penetrations.

B. Equipment Restraints:

1. Install seismic snubbers on HVAC equipment mounted on vibration isolators. Locate snubbers as close as possible to vibration isolators and bolt to equipment base and supporting structure.
2. Install resilient bolt isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch.
3. Install seismic-restraint devices using methods approved by an agency acceptable to authorities having jurisdiction providing required submittals for component.

C. Piping Restraints:

1. Comply with requirements in MSS SP-127.
2. Space lateral supports a maximum of 40 feet o.c., and longitudinal supports a maximum of 80 feet o.c.
3. Brace a change of direction longer than 12 feet.

D. Install cables so they do not bend across edges of adjacent equipment or building structure.

E. Install bushing assemblies for anchor bolts for floor-mounted equipment, arranged to provide resilient media between anchor bolt and mounting hole in concrete base.

F. Install bushing assemblies for mounting bolts for wall-mounted equipment, arranged to provide resilient media where equipment or equipment-mounting channels are attached to wall.

G. Attachment to Structure: If specific attachment is not indicated, anchor bracing to structure at flanges of beams, at upper truss chords of bar joists, or at concrete members.

H. Drilled-in Anchors:

1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.

3. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
4. Adhesive Anchors: Clean holes to remove loose material and drilling dust prior to installation of adhesive. Place adhesive in holes proceeding from the bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive.
5. Set anchors to manufacturer's recommended torque, using a torque wrench.
6. Install zinc-coated steel anchors for interior and stainless-steel anchors for exterior applications.

3.4 FIELD QUALITY CONTROL

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

B. Perform tests and inspections.

C. Tests and Inspections:

1. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.
2. Schedule test with Owner, through Architect, before connecting anchorage device to restrained component (unless postconnection testing has been approved), and with at least seven days' advance notice.
3. Obtain Architect's approval before transmitting test loads to structure. Provide temporary load-spreading members.
4. Test at least four of each type and size of installed anchors and fasteners selected by Architect.
5. Test to 90 percent of rated proof load of device.
6. Measure isolator restraint clearance.
7. Measure isolator deflection.
8. Verify snubber minimum clearances.
9. Air-Mounting System Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
10. Air-Mounting System Operational Test: Test the compressed-air leveling system.
11. Test and adjust air-mounting system controls and safeties.
12. If a device fails test, modify all installations of same type and retest until satisfactory results are achieved.

D. Remove and replace malfunctioning units and retest as specified above.

E. Prepare test and inspection reports.

3.5 ADJUSTING

A. Adjust isolators after piping system is at operating weight.

B. Adjust limit stops on restrained spring isolators to mount equipment at normal operating height. After equipment installation is complete, adjust limit stops so they are out of contact during normal operation.

C. Adjust air-spring leveling mechanism.

D. Adjust active height of spring isolators.

E. Adjust restraints to permit free movement of equipment within normal mode of operation.

3.6 HVAC VIBRATION-CONTROL DEVICE SCHEDULE

A. As scheduled on drawings or in following table.

Equipment	Base Type	Isolator Type	Minimum Static Deflection (inches)
Floor Mounted Air Handling Units	B-1	A	1.0
Floor Mounted Centrifugal Fans	B-1	A	1.0
Floor Mounted Tubular Fans	B-1	A	1.0
Ceiling Suspended Fan vent Sets	--	F	1.25
Ceiling Suspended Tubular Fans	--	F	1.25
Ceiling Suspended Centrifugal Fans	--	F	1.25
Ceiling Suspended FCU and FPB	--	F	1.25
Ceiling Suspended Split DX system	--	F	1.25
Ceiling Suspended Unit Heaters	--	F	1.25
Suspended Water Piping *	--	F	1.25
Pumps	B-2	B	2.5
Chillers	B-1	H	0.25

* Note: All water piping within MER's, and within 50 ft of Mechanical Rooms.

3.7 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain air-mounting systems. Refer to Division 01 Section "Demonstration And Training."

END OF SECTION 23 05 48

SECTION 23 05 53 - IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. Section Includes:

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

1.3 SUBMITTALS

A. Product Data: For each type of product indicated, manufacturer’s catalog data, including size, color and materials.

B. Sustainable Design Document Submittals: Refer to section 01 81 13.14 “Sustainable Design Requirements – LEED V4 BD+C.

1. Product Data: Documentation for Low Emitting Materials
   a. Low Emitting Materials for Paints and Coatings.
   b. Low Emitting Materials for Adhesives and Sealants.

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

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

E. Valve numbering scheme.

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

1.4 QUALITY ASSURANCE

A. Comply with ASME A 13.1 “Scheme for the Identification of Piping Systems.”

1.5 COORDINATION

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

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

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

PART 2 - PRODUCTS

2.1 EQUIPMENT LABELS

A. Metal Labels for Equipment:

1. Material and Thickness: Aluminum, 0.032-inch minimum thickness, and having predrilled or stamped holes for attachment hardware.
2. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
3. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
4. Fasteners: Stainless-steel rivets or self-tapping screws.
5. Adhesive: Labels to be self adhering or reference adhesives and sealant requirements for LEED v4 unless used underground or in building exterior. Contact-type permanent adhesive, compatible with substrate.

B. Plastic Labels for Equipment:

1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch (3.2 mm) thick, and having predrilled holes for attachment hardware.
2. Letter Color: White.
3. Background Color: Black.
4. Maximum Temperature: Able to withstand temperatures up to 160 deg F (71 deg C).
5. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch (64 by 19 mm).

6. Minimum Letter Size: 1/4 inch (6.4 mm) for name of units if viewing distance is less than 24 inches (600 mm), 1/2 inch (13 mm) for viewing distances up to 72 inches (1830 mm), and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
7. Fasteners: Stainless-steel rivets or self-tapping screws.
8. Adhesive: Labels to be self adhering or reference adhesives and sealant requirements for LEED v4 unless used underground or in building exterior. Contact-type permanent adhesive, compatible with substrate.

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

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

2.2 WARNING SIGNS AND LABELS

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

B. Letter Color: Red.

C. Background Color: White.

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

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

F. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

G. Fasteners: Stainless-steel rivets.

H. Adhesive: Labels to be self adhering or low emitting adhesives and sealant in compliance with the requirements for LEED v4 unless used underground or in building exterior. Contact-type permanent adhesive, compatible with substrate.

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

2.3 PIPE LABELS

A. General Requirements for Manufactured Pipe Labels: Preprinted, color-coded, with lettering indicating service, and showing flow direction.

B. Pretensioned Pipe Labels: Precoiled, semirigid plastic formed to cover full circumference of pipe and to attach to pipe without fasteners or adhesive.

1. NPS 5 (DN 125) and smaller: Attach to pipe without fasteners or adhesive.
2. NPS 6 (DN 150) and larger: Attach to pipe with stainless steel spring fasteners.

C. Pipe Label Contents: Include identification of piping service using same designations or abbreviations as used on Drawings, pipe size, and an arrow indicating flow direction.

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

D. Maximum Temperature: Able to withstand temperatures up to 180 deg F.

2.4 DUCT LABELS

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

B. Letter Color: Black.

C. Background Color: White.

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

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

F. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

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

H. Adhesive: Labels to be self adhering or reference adhesives and sealant requirements for LEED v4 unless used underground or in building exterior. Contact-type permanent adhesive, compatible with substrate.

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

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

2.5 STENCILS

A. Stencils: Prepared with letter sizes according to ASME A13.1 for piping; minimum letter height of 1-1/4 inches (32 mm) for ducts; and minimum letter height of 3/4 inch (19 mm) for access panel and door labels, equipment labels, and similar operational instructions.

1. Stencil Material: Fiberboard or metal.
2. Stencil Paint: Exterior, gloss, acrylic enamel black unless otherwise indicated. Paint may be in pressurized spray-can form. Use paint compliant with California Department of Public Heath (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario.if used indoors, refer to Sections 09 91 23 and 01 81 13.14 for requirements.
3. Identification Paint: Exterior, acrylic enamel in colors according to ASME A13.1 unless otherwise indicated. Use low VOC emitting paint if used indoors, complying with Sections 09 91 23 and 01 81 13.

2.6 VALVE TAGS

A. Valve Tags: Stamped or engraved with 1/4-inch letters for piping system abbreviation and 1/2-inch numbers.

1. Tag Material: Aluminum, 0.032-inch minimum thickness, and having predrilled or stamped holes for attachment hardware.
2. Fasteners: Brass wire-link or beaded chain; or S-hook.

B. Valve Schedules: For each piping system, on 8-1/2-by-11-inch bond paper. Tabulate valve number, piping system, system abbreviation (as shown on valve tag), location of valve (room or space), normal-operating position (open, closed, or modulating), and variations for identification. Mark valves for emergency shutoff and similar special uses.

1. Valve-tag schedule shall be included in operation and maintenance data.

2.7 CEILING GRID TAGS FOR EQUIPMENT LOCATED ABOVE HARD OR LAY - IN CEILING

A. Description: 3/4” x 3” vinyl label, 3.0 Mil self-adhesive vinyl similar to DuraLabel Pro. Label color shall be black text on a white background. The label shall contain the following information:

1. Equipment name: Per Scheduled Equipment Naming convention.

B. All scheduled equipment above finish hard or lay-in ceiling shall be identified with an Equipment Tag.

2.8 WARNING TAGS

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

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

PART 3 - EXECUTION

3.1 PREPARATION

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

B. Refer to Section 01 35 46 “Indoor Air Quality” and Section 01 74 23 “Final Cleaning” for additional requirements.

3.2 INSTALLATION

A. Piping and Equipment Identification:

1. Install pipe markers adjacent to each valve and fitting, at each branch connection, on each side of wall, floor, and ceiling penetrations, where entering and leaving underground areas, and at minimum 40 foot spacing on horizontal and vertical pipe runs. Markers shall be arranged for easy reading at eye level.

2. Provide valve tags on all valves exposed or concealed unless otherwise noted.

3. Attach valve tag to stem of each valve to be tagged. Valve numbers shall follow in sequence the Owner's existing valve numbers, where applicable.

4. Provide a marker for each valve and equipment to be tagged, located above lift-out tile ceilings.

5. Provide a minimum of 4 valve charts. Chart information shall indicate job name, Contractor name, date of installation, valve number, valve location, valve type, valve purpose, and system in which installed. Mount framed chart in equipment room, and insert copy of chart in each operating and maintenance manual under separate tabbed section labeled "Valve Chart". Where project drawings include a piping flow schematic, request AutoCad file from Engineer and label all of the valves according to the valve chart and frame in an 18” x 24” frame in main mechanical or pump room.

6. Provide air and water flow diagrams installed in waterproof, laminated frames on the wall in each Mechanical Room. Air flow diagrams shall show locations of dampers, sensors, and exhaust fans associated with the air handling unit. Water flow diagrams shall show shut-off valves and control valve locations.

7. Permanently affix nameplate to each item of equipment using stainless steel pop rivets. Where irregular surface impede direct attachment of plates, affix plate to sheet metal bracket and attach bracket to equipment with screws, bolts or suitable adhesive from nameplate manufacturer.

8. Refrigeration System - Additional Requirements:

   a. Marking and Signage:

      (1) Provide a permanent sign containing the following information:

         (a) Name and address of installer.
         (b) Kind of refrigerant.
         (c) Lbs. of refrigerant.
         (d) Field test pressure applied.

      (2) Provide a permanent sign: Main electrical supply, i.e., main compr. disc.
      (3) Provide metal tags with 0.5" letters:

         (a) Shut-off valves to each vessel, i.e., L.P. receiver shut-off.
         (b) Relief valve.

      (4) Piping shall be marked as either:

         (a) Refrigerant - High Pressure - Liquid or Hot Gas.
         (b) Refrigerant - Low Pressure - Suction, Pumped Liquid Supply or

Pumped Liquid Return.

3.3 EQUIPMENT LABEL INSTALLATION

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

B. Locate equipment labels where accessible and visible.

3.4 PIPE LABEL INSTALLATION

A. Piping Color-Coding: Painting of piping shall be the following:

1. Green for Condenser Water Piping
2. Blue for Chilled Water Piping
3. Purple for Reclaimed Water
4. Black for Potable Domestic Water

B. Stenciled Pipe Label Option: Stenciled labels may be provided instead of manufactured pipe labels, at Installer's option. Install stenciled pipe labels complying with ASME A13.1, on each piping system.

1. Identification Paint: Use for contrasting background, paint complying with the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario. Reference specification section 01 81 13.

2. Stencil Paint: Use for pipe marking.

C. Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:

1. Near each valve and control device.
2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
3. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.
4. At access doors, manholes, and similar access points that permit view of concealed piping.
5. Near major equipment items and other points of origination and termination.
6. Spaced at maximum intervals of 50 feet along each run. Reduce intervals to 25 feet in areas of congested piping and equipment.
7. On piping above removable acoustical ceilings. Omit intermediately spaced labels.

D. Pipe Label Color Schedule:

1. Chilled-Water Piping:

   a. Background Color: White.

b. Letter Color: Blue.

2. Condenser-Water Piping:

   a. Background Color: White.
   b. Letter Color: Black.

3. Refrigerant Piping:

   a. Background Color: Black.
   b. Letter Color: White.

4. Chemical Feed Piping:

   a. Background Color: Red.
   b. Letter Color: White.

5. Vent and Relief Piping:

   a. Background Color: Black.
   b. Letter Color: White.

6. Fuel and Diesel Oil Piping:

   a. Background Color: Brown.
   b. Letter Color: White.

7. Glycol Piping:
   a. Background Color: Green with Gold Band
   b. Letter Color: White.

3.5 DUCT LABEL INSTALLATION

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

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

B. Stenciled Duct Label Option: Stenciled labels, showing service and flow direction, may be provided instead of plastic-laminated duct labels, at Installer's option, if lettering larger than 1 inch (25 mm) high is needed for proper identification because of distance from normal location of required identification.

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

3.6 VALVE-TAG INSTALLATION

A. Install tags on valves and control devices in piping systems, except check valves; valves within factory-fabricated equipment units; shutoff valves; faucets; convenience and lawn-watering hose connections; and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units. List tagged valves in a valve schedule.

B. Valve-Tag Application Schedule: Tag valves according to size, shape, and color scheme and with captions similar to those indicated in the following subparagraphs:

1. Valve-Tag Size and Shape:

   a. Chilled Water: 2 inches square.
   b. Condenser Water: 2 inches square.
   c. Refrigerant: 2 inches round.
   d. Gas: 2 inches round.
   e. Chemical Feed: 2 inches round.
   f. Vent and Relief: 2 inches square.
   g. Fuel and Diesel Oil: 2 inches square.

2. Valve-Tag Color:

   a. Chilled Water: Natural.
   b. Condenser Water: Natural.
   c. Refrigerant: Natural.
   d. Gas: Yellow.
   e. Chemical Feed: Natural.
   f. Vent and Relief: Natural.
   g. Fuel and Diesel Oil: Natural.

3. Letter Color:

   a. Chilled Water: Black.
   b. Condenser Water: Black.
   c. Refrigerant: Black.
   d. Gas: Black.
   e. Chemical Feed: Black.
   f. Vent and Fill: Black.
   g. Fuel and Diesel Oil: Black.

3.7 CEILING GRID TAGS

A. Install to identify location of:

1. Valves.
2. Volume dampers.
3. Terminal Units.
4. Other concealed equipment requiring access.

3.8 WARNING SIGNS AND LABELS

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

B. Letter Color: Red.

C. Background Color: White.

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

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

F. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

G. Fasteners: Stainless-steel rivets.

H. Adhesive: Labels to be self adhering or low emitting adhesives and sealant requirements in compliance with LEED v4 unless used underground or in building exterior. Contact-type permanent adhesive, compatible with substrate.

3.9 WARNING-TAG INSTALLATION

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

END OF SECTION 23 05 53

SECTION 23 05 80 - AIR CONTROL AND ACCESSORIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Basic Requirements: Provisions of Section 23 00 10 - Basic HVAC Requirements are part of this Section.

1.2 WORK INCLUDED

A. Pressurized Expansion Tank

B. Air Separator

C. Manual Air Vent

D. High Capacity Automatic Air Vent

E. Automatic Air Vent

1.3 QUALITY ASSURANCE

A. Expansion tanks shall be constructed with materials and standards which comply with the following standards:

1. American Society of Mechanical Engineers (ASME) Codes:
2. Boiler and Pressure Vessel Code: Section VIII Pressure Vessels, Division 1.

1.4 SUBMITTALS

A. Submit shop drawings in accordance with Division 01 requirements.

B. Submit schedule indicating make, model, size, etc. by system.

C. Submit statement of Code compliance where applicable.

D. Submit manufacturer's installation instructions.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Pressurized Expansion Tank:

1. Armstrong Fluid Technology
2. Bell & Gossett
3. Taco, Inc.

B. Air Separator:

1. Armstrong Fluid Technology.
2. Bell & Gossett, Inc.
3. Taco, Inc.

C. Manual Air Vent:

1. Armstrong Fluid Technology
2. Bell & Gossett. Inc.
3. Taco, Inc.

D. High Capacity Automatic Air Vent:

1. Armstrong Fluid Technology
2. Bell & Gossett. Inc.
3. Taco, Inc.

E. Automatic Air Vent:

1. Armstrong Fluid Technology
2. Bell & Gossett. Inc.
3. Taco, Inc.

F. Engineered Expansion Fill System:

1. Armstrong Fluid Technology
2. PACO
3. Systecon.
4. VC Systems.

2.2 FABRICATION

A. Pressurized Expansion Tank:

1. Closed type, welded steel construction, ASME stamped according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1 and rated for 125 PSIG working pressure at 240°F, National Board Form U-1A attached.
2. Replaceable elastomeric bladder to separate water and air.
3. Tappings for system connection, remote air connection, charging valve enclosure, drain connection.
4. Air-Charge Fittings: Schrader valve, stainless steel with EPDM seats.
5. Tank provided with integral base mount or factory furnished saddles.
6. Bolted and gasketed handhole for bladder replacement, lifting ring top and side, integral steel base ring for vertical mounting.
7. Factory precharged with air to scheduled pressure.
8. Factory cleaned and coated outside with prime coat of rust inhibitive paint.

B. Air Separator:

1. Tangential flow pattern, welded steel construction, ASME stamped and rated for 125 PSIG working pressure at 350°F, National Board Form U-1A attached.
2. Connections for system inlet and outlet, expansion tank, drain.
3. Perforated stainless steel air collector tube.
4. All acceptable manufactures to submit on an air separator without a strainer.
5. Tank: One-piece cast iron with an integral weir constructed to decelerate system flow to maximize air separation.
6. Constructed and stamped in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code.
7. Coalescing media.
8. Available with or without removable cover.
9. Threaded connection up to 2 inch (DN 50) and flanged connection for larger than 2 inch (DN 50).
10. Tank with drain plug and automatic leak free vent.

C. Manual Air Vent: Hydroscopic air valve, manual shutoff valve thumb screw actuator.
1. Body: Bronze.
2. Internal Parts: Nonferrous.
3. Operator: Screwdriver or thumbscrew.
4. Inlet Connection: NPS 1/2.
5. Discharge Connection: NPS 1/8.
6. CWP Rating: 150 psig.
7. Maximum Operating Temperature: 225 deg F.

D. High Capacity Automatic Air Vent: Cast iron body and bolted bonnet, threaded connection stainless steel and brass internals, composition disc, pilot operated, snap action, high capacity, instant non-modulating venting thru full range of 2 psi thru 150 psi with backflow prevention to prevent air from entering the system should pressure drop below atmospheric. Rated at 150 psi and 240°F.

E. Automatic Air Vent:

1. Body: Bronze or cast iron.
2. Internal Parts: Nonferrous.
3. Operator: Noncorrosive metal float.
4. Inlet Connection: NPS 1/2.
5. Discharge Connection: NPS 1/4.
6. CWP Rating: 150 psig.
7. Maximum Operating Temperature: 240 deg F.

F. Engineered Expansion System:

1. The expansion system shall be a complete factory fabricated and tested package requiring, one electrical connection point, one suction connection, one discharge connection.

2. The expansion system shall be a constant flow, constant pressure, skid mounted pumping unit with pumps as scheduled and a 900 Gallon atmospheric makeup storage tank.

3. Structural Frame: All components shall be mounted on a structural steel base suitable for grouting. The base shall be large enough to support the packaged pumping systems pumps, piping and control panel(s). Steel supports shall be welded to the base to support the piping and control panel(s). Both the base and supports shall consist of structural steel components, all welded per the AISC Manual of Steel Construction, Part 4, "Welded Joints". The entire assembly shall be primed and painted with two coats of machine enamel after fabrication.

4. Pumps shall have a continuously rising curve from minimum head to shut off condition and shall have a motor installed that is suitable for the full range of the published performance curve. All hydraulic components shall be manufactured from Type 316 stainless steel. Each impeller shall be fitted with a Teflon® seal ring. The 316L stainless steel shaft shall be fitted with Tungsten Carbide intermediary bearing(s). The mechanical seal shall be suitable for the full pressure and temperature range of the pump and shall be fitted with Carbon rotating face and Silicon Carbide stationary face. The motor pedestal shall be fitted with an oversize thrust bearing. The thrust bearing must be connected to the adapter and shaft coupling in such a manner as to eliminate pump axial loads from the motor, allowing standard NEMA design motors to be used. The thrust bearing will also remove the necessity for adjustments of any other moving part during the pump life cycle. The base mounted pump shall be assembled in a vertical shaft configuration with the suction and discharge connections being in-line at the bottom. Suction and discharge connections shall have same size flanges drilled for ANSI 125 rating. Supply a Premium Efficiency NEMA design 2-pole motor with the electrical characteristics and enclosure as indicated on the drawings.

5. Suction and Discharge Manifold Piping and Specialties:

a. The package piping shall consist of fabricated welded Type 304 stainless steel or galvanized steel headers using manufactured fittings conforming to ASME Code B.31.1. Saddle welded or fish mouth joints shall not be acceptable. The suction and discharge connections for the system shall be field reversible by removal of a blind flange or pipe cap and shall be ANSI Class, 150 flange or grooved end connection as sized on the documents. All piping for the system shall be sized for a maximum velocity of 8 feet per second with no greater head loss per 100 feet of pipe than 4 feet. Branch piping to the pumps shall be sized for the design capacity of the pump. Base mounted supports shall be provided for the suction header, the suction and discharge piping on each pump and the discharge header. Piping shall be supported independently of pump connections. Pipe supports welded directly to the pipe are not acceptable.

b. Butterfly valves shall be furnished on the suction and discharge of each pump. Valves shall be constructed per Specification Section 230523 – General Duty Valves for HVAC Piping..

c. A spring-loaded check valve shall be installed on the discharge of each pump. Valve shall be constructed per Specification Section 230523 – General Duty Valves for HVAC Piping.

d. A suction strainer shall be installed in the main suction piping prior to any pump suction connection and shall be constructed per Specification Section 232116 - HydronicPiping Specialties.

e. Pressure gauges, 4-1/2” diameter complying with Specification Section 230519 – Meters and Gauges for HVAC – Piping Specialties shall be furnished and mounted on the control cubicle for indication of all individual pump discharge pressures and all common suction and discharge pressures. All control sensing lines and gauge connections shall be piped with ball style shut-off valves and fitted with piston style impulse snubbers to prolong gauge life. Gauges shall be mounted such that they can be viewed from the front of the control enclosure.

6. Power and Control Panel:

f. The power and control enclosure shall be of multiple compartment construction. A single main incoming power lugs with overcurrent protection shall be housed in a dedicated compartment, and pump sequencing controls shall be housed in a separate dedicated compartment. Panels constructed with barriers or partitions are unacceptable. An across the line motor starter shall be furnished for each pump. Power supply shall be 460 volt, 3 Ph, 60 Hz, as scheduled.

g. The sequencing controls compartment shall include:

1. Disconnect switch.

2. Control circuit transformer 480/120 or 480/24 as determined by the manufacturer with primary and secondary fuses.
3. System hand-off-auto switch with provisions for remote system start/stop.
4. System initialized light.
5. Hand-off-auto switch for each pump.
6. Run light for each pump, low voltage LED style.
7. Pump failure alarm light (low voltage LED style) and reset pushbutton.
8. Lead pump selector switch for manual alternation of pumps.
9. Make-Up Tank High Level pilot light, LED style.
10. Make-Up Tank Low Level pilot light, LED style.
11. High System Pressure pilot light, LED style.
12. Low System Pressure pilot light, LED style.
13. Necessary interface to the building automation system.
14. Elapsed run time meter.
15. Contact output for remote run indication.
16. Contact output for remote failure indication.
17. Input signal for remote setting of discharge pressure setpoint.

PART 3 - EXECUTION

3.1 GENERAL

A. Install in accordance with manufacturers written instructions.

B. Install air vents at all high points of system to facilitate air removal for proper flow and heat transfer.

3.2 INSTALLATION

A. Pressurized Expansion Tank:

1. Isolate tank from system during system flushing and cleaning operations.
2. Vent excess air from tank prior to system heat-up.
3. Ensure that tank is properly charged with air at start of warranty period.
4. Install automatic air vent and pressure gauge at inlet.
5. Provide equipment tag indicating required charging pressure.
6. Provide drain valve and hose bibb adaptor.

B. Air Separator:

1. Support independently of connecting piping.
2. Install tap size union and gate valve with locking hand wheel in line to expansion tank.
3. Install full tap sized nipple, ball valve and plug for drain valve assembly.

C. Manual Air Vent:

2. Allow access.
3. Install manual air vent on air chamber when used on system high points and where continuous venting may be coincided.
4. Construct air chamber from:

    a. 1/2" x 2" thread reducer.
    b. 2" x 0'-4" nipple.
    c. 1/4" x 2" thread reducer.
    d. 1/4" x 1/8" brass bushing.

4. Manual air vent.
5. Provide manual air vent on all high points. Where high point will be concealed, route vent to nearest accessible location.
6. In lieu of the manual air vent assembly a pressure and temperature test port may be used to vent air when used with the master air vent tool supplied with the pressure and temperature test kit specified in Section 23 05 19.

D. High Capacity Automatic Air Vent:

1. Install where shown on drawings or standard details.
2. Install 1/2" ball valve and nipple between automatic air vent and system.
3. Provide proper access.
4. Do not install automatic air vent in concealed or non-accessible areas or where leakage may cause damage.
5. Pipe discharge to nearest floor drain.

E. Automatic Air Vent:

1. Install where shown on drawings or standard details.
2. Install 1/2" ball valve and nipple between automatic air vent and system.
3. Provide proper access.
4. Do not install automatic air vent in concealed or non-accessible areas or where leakage may cause damage.
5. Pipe discharge to nearest floor drain.

END OF SECTION 23 05 80

SECTION 23 05 93 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

B. Commissioning Requirements: Provisions of Sections 01 91 13 – General Commissioning Requirements, 01 91 15 – Facility Exterior Enclosure Commissioning are part of this Section.

1.2 SUMMARY

A. This Section includes the providing of labor, materials, equipment, and services necessary for complete testing, adjusting, balancing (TAB) of all heating, ventilating and air conditioning systems in accordance with the contract documents and all applicable codes and authorities having jurisdiction, for the following:

1. Air Systems: Balancing of air distribution systems including supply, return and exhaust systems, condensing units, all fan-coils and related equipment for:
   a. Constant-volume air systems.
   b. Variable-air-volume systems.
   c. Terminal devices for HVAC systems.
2. Hydronic Piping Systems: Testing and balancing, including pumps, chillers, heat exchangers, coils, and all related equipment for:
   a. Constant-flow systems.
   b. Variable-flow systems.
   c. Primary-secondary systems.
3. HVAC equipment quantitative-performance settings.
4. Space pressurization testing and adjusting.
5. Verifying that automatic control devices are functioning properly.
6. Smoke control systems testing and adjusting.
7. Reporting results of activities and procedures specified in this Section.

1.3 DEFINITIONS

A. Adjust: To regulate fluid flow rate and air patterns at the terminal equipment, such as to reduce fan speed or adjust a damper.

B. Balance: To proportion flows within the distribution system, including submains, branches, and terminals, according to indicated quantities.

C. Barrier or Boundary: Construction, either vertical or horizontal, such as walls, floors, and ceilings that are designed and constructed to restrict the movement of airflow, smoke, odors, and other pollutants.

D. Draft: A current of air, when referring to localized effect caused by one or more factors of high air velocity, low ambient temperature, or direction of airflow, whereby more heat is withdrawn from a person's skin than is normally dissipated.

E. NC: Noise criteria.

F. Procedure: An approach to and execution of a sequence of work operations to yield repeatable results.

G. RC: Room criteria.

H. Report Forms: Test data sheets for recording test data in logical order.

I. Static Head: The pressure due to the weight of the fluid above the point of measurement. In a closed system, static head is equal on both sides of the pump.

J. Suction Head: The height of fluid surface above the centerline of the pump on the suction side.

K. System Effect: A phenomenon that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.

L. System Effect Factors: Allowances used to calculate a reduction of the performance ratings of a fan when installed under conditions different from those presented when the fan was performance tested.

M. TAB: Testing, adjusting, and balancing.

N. Terminal: A point where the controlled medium, such as fluid or energy, enters or leaves the distribution system.

O. Test: A procedure to determine quantitative performance of systems or equipment.

P. Testing, Adjusting, and Balancing (TAB) Firm: The entity responsible for performing and reporting TAB procedures.

1.4 SUBMITTALS

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

B. Contract Documents Examination Report: Within 30 days from Contractor's Notice to Proceed, submit the Contract Documents review report as specified in Part 3.

C. Strategies and Procedures Plan: Within 60 days from Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures as specified in Part 3 "Preparation" Article. Include a complete set of report forms intended for use on this Project.

D. Certified TAB Reports: Submit two copies of reports prepared, as specified in this Section, on approved forms certified by TAB firm.

E. Sample Report Forms: Submit two sets of sample TAB report forms.

F. Warranties specified in this Section.

G. At least fifteen (15) days prior to starting field work, submit three (3) copies of report forms filled out, including design flow values, installed equipment pressure drops and required air flow for air terminals. Submit a complete list of instruments proposed to be used, organized in appropriate categories and include data sheets for each. Indicate each manufacturer and model number, description and use when needed to further identify instrument, size or capacity range and latest calibration date.

1. Architect/Engineer will review submittals for compliance with Contract Documents, and will return one set marked to indicate discrepancies noted between data shown and Contract Documents, additional, or more accurate, instruments required and requests for recalibration of specific instruments.
2. Submit proposed method of balancing variable air volume systems to account for system diversity.

H. Submit as-built drawings showing locations of all readings.

1.5 QUALITY ASSURANCE

A. TAB Firm Qualifications: Engage a TAB firm certified by AABC, NEBB, or TABB.

1. Furnish documentation that TAB firm is a member of one of the noted entities and that it has satisfactorily balanced at least three systems of comparable type and size of this project. Include list of such projects. TAB contractor shall be a certified member of the Testing Adjusting and Balancing Bureau (TABB) or the National Environmental Balancing Bureau (NEBB).

B. TAB Field Supervisor: Employee of the TAB contractor and certified by Associated Air Balancing Counsel (AABC), NEBB or TABB.

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

D. TAB Conference: Meet with Owner's, Owner’s CxA and Architect's representatives on approval of TAB strategies and procedures plan to develop a mutual understanding of the details. Ensure the participation of TAB team members, equipment manufacturers' authorized service representatives, HVAC controls installers, and other support personnel. Provide seven days' advance notice of scheduled meeting time and location.

1. Agenda Items: Include at least the following:

   a. Submittal distribution requirements.
   b. The Contract Documents examination report.
   c. TAB plan.
   d. Work schedule and Project-site access requirements.
   e. Coordination and cooperation of trades and subcontractors.
   f. Coordination of documentation and communication flow.

E. Certification of TAB Reports: Certify TAB field data reports. This certification includes the following:

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

F. TAB Report Forms: Use standard forms from AABC's "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems"; NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems"; or TABB "Contractors Certification Manual."

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

H. Instrumentation Calibration: Calibrate instruments at least every six months or more frequently if required by instrument manufacturer.

1. Keep an updated record of instrument calibration that indicates date of calibration and the name of party performing instrument calibration.

I. ASHRAE Compliance: Applicable requirements in the latest edition of ASHRAE 62.1-, Section 7.2.2 - "Air Balancing."

J. ASHRAE/IESNA 90.1 Latest Edition Compliance: Applicable requirements in the latest edition of ASHRAE/IESNA 90.1, Section 6.7.2.3 - "System Balancing."

1.6 PROJECT CONDITIONS

A. Full Owner Occupancy: Owner will not occupy the building during entire TAB period. TAB operations shall be completed prior to Substantial Completion.

1.7 COORDINATION

A. Coordinate the efforts of factory-authorized service representatives for systems and equipment, HVAC controls installers, and other mechanics to operate HVAC systems and equipment to support and assist TAB activities.

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

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

1.8 WARRANTY

A. National Project Performance Guarantee: Provide a guarantee on AABC's "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems" forms stating that AABC will assist in completing requirements of the Contract Documents if TAB firm fails to comply with the Contract Documents. Guarantee includes the following provisions:

1. The certified TAB firm has tested and balanced systems according to the Contract Documents.
2. Systems are balanced to optimum performance capabilities within design and installation limits.

B. Special Guarantee: Provide a guarantee on NEBB or TABB forms stating that NEBB or TABB will assist in completing requirements of the Contract Documents if TAB firm fails to comply with the Contract Documents. Guarantee shall include the following provisions:

1. The certified TAB firm has tested and balanced systems according to the Contract Documents.
2. Systems are balanced to optimum performance capabilities within design and installation limits.

1.9 GENERAL COMMENTS

A. Water Balance: Readings from venturi flow meters, or automatic pressure independent flow control devices will be given highest priority as to accuracy. Where neither is specified pump curves and chiller pressure drops are to be correlated to establish flow. Pressure drop across coils or chillers is to be used to proportion flow. Volt and ampere readings will be used as checks. Temperature data will be used only as a performance check and not for balancing.

B. Air Balance: Readings from a pitot tube traverse will be given highest priority as to accuracy. Terminal flow shall be as taken from the terminal DDC flow readings. Outlet flow as established by flow hood will be used to pro-rate air flow. Pressure readings as well as voltage and ampere readings will be used for check purposes only. Temperature readings will be used as a check against performance.

C. All readings shall be cross-checked for accuracy. These cross-checks shall be tabulated within the report.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 EXAMINATION

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

1. Contract Documents are defined in the General and Supplementary Conditions of Contract.
2. Verify that balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers, are required by the Contract Documents. Verify that quantities and locations of these balancing devices are accessible and appropriate for effective balancing and for efficient system and equipment operation.

B. Examine approved submittal data of HVAC systems and equipment.

C. Examine Project Record Documents described in Division 01 Section "Project Record Documents."

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

E. Examine equipment performance data including fan and pump curves. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system. Calculate system effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from those presented when the equipment was performance tested at the factory. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," Sections 7 through 10; or in SMACNA's "HVAC Systems--Duct Design," Sections 5 and 6. Compare this data with the design data and installed conditions.

F. Examine system and equipment installations to verify that they are complete and that testing, cleaning, adjusting, and commissioning specified in individual Sections have been performed.

G. Examine system and equipment test reports.

H. Examine HVAC system and equipment installations to verify that indicated balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers, are properly installed, and that their locations are accessible and appropriate for effective balancing and for efficient system and equipment operation.

I. Examine systems for functional deficiencies that cannot be corrected by adjusting and balancing.

J. Examine HVAC equipment to ensure that clean filters have been installed, bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.

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

L. Examine plenum ceilings used for supply air to verify that they are airtight. Verify that pipe penetrations and other holes are sealed.

M. Examine strainers for clean screens and proper perforations.

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

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

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

Q. Examine equipment for installation and for properly operating safety interlocks and controls.

R. Conduct monthly site visits during construction to act as QA/QC agent on installation and provide report of any deficiencies found.

S. Examine automatic temperature system components to verify the following:

1. Dampers, valves, and other controlled devices are operated by the intended controller.
2. Dampers and valves are in the position indicated by the controller.
3. Integrity of valves and dampers for free and full operation and for tightness of fully closed and fully open positions. This includes dampers in multizone units, mixing boxes, and variable-air-volume terminals.
4. Automatic modulating and shutoff valves, including two-way valves and three-way mixing and diverting valves, are properly connected.
5. Thermostats and humidistats are located to avoid adverse effects of sunlight, drafts, and cold walls.
6. Sensors are located to sense only the intended conditions.
7. Sequence of operation for control modes is according to the Contract Documents.

8. Controller set points are set at indicated values.
9. Interlocked systems are operating.
10. Changeover from heating to cooling mode occurs according to indicated values.

T. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values. Submit report recommending addition and/or relocation of balancing devices, including, but not limited to, volume dampers, balancing valves, flow metering devices for air and water, and pressure and temperature measuring points.

3.2 PREPARATION

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

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

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

3.3 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in ASHRAE 111 and this Section.

1. Comply with requirements in the latest edition of ASHRAE 62.1, Section 7.2.2 - "Air Balancing."

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary to allow adequate performance of procedures. After testing and balancing, close probe holes and patch insulation with new materials identical to those removed. Restore vapor barrier and finish according to insulation Specifications for this Project.

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

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

3.4 PROCEDURES FOR DUCT PRESSURE TESTS

A. Refer to section 23 31 13 for procedures.

3.5 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

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

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

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

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

E. Check airflow patterns from the outside-air louvers and dampers and the return- and exhaust-air dampers, through the supply-fan discharge and mixing dampers, including flow patterns through dedicated outdoor air units.

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

G. Verify that motor starters and VFD’s are equipped with properly sized thermal protection.

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

I. Check for airflow blockages.

J. Check condensate drains for proper connections and functioning.

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

L. Check for proper sealing of air duct system.

3.6 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

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

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

a. Measure outlet static pressure as far downstream from the fan as practicable and upstream from restrictions in ducts such as elbows and transitions.

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

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

a. Simulate dirty filter operation and record the point at which maintenance personnel must change filters.

3. Measure static pressures entering and leaving other devices such as sound traps, heat recovery equipment, and air washers, under final balanced conditions.
4. Compare design data with installed conditions to determine variations in design static pressures versus actual static pressures. Compare actual system effect factors with calculated system effect factors to identify where variations occur. Recommend corrective action to align design and actual conditions.
5. Obtain approval from Engineer for adjustment of fan speed higher or lower than indicated speed. Make required adjustments to pulley sizes, motor sizes, and electrical connections to accommodate fan-speed changes.
6. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full cooling, full heating, economizer, and any other operating modes to determine the maximum required brake horsepower.

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

1. Measure static pressure at a point downstream from the balancing damper and adjust volume dampers until the proper static pressure is achieved.

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

2. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.

C. Measure terminal outlets and inlets without making adjustments.

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

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

1. Adjust each outlet in same room or space to within plus or minus 5 percent of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.
2. Adjust patterns of adjustable outlets for proper distribution without drafts.

3.7 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

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

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

1. Set outside-air dampers at minimum, and return- and exhaust-air dampers at a position that simulates full-cooling load.
2. Select the terminal unit that is most critical to the supply-fan airflow and static pressure. Measure static pressure. Adjust system static pressure so the entering static pressure for the critical terminal unit is not less than the sum of terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
3. Measure total system airflow. Adjust to within +10% of indicated airflow.
4. Set terminal units at maximum airflow and adjust controller or regulator to deliver the designed maximum airflow. Use terminal-unit manufacturer's written instructions to make this adjustment. When total airflow is correct, balance the air outlets downstream from terminal units as described for constant-volume air systems.
5. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow as described for constant-volume air systems.

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

6. Remeasure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets as described for constant-volume air systems.
7. Measure static pressure at the most critical terminal unit and adjust the static-pressure controller at the main supply-air sensing station to ensure that adequate static pressure is maintained at the most critical unit.
8. Record the final fan performance data.

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

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

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

8. Measure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets as described for constant-volume air systems.

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

1. Set system at maximum indicated airflow by setting the required number of terminal units at minimum airflow. Select the reduced airflow terminal units so they are distributed evenly among the branch ducts.
2. Adjust supply fan to maximum indicated airflow with the variable-airflow controller set at maximum airflow.
3. Set terminal units at full-airflow condition.
4. Adjust terminal units starting at the supply-fan end of the system and continuing progressively to the end of the system. Adjust inlet dampers of each terminal unit to indicated airflow. When total airflow is correct, balance the air outlets downstream from terminal units as described for constant-volume air systems.
5. Adjust terminal units for minimum airflow.
6. Measure static pressure at the sensor.
7. Measure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets as described for constant-volume air systems.

3.8 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

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

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

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

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

3.9 PROCEDURES FOR HYDRONIC SYSTEMS

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

1. Verify impeller size by operating the pump with the discharge valve closed. Read pressure differential across the pump. Convert pressure to head and correct for differences in gage heights. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.
2. Check system resistance. With all valves open, read pressure differential across the pump and mark pump manufacturer's head-capacity curve. Adjust pump discharge valve until indicated water flow is achieved.
3. Verify pump-motor brake horsepower. Calculate the intended brake horsepower for the system based on pump manufacturer's performance data. Compare calculated brake horsepower with nameplate data on the pump motor. Report conditions where actual amperage exceeds motor nameplate amperage.
4. Report flow rates that are not within plus or minus 5 percent of design.

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

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

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

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

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

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

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

G. Measure the differential-pressure control valve settings existing at the conclusions of balancing.

3.10 PROCEDURES FOR VARIABLE-FLOW HYDRONIC SYSTEMS

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

3.11 PROCEDURES FOR PRIMARY-SECONDARY-FLOW HYDRONIC SYSTEMS

A. Balance the primary system crossover flow first, then balance the secondary system.

3.12 PROCEDURES FOR HEAT EXCHANGERS

A. Measure water flow through all circuits.

B. Adjust water flow to within specified tolerances.

C. Measure inlet and outlet water temperatures.

D. Measure inlet steam pressure.

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

3.13 PROCEDURES FOR MOTORS

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

1. Manufacturer, model, and serial numbers.
2. Motor horsepower rating.
3. Motor rpm.
4. Efficiency rating.
5. Nameplate and measured voltage, each phase.
6. Nameplate and measured amperage, each phase.

7. Starter thermal-protection-element rating.

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

3.14 PROCEDURES FOR CHILLERS

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

1. Evaporator-water entering and leaving temperatures, pressure drop, and water flow.
2. If water-cooled chillers, condenser-water entering and leaving temperatures, pressure drop, and water flow.
3. Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.
4. Power factor if factory-installed instrumentation is furnished for measuring kilowatt.
5. Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatt.
6. Capacity: Calculate in tons of cooling.
7. If air-cooled chillers, verify condenser-fan rotation and record fan and motor data including number of fans and entering- and leaving-air temperatures.

3.15 PROCEDURES FOR COOLING TOWERS

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

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

3.16 PROCEDURES FOR CONDENSING UNITS

A. Verify proper rotation of fans.

B. Measure entering- and leaving-air temperatures.

C. Record compressor data.

3.17 PROCEDURES FOR HEAT-TRANSFER COILS

A. Water Coils: Measure the following data for each coil:

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

B. Electric-Heating Coils: Measure the following data for each coil:

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

C. Refrigerant Coils: Measure the following data for each coil:

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

3.18 PROCEDURES FOR SPACE PRESSURIZATION MEASUREMENTS AND ADJUSTMENTS

A. Before testing for space pressurization, observe the space to verify the integrity of the space boundaries. Verify that windows and doors are closed and applicable safing, gaskets, and sealants are installed. Report deficiencies and postpone testing until after the reported deficiencies are corrected.

B. Measurements shall be performed when the wind is less than 3mph and when the outdoor air temperature and humidity are within +/-5% from the interior space conditions.

C. Measure and record wind speed and direction, outside-air temperature, and relative humidity on each test day.

D. Measure and record indoor space temperature and relative humidity on each test day.

E. Measure, adjust, and record the pressurization of each room, each zone, and each building by adjusting the supply, return, and exhaust airflows to achieve the indicated conditions.

F. Measure space pressure differential where pressure is used as the design criteria, and measure airflow differential where differential airflow is used as the design criteria for space pressurization.

1. For pressure measurements, measure and record the pressure difference between the intended spaces at the door with all doors in the space closed. Record the high-pressure side, low-pressure side, and pressure difference between each adjacent space.
2. For applications with cascading levels of space pressurization, begin in the most critical space and work to the least critical space.
3. Test room pressurization first, then zones, and finish with building pressurization.

G. To achieve indicated pressurization, set the supply airflow to the indicated conditions and adjust the exhaust and return airflow to achieve the indicated pressure or airflow difference.

H. For spaces with pressurization being monitored and controlled automatically, observe and adjust the controls to achieve the desired set point.

1. Compare the values of the measurements taken to the measured values of the control system instruments and report findings.
2. Check the repeatability of the controls by successive tests designed to temporarily alter the ability to achieve space pressurization. Test overpressurization and underpressurization, and observe and report on the system's ability to revert to the set point.
3. For spaces served by variable-air-volume supply and exhaust systems, measure space pressurization at indicated airflow and minimum airflow conditions.

I. In spaces that employ multiple modes of operation, such as normal mode and emergency mode or occupied mode and unoccupied mode, measure, adjust, and record data for each operating mode.

J. Record indicated conditions and corresponding initial and final measurements. Report deficiencies.

3.19 TOLERANCES

A. Set HVAC system airflow and water flow rates within the following tolerances:

1. Supply, Return, and Exhaust Fans and Equipment with Fans: minus 5 to plus 10 percent.
2. Air Outlets and Inlets:
   a. One outlet or inlet in space: minus 5% to plus 10% of design.
   b. Two outlets or inlets in space – total space air quantity: Within minus 5% to plus 10% of design. Air quantity of each outlet: Within 10% of design.

c. Three or more outlets or inlets in space – total space air quantity: Within minus 5% to plus 10% of design. Air quantity of each outlet: Within 10% of design.

3. Cooling-Water Flow Rate: Within 5% of design.

3.20 REPORTING

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

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

3.21 FINAL REPORT

A. General: Typewritten, or computer printout in letter-quality font, on standard bond paper, in three-ring binder, tabulated and divided into sections by tested and balanced systems.

B. Include a certification sheet in front of binder signed and sealed by the certified testing and balancing engineer.

1. Include a list of instruments used for procedures, along with proof of calibration.

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

1. Pump curves.
2. Fan curves.
3. Manufacturers' test data.
4. Field test reports prepared by system and equipment installers.
5. Other information relative to equipment performance, but do not include Shop Drawings and Product Data.

D. General Report Data: In addition to form titles and entries, include the following data in the final report, as applicable:

1. Title page.
2. Name and address of TAB firm.
3. Project name.
4. Project location.
5. Architect's name and address.
6. Engineer's name and address.

7. Contractor's name and address.
8. Report date.
9. Signature of TAB firm who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
11. Summary of contents including the following:

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

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

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

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

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

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

1. Unit Data: Include the following:

    a. Unit identification.
    b. Location.
    c. Make and type.
    d. Model number and unit size.
    e. Manufacturer's serial number.
    f. Unit arrangement and class.
    g. Discharge arrangement.

h. Sheave make, size in inches, and bore.
i. Sheave dimensions, center-to-center, and amount of adjustments in inches.
j. Number of belts, make, and size.
k. Number of filters, type, and size.

2. Motor Data:

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

3. Test Data (Indicated and Actual Values):

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

G. Apparatus-Coil Test Reports:

1. Coil Data:

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

2. Test Data (Indicated and Actual Values):

a. Airflow rate in cfm.
b. Average face velocity in fpm.
c. Air pressure drop in inches wg.

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

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

1. Unit Data:

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

2. Test Data (Indicated and Actual Values):

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

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

1. Fan Data:

a. System identification.
b. Location.
c. Make and type.
d. Model number and size.
e. Manufacturer's serial number.
f. Arrangement and class.
g. Sheave make, size in inches, and bore.

h. Sheave dimensions, center-to-center, and amount of adjustments in inches.

2. Motor Data:

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

3. Test Data (Indicated and Actual Values):

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

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

1. Report Data:

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

K. Air-Terminal-Device Reports:

1. Unit Data:

a. System and air-handling unit identification.
b. Location and zone.
c. Test apparatus used.
d. Area served.
e. Air-terminal-device make.
f. Air-terminal-device number from system diagram.
g. Air-terminal-device type and model number.
h. Air-terminal-device size.
i. Air-terminal-device effective area in sq. ft..

2. Test Data (Indicated and Actual Values):

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

L. Packaged Chiller Reports:

1. Unit Data:

    a. Unit identification.
    b. Make and model number.
    c. Manufacturer's serial number.
    d. Refrigerant type and capacity in pounds.
    e. Starter type and size.
    f. Starter thermal protection size.
    g. Compressor make and model number.
    h. Compressor manufacturer's serial number.

2. Water-Cooled Condenser Test Data (Indicated and Actual Values):

    a. Refrigerant pressure in psig.
    b. Refrigerant temperature in deg F.
    c. Entering-water temperature in deg F.
    d. Leaving-water temperature in deg F.
    e. Entering-water pressure in feet of head or psig.
    f. Water pressure differential in feet of head or psig.

3. Air-Cooled Condenser Test Data (Indicated and Actual Values):

    a. Refrigerant pressure in psig.
    b. Refrigerant temperature in deg F.
    c. Entering- and leaving-air temperature in deg F.

4. Evaporator Test Reports (Indicated and Actual Values):

    a. Refrigerant pressure in psig.
    b. Refrigerant temperature in deg F.
    c. Entering-water temperature in deg F.
    d. Leaving-water temperature in deg F.
    e. Entering-water pressure in feet of head or psig.
    f. Water pressure differential in feet of head or psig.

5. Compressor Test Data (Indicated and Actual Values):

    a. Suction pressure in psig.

b. Suction temperature in deg F.
c. Discharge pressure in psig.
d. Discharge temperature in deg F.
e. Oil pressure in psig.
f. Oil temperature in deg F.
g. Voltage at each connection.
h. Amperage for each phase.
i. Kilowatt input.
j. Crankcase heater kilowatt.
k. Chilled-water control set point in deg F.
l. Condenser-water control set point in deg F.
m. Refrigerant low-pressure-cutoff set point in psig.
n. Refrigerant high-pressure-cutoff set point in psig.

6. Refrigerant Test Data (Indicated and Actual Values):

a. Oil level.
b. Refrigerant level.
c. Relief valve setting in psig.
d. Unloader set points in psig.
e. Percentage of cylinders unloaded.
f. Bearing temperatures in deg F.
g. Vane position.
h. Low-temperature-cutoff set point in deg F.

M. Compressor and Condenser Reports: For refrigerant side of unitary systems, stand-alone refrigerant compressors, air-cooled condensing units, or water-cooled condensing units, include the following:

1. Unit Data:

a. Unit identification.
b. Location.
c. Unit make and model number.
d. Compressor make.
e. Compressor model and serial numbers.
f. Refrigerant weight in lb.
g. Low ambient temperature cutoff in deg F.

2. Test Data (Indicated and Actual Values):

a. Inlet-duct static pressure in inches wg.
b. Outlet-duct static pressure in inches wg.
c. Entering-air, dry-bulb temperature in deg F.
d. Leaving-air, dry-bulb temperature in deg F.
e. Condenser entering-water temperature in deg F.
f. Condenser leaving-water temperature in deg F.
g. Condenser-water temperature differential in deg F.
h. Condenser entering-water pressure in feet of head or psig.
i. Condenser leaving-water pressure in feet of head or psig.

j. Condenser-water pressure differential in feet of head or psig.
k. Control settings.
l. Unloader set points.
m. Low-pressure-cutout set point in psig.
n. High-pressure-cutout set point in psig.
o. Suction pressure in psig.
p. Suction temperature in deg F.
q. Condenser refrigerant pressure in psig.
r. Condenser refrigerant temperature in deg F.
s. Oil pressure in psig.
t. Oil temperature in deg F.
u. Voltage at each connection.
v. Amperage for each phase.
w. Kilowatt input.
x. Crankcase heater kilowatt.
y. Number of fans.
z. Condenser fan rpm.
aa. Condenser fan airflow rate in cfm.
bb. Condenser fan motor make, frame size, rpm, and horsepower.
cc. Condenser fan motor voltage at each connection.
dd. Condenser fan motor amperage for each phase.

N. Cooling Tower or Condenser Test Reports: For cooling towers or condensers, include the following:

1. Unit Data:

a. Unit identification.
b. Make and type.
c. Model and serial numbers.
d. Nominal cooling capacity in tons.
e. Refrigerant type and weight in lb.
f. Water-treatment chemical feeder and chemical.
g. Number and type of fans.
h. Fan motor make, frame size, rpm, and horsepower.
i. Fan motor voltage at each connection.
j. Sheave make, size in inches, and bore.
k. Sheave dimensions, center-to-center, and amount of adjustments in inches.
l. Number of belts, make, and size.
m. Pump make and model number.
n. Pump manufacturer's serial number.
o. Pump motor make and frame size.
p. Pump motor horsepower and rpm.

2. Pump Test Data (Indicated and Actual Values):

a. Voltage at each connection.
b. Amperage for each phase.
c. Water flow rate in gpm.

3. Water Test Data (Indicated and Actual Values):

    a. Entering-water temperature in deg F.
    b. Leaving-water temperature in deg F.
    c. Water temperature differential in deg F.
    d. Entering-water pressure in feet of head or psig.
    e. Leaving-water pressure in feet of head or psig.
    f. Water pressure differential in feet of head or psig.
    g. Water flow rate in gpm.
    h. Bleed water flow rate in gpm.

4. Air Data (Indicated and Actual Values):

    a. Duct airflow rate in cfm.
    b. Inlet-duct static pressure in inches wg.
    c. Outlet-duct static pressure in inches wg.
    d. Average entering-air, wet-bulb temperature in deg F.
    e. Average leaving-air, wet-bulb temperature in deg F.
    f. Ambient wet-bulb temperature in deg F.

O. Heat-Exchanger Test Reports: For heat exchangers, include the following:

1. Unit Data:
    a. Unit identification.
    b. Location.
    c. Service.
    d. Make and type.
    e. Model and serial numbers.
    f. Ratings.
2. Primary Water Test Data (Indicated and Actual Values):
    a. Entering-water temperature in deg F.
    b. Leaving-water temperature in deg F.
    c. Entering-water pressure in feet of head or psig.
    d. Water pressure differential in feet of head or psig.
    e. Water flow rate in gpm.
3. Secondary Water Test Data (Indicated and Actual Values):
    a. Entering-water temperature in deg F.
    b. Leaving-water temperature in deg F.
    c. Entering-water pressure in feet of head or psig.
    d. Water pressure differential in feet of head or psig.
    e. Water flow rate in gpm.

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

1. Unit Data:

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

2. Test Data (Indicated and Actual Values):

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

Q. Air-to-Air Heat-Recovery Unit Reports:

1. Unit Data:

a. Unit identification.
b. Location.
c. Service.
d. Make and type.
e. Model and serial numbers.

2. Motor Data:

a. Make and frame type and size.
b. Horsepower and rpm.

c. Volts, phase, and hertz.
d. Full load amperage and service factor.
e. Sheave make, size in inches, and bore.
f. Sheave dimensions, center-to-center, and amount of adjustments in inches.

3. If fans are an integral part of the unit, include the following for each fan:

a. Make and type.
b. Arrangement and size.
c. Sheave make, size in inches, and bore.
d. Sheave dimensions, center-to-center, and amount of adjustments in inches.

4. Test Data (Indicated and Actual Values):

a. Total exhaust airflow rate in cfm.
b. Purge exhaust airflow rate in cfm.
c. Outside airflow rate in cfm.
d. Total exhaust fan static pressure in inches wg.
e. Total outside-air fan static pressure in inches wg.
f. Pressure drop on each side of recovery wheel in inches wg.
g. Exhaust air temperature entering in deg F.
h. Exhaust air temperature leaving in deg F.
i. Outside-air temperature entering in deg F.
j. Outside-air temperature leaving in deg F.
k. Calculate sensible and total heat capacity of each airstream in MBh.

R. Instrument Calibration Reports:

1. Report Data:

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

3.22 INSPECTIONS

A. Initial Inspection:

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

a. Measure airflow of at least 10 percent of air outlets.
b. Measure water flow of at least 5 percent of terminals.
c. Measure room temperature at each thermostat/temperature sensor. Compare the reading to the set point.

d. Measure sound levels at two locations.
e. Measure space pressure of at least 10 percent of locations.
f. Verify that balancing devices are marked with final balance position.
g. Note deviations to the Contract Documents in the Final Report.

B. Final Inspection:

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

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

1. TAB firm shall recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes and resubmit the final report.
2. Request a second final inspection. If the second final inspection also fails, Owner may contract the services of another TAB firm to complete the testing and balancing in accordance with the Contract Documents and deduct the cost of the services from the final payment.

3.23 ADDITIONAL TESTS

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

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

C. Test all smoke and fire protection devices and systems related to the ventilating systems to verify that they are functioning properly. Where possible, this test shall be carried out at the same time as the Fire Department Inspector’s inspection.

1. In case of fusible link fire dampers, spot check as many dampers as necessary to be fully convinced of the acceptability of the installation.

3.24 COMMISSIONING

A. TAB firm shall provide necessary support to complete necessary Pre-functional testing, Functional Testing, and any retesting required as required to complete the commissioning process of the chiller/cooling tower/pumping systems to be performed by Engineering Team.

B. TAB firm shall provide Test and Balance during the commissioning process on an as needed basis during that commissioning effort.

END OF SECTION 23 05 93

SECTION 23 07 19 - HVAC INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to this Section.

1.2 SUMMARY

A. Section includes insulating the following HVAC systems:

1. Condensate drain piping, indoors and outdoors.
2. Chilled-water and brine piping, indoors and outdoors.
3. Condenser-water piping, indoors and outdoors.
4. Duct Systems Insulation.
5. Heated fuel-oil piping, indoors and outdoors.
6. Engine exhaust piping.
7. Equipment Insulation
8. Cold Pipe Hanger Support Blocks
9. Accessories

1.3 SUBMITTALS

A. Action Submittals:
1. Submit schedule indicating type of insulation, thickness, vapor barrier or coating by system and size.
2. Product Data: For each type of product indicated. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory and field applied if any).
3. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
   a. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
   b. Detail attachment and covering of heat tracing inside insulation.
   c. Detail insulation application at pipe expansion joints for each type of insulation.
   d. Detail insulation application at mechanical couplings, grove-joint piping, elbows, fittings, flanges, valves, and specialties for each type of insulation.
   e. Detail removable insulation at piping specialties.
   f. Detail application of field-applied jackets.
   g. Detail application at linkages of control devices.

4. Samples: For each type of insulation and jacket indicated. Identify each Sample, describing product and intended use.
    a. Preformed Pipe Insulation Materials: 12 inches long by NPS 2.
    b. Sheet Form Insulation Materials: 12 inches square.
    c. Jacket Materials for Pipe: 12 inches long by NPS 2.
    d. Sheet Jacket Materials: 12 inches square.
    e. Manufacturer's Color Charts: For products where color is specified, show the full range of colors available for each type of finish material.

B. Sustainable Design Documentation Submittals: Refer to section 01 81 13.14 “Sustainable Design Requirements – LEED V4 BD+C”.
1. Product Data: Documentation for Leadership Extraction Practices
    a.
2. Product Data: Documentation for Low Emitting Materials
    a. Low Emitting Materials for Paints and Coatings
    b. Low Emitting Materials for Adhesives and Sealants
3. Product Certificates: Provide the following:
    a. Environmental Product Declarations (EPD’s)

C. Informational Submittals
1. Qualification Data: For qualified Installer.
2. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.
3. Field quality-control reports.
4. Product data, along with installation operation and maintenance instructions, shall be included in the operation and maintenance manuals.

1.4 QUALITY ASSURANCE

A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or another craft training program certified by the Department of Labor, Bureau of Apprenticeship and Training.

B. All insulation shall be installed in accordance with National Commercial & Industrial Insulation Standards (NCIA).

C. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84, by a testing and inspecting agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.

1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

D. Mockups: Before installing insulation, build mockups for each type of insulation and finish listed below to demonstrate quality of insulation application and finishes. Build mockups in the location indicated or, if not indicated, as directed by Architect. Use materials indicated for the completed Work.

1. Piping Mockups:

   a. One 10-foot section of NPS 2 straight pipe.
   b. One each of a 90-degree threaded, welded, and flanged elbow.
   c. One each of a threaded, welded, and flanged tee fitting.
   d. One NPS 2 or smaller valve, and one NPS 2-1/2 or larger valve.
   e. Four support hangers including hanger shield and insert.
   f. One threaded strainer and one flanged strainer with removable portion of insulation.
   g. One threaded reducer and one welded reducer.
   h. One pressure temperature tap.
   i. One mechanical coupling.
2. Equipment Mockups:
   a. One chilled-water pump
   b. One tank or vessel
3. Ductwork Mockups:
   a. One 10-foot section each of rectangular and round straight duct
   b. One each of a 90-degree mitered round and rectangular elbow, and one each of a 90-degree radius round and rectangular elbow.
   c. One rectangular branch takeoff and one round branch takeoff from a rectangular duct. One round tee fitting.
   d. One rectangular and round transition fitting.
   e. Four support hangers for round and rectangular ductwork.
   f. Each type of damper and specialty

4. For each mockup, fabricate cutaway sections to allow observation of application details for insulation materials, adhesives, mastics, attachments, and jackets.
5. Notify Architect seven days in advance of dates and times when mockups will be constructed.
6. Obtain Architect's approval of mockups before starting insulation application.
7. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.
8. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.
9. Demolish and remove mockups when directed.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

B. Packages and standard containers of materials shall be delivered unopened to job site and shall have the manufacturer's label attached giving a complete description of the material.

C. Refer to Section 23 00 10, Subsection 3.7 for handling, protection and storage of insulation materials.

1.6 COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

B. Coordinate clearance requirements with piping Installer for piping insulation application. Before preparing piping Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

C. Coordinate installation and testing of heat tracing.

1.7 DEFINITIONS

A. The term "exposed" means exposed to view in finished spaces, in equipment rooms, in fan rooms, in closets, in utility corridors, in tunnels, on roof, in storage rooms, and in other spaces as indicated.

B. The term "concealed" means concealed from view, and includes all spaces not defined as exposed.

C. The term "unconditioned" space shall mean all places where the temperature surrounding the pipe has not been conditioned consistent with conditioned spaces, and shall include mechanical equipment rooms, non-active ceiling plenums, and non-accessible chases. This term shall also include conditioned spaces where the humidity levels are allowed to rise above 70% RH.

1.8 SCHEDULING

A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.

B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

A. Comply with requirements in "Piping Insulation Schedule, General," "Indoor Piping Insulation Schedule," "Outdoor, Aboveground Piping Insulation Schedule, “Outdoor, Underground Piping Insulation Schedule", "Equipment Insulation Schedule”, "Duct Insulation Schedule, General," "Indoor Duct and Plenum Insulation Schedule," and "Aboveground, Outdoor Duct and Plenum Insulation Schedule" articles for where insulating materials shall be applied.

B. Products shall not contain asbestos, lead, mercury, or mercury compounds.

C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.

D. Insulation shall comply with ASHRAE/IESNA 90.1, all applicable codes and requirements of the Authority having jurisdiction.

E. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.

F. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.

G. Calcium Silicate:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

    a. Industrial Insulation Group (IIG); Thermo-12 Gold.
    b. Owner Approved Substitution.

2. Thermal Conductivity (k-value) at 300°F mean temperature is 0.40 Btu x in./hr. x ft. x degree F. or less.
3. Preformed Pipe Sections: Flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement. Comply with ASTM C 533, Type I.
4. Flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement. Comply with ASTM C 533, Type I.
5. Prefabricated Fitting Covers: Comply with ASTM C 450 and ASTM C 585 for dimensions used in preforming insulation to cover valves, elbows, tees, and flanges.

H. Cellular Glass: Inorganic, incombustible, foamed or cellulated glass with annealed, rigid, hermetically sealed cells. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

    a. Pittsburgh Corning Corporation; Foamglas.
    b. Cell-U-Foam Corp.
    c. Owner Approved Substitution.

2. Thermal Conductivity (k-value) at 75°F mean temperature is 0.27 Btu x in./hr. x ft. x degree F. or less.

3. Block Insulation: ASTM C 552, Type I.
4. Special-Shaped Insulation: ASTM C 552, Type III.
5. Board Insulation: ASTM C 552, Type IV.
6. Preformed Pipe Insulation without Jacket: Comply with ASTM C 552, Type II, Class 1.
7. Preformed Pipe Insulation with Factory-Applied ASJ-SSL: Comply with ASTM C 552, Type II, Class 2.
8. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.

I. Flexible Elastomeric Insulation: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type I for tubular materials.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

    a. Armacell LLC; AP Armaflex.
    b. K-Flex USA; Insul-Lock, Insul-Tube, and K-FLEX LS.
    c. Johns Manville.
    d. Owner Approved Substitution.

2. Thermal Conductivity (k-value) at 75°F mean temperature is 0.245 Btu x in./hr. x ft. x degree F. or less. Water absorption not be more than 0.2% by volume.

J. Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type II and ASTM C 1290, Type III with factory-applied FSK jacket. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

    a. CertainTeed Corp.; SoftTouch Duct Wrap.
    b. Johns Manville; Microlite.
    c. Knauf Insulation; Friendly Feel Duct Wrap.
    d. Manson Insulation Inc.; Alley Wrap.
    e. Owens Corning; SOFTR All-Service Duct Wrap.

2. Thermal Conductivity (k-value) at 75°F (24°C) mean temperature is 0.29 Btu x in./hr. x ft. x degree F. (0.043 W/m x K) or less.

K. Mineral-Fiber, Preformed Pipe Insulation:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Johns Manville; Micro-Lok.
   b. Knauf Insulation; 1000-Degree Pipe Insulation.
   c. Manson Insulation Inc.; Alley-K.
   d. Owens Corning; Fiberglas Pipe Insulation.

2. Type I, 850 deg F Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A, with factory-applied ASJ-SSL. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
3. Type II, 1200 deg F Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type II, Grade A, with factory-applied ASJ-SSL. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
4. Thermal Conductivity (k-value) at 75°F mean temperature is 0.23 Btu x in./hr. x ft. x degree F. or less.

L. Mineral-Fiber, Pipe and Tank Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semirigid board material with factory-applied ASJ complying with ASTM C 1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C 612, Type IB. Nominal density is 2.5 lb/cu. ft. or more. Thermal conductivity (k-value) at 75 deg F is 0.27 Btu x in./h x sq. ft. x deg F or less. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

   a. CertainTeed Corp.; CrimpWrap.
   b. Johns Manville; MicroFlex.
   c. Knauf Insulation; Pipe and Tank Insulation.
   d. Manson Insulation Inc.; AK Flex.
   e. Owens Corning; Fiberglas Pipe and Tank Insulation.

M. Phenolic:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

   a. Kingspan Tarec Industrial Insulation NV; Koolphen K.
   b. Resolco International BV; Insul-phen.

2. Thermal Conductivity (k-value) at 75°F (24°C) mean temperature is 0.22 Btu x in./hr. x ft. x degree F. (0.031 W/m x K) or less.
3. Preformed pipe insulation of rigid, expanded, closed-cell structure. Comply with ASTM C 1126, Type III, Grade 1.

4. Block insulation of rigid, expanded, closed-cell structure. Comply with ASTM C 1126, Type II, Grade 1.
5. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.
6. Factory-Applied Jacket: Requirements are specified in "Factory-Applied Jackets" Article.

   a. Preformed Pipe Insulation: ASJ.

N. Rigid Fiberglass: Resin bonded fibrous glass, flame retardant, factory applied all service jacket (ASJ) vapor barrier, maximum vapor permeance of .02 perm/in and puncture resistance of 50 units, maximum conductivity per 1" thickness of .23 at 75°F mean temperature. Rigid fiberglass board insulation shall conform with ASTM C 612, Type 1A or Type 1B with a density not less than 3 lbs per cubic foot. The insulation shall be Johns Manville “817 SPIN-GLAS,” or approved equal.

2.2 ADHESIVES

A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

B. Low Emitting Adhesives and Sealants
   1. Provide Manufacturer statements that confirm the product used meets the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario.

   2. Refer to Section 01 81 13.14 “Sustainable Design Requirements – LEED v4 BD+C” for additional requirements.

C. Calcium Silicate Adhesive: Fibrous, sodium-silicate-based adhesive with a service temperature range of 50 to 800 deg F.

   1. Products: Subject to compliance with requirements, available manufacturer’s products that may be incorporated into the Work include, but are not limited to, the following:

      a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
      b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
      c. Mon-Eco Industries, Inc.
      d. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

D. Cellular-Glass Adhesive: Two-component, thermosetting urethane adhesive containing no flammable solvents, with a service temperature range of minus 100 to plus 200 deg F.

1. Products: Subject to compliance with requirements, available manufacturer's products that may be incorporated into the Work include, but are not limited to, the following:

    a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
    b. TremcoHenkel
    c. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.
    d. .

E. Phenolic Adhesive: Solvent-based resin adhesive, with a service temperature range of minus 75 to plus 300 deg F (minus 59 to plus 149 deg C).

1. Products: Subject to compliance with requirements, available manufacturer's products that may be incorporated into the Work include, but are not limited to, the following:

    a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
    b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
    c. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

F. Flexible Elastomeric Adhesive: Comply with MIL-A-24179A, Type II, Class I.

1. Products: Subject to compliance with requirements, available manufacturer's products that may be incorporated into the Work include, but are not limited to, the following:

    a. Armacell LLC.
    b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
    c. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

G. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.

1. Products: Subject to compliance with requirements, available manufacturer's products that may be incorporated into the Work include, but are not limited to, the following:

    a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.

b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
c. Mon-Eco Industries, Inc.
d. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

2. For indoor applications, adhesive shall comply with the requirements of section 01 81 13.14.

H. ASJ Adhesive, and FSK and PVDC Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.

1. Products: Subject to compliance with requirements, available manufacturer’s products that may be incorporated into the Work include, but are not limited to, the following:

a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
c. Mon-Eco Industries, Inc.
d. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

I. PVC Jacket Adhesive: Compatible with PVC jacket.

1. Products: Subject to compliance with requirements, available manufacturer’s products that may be incorporated into the Work include, but are not limited to, the following:

a. Dow Corning Corporation.
b. Johns Manville.
c. P.I.C. Plastics, Inc.
d. Speedline Corporation.
e. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

2.3 MASTICS

A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.

B. Vapor-Barrier Mastic: Water based; suitable for indoor use on below-ambient services.

1. Products: Subject to compliance with requirements, available manufacturer's products that may be incorporated into the Work include, but are not limited to, the following:

   a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
   b. Henkel.
   c. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

2. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm at 43-mil dry film thickness.
3. Service Temperature Range: Minus 20 to plus 180 deg F.
4. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
5. Color: White.
6. For indoor applications, adhesive shall comply with the requirements of section 01 81 13.14.

C. Vapor-Barrier Mastic: Solvent based; suitable for indoor use on below-ambient services.

1. Products: Subject to compliance with requirements, available manufacturer's products that may be incorporated into the Work include, but are not limited to, the following:

   a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
   b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
   c. Mon-Eco Industries, Inc.
   d. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

2. Water-Vapor Permeance: ASTM F 1249, 0.05 perm (0.03 metric perm) at 35-mil (0.9-mm) dry film thickness.
3. Service Temperature Range: 0 to 180 deg F (Minus 18 to plus 82 deg C).
4. Solids Content: ASTM D 1644, 44 percent by volume and 62 percent by weight.
5. Color: White.

D. Vapor-Barrier Mastic: Solvent based; suitable for outdoor use on below-ambient services.

1. Products: Subject to compliance with requirements, available manufacturer's products that may be incorporated into the Work include, but are not limited to, the following:

   a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.

b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company
c. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.
d. .

2. Water-Vapor Permeance: ASTM F 1249, 0.05 perm (0.033 metric perm) at 30-mil (0.8-mm) dry film thickness.
3. Service Temperature Range: Minus 50 to plus 220 deg F (Minus 46 to plus 104 deg C).
4. Solids Content: ASTM D 1644, 33 percent by volume and 46 percent by weight.
5. Color: White.

E. Breather Mastic: Water based; suitable for indoor and outdoor use on above-ambient services.

1. Products: Subject to compliance with requirements, available manufacturer's products that may be incorporated into the Work include, but are not limited to, the following:

a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
c. Mon-Eco Industries, Inc.

2. Water-Vapor Permeance: ASTM F 1249, 1.8 perms at 0.0625-inch dry film thickness.
3. Service Temperature Range: Minus 20 to plus 180 deg F.
4. Solids Content: 60 percent by volume and 66 percent by weight.
5. Color: White.

2.4 LAGGING ADHESIVES

A. Description: Comply with MIL-A-3316C, Class I, Grade A and shall be compatible with insulation materials, jackets, and substrates.

1. Products: Subject to compliance with requirements, available manufacturer's products that may be incorporated into the Work include, but are not limited to, the following:

a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.

2. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over pipe insulation.
3. Service Temperature Range: 0 to plus 180 deg F.
4. Color: White.

2.5 SEALANTS

A. Joint Sealants:

1. Joint Sealants for Cellular-Glass and Phenolic Products: Subject to compliance with requirements, available manufacturer’s products that may be incorporated into the Work include, but are not limited to, the following:

    a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
    b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
    c. Mon-Eco Industries, Inc.
    d. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Permanently flexible, elastomeric sealant.
4. Service Temperature Range: Minus 100 to plus 300 deg F (Minus 73 to plus 149 deg C).
5. Color: White or gray.

B. FSK and Metal Jacket Flashing Sealants:

1. Products: Subject to compliance with requirements, available manufacturer’s products that may be incorporated into the Work include, but are not limited to, the following:

    a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
    b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
    c. Mon-Eco Industries, Inc.
    d. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg.
5. Color: Aluminum.

C. ASJ Flashing Sealants, and Vinyl, PVDC, and PVC Jacket Flashing Sealants:

1. Products: Subject to compliance with requirements, available manufacturer's products that may be incorporated into the Work include, but are not limited to, the following:

    a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company.
    b. Alternate product meeting specified requirements and the California Department of Public Health (CDPH) Standard Method v1.1 2010 using the applicable exposure scenario for indoor applications.

2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F.
5. Color: White.

2.6 FACTORY-APPLIED JACKETS

A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:

1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C 1136, Type I.
2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.
3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.
4. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C 1136, Type II.
5. PVDC Jacket for Indoor Applications: 4-mil- thick, white PVDC biaxially oriented barrier film with a permeance at 0.02 perm when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 20 when tested according to ASTM E 84.

    a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

        1) Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
        2) ITW Insulation Systems.

6. PVDC Jacket for Outdoor Applications: 6-mil- (0.15-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at 0.01 perm (0.007 metric perm) when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 25 when tested according to ASTM E 84.

a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

1) Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
2) ITW Insulation Systems.

7. PVDC-SSL Jacket: PVDC jacket with a self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.

a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

1) Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
2) ITW Insulation Systems.

8. Vinyl Jacket: White vinyl with a permeance of 1.3 perms (0.86 metric perms) when tested according to ASTM E 96/E 96M, Procedure A, and complying with NFPA 90A and NFPA 90B.

2.7 FIELD-APPLIED FABRIC-REINFORCING MESH

A. Woven Glass-Fiber Fabric: Approximately 2 oz./sq. yd. with a thread count of 10 strands by 10 strands/sq. in. for covering pipe and pipe fittings.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Chil-Glas Number 10.
b. Owner Approved Substitution.

B. Woven Polyester Fabric: Approximately 1 oz./sq. yd. with a thread count of 10 strands by 10 strands/sq. in., in a Leno weave, for pipe.

1. Products: Subject to compliance with requirements, provide one of the following:

a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Mast-A-Fab.
b. Vimasco Corporation; Elastafab 894.
c. Owner Approved Substitution.

2.8 FIELD-APPLIED CLOTHS

A. Woven Glass-Fiber Fabric: Comply with MIL-C-20079H, Type I, plain weave, and presized a minimum of 8 oz./sq. yd.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

a. Alpha Associates, Inc.; Alpha-Maritex 84215 and 84217/9485RW, Luben 59.
b. Owner Approved Substitution.

2.9 FIELD-APPLIED JACKETS

A. Field-applied jackets shall comply with ASTM C 921, Type I, unless otherwise indicated.

B. FSK Jacket: Aluminum-foil-face, fiberglass-reinforced scrim with kraft-paper backing.

C. PVC Jacket: High-impact-resistant, UV-resistant PVC complying with ASTM D 1784, Class 16354-C; thickness as scheduled; roll stock ready for shop or field cutting and forming. Thickness is indicated in field-applied jacket schedules.

1. Products: Subject to compliance with requirements, available manufacturer’s products that may be incorporated into the Work include, but are not limited to, the following:

a. Johns Manville; Zeston.
b. P.I.C. Plastics, Inc.; FG Series.
c. Proto Corporation; LoSmoke.
d. Speedline Corporation; SmokeSafe.
e. Owner Approved Substitution.

2. Adhesive: As recommended by jacket material manufacturer and complying with the requirements of section 01 81 13.14.
3. Color: White.
4. Factory-fabricated fitting covers to match jacket if available; otherwise, field fabricate.

a. Shapes: 45- and 90-degree, short- and long-radius elbows, tees, valves, flanges, unions, reducers, end caps, soil-pipe hubs, traps, mechanical joints, and P-trap and supply covers for lavatories.

D. Metal Jacket:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Metal Jacketing Systems.
b. ITW Insulation Systems; Aluminum and Stainless Steel Jacketing.
c. RPR Products, Inc.; Insul-Mate.
d. Owner Approved Substitution.

2. Aluminum Jacket: Comply with ASTM B 209, Alloy 3003, 3005, 3105, or 5005, Temper H-14.

a. Sheet and roll stock ready for shop or field sizing.
b. Finish and thickness are indicated in field-applied jacket schedules.
c. Moisture Barrier for Indoor Applications: 3-mil- thick, heat-bonded polyethylene and kraft paper.
d. Moisture Barrier for Outdoor Applications: 3-mil- thick, heat-bonded polyethylene and kraft paper.
e. Factory-Fabricated Fitting Covers:

1) Same material, finish, and thickness as jacket.
2) Preformed 2-piece or gore, 45- and 90-degree, short- and long-radius elbows.
3) Tee covers.
4) Flange and union covers.
5) End caps.
6) Beveled collars.
7) Valve covers.
8) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.

E. Underground Direct-Buried Jacket: 125-mil- (3.2-mm-) thick vapor barrier and waterproofing membrane consisting of a rubberized bituminous resin reinforced with a woven-glass fiber or polyester scrim and laminated aluminum foil.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

a. Pittsburgh Corning Corporation; Pittwrap.
b. Polyguard Products, Inc.; Insulrap No Torch 125.

F. Self-Adhesive Outdoor Jacket: 60-mil- (1.5-mm-) thick, laminated vapor barrier and waterproofing membrane for installation over insulation located aboveground outdoors; consisting of a rubberized bituminous resin on a crosslaminated polyethylene film covered with stucco-embossed aluminum-foil facing.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

a. Polyguard Products, Inc.; Alumaguard 60.

G. PVDC Jacket for Indoor Applications: 4-mil- (0.10-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at 0.02 perms (0.013 metric perms) when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 20 when tested according to ASTM E 84.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

a. Dow Chemical Company (The); Saran 540 Vapor Retarder Film.
b. ITW Insulation Systems.

H. PVDC Jacket for Outdoor Applications: 6-mil- (0.15-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at 0.01 perms (0.007 metric perms) when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 25 when tested according to ASTM E 84.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

a. Dow Chemical Company (The); Saran 560 Vapor Retarder Film.
b. ITW Insulation Systems.

I. PVDC-SSL Jacket: PVDC jacket with a self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

a. Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.
b. ITW Insulation Systems.

2.10 FIELD-APPLIED DUCT INSULATION FOR TYPE I AND TYPE II KITCHEN EXHAUST

A. Type I and Type II kitchen exhaust duct shall be insulated with an approved fire rated field-applied 2-layer duct wrap system conforming to ASTM E2336 requirements.

B. Duct wrap shall be installed in strict compliance with manufacturer’s requirements, using all components from a single manufacturers.

C. Duct wrap shall be FyreWrap Elite 1.5 Duct Insulation – Grease Duct ASTM E2336 System, or approved equal.

2.11 TAPES

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following]:

    a. ABI, Ideal Tape Division; 428 AWF ASJ.
    b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0836.
    c. Compac Corporation; 104 and 105.
    d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ.
    e. Owner Approved Substitution.

2. Width: 3 inches.
3. Thickness: 11.5 mils.
4. Adhesion: 90 ounces force/inch in width.
5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.
7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

    a. ABI, Ideal Tape Division; 491 AWF FSK.
    b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0827.
    c. Compac Corporation; 110 and 111.
    d. Venture Tape; 1525 CW NT, 1528 CW, and 1528 CW/SQ.
    e. Owner Approved Substitution.

2. Width: 3 inches.
3. Thickness: 6.5 mils.
4. Adhesion: 90 ounces force/inch in width.
5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.
7. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

C. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive; suitable for indoor and outdoor applications.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

    a. ABI, Ideal Tape Division; 370 White PVC tape.
    b. Compac Corporation; 130.
    c. Venture Tape; 1506 CW NS.
    d. Owner Approved Substitution.

2. Width: 2 inches.
3. Thickness: 6 mils.
4. Adhesion: 64 ounces force/inch in width.

5. Elongation: 500 percent.
6. Tensile Strength: 18 lbf/inch in width.

D. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

a. ABI, Ideal Tape Division; 488 AWF.
b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0800.
c. Compac Corporation; 120.
d. Venture Tape; 3520 CW.
e. Owner Approved Substitution.

2. Width: 2 inches.
3. Thickness: 3.7 mils.
4. Adhesion: 100 ounces force/inch in width.
5. Elongation: 5 percent.
6. Tensile Strength: 34 lbf/inch in width.

E. PVDC Tape for Indoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

a. Dow Chemical Company (The); Saran 540 Vapor Retarder Tape.
b. ITW Insulation Systems.

2. Width: 3 inches (75 mm).
3. Film Thickness: 4 mils (0.10 mm).
4. Adhesive Thickness: 1.5 mils (0.04 mm).
5. Elongation at Break: 145 percent.
6. Tensile Strength: 55 lbf/inch (10.1 N/mm) in width.

F. PVDC Tape for Outdoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

a. Dow Chemical Company (The); Saran 540 Vapor Retarder Tape.
b. ITW Insulation Systems.

2. Width: 3 inches (75 mm).
3. Film Thickness: 6 mils (0.15 mm).
4. Adhesive Thickness: 1.5 mils (0.04 mm).
5. Elongation at Break: 145 percent.
6. Tensile Strength: 55 lbf/inch (10.1 N/mm) in width.

2.12 SECUREMENTS

A. Bands:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

    a. ITW Insulation Systems; Gerrard Strapping and Seals.
    b. RPR Products, Inc.; Insul-Mate Strapping, Seals, and Springs.
    c. Owner Approved Substitution.

2. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, Type 316; 0.015 inch (0.38 mm) thick, 3/4 inch (19 mm) wide with wing seal.
3. Aluminum: ASTM B 209, Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch thick, 3/4 inch wide with wing seal or closed seal.
4. Springs: Twin spring set constructed of stainless steel with ends flat and slotted to accept metal bands. Spring size determined by manufacturer for application.

B. Staples: Outward-clinching insulation staples, nominal 3/4-inch- wide, stainless steel or Monel.

C. Wire: 0.062-inch (1.6-mm) soft-annealed, stainless steel.

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. C & F Wire.

D. Insulation Pins and Hangers:

1. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.135-inch- diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.
    a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following.
        1) AGM Industries, Inc.; CHP-1.
        2) GEMCO; Cupped Head Weld Pin.
        3) Midwest Fasteners, Inc.; Cupped Head.
        4) Nelson Stud Welding; CHP.
2. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- thick, galvanized-steel sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.
    a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
        1) AGM Industries, Inc.; RC-150.
        2) GEMCO; R-150.

3) Midwest Fasteners, Inc.; WA-150.
4) Nelson Stud Welding; Speed Clips.

b. Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.

3. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements.
   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) AGM Industries, Inc.; Tactoo Perforated Base Insul-Hangers.
      2) GEMCO; Perforated Base.
      3) Midwest Fasteners, Inc.; Spindle.
   b. Baseplate: Perforated, galvanized carbon-steel sheet, 0.030 inch (0.76 mm) thick by 2 inches (50 mm) square.
   c. Spindle: Aluminum, fully annealed, 0.106-inch- (2.6-mm-) diameter shank, length to suit depth of insulation indicated.
   d. Adhesive: Recommended by hanger manufacturer and complying with the requirements of section 01 81 13.14. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

4. Nonmetal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate fastened to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements.
   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) GEMCO; Nylon Hangers.
      2) Midwest Fasteners, Inc.; Nylon Insulation Hangers.
   b. Baseplate: Perforated, nylon sheet, 0.030 inch (0.76 mm) thick by 1-1/2 inches (38 mm) in diameter.
   c. Spindle: Nylon, 0.106-inch- (2.6-mm-) diameter shank, length to suit depth of insulation indicated, up to 2-1/2 inches (63 mm).
   d. Adhesive: Recommended by hanger manufacturer and complying with Low Emitting Adhesives and Sealant requirements of section 01 81 13.14. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

5. Self-Sticking-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements.
   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) AGM Industries, Inc.; Tactoo Self-Adhering Insul-Hangers.

2) GEMCO; Peel & Press.
3) Hardcast, Inc.
4) Midwest Fasteners, Inc.; Self Stick.

b. Baseplate: Galvanized carbon-steel sheet, 0.030 inch (0.76 mm) thick by 2 inches (50 mm) square.

c. Spindle: Aluminum, fully annealed, 0.106-inch- (2.6-mm-) diameter shank, length to suit depth of insulation indicated.

d. Adhesive-backed base with a peel-off protective cover.

6. Nonmetal Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- (0.41-mm-) thick nylon sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches (38 mm) in diameter.

a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

1) GEMCO.
2) Midwest Fasteners, Inc.

PART 3 - EXECUTION

3.1 GENERAL REQUIREMENTS

A. Install all insulation in strict accordance with the manufacturers written installation instructions.

B. All insulation work shall be performed by skilled mechanics regularly engaged in the insulation trade.

C. Properly coordinate the insulation work with the other trades so that installation is performed with a minimum of conflict.

D. Insulation shall not be applied on any piping or duct system requiring testing until testing is completed and approved by Owner's Representative.

E. Insulation shall not be applied until all systems are clean, dry, free of dirt, dust or grease.

F. The finished installation shall present a neat and acceptable appearance which includes but is not limited to: all jackets smooth, all vapor barriers sealed properly, no evidence of "ballooning" of the jackets, or sagging insulation, all valves, dampers, gauges, unions, etc. accessible. The Owner's Representative shall be the final judge of acceptance of workmanship.

G. All equipment nameplates on hot equipment shall be left uncovered. All equipment nameplates on cold equipment shall have a removable section sized to expose the name-plate. This section shall be clearly marked "NAMEPLATE".

H. If proper maintenance procedures require access to the insulated equipment removable panels, sections or covers shall be provided to accomplish this. These access devices shall be constructed in a manner to assure easy access and sturdy construction. The contractor shall assume the responsibility to coordinate all equipment requiring insulation to be either factory or field insulated.

I. Insulation and accessories shall be applied only at suitable application temperature and conditions as recommended by the manufacturer. Do not apply insulation to any surface while it is wet.

J. Insulation shall be protected from moisture and weather during storage and installation.

K. Insulation which has sustained moisture damage, torn jackets, or other damage due to improper storage or other reasons shall not be used. If evidence of this is sighted the Owner's representative reserves the right to require the insulating contractor to remove any and/or all insulation until the Owner's Representative is satisfied that there is no longer any inferior insulation installed on this project.

L. Insulation, fabric and jacketing shall be protected from damage during construction. Damage by the insulator shall be repaired without cost to the Owner. Damage by others shall be reported in writing to the contractor.

M. The insulation subcontractor is responsible for proper material storage at the work site.

N. Work performed prior to receipt of approved documents or submittals, which later proves to be incorrect or inappropriate, shall be promptly replaced by the contractor without cost to the purchaser.

O. Insulation shall not be installed until adequate access and clearances at control mechanisms, dampers, sleeves, columns and walls have been provided.

P. All insulation at handholes, access doors or other openings, and adjacent to flanges and valves shall be neatly finished where exposed to view.

Q. Where an insulated pipe or ductwork passes through a sleeve or opening in a non-rated partition, the full specified thickness of the insulation shall pass through the sleeve or opening. Where an insulated pipe or ductwork passes through a rated partition, the insulation shall be stopped at the partition. The void between the pipe and the sleeve shall be sealed with an approved fire-stopping material, and the insulation trimmed and sealed to the partition sufficient to cover the sleeve.

R. All materials, accessories and methods of installation and fabrication are subject to the Owner's Representatives inspection and approval during any phase of the work.

S. The insulation subcontractor shall prevent the accumulation of insulation debris in the buildings and on the premises of the Owner.

T. The insulation subcontractor shall be responsible for his own safety program at the work site, and shall provide instruction on safe practices for his workers assigned to the project.

All employees are subject to the work rules at the job site.

U. The insulation subcontractor shall familiarize himself with the progress and execution of the job and notify the proper parties of interferences and any problems with the proper installation of his materials.

3.2 INSTALLATION

A. Duct Insulation:

1. General:

a. Insulate or internally line all flexible duct connectors equal to or greater than adjacent insulation thickness.
b. The tops of all diffusers shall be insulated same as connecting ductwork to prevent condensation.
c. Duct insulation at fire dampers shall be extended over supporting angle iron and sealed to wall.

2. Rigid Fiberglass Insulation:

a. Use boards in largest possible size to minimize seams. Do not use "scraps".
b. Shall be installed in all non-public exposed areas up to 10'-0" above finished floor.
c. Provide corner angles where insulation is subject to harm.
d. All fasteners shall be non corroding.
e. The insulation shall be applied by use of cup head weld pins. Such fasteners shall be spaced in accordance with NCIA recommendations, where NCIA standards do not address exact dimensions, cup head weld pins shall be spaced on 12" centers. Pin caps shall be covered with a round vapor seal patch that matches the jacket on the ASJ board. On cold ducts, these shall be coated so as to not cause condensation.
f. Ducts having sharp bends shall have the insulation scored as required to conform to the curved surfaces to provide a neat and acceptable appearance when finished.
g. Insulation edges and joints shall be finished with two coats of an approved vapor barrier coating, reinforced with reinforcing mesh extending 2 inches onto adjacent insulation. One coat of coating shall be applied to the insulation prior to the application of the reinforcing mesh, which shall be embedded in the coating to ensure complete adhesion of the mesh.
h. Generally, rigid fiberglass material will only be used in finished or exposed areas, and it is intended that the finish present a neat and uniform appearance as to color and workmanship.
i. In finished areas, molded glass fiber insulation shall be used to insulate round ducts where commercially available sizes can be used.
j. Fittings on round ducts in finished areas shall be covered with premolded fiberglass fitting insulators equal to Insul-Coustic where sizes are available.

For sizes where premolded fittings are not available use miter-cut segments of molded pipe insulation, wired in place, with all joints sealed with adhesive and smoothed out with a coat of insulating cement.

k. On cold ducts, the fittings shall be finished with two coats of an approved vapor barrier coating, reinforced with reinforcing mesh extending 2 inches onto adjacent insulation. One coat of coating shall be applied to the insulation prior to the application of the reinforcing mesh, which shall be embedded in the coating to ensure complete adhesion of the mesh. Hot ducts shall be finished in a similar manner, except the mastic need be of the weather barrier breather mastic type. Foster 46-50 Weatherite and Childers CP-10 Vi Cryl or Pittsburgh Corning 404 or Owner Approved Substitution.

3. Blanket Fiberglass Insulation:

a. Insulation shall be wrapped, with the compression no greater than stated in the manufacturer's installation instructions, on the ductwork with all circumferential joints butted and longitudinal joints lapped 2 inches and stapled. Joints shall be finished with two coats of an approved vapor barrier coating, reinforced with reinforcing mesh extending 2 inches onto adjacent insulation. One coat of coating shall be applied to the insulation prior to the application of the reinforcing mesh, which shall be embedded in the coating to ensure complete adhesion of the mesh. Additionally secure insulation to bottom of rectangular ducts over 24 inches wide with weld pins at no more than 18 inches on center.

B. Insulation shall be butted with facing overlapping all joints shall be finished with two coats of an approved vapor barrier coating, reinforced with reinforcing mesh extending 2 inches onto adjacent insulation. One coat of coating shall be applied to the insulation prior to the application of the reinforcing mesh, which shall be embedded in the coating to ensure complete adhesion of the mesh. Breaks, punctures, pin penetrations in facing shall be sealed with vapor barrier tape and vapor barrier coating.

C. Pipe Insulation:

1. General:

a. All locations where the insulated surface is supported by hangers, the insulation shall be protected by shields or saddles properly skimmed to maintain a smooth outer surface, and proper insulation thickness. Chilled water piping, 3" and over shall have a section of foamglas insulation installed between the pipe and shield. 3 and 4" to be 12" long, 5" and 6" to be 18" long and 8" and over, 24" long. If the possibility exists that the hanger may conduct the temperature of the conveyed medium and thus cause condensation or personal injury due to high temperature, the hanger shall also be insulated. Joints between foamglas and pipe insulation shall be properly sealed with insulation joint sealant on all longitudinal and butt joints.

b. All devices connected to or in line with the piping system shall be insulated greater than or equal to the connecting piping. This includes but is not limited to valves, air separators, expansion tanks, control valves, control devices, gauge connections, thermometer stems, chemical feed equipment, piping flexible connectors, etc. This is particularly important on ice water and refrigerant lines.

c. Insulate exterior surfaces of all anchors and guides for chilled water and dual temperature piping systems.
d. A complete moisture and vapor barrier shall be installed wherever insulation is penetrated by hangers or other projections through insulation and in contact with cold surfaces for which a vapor seal is specified.
e. Cover fittings, flanges, unions, valves, anchors, and accessories with premolded or segmented insulation of the same thickness and material as the adjoining pipe insulation. Apply vapor barrier coating and reinforcing mesh in two coats to a minimum dry thickness of 32 mils on all below ambient piping. Where nesting size insulation is used overlap pipe insulation 2 inches or one pipe diameter. Fill voids with insulating cement and trowel smooth. Elbows shall have not less than 3 segments per elbow. Secure insulation with wire or tape until finish is applied. Blanket inserts in lieu of premolded or segmented insulation is not allowed. Cover fittings with preformed PVC fitting covers.
f. Wrap all pressure gauge taps, thermometer wells and all other penetrations through insulation with closed cell insulation tape so as to prevent condensation.
g. Seal all raw edges of insulation with vapor barrier coating or lagging adhesive.
h. For piping supported by hangers outdoors, apply a rainshield to prevent water entry.

3. Closed Cell Elastomeric:

a. All joints shall be sealed with adhesives.
b. Where the thickness is to be obtained by use of two layers of insulation, install with staggered joints.
c. Finish:

1) Concealed Indoors: No additional finish.
2) Exposed Indoors: Provide PVC jacket over all insulation.
3) Concealed Indoors: Provide PVC jacket over fittings fabricated from insulation sections or sheet.
4) Outdoors: Provide aluminum pipe jacket.

4. Foamglas:

a. Below ambient piping: All joints, both longitudinal and circumferential shall be sealed with an insulation joint sealant.
b. Thickness shown for refrigeration pipe to be obtained by use of two layers of insulation with staggered joints.
c. Above ambient piping finish: Weather barrier breather mastic. Foster 46-50, Childers CP-10 or Pittcote 404.
d. Below ambient piping finish:

1) Before PVC jacket is used, seal all insulated elbows, fittings, and valves with vapor barrier coating and reinforcing mesh.

2) Exposed Indoors: Provide PVC jacket over all insulation that shall be sealed with an acrylic latex finish.
3) Concealed: Provide PVC jacket over fittings fabricated from insulation sections or sheet. Provide ASJ over all other. Vapor seal ASJ with vapor barrier coating.
4) Exposed Outdoors: Provide acrylic latex finish and aluminum pipe jacket.

D. Equipment Insulation:

1. Vessel and Large Pipe Insulation:

a. Insulation shall be of the same material as the piping which serves it and it shall be layered to obtain the required thickness. Maximum of 1-1/2" thick per layer.
b. All joints shall be staggered to avoid thermal gaps.
c. Sheet size shall be as large as possible to minimize seams. Do not use "scraps".
d. Securing shall be by welded studs and/or non-corrosive banding wire. Do not weld brackets, clips or other devices to ASME coded pressure vessels or piping. Insulation pins or studs shall be as specified and installed in accordance with NCIA standards.
e. Finish shall be with PVC jacket or galvanized steel mesh wire and a finish coat of insulating cement minimum of 1/4" thick. After cement has cured apply glass lagging cloth and proper coating as directed by manufacturer. All corners shall have metal corner beads and provide acrylic latex finish.

3. Removable Covers:

a. Equipment specified to have removable covers shall have insulation as specified in Paragraph 2.4, fastened to the inside surfaces of a 20 gauge galvanized sheet metal equipment cover.
b. The covers shall be of a sectionalized design, and shall be custom-fitted around each piece of equipment. For ease of removal, joints between sections shall coincide with the splits or joints in the equipment. Joints between sections of the cover shall be held together with quick-connect trunk latches, and shall be gasketed to form a vapor-tite seal cover (for the passage of pipes, etc.) shall be provided with closed cell elastomeric collars to ensure a tight fit.
c. The box shall be fitted around each piece of equipment and split for removal to coincide with the split in the casing. The sections of the box shall be held together with quick disconnect trunk latches. Joints between box sections shall be gasketed to form a vapor seal. Void spaces in the box shall be packed with flexible fiberglass insulation. Openings around pump casing shall be provided with closed cell elastomeric collar to ensure tight fit.
d. Provide acrylic latex finish.
e. Coordinate the piping of the drain, vent, gauge, and control lines to exit through the base or back section of the removable cover. The insulation of these pipes

shall be totally independent of the removable cover.

f. Pipe strainers shall also have removable covers for insulation to facilitate service and maintenance.

1.

4. Chilled Water Compression Tank and Filtering Systems: Surfaces shall be insulated with 1 inch thick closed cell elastomeric insulation board or pipe insulation, as applicable. Finish as specified for vessel and large pipe insulation.

E. Cold Pipe Hanger Support Blocks:

1. Provide on all chilled fluid systems pipe hangers and supports.
2. Apply acrylic latex mastic filler over insulation and on ends.
3. Apply joint and penetration sealant at joint between foamglas and adjacent insulation,
4. Provide vapor barrier system to match the vapor barrier on the adjacent system.
5. Provide 20 gauge (min.) galvanized shield between the insulation and the hanger or support.

F. Weatherproof Duct Jacket:

1. Locate joints and seams to shed water.
2. All joints shall be sealed.
3. Securing shall be by non-corrosive wire banding. Maximum banding spacing 9" on center.
4. Finishing shall be with a minimum of 1/4" coat of insulating weatherproofing.
5. Provide on all ducts exposed to the weather.

G. Aluminum Pipe Jacket:

1. Provide aluminum jacket over all exposed pipe insulation located outdoors.
2. Align all seams.
3. Securing shall be with 3/4" wide draw bands. Maximum band spacing 18" on center.
4. All openings and voids shall be sealed air and water tight with metal jacketing sealant.

H. PVC Jacket:

1. Provide PVC sheet jacket over all exposed, indoor piping or insulation.
2. Provide PVC pipe jacket over all exposed, indoor foamglas or elastomeric pipe insulation.
3. Provide PVC fitting covers over all fittings fabricated from insulation sections or sheet material.
4. PVC pipe jacket shall be applied with special attention given to achieving positive seal at all longitudinal and circumferential joints using a welding solvent on the longitudinal joint as recommended by the manufacturer. Slip joints to have 4" minimum lap and no welding solvent.

I. Self Adhesive Indoor/Outdoor Jacket (Non Asphaltic):

1. Vapor barrier and waterproofing jacketing for installation over insulation located aboveground outdoors or indoors.
2. Specialized jacket with five layers of laminated aluminum and polyester film with low temperature, acrylic, pressure sensitive adhesive; outer aluminum surface coated with UV resistant coating for protection from environmental contaminants.
3. Permeance: 0.00 perm as tested by ASTM F 1249.
4. Flame Spread <25, Smoke Developed <50 tested by ASTM E-84. Aluminum finish. Embossed.

J. Glass Cloth Jacket:

1. Provide where specified.
2. Provide acrylic latex finish.

K. Flexible Acrylic Latex:

1. Apply two coats to glass cloth jacket, concealed foamglas and closed cell elastomeric insulation.
2. Refer to Division 09 for color to be used. If no instructions are given, provide a white finish.

3.3 MISCELLANEOUS ITEMS

A. General: Provide insulation of any portion of a system or piece of equipment not previously discussed where ambient operating conditions will allow condensation to occur or whose surface temperature exceeds 115°F. Insulation materials and method shall be as directed by the Designer.

B. Final Inspection: At final inspection, the finished surfaces of all exposed insulation shall be clean and without stains or blemishes. Repair and clean the insulation surfaces and, if necessary, to obtain a new appearance, shall coat discolored surfaces with off-white latex water-base semi-gloss paint or lagging adhesive, without a change in the contract price.

3.4 INDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. General:

1. Provide continuous unbroken vapor barrier on ducts and plenums with surface temperature below ambient.

B. Concealed supply-air duct insulation shall be the following:
1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.

C. Concealed return-air duct insulation shall be the following:
   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 0.75-lb/cu. ft. (12-kg/cu. m) nominal density.

D. Concealed outdoor-air duct insulation shall be the following:
   1. Mineral-Fiber Blanket: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

E. Concealed Exhaust-air duct insulation shall be one of the following:
   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 0.75-lb/cu. ft. (12-kg/cu. m) nominal density.

F. Supply-air plenum insulation shall be one of the following:
   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. M) nominal density.
   2. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. M) nominal density.

G. Return-air plenum insulation shall be one of the following:
   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.
   2. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) nominal density.

H. Outdoor-air plenum insulation shall be one of the following:

   1. Mineral-Fiber Blanket: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.
   2. Mineral-Fiber Board: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

I. Exhaust-air plenum insulation shall be one of the following:

   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 0.75-lb/cu. ft. (12-kg/cu. m) nominal density.
   2. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) nominal density.

J. Exposed supply-air duct insulation shall be the following:
   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.

K. Exposed return-air duct insulation shall be the following:
   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 0.75-lb/cu. ft. (12-kg/cu. m) nominal density.

L. Exposed outdoor-air duct insulation shall be the following:
   1. Mineral-Fiber Blanket: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

M. Exposed exhaust-air duct insulation shall be one of the following:
   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 0.75-lb/cu. ft. (12-kg/cu. m) nominal density.

3.5 INDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Ducts and Plenums, Concealed:

   1. None.

D. Ducts and Plenums within MER, Exposed and less than 7'-0" above finished floor (AFF)
   1. Aluminum, Smooth: 0.020 inch (0.51 mm) thick.

E. Ducts and Plenums, Exposed, other than D above:
   1. None.

3.6 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Ducts and Plenums, Concealed:
   1. Aluminum, Corrugated: 0.032 inch (0.81 mm) thick.
   2. Self-Adhesive Outdoor Jacket

D. Ducts and Plenums, Exposed, up to 48 Inches (1200 mm) in Diameter or with Flat Surfaces up to 72 Inches (1800 mm):

   1. Aluminum, Corrugated: 0.032 inch (0.81 mm) thick.

   2. Self-Adhesive Outdoor Jacket

E. Ducts and Plenums, Exposed, Larger Than 48 Inches (1200 mm) in Diameter or with Flat Surfaces Larger Than 72 Inches (1800 mm):

   1. Aluminum, Stucco Embossed with 2-1/2-Inch- (65-mm-) Deep Corrugations thick.

   2. Self-Adhesive Outdoor Jacket

3.7 INDOOR PIPING INSULATION SCHEDULE

A. Thickness shall be as follows:

B. Condensate and Equipment Drain Water below 60 Deg F:

1. All Pipe Sizes: Insulation shall be the following:

a. Flexible Elastomeric
b. Mineral-Fiber

C. Chilled Water and Brine:

1. Insulation shall be one of the following:
a. Cellular glass

2. Flexible Elastomeric insulation can be used for run-outs (maximum of 4 feet), to AHU's and FCU's cooling coils for pipe sizes up to NPS 4.

3. Insulation thickness:

Piping System	Insulation Material	Pipe Size, NPS	Insulation thickness
CHW Piping (Indoor areas)	Cellular Glass	2" and smaller	1-1/2"
		2-1/2" to 20"	2"
		22" and larger	2-1/2"

Piping System	Insulation Material	Pipe Size, NPS	Insulation thickness
CHW Piping (Outdoor, Baggage Handling System areas, Sortation areas)	Cellular Glass	2" and smaller	1-1/2"
		2-1/2" to 8"	2"
		10" and larger	2-1/2"

D. Refrigerant:

1. Insulation shall be one of the following:
a. Flexible Elastomeric
b. Owner Approved Substitution

E. Engine Exhaust Piping:

1. Insulation shall be one of the following:

a. Calcium Silicate
b. Owner Approved Substitution

3.8 OUTDOOR, ABOVEGROUND PIPING INSULATION SCHEDULE

A. The minimum insulation thickness shall be 3 inches thick for pipe sizes up to and including 4 inch and a minimum 3.5 inches thick for pipe sizes 6-8 inches and larger.

B. Chilled Water and Brine:

1. All Pipe Sizes: Insulation shall be the following:

a. Cellular Glass

C. Fuel Oil Piping, Heated:

1. All Pipe Sizes: Insulation shall be one of the following:

a. Cellular Glass: 2 inches (50 mm) thick
b. Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches (50 mm) thick

D. Refrigerant:

1. Insulation shall be one of the following:
a. Flexible Elastomeric
b. Owner Approved Substitution

3.9 OUTDOOR, UNDERGROUND PIPING INSULATION SCHEDULE

A. Fuel Oil Piping, All Sizes, Heated: Cellular glass.

3.10 INDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Piping, Exposed:
1. PVC: 20 mils (0.5 mm) thick.

3.11 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Piping, Exposed:

1. PVC: 30 mils (0.8 mm) thick.
2. Aluminum, Corrugated with Z-Shaped Locking Seam: 0.040 inch (1.0 mm) thick.

3.12 EQUIPMENT INSULATION SCHEDULE

A. Insulation materials and thicknesses are identified below. If more than one material is listed for a type of equipment, selection from materials listed is Contractor's option.

B. Insulate indoor and outdoor equipment that is not factory insulated.

C. Chillers: Insulate cold surfaces on chillers, including, but not limited to, evaporator bundles, condenser bundles, suction piping, compressor inlets, tube sheets, water boxes, and nozzles with the following:
1. Flexible Elastomeric: 1 inch (25 mm) thick.

D. Chilled-water pump insulation shall be one of the following:

1. Cellular Glass: 3 inches (75 mm) thick.
2. Flexible Elastomeric: 2 inch (50 mm) thick.

3. Mineral-Fiber Board: 2 inches (50 mm) thick and 6-lb/cu. ft. (96-kg/cu. m) nominal density.

E. Chilled-water expansion/compression tank insulation shall be the following:
1. Flexible Elastomeric: 1 inch (25 mm) thick.

F. Chilled-water air-separator insulation shall be the following:

1. Flexible Elastomeric: 1 inch (25 mm) thick.

G. Piping system filter-housing insulation shall be one of the following:

1. Flexible Elastomeric: 1 inch (25 mm) thick.

3.13 INDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Equipment, Concealed:

1. None.

D. Equipment, Exposed, up to 48 Inches (1200 mm) in Diameter or with Flat Surfaces up to 72 Inches (1800 mm):
1. Aluminum, Smooth: 0.024 inch (0.61 mm) thick.

E. Equipment, Exposed, Larger Than 48 Inches (1200 mm) in Diameter or with Flat Surfaces Larger Than 72 Inches (1800 mm):
1. Aluminum, Smooth with: 0.032 inch (0.81 mm) thick.

3.14 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Equipment, Concealed:

1. None.

D. Equipment, Exposed, up to 48 Inches (1200 mm) in Diameter or with Flat Surfaces up to 72 Inches (1800 mm):

1. Aluminum, Corrugated with Z-Shaped Locking Seam: 0.032 inch (0.81 mm) thick.

E. Equipment, Exposed, Larger Than 48 Inches (1200 mm) in Diameter or with Flat Surfaces Larger Than 72 Inches (1800 mm):

1. Aluminum, Stucco Embossed with 2-1/2-Inch- (65-mm-) Deep Corrugations: 0.040 inch (1.0 mm) thick.

END OF SECTION 23 07 00

SECTION 23 09 00 – INSTRUMENTATION AND CONTROL FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1. Summary
   a. The South Terminal Building Management System (BMS) sub-contractor is responsible to provide and install all control and monitoring devices to provide a complete system in Terminal C, PH 1X-Airside Concourse (including PCA), and integrate with existing BMS in Airside Concourse PH 1 (ASC), Landside Terminal (LST), Central Energy Plant (CEP), Electrical Power Generation (EPG) facility, Ground Support Equipment (GSF) Checkpoint Delta, and the North Terminal Maintenance Control Room. The BMS Contractor shall provide a complete system consisting of Direct Digital Control Panels (DDCPs), field I/O devices, power supplies and supportive software, to meet the written sequences of operations, as written in contract specifications. The system shall support communications to DDCP's, and provide operator interaction, data consolidation and global control functions via existing BMS network.
   b. The BMS network connectivity shall reside on the existing BMS network. BMS infrastructure backbone cabling from IDF closet to IP DDC Controller locations provided by Division 27 IT Contractor. BMS Contractor shall provide local network wiring, ethernet switches (in each MER), etc. for connectivity of new Terminal C PH 1X-Airside Concourse IP controllers.
   c. Work shall include HVAC control, energy management, alarm monitoring, point trending, point reporting and maintenance management functions. Coordinate with all site low voltage systems as specified.
   d. The project will utilize LEED EA prerequisite: Energy metering of consumption at one-month intervals and share with USGBC for a 5 year period. (Reporting shall be provided during period upon request of GOAA).
   e. All labor, material, equipment and software not specifically referred to herein or on the plans, that is required to meet the functional intent of this specification, shall be provided without additional cost to the Owner.
   f. The BMS Contractor shall be selected by the owner-CR@R based on Technical Proposal submission that meets or exceeds "BMS Contractor Installer Qualifications paragraph section 1.14."
   g. Refer to "Scope of Work" paragraph for additional information.

1.2 RELATED SECTIONS

A. Division 23 - Mechanical Section

1. 23 05 14-Variable Frequency Motor Controllers
2. 23 09 20-Refrigerant Detection and Alarm
3. 23 33 00-Air Duct Accessories
4. 23 72 00-Air to Air Energy Recovery Units
5. 23 73 13-Modular Air Handling Units
6. 23 74 33-Dedicated Outdoor Units
7. 23 08 00-Commissioning of HVAC System
8. 23 81 23-Computer Room Air Conditioners
9. 23 81 26-Split System Air Conditioners
10. 23 82 19-Fan Coil Units

B. Division 26 - Electrical Section
1. 26 07 17-SCADA Monitoring and Control System
2. 26 05 13-Conduit
3. 26 05 19-Building Wire and Cable
4. 26 09 24-Architectural Lighting Control Systems
5. 26 27 13-Electrical Metering and Monitoring

C. Division 27
1. 27 05 00-Common Work Elements for Communications

1.3 ABBREVIATIONS

A/C - Air Conditioning
ADA - American Disabilities Act.
AHU - Air Handling Unit
ASHRAE - American Society of Heating, Refrigeration and Air Conditioning Engineers
AMBCx: - Automated Monitoring Based Commissioning
ANSI - American National Standards Institute
AODB - Airport Operational Data Base
API - Application Programming Interface
BACnet - Building Automation Controls Network
BTL - BACnet Testing Laboratory
BIBB - BACnet Interoperability Building Block
BIM - Building Information Modeling
BMA - BACnet Manufacturers Association
BMS - Building Management System
CCDT - Configuration, Commissioning and Diagnostic Tool
CCP - Communications Control Panel
CCR - Central Command Room
CD-RW - Compact Disk with Read and Write Capability
CIBSE - Chartered Institution of Building Services Engineers
CM - Construction Manager
CPU - Central Processing Unit
DAT - Digital Audio Tape
DDCP - Direct Digital Control Panel
DDC - Direct Digital Control
DDR - Double Data Rate

DCV	-	Demand Control Ventilation
DR	-	Demand Response
EIA	-	Electronics Industries Association
EMI	-	Electro-Magnetic Interference
EMMS	-	Electrical Metering and Monitoring System
ELV	-	Extra Low Voltage
EP	-	Electric-to-Pneumatic
FAS	-	Fire Alarm System
FCU	-	Fan Coil Unit
FDD	-	Fault Detection and Diagnostics
FSD	-	Fire Smoke Damper
GOAA	-	Greater Orlando Aviation Authority
GUI	-	Graphical User Interface
GSE	-	Ground Support Equipment
HMI	-	Human Machine Interface
HVAC	-	Heating, Ventilating and Air Conditioning
HT	-	Humidity Transmitter
IBSS	-	Integrated Building Security System
IT	-	Information and Communication Technology
IDE	-	Integrated Drive Electronics (Hard Disk)
IEEE	-	Institute of Electrical and Electronic Engineers
IP	-	Internet Protocol
ISO	-	International Standards Organization
ID	-	Identification
I/O	-	Input/Output
ISA	-	Instrument Society of America (also known as International Society for Measurement and Control)
LAN	-	Local Area Network
LCD	-	Liquid Crystal Display
LEED	-	Leadership in Energy and Environmental Design
LED	-	Light Emitting Diode
LLA	-	Low Level Alarm
MCC	-	Motor Control Center
MER	-	Mechanical Equipment Room
NEMA	-	National Electric Manufacturers' Association
NFPA	-	National Fire Protection Association (US Standards)
ODBC	-	Open database Connectivity
OEM	-	Original Equipment Manufacturer
OIW	-	Operator Interface Workstation
OLE	-	Object Linking and in Embedding
OPC	-	Open Process Control
OSHA	-	Occupational Safety and Health Administration
PABX	-	Private Automatic Branch Exchange
PC	-	Personal Computer
PCA	-	Pre-Conditioned Air
PCI	-	Peripheral Component Interconnect
PE	-	Pneumatic-to-Electric
PICS	-	Protocol Implementation Conformance Statement

PID	-	Proportional, Integral, Derivative
PDA	-	Personal Digital Assistant
PIM	-	I/O Point Interface Module
POT	-	Portable Operator Terminal
PTFE	-	Polytetrafluoroethylene (Teflon)
PT	-	Pressure Transmitter
RAID	-	Redundant Array of Inexpensive Disks
RAM	-	Random Access Memory
RFI	-	Radio Frequency Interference
RH	-	Relative Humidity
RTD	-	Resistance Temperature Device
RTU	-	Remote Terminal Unit
SCADA	-	Supervisory Control and Data Acquisition
SQL	-	Structured Query Language
SSPC	-	Standing Standard Project Committee (ASHRAE)
SVGA	-	Super Video Graphics Adapter
TT	-	Temperature Transmitter
TPM		Technical Project Manager
UC	-	Unitary Controller
UPS	-	Uninterruptible Power Supply
UL	-	Underwriters Laboratories
USGBC	-	US Green Building Council
VAV	-	Variable Air Volume
VDU	-	Video Display Unit
VPN	-	Virtual Private Network
VFD	-	Variable Frequency Drive
VLAN	-	Virtual Local Area Network
WAN	-	Wide Area Network
XIF	-	External Interface File
XML	-	Extensible Mark-up Language

1.4 DEFINITIONS

A. Algorithm: A software procedure for solving a recurrent mathematical or logical problem.

B. Analog: A continuously varying signal or value (temperature, current, velocity, etc.).

C. BACnet: The Building Automation and Control Network open protocol communication standard develop by ASHRAE (ASHRAE SSPC/135) and which is now an ISO and ANSI standard. BACnet can operate over multi-media including Ethernet, and MSTP. BACnet components shall be UL listed; and shall be fully complaint with ASHRAE Standard SSPC/135 and all other applicable codes.

D. BACnet Object: A physical or virtual point with a set of associated properties such as a temperature sensor that has properties including – name, current value, maximum/minimum values, high/low alarm levels, etc.

E. BACnet Conformance: A description of the capabilities of a device for communicating information to other BACnet devices. It is usually a set of requirements to be met in order for a device to conform to BACnet standards. There are 6 class levels of conformance for standard BACnet objects and services. The higher the conformance class level, the more features that are covered. The BACnet devices furnished under this sub-contract shall at a minimum, be conformance class 3. Preference will be given to higher conformance class of the latest controllers at time of purchase.

F. BACnet Interoperability Building Blocks (BIBBs): A BIBB defines a small portion of BACnet functionality needed to perform a particular task. BIBBs come in pairs, A and B, which reflect the client/server nature. The “A” BIBB represents the client, i.e. the device furnishing the information. The “B” BIBB represents the server, i.e. the device furnishing the information or executing the command. For 2 devices to be interoperable the “A” BIBB and the “B” BIBB must be the same.

G. BACnet/IP: The Building Automation and Control Network open protocol communication standard using Internet Protocol (IP) complying with Annex J of the ASHRAE SSPC/135 standard.

H. Binary: A two-state system where an “ON” condition is represented by a high signal level and an “OFF” condition is represented by a low signal level.

I. Building Management System (BMS): The entire system of hardware and software specifically designed to centrally manage building HVAC and related utilities. The BMS includes the DDC subsystem, open system ports, and open protocol bus or integrators and network routers for connection to information networks. It includes components at the Field, Automation and Management Levels.

J. BMS Contractor: The Building Management System Contractor responsible for the installation of the Building Management System specified herein.

K. Control Process: The software required to perform a complete control loop from input signal to interlock logic, process calculation to final output signal control.

L. Component: Any individual element of the BMS furnished under this sub-contract including hardware, software and materials.

M. Control Wiring: Includes conduit, wire and wiring devices to install a complete Control System including motor control circuits, interlocks, thermostats, PE and EP switches and like devices. Includes all wiring from controllers to all sensors and points specified herein and required to execute the sequence of operation. Does not include line voltage power wiring.

N. Dead band: A temperature range over which no heating or cooling energy is supplied, such as 74-78 degrees F, i.e. as opposed to single point changeover or overlap, or a range from setpoint over which no control action is taken.

O. Diagnostic Program: Machine executable instructions used to detect and isolate system and component malfunctions.

P. Direct Digital Control System: The portion of the BMS that involves the connection of microprocessor-based controllers to field level sensors and actuators. The signals received from field level instrumentation are converted from analog to digital format so that the data can be used in software logic. Control signals are determined by software logic and they are converted from digital to analog format so that the final control element can be adjusted.

Q. Distributed Control: A system whereby all control processing is decentralized and independent of a central computer. The control system is built up of stand-alone controllers. A single controller failure shall not impact more than one system.

R. Furnish: Purchase and deliver to the appropriate installing sub-contractor, complete with every appurtenance, document, commission and warranty.

S. Integration: The ability of control system components from different manufacturers connect together while providing coordinated control via real-time data exchange through a common communications data exchange protocol. Integration shall extend to the operator’s workstation software, which shall support user interaction with all control system components. Methods of integration include industry standard protocols such as: BACnet, Modbus and OLE for Process Control (OPC) or integrator interfaces between cooperating manufacturer’s systems.

T. Interoperability: The ability of systems from different manufacturers and of different types to share information with each other without losing any of their independent functional capabilities and without the need for complex programming.

U. Native BACnet: This term is used to imply that BACnet devices (i.e. the BMS controllers and workstation) only communicate in BACnet protocol and do not require an intermediate gateway for protocol conversion. The BACnet devices shall be connected on a peer-to-peer network using one of the approved LAN technologies such as Ethernet, MS/TP, or BACnet/IP.

V. Network: A system of distributed control units that are linked together on a communication highway. A network allows sharing of point information between all control units. Additionally, a network provides central monitoring and control of the entire system from any distributed control unit location. First tier (Management Level) networks shall provide “Peer-to-Peer” communications. Second tier (Automation Level) networks shall provide either “Peer-to-Peer”, Master-Slave or Supervised Token Passing communications.

W. Open Protocol Bus (OPB): A pre-programmed communications integrator that allows devices from one manufacturer to communicate and interact with those of another.

X. Operating System (OS): Software that controls the execution of computer programs and which provides scheduling, debugging, input/output controls, accounting, compilation, storage assignment, data management and related services.

Y. Open System Port (OSP): A user programmable communications port that provides the ability to develop custom communications processes to integrate other operating systems with the BMS System.

Z. Operator Interface Workstation (OIW): The OIW consists of a high-level processing personal computer and peripheral I/O devices that enable access to the PC and to the entire Management Level Network. The OIW allows an operator to command, monitor, and program the system.

AA. Peer-to-Peer Communications: Communications directly between devices that operate on the same communications level of a network, without intervention from any intermediary devices such as a host computer or server.

BB. Peripheral: Input/Output equipment used to communicate with the computer and make copies of system outputs; peripherals include VDUs, printers, hard drives, disk drives and modems, etc.

CC. Portable Operator Terminal (POT): Permits portable operator interface remotely from the Operator Interface Workstation (OIW) to facilitate network management, point-to-point node commissioning, diagnostics and general operator interface with the BMS.

DD. Programmable Device: A device that does not have a pre-established built-in application. An application creation software tool is required for an application to be created and downloaded to the device.

EE. Pick Point: A pick point is a graphical display element that allows the operator to “click” the item and automatically display the associated screen or service. Any screen may have pick points to or be linked from any other screen. Pick points shall be configured on each display screen to provide a logical user navigation system using a ladder tree hierarchy.

FF. PID Control Loop: A mathematical calculation used to evaluate a control input and determine the control output value required to maintain the input value at setpoint. The PID (Proportional, Integral, and Derivative) control loop shall have operator adjustable maximum rate of change, P and D gains and loop response time delay. The loop shall be self-integrating so that no integral constant is required, and the loop shall not be subject to “Integral Windup”.

GG. Provide: The term “provide” means “provide complete in place”, that is, furnish, install, commission, test, warrant and ready for operation and use. Refer to the definition of “Furnish”.

HH. Router: A device that routes messages destined for another segment sub-net or domain of the control network. The device controls message traffic based on node address and priority. Media converters which serve as communication links between power line, twisted pair, fiber optic, coax and RF media are sometimes referred to as Routers.

II. Software: Programs that are executed by a computer based BMS beyond the physical hardware of the computer system, encompasses any programs such as operating systems (OS), application programs, operating sequences and databases. The term "Software" in this specification shall also include all firmware provided with read-only memory as part of the BMS to meet all applicable criteria detailed to meet sequence of operations.

JJ. Unitary Controller: A controller generally designed for a specific application and for a single piece of equipment. Fully programmable unitary controllers shall be provided for this project.

KK. Virtual Private Network (VPN): This is a network that uses encryption and other technologies to provide secure communications over the Internet or an Intranet.

LL. XIF: External Interface File that contains contents of the manufacturer's product documentation.

MM. SOAP: Simple Object Access Protocol (SOAP) is a simple extensible mark-up language (XML) - based protocol that enables applications to exchange information through a WEB Service.

1.5 BMS SYSTEM ARCHITECTURE

A. The BMS shall connect to the existing BMS network using BACnet/IP over Ethernet. This LAN is hereafter referred to as the "Site Management Level".

B. The Site Management Level
   1. All servers, Operator Interface Workstations (OIW), Operating Systems (OS) and related applications shall reside on the management level of the existing BMS network.
   2. Communication Control Panels (CCPs) shall reside on the management level.
   3. All Management Level components (DDCP panel, , etc.) shall be support by a local ½ hour Uninterruptible Power Supply (UPS).

C. The Automation Level
   1. The automation level shall comprise of Unitary Controllers (UC) for terminal equipment including VAV, , FCU's, etc. The controllers shall be in compliance to ASHRAE SSPC/135, BACnet standards latest revision.
   2. Supervisory controllers shall reside on the Automation level.

D. The Field Level
   1. The field level shall include all instrumentation interfaced to the automation level controllers such as temperature, humidity, level, pressure and switches, etc.
   2. It shall also include the final control elements such as the control valves, damper actuators and control relays.
   3. All field level cables shall be Plenum-type Teflon insulated (LSF - Low Smoke and Fire) rated installed in conduit.

1.6 SCOPE OF WORK

A. Installation of Building Management System (BMS)

1. The BMS Contractor shall furnish and install a complete Building Management System (BMS) for all mechanical systems and other facility systems as included in the project documents. The BMS Contractor shall provide, test and commission a fully integrated BMS (software platform incorporating an integrated systems database) with the capability to interface seamlessly with other subsystems. The BMS shall allow full integration of subsystems with capability to support multi-vendor environments utilizing standard protocols and be able to integrate third-party systems using standard or subsystem vendor proprietary protocols. The BMS Contractor shall cross-reference this specification with each of the subsystem specifications and identify any gaps and/or conflicts at the time of bid. The BMS Contractor is responsible to obtaining a complete set of drawings and specifications for review for inclusion of all points, systems and values referenced in this specification. The BMS will provide the functional features as defined in Part 1-General requirements, Part 2-Products, and Part 3- Execution of these Specifications. The BMS Contractor shall provide a complete and operational system that will perform sequences of operations as verified by Owner Representative and Engineer. The BMS Contractor shall be responsible for all controls, wiring and scope detailed in Contract document M8.01.01 (BMS Responsibility Matrix).
2. The components furnished shall be the most recent products offered by the BMS manufacturer that meet the specifications. Any originally installed product (including controller hardware, operating system software, etc.) that becomes obsolete (end of shelve life-product replaced with newer product) within 5 years of project completion shall be replaced free of charge. No additional compensation shall be awarded for replacement of older generation product. If there are improved models of any components that become available before the on-site commencement of installation, then these shall be offered by the BMS Contractor to the CM at no additional cost to the Owner. The Owner shall have the option to accept or decline the offer. The components offered shall have been in successful operation in at least 2 similar large facility applications for a minimum of 12 months.
3. The BMS Contractor shall provide all software licenses necessary for the legal operation of the BMS. Coordinate with Owner-CM.
4. The BMS Contractor is responsible to coordinate all installation activities with CM Site Facility personnel and the Engineer by submitting a written installation schedule outlining all proposed BMS installation activities. The schedule should include the anticipated time to install new controllers and network equipment, installation of new monitoring devices and wiring, software programming, testing/commissioning, training, and system acceptance.
5. Commissioning of Mechanical Systems: The BMS Contractor shall provide all labor as required to assist with the commissioning of all equipment and systems as scheduled and required by the project’s Commissioning Agent.
6. In addition, the following apply:
   a. The work under this Section shall include all materials and labor to perform all work required for the installation of the BMS as specified.

b. The drawings and Specifications are complementary to one another—meaning that what is called for on one is to be considered called for in both. Where conflicts exist between the Specifications and/or drawings, the more stringent requirement shall apply.

c. Where work specified under other Sections of this Specification connects to equipment or systems that are listed and described in this Section, the BMS Contractor shall provide proper connection(s) to such equipment, including trade coordination.

B. The BMS shall enable an open architecture that utilizes ANSI/ASHRAE Standard 135-2007, BACnet functionality to assure interoperability between all system components. Native support for ANSI/ASHRAE standard 135-2007, BACnet protocol are required to assure that the project is fully supported by the HVAC open protocols to reduce future building maintenance, upgrade and expansion cost.

C. The system shall support Modbus TCP and RTU protocols natively, and not require the use of gateways.

D. New BACnet/IP based DDC cabinets shall be strategically installed in MER's and other locations in the facility (refer to BMS riser diagrams) to control and monitor new mechanical, electrical and plumbing equipment in Airside Concourse P1X .The BMS shall provide a single and unified graphical user interface for all subsystems. System included (but not limited to) the following:

1. VAV air handling units. (Type A)
2. DOAS VAV air handling units (Type B)
3. 100% outside air units (Type C)
4. AHU's with fan arrays include one VFD per fan in array. Provide airflow probes for each fan in fan array.
5. PCA equipment (Airside Building). Integrated with the BMS. All PCA control, monitoring and alarm functions shall be available at the new BMS workstations in the CEP and the North Terminal Maintenance Office.
6. EMMS integrated with BMS (monitor electrical usage of lighting and plug load electrical panels). Refer to section 26 27 13. BMS Contractor to coordinate and confirm integration requirements with system manufacturer, and GOAA IT (REST API with event subscription and HTTP authentication).
   a. Building total receptacle panel KWH power usage
   b. Building total lighting panel KWH power usage.
   c. Baggage Handling System KWH power usage.
   d. Pre-conditioned air (Main Plant) KWH power usage.
   e. Pre-conditioned air (per gate) KWH power usage.
   f. 400 Hz System (per gate) KWH power usage.
   g. SCADA system monitoring "read only" (, electrical equipment , etc.)
7. Lighting control systems (expansion of existing) (BMS integration-read/write via BACnet TCP/IP). Refer to section 26 09 23). BMS shall be programmed to send "enable-disable" request to lighting control system to override zone control manually from the BMS workstation and automatically based on information from the AODB. BMS Contractor to coordinate integration requirements with system manufacturer, and GOAA IT (REST API with event subscription and HTTP authentication).

8. BMS integration with existing Airport Operational Database (AODB-read only) required for additional P1X gates. The AODB and the BMS shall be made interoperable through the use of an open API. The BMS manufacturer and the AODB manufacturer shall provide a fully operable seamless platform through the API based integration between both systems. The API shall transfer status points from the AODB to the BMS including gate occupancy. The BMS shall include the ability to control AHU and terminal zone schedules for occupied-unoccupied modes of operation based on information from AODB. BMS Contractor to coordinate and confirm integration requirements with system provider, and GOAA IT (Information message broker). .
9. Constant and variable speed pump control.
10. Variable air volume terminal boxes (BMS contractor shall furnish controls for factory installation by VAV terminal box manufacturer).
11. VAV duct damper control.
12. Miscellaneous exhaust fans.
13. CRAC units (integrated with BMS via BACnet MSTP or Modbus).
14. Split AHU.
15. Fan coil units.
16. VFD integration with BMS (BACnet MSTP).
17. Electric duct heating coil KWH usage monitoring via the BMS (meter provided by duct heater manufacturer-integrate with BMS via BACnet MSTP).
18. AHU electric duct heating coil KWH usage meter monitoring via the BMS (meter provided by the BMS Contractor).
19. Fire/Smoke Damper end switch monitoring (closed position) via the BMS (hardwired-Coordinate with FAS manufacturer)..
20. Pre-conditioned air system chilled water BTU meter interface with BMS.
21. Domestic water booster pump (failure alarm indication at BMS).
22. Circulating pumps (status indication at BMS).
23. Duplex sump pumps (failure alarm indication at BMS)
24. Elevator sump pump (overflow alarm indication at BMS).
25. Domestic Water Heaters (supply temperature)
26. Sequence of operations: Refer to control drawings.
27. Plumbing Drip Pan Leak Detection (leak detector provided by BMS Contractor-Typical-Refer to plumbing and mechanical drawings for quantity and location).

E. Except as otherwise noted, the control system shall consist of all necessary Ethernet controllers, standalone digital control units,, software, sensors, transducers, relays, transformers, valves, dampers, automatic damper operators, control panels, and other necessary equipment, along with a complete system of electrical interlocking wiring to fill the intent of the specification and provide for a complete and operable system. Except as otherwise specified, provide operators for equipment such as dampers if the equipment manufacturer does not provide these. Coordinate requirements with the various Contractors.

F. Provide all miscellaneous low voltage field device mounting and interconnecting wiring for all Building mechanical systems. All interlock wiring, wiring and installation of control devices associated with equipment listed below shall be provided under this contract. When the BMS is fully installed and operational, the BMS Contractor and representatives of the owner will review and check out the system-refer to System Acceptance and testing section of this document. At that time, the BMS Contractor shall demonstrate the operation of the system and prove that it complies with the intent of the drawings and specifications.

G. Provide services and manpower necessary for commissioning of the system in coordination with the HVAC Contractor, Balancing Contractor, Design Engineer and Owner's representative.

H. All work performed under this section of the specifications will comply with all governing codes, laws and governing bodies. The Contractor shall obtain and pay for all necessary construction permits and licenses.

I. Provide control power transformers/power supplies for all new equipment.

J. Provide and install proper earth ground on all BMS equipment to prevent the build-up of electromagnetic voltage potential. All BMS equipment shall be EMI immune.

K. All components of the BMS at the Management level and at the BMS Automation level, except for the unitary controllers, shall be support by the Uninterruptible Power Supply (UPS). UPS provided by BMS Contractor.

L. Interface/integrate with third-party equipment as defined and specified.

M. Provide hardwire interlocks for all systems requiring interlock as noted (Fire Alarm System, Mechanical, etc.).

N. Provide system graphics for each HVAC, electrical, plumbing, and piping system. Provide scaled floor plans indicating equipment location, service, and system data as required by this specification. Graphics to incorporate integrated points communicated via multiple sources including direct protocol integration, gateways and third – party interfaces. Origin of information shall be transparent to the operator and shall be controlled, displayed, trended, etc. as if the points were hardwired to the BMS. Provide dynamic dashboard graphics for energy usage monitoring.

O. System Performance:
   1. Graphic Display: Display graphics with minimum 20 dynamic points and current data within 5 seconds.
   2. Graphic Refresh: Update graphic with minimum 20 points with current data within 5 seconds.
   3. Object Command: Reaction time of less than 2 seconds between operator command of a binary object and device reaction.
   4. Object Scan: Transmit change of state and change of analog value to control unit or workstation within 5 seconds.

5. Alarm Response Time: Annunciate alarm at workstation within 10 seconds from initiation. Multiple workstations must receive alarms within 5 seconds of each other.
6. Program Execution Frequency: Run capability of applications as often as five seconds but selected consistent with mechanical processes under control.
7. Program Execution Summary: Programmable controllers shall execute DDC PID control loops, and scan and update process values and outputs every second.
8. Performance: Programmable controllers shall execute BMS PID control loops, and scan and update process values and outputs at least once per second.
9. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows:
    a. Water Temperature: Plus or minus 1 degF.
    b. Water Flow: Plus or minus 2 percent of full scale.
    c. Water Pressure: Plus or minus 5 percent of full scale.
    d. Space Temperature: Plus or minus 1 degF
    e. Ducted Air Temperature: Plus or minus 1 degF.
    f. Outside Air Temperature: Plus or minus 2 degF.
    g. Dew Point Temperature: Plus or minus 3 degF.
    h. Temperature Differential: Plus or minus 0.25 degF.
    i. Relative Humidity: Plus or minus 2 percent.
    j. Airflow (Pressurized Spaces): Plus or minus 3 percent of full scale.
    k. Air Pressure (Space): Plus or minus 0.01-inch wg.
    l. Air Pressure (Ducts): Plus or minus 0.1-inch wg.

P. Provide a remote notification and monitoring system (minimum requirements-connect to existing):
1. Existing BMS workstation (-) shall be configured for P1X to send out messages via email, phones (via speech to text technology), SMS, text messaging-cellular, mobile handsets).
2. There should be no limit to the number of points (analog or digital), that can be configured to remote notification of alarm condition and no limit to the amount of devices which can receive messages from the BMS.
3. On a per point message, system can be configured to send messages to an individual or group and shall be configured to send different messages to different-to-different remote devices based on alarm message priority level.
4. Remote devices may be scheduled as to when they receive messages from the system to account for the operator work schedules.
5. System must be configured to send messages to an escalation list so that if the first device does not respond, the message is sent to the next device after a configurable time has elapsed. Message detail shall be configurable on a per user basis.
6. During a “flood” of alarms, remote notification messages shall have the ability to optimize several alarms into an individual remote notification message.
7. BMS workstation shall have the ability to send manual messages allowing an operator to type a message to be sent immediately.
8. BMS workstation shall have a feature to send a “heartbeat” message to periodically notify users that they have normal communication with the system.

9. Notification and monitoring system shall have the capability to be de-activated at the end of construction. Owner will have capability to re-activate system as needed via command at the BMS workstation.
10. BMS Contractor shall coordinate, confirm and implement remote notification and responder requirements with GOAA. GOAA to provide BMS Contractor contact information of responders for alarm/programming.

Q. Provide the following support for all components furnished under this sub-contract:
1. Warranty and service during the defect's liability period.
2. Submittals, samples and record documentation.
3. Comprehensive commissioning and testing services.
4. Detailed theoretical and practical training services for the BMS Supervisors and Operators.
5. BMS equipment coordination with other site Specialists (Fire Alarm, etc.).
6. Comprehensive and complete interoperability documentation and method statement for all third-party systems.
7. Comprehensive PICS documentation regarding the BACnet object ID, component IP addresses, databases for all system database points.

R. The BMS must comply with GOAA's IT and IT Security policies and standards including enhanced security to provide authentication, authorization, network security monitoring, intrusion detection/prevention, network flow behavioral analysis and intrusion response capabilities. Normal BMS network traffic shall be base lined and a GOAA's endpoint and network tools and products used to detect an alert on anomalous network traffic patterns or potential network intrusions. BMS shall provide a method to respond to detected anomalous events by blocking access. Each network connection shall be monitored, analyzed for malicious activity and blocked if required

1.7 SYSTEM DESCRIPTION

A. In accordance to the scope of work, the system shall also provide a graphical, web-based, operator interface that allows for instant access to any system through a standard browser. The PC-based programming workstations, operator workstations (workstations -existing) and microcomputer controllers of modular design providing distributed processing capability,and allowing future expansion of both input/output points and processing control functions. For this project the system shall consist of the following components:
1. Administration and Programming Workstation(s) for commissioning as required to meet project schedule. Temporary workstations provided by BMS Contractor.
2. Ethernet-based Network Router and/or Network Server Controller
3. Network controllers shall be tested and certified by the BACnet Testing Laboratory (BTL) as Network Server Controller (B-BC).

B. The Term C, PH 1X-Airside Concourse BMS connectivity on existing BMS network shall be either a 10 or a 100 Mpbs Ethernet network supporting BACnet, Modbus, Java, XML, HTTP and Cobra IIOP for maximum flexibility for integration of building data with enterprise information systems and providing support for multiple Network server controllers, user workstations and a local host computer.

C. The system shall enable an open architecture that utilizes ANSI/ASHRAE Standard 135-2007, BACnet functionality to assure interoperability between all system components. Native support for the ANSI/ASHRAE Standard 135-2007, BACnet protocol are required to assure that the project is fully supported by the HVAC open protocols to reduce future building maintenance, upgrade and expansion costs.

D. The software tools required for network management of the ANSI/ASHRAE Standard 135-2008, BACnet protocol must be provided with the system. Drawings are diagrammatic only. Equipment and labor not specifically referred to herein or on the plans and are required to meet the functional intent, shall be provided without additional cost to the owner. Minimum BACnet compliance is Level 4, with the ability to support data read and write functionality. Physical connection of BACnet devices shall be via Ethernet IP or MS/TP.

E. The system shall support Modbus TCP and RTU protocols natively, and not require the use of gateways.

F. All work described in this section shall be installed, wired, circuit tested and calibrated by factory certified technicians qualified for this work and in the regular employment of the approved manufacturers local field office.

G. Provide the Commissioning, configuration and diagnostic tool (CCDT), color display personnel computer, software, and interfaces to provide uploading/downloading of High Point Count Controllers, Unitary Controllers, and VAV controllers monitoring all BACnet objects, monitoring overrides of all controller physical input/output points and editing of controller resident time schedules.

H. The system shall provide the capability for connectivity to existing on-site server AMBCx (automated monitoring-based commissioning) system. The AMBCx system shall be able to interface directly with the project BMS and energy/performance metering system to provide information on HVAC, electrical, metering and lighting systems that are being controlled. BMS Contractor shall provide equipment, software, installation labor, programming, assist Cx in functional testing, training and documentation during implementation and warranty period. Provide training as per Section 1.20. The BMS Contractor will be responsible for firmware maintenance, FDD database maintenance and upgrades and collected BMS data maintenance and integrity. The AMBCx system provided shall satisfy FDD, building analytics and analysis for all major mechanical, electrical and energy systems included in the scope of this specification. The AMBCx shall analyze a combination of hard-wired (analog and digital I/O) and virtual points (setpoints, calculated variables) in a system using real-time and historical time-series data to the following as a minimum:
1. Determine the stability of control devices (valves/actuators/speed drives)
2. Determine the degree of error above reasonable thresholds.
3. Compare sensor readings to setpoint and flag out-of-range errors from faulty sensors.
4. Compare outputs (controllers) setpoints to actual conditions to find failed devices.

5. Calculate and report on energy consumption for systems under BMS control.
6. Diagnose flow measurement systems to ensure readings are in range of expectations.
7. Categorize faults according to various priorities (energy, comfort and system maintenance impact).
8. Identify simultaneous heating and cooling in a system and subsystem.
9. Ensure ventilation rates are adequate (testing minimum outdoor air volume settings).
10. Optimize air filter replacement by monitoring changes in filter pressure drop.
11. System shall be monitored from the existing North Terminal BMS workstation. BMS Contractor shall install, test and train owner employees on its use and capability.

1.8 COORDINATION WITH OTHER TRADES

A. Contractors, Sub-contractors, Employees
1. It will be the duty of this Contractor to work in cooperation with other contractors, and with other sub-contractors and employees, rendering assistance and arranging his or her work so that the entire project will be delivered in the best possible condition and in the shortest time. The BMS Contractor will coordinate with other Trade Contractors regarding the location and size of pipes, equipment, fixtures, conduit, ducts, openings, switches, outlets, structural, architectural features and so forth, in order to eliminate any delays in the progress of the job.
2. Any task related to the BMS turnkey installation that is not clearly identified in this document as being the responsibility of another trade shall be the responsibility of the BMS Contractor.

B. Coordination with Owner & Engineer
1. The BMS Contractor shall cooperate with Owner and the Engineer when performing work on this project as necessary to achieve a complete and neat installation. The Contractor shall also consult the drawings and specifications of existing on-site documentation, if applicable to further determine the nature and extent of BMS work.

1.9 BMS EXPANSION

A. Network architecture and software shall allow unlimited expandability by the addition of new sub networks and associated routers, gateways and controllers, etc.

B. Each BMS as installed shall be capable to be expandable, at minimum to incorporate the following in addition to the above:
1. A minimum of 50% percent additional hardware (field) point modules (each type analog, digital, inputs and outputs) with the addition of CCP, DDCP and UC.
2. A minimum of 2 additional communication interfaces to other low voltage building systems to those integrated under this contract.

C. Subsequent to the potential expansion cited in “B” above, the BMS performance shall not be degraded in any manner and shall meet all performance criteria detailed in these specifications.

D. Terminal equipment controller sub-networks shall be configured and designed at 75% capacity to allow for future expansion.

1.10 SUBMITTALS

A. Product Data: Include manufacturer's technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated.
   1. Each control device labeled with setting or adjustable range of control.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   1. Shop drawings shall be AutoCAD generated, minimum 11 X 17 inches. Drawings shall include diagrams, mounting instructions, installation procedures, equipment details and software descriptions for all aspects of the system to be installed. In addition to the drawings, the Contractor shall furnish a CD containing the identical information.
   2. Shop drawings shall include a riser diagram depicting locations of all controllers and workstations, with associated network wiring. Also included shall be individual schematics of each mechanical system showing all connected points with reference to their associated controller. Typicals will be allowed where appropriate.
   3. Software submittals shall contain narrative descriptions of sequences of operation, program listings, point lists, and a complete description of the graphics, reports, alarms and configuration to be furnished with the workstation software. Information shall be submitted electronically. Diagrams shall be on a minimum of 11” by 17” foldouts.
   4. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
   5. Wiring Diagrams: Power, signal, and control wiring. Differentiate between manufacturer-installed and field-installed wiring.
   6. Details of control panel faces, including controls, instruments, and labeling.
   7. Submit shop drawings of all control field panels for review and approval before fabrication.
   8. Written description of sequence of operation.
   9. Schedule of dampers including size, leakage, construction data, and flow characteristics.
   10. Schedule of valves including leakage, construction data, and flow characteristics. Submit valve calculations for each valve for Engineer’s approval.
   11. Trunk cable schematic showing programmable control unit locations and trunk data conductors.
   12. Listing of connected data points, including connected control unit and input device (Excel format for BIM requirements).

13. Submit graphic samples of actual resolution for a 42-inch flat screen monitor (colorized) as a minimum, for each major monitored system, indicating all data (connected and calculated) point addresses, and operator notations as specified. System configuration showing peripheral devices, batteries, power supplies, diagrams, modems, and interconnections.
14. Provide Table of Contents for Devices' data Sheets.
15. Submit electronic transmittal submittal data and shop drawings to the Engineer for review and approval prior to ordering or fabrication of the equipment. The Contractor, prior to submitting, shall check all documents for accuracy.
16. The Engineer will make corrections, if required, and return to the Contractor. The Contractor will then resubmit with the corrected or additional data. This procedure shall be repeated until all corrections are made to the satisfaction of the Engineer and the submittals are fully approved.

C. Samples: For each color required, of each type of thermostat cover.

D. Software and Firmware Operational Documentation: Include the following:
1. Software operating and upgrade manuals.
2. Program Software Backup: On a magnetic media or compact disc, complete with data files or as per current GOAA standards.
3. Device address list.
4. Printout of software application and graphic screens.
5. Software license required by and installed for BMS workstations and control systems.

E. Software Upgrade Kit: For Owner to use in modifying software to suit future monitoring and control revisions. Coordinate and confirm requirements with GOAA.

F. Field Test Reports: Indicate and interpret test results for compliance with performance requirements.

G. Maintenance Data: For systems to include in maintenance manuals as specified. Include the following:
1. Maintenance instructions and lists of spare parts for each type of control device.
2. Interconnection wiring diagrams with identified and numbered system components and devices.
3. Keyboard illustrations and step-by-step procedures indexed for each operator function.
4. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
5. Calibration records and list of set points.

H. Qualification Data:
1. General: Project Record Documents: Record actual locations of control components, including control units, thermostats, and sensors. Revise Shop Drawings to reflect actual installation and operating sequences.

I. <u>Contract Closeout Submittals</u>: All manuals shall be <u>100 percent custom written for this project</u>. Closeout documents will include all as-built software and hardware revision documentation, including a step-by-step, `easy to read' decision tree diagram, which would lead facility operating personnel to specific manual sections for operating procedures, maintenance procedures, and diagnostic/trouble-shooting procedures. All manuals will be subject to the approval of Owner and Engineer prior to the warranty period, and shall provide as a minimum:

1. Project Record Documents for:
    a. Electronic As-Built Drawings in AutoCAD and or BIM Format, including the following:
        1) System architecture drawing.
        2) As-Built Riser Diagram.
        3) Layout drawing for each control panel.
        4) Wiring diagram for individual components.
        5) System flow diagram for each controlled system.
        6) Instrumentation list for each controlled system.
        7) Sequence of control.
        8) Binding map.
        9) IP address, network, MAC port openings provided by GOAA and documented in BMS as-builts.
    b. Final software database (electronic). Includes PICS documentation regarding the BACnet object ID, component IP addresses, databases for all system database points.
    c. Complete program listing with section and line by line comments.
    d. Color coding, labeling, and other identification for point-to-point wiring.
2. Operation and Maintenance Documentation for:
    a. Operation and maintenance manuals for each system component.
    b. List of recommended system spare parts.
3. Information common to the entire system shall be provided. This shall include but not be limited to the following:
    a. Product manuals for the key software tasks.
    b. Operating the system.
    c. Administrating the system.
    d. Engineering the operator workstation.
    e. Application programming.
    f. Engineering the network.
    g. Setting up the web server.
    h. Report creation.
    i. Graphics creation.
    j. All other engineering tasks.
    k. System Architecture Diagram.
    l. List of recommended maintenance tasks associated with the system servers, operator workstations, data servers, web servers and web clients.
    m. Define the task.
    n. Recommend a frequency for the task.
    o. Reference the product manual that includes instructions on executing the task.
    p. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
    q. Licenses, guarantees, and warranty documents for equipment and systems.

r. Submit one copy for each building, plus two extra copies.

4. Test Data for:
   a. All final system field test data to of temperature, humidity, air flow measurement, room differential pressure, etc. shall be provided in a standalone document to the Owner.
5. Warranty Documentation for:
   a. Materials, manufactured units, equipment and components.
   b. Software.
   c. Auxiliary system equipment.

1.11 WARRANTY AND SERVICES DURING THE WARRANTY PERIOD

A. Material and Labor:

1. The Control System shall be free from defects in material and workmanship under normal use and service. If within five years from the date of project acceptance by the Owner any of the equipment herein described is defective in operation, workmanship or materials, it will be replaced, repaired or adjusted at the option of the BMS Contractor free of charge. The warranty period for all components of the BMS and their installation shall be five years following the date of project substantial completion and beneficial use as demonstrated to the Owner.
2. Updates to hardware, firmware, and software shall be installed for a period of 5 years with no additional cost to the owner. Updates shall be installed within 60 days of availability.
3. The temperature control contractor shall provide a 5-year extended warranty and preventative maintenance agreement for the temperature control system, as part of the original bid. Any manufacturing defects arising during this extended warranty period shall be corrected without cost to the Owner. The preventative maintenance agreement shall include a minimum of quarterly service visits, include defective parts replacement and commence upon date of project acceptance by the Owner of the temperature control system installation.
4. This agreement shall include 2 hours on-site response for items deemed critical by the airport and 4-hour response for items deemed non-critical emergency on-site service response as part of the warranty period coverage.
5. The temperature control contractor shall provide a manufacturer's scope description as per owner provided scope of maintenance services of the extended warranty/preventative maintenance agreement, as part of the temperature control submittal (Preventive and corrective maintenance program shall be given thru the purchasing department similar to the current North Terminal Contract Specifications) . This agreement shall contain manufacturer's standard schedules of service procedures, work task definitions, and recommended frequencies of performance. The preventative maintenance agreement shall include the temperature control system and its peripherals as specified in this section. This agreement shall include the provision and installation of all manufacturer's standard Host software and product firmware upgrades released during the term of this agreement. The temperature control submittal will not be approved without the warranty/preventative maintenance agreement. There will be no charge to the customer for preventative maintenance of the control system during the extended warranty period.

B. Any material furnished by the BMS contractor which is defective or fails during normal operation of the system, shall be remedied (replaced or repaired) immediately within 2 hours on-site for items deemed critical by the airport and 4 hours for non-critical items by the BMS Contractor at no additional cost to the Owner, during the period prior to the period prior to the start of the warranty, and during the warranty period.

C. Repair work shall only be undertaken at times approved by the Owner.

D. Repair work shall not include routine maintenance during the start of Defects Liability Period.

E. Work to troubleshoot and identify the cause of the BMS system or component failure shall begin immediately and shall continue until repaired to the satisfaction of the Site Engineer and Employer.

F. Any software upgrades and new software programs that become standard product offerings from the BMS Contractor and/or BMS equipment vendors during the Defects Liability Period (Warranty) shall be brought to the attention of the Owner and made available at no additional cost. If at my time during ‘the Defects Liability Period, software patches that correct ‘software errors become available the Owner shall be notified immediately and they shall be made available to the Owner at no additional cost. Owner shall be provided with a back-up copy of software package, with compiled and un-compiled read/write capability. Ownership of the original software shall be turned over to owner at their request within 30 calendar days.

1.12 CODES, PERMITS AND APPROVAL

A. All work shall conform to the following Codes and Standards, where applicable:
1. Local Electrical Codes.
2. National Fire Protection Association (NFPA) Standards, as specified.
3. National Electrical Code (NEC)
4. Underwriters Laboratories (UL) listing and labels, as specified.
5. American National Standards Institute (ANSI).
6. National Electric Manufacturers' Association (NEMA).
7. Building Automation and Control Network (BACnet) open protocol communication standard develop by ASHRAE (ASHRAE SSPC/135).
8. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).
9. American Society of Mechanical Engineers (ASME).
10. Air Movement and Control Association (AMCA).
11. Institute of Electrical and Electronic Engineers (IEEE).
12. American Standard Code for Information Interchange (ASCII).
13. Electronics Industries Association (EIA).
14. Occupational Safety and Health Administration (OSHA).
15. American Society for Testing and Materials (ASTM).
16. State Energy Code.
17. State Building Code and applicable local Building Code.

18. ANSI/TIA/EIA-862, Building Automation Systems Cabling Standards for Commercial Building.
19. NFPA 92A and 92B/UL 864/UUKL Smoke Purge Control Equipment.

B. Obtain all required permits and inspection certificates. All permits and certificates shall be made available to the Owner.

C. The latest requirements of all national, county, municipal and other authorities having jurisdiction shall be met.

D. Work shall be performed in compliance with Owner's insurance underwriter & requirements. GOAA to confirm and provide requirements in bid package if applicable.

E. All electrical equipment, devices and components and their installation shall comply with the latest edition of the IEEE Wiring and all associated addenda.

F. Interior enclosures shall be, at minimum, NEMA 12 and exterior enclosures shall be weatherproof NEMA IV unless specifically noted otherwise within these documents.

G. The BMS Contractor shall only offer equipment that meets UL 916 requirements, and all electrical components shall be UL listed and shall carry the UL label.

H. The BMS shall be listed and manufactured to ISO 9001 and ISO 9002 standards.

I. All electrical work shall conform to the requirements detailed in the electrical specifications. Where there is any conflict between the requirements of the different project trade sub-contract documents, statutes, codes, regulations, local ordinances and any requirement of an agency having jurisdiction over the project, the most stringent requirement shall apply unless determined otherwise by the Owner, Advise the Engineer of any discrepancy or conflicts between the various requirements for the project.

J. Equipment, devices and materials shall be immune against Electro-Magnetic interferences and shall conform to all performance requirements of' the specifications when exposed to the following interferences:
1. Project lighting, telephone and elevator equipment.
2. AM signals as generated from transmitters.
3. VHF and UHF signals as generated by external or internal portable or fixed transmitters.
4. Electrical noise on the building power system, both spurious and harmonies.
5. The installations shall not radiate signals that cause interference that hinder the correct operation of the Owner's on-site equipment.
6. The BMS and all individual electrical equipment, devices and components shall comply with the requirements of the Federal Communication Commission (FCC) rules and regulations Part 15, sub part J and all other applicable codes and statutes with respect to the radiation and conduction of radio frequency interference.

1.13 SCHEDULE

A. Complete site requirements of the BMS sub-contract in accordance with the project program and prior to the scheduled Substantial Completion date for each phase.

B. Attend project meetings as requested by the CM.

C. Provide to the CM a schedule indicating the sequence of work, durations of individual tasks, delivery dates for all material, devices and equipment and detail any interface that must be coordinated with any other Specialists.

D. Provide written status reports at required intervals in an electronic format acceptable to the Engineer. An updated schedule of work shall be included in each status report.

E. Comply with, the Project Construction Schedule. Provide additional staffing or work overtime as required to comply with the Project Schedule so as not to interfere with other on-site Specialists in their effort to comply with the Overall Project Schedule. Confirm, prior to tender submittal that all equipment, devices, material and services proposed are available and will be delivered accordingly to comply with the Overall Project Schedule.

F. Provide written Request ‘For Information (RFI) notices to the Engineer when specific information or clarification of the specifications is required. Request For Information notices shall be provided at least two (2) weeks prior to the need for the information to the Engineer.

1.14 HEALTH AND SAFETY

A. Work shall comply with the requirements of Occupational Safety and Health Administration (OSHA), the Health and Safety requirements for the project and with all of the daily Health and Safety instructions given by the General Contractor

1.15 DELIVERY, STORAGE AND HANDLING

A. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping of control devices to equipment manufacturer.

B. Provide factory-shipping cartons for each piece of equipment and control device. Maintain cartons through shipping, storage, and handling as required to prevent equipment damage.

C. Deliver, store, protect, and handle products to site under provisions of the contract Documents. Coordinate all site delivers with Construction project Manager.

D. Accept products on-site and verify any damage equipment. Damage equipment shall be re-ordered/replaced immediately without cost to the Owner.

E. Protect products from construction operations, dust, and debris, by storing materials inside, protected from weather in a conditioned space.

F. System Software: Update to latest version of software prior to final commissioning. .

1.16 QUALITY ASSURANCE

A. General
1. The Building Management System (BMS) herein specified shall be fully integrated and installed as a complete package by the Building Management System Contractor. The System shall include all wiring, piping, installation supervision, calibration, adjustments, and checkout necessary for a complete and fully operational system.
2. The Building Management System Contractor shall be a factory owned or authorized representative branch office that is regularly engaged in the engineering, programming, installation and service of Building Management Systems of similar size and complexity.
3. The BMS Contractor shall be responsible for all work fitting into place in a satisfactory and neat workmanlike manner acceptable to the Owner/Architect/Engineer.

B. Products
1. The Building Management System architecture shall consist of the products of a manufacturer regularly engaged in the production of Building Management Systems and shall be the manufacturer’s latest standard of design. DDCP, CCP and UC system components shall be latest (current) production products.
2. All other equipment shall be the products of the BMS manufacturers or of an approved manufacturer regularly engaged in production of specialized Building Management System materials or equipment.

C. ISO-9001
1. The manufacturer of the Building Management System shall provide documentation supporting compliance with ISO-9001 (Model of Quality Assurance in Design/Development, Production, Installation, and Servicing). Product Literature provided by the BMS manufacturer shall contain the ISO-9001 Certification Mark from the applicable registrar. Manufacturers delivering products that do not comply with the ISO-9001 certification requirement shall provide the following information to assure that quality systems are in place and are equivalent to the ISO-9001 standard:
   a. Marketing Specification Standards
   b. Design File Standards
   c. Manufacturing Test Standards
   d. Calibration Standards
   e. Quality System Standards
   f. Quality System Procedures
   g. Documented management commitment that all employees participate in quality programs
   h. Training Procedures

i. Methods by which corrective actions are taken for problems identified within the factory process.

D. Quality Assurance Program
1. The BMS Contractor shall implement a Quality Assurance Program. At minimum, this program shall consist of the following requirements:
a. The BMS Contractor shall assign a single individual to serve as the Quality Assurance Manager, who is to be responsible for the management of the program.
b. The Quality Assurance Manager shall provide or maintain:
1) Documentation of training for employees—including office, field, and subcontractors—on the Quality Assurance Program.
2) Written verification that each worker on the project has read the Specification sections outlining the project requirements for his or her area of specialty. The initial project team shall be documented in the first project submittal.
3) A detailed audit trail for all Quality Assurance issues, including problem ID number, date of original problem report, name of individual initiating report, and individual assigned responsibility for resolving the problem.
c. Each individual team member shall be responsible for identifying and reporting Quality Assurance problems and for assisting, as requested by the Quality Assurance Manager, in the resolution thereof.

E. Each point in the system shall be tested for both hardware and software functionality. In addition, each mechanical and electrical system under control of the BAS will be tested against the appropriate sequence of operation specified herein. Successful completion of the system test shall constitute the beginning of the warranty period. A written report will be submitted to the owner indicating that the installed system functions in accordance with the plans and specifications.

F. The BMS Contractor shall commission and set in operating condition all major equipment and systems, such as the chilled water, and all air handling systems, in the presence of the equipment manufacturer's representatives, as applicable, and the Owner and Architect's representatives.

G. The BMS Contractor shall provide a technician for manpower and engineering services required to assist the HVAC Contractor and Balancing Contractor in testing, adjusting, and balancing all systems in the building. The BAS Contractor shall coordinate all requirements to provide a complete air balance with the Balancing Contractor and shall include all labor and materials in his contract.

H. Startup Testing shall be performed for each task on the startup test checklist, which shall be initialed by the technician and dated upon test was completion along with any recorded data such as voltages, offsets or tuning parameters. Any deviations from the submitted installation plan shall also be recorded.

I. Required elements of the startup testing include:
1. Measurement of voltage sources, primary and secondary
2. Verification of proper controller power wiring.

3. Verification of component inventory when compared to the submittals.
4. Verification of labeling on components and wiring.
5. Verification of connection integrity and quality (loose strands and tight connections).
6. Verification of bus topology, grounding of shields and installation of termination devices.
7. Verification of point checkout.
8. Each I/O device is landed per the submittals and functions per the sequence of control.
9. Analog sensors are properly scaled, and a value is reported
10. Binary sensors have the correct normal position, and the state is correctly reported.
11. Analog outputs have the correct normal position and move full stroke when so commanded.
12. Binary outputs have the correct normal state and respond appropriately to energize/de-energize commands.
13. Documentation of analog sensor calibration (measured value, reported value and calculated offset).
14. Documentation of Loop tuning (sample rate, gain and integral time constant).

J. A performance verification test shall also be completed for the operator interaction with the system. Test elements shall be written to require the verification of all operator interaction tasks including, but not limited to the following.
1. Graphics navigation.
2. Trend data collection and presentation.
3. Alarm handling, acknowledgement and routing.
4. Time schedule editing.
5. Application parameter adjustment.
6. Manual control.
7. Report execution.
8. Automatic backups.
9. Web Client access.

K. A Startup Testing Report and a Performance Verification Testing Report shall be provided upon test completion

L. Governing Code Compliance
1. The BMS Contractor shall comply with all current governing codes ordinances and regulations as specified within these specifications, including UL, NFPA, the local Building Code, local Electrical Code and so forth.

M. FCC Regulation
1. All electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Section 15, Governing Radio Frequency Electromagnetic Interference and Subpart J, governing Class A Computing Devices and be so labeled.

1.17 COORDINATION

A. Coordinate location of thermostats, humidistats, and other exposed control sensors with plans and room details before installation.

B. Coordinate supply of conditioned electrical branch circuits for control units and operator workstation.

C. Coordinate equipment with Division 26 Section "Electrical Power Monitoring and Control" to achieve compatibility of communication interfaces.

D. Coordinate equipment with Division 26 Section "Panelboards" to achieve compatibility with starter coils and annunciation devices.

E. Coordinate equipment with Division 26 Section “Emergency Generators” to achieve compatibility with monitoring of system.

1.18 TRAINING

A. MC2, Inc. an authorized Schneider Electric Representative shall provide both on-site and classroom training to the Owners representative and maintenance and operations personnel per the following description.

B. On-site training shall consist of a minimum of (24) hours of hands-on instruction geared at the operation and maintenance of the systems. The curriculum shall include:

1. System Overview
2. System Software and Operation
3. System access
4. Software features overview
5. Changing setpoints and other attributes
6. Scheduling
7. Editing programmed variables
8. Displaying color graphics
9. Running reports
10. Workstation maintenance
11. Viewing application programming
12. Operational sequences including start-up, shutdown, adjusting and balancing.
13. Equipment maintenance.

C. All training sessions will be recorded via video and turned over to GOAA for future reference.

PART 2 - PRODUCTS

2.1 APPROVED SYSTEM MANUFACTURERS

A. Building Automation Contractors in the business of installing direct digital control building automation systems for a minimum of 10 years with extensive experience working on operational, aviation facilities.

B. The Building Management System Contractor shall have a full-service facility within 50 miles of the project that is staffed with engineers trained and certified by the manufacturer in the configuration, programming, and service of the automation system. The Contractor's technicians shall be fully capable of providing instructions and routine emergency maintenance service on all controllers listed.

C. The system shall be an extension of the existing SmartStructure system by MC2 for the North Terminal Complex and the South Terminal Complex. No other exceptions shall be allowed.

D. MC2, Inc. an authorized Schneider Electric Representative shall furnish and install a complete building automation system including all necessary hardware and all operating and application software necessary to perform the control sequence of operations as called for in specification and contract drawings.

2.2 EQUIPMENT AND MATERIAL – GENERAL

A. When a Specific reference to a manufacturer of a product is made, and the term "equal and approved" is used, substitutions of a product by another manufacturer will be allowed, but the substituted product must conform to all specified requirements and be pre-approved prior to installation via written notification as part of submittal process. The Engineer's determination on the acceptability of substitutes shall be final. Approved substituted equipment shall conform to available space requirements. Substituted equipment that does not conform to the available space requirements shall be replaced or required modifications shall be made at no additional cost to the Owner.

B. All equipment and materials shall be new and without any defect.

C. Hazardous Materials Notification: In the event no product or material is available that does not contain asbestos, PCB, or other hazardous material; as determined by the Engineer, a written application shall be made by the BMS Contractor to the Engineer providing all relevant details concerning a proposed product or material that contains hazardous material prior to installation.

D. Asbestos and PCB Certification: After completion of installation, but prior to Substantial Completion, the BMS Contractor shall certify in writing that products and materials installed, and processes used, do not contain asbestos or polychlorinated biphenyls (PCB).

2.3 PERFORMANCE CERTIFICATION

A. The BMS Contractor shall certify in writing with the tender submittal that all components proposed for this project comply with all of the following requirements:
   1. Complete and thorough testing has proven that performance shall not be affected when the building electrical distribution system experiences disturbances of the type and magnitude normally encountered in buildings of this nature.
   2. An independent testing laboratory has verified that the VAV terminal unit unitary controller meets the performance requirements detailed in these specifications. If so required by the Construction Manager, the testing laboratory shall test a project VAV terminal unit complete with the BMS unitary controller and the BMS Contractor shall demonstrate that the VAV terminal unit UC can meet all of the requirements for monitoring and control accuracy and can undertake all of the sequences of operation associated with the VAV as detailed in these specifications. The independent testing laboratory test report is to be submitted with the shop drawings.
   3. Provide power line disturbance tests involving the cycling of mains voltage that will show that all BMS components operate satisfactorily when voltage drops to 75% or less of the nominal mains voltage and normal operation resumed when the voltage returned to less than 85% of the normal mains voltage. Following these brownout conditions, BMS components shall be free of any stress and/or damage and shall operate normally with no data at the PC, CCP, DDCP and/or UC lost or corrupted.

B. The BMS Contractor shall certify in writing with the tender submittal that all components are free of date related problems.

2.4 AMBIENT CONDITIONS

A. Provide equipment, devices and materials for interior and exterior applications that shall be capable of withstanding and operating satisfactory in, at a minimum, at the following ambient conditions:
   1. BMS central hardware (processors, console, and peripherals): 50 deg F to 100 deg F 10 percent to 90 percent RH.
   2. Indoor hardware: 32 deg F to 120 deg F, 10 percent to 90 percent RH.
   3. Outdoor hardware: -30 deg F to 150 deg F, 0 percent to 100 percent RH.

2.5 SPARE PARTS

A. Submit spare parts for each different item of equipment furnished. Data to include a complete list of each supplier and product by part number, a list of parts and supplies that are either normally furnished at extra cost with the purchase of the equipment or specified hereinafter as “Extra Materials” to be furnished as part of the sub-contract.

B. Submit a list of additional items recommended by the manufacturer to assure efficient operation for a period of 790 days at the particular installation. The foregoing shall not relieve the BMS Contractor of any responsibilities during the BMS Warranty Period.

2.6 EXTRA MATERIALS

A. Provide special hardware and software tools required for maintenance.

2.7 LABELING

A. Provide labeling for all DDC controllers, gateways, routers, hubs, field level components, panels and enclosures, etc., Labeling shall meet, at minimum, the following requirements:
   1. Plastic laminated label that shall be affixed to the panel or enclosure with rivets or permanent adhesive.
   2. Lettering 6mm (0.25 inch) high that sharply contracts the background color.
   3. Consistent throughout the project.
   4. Indicated on the record (close-out) documentation.

B. Provide labeling of all cabling and containment. Labeling shall meet, at minimum, the following requirements:
   1. Identified with permanent tag or self-adhesive label within the panel.
   2. Cross referenced on the associated record (close-out) documentation and laminated record drawing within the panel enclosure.
   3. The BMS Contractor shall provide labeling for all cable furnished and installed by the BMS Contractor.

2.8 PANEL AND ENCLOSURES

A. Install equipment (servers, printers, routers, etc.) in a secure, lockable Hoffmann enclosure, suitable for mounting peripheral equipment and data network equipment. Enclosure will be free-standing, with a minimum height of 4.5 foot from finish floor.

B. Servers shall be installed physically separate from each other.

C. Provide panels and enclosures for all components of the BMS except where it is specifically identified within these contract documents that the enclosure shall be furnished by another trade. Panels and enclosures shall meet, at minimum, the following requirements:
   1. Painted steel panels with locking door. All panels shall be lockable with the same key.
   2. Ventilated to prevent excessive heat buildup, where required.
   3. Field cabling shall be terminated on a terminal strip. Provide cable support.
   4. Internal components shall be installed to allow easy access for diagnostics, maintenance, removal or replacement.

5. Panel or enclosure shall be suitable rated for the environment for which it is to be installed, Interior enclosures shall he, at minimum, NEMA 12 and exterior enclosures shall be weatherproof NEMA IV unless specifically noted otherwise within these documents.
6. Panel or enclosures shall have 25% spare space for future addition of BMS controllers.

D. Panels and enclosures shall only be located as indicate on the drawings and at Engineer approved locations.

E. The BMS Contractor shall coordinate with the trade furnishing the motor starters and variable frequency drives to provide an interface terminal strip (for BMS Contractor use) in a dedicated external enclosure or may be a compartment within the motor starter enclosure. Refer to the sub-contract documents for the trade furnishing the motor starter and the variable frequency drive controllers for the details of the enclosure. DDC controllers shall not be located in the MCC panels.

2.9 CONDUIT AND FITTING

A. The BMS Contractor shall provide conduit and fittings as necessary for a fully functioning system as detailed in these specifications.

B. Flexible metallic rustproof conduit shall be provided for the final one (1) meter before connection from a non-vibrating location to equipment subject to vibration or movement. Flexible metallic conduit shall be provided for between the last 300mm and the last l000mm of connection to field instrumentation, relays and final control elements as necessary to facilitate the removal of devices without the disconnection or the bending of the non-flexible conduit. Watertight conduit to be provided where appropriate.

C. Conduit shall be securely mounted in accordance with IEEE Regulations and shall be concealed in all, areas to which the public have access.

D. Conduit shall run parallel or perpendicular to the building lines and shall be installed in a workmanlike manner. Avoid obstructions and crossovers where possible.

E. Conduit shall be installed such that any condensation in the conduit cannot run into BMS equipment. Where necessary conduit shall enter enclosures from the bottom or shall be sloped up to the enclosure.

F. Junction and pull boxes shall be securely fastened to the conduit and be accessible where required by code or where necessary to facilitate the pulling of cables.

G. Coordinate installation of conduit with building structure and other trades.

H. Containment shall be provided, for all BMS cable. .

I. Signal wiring and cables shall be installed in minimum sized raceways and/or electric metallic tubing (EMT) where required by local code authorities.

J. Following shall be minimum approved raceways for their specific application (no exceptions):
1. EMT: All interior building locations.
2. Rigid Conduit: Building exterior.
3. Plenum rated cable freely run-in concealed ceiling plenums is not acceptable for any applications on this project.
4. Refer to Division 26 specification for strict project electrical requirements.

K. Refer to electrical specification 26 00 00 series for all wiring, conduit and installation requirements.

2.10 CABLE – COPPER

A. Provide all cables for the BMS Automation and Field levels, including all cables to interconnect the BMS Management level devices and the BMS Management level Network as detailed in these specifications. Cables shall meet, at minimum, the following requirements:
1. Minimum 98% conductivity copper.
2. Stranded conductors.
3. Proper impedance for the application as recommended by the BMS component manufacturer.
4. Monitoring and control cable shall be screen #18 AWG (1.02362 mm) or larger dependent on the application.
5. LAN cable shall be screened #24 AWG (0.51054 mm) CAT 6 or twisted pair as identified elsewhere in these documents.
6. All monitoring and control cable shall be screened with the screen earthed at the CCP, DDCP, UC or control panel end only so as to avoid earth loops.
7. Continuous runs without splices.
8. Identification of each end at the termination point. Field identification of all BMS cables shall correspond to the record drawings.
9. All cabling installed without conduit shall be suitable rated for the application and the cable jacket shall be clearly marked. Use unique color schemes for easy identification and prevention of inadvertent splicing of cabling. If there no conflict with existing color schemes, the color for exposed cable shall be purple.

B. Power wiring shall be sized in accordance with the applicable codes and shall be a minimum of # 12 AWG (1.62814 mm) stranded copper. The Electrical contractor shall provide all power cable and containment and shall terminate the dedicated power cable at a power outlet nearest to the BMS component to be powered. The BMS Contractor shall be responsible to provide final power terminations (120VAC and 24 VAC) to all devices, DDC panels, terminal box controllers, control valves, etc. The Electrical contractor shall terminate the power cable at the MCC/distribution board as applicable. The BMS Contractor shall coordinate all BMS equipment power requirements at all BMS equipment locations with the Electrical contractor.

C. The BMS Contractor shall provide all step-down transformers (120VAC and 3 phase primary step down to 24VAC) as required for all devices and controllers.

D. The BMS Contractor shall provide power connection and step-down transformers from FCU and FPVAV terminal box motors to 24 VAC terminal equipment controllers.

E. All field level cables shall be Plenum-type Teflon insulated (LSF - Low Smoke and Fire) rated installed in conduit as specified in Division 26.

F. Terminations shall be mechanically and electrically secure. Twist type wire nuts shall not be acceptable. Insulated tinned copper lugs shall be provided.

G. Cable within panels or enclosures shall be installed in wiring guides.

H. .All wiring terminations from field devices and within field panels shall be terminated at panel terminal strips and shall be marked by identification tags on each end of the cable at each terminal strip. All termination strips shall be labeled.

I. Cable run in conduit in vertically shall have means of cable support, at minimum, every 3 m.

J. Cables shall comply with all applicable codes including, but not limited to, the IEEE wiring regulations latest edition and the electrical sub-contract documents. Where there is a conflict between any codes, standards, ordinances, regulations or the requirements of the jurisdiction having authority, the most stringent requirements shall apply. BMS Contractor shall provide cable testing report prior to and after installation.

2.11 UNINTERRUPTIBLE POWER SUPPLY (UPS)

A. The BMS contractor shall provide local uninterruptible power (1/2 hour rated) for all BMS components, such as CCP, DDCP, routers, gateways, field instrumentation, final control elements etc., as necessary to ensure continuous monitoring and control by the BMS and the associated satellite OIW of all equipment that operates on emergency power. The BMS shall monitor a trouble alarm from each DDC panel UPS.

2.12 ETHERNET SWITCHES

A. BMS Contractor shall provide ethernet switches compatible with existing BMS network installation.

2.13 OPERATOR INTERFACE WORKSTATIONS (OIW)

A. Existing operator workstation and software shall be upgraded as required for PH 1-X Airside Concourse extension.

B. Refer to Contract drawings for locations & quantities.

C. The OIW shall comprise of a PC and associated peripheral operator I/O devices.

D. The OIW PC, shall have a Microsoft Windows 10 Professional 64-bit operating system or the latest version of this software at the time of implementation. The workstations and server shall be furnished by GOAA. The BMS Contractor shall be responsible to coordinate workstation and server hardware and microprocessor features and requirements with GOAA. The BMS Contractor is responsible to provide, install and test all software on GOAA furnished equipment required for a “turnkey” installation.

E. Universal power supply – sine wave type, with sufficient backup battery capacity to last through a 60 minute power failure.

F. Provide an alarm to uniquely identify a PC communication failure. One way that this might be accomplished is by using a watchdog timer at a DDC controller.

G. Following an extended power failure, all PCs shall return to a fully operational status without operator intervention within two (2) minutes of the return of mains power. Software changes, including modifications to database(s), shall not be lost in a power failure.

H. The following peripheral I/O devices shall be provided at each OIW:
   1. Keyboard and mouse.
   2. Two – 42-inch diagonal (minimum) 4K, Industrial-grade, Black colored frame, Flat panel LCD video display units.
   3. Report printer
   4. Alarm printer

I. The BMS OIW at each location shall have one (I) Report Printer and one (1) Alarm Printer. Where there are multiple OIW at one location, Report and Alarm printers shall be networked such that they are available to each OIW.

J. The operator interfaces for the Operator Interface Workstation (OIW) and the Portable Operator Terminal (POT) shall be the same.

2.14 SYSTEM SOFTWARE

A. General
   1. All necessary software to form a complete operating system as described in this specification shall be provided. BMS Contractor shall utilize existing BMS operating system software for Terminal C, PH 1X-Airside Concourse expansion.
   2. The software programs specified in this section shall be provided as an integral part of the DDC controller and shall not be dependent upon any higher-level computer for execution.

B. Control Software Description:
   1. Pre-Tested Control Algorithms: The DDC controllers shall have the ability to perform the following pre-tested control algorithms:
      a. Two Position Control
      b. Proportional Control
      c. Proportional plus Integral Control

d. Proportional, Integral, plus Derivative Control
e. Automatic Control Loop Tuning

2. Equipment Cycling Protection: Control software shall include a provision for limiting the number of times each piece of equipment may be cycled within any one-hour period.
3. Heavy Equipment Delays: The system shall provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads.
4. Power fail Motor Restart: Upon the resumption of normal power, the DDC panel shall analyze the status of all controlled equipment, compare it with normal occupancy scheduling, and turn equipment on or off as necessary to resume normal operation. (i.e. - Restart of equipment following the return to normal condition after equipment shutdown by the Fire Alarm System).
5. Sequential Start: Provide sequential start for all equipment. After a power failure, and after restoration of normal power, equipment shall start per a predetermined sequence as programmed via the BMS.

C. Energy Management Applications: DDC controllers shall have the ability to perform any or all of the following energy management routines:
1. Time-of-Day Scheduling.
2. Calendar Based Scheduling.
3. Holiday Scheduling.
4. Temporary Schedule Overrides.
5. Optimal Start/Optimal Stop.
6. Night Setback Control.
7. Peak Demand Limiting.
8. Energy Usage & Demand.
9. Fan Speed/CFM Control.
10. Heating/Cooling Interlock.
11. Supply Air Reset.

D. All programs shall be executed automatically without the need for operator intervention and shall be flexible enough to allow operator customization. Programs shall be applied to building equipment as described in the Execution portion of this specification.

E. Custom Process Programming Capability: DDC controllers shall be able to execute custom, job-specific processes defined by the operator, to automatically perform calculations and special control routines.
1. Process Inputs and Variables: It shall be possible to use any of the following in a custom process:
   a. Any system-measured point data or status.
   b. Any calculated data.
   c. Any results from other processes.
   d. User-Defined Constants.
   e. Arithmetic functions (+,-,*, /, square root, exponential, etc.).
   f. Boolean logic operators (and, or, exclusive or, etc.).
   g. On-delay/Off-delay/One-shot timers.
2. Process Triggers: Custom processes may be triggered based on any combination of the following:

a. Time interval.
b. Time of day.
c. Date.
d. Other processes.
e. Time programming.
f. Events (e.g., point alarms).
g. Restart of equipment following the return to normal condition after equipment shutdown by the Fire Alarm System (FAS).

F. Dynamic Data Access: A single process shall be able to incorporate measured or calculated data from any and all other DDC controllers on the local area network. In addition, a single process shall be able to issue commands to points in any and all other DDC panels on the local area network.

G. Advisory/Message Generation: Processes shall be able to generate operator messages and advisories to operator I/O devices. A process shall be able to directly send a message to a specified device, buffer the information in a follow-up file, or cause the execution of a dial-up connection to a remote device such as a printer.

H. Custom Process Documentation: The custom control programming feature shall be self-documenting. All interrelationships defined by this feature shall be documented via graphical flowcharts and English language descriptors.

I. Alarm Management: Alarm management shall be provided to monitor, buffer, and direct alarm reports to operator devices and memory files. Each DDC controller shall perform distributed independent alarm analysis and filtering to minimize operator interruptions due to non-critical alarms, minimize network traffic, and prevent alarms from being lost. At no time shall the DDC's ability to report alarms be affected by either operator activity at a PC Workstation or local I/O device, or communications with other panels on the network. Each analog input shall have associated alarm and pre-alarm (warning) levels that are software adjustable. Provide a minimum of one high alarm, one high warning alarm, one low alarm and one low warning alarm level per analog input.

1. Point Change Report Description: All alarm or point change reports shall include the point's English language description and the time and date of occurrence.
2. Prioritization: The user shall be able to define the specific system reaction for each point. Alarms shall be prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of three priority levels shall be provided. Each DDC shall automatically inhibit the reporting of selected alarms during system shutdown and start-up. Users shall have the ability to manually inhibit alarm reporting for each point as well as be able to define under which conditions point changes need to be acknowledged by an operator, and/or sent to follow-up files for retrieval and analysis at a later date.
3. Report Routing: Alarm reports, messages, and files will be directed to a user-defined list of operator devices or PC disk files used for archiving alarm information. Alarms shall also be automatically directed to a default device in the event a primary device is found to be off-line.
4. Alarm Messages: In addition to the point's descriptor and the time and date, the user shall be able to print, display or store a minimum 65-character alarm message to more fully describe the alarm condition or direct operator response. Each

standalone DDC shall be capable of storing a library of at least 250 Alarm Messages which are assignable to any number of points in the panel.

5. Auto-Dial Alarm Management: In Dial-up applications, only critical alarms shall initiate a call to a remote operator device. In all other cases, call activity shall be minimized by time-stamping and saving reports until an operator scheduled time, a manual request, or until the buffer space is full. The alarm buffer must store a minimum of 50 alarms.
6. Transaction Logging: Operator commands and system events shall be automatically logged to disk in Personal Computer industry standard database format. Operator commands initiated from Direct-connected workstations, dial-up workstations, and local DDC panel Network Terminal devices shall all be logged to this transaction file. This data shall be available at the Operator Interface Workstation (OIW). Facility shall be provided to allow the user to search the transaction file using standard database query techniques, including searching by dates, operator name, data point name, etc. In addition, this transaction file shall be accessible with standard third-party database and spreadsheet packages.

J. Historical Data and Trend Analysis: A variety of historical data collection utilities shall be provided to automatically sample, store, and display system data in all of the following ways:
1. Continuous Point Histories: Standalone DDC's shall store Point History Files for all analog and binary inputs and outputs. The Point History routine shall continuously and automatically sample the value of all analog inputs at half hour intervals. Samples for all points shall be stored for the past 24 hours to allow the user to immediately analyze equipment performance and all problem-related events for the past day. Point History Files for binary input or output points and analog output points shall include a continuous record of the last ten status changes or commands for each point.
2. Control Loop Performance Trends: Standalone DDC's shall also provide high resolution sampling capability in one-second increments for verification of control loop performance.
3. Extended Sample Period Trends: Measured and calculated analog and binary data shall also be assignable to user-definable trends for the purpose of collecting operator-specified performance data over extended periods of time. Sample intervals of 1 minute to 2 hours shall be provided. Each standalone DDC shall have a dedicated buffer for trend data and shall be capable of storing a minimum of 5000 data samples. The system shall have the capability of trending and storing all data points.
4. Data Storage and Archiving: Trend data shall be stored at the Standalone DDC's and uploaded to hard disk storage when archival is desired. Uploads shall occur based upon either user-defined interval, manual command, or when the trend buffers become full. All trend data shall be available in disk file format compatible with Third Party personal computer applications.

K. Runtime Totalization: Standalone DDC panels shall automatically accumulate and store runtime hours for binary input and output points as specified in the Execution portion of this specification.
1. The Totalization routine shall have a sampling resolution of one minute or less.

2. The user shall have the ability to define a warning limit for Runtime Totalization. Unique, user-specified messages shall be generated when the limit is reached.

L. Analog/Pulse Totalization: Standalone DDC’s shall automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis for user-selected analog and binary pulse input-type points.
   1. Totalization shall provide calculation and storage of accumulations of up to 99,999.9 units (e.g., KWH, gallons, KBTU, tons. etc.).
   2. The Totalization routine shall have a sampling resolution of one minute or less.
   3. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.

M. Event Totalization: Standalone DDC panels shall have the ability to count events such as the number of times a pump or fan system is cycled on and off. Event totalization shall be performed on a daily, weekly, or monthly basis.
   1. The Event Totalization feature shall be able to store the records associated with a minimum of 9,999,999 events before reset.
   2. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.

N. Operator Interface Workstation (OIW) Software (resident on each existing operating workstation-:
   1. Operator Interface Software – General
      a. An integrated software package shall be used as the operator interface program.
      b. All Inputs, Outputs, Setpoints, and all other parameters as defined within Part 3, shown on the design drawings, or required as part of the system software, shall be displayed for operator viewing and modification from the operator interface software.
      c. The operator workstation software shall provide context-sensitive help menus and instructions for each operation and/or application currently being performed.
      d. All controller software operating parameters shall be displayed for the operator to view/modify from the operator workstation. These include: setpoints, alarm limits, time delays, PID tuning constants, run-times, point statistics, schedules, and so forth.
      e. The operation of the control system shall be independent of the operator workstation, which shall be used for operator communications only. Systems that rely on the operator workstation to provide supervisory control over controller execution of the sequences of operations or system communications shall not be acceptable.
   2. Alarms
      a. Each workstation shall receive, and process alarms sent to it by the control system. The alarm management portion of the operator workstation software shall, at the minimum, provide the following functions:
         1) Log date and time of alarm occurrence.
         2) Generate a “Pop-Up” window informing an operator that an alarm has been received.

3) Allow an operator, with the appropriate security level, to acknowledge, delete, or disable an alarm.
4) Provide an audit trail for alarms by recording operator acknowledgment, deletion, or disabling of an alarm. The audit trail shall include the name of the operator, the alarm, the action taken on the alarm, and a time/date stamp.
5) Record all alarms received at an operator's workstation to that workstation's hard drive.
6) Allow the operators to view/manage the alarm data archived to hard disk. Selection of a single menu item or tool bar button shall allow the user to acknowledge, disable, delete, or print the selected alarm.

b. Alarms shall be generated by the operator workstation for any controller that is "Off-Line" and is not communicating, or that does not have an active control program loaded.
c. Changes made to alarm setpoints from the Operator Workstation shall directly modify the controller alarm management database.
d. Selection of a single menu item or tool bar button shall print any displayed alarm report on the system printer for use as a building management and diagnostics tool.

3. Reports
a. Reports shall be generated and directed to one of the following: workstation displays, printers, or disk. As a minimum, the system shall provide the following reports:
1) All points in the network.
2) All points in a specific controller.
3) A listing of a user-defined group of points in the network. There shall be no limit to the number of user-defined groups
4) All points currently in alarm.
5) All points in hardware override.
6) All disabled points.
7) All weekly schedules.
8) All or selected point attributes, including, but not limited to:
a) Values
b) Setpoints
c) Alarm Limits
d) Statistics
e) Run Times
9) All programmed holidays and associated schedules.
10) All disabled alarms.
11) All active, unacknowledged alarms.
12) All active, acknowledged alarms.
13) Any and all other controller operating parameters.

b. Reports shall be provided for specific point types, for each logical point group, for user-defined groups, or for the entire facility without restriction due to the hardware configuration of the control system or communications network.
c. The system shall allow for the creation of custom report point groups that shall be capable of including points from multiple controllers. Systems

limiting point report displays to only a single controller's point database shall not be accepted.

d. The number of custom reports or display groups shall be limited by the amount of available system memory.

e. Selection of a single menu item, tool bar item, or tool bar button shall print any displayed report on the system printer for use as a building management and diagnostics tool.

4. Schedules

a. A spreadsheet-type schedule input form for time-of-day scheduling and override scheduling of building operations shall be provided. At a minimum, the following spreadsheet types shall be provided:

1) Weekly schedules, by system.
2) Temporary override schedules, by system.
3) Special "Only Active If Today Is A Holiday" schedules, by system.
4) Monthly calendars.
5) Holiday scheduling system, including the ability to define floating holidays.

b. Weekly schedules shall be provided for each piece of equipment with a specific time use schedule. Each schedule shall include columns for each day of the week, as well as holiday and special day columns for alternate scheduling on user-defined days. Equipment scheduling shall be accomplished by simply inserting use and non-use times into appropriate information blocks on the spreadsheet.

c. It shall be possible to define one or more master holiday schedules to allow the operator to define in one location the holidays for all associated schedules. Systems requiring the operator to change holiday definitions on a schedule-by-schedule basis shall not be accepted.

d. Standard weekly schedules shall be inactive on a holiday. The system shall allow the user to include in a schedule group a schedule that will only be active if today is a holiday.

e. In addition, temporary override schedules may be inserted into schedule groups for modifying operating schedules. After overrides have been executed, the original schedule will automatically be restored.

f. Schedules shall be provided for each system or sub-system in the facility. Each schedule shall include all commandable points residing within the system. Each point may have a unique schedule of operation relative to the system use schedule, allowing for sequential starting and control of equipment within the system. Scheduling and rescheduling of points shall be accomplished easily via the system schedule spreadsheets.

g. Monthly calendars for a 12-month period shall be provided that allow for simplified scheduling of holidays and special days in advance. Holidays and special days shall be user-selected with the pointing device or keyboard and shall automatically reschedule equipment operation as previously defined on the weekly schedules.

h. Changes to schedules made from the Operator Workstation shall directly modify the controller schedule database. Systems that require permanent schedule changes to be made with a program editor shall not be acceptable.

i. Formatted schedule displays shall be provided for each system. These shall include all schedule data and associated parameters.
j. Selection of a single menu item or tool bar button shall print any displayed schedule on the system printer for use as a building management and diagnostics tool.

5. User Interface:
   a. The BAS workstation software shall allow the creation of a custom, browser-style interface linked to the user when logging into any workstation. Additionally, it shall be possible to create customized workspaces that can be assigned to user groups. This interface shall support the creation of “hot-spots” that the user may link to view/edit any object in the system or run any object editor or configuration tool contained in the software. Furthermore, this interface must be able to be configured to become a user’s “PC Desktop” – with all the links that a user needs to run other applications. This, along with the Windows user security capabilities, will enable a system administrator to setup workstation accounts that not only limit the capabilities of the user within the BAS software, but may also limit what a user can do on the PC and/or LAN/WAN. This might be used to ensure, for example, that the user of an alarm monitoring workstation is unable to shut down the active alarm viewer and/or unable to load software onto the PC.
   b. System shall be able to automatically switch between displayed metric vs. imperial units based on the workstation localization.

6. Password
   a. Multiple-level password access protection shall be provided to allow the user/manager to limit workstation control, display, and database manipulation capabilities as he or she deems appropriate for each user, based on an assigned password.
   b. Each user shall have the following: a username (12 characters minimum); a password (12 characters minimum).
   c. The system shall not allow each user to change his or her username or password.
   d. When entering or editing passwords, the system shall not echo the actual characters for display on the monitor.
   e. A minimum of 256 unique passwords, including user initials, shall be supported.
   f. Operators shall be able to perform only those commands available for their respective passwords. Display of menu selections shall be limited to only those items defined for the access level of the password used to log-on.
   g. The system shall automatically generate a report of log-on/log-off and system activity for each user. Any action that results in a change in the operation or configuration of the control system shall be recorded, including modification of point values, schedules or history collection parameters, and all changes to the alarm management system, including the acknowledgment and deletion of alarms.

h. User-definable, automatic log-off timers of from 1 to 60 minutes shall be provided to prevent operators from inadvertently leaving the operator workstation logged on.

7. Screen Manager - The BMS workstation shall be provided with a screen management application that allows the user to activate, close, and simultaneously manipulate a minimum of 16 windows across a minimum of 3 physical screens.
8. Graphical User Interface (GUI) Software (Existing to be expanded for PH 1X-Airside Concourse expansion)
   a. Operating System: The GUI shall run on the latest Microsoft Windows operating system.
   b. The GUI shall employ browser-like functionality for ease of navigation. It shall include a tree view (similar to Windows Explorer) for quick viewing of, and access to, the hierarchical structure of the database. In addition, menu-pull downs, and toolbars shall employ buttons, commands and navigation to permit the operator to perform tasks with a minimum knowledge of the HVAC Control System and basic computing skills. These shall include, but are not limited to, forward/backward buttons, home button, and a context sensitive locator line (similar to a URL line), that displays the location and the selected object identification.
   c. Real-Time Displays. The GUI, shall at a minimum, support the following graphical features and functions:
      1) Graphic screens shall be developed using any drawing package capable of generating a GIF, BMP, or JPG file format. Use of proprietary graphic file formats shall not be acceptable. In addition to, or in lieu of a graphic background, the GUI shall support the use of scanned pictures.
      2) Graphic screens shall have the capability to contain objects for text, real-time values, animation, color spectrum objects, logs, graphs, HTML5 or XML document links, schedule objects, hyperlinks to other URL's, and links to other graphic screens.
      3) Graphics shall support layering and each graphic object shall be configurable for assignment to a layer. A minimum of six layers shall be supported.
      4) Modifying common application objects, such as schedules, calendars, and set points shall be accomplished in a graphical manner.
      5) Schedule times will be adjusted using a graphical slider, without requiring any keyboard entry from the operator.
      6) Holidays shall be set by using a graphical calendar, without requiring any keyboard entry from the operator.
      7) Commands to start and stop binary objects shall be done by right-clicking the selected object and selecting the appropriate command from the pop-up menu. No entry of text shall be required.
      8) Adjustments to analog objects, such as set points, shall be done by right-clicking the selected object and using a graphical slider to adjust the value. No entry of text shall be required.
   d. System Configuration. At a minimum, the GUI shall permit the operator to perform the following tasks, with proper password access:
      1) Create, delete or modify control strategies.

2) Add/delete objects to the system.
3) Tune control loops through the adjustment of control loop parameters.
4) Enable or disable control strategies.
5) Generate hard copy records or control strategies on a printer.
6) Select points to be alarmable and define the alarm state.
7) Select points to be trended over a period of time and initiate the recording of values automatically.

e. Symbol library – The BMS system shall be provided with a very complete symbol library containing all of the basic symbols used to represent HVAC, Fire, and Security components of a typical BMS system.
f. Symbols shall be able to be added to any graphic display being constructed by simply dragging the symbol from the library to the graphic under construction.
g. Creating symbols – The user shall be able to add any number of new symbols to the symbol library. Symbol generation shall include all of the abilities described for the graphic editor.

9. Historical trending and data collection
   a. Each Network Controller shall store trend and point history data for all analog and digital inputs and outputs, as follows:
      1) Any point, physical or calculated, may be designated for trending. Three methods of collection shall be allowed: Defined time interval, upon a change of value and whenever a value is out of range.
      2) Each network controller shall have a dedicated RAM-based buffer for trend data and shall store 10,000 samples for each physical point and software variable, including an individual sample time/date stamp. Points may be assigned to multiple history trends with different collection parameters.
   b. Trend and change of value data shall be stored within the controller and then uploaded to the trend database(s). Uploads shall occur based upon one of the following: user-defined interval, manual command, or when the trend buffers are full.
   c. The system shall provide a configurable data storage subsystem for the collection of historical data. Data can be stored in Microsoft Access, SQL, HTML or XML database format.
   d. To enable users to easily access stored data, the system shall provide the capability to store historical data in more than one file system (i.e., removable media, separate hard drives, or a remote network file system).
   e. Provide the capability to perform statistical functions on the historical database without having to design special queries. On a specified data interval, provide functions for calculating:
      1) Average.
      2) Arithmetic mean.
      3) Maximum/minimum values.
      4) Range – difference between minimum and maximum values.
      5) Standard deviation.
      6) Sum of all values.
      7) Variance.
10. Trend data viewing and analysis

a. Provide a trend viewing utility that shall have access to all database points.
b. Provide database access through an Open Database Connectivity (ODBC) interface – a standard Application Programming Interface (API) for accessing data from relational databases. Client applications can reside within a Windows 10 Professional.
c. It shall be possible to retrieve any historical database point for use in displays and reports by specifying the point name.
d. The trend viewing utility shall have the capability to view up to 100 data sources at one time in a tabular or graphical format.
e. Graphic displays shall be able to be single or stacked graphs with on-line selectable display characteristics, such as ranging, color, and plot style.
f. It shall be possible to display trend data in histogram (X-Y plots) format as well as area and bar graphs.
g. Display magnitude and units shall both be selectable by the operator at any time without reconfiguring the processing or collection of data. This is a zoom capability.
h. Display magnitude shall automatically be scaled to show full graphic resolution of the data being displayed. This function shall also be operator selectable.
i. The display range shall consist of magnitude and units' fields. The units are seconds, minutes, hours, days, and months.
j. Provide a wild card capability when specifying a display range for data retrieval within the historical database. Wild carding will allow the user to easily specify relative time-based date ranges for the retrieval of data.
k. A time-offset capability shall be available to assist in a user's analysis. The offset visually shifts the data being displayed to allow a user to concurrently view information without having to scroll the display.
l. The system shall be capable of printing a hard copy record of the trends as they are displayed on the workstation.

O. Energy Usage Dashboard Graphical User Interface (existing to be expanded for PH 1X):
1. Provide separate "dashboard" dynamic system animation colorgraphics for the on-going accountability of building energy usage over time as required for LEED energy usage accounting (Point and click icon on building BMS navigation page for graphics and reports). Provide dynamic historical trending and totalization of each piece of equipment (energy use by each component). GUI shall totalize data for the continuous monitoring of metering equipment for constant (KWH/BTU's via runtime) and variable motor loads, variable frequency drive operation (KWH/BTU's, building lighting panel load (each building),, building receptacle panel load (each building), electric heaters via integration with BMS integration with the VFD). Energy usage data shall be graphically represented for each systems daily energy usage, weekly energy usage, monthly energy usage and yearly energy usage. Energy usage shall be retrievable for any day, month or year. The BMS shall collect energy meter and other energy usage data shall be totalized and recorded in 15-minute intervals (adjustable-to 1 minute). Report generation shall be via a single screen interface.

P. Integration

1. Open, Interoperable, Integrated Architectures
    a. The intent of this specification is to provide a peer-to-peer networked, stand-alone, distributed control system utilizing ANSI/ASHRAE SSPC/135 (BACnet) communication protocol in an open, interoperable system.
    b. In addition, adherence to BACnet industry standard ANSI / ASHRAE SSPC/135 to assure interoperability between all system components is required. For each BACnet device, the device supplier must provide a PICS document showing the installed device's compliance level. Minimum compliance is Level 3; with the ability to support data read and write functionality. Physical connection of BACnet devices shall be via Ethernet.
    c. All components and controllers supplied under this contract shall be true "peer-to-peer" communicating devices. Components or controllers requiring "polling" by a host to pass data shall not be acceptable.

    d. The supplied system must incorporate the ability to access all data using Java enabled browsers without requiring proprietary operator interface and configuration programs. An Open Database Connectivity (ODBC), Open Process Control (OPC) DX and Structured Query Language (SQL) compliant server database is required for all system database parameter storage. This data shall reside on a supplier-installed server for all database access. Systems requiring proprietary database and user interface programs shall not be acceptable.
    e. Protocols: The following standard control protocols shall be provided for Programmable Logic Controller (PLC) and Direct Digital Control (DDC) platforms for control and data acquisition:
        1) ModBus (IP, RS-485 RTU)
        2) BACNet (IP, MSTP)
        3) TCP/IP
    f. A network topology is required to assure reasonable system response times and to manage the flow and sharing of data without unduly burdening the customer's internal Intranet network.
    g. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation <u>shall not exceed 5 seconds for network connected user interfaces</u>.
    h. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 60 seconds for remote or dial-up connected user interfaces.
2. Third Party Communication Software
    a. Provide direct Protocol Integration software to allow bi-directional data communications between the BMS system and 3rd party manufacturers' control panels. The BMS shall receive, react to, and return information from multiple building systems, including but not limited to the chillers, , variable frequency drives, EMMS, , , , lighting systems, etc. Refer to Section 1.6 (Scope of Work).
    b. All data required by the application shall be mapped into the Network Controller's database and shall be transparent to the operator.
    c. Point inputs and outputs from the third-party controllers shall have real-time interoperability with BMS software features such as: Control Software,

Energy Management, Custom Process Programming, Alarm Management, Historical Data and Trend Analysis, Totalization, and Dial-Up and Local Area Network Communications.

d. The Building Management System shall provide any combination of third-party controllers on a single network. Integration shall be via BACnet or Modbus.

e. The system operator shall have the ability to verify and diagnose communication messages and point information between third-party controllers and the BMS.

2.15 NETWORK SERVER CONTROLLERS

A. Automation Server’s 1.5

1. Automation Server
2. Terminal Base AS
3. PS-24V Power Supply
4. Terminal Base Power

B. Upgrade as required for new PH 1 extension.

C. Manage multiple Automation Servers for large installations - maintaining all of the same features as the AS including alarming, scheduling, trend logging, function block, and script

D. Safely manage account and database information with fully secure integration into Windows Domain user accounting, making one less IT admin tool, and ensuring policy adherence

E. Complete audit trail records changes, time, and user to facilitate thorough post situation analysis

F. Network Router Controllers shall combine both network routing functions, control functions, and server functions into a single unit.

G. The BACnet NSC shall be classified as a “native” BACnet device, supporting the BACnet Network Server Controller (B-BC) profile. Controllers that support a lesser profile such as B-SA are not acceptable. NSCs shall be tested and certified by the BACnet Testing Laboratory (BTL) as BACnet Network Server Controllers (B-BC).

H. The Network Server Controller shall provide the interface between the LAN or WAN and the field control devices and provide global supervisory control functions over the control devices connected to the NRS.

I. They shall also be responsible for monitoring and controlling their own HVAC equipment such as an AHU or boiler.

J. They shall also contain graphics, trends, trend charts, alarm views, and other similar presentation objects that can be served to workstations or web-based interfaces. A sufficient number of NSCs shall be supplied to fully meet the requirements of this specification and the attached point list.

K. It shall be capable of executing application control programs to provide:

1. Calendar functions
2. Scheduling
3. Trending
4. Alarm monitoring and routing
5. Time synchronization by means of an Internet site including automatic synchronization
6. Native integration of Modbus controller data or BACnet controller data and Modbus controller data

L. Hardware Specifications

1. Memory:

    a. The operating system of the controller, application programs, and all other portions of the configuration database, shall be stored in non-volatile, FLASH memory. Servers/Controllers shall contain enough memory for the current application, plus required history logging, plus a minimum of 100% additional free memory.

2. Each NRC shall provide the following on-board hardware for communication:

    a. One 10/100bT Ethernet for communication to Workstations, other NRCs and onto the Internet
    b. Two RS-485 ports for communication to BACnet MSTP bus or serial Modbus (software configurable)

    c. One Device USB port
    d. Two host USB Ports

3. The NSC shall conform to a small footprint no larger than 100W x 125H x 75D mm (3.94W x 4.92H x 2.95D in).

M. Modular Expandability:

1. The system shall employ a modular I/O design to allow expansion. Input and output capacity is to be provided through plug-in modules of various types. It shall be possible to combine I/O modules as desired to meet the I/O requirements for individual control applications.
2. One shall be able to “hot-change” (hot-swap) the I/O modules preserving the system on-line without any intervention on the software; addressing and configuration shall be automatic

N. Hardware Override Switches:

1. All digital outputs shall, optionally, include three position manual override switches to allow selection of the ON, OFF, or AUTO output state. These switches shall be built into the unit and shall provide feedback to the controller so that the position of the override switch can be obtained through software. In addition, each analog output shall be equipped with an override potentiometer to allow manual adjustment of the analog output signal over its full range, when the 3 position manual override switch is placed in the ON position.

O. Universal Input Temperatures

1. All universal inputs directly connected to the NSC via modular expansion shall be capable of using the following thermistors for use in the system without any external converters needed.

   a. 10 kohm Type I (Continuum)
   b. 10 kohm Type II (I/NET)
   c. 10 kohm Type III (Satchwell)
   d. 10 kohm Type IV (FD)
   e. Linearized 10 kohm Type V (FD w/11k shunt)
   f. Linearized 10 kohm (Satchwell)
   g. 1.8 kohm (Xenta)
   h. 1 kohm (Balco)
   i. 20 kohm (Honeywell)
   j. 2.2 kohm (Johnson)

2. In addition to the above, the system shall be capable of using the below RTD sensors, however it is not required that all universal inputs be compatible with them.

   a. PT100 (Siemens)
   b. PT1000 (Sauter)
   c. Ni1000 (Danfoss)

P. Local Status Indicator Lamps:

1. The NSC shall provide as a minimum LED indication of CPU status, Ethernet LAN status, and field bus status. For each input or output, provide LED indication of the value of the point (On/Off). The LED indication shall support software configuration to set whether the illumination of the LED corresponds to On or Off or whether the color when illuminated is Red or Green.

Q. Real Time Clock (RTC):

1. Each NSC shall include a battery-backed, real-time clock, accurate to 10 seconds per day. The RTC shall provide the following: time of day, day, month, year, and day of week. Each NSC will allow for its own UTC offset, depending upon the time zone. When the time zone is set, the NSC will also store the appropriate times for daylight savings time.

R. Power Supply:

1. The 24 VDC power supply for the NSCs shall provide 30 watts of available power for the NSC and associated IO modules. The system shall support the use of more than one power supply if heavily power consuming modules are required.
2. The power supply, NSC, and I/O modules shall connect power wise and communication wise via the separate terminal base allowing for ease of replacement and no separate or loose wiring.

S. Automatic Restart After Power Failure:

1. Upon restoration of power after an outage, the NSC shall automatically and without human intervention update all monitored functions, resume operation based on current, synchronize time and status, and implement special start-up strategies as required.

T. Battery backup:

1. The NSC shall include an on-board battery to back up the controller's RAM memory. The battery shall provide accumulated backup of all RAM and clock functions for at least 30 days. In the case of a power failure, the NSC shall first try to restart from the RAM memory. If that memory is corrupted or unusable, then the NSC shall restart itself from its application program stored in its FLASH memory.

U. Software Specifications

1. The operating system of the controller, application programs, and all other portions of the configuration database such as graphics, trends, alarms, views, etc., shall be stored in non-volatile, FLASH memory. There will be no restrictions placed on the type of application programs in the system. Each NSC shall be capable of parallel processing, executing all control programs simultaneously. Any program may affect the operation of any other program. Each program shall have the full access of all I/O facilities of the processor. This execution of control function shall not be interrupted due to normal user communications including interrogation, program entry, printout of the program for storage, etc.
2. Each NSC shall have an available capacity of 4 GB of memory. This shall represent 2 GB for application and historical data and 2 GB dedicated for backup storage.

V. User Programming Language:

1. The application software shall be user programmable. This includes all strategies, sequences of operation, control algorithms, parameters, and setpoints. The source program shall be either a script-based structured text or graphical function block based and fully programmable by the user. The language shall be structured to allow for the configuration of control programs, schedules, alarms, reports, telecommunications, local displays, mathematical calculations, and histories. Users shall be able to place comments anywhere in the body of either script or function block programs.

2. Network Server Controllers that use a “canned” program method will not be accepted.

W. Control Software:

1. The NSC shall have the ability to perform the following pre-tested control algorithms:

    a. Proportional, Integral plus Derivative Control (PID)
    b. Two Position Control
    c. Digital Filter
    d. Ratio Calculator
    e. Equipment Cycling Protection

X. Mathematical Functions:

1. Each controller shall be capable of performing basic mathematical functions (+, -, *, /), squares, square roots, exponential, logarithms, Boolean logic statements, or combinations of both. The controllers shall be capable of performing complex logical statements including operators such as >, <, =, and, or, exclusive or, etc. These must be able to be used in the same equations with the mathematical operators and nested up to five parentheses deep.

Y. NSCs shall have the ability to perform any or all of the following energy management routines:

1. Time of Day Scheduling
2. Calendar Based Scheduling
3. Holiday Scheduling
4. Temporary Schedule Overrides
5. Optimal Start
6. Optimal Stop
7. Night Setback Control
8. Peak Demand Limiting
9. Temperature Compensated Duty Cycling
10. CFM Tracking
11. MER Space Pressurization Control
12. Heating/Cooling Interlock

Z. History Logging:

1. Each NSC controller shall be capable of LOCALLY logging any input, output, calculated value or other system variable either over user defined time intervals ranging from 1 second to 1440 minutes or based upon a user configurable change of value. A minimum of 1000 logs, with a minimum of 100,000 records, shall be stored. Each log can record either the instantaneous, average, minimum or maximum value of the point. Logged data shall be downloadable to a higher level NSC long term archiving based upon user-defined time intervals, or manual command.

2. For extended trend logging a minimum of 1500 trends shall be capable, with a minimum number of 600,000 records within.
3. Management of a power meter replacement to ensure meter log data is accurate shall be possible in the NSC.
4. Every hardware input and output point, hosted within the NSC and attached I/O modules, shall be trended automatically without the requirement for manual creation, and each of these logs shall log values based upon a change of value and store at least 500 trend samples before replacing the oldest sample with new data.
5. The presentation of logged data shall be built into the server capabilities of the NSC Presentation can be in time stamped list formats or in a chart format with fully configurable pen colors, weights, scales and time spans.

AA. Alarm Management:

1. For each system point, alarms can be created based on high/low limits or in comparison to other point values. All alarms will be tested each scan of the NSC and can result in the display of one or more alarm messages or reports.
2. There is no limit to the number of alarms that can be created for any point
3. Alarms can be configured to be generated based upon a single system condition or multiple system conditions.
4. Alarms will be generated based on an evaluation of the alarm conditions and can be presented to the user in a fully configurable order, by priority, by time, by category, etc.
5. The alarm management system shall support the ability to create and select cause and action notes to be selected and associated with an alarm event. Checklists shall also be possible in order to present to an operator a suggested mode of troubleshooting. When acknowledging an alarm, it shall be possible to assign it to a user of the system such that the user is notified of the assignment and is made responsible for the alarm resolution.
6. Alarms must be capable of being routed to any BACnet workstation that conforms to the B-OWS device profile and uses the BACnet/IP protocol.

2.16 BMS CONTROLLERS: GENERAL

A. There shall be 3 types of BMS control panels:
   1. Communications Control Panels (CCP).
   2. Direct Digital Control Panels (DDCP).
   3. Unitary Controllers (UC).

B. All BACnet controllers shall be based on native BACnet and shall support all applicable BIBBs from the data sharing, alarm event, schedule, trend and device manager groups. Standard BACnet object types supported by the controllers shall include:
   1. Binary input and output and value.
   2. Analog input, output and value.
   3. Multi-state input and output.
   4. Loop calendar, notification class, command, file, program, schedule, group, event enrollment and device.

5. Proprietary object types shall not be used unless specifically approved by the Engineer.

C. All Controllers shall have a minimum of 10-bit Input /Output resolution.

D. Following a loss of power, the PC, CCP, DDCP and UC shall reboot in an orderly fashion and attain a normal operating status within 2 minutes of the return of power. That shall be accomplished without operator intervention.

2.17 COMMUNICATION CONTROL PANELS (CCP)

A. The Communication Control Panels shall be programmable controllers on the BMS primary LAN and shall undertake two roles:
   1. Gateway interface to third-party controllers, if the data communicated from the third-party system cannot be provided in the form of BACnet Objects.

B. The CCP shall incorporate software as necessary to provide communications on the network including Network interface Cards if necessary. Additionally, if the CCP acts as a gateway, then the CCP shall incorporate all software as necessary to perform this function including any change of protocol between the networks. The BMS Contractor shall provide all third-party controller gateways and complete software/hardware documentation.

C. Communication Control Panels shall also meet the following requirements:
   1. Provide integral network communication connections.
   2. CCP shall be totally independent of any other LAN/BMS Management Level Network nodes for their operating functions.
   3. CCP failure shall not place any BMS component, or any component controlled by the BMS in a situation that may cause damage to equipment or harm or discomfort to building occupants and operations staff. The failure of a CCP shall not affect the operation of any other network node.
   4. The failure of any CCP shall be annunciated as a critical alarm at the OIW.
   5. Cabling shall be terminated on rugged and easily accessible terminal strips. Each termination shall be clearly marked and shall be as detailed in the shop and record drawings.
   6. Each CCP shall have, at minimum, a 32-bit microprocessor.
   7. All CCP shall be powered from a UPS source, but memory shall be battery-backed RAM. Battery shall be rechargeable with a minimum life of 7 years and shall be capable of providing data retention for a minimum of 60 days.
   8. Provide a real-time clock at each CCP. The real-time clock at the CCP shall be synchronized at least once every 24 hours.
   9. Provide a hardware or software watchdog timer.
   10. Provide interoperability documentation for the CCP. All the data related to the CCP shall be presented along with their respective BACnet object ID created in the system, along with their PICS, BIBBS, addresses and method statements to read and write data via integration of the CCP with another system in the future. This may be part of the overall interoperability documentation.
   11. The CCP shall have a port for the connection of POT.

D. The CCP shall be housed in the enclosure panels as detailed in the “Panels and Enclosures” Paragraph.

E. Diagnostics – Controller shall continuously perform self-diagnostics, communication diagnosis, and diagnosis of all panel components. The network controller shall provide both local and remote annunciation of any detected component failures, low battery conditions, or repeated failures to establish communication.

F. Certification – All controllers shall be listed by Underwriters Laboratories (UL).

2.18 DIRECT DIGITAL CONTROL PANELS (DDCP)

A. The BACnet IP DDCPs shall be standalone, shall reside on the Automation Level and shall meet the following requirements:
   1. DDCP controllers shall be freely programmable and shall have an I/O capability to handle major items of equipment such as air handling units.
   2. DDCP shall interface via Point Interface Modules (PIM) to the field instrumentation and final control elements.
   3. DDCP may be used for any equipment monitored and controlled by the BMS. A dedicated DDCP shall be provided at minimum to monitor and control the following:
      a. A Single Air Handling Unit (each AHU shall have a dedicated DDCP).
      b. Other major items of equipment.
   4. The DDCP shall control its own communications so that the failure of any one node, including any PC shall not inhibit communications on the network between the remaining nodes. Provide integral network communications connections.
   5. DDCP shall be totally independent of any other primary and secondary LAN nodes for their monitoring and control functions. DDCP shall monitor and control entire systems, multiple DDCP for a single system shall not be allowed.
   6. Where a DDCP receives data from other nodes, such as an outdoor air temperature, which is used for a global system program strategy executed at that DDCP, then alternative control strategies shall be automatically initiated, based on operator definable default values, if there is a loss of communication of the required data.
   7. DDCP failure shall not place any BMS component or any BMS controlled component in a situation that may cause damage to equipment or harm or discomfort to building occupants and operations staff. The failure of a DDCP shall not affect the operation of any other network node.
   8. The failure of any DDCP shall be annunciated as a critical alarm at the OIW.
   9. Cabling shall be terminated on rugged and easily accessible terminal strips. Each termination shall be clearly marked and shall be as detailed in the shop and record drawings.
   10. Each DDCP shall have its own power supplies that shall be rated such that they will adequately accommodate all foreseeable uses of the DDCP.
   11. Each DDCP shall have, at minimum, a 32 bit microprocessor.
   12. All operating sequences, schedules and trend data for equipment controlled by the DDCP shall reside at the DDCP.

13. Provide each DDCP with a battery back-up for the protection of volatile memory for a minimum of 72 hours. Provide a 10-hour minimum full function, battery support capability.
14. Provide a real-time clock, at each DDCP. The real-time clock at the DDCP shall be synchronized at least once every 24 hours.
15. The DDCP shall have a port for the connection of the POT.
16. DDCP shall be housed in enclosures that shall meet the requirements detailed in Section titled "Panels and Enclosures" of these specifications. The DDCP shall be placed at the same location as the equipment they control. The BMS Contractor shall provide a suitably rated enclosure for all associated BMS components, including the controllers, relays, wiring guides, terminal strips, etc. The installation of the control enclosure and the installation of all cable and containment between the field instrumentation, including any current sensing relays in the MCC panels, and the DDCP shall be by the BMS Contractor.
17. Interfaces to field instrumentation and final control elements shall have Point Interface Modules (PIM) that shall:
    a. Enable the DDCP to receive signals from the digital and analog instrumentation.
    b. Enable the DDCP to output control signals to the final control elements.
18. PIM shall be incorporated into the DDCP by one or the following methods:
    a. Plug-in type modules with specific or universal input/output capabilities.
    b. Integral to the DDCP controller board.
19. PIM shall accommodate the following point types:
    a. Analog and digital inputs.
    b. Analog and digital outputs.
    c. Pulse inputs.
20. Analog input PIM shall have a minimum 10-bit analog-to-digital conversion and shall interface to all of the signal types required by the sequence of operations.
21. Analog output PIM shall have a minimum 10-bit digital-to-analog conversion and shall meet all of the output signal required by the sequence of operations.
22. Digital input and output PIM shall have electrical isolation and all relay contacts shall be suitably rated for the application.
23. All PIM shall be easily exchanged, and the failure of one PIM shall not affect any other PIM. Field terminations shall be such that the removal of a failed PIM shall not require the removal and reconnecting of field device cable terminations.
24. All PIM shall be such that all output points can be manually positioned via an on board on-off-auto or potentiometer dial as applicable to the individual point.
25. Control shall be based on either three term algorithms, i.e. proportional plus integral plus derivative, or two term algorithms, i.e. proportional plus integral, unless specified otherwise.
26. DDCP mounted on vibrating equipment, such as an air handling units, shall have vibration isolation protection that ensures their satisfactory operation.
27. DDCP shall have optic-isolation or equivalent.
28. DDCP shall be BACnet compliant and shall comply with all of the requirements of ASHRAE SSPC/135.
29. The BMS Contractor shall provide interoperability documentation for the DDCP. All the data related to the DDCP shall be presented along with their respective BACnet object ID created in the system, along with their PICS, BIBBS, addresses

and method statements to read and write data via integration of the DDCP with another system in the future. This may be part of the overall interoperability documentation.

2.19 UNITARY CONTROLLERS (UC) – GENERAL

A. Unitary Controllers (UC) shall be “freely programmable” controllers with pre-packaged operating sequences maintained in EEPROM or flash EPROM.

B. Unitary controllers shall reside at the BMS Automation Level.

C. UC shall reside on a BACnet MSTP BMS LAN.

D. UC shall provide an interface via PIM to the field instrumentation and final control elements of the following types of equipment:
   1. One (1) Fan Powered VAV terminal unit with or without Electric Reheat
   2. One (1) Fan Coil Unit with or without Electric Reheat
   3. One (1) VAV terminal unit (cooling only).
   4. Up to Six (6) miscellaneous fans.
   5. Up to Four (4) miscellaneous pumps.
   6. Up to Two (2) self-contained A/C units.
   7. Miscellaneous equipment input monitoring.

E. Panels meeting the requirements of DDCP shall control all other types of ‘equipment and systems.

F. The UC shall be a node on the primacy BMS LAN. The UC shall control its own communications so that the failure of any one node shall not inhibit communications on the network between the remaining nodes and the BMS Management Level Network.

G. UC shall be totally independent of other Management and BMS Automation Level components for their monitoring and control functions.

H. UC failure shall not place any BMS component or any BMS controlled component in a situation that may cause damage to equipment or harm or discomfort to building occupants and operations staff. The failure of a UC shall not affect the operation of any other network node.

I. The failure of any UC shall be annunciated as a critical alarm at the OIW.

J. Cabling shall be terminated on rugged and easily accessible terminal strips. Each termination shall be clearly marked and shall be as detailed in the shop and record drawings.

K. UC shall be powered from the electrical service that serves the equipment monitored and controlled by the UC. The BMS Contractor shall furnish transformers suitably rated for the application. The UC shall be housed in an enclosure that provides adequate physical and electrical protection.

L. Each UC shall have, at minimum, an 8-bit microprocessor.

M. Provide each UC with a battery back-up for the protection of volatile memory for a minimum of 72 hours. Batteries shall be rated for a 7-year life. The UC serving VAV terminal units and FCU shall not be placed on UPS power.

N. Provide a real time clock at each UC. The real-time clock at the UC shall be synchronized from the real-time clock at the BMS Network Data Servers (NDS) at least once every 24 hours.

O. UC shall be housed in enclosures that shall meet the requirements detailed in Section titled “Panels and Enclosures” of these specifications. The UC shall be placed at the same location as the equipment they control. The BMS Contractor shall provide a suitably rated enclosure for all associated BMS components, including the controllers, relays, wiring guides, terminal strips, etc. The installation of the control enclosure and the installation of all cable and containment between the field instrumentation and the UC shall be by the BMS Contractor.

P. Interfaces to field instrumentation and final control elements shall have Point Interface Modules (PIM) that shall:
   1. Enable the UC to receive signals from the digital and analog instrumentation.
   2. Enable the UC to output control signals to the final control elements.

Q. PIM shall accommodate the following point types:
   1. Analog and digital inputs.
   2. Analog and digital outputs.
   3. Pulse inputs.

R. Analog input PIM shall have a minimum 8-bit analog-to-digital conversion and shall interface to all of the signal types required by the sequence of operations.

S. Analog output PIM shall have a minimum 8-bit digital-to-analog conversion and shall meet all of the output signal required by the sequence of operations.

T. Digital input and output PIM shall have electrical isolation and all relay contacts shall be suitably rated for the application.

U. UC shall control and monitor all points associated with a system. Multiple UC shall not be used to control and monitor a single system.

V. All application programs shall reside at the UC.

W. Operating sequences for UC shall be resident at the UC. Database changes shall be undertaken from the OIW and POT. Schedules and trend data shall reside at the UC.

X. Control shall be based on either three term algorithms, i.e. proportional plus integral plus derivative, or two term algorithms, i.e. proportional plus integral, unless specified otherwise.

Y. UC mounted on vibrating equipment, such as on FCUs, shall have vibration isolation protection that ensures their satisfactory operation.

Z. UC shall be BACnet compliant and shall comply with all of the requirements of ASHRAE SSPC/135.

AA. The BMS Contractor shall provide interoperability documentation for the UC. All the data related to the UC shall be presented along with their respective BACnet object ID created in the system, along with their PICS, BIBBS, addresses and method statements to read and write data via integration of the UC with another system in the future. This may be part of the overall interoperability documentation.

2.20 VAV TERMINAL UNIT CONTROLLER (VAV - UC)

A. General: Ship VAV-UC Controllers to terminal box manufacturer's factory for controller mounting prior to shipping to site. Coordinate with Box manufacturer.

B. The VAV UC shall provide both standalone and networked direct digital control of pressure-independent, variable air volume terminal units.

C. The integral damper actuator shall be a fast response stepper motor capable of stroking 90 degrees in 30 seconds for quick damper positioning to speed commissioning and troubleshooting tasks.

D. The VAV UC shall be a configurable digital controller with an integral differential pressure transducer. It shall be compatible with 3 wire (incremental) and proportional damper actuators.

E. The VAV UC shall determine airflow by dynamic pressure measurement using an integral dead-ended differential pressure transducer. The transducer shall be maintenance-free and shall not require air filters.

F. Each VAV UC shall have the ability to automatically calibrate the flow sensor to eliminate pressure transducer offset error due to ambient temperature / humidity effects.

G. The VAV UC shall utilize a proportional plus integration (PI) algorithm for the space temperature control loops.

H. Each VAV UC shall continuously, adaptively tune the control algorithms to improve control and controller reliability through reduced actuator duty cycle. In addition, this tuning reduces commissioning costs, and eliminates the maintenance costs of manually re-tuning loops to compensate for seasonal or other load changes.

I. The VAV UC shall provide the ability to download and upload UC configuration files, both locally and via the communications network. Controllers shall be able to be loaded individually or as a group using a zone schedule generated spreadsheet of controller parameters.

J. UC control setpoint changes initiated over the network shall be written to UC non-volatile memory to prevent loss of setpoint changes and to provide consistent operation in the event of communication failure.

K. The VAV UC firmware shall be flash-upgradeable remotely via the communications bus to minimize costs of feature enhancements.

L. The VAV UC shall provide fail-soft operation if the airflow signal becomes unreliable, by automatically reverting to a pressure-dependent control mode.

M. The VAV UC shall interface with balancer tools that allow automatic recalculation of box flow pickup gain (“K” factor), and the ability to directly command the airflow control loop to the box minimum and maximum airflow setpoints.

N. The VAV UC performance shall be self-documenting via on-board diagnostics. These diagnostics shall consist of control loop performance measurements executing at each control loop’s sample interval, which may be used to continuously monitor and document system performance. The UC shall calculate exponentially weighted moving averages (EWMA) for each of the following. These metrics shall be available to the end user for efficient management of the VAV terminals.
1. Absolute temperature loop error.
2. Signed temperature loop error.
3. Absolute airflow loop error.
4. Signed airflow loop error.
5. Average damper actuator duty cycle.

O. The VAV UC shall detect system error conditions to assist in managing the VAV zones. The error conditions shall consist of:
1. Unreliable space temperature sensor.
2. Unreliable differential pressure sensor.
3. Starved box.
4. Insufficient cooling.
5. Insufficient heating.

P. The VAV UC shall provide a compliant interface for ASHRAE Standard 62 (indoor air quality),and shall be capable of resetting the box minimum airflow based on the percent of outdoor air in the primary air stream.

Q. The VAV UC shall comply with ASHRAE Standard 90.1 (energy efficiency) by preventing simultaneous heating and cooling, and where the control strategy requires reset of airflow while in reheat, by modulating the box reheat device fully open prior to increasing the airflow in the heating sequence.

R. The VAV UC shall be compatible with the U.S. EPA Energy Star Buildings recommendations for fan energy reduction via demand-based static pressure reset down to 2/3 of duct static pressure set point, “VSD 2/3 Reset.”

S. Inputs:

1. Analog inputs shall monitor the following analog signals, without the addition of equipment outside the terminal controller cabinet:
   a. 0-10 VDC Sensors
   b. 4-20 mA Sensors
   c. 1000ohm RTDs
   d. NTC Thermistors
2. Binary inputs shall monitor dry contact closures. Input shall provide filtering to eliminate false signals resulting from input “bouncing.”
3. For noise immunity, the inputs shall be internally isolated from power, communications, and output circuits.

T. Outputs
   1. Analog outputs shall provide the following control outputs:
      a. 0-10 VDC
      b. 4-20 mA
   2. Binary outputs shall provide a SPST Triac output rated for 500mA at 24 VAC.
   3. For noise immunity, the outputs shall be internally isolated from power, communications, and other output circuits.

2.21 BACNET ROUTERS

A. Provide all BACnet routers as necessary to meet the requirements of these specifications.

B. BACnet routers shall be native BACnet only. Proprietary and other standard protocols shall not be provided. Routers shall be provided at necessary to connect one medium to another, e.g. BACnet/IP to BACnet MS/TP, etc.

C. The BACnet routers shall, at minimum, support BIBBs for data sharing, alarm and event management.

2.22 HVAC INPUT DEVICES

A. General Requirements
   1. Installation, testing, and calibration of all sensors, transmitters, and other input devices shall be provided to meet the system requirements.

B. Temperature Sensors
   1. Acceptable Manufacturers: Veris Industries or Owner Approved Substitution.
   2. General Requirements:
      a. Sensors and transmitters shall be provided, as outlined in the input/output summary and sequence of operations.
      b. The temperature sensor shall be of the resistance type, and shall be either two-wire 1000 ohm nickel RTD, or two-wire 1000 ohm platinum RTD.
      c. The following point types (and the accuracy of each) are required, and their associated accuracy values include errors associated with the sensor, lead wire, and A to D conversion:

Point Type	Accuracy
Chilled Water	$\pm$ .5°F.
Room Temp	$\pm$ .5°F.
Duct Temperature	$\pm$ .5°F.
All Others	$\pm$ .75°F.

3. Room Temperature Sensors with Integral Display
    a. Room sensors shall be constructed for either surface or wallbox mounting. Thermistors are acceptable for space temperature monitoring
    b. Room sensors in public spaces, back of house space, service corridors, MER's, storage, IT rooms, IT closets, lounges, etc.) shall have blank faceplates.
    c. Room sensors in office areas (including occupied rooms by airline, TSA, security, airport personnel) shall have an integral LCD display and four button keypad with the following capabilities:
        1) Display room temperature.
        2) Display and adjust room comfort setpoint.
        3) Display and adjust fan operation status (if required for application).
        4) Timed override request push button with LED status for activation of after-hours operation.
4. Thermowells
    a. When thermowells are required, the sensor and well shall be supplied as a complete assembly, including well head and Greenfield fitting.
    b. Thermowells shall be pressure rated and constructed in accordance with the system working pressure.
    c. Thermowells and sensors shall be mounted in a threadolet or 1/2" NFT saddle and allow easy access to the sensor for repair or replacement.
    d. Thermowells shall be constructed of 316 stainless steel.
5. Outside Air Sensors
    a. Outside air sensors shall be designed to withstand the environmental conditions to which they will be exposed. They shall also be provided with a solar shield.
    b. Sensors exposed to wind velocity pressures shall be shielded by a perforated plate that surrounds the sensor element.
    c. Temperature transmitters shall be of NEMA IV construction and rated for ambient temperatures.
6. Duct Mount Sensors
    a. Duct mount sensors shall mount in an electrical box through a hole in the duct, and be positioned so as to be easily accessible for repair or replacement.
    b. Duct sensors shall be insertion type and constructed as a complete assembly, including lock nut and mounting plate.
    c. For outdoor air duct applications, a weatherproof mounting box with weatherproof cover and gasket shall be used.

7. Averaging Sensors
    a. For ductwork greater in any dimension that 48 inches and/or where air temperature stratification exists, an averaging sensor with multiple sensing points shall be used.
    b. For plenum applications, such as mixed air temperature measurements, a string of sensors mounted across the plenum shall be used to account for stratification and/or air turbulence. The averaging string shall have a minimum of 4 sensing points per 12-foot-long segment.
    c. Capillary supports at the sides of the duct shall be provided to support the sensing string.

C. Humidity Sensors
1. Acceptable Manufacturers: Veris Industries or Owner Approved Substitution.
2. The sensor shall be a solid-state type, relative humidity sensor of the Bulk Polymer Design. The sensor element shall resist service contamination.
3. The humidity transmitter shall be equipped with non-interactive span and zero adjustments, a 2-wire isolated loop powered, 4-20 mA, 0-100% linear proportional output.
4. The humidity transmitter shall be factory calibrated to an accuracy of plus or minus 2% RH over a range of 0% - 90% RH meet the following overall accuracy, including lead loss and Analog to Digital conversion.
5. Outside air relative humidity sensors shall be installed with a rain proof, perforated cover. The transmitter shall be installed in a NEMA IV enclosure with sealtite fittings and stainless-steel bushings.
6. A single point humidity calibrator shall be provided, if required, for field calibration. Transmitters shall be shipped factory pre-calibrated.
7. Duct type sensing probes shall be constructed of 304 stainless steel, and shall be equipped with a neoprene grommet, bushings, and a mounting bracket.

D. Combination Humidity and Temperature Transmitter Assembly
1. Assembly shall consist of capacitive type humidity sensing element with 1000-ohm platinum RTD and a solid-state, 2-wire, 4-20mA transmitter mounted in housing suitable for outdoor installation (NEMA IV) or indoor (wall-mounted) applications. Sensing elements shall be installed in a weatherproof aspirating enclosure.
2. Assembly shall be factory calibrated to an accuracy of plus or minus 2% RH over a range of 0% - 90% RH.
3. Acceptable Manufacturers: Veris Industries or Owner Approved substitution.

E. Differential Pressure Transmitters
1. General Air and Water Pressure Transmitter Requirements:
    a. Pressure transmitters shall be constructed to withstand 100% pressure over-range without damage, and to hold calibrated accuracy when subject to a momentary 40% over-range input.
    b. Pressure transmitters shall transmit a 0 to 5 VDC, 0 to 10 VDC, or 4 to 20 mA output signal.
    c. Differential pressure transmitters used for flow measurement shall be sized to the flow sensing device and shall be supplied with Tee fittings and shut-off valves in the high and low sensing pick-up lines to allow the balancing Contractor and Owner permanent, easy-to-use connection.

d. A minimum of a NEMA 1 housing shall be provided for the transmitter. Transmitters shall be located in accessible local control panels wherever possible.
e. Acceptable Manufacturers: Veris Industries or Owner Approved Substitution.

2. Low Differential Water Pressure Applications (0” - 20” w.c.)
    a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of flow meter differential pressure or water pressure sensing points.
    b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
        1) .01-20” w.c. input differential pressure range.
        2) 4-20 mA output.
        3) Maintain accuracy up to 20 to 1 ratio turndown.
        4) Reference Accuracy: +0.2% of full span.
    c. Acceptable Manufacturers: Setra . or approved equal by Engineer.
3. Medium to High Differential Water Pressure Applications (Over 21” w.c.)
    a. The differential pressure transmitter shall meet the low-pressure transmitter specifications with the following exceptions:
        1) Differential pressure range 10” w.c. to 300 PSI.
        2) Reference Accuracy: ±1% of full span (includes non-linearity, hysteresis, and repeatability).
    b. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.
    c. Acceptable Manufacturers: Siemens Sitran, Rosemount - Model 1151 DP, Fisher Porter, or Dieterich Standard Co. - Pro-ducer series.
4. Building Differential Air Pressure Applications (-1” to +1” w.c.)
    a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.
    b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
        1) -1.00 to +1.00 w.c. input differential pressure ranges. (Select range appropriate for system application)
        2) 4-20 mA output.
        3) Maintain accuracy up to 20 to 1 ratio turndown.
        4) Reference Accuracy: +0.2% of full span.
    c. Acceptable Manufacturers: Setra or approved equal by Engineer.
5. Low Differential Air Pressure Applications (0” to 5” w.c.)
    a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.

b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
   1) (0.00 - 1.00” to 5.00”) w.c. input differential pressure ranges. (Select range appropriate for system application.)
   2) 4-20 mA output.
   3) Maintain accuracy up to 20 to 1 ratio turndown.
   4) Reference Accuracy: +0.2% of full span.

c. Acceptable Manufacturers: Setra or approved equal by Engineer.

6. Medium Differential Air Pressure Applications (5” to 21” w.c.)
   a. The pressure transmitter shall be similar to the Low Air Pressure Transmitter, except that the performance specifications are not as severe. Differential pressure transmitters shall be provided that meet the following performance requirements:
      1) Zero & span: (c/o F.S. /Deg. F): .04% including linearity, hysteresis, and repeatability.
      2) Accuracy: 1% F.S. (best straight line) Static Pressure Effect: 0.5% F.S. (to 100 PSIG.
      3) Thermal Effects: <+.033 F.S. /Deg. F. over 40°F. to 100°F. (calibrated at 70°F.).
   b. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.
   c. Acceptable manufacturers: Setra or approved equal by Engineer.

F. Indoor Air Quality (CO2) Sensors- Wall and Duct Mounted
   1. Acceptable Manufacturers: Veris Industries or Owner Approved Substitution.
   2. Provide indoor air quality sensors to monitor Carbon Dioxide (CO2). The sensors shall be of microprocessor-based photo-acoustic type with heated stannic dioxide semiconductor.
   3. The CO2 sensors shall have no more than 1% drift during the first year of operation and minimal drift thereafter so that no calibration will be required.
   4. The units shall be wall or duct mounted type as indicated on plans and in the sequence of operation.
   5. Wall mounted sensors shall be provided with white plastic cover, without LED indicators.
   6. Duct mounted sensors shall be provided with LED indicators in a dust proof plastic housing with transparent cover.
   7. The sensor shall meet the following requirements:
      a. Operating voltage: 24 VAC +/- 20%
      b. Frequency: 50/60 Hz
      c. Power consumption: max. 6 VA
      d. CO2 measuring range: 0 – 2000 ppm
      e. Tolerance: +/- 100 ppm
      f. Output: 0 – 10 VAC
      g. Calibration: none required

h. Permissible air velocity in duct: <26.2 Ft/s.
i. Manufacturer: Veris Industries or Owner Approved Substitution.

G. Carbon Monoxide (CO) Transmitter
1. UL listed sensor assembly suitable for N.E.C. installations (NEMA 4x enclosure).
2. Continuous carbon monoxide analysis shall be capable of measurement in the range of 0-500 part per million with 4-20mA output.
3. Minimum indicated concentration: 3ppm
4. Accuracy: +/-5% of reading.
5. Span drift: less than 5% change per year.
6. Operating temperature range: -20degC to 50 degC.
7. Humidity range (continuous): 15-90% RH non-condensing
8. Humidity range (intermittent): 0-99%RH non-condensing.
9. Stability: +/-1%
10. Repeatability: +/-2% of reading
11. Provide audible and visual alarm beacons.
12. Provide multichannel controller to monitor multiple variables in each space as required.
13. Manufacturer: Mine Safety Appliances (MSA), Sensidyne

H. Nitrogen Dioxide (NO2) Detection System:
1. Provide UL listed nitrogen dioxide sensor in NEMA 4x enclosure. Sensor to include LED display, an audible and visual alarm beacon for local alarm annunciation.
2. Minimum Indicated Concentration: 0.3ppm.
3. Repeatability: +/-2% of Reading
4. Accuracy: +/-10% of Reading.
5. Span Drift: less than 12% change per 6 months
6. Temperature Range: -20degC to 50degC
7. Humidity Range (Continuous): 15-90% RH non-condensing
8. Humidity Range (intermittent): 0-99% RH non-condensing
9. Pressure Range: Ambient atmospheric: +/-1psi
10. Sensor life: 2 years from shipping date.
11. Provide multichannel controller.
12. Manufacturer: MSA Ultimo X, Sensidyne

I. Flow and Pressure Monitoring
1. Air Flow Monitoring
a. Duct and Outside Air Flow Measuring Stations
1) Each device shall be designed and built to comply with, and provide results in accordance with, accepted practice as defined for system testing in the ASHRAE Handbook of fundamentals, as well as in the Industrial Ventilation Handbook.
2) Each sensor assembly shall contain two individually wired, hermetically sealed bead-in-glass thermistors.
3) Probes shall be constructed of extruded, gold anodized aluminum tube. All wires within the aluminum tube shall be Kynar coated.
4) Transmitters shall include a 16-character alpha-numeric display capable of displaying airflow, temperature, system status,

configuration settings, and diagnostics. The transmitter shall have the capability of field configuration and diagnostics using an on-board pushbutton interface and LCD display. The operating temperature range of the transmitter shall be installed at a location that is protected from weather and water.

Each unit shall measure the airflow rate within an accuracy of plus 2% as determined by U.S. – GSA certification tests.

The units shall have a self-generated sound rating of less than NC40, and the sound level within the duct shall not be amplified nor shall additional sound be generated.

Where the stations are installed in insulated ducts, the airflow passage of the station shall be the same size as the inside airflow dimension of the duct. Station flanges shall be two inch to three inch to facilitate matching connecting ductwork.

Where control dampers are shown as part of the airflow measuring station, opposed blade precision controlled volume dampers integral to the station and complete with actuator, pilot positioner, and linkage shall be provided. Stations shall be installed in strict accordance with the manufacturer's published requirements, and in accordance with ASME Guidelines affecting non-standard approach conditions.

5) Air flow measurement accuracy shall be ±3% of actual flow over a range of 6 to 1 capacity turndown. The probe installation shall not produce any static barrier (resistance to air flow). Provide a minimum of two (2) probes per each outdoor air intake. Follow manufacturer guidelines for installation and additional probe requirements.
6) Acceptable manufacturers: , Ebtron Gold series GP1 with standoff mounting bracket option.

b. Fan Inlet Probe Type:
1) Fan Inlet Type: Provide where indicated on the plans, airflow measuring stations of fan inlet type. Airflow traverse probes shall be suitable for mounting in the inlet bell(s) of the indicated fan.
2) Probes shall be provided with the appropriate end support brackets for mounting in the inlet bell(s). Where fans are of dual inlet type, two sets of inlet probes must be provided. Provide inlet probes for each fan in fan array arrangements.
3) Fan inlet airflow traverse probes shall be suitable for mounting in the inlet bell(s) of the indicated fans. Each sensor assembly shall contain individually wired hermetically sealed bead-in glass thermistors.
4) Airflow accuracy of +/-2% of reading over the entire operating range.
5) Fan inlet probes shall be Ebtron Gold series or approved equal by Engineer.

c. Space Pressurization Sensor:

1). Provide UL listed bi-directional bleed/differential pressure thermal dispersion airflow sensor in a ½ inch diameter tube. Sensor hermetically sealed bead-in glass thermistor.
2). Include all mounting kits as required.
3). NIST-traceable calibrated.
4). Accuracy: +/-2% of reading.
5). Manufacturer: Ebtron Bleed sensor assembly.

d. Static Pressure Traverse Probe
1) Duct static probes shall be provided where required to monitor duct static pressure.
2) Acceptable manufacturers: Setra or approved equal by Engineer.

2. BTU Monitoring Devices:
a. Accuracy: Temperature: Overall differential temperature: +/-0.15% over the stated range
b. Calculating nonlinearity within +/-0.05%
c. Temperature sensors: solid state matched sensors custom calibrated using NIST traceable temperature standards (1/2 inch NPT stainless steel thermowells.
d. Factory programmed for specific applications
e. Memory: Nonvolatile EEPROM memory retains all program parameters and totalized values in the event of power loss.
f. Display: Alphanumeric LCD displays total energy, total flow, energy rate, flow rate, supply temperature, return temperature, and alarm status.
g. Integrated with BMS via BACnet MSTP protocol.
h. Flow meter: Onicon F-3500.
i. Enclosure: Steel NEMA 13.
j. Power: 24 VAC
k. Manufacturer: Onicon System-10 BTU meter

3. Water Flow Monitoring Devices
a. Accuracy: +/-1% of reading from 2 to 20 ft/sec, +/-0.02 ft/sec below 2 ft/sec
b. Sensing method: Electromagnetic, no moving parts
c. Input power: 20-28 VAC 50/60 Hz
d. Liquid temperature range 15degF to 250degF
e. Operating Pressure: 400 PSI maximum
f. Pressure drop: Less than 0.1 psi at 12 ft/sec velocity
g. Materials of Construction: Wetted metal components-316L stainless steel
h. Enclosure rating: Weather-tight, NEMA 4
i. Manufacturer: Onicon F-3500

J. Status and Safety Switches
1. General Requirements
a. Switches shall be provided to monitor equipment status, safety conditions, and generate alarms at the BMS when a failure or abnormal condition occurs. Safety switches shall be provided with two sets of contacts and shall be interlock wired to shut down respective equipment.
2. Current Sensing Switches
a. The current sensing switch shall be self-powered with solid state circuitry and a dry contact output. It shall consist of a current transformer, a solid state

current sensing circuit, adjustable trip point, solid state switch, SPDT relay, and an LED indicating the on or off status. A conductor of the load shall be passed through the window of the device. It shall accept over-current up to twice its trip point range.

b. Current sensing switches shall be used for run status for fans, pumps, and other miscellaneous motor loads.

c. Current sensing switches shall be calibrated to show a positive run status only when the motor is operating under load. A motor running with a broken belt or coupling shall indicate a negative run status.

d. Acceptable manufacturers: Veris Industries or Hawkeye

3. Leak Detection
   a. Provide Liqui-tect 410 (LT410) for leak detection application.
   b. Application: Leak spot detector.
   c. Power Input: 24 VAC, 50/60 Hz, 100mA, 3 VA
   d. Manufacturer: Liebert (Vertiv).
4. Water Flow Switches
   a. Water flow switches shall be equal to the Siemens, Johnson Controls P74, Honeywell.
5. Low Temperature Limit Switches
   a. The low temperature limit switch shall be of the manual reset type with Double Pole/Single Throw snap acting contacts rated for 16 amps at 120VAC.
   b. The sensing element shall be a minimum of 15 feet in length and shall react to the coldest 18-inch section. Element shall be mounted horizontally across duct in accordance with manufacturers recommended installation procedures.
   c. For large duct areas where the sensing element does not provide full coverage of the air stream, additional switches shall be provided as required to provide full protection of the air stream.
   d. The low temperature limit switch shall be equal to Johnson Controls A70, Honeywell, Siemens.

2.23 HVAC OUTPUT DEVICES

A. Actuators
1. General Requirements
   a. Damper and valve actuators shall be electric/electronic. Provide local position indicator dial on all actuators.
   b. Provide a separate actuator for each damper bank. Linkages are not allowed.
2. Electronic Damper Actuators
   a. Electronic damper actuators shall be direct shaft mount.
   b. Modulating and two-position actuators shall be provided as required by the sequence of operations. Damper sections shall be sized based on actuator manufacturer’s recommendations for face velocity, differential pressure and damper type. The actuator mounting arrangement and spring return feature shall permit normally open or normally closed positions of the dampers, as required. All actuators (except terminal units) shall be furnished with

mechanical spring return unless otherwise specified in the sequences of operations. All actuators shall have external adjustable stops to limit the travel in both direction, and a gear release to allow manual positioning. Spring-return actuators with more than 7 Nm (60 in.-lb) torque capacity shall have a manual crank for this purpose.

c. Minimum Torque Requirements: 150 inch-lbs.
d. Modulating actuators shall accept 24 VAC or VDC power supply, consume no more than 15 VA, and be UL listed. The control signal shall be 2-10 VDC or 4-20 mA, and the actuator shall provide a clamp position feedback signal of 2-10 VDC. The feedback signal shall be independent of the input signal and may be used to parallel other actuators and provide true position indication. The feedback signal of one damper actuator for each separately controlled damper shall be wired back to a terminal strip in the control panel for trouble-shooting purposes.
e. Two-position or open/closed actuators shall accept 24 or 120 VAC power supply and be UL listed. Isolation, smoke, exhaust fan, and other dampers, as specified in the sequence of operations, shall be furnished with adjustable end switches to indicate open/closed position or be hard wired to start/stop associated fan. Two-position actuators, as specified in sequences of operations as “quick acting,” shall move full stroke within 20 seconds. All smoke damper actuators shall be quick acting and be UL listed for smoke control service.
f. Provide normally open spring-return actuators for dampers serving all battery room locations.
g. Acceptable manufacturers: Belimo, Siemens, Honeywell or approved equal by Engineer.

3. Electronic Valve Actuators
   a. Electronic valve actuators shall be manufactured by the valve manufacturer.
   b. Each actuator shall have current limiting circuitry incorporated in its design to prevent damage to the actuator.
   c. Provide electric/electronic actuators in all areas, sized by the manufacturer, of sufficient size and power to operate the valve under all conditions and to close the valve tight against 150% maximum differential pressure.
   d. Valve actuators for finned tube radiation and terminal units shall be electronic, floating control, fail to last position.
   e. Modulating and two-position actuators shall be provided as required by the sequence of operations. Actuators shall provide the minimum torque required for proper valve close-off against the system pressure for the required application. The valve actuator shall be sized based on valve manufacturer’s recommendations for flow and pressure differential. All actuators shall fail in the last position unless specified with mechanical spring return in the sequence of operations. The spring return feature shall permit normally open or normally closed positions of the valves, as required. All direct shaft mount rotational actuators shall have external adjustable stops to limit the travel in either direction.
   f. Modulating Actuators shall accept 24 VAC or VDC and 120 VAC power supply and be UL listed. The control signal shall be 2-10 VDC or 4-20 mA and the actuator shall provide a clamp position feedback signal of 2-10 VDC.

The feedback signal shall be independent of the input signal and may be used to parallel other actuators and provide true position indication. The feedback signal of each valve actuator (except terminal valves) shall be wired back to a terminal strip in the control panel for trouble-shooting purposes.

g. Two-position or open/closed actuators shall accept 24 or 120 VAC power supply and be UL listed. Butterfly isolation and other valves, as specified in the sequence of operations, shall be furnished with adjustable end switches to indicate open/closed position or be hard wired to start/stop the associated equipment such as a pump, chiller, etc.

B. Control Dampers/Smoke Control Dampers

1. The BMS Contractor shall furnish all automatic dampers. All automatic dampers shall be sized for the application by the BMS Contractor or as specifically indicated on the Drawings.
2. All dampers used for throttling airflow shall be of the opposed blade type arranged for normally open or normally closed operation, as required. The damper is to be sized so that, when wide open, the pressure drop is a sufficient amount of its close-off pressure drop to shift the characteristic curve to near linear.
3. All dampers used for two-position, open/close control shall be parallel blade type arranged for normally open or closed operation, as required.
4. Damper frames and blades shall be constructed of either stainless steel or aluminum. Maximum blade length in any section shall be 48”. Damper blades shall be 16-gauge minimum and shall not exceed six (6) inches in width. Damper frames shall be 16-gauge minimum hat channel type with corner bracing. Additional stiffening or bracing shall be provided for any section exceeding 48” in height. All damper bearings shall be made of stainless steel or oil-impregnated bronze. Dampers shall be tight closing, low leakage type, with synthetic elastomer seals on the blade edges and flexible stainless steel side seals. Dampers of 48”x48” size shall not leak in excess of 6 cfm per square foot when closed against 4” w.g. static pressure when tested in accordance with AMCA Std. 500.
5. Air foil blade dampers of double skin construction with linkage out of the air stream shall be used whenever the damper face velocity exceeds 1500 FPM or system pressure exceeds 2.5” w.g., but no more than 4000 FPM or 6” w.g.
6. Acceptable manufacturers: Control Damper – Tamco, Siemens, Johnson Controls D-1300, Ruskin CD50.
7. One piece rolled blade dampers with exposed linkage may be used with face velocities of 1500 FPM or below. Acceptable manufacturers are: Johnson Controls D-1100, Ruskin CD36.
8. Multiple section dampers may be jack-shafted to allow mounting of direct connect electronic actuators. Each end of the jack shaft shall receive at least one actuator to reduce jack shaft twist.

C. VAV Duct Damper (integral flow station)

1. Provide Ebtron/Tamco AIR-IQ/GTC-PC (refer to mechanical drawings for locations).

D. Step-Down Transformers:

1. Provide and install all step-down transformers for a complete system. Transformers shall be machine tool type and shall be UL listed. Primary and secondary sides shall

be fused in accordance with NEC. Transformers shall be properly sized for application and mounted in NEMA enclosure with overload circuit breaker.

2. Manufacturer: RIB or equal.

E. Control Relays
   1. Control Pilot Relays
      a. Control pilot relays shall be of a modular plug-in design with retaining springs or clips.
      b. Mounting bases shall be snap-mount.
      c. DPDT, 3PDT, or 4PDT relays shall be provided, as appropriate for application.
      d. Contacts shall be rated for 10 amps at 120VAC.
      e. Relays shall have an integral indicator light and check button.
      f. Acceptable manufacturers: Johnson Controls, Honeywell, ASCO or Lectro.

F. Control Valves (PICBV-Pressure Independent Control and Balancing Valve)

   1. Provide pressure independent control valves to compensate for pressure variations, performing a continual balancing function to maintain system performance at varying loads. Valves shall be configured with one integrated valve body that incorporates chamber with adjustable Cv and a separate pressure regulating used to maintain a constant differential pressure across the control surface. Each control valve shall be individually flow tested at the factory and verified to deviate no more than +/-5% through the selected operating pressure range. A calibrated performance tag (or factory provided calibration documentation) shall be provided with each valve that verifies the flow rate in 10 degree increments up to the full rated flow. All testing shall be performed with instruments calibrated to the requirements of ANSI/ ISA-S75. 11-1985, with traceability to NIST and/or ISO standards. Control valve rangeability shall be 100:1 minimum. The valve shall be rated for pressure and temperature as required. Each control valve shall subjected to 70 psid and tested to exceed ANSI/FCI 70-2-1998 leakage rating. Class IV leakage or better is required for control valves 2 inch nominal size or less. Class III leakage or better is required for control valves large than 2 inch. The control valve bodies shall be steel or bronze. All internal parts shall be stainless steel, steel, Teflon, brass or bronze. Plastic internal parts are not acceptable. The proportional control valve actuator shall modulate from 0 to 100% design flow. The control valve and factory mounted actuator shall be rated to shut-off against 150 psi minimum. When proportional actuators are utilized the end-stroke of the actuator shall be set on-site with the software (limit control signal) at full design flow from coil or from data listed on performance tag. Torque requirements for actuator selection shall be provided by the valve manufacturer. There are shall test ports installed at the factory integral for each valve and capable of being used to measure pressure or temperature. The differential pressure between the test ports shall be used to verify proper valve operation and flow regulation.

   2. For valves without factory mounted test ports provide/furnish test port assemblies on the inlet and outlet side of the pressure independent control valves for field installation. Coordinate and confirm test port and pressure independent valve manufacturer’s recommended installation requirements with mechanical contractor.

3. Pressure independent control valves shall be furnished for HVAC equipment as shown on mechanical drawings and mechanical schedules..
4. All valve and actuator assemblies shall be warranted by the manufacturer for no less than 5 years from the date of purchase.
5. Manufacturers:
   a. Flow Control Industries-Delta Valve (Basis of Design)
   b. Belimo PICCV
   c. Oventrop Cocon Q
   d. IMI Hydronic-TA (TA-FUSION-P)

G. Control Valves
1. All automatic control valves shall be fully proportioning and provide near linear heat transfer control. The valves shall be quiet in operation and fail-safe open, closed, or in their last position. All valves shall operate in sequence with another valve when required by the sequence of operations. All control valves shall be sized by the control manufacturer and shall be guaranteed to meet the heating and cooling loads, as specified. All control valves shall be suitable for the system flow conditions and close against the differential pressures involved. Body pressure rating and connection type (sweat, screwed, or flanged) shall conform to the mechanical pipe schedule.
   a. Leakage: Control valves shall provide tight shut off in the closed position at 150 percent of maximum working pressure.
2. Chilled water control valves shall be modulating plug, ball, and/or butterfly, as required by the specific application. Modulating water valves shall be sized per manufacturer’s recommendations for the given application. In general, valves (2 way) serving variable flow air handling unit coils shall be sized for a pressure drop equal to the actual coil pressure drop, but no less than 3 PSI. Valves for terminal reheat coils shall be sized for a 2 PSIG pressure drop, but no more than a 5 PSI drop.
3. Characteristics:
   a. Chilled Water Service: equal percentage flow characteristics, single seated type.
   b. Bypass service: linear flow characteristics. Double seated.
4. Valve action: Cooling valves normally closed; humidity control valve normally closed (spring return type).
5. Modulating plug water valves of the single-seat type with equal percentage flow characteristics shall be used for all chilled water applications, except those described hereinafter. The valve discs shall be composition type. Valve stems shall be stainless steel.
6. Characterized Ball valves shall be acceptable for fan coil units.
7. Globe valves are acceptable for use with Air Handlers. Automatic control valves for temperature control shall be fully proportioning with V-port inner guides, unless otherwise specified. Valves shall be quiet in operation and fail safe in either normally open or normally closed position in the event of control air failure. Valves shall be capable of operation in sequence when required by the sequence of operation. Size all globe control valves by the control manufacturer and

guarantee they meet the heating and cooling loads as specified. Control valves shall be suitable for the system pressure conditions and shall close against the differential pressure involved.

8. Pressure independent control valves shall be furnished for HVAC equipment as shown on mechanical drawings and schedules.
9. All automatic control valves shall be furnished by the BMS Contractor and installed by the Mechanical Contractor.

2.24 ELECTRICAL

A. Electrical Power Monitors, Single Point (Easy Install):

1. Acceptable Manufacturer: Veris Industries or Owner Approved Substitution.
2. General: Consist of three split-core CTs, factory calibrated as a system, hinged at both axes with the electronics embedded inside the master CT. The transducer shall measure true (rms.RMS) power demand real power (kW) consumption (kWh). Conform to ANSI C12.1 metering accuracy standards.
3. Voltage Input: Load capacity as shown on drawings. 208-480 VAC, 60 Hz
4. Maximum Current Input: Up to 2400A
5. Performance:

   a. Accuracy: +/- 1% system from 10% to 100% of the rated current of the CT’s
   b. Operating Temperature Range: 32-140°F, 122°F for 2400A.

6. Output: 4 to 20 mA, Pulse. or Modbus RTU
7. Ratings:

   a. Agency: UL508 or equivalent
   b. Transducer internally isolated to 2000 VAC.
   c. Case isolation shall be 600 VAC.

8. Basis of Design: Similar to Hawkeye Veris H80xx40 series
9. Accessories: BACnet communications gateway

B. Electrical Power Monitors, Single Point (High Accuracy):

1. Acceptable Manufacturer: Veris Industries or Owner Approved Substitution.
2. General: Revenue grade meter. Measures voltage, amperage, real power (kW), consumption (kWh), and reactive power (kVARar), and power factor (PF) per phase and total load for a single load. Factory calibrated as a system using split core CT’s. Neutral voltage connection is required.
3. Voltage Input: 208-480 VAC, 60 Hz
4. Current Input: Up to 2400A
5. Performance:

   a. Accuracy: +/- 1% system from 2% to 100% of the rated current of the CT’s
   b. Operating Temperature Range: 32-122°F

6. Output: Pulse, BACnet, Modbus RTU
7. Display: Backlit LCD
8. Enclosure: NEMA 1
9. Agency Rating: UL508 or equivalent
10. Basis of Design: Veris Industries H81xx00 series.

C. Electrical Power Monitors, Single Point (High Accuracy/Versatility):

1. Acceptable Manufacturer: Veris Industries or Owner Approved Substitution.
2. General: Revenue grade meter. Measures voltage, amperage, real power (kW), consumption (kWh), reactive power (kVAR), apparent power (kVA) and power factor (PF) per phase and total load for a single load. Available with data logging , Bi-directional (4-quadrant) metering, and pulse contact accumulator inputs.
3. Voltage Input: 90-600 VAC, 50/60 Hz, 125-300 VDC
4. Current Input: 5A – 32,000A, selectable 1/3V or 1V CT inputs
5. Performance:

   a. Accuracy shall be +/- 0.2% revenue grade
   b. Operating Temperature Range: -22-158°F

6. Output shall be BACnet
7. Display: Backlit LCD
8. Enclosure: NEMA 4x optional
9. Agency Rating: UL508, ANSI C12.20
10. Basis of Design: Veris E5xxx series.

D. Electrical Power Monitors, Multiple Point (92 loads, High Accuracy):

1. Acceptable Manufacturer: Veris Industries or Owner Approved Substitution.
2. General: Revenue grade meter. Measures volts, amps, power and energy for each circuit. 1/4 amp to 200 amp monitoring. 4 configurable alarm threshold registers.
3. Voltage Input: 90-277 VAC, 60 Hz
4. Current Input: 5A – 32,000A, 1/3V CT inputs
5. Performance:

   a. Accuracy: +/- 0.5% meter (split core), +/- 1% system from 1/4-100A (solid core)
   b. Operating Temperature Range: 32-140°F

6. Output: Modbus RTU
7. Agency Rating: UL508, ANSI C12.10, IEC Class 1
8. Basis of Design: Veris E3xxx series

2.25 HVAC MISCELLANEOUS DEVICES

A. Local Control Panels
1. All control panels shall be factory constructed, incorporating the BMS manufacturers standard designs and layouts. All control panels shall be UL inspected and listed as an assembly and carry a UL 508 label listing compliance.

Control panels shall be fully enclosed, with sub-panel, hinged door, and key-locking latch.

2. In general, the control panels shall consist of the DDC controller(s), display module, and I/O devices—such as relays, transducers, and so forth—that are not required to be located external to the control panel due to function. The display module shall be flush mounted in the panel face unless otherwise noted.
3. All I/O connections on the DDC controller shall be extended to a numbered, color-coded, and labeled terminal strip for ease of maintenance and expansion. Wiring to I/O devices shall be made from this terminal strip.
4. All other wiring in the panel, internal and external, shall be made to additional line or low voltage color-coded and labeled terminal strips. Low and line voltage wiring shall be segregated. All terminal strips and wiring shall be UL listed 300-volt service and provide adequate clearance for field wiring.
5. All wiring for every control panel shall follow a common color-coded format. All terminal strip color coding and numbering shall follow a common format. All wiring shall be neatly installed in plastic trays or tie wrapped.
6. A convenience 120 VAC duplex receptacle shall be provided in each enclosure, fused on/off power switch, and required transformers.

B. Outside Air Damper Override Switch: Provide UL listed mushroom switch (momentary switch) with time delay relay (time delay adjustable up to one hour) with auxiliary contacts for BMS interface. Provide EN 418 compliant safety guard (safety yellow). Refer to mechanical drawings for quantity and location.

C. Power Supplies (Provide new power supplies for all new BMS control panels)
1. DC power supplies shall be sized for the connected device load. Total rated load shall not exceed 75% of the rated capacity of the power supply.
2. Input: 120 VAC +10%, 60Hz.
3. Output: 24 VDC.
4. Line Regulation: +0.05% for 10%-line change.
5. Load Regulation: +0.05% for 50% load change.
6. Ripple and Noise: 1 mV rms., 5-mV peak to peak.
7. An appropriately sized fuse and fuse block shall be provided and located next to the power supply.
8. A power disconnect switch shall be provided next to the power supply.

PART 3 - EXECUTION

3.1 INSTALLATION PRACTICES

A. Control System Wiring:
1. All conduit, wiring, accessories and wiring connections required for the installation of the Building Management System, as herein specified, shall be provided by the BMS Subcontractor. All wiring shall comply with the requirements of applicable local and national electric codes, unless specified otherwise in this section.
2. The BMS Contractor is responsible for the installation of all low voltage control, monitoring and network wiring.

3. Power wiring 120VAC and greater shall be provided by the Electrical Sub-Contractor. BMS Contractor shall provide and coordinate all 120v power requirements with the electrical engineer of record and electrical contractor during the submittal phase. Final 120VAC terminations from Division 26 electrical power junction boxes to all BMS equipment and devices including DDC controllers, terminal equipment controllers, control valves, meters, sensors, etc. shall be provided by the BMS Contractor.
4. All system-input wiring shall be twisted shielded pair, minimum 18-gauge wire. All system analog output wiring shall be twisted shielded pair/3-wire as required, minimum 18-gauge wire. Preconfigured cables between Terminal Unit Controllers and Thermostats are acceptable, minimum 24 gauge.
5. All internal panel device wiring for binary outputs and pilot relay shall be minimum 16-gauge wire.
6. All Class 2 (24VAC or less) wiring shall be installed in conduit unless otherwise specified.
    a. Class 2 wiring not installed in conduit shall be supported every 5' from the building structure utilizing metal hangers designed for this application. Wiring shall be installed parallel to the building structural lines. All wiring shall be installed in accordance with local code requirements. Exposed wiring shall only be allowed in concealed accessible locations.
7. Low voltage control wiring and 24VAC can be run in the same conduit. Power wiring 50VAC and greater must be in a separate conduit.
8. All wiring in mechanical rooms shall be in conduit. Minimum control wiring conduit size 3/4".
9. All cabling installed without conduit shall be suitable rated for the application and the cable jacket shall be clearly marked.

B. Identification Standards
1. Controller Identification: All controllers shall be identified by a plastic engraved nameplate securely fastened to the outside of the controller enclosure.
2. Panel Identification: All local control panels shall be identified by a plastic engraved nameplate securely fastened to the outside of the controller enclosure.
3. Field Devices: All field devices shall be identified by a typed (not handwritten) securely attached tag label.
4. Panel Devices: All panel devices shall be identified by a typed label securely fastened to the backplane of the local control panel.
5. Raceway Identification: All the covers to junction and pull boxes of the control system raceways shall be painted blue or have identification labels stating "Control System Wiring" affixed to the covers. Labels shall be typed, not handwritten.
6. Wire Identification: All low and line voltage control wiring shall be identified by a number, as referenced to the associated control diagram, at each end of the conductor or cable. Identification number shall be permanently secured to the conductor or cable and shall be typed.

C. Dedicated Digital Controller Per Major System
1. Each major system will be provided with its own dedicated BMS controller. Mechanical systems such as AHUs <u>shall not</u> share or be controlled from the same BMS controller.

D. Input Devices
1. All Input devices shall be installed per the manufacturer's recommendation. The mechanical contractor shall install all in-line devices such as temperature wells, pressure taps, duct smoke detectors, air flow stations, etc.
a. Low Differential Air Pressure Applications (Under 5" w.c.) Differential pressure transmitters used for flow measurement shall be sized to the flow sensing device and shall be supplied with Tee fittings and shut-off valves in the high and low sensing pick-up lines to allow the balancing contractor and Owner permanent easy-to-use connection. Provide a minimum of a NEMA 1 housing for the transmitter. Locate transmitters in accessible local control panels wherever possible. Except on VAV box applications.
b. Medium Differential Air Pressure Applications (5" to 21" w.c.) Mount stand-alone pressure transmitters in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with hi and low connections piped and valved. Air bleed units, bypass valves and compression fittings shall be provided.
c. Medium to High Differential Water Pressure Applications (Over 21" w.c.): Mount stand-alone pressure transmitters in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with hi and low connections piped and valved. Air bleed units, bypass valves and compression fittings shall be provided.
d. Building Differential Air Pressure Applications (-1" to +1" w.c.): Mount pressure transmitter in the local control panel. Transmitter's exterior sensing tip shall be installed with a shielded static air probe to reduce pressure fluctuations caused by wind. The interior tip shall be inconspicuous and located within a central corridor shown on the drawings.
e. Air Flow Measuring Stations: Where the stations are installed in insulated ducts, the airflow passage of the station shall be the same size as the inside airflow dimension of the duct. Station flanges shall be two inch to three inch to facilitate matching connecting ductwork. Stations shall be installed in strict accordance with the manufacturer's published requirements, and with ASME Guidelines affecting non-standard approach conditions.
f. Water Flow Monitoring Stations: Water Flow Monitoring Stations shall be installed in strict accordance with the manufacturer's published requirements, and with ASME Guidelines affecting non-standard approach conditions.
g. Outside Air Humidity Sensors: Outside air relative humidity sensors shall be installed with a rain proof, perforated cover. The transmitter shall be installed in a NEMA IV enclosure with sealtite fittings and stainless-steel bushings.
h. Outside Air Sensors: Outside air sensors shall be mounted on the North wall to minimize solar radiant heat impact or located in a continuous intake flow adequate to monitor outside air temperatures accurately. Sensors exposed to solar radiation must be installed with solar shields. Sensors exposed to wind velocity pressures shall be shielded by a perforated plate surrounding the sensor element.
i. Duct Temperature Sensors: Duct mount sensors shall mount in an electrical box through a hole in the duct and be positioned so as to be easily accessible for repair or replacement. The sensors shall be insertion type and

constructed as a complete assembly including lock nut and mounting plate. For ductwork greater in any dimension that 48 inches and/or air temperature stratification exists such as a mixed air plenum, utilize an averaging sensor with multiple sensing points. The sensor shall be mounted to suitable supports using factory approved element holders. For large plenum applications such as mixed air temperature measurements, utilize a string of sensors mounted across the plenum to account for stratification and/or air turbulence. The averaging string shall have a minimum of 4 sensing points per 12-foot-long segment.

j. Space Temperature Sensors: Shall be mounted as per ADA or architectural requirements (coordinate height of all space devices with architect. above the finished floor. Temperature sensors installed in public areas (blank face plates) shall be provided with lockable covers to prevent tampering. Coordinate with architect and GOAA for requirements.

k. Low Temperature Limit Switches: Mount element horizontally across duct in a serpentine pattern ensuring each square foot of coil is protected by 1 foot of sensor. For large duct areas where the sensing element does not provide full coverage of the air stream, provide additional switches as required to provide full protection of the air stream.

l. Differential Pressure Status Switches: Provide complete installation kit including; static pressure tops, tubing, fittings and air filters. Provide appropriate scale range and differential adjustment for intended service.

m. Valve Limit Switches: Mount limit switch on valve yolk as recommended by switch manufacturer. Provide valve limit switches that will indicate both 100% Open and 100% Closed Positions.

E. Output Devices

1. All output devices shall be installed per the manufacturer's recommendation. The mechanical contractor shall install all in-line devices such as control valves, dampers, etc.
2. Actuators: All control actuators shall be sized capable of closing against the maximum system shut-off pressure. The actuator shall modulate in a smooth fashion through the entire stroke.
3. Control Dampers: Shall be opposed blade for modulating control of air flows. Parallel blade dampers shall be installed for two position applications.
4. Control Valves: Shall be sized for proper flow control with equal percentage valve plugs. The maximum pressure drop for water applications shall be 5 PSI. The maximum pressure drop for steam applications shall be 7 PSI.
5. Electronic Signal Isolation Transducers: Whenever an analog output signal from the Building Management System is to be connected to an external control system as an input (such as a chiller control panel), or is to receive as an input a signal from a remote system, provide a signal isolation transducer. Signal isolation transducer shall provide ground plane isolation between systems. Signals shall provide optical isolation between systems.

3.2 TRAINING

A. General

1. The controls contractor shall provide the following training services.
2. Operator Training (provide 24 hours): Operator training shall include the detailed review of the control installation drawings, points list, and equipment list. The instructor shall then walk through the building identifying the location of the control devices installed. For each type of systems, the instructor shall demonstrate how the system accomplishes the sequence of operation.
   a. From the workstation, the operator shall demonstrate the software features of the system. As a minimum, the operator demonstrates and explain logging on, setting passwords, setting up a schedule, trend, point history, alarm, and archiving the database.
   b. One day (8 hours) of the 24 hours will be devoted to on-site orientation by a field engineer who is fully knowledgeable of the specific installation details of the project. This orientation shall, at a minimum, consist of a review of the project as-built drawings, the control system software layout and naming conventions, and a walk through of the facility to identify panel and device locations.
3. The owner representatives shall be issued Continuing Education Credits (C.E.U.s) for the factory training.

3.3 COMMISSIONING & TESTING

A. General
   1. Commissioning the Building Management System is a mandatory documented performance requirement of the selected BMS Contractor for all control systems detailed in this Specification and sequence of operations. Commissioning shall include verification of proper installation practices by the BMS Contractor and subcontractors under the BMS Contractor, point verification and calibration, system/sequence of operation verification with respect to specified operation, and network/workstation verification. Documentation shall be presented upon completion of each commissioning step and final completion to ensure proper operation of the Building Management System.
   2. BMS commissioning and testing documentation is to be provided separately to the Owner.

B. Testing Requirements
   1. Intent: Demonstrate to satisfaction of authorized representative that BMS is performing in accordance with specification requirements.
   2. Logs of Tests: Complete logs of tests retained by Contractor for inspection and review of authorized representative at any time after testing started. Upon final completion of system tests log records submitted.
   3. Witness of Tests: At time directed by authorized representative complete functional, operational test shall be performed by contractor. Test witnessed by personnel directed by authorized representative. Tests continue until functions of points, of alarms and command functions are proven to satisfaction of authorized representative.
   4. Performance of Field Tests: Complete tests required at different and distinct times for various phases of construction as designated by authorized representative.

5. BMS Contractor shall provide a bench-test and mock-up system (typical DDC controller and networked typical terminal equipment controllers) set-up for GOAA review and approval six months prior to scheduled deployment. Refer to Section 1.6 Scope of Work for participation and testing equipment connectivity in low voltage testing lab.

C. Testing Procedure
   1. Upon completion of the installation, the BMS Contractor shall start-up the system and perform all necessary testing and run diagnostic tests to ensure proper operation. The BMS Contractor shall be responsible for generating all software and entering all database information necessary to perform existing control sequences.

D. Testing Documentation
   1. Prior to acceptance testing, BMS Contractor shall create, on an individual system basis, trend logs of input and output points, or have an automatic Point History feature for documentation purposes.

E. Field Points Testing
   1. This step shall verify that all of the installed points receive or transmit the correct information prior to loading/activating the system software.
   2. ON/OFF commands from the workstation shall be performed in order to verify each binary output point.
   3. All binary input points are to be tested by observing a change of state upon command at PC workstation or locally in the field.
   4. All analog output points shall be tested using a command from the PC workstation to modulate the output device from minimum calibrated signal to maximum calibrated output.
   5. All analog input points are to be tested by comparing the reading obtained through the workstations to the value of an independent testing meter
   6. All two-way communication interfaces (Modbus, BACnet, etc.) tested and monitored values and commanded verified at the BMS workstation and in the field.

F. Verify that activation of site related alarms specifically identifies and notifies the Owner remote monitoring sites and selected personnel.

G. VAV box performance verification and documentation: (Perform testing if required).
   1. As part of the commissioning of the terminal unit control (UC) and air distribution system, the Contractor shall initiate an automated test where the dampers in one half of a group of boxes are stepped towards full open while the other half are stepped towards full closed. At each step, after a settling time, box airflow and damper positions will be sampled. Following the cycle, a pass/fail report indicating results shall be produced. Possible results are Pass, No change in flow between full open and full close, reverse operation, or Maximum flow not achieved. The report shall be submitted as documentation of the installation.
   2. The controls contractor shall issue a report based on a sampling of the UC calculated loop performance metrics. The report shall indicate performance criteria, include the count of conforming and non-conforming boxes, list the non-conforming boxes along with their performance data, and shall also include graphical representations of performance. The sampling shall take place after

completion of Test and Balance, when design cooling and heating media have been available and occupied conditions approximated for five consecutive days.

3. Verify that new graphics are complete and contain dynamic (real-time) information that can be viewed at both workstation locations.

H. Non-compliant Items

1. The Contractor shall remove and replace, at its expense, all items that are not in compliance with the Specification requirements.

END OF SECTION 23 0900

SECTION 23 21 13 - HYDRONIC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes pipe and fitting materials and joining methods for the following:

1. Chilled-water piping.
2. Condenser-water piping.
3. Makeup-water piping.
4. Condensate-drain piping.
5. Blowdown-drain piping.
6. Air-vent piping.
7. Safety-valve-inlet and -outlet piping

B. Related Sections include the following:

1. Division 1 Section 01 35 46: “Indoor Air quality Management”
2. Division 1 Section 01 74 23: “Final Cleaning”
3. Division 1 Section 01 81 13.14: “Sustainable Design Requirements - LEED V4 BD+C.

4. Division 23 Section "Hydronic Pumps" for pumps, motors, and accessories for hydronic piping.
5. Division 23 Section “HVAC Piping Insulation”.
6. Division 23 Sections “General Duty Valves For HVAC Piping”.
7. Division 23 Section “HVAC Water treatment”.
8. Division 23 Section “Vibration Controls for HVAC Piping and Equipment”.

C. Abbreviations

1. PTFE: Polytetrafluoroethylene.
2. DWV: Drain-Waste-Vent piping system.
3. RTRP: Reinforced Thermosetting Resin Pipe
4. RTRF: Reinforced Thermosetting Resin Fitting

1.3 SUBMITTALS

A. Action Submittals

1. Product Data: Submit manufacturer’s standard technical product data indicating conformance to the stipulated reference specifications, construction materials, dimensions, construction details, and test and operating pressures. Submit manufacturer’s product data on the following:
   a. Pipe materials.
   b. Unions and flanges, including gaskets, nuts, and bolts.
   c. Welding fittings.
   d. Sleeves and packings.
   e. Plastic pipe and fittings with solvent cement.
   f. RTRP and RTRF with adhesive.
   g. Pressure-seal fittings.
   h. Air control devices.
   i. Chemical treatment.
   j. Grooved-joint couplings and fittings

B. Sustainable Design Documentation Submittals: Refer to section 01 81 13.14 “Sustainable Design Requirements – LEED V4 BD+C”.
1. Product Data: Documentation for Leadership Extraction Practices in the following:
   a. Leadership Extraction Practices for Recycled Content
2. Product Data: Documentation for Low Emitting Materials
   a. Low Emitting Materials for Paints and Coatings
   b. Low Emitting Materials for Adhesives and Sealants
3. Product Certificates: Provide the following:
   a. Environmental Product Declarations (EPD’s)
   b. Corporate Sustainability Reporting (CSR’s)
   c. Health Product Declarations (HPD’s)

C. Delegated-Design Submittal:

1. Design calculations and detailed fabrication and assembly of pipe anchors and alignment guides, hangers and supports for multiple pipes, expansion joints and loops, and attachments of the same to the building structure.
2. Locations of pipe anchors and alignment guides and expansion joints and loops.
3. Locations of and details for penetrations, including sleeves and sleeve seals for exterior walls, floors, basement, and foundation walls.
4. Locations of and details for penetration and firestopping for fire- and smoke-rated wall and floor and ceiling assemblies.

D. Shop Drawings: Provide piping layout drawings, drawn to a scale of not less than 1/4 inch to 1 ft. showing the proposed layout of piping system including valves, fittings, equipment, pumps, hangers, grading, high points, low points, drain points, guides, anchors, ball joints, and expansion devices. Piping below 3 inches show single line, all

3 inches and above show double line. Coordination Drawings: Show double line at 3/8 inch to 1 ft. Calculations required for stressed piping at anchors. Provide shop drawings for the following locations:

1. Refrigeration rooms.
2. Cooling towers.
3. Air handling equipment rooms.
4. Pipe shafts.
5. Cooling coils.
6. Refrigeration machines
7. All floor plans and roof plans.

E. Schedules:

   1. Submit schedule of pipe type and rating for each system.

F. Informational Submittals
   1. Coordination Drawings: Piping layout, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved. Submit shop drawings for piping systems drawn at a minimum scale of ¼ inch per foot to verify clearances and equipment locations. Show required maintenance and operational clearances. Include the following:
      a. Architectural and structural backgrounds with room names and numbers, including but not limited to plans, sections, suspended ceiling components, elevations, details and structural members.
      b. Fabrication and erection dimensions.
      c. Arrangements and sectional views.
      d. Details, including complete information for making connections to equipment.
      e. Descriptive names of equipment.
      f. Modifications and options to standard equipment required by Contract Documents.
      g. Suspended ceiling components.
      h. Other building services.
      i. Structural members.
   2. Qualification Data: For Installer.
   3. Welding certificates.
   4. Field quality-control reports.
   5. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project site.

G. General: Provide shop drawing and manufacturer's data sheet for the following items:

   1. Manufacturers Literature:

      a. Complete design and construction data for dielectric unions and flanges.

b. Complete design and construction data for grooved mechanical fittings and couplings for steel piping systems.
c. Complete design and construction data for grooved mechanical fittings and couplings for copper piping systems.
d. Manufacturer's data on piping and fittings used, with an indication of each specific application

2. Performance Data: Submit a copy of the Welding Procedure Specification with the Procedure Qualification Record and certificates of the welders and welding operators required by Section IX of the ASME Boiler and Pressure Vessel Code.

3. Installation Data:

a. Manufacturer's printed instructions for the installation of grooved mechanical fittings and couplings for steel pipe.
b. Manufacturer's printed instructions for the installation of grooved mechanical fittings and couplings for copper pipe.
c. UL approval number, installation materials, and procedures for pipe penetrations of fire-rated walls and floor.

1.4 QUALITY ASSURANCE

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

1. American Society of Mechanical Engineers (ASME):

a. B16.1: Cast iron pipe flanges and flanged fittings Class 25, 125, 250, and 800.
b. B16.4: Cast iron threaded fittings Classes 125 and 250.
c. B16.3: Malleable iron threaded fittings.
d. B16.5: Pipe flanges and flanged fittings.
e. B16.9: Factory-made wrought steel buttwelding fittings.
f. B16.1: Forged steel fittings, socket-welding and threaded.
g. B16.18: Cast copper alloy solder joint pressure fittings.
h. B16.22: Wrought copper and copper alloy solder joint pressure fittings.
i. B16.39: Malleable iron threaded pipe unions Classes 150, 250, and 300.
j. B31: Code for pressure piping.
k. B31.1: Power piping.
l. B31.9: Building Services Piping.

2. Installation of piping at Central Energy Plant (CEP) shall conform to the requirements of ASME B31.1 “Power Piping.” At all other locations, piping installation shall conform to the requirements of ASME B31.9 “Building Services Piping.”

3. American Society for Testing and Materials (ASTM):

a. A 53: Standard specification for pipe, steel, black and hot-dipped, zinc-coated welded seamless.
b. A 106: Standard specification for seamless carbon steel pipe for high-temperature service.
c. A 126: Standard specification for gray iron castings for flanges, and pipe fittings.
d. A 193/A 193M: Standard specification for alloy-steel and stainless steel bolting materials for high-temperature service.
e. A 194/A 194M: Standard specification for carbon and alloy steel nuts for bolts for high-pressure and high-temperature service.
f. A 216/A 216M: Standard specification for steel castings, carbon, suitable for fusion welding for high-temperature service.
g. A 276: Standard specification for stainless and heat-resisting steel bars and shapes.
h. A 307: Standard specification for carbon steel bolts and studs, 60,000 psi tensile strength.
i. B 88: Standard specification for seamless copper water tube.

B. Codes and Standards: Provide hydronic specialties conforming to the requirements of the following:

1. Published specifications' standards, tests or recommended methods of trade, industry or governmental organizations apply to work in this section.
2. Comply with all applicable national, state, and local codes and refer to Section "General Provisions" for mechanical for additional Reference Standards.
3. In addition, comply with all standards or associations as specified herein including, but not limited to, the following, as applicable:

a. American Society for Mechanical Engineers (ASME).
b. American Society for Testing and Materials (ASTM).
c. American National Standards Institute (ANSI).

C. Installer Qualifications:

1. Installers of Pressure-Sealed Joints: Installers shall be certified by pressure-seal joint manufacturer as having been trained and qualified to join piping with pressure-seal pipe couplings and fittings.

D. Steel Support Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

E. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

1. Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.

2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

F. To assure uniformity and compatibility of piping components in grooved piping systems, all grooved products utilized shall be supplied by the same manufacturer. Grooving tools shall be designed, manufactured and supplied by the same manufacturer as the grooved components

1. All castings used for coupling housings, fittings, valve bodies, etc., shall be date stamped for quality assurance and traceability

2. Grooved steel pipe (in applicable sizes to the tools current capability) shall be produced using the Victaulic RG5200i fully automated grooving tool that provides groove traceability documents, corresponding identification marks on the pipe, and confirmation that all critical dimensions fall into the required tolerance range as listed by the tool manufacturer

3. Inspection Requirement for Grooved Piping Systems:

a. A manufacturer's factory trained representative (a direct employee of the manufacturer) shall periodically visit the job site and review the installation for best practices. This shall be at the expense of the installing contractor. The installing Contractor shall correct any identified deficiencies

b. Product that has been examined and has not met the visual inspection criteria for proper installation must be corrected and re-examined by Inspection Services prior to the completion of the project. Any product that has not been corrected or was not examined will not be considered as part of the successful completion of Inspection Services. Any products that require a torque per written manufacturer's installation instructions shall be verified as torqued with a properly-certified torque wrench

c. At the completion of system inspection, a report shall be provided to the project team and a limited-term installation warranty may be provided to the Owner covering inspected joints.

1.5 APPLICABLE STANDARDS

A. General: All equipment, material, accessories, methods of construction and reinforcement, finish quality, workmanship and installation shall be in compliance with the applicable standards and codes listed in paragraph entitled "Code Compliance" in Section 23 00 10.

B. Quality and Weight: The quality and weight of materials shall comply with requirements and specifications of the appropriate standards of the American Society of Testing and Materials, American National Standards Institute, American Society of Mechanical Engineers, and the American Welding Society.

C. Piping System: All pressurized piping systems shall conform to ASME B31.9, Code for Pressure Piping, Building Services Piping and ASME B31.1, Power Piping

D. Welder Certification: Welders shall be tested and certified within the last 2 years by the National Certified Pipe Welding Bureau or recognized testing agency acceptable to the Designer. Competent certified welders shall perform all welding operations. Each welder shall possess a stamp to identify his work and shall stamp each weld. A copy of the certification shall be available at the jobsite for each welder.

E. Welding Installation: Welding shall be in accordance with the welding procedures and requirements set forth in "Welding of Pipe Joints" of the "Code for Pressure Piping" in the American Welding Society Welding handbook. Pipe welding shall comply with the provisions of the latest revision of the applicable code, whether ASME Boiler and Pressure Vessel Code, ANSI Code for Pressure Piping, or state or local requirements as may supersede these codes.

F. Brazing: Brazing of copper tubing shall be in accordance with the standards of the American Welding Society, the Copper Development Association Copper Tube Handbook instructions on brazing, and ASME Boiler code Section IX.

G. Soldering: Soldering of copper tubing shall be done in accordance with the Copper Development Association, Copper Tube Handbook instructions on Joining and Forming Copper Tube, Soldered Joints.

H. Grooving: Pipe grooving shall be in accordance with manufacturer’s most current written operating instructions and shall include direct manufacturer field training

PART 2 - PRODUCTS

2.1 PRODUCT, GENERAL

A. Recycled Content of Steel Products: Post-consumer recycled content plus one-half of pre-consumer recycled content not less than 25%.

B. Recycled Content of Copper Products: Post-consumer recycled content plus on-half of pre-consumer recycled content not less than 25%.

C. Refer to Section 01 81 13.14 “Sustainable Design Requirements – LEED v4 BD+C” for additional information and requirements for recycled content. Provide material cost data specific to this material.

D. Environmental Product Disclosure: Provide an Environmental Product Declarations (EPD) that conforms with one of the followings:
   1. Product specific declarations in accordance to ISO 1404
   2. Environmental Product Declarations conforming to ISO 14025, 14040, 14044 and EN 15804 or ISO 21930.
   3. Industry Wide Product Specific Type III EPD Third Party Certification.

2.2 PERFORMANCE REQUIREMENTS

A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature unless otherwise indicated:

   1. Chilled-Water Piping: 150 psig at 200 deg F.
   2. Condenser-Water Piping: 150 psig at 150 deg F
   3. Makeup-Water Piping: 80 psig at 150 deg F.
   4. Condensate-Drain Piping: 150 deg F
   5. Blowdown-Drain Piping: 200 deg F
   6. Air-Vent Piping: 200 deg F.
   7. Safety-Valve-Inlet and -Outlet Piping: Equal to the pressure of the piping system to which it is attached.

2.3 COPPER TUBE AND FITTINGS

A. Drawn-Temper Copper Tubing: ASTM B 88, Type K.

B. DWV Copper Tubing: ASTM B 306, Type DWV.

C. Grooved, Mechanical-Joint, Wrought-Copper Fittings: ASME B16.22.

   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

      a. Victaulic Company.
      b. Owner approved Substitution.

   2. Grooved-End Copper Fittings: ASTM B 75, copper tube or ASTM B 584, bronze casting.
   3. Grooved-End-Tube Couplings: Rigid pattern unless otherwise indicated; gasketed fitting. Ductile-iron housing with keys matching pipe and fitting grooves, prelubricated EPDM gasket rated for minimum 250 deg F (121 deg C) for use with housing, and steel bolts and nuts. Housing shall be cast with offsetting, angle-pattern bolt pads with keys matching pipe and fitting grooves to provide system rigidity upon visual metal-to-metal pad contact without a torque requirement

D. Copper or Bronze Pressure-Seal Fittings:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Viega, LLC
   b. Owner approved Substitution.

2. Housing: Copper.
3. O-Rings and Pipe Stops: EPDM.
4. Tools: Manufacturer's special tools.
5. Minimum 200-psig working-pressure rating at 250 deg F.

E. Wrought-Copper Unions: ASME B16.22.

2.4 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; electric resistance welded (ERW) and seamless (S), Grade B, and wall thickness as indicated in "Piping Applications" Article.

B. Cast-Iron Threaded Fittings: ASME B16.4; Classes 125 and 250 as indicated in "Piping Applications" Article.

C. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300 as indicated in "Piping Applications" Article.

D. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in "Piping Applications" Article.

E. Cast-Iron Pipe Flanges and Flanged Fittings: ASME B16.1, Classes 25, 125, and 250; raised ground face, and bolt holes spot faced as indicated in "Piping Applications" Article.

F. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.

G. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

1. Material Group: 1.1.
2. End Connections: Butt welding.
3. Facings: Raised face.

H. Grooved Mechanical-Joint Fittings and Couplings:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Victaulic Company.
b. Owner approved Substitution.

2. Joint Fittings: ASTM A 536, Grade 65-45-12 ductile iron;; ASTM A 53/A 53M, Type F, E, or S, Grade B fabricated steel; or ASTM A234, Grade WPB steel fittings with grooves or shoulders constructed to accept grooved-end couplings; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

3. Couplings: Ductile- -iron housing and EPDM gasket of central cavity pressure-responsive design; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

   a. Rigid Type: Housings 12” and smaller shall be cast with offsetting, angle-pattern bolt pads to provide system rigidity and support and hanging in accordance with ASME B31.1 and B31.9 upon visual metal-to-metal pad contact without a torque requirement.
      1) 2” through 12”: Installation-Ready, for direct installation with-out field disassembly, with grade EHP gasket rated to +250 deg F / 120 deg C. Victaulic Style 107N.
      2) 14” and larger: AGS Style W07 with wide-width groove and lead-in chamfer.

   b. Flexible Type: Use in locations where thermal stress relief are required such as expansion loops or piping offsets. In lieu of each flexible connector at major equipment, three (3) flexible couplings may be used for vibration attenuation and shall be placed in close proximity to the vibrating source.
      1) 2” through 8”: Installation-Ready, for direct installation without field disassembly, with grade EHP gasket rated to +250 deg F / 120 deg C. Victaulic Style 177N.
      2) 10” and 12”: Standard rigid coupling with Grade “E” EPDM gasket rated to +230F. Victaulic Style 77.
      3) 14” and larger: AGS Style W177 with wide-width groove and lead-in chamfer.

4. Factory-Assembled Pump Drops;

   a. Factory assembled grooved end drop for pipe sizes 3” through 12”. Orange enamel coated assembly, consisting of a Class 150 flange for pump connection, required elbow and reducers, valves, specialties, and pipe spool with thermometer and pressure ports. (Butterfly valves used in assemblies shall have a pressure responsive seat and stem offset from the disc centerline to provide complete 360-degree circumferential seating. Assembly is installation-ready, with flexible couplings to accommodate vibration attenuation and stress relief. Assembly rated for working pressure to 300-psig.

1). Grooved end vibration pump discharge drop with tri-service valve assembly consisting of a spring-actuated check [Venturi-Check] valve and butterfly valve. Victaulic Series 380 or Owner approved Substitution

2). Grooved end vibration pump suction drop consisting of a suction diffuser with stainless steel basket and diffuser and Class 150 flange for pump connection, and butterfly valve. Victaulic Series 381 or Owner approved Substitution

3). Grooved end vibration pump suction drop consisting of a 90-degree base elbow, Wye pattern strainer with stainless steel perforated metal basket, and butterfly valve. Victaulic Series 382 or Owner approved Substitution.

5. Factory-Fabricated Header:

   a. Factory-fabricated grooved end header [manifold] all-in-one assembly for fluid distribution. Header shall consist of an ASTM A53, Grade B, standard weight pipe spool with required outlet connections. Grooved ends roll grooved to Victaulic [OGS] [AGS] dimensions, with enamel coating or galvanized to project requirements. Victaulic or Owner approved Substitute

I. Steel Pressure-Seal Fittings:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Viega LLC.
   b. Owner Approved substitution.

2. Housing: Steel.
3. O-Rings and Pipe Stop: EPDM.
4. Tools: Manufacturer's special tool.
5. Minimum 300-psig working-pressure rating at 230 deg F.

2.5 Steel Pipe Nipples: ASTM A 733, made of same materials and wall thicknesses as pipe in which they are installed.

2.6 PLASTIC PIPE AND FITTINGS

A. CPVC Plastic Pipe: ASTM F 441/F 441M, with wall thickness as indicated in "Piping Applications" Article.

1. CPVC Plastic Pipe Fittings: Socket-type pipe fittings, ASTM F 438 for Schedule 40 pipe; ASTM F 439 for Schedule 80 pipe.

B. PVC Plastic Pipe: ASTM D 1785, with wall thickness as indicated in "Piping Applications" Article.

1. PVC Plastic Pipe Fittings: Socket-type pipe fittings, ASTM D 2466 for Schedule 40 pipe; ASTM D 2467 for Schedule 80 pipe.

2.7 JOINING MATERIALS

A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.

1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8-inch maximum thickness unless otherwise indicated.

a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.

B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.

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

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

E. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for joining copper with copper; or BAg-1, silver alloy for joining copper with bronze or steel.

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

G. Solvent Cements for Joining Plastic Piping:

1. CPVC Piping: ASTM F 493.

a. CPVC solvent cement shall have a VOC content of 490 g/L or less.
b. Adhesive primer shall have a VOC content of 550 g/L or less.
c. Solvent cement and adhesive primer shall comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Health Services') "Standard Method v1.1 2010 and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

2. PVC Piping: ASTM D 2564. Include primer according to ASTM F 656.

a. PVC solvent cement shall have a VOC content of 510 g/L or less.
b. Adhesive primer shall have a VOC content of 550 g/L or less.
c. Solvent cement and adhesive primer shall comply with the testing and product requirements of the California Department of Public Health's (formerly, the California Health Services') "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

H. Gasket Material: Thickness, material, and type suitable for fluid to be handled and working temperatures and pressures.

2.8 TRANSITION FITTINGS

A. Plastic-to-Metal Transition Fittings:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Charlotte Pipe and Foundry Company.
b. IPEX USA LLC.
c. KBI (King Bros. Industries).
d. Viega LLC.

2. One-piece fitting with one threaded brass or copper insert and one solvent-cement-joint end of material and wall thickness to match plastic pipe material.

B. Plastic-to-Metal Transition Unions:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Charlotte Pipe and Foundry Company.
b. IPEX USA LLC.
c. KBI (King Bros. Industries).
d. NIBCO INC.

2. Brass or copper end, solvent-cement-joint end of material and wall thickness to match plastic pipe material, rubber gasket, and threaded union.

2.9 DIELECTRIC FITTINGS

A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.

B. Dielectric Unions:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    a. Capitol Manufacturing Company.
    b. Central Plastics Company.
    c. Hart Industries International, Inc.
    d. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
    e. Zurn Industries, LLC.

2. Description:

    a. Standard: ASSE 1079.
    b. Pressure Rating: 125 psig minimum at 180 deg F.
    c. End Connections: Viega Pro-Press or Owner approved substitution.

C. Dielectric Flanges:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    a. Capitol Manufacturing Company.
    b. Central Plastics Company.
    c. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
    d. Zurn Industries, LLC.

2. Description:

    a. Standard: ASSE 1079.
    b. Factory-fabricated, bolted, companion-flange assembly.
    c. Pressure Rating: 125 psig minimum at 180 deg F.
    d. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solder-joint copper alloy and threaded ferrous.

D. Dielectric-Flange Insulating Kits:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Advance Products & Systems, Inc.
    b. Calpico, Inc.
    c. Central Plastics Company.
    d. Pipeline Seal and Insulator, Inc.

2. Description:

    a. Nonconducting materials for field assembly of companion flanges.
    b. Pressure Rating: 150 psig.
    c. Gasket: Neoprene or phenolic.
    d. Bolt Sleeves: Phenolic or polyethylene.

e. Washers: Phenolic with steel backing washers.

E. Dielectric Nipples:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Elster Perfection Corporation.
b. Grinnell Mechanical Products.
c. Matco - Norca.
d. Precision Plumbing Products, Inc.
e. Victaulic Company.

2. Description:

a. Standard: IAPMO PS 66.
b. Electroplated steel nipple, complying with ASTM F 1545 or unlined copper-silicone body.
c. Pressure Rating: 300 psig at 225 deg F.
d. End Connections: Male threaded or grooved.
e. Lining: Inert and noncorrosive, propylene.

2.10 MECHANICAL SLEEVE SEALS

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

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Advance Products & Systems, Inc.
b. Calpico, Inc.
c. Metraflex Co.
d. Pipeline Seal and Insulator, Inc.

2. Sealing Elements: EPDM interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
3. Pressure Plates: Carbon steel. Include two for each sealing element.
4. Connecting Bolts and Nuts: Carbon steel with corrosion-resistant coating of length required to secure pressure plates to sealing elements. Include one for each sealing element.

2.11 SLEEVES

A. Galvanized-Steel Sheet: 0.0239-inch minimum thickness; round tube closed with welded longitudinal joint.

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

C. Cast Iron: Cast or fabricated "wall pipe" equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.

D. Stack Sleeve Fittings: Manufactured, cast-iron sleeve with integral clamping flange. Include clamping ring and bolts and nuts for membrane flashing.

1. Under deck Clamp: Clamping ring with set screws.

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

F. PVC Pipe: ASTM D 1785, Schedule 40.

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

2.12 ESCUTCHEONS

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

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

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

1. Finish: Polished chrome-plated.

D. Split-Casting, Cast-Brass Type: With concealed hinge and set screw.

1. Finish: Polished chrome-plated.

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

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

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

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

2.13 BYPASS CHEMICAL FEEDER

A. Description: Welded steel construction; 125-psig working pressure; 5-gal. capacity; with fill funnel and inlet, outlet, and drain valves.

1. Chemicals: Specially formulated, based on analysis of makeup water, to prevent accumulation of scale and corrosion in piping and connected equipment.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Chilled-water piping, aboveground, NPS 2 and smaller, shall be the following:

1. Type K, drawn-temper copper tubing, wrought-copper fittings, and soldered joints. Viega Pro-Press fittings or Owner approved substitution pressure-seal joints.

B. Chilled-water piping, aboveground, NPS 2-1/2 to 4, shall be any of the following:

1. Type K, drawn-temper copper tubing, wrought-copper fittings, and brazed joints. Viega Pro-Press fittings or Owner approved substitution pressure-seal joints.

C. Chilled-water piping, aboveground, NPS 5 to 12, shall be any of the following:

1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
2. Schedule 40 steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.

D. Chilled-water piping, aboveground, NPS 14 and larger, shall be any of the following:

1. Standard Schedule steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
2. Standard Schedule steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.

E. Chilled-water piping installed belowground and within slabs shall be the following:

1. Pre-insulated piping system as specified in section 23 21 13.15.

F. Condenser-water piping, aboveground, NPS 4 and smaller, shall be any of the following:

1. Type K, drawn-temper copper tubing, wrought-copper fittings, and brazed joints. Piping shall be painted green.

G. Condenser-water piping, aboveground, NPS 6 to 12 , shall be any of the following:

1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
2. Schedule 40 steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.
3. Condenser water piping shall be painted with three coats of epoxy paint throughout, color green.

H. Condenser-water piping, aboveground, NPS 14 and larger, shall be any of the following:

1. Standard Schedule steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
2. Standard Schedule steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.
3. Condenser water piping shall be painted with three coats of epoxy paint throughout, color green.

I. Underground condenser-water piping shall be black steel with three coats of epoxy paint.

J. Makeup-water piping installed aboveground shall be the following:

1. Type K, drawn-temper copper tubing, wrought-copper fittings, and brazed joints.

K. Condensate-Drain Piping: Type K annealed-temper copper tubing, wrought-copper Viega Pro-Press fittings, or Owner approved substitution or Schedule 40 PVC plastic pipe and fittings and solvent-welded joints.

L. Blowdown-Drain Piping: Same materials and joining methods as for piping specified for the service in which blowdown drain is installed.

M. Air-Vent Piping:

1. Inlet: Same as service where installed with metal-to-plastic transition fittings for plastic piping systems according to piping manufacturer's written instructions.
2. Outlet: Type K, annealed-temper copper tubing with soldered or flared joints.

N. Underground Petroleum Products Piping Additional Requirements:

1. Provide a pipe system, complete with all piping, tools, and accessories for a proper and safe installation, in accordance with the current EPA regulations, to prevent contamination of ground in the event of a rupture or leak in fluid carrier pipe.
2. Provide a 'Marker Tape', located 6" below finished grade, above all underground petroleum products piping.
3. The piping system shall be compatible with Section 23 11 13 - Fuel Storage Tank and Accessories.

4. Provide filter fabric barrier at bottom of piping excavation for containment in event of pipe leak.
5. Piping shall be in accordance with FDEP Chapter 62-761.

3.2 PIPING INSTALLATIONS

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

B. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.

C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

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

E. Install piping to permit valve servicing.

F. Install piping at indicated slopes.

G. Install piping free of sags and bends.

H. Install fittings for changes in direction and branch connections.

I. Install piping to allow application of insulation.

J. Select system components with pressure rating equal to or greater than system operating pressure.

K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

L. Install drains, consisting of a tee fitting, ball valve, and short threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage. Ball valve and threaded nipple with cap: Up to 6 inches pipe use NPS 3/4 and 8 inches and larger pipe use NPS 1-1/2.

M. Install piping at a uniform grade of 0.2 percent upward in direction of flow.

N. Reduce pipe sizes using eccentric reducer fitting installed with level side up.

O. Install branch connections to mains using tee fittings in main pipe, with the branch connected to the bottom of the main pipe. For up-feed risers, connect the branch to the top of the main pipe.

P. Install valves according to Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," Section 230523.14 "Check Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."

Q. Install unions in piping, NPS 2 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

R. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated.

S. Install shutoff valve immediately upstream of each dielectric fitting.

T. Comply with requirements in Section 230516 "Expansion Fittings and Loops for HVAC Piping" for installation of expansion loops, expansion joints, anchors, and pipe alignment guides.

U. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for identifying piping.

V. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

W. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

X. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230518 "Escutcheons for HVAC Piping."

Y. Install strainers on inlet side of each control valve, pressure-reducing valve, solenoid valve, pump, and elsewhere as indicated.

Z. Install no piping in elevator machine rooms, electric rooms and closets, and telephone rooms and closets, other than the piping serving the air conditioning equipment in the respective room. Install drain pan for the length of the piping in the room.

3.3 DIELECTRIC FITTING INSTALLATION

A. Install dielectric fittings in piping at connections of dissimilar metal piping and tubing.

B. Dielectric Fittings for NPS 2 and Smaller: Use dielectric unions.

C. Dielectric Fittings for NPS 2-1/2 to NPS 4: Use dielectric flanges.

D. Dielectric Fittings for NPS 5 and Larger: Use dielectric flange kits.

3.4 HANGERS AND SUPPORTS

A. Comply with requirements in Section 230529 "Hangers and Supports for HVAC Piping and Equipment" for hanger, support, and anchor devices. Comply with the following requirements for maximum spacing of supports.

B. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.

C. Install the following pipe attachments:

1. Adjustable steel clevis hangers for individual horizontal piping less than 20 feet long.
2. Adjustable roller hangers and spring hangers for individual horizontal piping 20 feet or longer.
3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.
4. Provide copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.
5. Supports of wire, rope, wood, chain, strap, perforated bar or any other makeshift device will not be permitted.
6. Minimum spacing and minimum rod diameter shall comply with latest edition of MSS SP-58.

D. Install hangers for steel piping with the following maximum spacing and minimum rod sizes:

1. NPS 3/4: Maximum span, 7 feet; minimum rod size, 3/8 inch.
2. NPS 1: Maximum span, 7 feet; minimum rod size, 3/8 inch.
3. NPS 1-1/4: Maximum span, 7 feet; minimum rod size, 3/8 inch.
4. NPS 1-1/2: Maximum span, 9 feet; minimum rod size, 3/8 inch.
5. NPS 2: Maximum span, 10 feet; minimum rod size, 3/8 inch.
6. NPS 2-1/2: Maximum span, 11 feet; minimum rod size, 1/2 inch.
7. NPS 3: Maximum span, 12 feet; minimum rod size, 1/2 inch.
8. NPS 4: Maximum span, 14 feet; minimum rod size, 5/8 inch.
9. NPS 6: Maximum span, 17 feet; minimum rod size, 3/4 inch.
10. NPS 8: Maximum span, 19 feet; minimum rod size, 3/4 inch.
11. NPS 10: Maximum span, 20 feet; minimum rod size, 7/8 inch.
12. NPS 12: Maximum span, 23 feet; minimum rod size, 7/8 inch.
13. NPS 14: Maximum span, 25 feet; minimum rod size, 1 inch.
14. NPS 16: Maximum span, 27 feet; minimum rod size, 1 inch.
15. NPS 18: Maximum span, 28 feet; minimum rod size, 1-1/4 inches.
16. NPS 20 and Larger: Maximum span, 30 feet; minimum rod size, 1-1/4 inches.

E. Install hangers for drawn-temper copper piping with the following maximum spacing and minimum rod sizes:

1. NPS 3/4: Maximum span, 5 feet; minimum rod size, 3/8 inch.
2. NPS 1: Maximum span, 6 feet; minimum rod size, 3/8 inch.
3. NPS 1-1/4: Maximum span, 7 feet; minimum rod size, 3/8 inch.
4. NPS 1-1/2: Maximum span, 8 feet; minimum rod size, 3/8 inch.
5. NPS 2: Maximum span, 8 feet; minimum rod size, 3/8 inch.
6. NPS 2-1/2: Maximum span, 9 feet; minimum rod size, 1/2 inch.
7. NPS 3: Maximum span, 10 feet; minimum rod size, 1/2 inch.
8. NPS 4: Maximum span, 12 feet; minimum rod size, 1/2 inch.
9. NPS 6: Maximum span, 14 feet; minimum rod size, 5/8 inch.
10. NPS 8: Maximum span, 16 feet; minimum rod size, 3/4 inch.
11. NPS 10: Maximum span, 18 feet; minimum rod size, 3/4 inch.
12. NPS 12: Maximum span, 19 feet; minimum rod size, 3/4 inch.

F. Plastic Piping Hanger Spacing: Space hanger according to pipe manufacturer’s written instructions for service conditions. Avoid point loading. Space and install hangers with the fewest practical rigid anchor points.

G. Support vertical runs at roof, at each floor.

1. Base Elbow Support: Provide bearing plate on structural support, similar to F&S Manufacturing Corp. Fig. 720.
2. Provide guides at every third floor but not to exceed:
    a. 25 ft. for piping to 2 inches.
    b. 36 ft. for piping 2-1/2 inches to 12 inches.
    c. 50 ft. for piping 14 inches and larger.
3. Top Support: Provide special hanger or saddle in horizontal connection and make provisions for expansion.
4. Intermediate Supports: Steel pipe clamp at floor. Bolt and weld to pipe with extension ends bearing on structural steel or bearing plates.
5. For multiple pipes, coordinate guides bearing plates and accessory steel.

3.5 PIPE JOINT CONSTRUCTION

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

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

C. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.

D. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8/A5.8M.

E. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

F. Welded Joints: Construct joints according to AWS D10.12M/D10.12, using qualified processes and welding operators according to "Quality Assurance" Article.

G. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

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

1. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.
2. CPVC Piping: Join according to ASTM D 2846/D 2846M Appendix.
3. PVC Pressure Piping: Join ASTM D 1785 schedule number, PVC pipe and PVC socket fittings according to ASTM D 2672. Join other-than-schedule number PVC pipe and socket fittings according to ASTM D 2855.
4. PVC Nonpressure Piping: Join according to ASTM D 2855.

I. Grooved Joints: Assemble joints with coupling and gasket, lubricant, and bolts. Cut or roll grooves in ends of pipe based on pipe and coupling manufacturer's written instructions for pipe wall thickness. Use grooved-end fittings and rigid or flexible, grooved-end-pipe couplings. The gasket style and elastomeric material (grade) shall be verified as suitable for the intended service as specified. Gaskets shall be molded and produced by the grooved coupling manufacturer. Grooved end shall be clean and free from indentations, projections, and roll marks in the area from pipe end to groove. A factory-trained field representative shall provide on-site training for contractor's field personnel in the use of grooving tools, application of groove, and installation of grooved piping products. Representative shall be a direct employee of the grooved system manufacturer. A distributor representative is not qualified for this site service. Factory trained representative shall periodically review the product installation. Contractor shall remove and replace any improperly installed products at no additional charges.

J. Pressure-Sealed Joints: Use manufacturer-recommended tool and procedure. Leave insertion marks on pipe after assembly.

3.6 TERMINAL EQUIPMENT CONNECTIONS

A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.

B. Install control valves in accessible locations close to connected equipment.

C. Install bypass piping with globe valve around control valve. If parallel control valves are installed, only one bypass is required.

D. Install ports for pressure gages and thermometers at coil inlet and outlet connections. Comply with requirements in Section 230519 "Meters and Gages for HVAC Piping."

3.7 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.
2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.
5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Installation: Pipe and fittings shall be installed as specified in this section unless specific installation instructions are provided in the individual sections covering the piping system. Install each run with a minimum of joints and couplings, but with adequate and accessible unions for disassembly and maintenance/replacement of valves and equipment. Reduce sizes where indicated using reducing fittings. Align piping at connections within 1/16 inch misalignment tolerance.

C. Routing and Placement: Piping shall be run without traps or pockets and pitched a minimum 1 inch per 40 feet in the direction of flow, unless indicated or required to be pitched steeper. Grade piping so that air in the mains and risers will be carried up and discharged at venting points. Coordinate installation with structural features, and with other piping, equipment and the work of other trades. All piping shall be installed as close to the structure overhead as possible.

D. Prohibited Installation: Do not run piping through transformer vaults, elevator equipment rooms, other electrical or electronic equipment spaces and enclosures. Do not run piping over electrical panels. Where pipe joints or valves in water lines occur within two feet in horizontal directions from electrical panels or equipment, provide drip pans sized to afford protection. Pans shall be 20-gauge galvanized steel with edges turned up 2-1/2 inches on all sides, reinforced with galvanized steel angles or by rolling edges over 1/4-inch diameter steel wire. Provide a drain with 3/4-inch flange and pipe to nearest floor drain, and support the pan assemblies as required to prevent sagging or swaying.

E. Interior Piping: Interior piping shall be run parallel to the walls and ceilings; avoid diagonal runs. Provide a minimum 6-inch clearance between walls and horizontal piping.

F. Exterior Piping: Exterior piping (above and below grade) shall essentially be routed and located as indicated on the drawings; however, actual placement shall be verified by confirming exact location of structures and other utilities in the field and by careful layout prior to execution of the work.

G. Insulated Piping: Pipe requiring insulation shall be installed with sufficient clearances to permit proper application of insulation.

H. Perform the following tests on hydronic piping:

1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
3. Isolate expansion tanks and determine that hydronic system is full of water.
4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's design pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times the "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components and repeat hydrostatic test until there are no leaks.
6. Prepare written report of testing.

I. Perform the following before operating the system:

1. Open manual valves fully.
2. Inspect pumps for proper rotation.
3. Set makeup pressure-reducing valves for required system pressure.
4. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type), or bleed air completely (manual type).
5. Set temperature controls so all coils are calling for full flow.
6. Inspect and set operating temperatures of hydronic equipment, such as boilers, chillers, cooling towers, to specified values.

7. Verify lubrication of motors and bearings.

END OF SECTION 23 21 13

SECTION 23 21 16 - HYDRONIC PIPING SPECIALTIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Basic Requirements: Provisions of Section 230010, BASIC MECHANICAL REQUIREMENTS are a part of this Section.

1.2 SUMMARY

A. Section includes special-duty valves and specialties for the following:

1. Chilled-water piping.
2. Condenser-Water Piping
3. Air-vent piping.
4. Strainers
5. Suctions diffusers
6. Differential Pressure Controller
7. Treaded connections
8. Solder connections
9. Flanged connections
10. Grooved connections
11. Flexible connections
12. Ball joints

1.3 ACTION SUBMITTALS

A. Sustainable Design Documentation Submittals: Refer to section 01 81 13.14 “Sustainable Design Requirements – LEED V4 BD+C”.
   1. Product Data: Documentation for Leadership Extraction Practices in the following:
      a. Leadership Extraction Practices for Recycled Content
   2. Product Data: Documentation for Low Emitting Materials
      a. Low Emitting Materials for Paints and Coatings
      b. Low Emitting Materials for Adhesives and Sealants
   3. Product Certificates: Provide the following:
      a. Environmental Product Declarations (EPD’s)
      b. Corporate Sustainability Reporting (CSR’s)

B. Product Data: For each type of the following:

1. Valves: Include flow and pressure drop curves based on manufacturer's testing for calibrated-orifice balancing valves and automatic flow-control valves.
2. Air-control devices.
3. Hydronic specialties.

1.4 APPLICABLE STANDARDS

A. General: All equipment, material, accessories, methods of construction and reinforcement, finish quality, workmanship and installation shall be in compliance with the paragraph entitled "Code Compliance" in Section 230010.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air-control devices, hydronic specialties, and special-duty valves to include in emergency, operation, and maintenance manuals.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature unless otherwise indicated:

1. Chilled & Condenser-Water Piping: 150 psig at 200 deg F.
2. Makeup-Water Piping: 80 psig at 150 deg F.
3. Air-Vent Piping: 200 deg F.
4. Condensate-Drain Piping: 150 deg F.

2.2 VALVES

A. Check, Ball, and Butterfly Valves: Comply with requirements specified in Section 230523 "General-Duty Valves for HVAC Piping.

B. Automatic Temperature-Control Valves, Actuators, and Sensors: Comply with requirements specified in Section 230900 "Instrumentation and Control for HVAC.

2.3 AIR-CONTROL DEVICES

A. Manual and Automatic Air Vents: Comply with requirements specified in Section 230580 "Air Control and Accessories”.

2.4 HYDRONIC PIPING SPECIALTIES

A. Y-Pattern Strainers:

1. Body: ASTM A 126, Class B, ASTM A536 or ASTM A395 Wye type shall be full line size of the connecting pipe, ductile iron ASTM A-395 Class 60-40-18, cast or ductile-iron or forged steel shall be used in steel piping and all bronze in copper piping systems. Flanged wye-type shall have bolted covers in 2-1/2 through 8 inches and hinged covers in 10 inch and larger. Grooved shall have coupled or T-bolt hinged cover (dictated by size). Threaded shall have threaded gasketed caps 2 inches and smaller with NPT blowdown outlet. Provide cover and bottom drain connection. Provide blowdown valve where indicated.
2. End Connections: Threaded ends for NPS 2 and smaller; flanged or grooved ends for NPS 2-1/2 and larger.
3. Strainer Screen: Stainless-steel, 40-mesh strainer, or perforated stainless-steel basket.
4. CWP Rating: 125 psig.

B. Suction Diffusers:
1. Body: Constructed of either cast iron or ductile iron, rated for a maximum allowable working pressure of 175 psig and a maximum temperature of 250 Deg. F. Flange or groved end connections. Flanged end connections shall be designed according to ANSI Class 150 standards.
2. Straightening vanes: full length, 4 plane, removable.
3. Strainer cylinder: 304 stainless steel with 3/16” perforations.
4. Startup strainer: full length, removable with 16 mesh screen.
5. Accessories:
   a. Adjustable support foot.
   b. Pressure Temperature ports on the inlet and outlet sides of the strainer cylinder.
6. Manufacturer:
   a. Xylem Inc, Bell & Gossett
   b. Armstrong Pump
   c. Aurora
   d. Flow Solutions International (FSI)

C. Basket Strainers:

1. Body: ASTM A 126, Class B, high-tensile cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for NPS 2 and smaller; flanged ends for NPS 2-1/2 and larger.
3. Strainer Screen: 40-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area. Free area not less than three times inlet area.
4. CWP Rating: 125 psig.

D. Differential Pressure Controller
1. Manufacturer:
   a. IMI TA, Model TA-PILOT-R

2. Material: Valve body: Ductile iron EN-GJS-400 Pilot body: AMETAL® O-rings: EDPM rubber Seat seal: EPDM/Stainless steel Plug mechanism: Stainless steel and brass Membrane: EPDM rubber Springs: Stainless steel Screws and nuts: Stainless steel

3. Surface treatment: Pilot body: Non treated Valve body: Electrophoretic painting.
4. Flanges: According to ASME/ANSI B16.42 Class 150.
5. Temperature: Max. working temperature: - with measuring points, standard: 245F - with measuring points, double secured: 300F Min. working temperature: -4F
6. Pressure class: Class 150 Max. differential pressure (ΔpV): 115Psi
7. Leakage rate: Tight sealing

E. Bronze Body with Threaded Connections:

1. Manufacturer:

   a. Mueller Steam Specialties
   b. Spirax/Sarco
   c. Armstrong
   d. O.C. Keckley Co.
   e. Metraflex Co.

F. Bronze Body with Solder Connection: Solder type wye strainers shall be class 250 SWP/400 WOG.

1. Manufacturer:

   a. Mueller Steam Specialties
   b. Spirax/Sarco
   c. O.C. Keckley Co.

G. Cast Iron Body with Threaded Connection: Y-type strainers shall be class 250 SWP/300 WOG.

1. Manufacturer:

   a. Mueller Steam Specialties
   b. Spirax/Sarco
   c. Armstrong Machine Co.
   d. O.C. Keckley Co.

H. Cast Iron Body with Flanged Connections:

1. Manufacturer:

   a. Mueller Steam Specialties
   b. Spirax/Saro
   c. Armstrong Machine Works
   d. O.C. Keckley Co.
   e. Metraflex Co.

I. Grooved Connection: Ductile iron body, minimum 300 psi working pressure for 12” and smaller and 230 psi working pressure for 14” and larger.

1. Manufacturer:

   a. Victaulic

b. Owner-approved substitution

J. Ball Joints: Wrought steel for the ball, case and retainer designed for Class 150, weld neck connections. The ball sealing surface shall be chrome plated and coated with molybdenum disulfide, with a minimum flex angle of 15°.

1. Manufacturer:
   a. Hyspan Barco Type N Style I weld end ball joint
   b. Owner-approved.

2.5 FLEXIBLE CONNECTORS

A. Stainless-Steel Bellow, Flexible Connectors:

1. Body: Stainless-steel bellows with woven, flexible, bronze, wire-reinforcing protective jacket.
2. End Connections: Threaded or flanged to match equipment connected.
3. Performance: Capable of 3/4-inch misalignment.
4. CWP Rating: 150 psig.
5. Maximum Operating Temperature: 250 deg F.

B. On grooved installations, three flexible couplings may be used in lieu of each flexible connector for vibration attenuation at major equipment. Couplings shall be placed in close proximity to the vibrating source in accordance with published guidelines.

PART 3 - EXECUTION

3.1 VALVE APPLICATIONS

A. Install shutoff-duty valves at each branch connection to supply mains and at supply connection to each piece of equipment.

B. Install check valves at each pump discharge and elsewhere as required to control flow direction.

C. Install pressure-reducing valves at makeup-water connection to regulate system fill pressure.

3.2 HYDRONIC SPECIALTIES INSTALLATION

A. Install automatic air vents at high points of system piping in mechanical equipment rooms only. Install manual vents at heat-transfer coils and elsewhere as required for air venting.

B. Install expansion tanks on the floor. Vent and purge air from hydronic system, and ensure that tank is properly charged with air to suit system Project requirements.

C. Install piping from air separator to expansion tank with a 2 percent upward slope toward tank.

D. Install piping from to drain point with a 2 percent downward slope toward closest drain point

E. Install in-line air separators in pump suction. Install drain valve on air separators NPS 2 and larger.

F. Install tangential air separator in pump suction. Install blowdown piping with gate or full-port ball valve; extend full size to nearest floor drain.

G. Install expansion tanks on the floor on 4 inch high concrete housekeeping pad. Vent and purge air from hydronic system, and ensure that tank is properly charged with air or nitrogen to suit system project requirements. Charge the diaphragm/bladder type expansion tank with air prior to filling the piping system with fluid. The tank shall be charged to a pressure as indicated in the tank schedule on design documents.

END OF SECTION 23 21 16

SECTION 23 21 23 - HYDRONIC PUMPS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes the following:

1. Close-coupled, in-line centrifugal pumps.
2. Close-coupled multi-stage in-line centrifugal pumps
3. Separately coupled, vertical, in-line centrifugal pumps.
4. Separately coupled, base-mounted, end-suction centrifugal pumps.
5. Separately coupled, base-mounted, double-suction centrifugal pumps.
6. Separately coupled, vertical-mounted, turbine centrifugal pumps.
7. Automatic condensate pump units.

1.3 ABBREVIATIONS

A. Buna-N: Nitrile rubber.

B. EPT: Ethylene propylene terpolymer.

C. HI: Hydraulic Institute.

1.4 SUBMITTALS

A. Product Data: Include certified performance curves and rated capacities, power requirement, operating characteristics, furnished specialties, final impeller dimensions, material specifications, and accessories for each type of product indicated. Indicate pump's operating point on curves, including brake horsepower, pump efficiency and NPSH indicated on curves. Where two or more pumps are operating in parallel, submit combined pump curve with all pump operating points plotted, system curve indicated and brake horsepower and pump efficiency indicated on curves.

B. Shop Drawings: Show pump layout and connections. Include setting drawings with templates for installing foundation and anchor bolts and other anchorages.

1. Wiring Diagrams: Power, signal, and control wiring.

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

1.5 QUALITY ASSURANCE

A. Source Limitations: Obtain hydronic pumps through one source from a single manufacturer.

B. Product Options: Drawings indicate size, profiles, and dimensional requirements of hydronic pumps and are based on the specific system indicated. Refer to Division 01 Section "Product Requirements."

C. Maximum suction velocity shall be less than 10 FPS. Pump discharge velocity shall be less than to 14 FPS

D. Pump selections shall be no more than 5% less than the scheduled pump efficiency.

E. Maximum impeller diameter shall not exceed 85% of the cutwater diameter.

F. Pump motors shall be NEMA Premium™ Efficiency. Motors for pumps with variable speed drive must have Class F insulation.

G. Pumps shall be factory tested, thoroughly cleaned and painted. Discharge and suction shall be factory covered to protect the volute/impeller from dirt and damage during shipment and storage.

H. Pumps shall be constructed with materials and standards which have been tested or proven and have published test data available if requested, stating that these materials and standards have been found acceptable for use in pump manufacturing by one or more of the following:

1. American Society for Testing and Materials (ASTM)
2. International Organization for Standardization (ISO)
3. American National Standards Institute (ANSI)
4. National Electrical Manufacturers Association (NEMA)

I. Provide full two year on-site parts and labor warranty including travel time and expense. Warranty period shall begin at date of Substantial Completion.

J. Provide shaft grounding rings on all pump motors driven by a VFD. Typically to an AEGIS – SGR.

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

L. UL Compliance: Comply with UL 778 for motor-operated water pumps.

M. Pump Performance: Ensure pumps operate at specified system fluid temperatures without vapor binding and cavitation, are non-overloading in parallel or individual operation, and operate within 25% of midpoint of published maximum efficiency curve.

N. Pump tests: Manufacturer shall test pumps in the shop prior to shipment. For identical pumps, only one pump of each specified capacity need to be tested. Tests shall be in accordance with the Hydraulic Institute Test Code.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Manufacturer's Preparation for Shipping: Clean flanges and exposed machined metal surfaces and treat with anticorrosion compound after assembly and testing. Protect flanges, pipe openings, and nozzles with wooden flange covers or with screwed-in plugs.

B. Store pumps in dry location.

C. Retain protective covers for flanges and protective coatings during storage.

D. Protect bearings and couplings against damage from sand, grit, and other foreign matter.

E. Comply with pump manufacturer's written rigging instructions.

1.7 COORDINATION

A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

1.8 EXTRA MATERIALS

A. Furnish extra materials described below 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 for each pump.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Manufacturers: Subject to compliance with requirements, provide products by one of the manufacturers specified.

2.2 GENERAL

A. Factory assembled, packaged and motor.

B. Centrifugal: Single stage, or multi-stage as noted.

C. Statically and dynamically balance rotating parts.

D. Pumps to operate at 1750 rpm unless specified otherwise.

E. Pump and motor capacities:

1. Minimum as scheduled on Drawings.
2. Suitable for parallel operation.
3. Motor to operate over entire head capacity range of pump without exceeding horsepower rating.
4. Motors shall be NEMA "Premium™-Efficiency" type specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

F. Pump characteristics:

1. Pump curve shall rise continuously from maximum capacity to shutoff.
2. Shutoff head shall be approximately 10% greater than design head.
3. Operation shall be at or near peak efficiency.
4. Capable of operating at 25% beyond design capacity in gpm without exceeding break off point.
5. Impeller diameter: Maximum 85% of the cutwater diameter.
6. Scheduled maximum NPSH required to apply over full operating range of pump.

G. Tested and guaranteed to withstand 1 1/2 times specified working pressures.

H. Pumps to be suitable for handling fluids at scheduled temperatures.

I. Abrasive Separator: Except as noted, provide seal flush piping connections with stainless steel abrasive separator.

2.3 CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

A. Manufacturers:

1. Armstrong Pumps Inc.
2. Aurora Pump; Division of Pentair Pump Group.
3. Bell & Gossett; Div. of ITT Industries.
4. PACO Pump: Division of Grundfos Pumps Corporation.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 200 deg F.

C. Pump Construction:

1. Casing: Radially split, cast iron, with replaceable bronze wear rings, threaded gage tappings at inlet and outlet, and threaded companion-flange connections.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
3. Pump Shaft: Stainless steel.
4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Include water slinger on shaft between motor and seal.
5. Pump Bearings: Permanently lubricated ball bearings.

D. Motor: Single speed, with grease-lubricated ball bearings, unless otherwise indicated; and rigidly mounted to pump casing. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

E. Capacities and Characteristics: As scheduled on Drawings.

2.4 CLOSE-COUPLED MULTI-STAGE IN-LINE CENTRIFUGAL PUMPS

A. Manufacturers
1. Goulds

B. Description: a non-self-priming vertical multistage pump coupled to a standard motor. The liquid end, located between the upper cover and the pump casing, is held in place by tie rods. The pump casing is available with different configurations and connection types. Temperature of pumped liquid: -20.0°F to 250.0°F standard version. Direction of rotation: clockwise looking at the pump from the top down (marked with an arrow on the adapter and on the coupling).

C. Pump Construction: Cast Iron/304SS ANSI Flange with Class 125 Flange Rating. Maximum Allowable Working Pressure of 200 Psi g. Seal housing chamber designed to prevent the accumulation of air in the critical area next to the mechanical seal. Mechanical seal according to EN 12756 (ex DIN 24960) and ISO 3069.

D. Motor: Standard NEMA 182TC Frame motor premium efficient totally enclosed fan cooled. 1800 RPM nominal. 3 phase version, 4 pole: 208-230/460 V, 60Hz.

E. Capacities and Characteristics: As scheduled on Drawings.

2.5 SEPARATELY COUPLED, VERTICAL, IN-LINE CENTRIFUGAL PUMPS

A. Manufacturers:

1. Armstrong Pumps Inc.
2. Aurora Pump; Division of Pentair Pump Group.
3. Bell & Gossett; Div. of ITT Industries.

4. PACO Pump: Division of Grundfos Pumps Corporation.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted vertically on a cast iron support stand. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 200 deg F.

C. Pump Construction:

1. Casing: Radially split, cast iron, with replaceable bronze wear rings, threaded gage tappings at inlet and outlet, and flange connections.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
3. Pump Shaft: Carbon steel, uniform diameter thru water chamber with 316 stainless steel shaft sleeves or 416 stainless steel continuous construction.
4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and EPT bellows and gasket. Include water slinger on shaft between motor and seal.
5. Pump Bearings: Radial and thrust bearings; single row, inboard and double row outboard, regreaseable ball bearings, 100,000 hours average life. Bearings to be removable without disassembling the pump.

D. Shaft Coupling: T.B. Woods Dura-Flex® flexible shock arresting coupling and coupling guard for pumps less than 100HP and a Falk Steelflex® Grid coupling and guard for 100HP and larger.

E. Motor: Single speed, with grease-lubricated ball bearings, unless otherwise indicated; rigidly mounted to pump casing with lifting eye and supporting lugs in motor enclosure. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment." Outdoor applications shall have a TEFC (Totally Enclosed Fan Cooled) motor and indoor locations shall have an open drip-proof motor; voltage and horsepower as scheduled.

F. Capacities and Characteristics: As scheduled on Drawings.

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

A. Manufacturers:

1. Armstrong Pumps Inc.
2. Aurora Pump; Division of Pentair Pump Group.
3. Bell & Gossett; Div. of ITT Industries.
4. PACO Pump: Division of Grundfos Pumps Corporation.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, end-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for base mounting, with pump and motor shafts horizontal. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 200 deg F.

C. Pump Construction:

1. Casing: Radially split, cast iron, with replaceable bronze wear rings, threaded gage 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 attached piping to allow removal and replacement of impeller without disconnecting piping or requiring the realignment of pump and motor shaft.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
3. Pump Shaft: Stainless steel.
4. Shaft Sleeve: Renewable ceramic coated stainless steel of minimum 600 Brinell hardness.
5. Mechanical Seal: Babbit filled carbon rotating ring against a tungsten carbide stationary seat held by a stainless steel spring, and Buna-N bellows and gasket. Water flush design to provide flush across face of mechanical seal.
6. Pump Bearings: Grease-lubricated ball bearings contained in cast-iron hosing with grease fittings, suitable for in-service lubrication. Rated life of bearings not less than 80,000 hours.

D. 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. EPDM coupling sleeve for variable-speed applications.

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

F. Baseplate: Cast iron or rolled steel, factory fabricated with raised lip and drain tappings. Fabricate to mount pump casing, coupling guard, and motor.

G. Motor: Single speed, with grease-lubricated ball bearings, unless otherwise indicated; secured to baseplate, with adjustable alignment. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

H. Capacities and Characteristics: As scheduled on drawings.

2.7 SEPARATELY COUPLED, BASE-MOUNTED, DOUBLE-SUCTION CENTRIFUGAL PUMPS

A. Manufacturers:

1. Armstrong Pumps Inc.
2. Aurora Pump; Division of Pentair Pump Group.
3. Bell & Gossett; Div. of ITT Industries.
4. PACO Pump: Division of Grundfos Pumps Corporation.

B. Description: Factory-assembled and -tested, centrifugal, impeller-between-bearings, separately coupled, double-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for base mounting, with pump and motor shafts horizontal. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 200 deg F.

C. Pump Construction:

1. Casing: Horizontally split, cast iron, with replaceable bronze wear rings, threaded gage tappings at inlet and outlet, drain plug at bottom and air vent at top of volute, and ASME B16.1, Class 125 flanges. Casing supports shall allow removal and replacement of impeller without disconnecting piping.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, and keyed to shaft. Trim impeller to match specified performance.
3. Pump Shaft: Stainless steel.
4. Shaft Sleeve: Renewable hardened stainless steel or ceramic coated stainless steel of minimum 600 Brinell hardness.
5. Mechanical Seal: Babbit filled carbon rotating ring against a tungsten carbide stationary seat held by a stainless steel spring, and EPT bellows and gasket. Water flush design to provide flush across face of mechanical seal.
6. Pump Bearings: Radial and thrust bearings; single row, inboard and double row outboard, regreaseable ball bearings, 100,000 hours average life. Bearings to be removable without disassembling the pump.

D. Shaft Coupling: Molded rubber insert and interlocking spider capable of absorbing vibration. T.B. Woods Dura-Flex® flexible shock arresting coupling and coupling guard for pumps less than 100HP and a Falk Steelflex® Grid coupling and guard for 100HP and larger.

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

F. Baseplate: Cast or rolled steel, factory fabricated with raised lip and drain tappings. Fabricate to mount pump casing, coupling guard, and motor.

G. Motor: Single speed, with grease-lubricated ball bearings, unless otherwise indicated; secured to mounting frame, with adjustable alignment. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment." Outdoor applications shall have a TEFC (Totally Enclosed Fan Cooled) motor and indoor locations shall have an open drip-proof motor; voltage and horsepower as scheduled.

H. Capacities and Characteristics: As scheduled on drawings.

2.8 SEPARATELY COUPLED, VERTICAL-MOUNTED, TURBINE CENTRIFUGAL PUMPS

A. Manufacturers:

1. Armstrong Pumps Inc.
2. Aurora Pump; Division of Pentair Pump Group.
3. Bell & Gossett; Div. of ITT Industries.
4. PACO Pump: Division of Grundfos Pumps Corporation.

B. Description: Factory-assembled and -tested, single-stage, centrifugal, impeller-between-bearings, end-suction pump as defined in HI 2.1-2.2 and HI 2.3; designed for installation with pump and motor shafts mounted vertically and projecting into a sump.

Rate pump for 175-psig minimum working pressure and a continuous water temperature of 200 deg F.

C. Pump Construction:

1. Pump Bowl: Cast iron, with replaceable bronze wear ring, cone strainer, and suction bell.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, and keyed to shaft. For pumps not frequency-drive controlled, trim impeller to match specified performance. All impellers shall be dynamically balanced, and shall be securely fastened to the shaft with tapered steel lock collars, threaded lock collars or double keys. The impellers shall be adjustable vertically by external means at the driver location.
3. Pump Shaft: AISI Type 416 stainless steel turned and ground, supported by bronze bearings above and below each impeller. The suction bell bearing shall be extra long and permanently lubricated and sealed with a bronze sand collar. The discharge case shall also contain an extra long support bearing. Provide in sections not over 10 feet in length. The size of the shaft shall be no less than determined by ANSI specification B58.1. Steel lineshaft couplings with a safety factor of 1-1/2 times shaft safety factor shall join the lineshafts; these threaded couplings shall have left-hand threads to tighten during pump operation.
4. Pump Bearings: Water-lubricated bronze and rubber sleeve bearings contained in cast-iron housing. A rigid type bearing retainer shall be provided at each column joint to support the lineshaft bearings at maximum 5 foot centers. 304 or 410 stainless steel sleeves shall be provided on the lineshaft at each lineshaft bearing location; these shall be field replaceable and securely fastened to the shaft.
5. Pump Column: ASTM A 53/A 53M, Grade B steel pipe.
6. Mechanical Seal: Mechanical seal consisting of AISI Type 416 stainless steel rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Include water slinger on shaft between motor and seal. Flushing fit.: Utex or Owner approved substitution. Seal shall be replaceable without removing the motor or disturbing the piping.
7. Packed Seal: Heavy duty stuffing box, with a minimum of four rings of asbestos free graphite-impregnated braided yarn with bronze split lantern ring between center two graphite rings, and bronze packing gland.

D. Shaft Coupling: Keyed with locking collets.

E. Discharge Head: ASME B16.1, Class 250 discharge flange with threaded gage tapping. Top of discharge head shall have a registered fit to accurately locate the driver.

F. Drive Ratchet: Nonreversing ratchet.

G. Hollow Shaft Motor: Single speed, with grease-lubricated ball bearings, unless otherwise indicated; secured to discharge head. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment." Electric motors for vertical turbine pumps shall be of the vertical solid shaft or vertical hollowshaft high thrust design. The motors shall be designed to carry the thrust load of the pump. The motor shall be keyed to the steel shaft, and shall have an adjustable coupling.

1. Enclosure: Totally Enclosed - Severe duty.
2. Enclosure Materials: Cast iron.
3. Motor Bearings: Grease lubricated.

H. Unusual Service Conditions:

1. Ambient Temperature: 95 deg F.
2. Altitude: 100 feet above sea level.
3. High humidity.

I. Capacities and Characteristics: As scheduled on drawings.

2.9 AUTOMATIC CONDENSATE PUMP UNITS

A. Manufacturers:

1. Aurora Pump; Division of Pentair Pump Group.
2. Beckett Corporation.
3. Flowserve Corporation; Div. of Ingersoll-Dresser Pumps.
4. Hartell Pumps Div.; Milton Roy Co.
5. Little Giant Pump Co.; Subsidiary of Tecumseh Products Co.

B. Description: Packaged units with corrosion-resistant pump, plastic tank with cover, and automatic controls. Include factory- or field-installed check valve and a 72-inch-minimum, electrical power cord with plug.

2.10 PUMP SPECIALTY FITTINGS

A. Suction Diffuser: Angle pattern, 175-psig pressure rating, cast or ductile-iron body and end cap, flanged pump-inlet fitting with flanged or grooved system outlet fitting; with bronze or stainless steel startup and bronze or stainless-steel permanent strainers; bronze or stainless-steel straightening vanes; drain plug; and 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 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 are to be installed.

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

3.2 CONCRETE BASES

A. Install pumps on concrete bases of dimensions required for pumps and controllers. Refer to Division 23 Section "Common Work Results for HVAC" And see Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around full perimeter of base.
2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
4. Install anchor bolts to elevations required for proper attachment to supported equipment.

B. Cast-in-place concrete materials and placement requirements are specified in Division 03.

3.3 PUMP INSTALLATION

A. Comply with HI 1.4 or HI 2.4 as applicable.

B. Install pumps with access for periodic maintenance including removal of 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. Provide supports under elbows on pump suction and discharge lines.

D. Install continuous-thread hanger rods of sufficient size to support pump weight. Vibration isolation devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment." Fabricate brackets or supports as required. Hanger and support materials are specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."

E. Suspend vertically mounted, in-line centrifugal pumps independent of piping. Install pumps with motor and pump shafts vertical. Use continuous-thread hanger rods of sufficient size to support pump weight. Vibration isolation devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment." Hanger and support materials are specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."

F. Set base-mounted pumps on concrete foundation. Disconnect coupling before setting. Do not reconnect couplings until alignment procedure is complete.

1. Support pump baseplate on rectangular metal blocks and shims, or on metal wedges with small taper, at points near foundation bolts to provide a gap of 3/4 to 1-1/2 inches between pump base and foundation for grouting.
2. Adjust metal supports or wedges until pump and driver shafts are level. Check coupling faces and suction and discharge flanges of pump to verify that they are level and plumb.

G. Automatic Condensate Pump Units: Install units for collecting condensate and extend discharge as shown on drawings.

3.4 ALIGNMENT

A. Align pump and motor shafts and piping connections after setting on foundation, grout has been set and foundation bolts have been tightened, and piping connections have been made.

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

C. Adjust pump and motor shafts for angular and offset alignment by methods specified in HI 1.1-1.5, "Centrifugal Pumps for Nomenclature, Definitions, Application and Operation and HI 2.1-2.5, " Vertical Pumps for Nomenclature, Definitions, Application and Operation."

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.

3.5 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to machine to allow service and maintenance.

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

D. Install suction and discharge pipe sizes equal to or greater than diameter of pump nozzles. Decrease to pump nozzles from line size with long radium reducing elbows or reducers.

E. Install silent spring loaded check valve and throttling valve on discharge side of pumps.

F. Install Y-type or T-type (grooved) strainer and shutoff valve on suction side of pumps.

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

H. Install pressure gages on pump suction and discharge, at integral pressure-gage tapping.

I. Install check valve and ball valve on each condensate pump unit discharge.

J. Provide drains from baseplates and stuffing boxes, piped to spill over floor drains.

K. Provide vent valves and drain on pump casings.

L. Pipe up flush filter for mechanical seals, with bypass line from pump discharge to external gland connection and filter or cyclone separator in line.

M. Install electrical connections for power, controls, and devices.

N. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

O. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.6 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. Check piping connections for tightness.
3. Clean strainers on suction piping.
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. If pump is bound or drags, do not operate until cause of trouble is determined and corrected.
    c. Verify that pump is rotating in the 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.

3.7 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps. Coordinate with the requirements of Sections 01 91 13 and 23 08 00.

END OF SECTION 23 21 23

SECTION 23 23 00 - REFRIGERANT PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Basic Requirements: Provisions of Section 23 00 10, Basic HVAC Requirements are part of this Section.

1.2 WORK INCLUDED

A. Refrigerant (RS/RL/RHG) Piping.

B. Valves and Specialties

1.3 DEFINITIONS

A. The pipe sizes given in this document shall be construed as nominal pipe sizes.

1.4 QUALITY ASSURANCE

A. All material provided under this section shall be standard catalogued products of recognized manufacturers regularly engaged in the production of such products, and shall be of the manufacturer's most recent design that is in regular production.

B. Each item provided under this section shall meet the requirements for that item as installed and used, in accordance with the following standards:

1. Metallic Piping Systems employing mechanical joints and grooved-end pipe - ASME/ANSI B-31.9
2. Refrigeration Piping and Heat Transfer Components - ASME/ANSI B31.5
3. Safety Code for Refrigeration Systems – ASHRAE 15
4. Refrigerant Containing Components and Accessories – UL 207

C. Each piping system shall be in accordance with the system design pressures shown in paragraph 2.1 - Materials, this specification section.

D. All materials provided under this section shall be new, except where the specifications and/or drawings permit the reuse of certain existing materials.

1.5 APPLICABLE PUBLICATIONS

A. The publications listed below form a part of this Section to the extent referenced. The publications are referenced in the text by the basic designation only.

B. The work and materials listed in this Section shall be provided in accordance with the standards and requirements set forth in the applicable portions of the latest editions of the referenced publications.

1. American National Standards Institute (ANSI) Standards
2. American Petroleum Institute (API) Specification
3. American Society of Mechanical Engineers (ASME) Publications
4. American Society for Testing and Materials (ASTM) Publications
5. American Welding Society (AWS) Publication
6. American Water Works Association (AWWA) Standards
8. The Manufacturer's Standardization Society of the Valve and Fittings Industry (MSS) Publications
9. National Fire Protection Association (NFPA) Standards
10. National Sanitation Foundation (NSF) Testing Laboratory Standards.
11. Plastic Pipe Institute (PPI) Manual.
12. Underwriters Laboratories (UL)

1.6 SUBMITTALS

A. All submittals shall be made in accordance with Division 01 requirements.

B. Materials List: Submit a list identifying the specific type of material that will be used for each piping system. Include pipe, pipefittings, valves and joints. Include the basic designation of the publication applicable for each type of material and method.

C. Refrigeration Piping Requirements: Submit a letter from the refrigeration equipment manufacturer stating that the refrigeration piping system, as shown on the contract documents, is acceptable for the equipment the manufacturer proposes to furnish, or submit drawings prepared by an authorized representative of the refrigeration equipment manufacturer.

PART 2 – PRODUCTS

2.1 PRODUCT, GENERAL

A. Recycled Content of Steel Products: Post-consumer recycled content plus one-half of pre-consumer recycled content not less than 25%.

B. Recycled Content of Copper Products: Post-consumer recycled content plus on-half of pre-consumer recycled content not less than 25%.

C. Refer to Section 01 81 13.14 “Sustainable Design Requirements – LEED v4 BD+C” for additional information and requirements for recycled content. Provide material cost data specific to this material.

D. Environmental Product Disclosure: Provide an Environmental Product Declarations (EPD) that conforms with one of the followings:

1. Product specific declarations in accordance to ISO 1404
2. Environmental Product Declarations conforming to ISO 14025, 14040, 14044 and EN 15804 or ISO 21930.
3. Industry Wide Product Specific Type III EPD Third Party Certification.

E. Provide detailed material cost data for this scope of work.

22 MATERIALS

A. Refrigerant (RS/RL/RHG) Piping.

1. Piping carrying Refrigerants shall be ACR copper.
2. ACR Copper Refrigerant Piping:

   a. Piping, 3" and smaller: Type ACR hard-drawn copper tubing, ASTM B88, ANSI H23.1.
   b. Fittings, 3" and smaller, all types, wrought copper: ASTM B16.22, ANSI B16.22. All 90° elbows shall be the long radius type.
   c. Brazing: Contractors Option:

      (1) 5% silver, 6% phosphorus, balance copper, 1190°F melting point. AWS A5.8 number BCuP -3. J.W. Harris Stay-Silv® 5 or approved substitution.
      (2) 15% silver, 5% phosphorus, balance copper, 1190°F melting point. AWS 5.8 number BCuP-5. J.W. Harris Stay-Silv® 15 or approved substitution.
      (3) 6% silver, 6.1% phosphorus, balance copper, 1190°F melting point. QQ-B-654A number BCuP -5. J.W. Harris Dynaflow® 5 or approved substitution.

   d. Unions used shall be specifically designed for refrigeration piping.

2.3 VALVES AND SPECIALTIES

A. Solenoid Valves:

1. Liquid line shut off.
2. Normally closed.
3. Manual lift stem.
4. Pilot operated.
5. Synthetic seat for permanent tight shut-off.
6. 120 volt solenoid coil (interchangeable).
7. Top grade brass, bronze and/or semi-steel body materials.
8. Acceptable Manufacturers: Sporlan, Alco, Hubbell.

B. Filter Drier:

1. Replaceable core type.
2. Heavy steel, cadmium plated with external coat of paint.
3. All internal parts cadmium plated.
4. Outlet seal gasket with spring to prevent bypassing.
5. Copper fittings brazed to steel shell, suitable for soldering with Sil-Fos or Phos-Copper solder.

6. Molded porous core elements.
7. Tie rod assembly to permit external assembly with one piece insert.
8. Bolt and nut attachment.
9. Size for refrigerant capacity and tonnage at 2 psi pressure drop.
10. Acceptable Manufacturers: Sporlan, Alco, Hubbell.

C. Moisture and Liquid Indicators:

1. Suitable for R-407c.
2. Accurately calibrated to change color for indication of moisture.
3. Large full view sight glass.
4. Removable indicator element for sizes 1-3/8" and up. Remove before soldering.
5. Full line size for liquid lines up to 2-1/8" O.D. 3/8" bypass indicator with preformed installation kit on larger sizes.
6. Acceptable Manufacturers: Sporlan, Alco, Hubbell.

D. Sight Glasses:

1. Similar to Sporlan "See-all" moisture and liquid indicator with solder type connections.
2. Install sight glass of the same size as the liquid line.

E. Miscellaneous Valves and Accessories:

1. Drain valves for all pressure vessels.
2. Dual pressure relief valves with manifold for all pressure vessels.
3. Refrigerant service valves where indicated.
4. Pressure - Temperature Test Ports and Test Kit:

   a. Brass or stainless steel body with threaded cap and gasket.
   b. Two self closing valves with intermediate pocket for added pressure protection.
   c. Pressure temperature test kits consisting of 0- 150 psi pressure gauge with adapter, 25-125°F testing thermometer, 0-220°F testing thermometer, gauge adopted and protective carrying case (two required).

F. Thermometers:

1. Red reading type, glass front, iron or phenol case, adjustable pattern, separable socket.
2. Shall have 9 inch scale and 12 inch case.
3. Operating range shall occur in middle half of total range
4. Acceptable Manufacturers: Mueller, Taylor, Rochester.

G. Gauges:

1. Liquid pressure gauges constructed with bronze tube, stainless steel movement, white dial, black micrometer, adjustable pointer, iron case with black flange iron or phenol screwed ring, bottom connection.
2. Case diameter size shall be 4-1/2 inches minimum.
3. Operating range shall occur in middle half of total gauge range.
4. Provide needle valve for all gauges.
5. Acceptable Manufacturers: Crosby-Ashton Type AAO, Ashcroft, Lonegran

H. Refrigerant Charge: Complete operating charge of R-407C.

I. High pressure receiver designed and constructed for 300 psi design working pressure with liquid seal float control, automatic liquid feed valve, drain and equalizer connections, liquid line filter-drier, moisture indicator, three service and bypass valves, charge valve and manual purge valve.

J. Locking Refrigerant Caps: Precision machined from high grade brass surrounded by a protective aluminum shroud. Provide a 3 year warranty. Provide one multi key per project to maintenance personnel.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General:

1. Furnish and install piping, fittings and appurtenances required to complete the piping systems shown on the drawings. Elbows shall be long radius type. Tees may not be field fabricated.
2. Run piping to true alignment, generally parallel or perpendicular to building walls, floors and ceilings, and with uniform grades and spacing, so as to present a neat and workmanlike appearance.
3. Care shall be paid to the exact locations of piping with respect to equipment, ducts, conduits, slabs, beams, lighting fixtures, columns, ceiling suspension systems, etc. to provide maximum access to mechanical and electrical equipment in the building. Close coordination and cooperation shall be exercised with other trades in locating the piping in the best interests of the Owner. The drawings and specifications covering other work to be done in the building shall be carefully studied and arrangements made to avoid conflict.
4. Not all necessary pipe offsets are indicated on the drawings because of the small scale. The various runs of piping to be installed shall be studied and adjustments made in exact routings as may be required for proper installation.
5. Conflicts arising during the erection of piping shall be brought to the attention of the Owner's Representative. No improvising or field changes will be permitted without the approval of the Owner's Representative.
6. Use full lengths of pipe wherever possible. Short lengths of pipe with couplings will not be permitted. Cut to exact measurement and install without forcing or spring unless otherwise shown on the drawings or specified.
7. Avoid tool marks and unnecessary pipe threads. Burrs formed when cutting pipe shall be removed by reaming. Before installing any pipe, care shall be taken that the inside is thoroughly cleaned and free of cuttings and foreign matter. Measures shall be taken to preserve this cleanliness after erection.
8. Arrange pipe connections to valves and specialties so that there is clearance for easy removal of the valve or specialty from the line, and also for the removal of the valve bonnet and interior, and the specialty top and bottom and interior, except where otherwise approved by the Owner's Representative.
9. Erect piping in such a manner so as to obtain sufficient flexibility and to prevent excessive stresses in materials and excessive bending movements at joints or connections to equipment. Make allowances throughout for expansion and contraction of piping. Provide each riser and horizontal run of piping with expansion loops, expansion joints, or expansion compensators where indicated and required. Securely anchor and adequately guide pipe as required or where indicated to force expansion to the expansion device without bending, binding, or misalignment of pipe. Branch connections from mains to risers shall be made

with ample swing or offset to avoid undue strain on fittings or short pipe lengths. Where indicated, in lieu of expansion loops, expansion joints, or expansion compensators, horizontal runs of pipe shall be anchored at approximately midway of the run to force expansion, evenly divided, toward the mains and risers to provide for expansion and contraction of piping. Flexibility shall be provided by installing one or more turns in the line so that piping will spring enough to allow for expansion without straining.

10. Installed piping shall not interfere with the operations or accessibility of doors or windows and shall not encroach on aisles, passageways and equipment, and shall not interfere with the servicing or maintenance of any equipment. Adjacent pipelines shall be grouped in the same horizontal or vertical plane.
11. Where lines are purposely pitched for drainage, an accurate grade shall be maintained. No lines shall be supported in such a manner as to permit deflection, due to gravity, sufficient to pocket the lines when full of liquid. Grade mains as indicated by arrows on the drawings and in accordance with gradient as indicated in attached Piping Schedule.
12. Piping found to have water hammer or other objectionable vibrations which cannot be eliminated by proper grading or other natural means, shall be braced, trapped or hung with shock absorbing hangers and equipped with air chambers, mechanical shock absorbers, flexible pipe connections or otherwise silenced using approved means.
13. Use building steel wherever possible for supporting pipe hangers. Main structural steel shall not be drilled, cut or burned for hangers without the approval of the Owner's Representative. Expansion bolts shall be used only upon the approval of the Owner's Representative.
14. Install unions or flanges in piping connections to equipment, regulating valves, and wherever necessary to facilitate the dismantling of piping and/or removal of valves and other items requiring maintenance.
15. Avoid bushings. Reducing fittings shall be used wherever practical.
16. The drawings indicate the size of piping and connections, and if certain sizes are omitted or unclear, obtain additional information before proceeding.
17. The piping drawings have been worked out with a view to the most economical installation, taking into consideration accessibility and appearances, and the Contractor must follow the drawings accurately and if it is found impractical to install the work in accordance with the drawings and specifications, the Contractor shall notify the Owner's Representative before making any changes and get their approval or revised drawings before proceeding with the work. Verify all measurements on the job before cutting pipes or having piping fabricated, and be responsible for the correct location of all pipe connections, also check sizes and standard of outlets on the equipment, including the dimensions and drilling of flanges, etc.
18. Copper tubing and galvanized steel shall not be mixed in any one run of piping.
19. Change in direction shall be made with fittings, except that bending of steel and copper pipe 4 inches and smaller will be permitted, provided a pipe bender is used and wide sweep bends are formed. The center-line radius of bends shall be not less than 6 diameters of the pipe. Bent pipe showing kinks, wrinkles, flattening, or other malformations is not acceptable.
20. Threaded joints shall be made with tapered threads in accordance with ANSI B2.1, and made tight with an approved pipe thread joint compound or material, applied to the male threads only. Use compounds sparingly and apply with caution to ensure that compounds do not enter piping systems. When pipe joint is made up a maximum of 3 threads shall be visible.
21. Joints for plastic pipe shall be made in accordance with PPI Piping Manual.
22. Connections between ferrous and nonferrous metallic pipe shall be made with dielectric unions or flanges.
23. Connections between plastic and metallic pipe, between plastic and glass pipe, and between metallic and glass pipe, shall be made with transition fittings manufactured for the specific purpose.

24. Unions and flanges shall not be concealed in walls, partitions, or above inaccessible ceilings.

B. Valve and Specialties Applications

1. Install service valves for gage taps at inlet and outlet of hot-gas bypass valves and strainers if they are not an integral part of valves and strainers.
2. Install a check valve at the compressor discharge and a liquid accumulator at the compressor suction connection.
3. Install solenoid valves upstream from each expansion valve and hot-gas bypass valve. Install solenoid valves in horizontal lines with coil at top.
4. Install thermostatic expansion valves as close as possible to distributors on evaporators.

    a. Install valve so diaphragm case is warmer than bulb.
    b. Secure bulb to clean, straight, horizontal section of suction line using two bulb straps. Do not mount bulb in a trap or at bottom of the line. Verify proper location for the bulb with the valve manufacturer
    c. If external equalizer lines are required, make connection where it will reflect suction-line pressure at bulb location.

5. Install safety relief valves where required by ASME Boiler and Pressure Vessel Code. Pipe safety relief-valve discharge line to outside according to ASH RAE 15.
6. Install moisture/liquid indicators in liquid line at the inlet of the thermostatic expansion valve or at the inlet of the evaporator coil capillary tube on each circuit.
7. Install strainers upstream from and adjacent to the following unless they are furnished as an integral assembly for device being protected:

    a. Solenoid valves.
    b. Thermostatic expansion valves.
    c. Hot-gas bypass valves.
    d. Compressor.

8. Install filter dryers in liquid line between compressor and thermostatic expansion valve on each circuit.
9. Install receivers sized to accommodate pump-down charge.
10. Install flexible connectors at compressors.
11. Locking Refrigerant Caps: Provide at all exterior refrigerant service access ports (Schrader valves).
12. Install gauges with dial in vertical position. Locate between shut-off valve and equipment directly adjacent to equipment within normal visual range of operator standing on floor.
13. Provide gauges where shown on drawings, including the following locations:

    a. Ice builders; leaving each builder on the pumped liquid return header.
    b. Barrel chiller; entering and leaving the pumped liquid lines.
    c. Compressor oil coolers; entering and leaving condenser water lines.
    d. Evaporative condenser; entering and leaving refrigerant lines.
    e. Refrigerant pumps; entering and leaving the pumped liquid lines.

14. Provide nickel plated brass escutcheons or floor plates, around pipes piercing floors and walls in finished spaces. Fit around insulation or around pipe if uninsulated. Secure to pipe with setscrew. Provide deep escutcheon where sleeve projects beyond finished surface

C. Refrigerant Systems Additional Requirements:

1. Installation shall be in accordance with ANSI B31.5 Refrigeration Piping, unless specified otherwise herein.
2. Brazing procedures and operators shall be qualified in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.
3. Refrigerant pipeline accessories that may be damaged by heat shall be disassembled prior to joint brazing. Reassemble accessories after joint brazing operations are completed.
4. Joints shall be made with solder-type fittings. The outside surface of the tube where engaged in the fitting, and the inside surface of the fitting in contact with the tube, shall be cleaned with an abrasive material before brazing. Self-cleaning compounds are not allowed. Care shall be taken to prevent annealing of tube and fittings when making connections. Brazed joints shall be made with flux and the previously specified silver-brazing alloy. The brazing alloy shall be applied and drawn through the full fitting length. Excess brazing alloy shall be wiped from the joint before the brazing alloy hardens. Joints shall be made with heat applied uniformly around the entire circumference of the tube and fittings. Remove all excess flux for a clear visual inspection of all brazed connections.
5. Refrigerant piping installed below concrete slab- on-grade shall be installed in continuous runs without joints, and shall be encased in SCH 40 PVC conduit. Ends of conduit shall be sealed watertight.

3.2 BRAZING AND SOLDERING

A. Operator and Procedure Qualifications: All brazing operators and all brazing procedures shall be qualified in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

B. Brazing: Silver braze joints in accordance with MSS-SP-73 "Silver Brazing Joints for Wrought and Cast Solder Joint Fittings".

C. Soldering:

1. Joints in copper tubing shall be made with solder- type fittings. Outside surface of the tube where engaged in the fitting, and inside surface of the fitting in contact with the tube, shall be cleaned with an abrasive material before soldering. Self- cleaning compounds shall not be used. Care shall be taken to prevent annealing of tube and fittings when making connections. The solder joint shall be made with flux and wire form solder, except brazed joints. The flux shall be a mildly corrosive liquid or a petroleum based paste containing chlorides of zinc and ammonium. Solder shall be applied and drawn through the full fitting length. Excess solder shall be wiped from joint before solder hardens. Joints in copper tube sizes 2-1/2 inches and larger shall be made with heat applied uniformly around the entire circumference of the tube and fittings by a multi-flame torch. Use of oxy-acetylene cutting torch in lieu of multi-flame torch is not permitted. Disassemble valves and other accessories that may be damaged by heat before soldering.

3.3 TESTING OF PIPING SYSTEMS:

A. Each piping system, after erection, shall be subjected to a pressure test. The test requirements shall be as follows:

1. General: Furnish everything required for the tests. Notify Architect/Engineer at least 48 hours before any testing is performed. Independent Agent/Owner shall verify pressure test

and sign off. Report to be furnished to Architect/Engineer. Testing shall be performed at the completion of each phase of the project.

2. Refrigerant Piping Systems shall be tested with dry carbon dioxide, or nitrogen, at 315 psig for the high side, and at 245 psig for the low side. If leaks are to be detected by use of an electronic halogen detector, or a halide torch, the system shall be pressurized with refrigerant gas prior to introduction of dry carbon dioxide or nitrogen into the system. Pre-charging of system with refrigerant gas is not necessary for soap bubble leak detection method.
3. Leaks, if any, shall be located, repaired, and retested in accordance with the test method specified for the system in which the leaks are located.

B. Prior to testing a system, the Contractor shall provide the proper Building Official and the Owner's Representative with not less than 72 hours notice of the proposed test. The Contractor shall obtain approval of the test results. Where written approval is required, the Contractor shall obtain such written approval, and submit a copy of the approval.

C. Work requiring testing shall not be covered, or otherwise concealed, until testing is completed and approval is granted.

D. Work, or portions of work, that is altered in any way after testing and approval shall be retested, witnessed, and approval obtained.

E. Systems requiring hydrostatic tests shall be protected from damage caused by freezing. After tests are completed drain all sections of pipe, including traps, or fill undrained sections and traps with antifreeze solution. Vent all high points to release vacuum and ensure complete drainage of closed systems, and blow out piping with compressed air to remove trapped water.

F. Duration of tests, unless specified otherwise, shall be the time required to examine each joint in the system being tested.

G. During tests, isolate system components that have test pressures less than pressures specified for system tests.

H. Use clean soapy water applied to exterior of joints to locate leaks in systems using compressed air, dry carbon dioxide, or nitrogen, under positive pressure as a test medium.

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SECTION 23 3113 - METAL DUCTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. Section Includes:

1. Single-wall rectangular ducts and fittings.
2. Double-wall rectangular ducts and fittings.
3. Single-wall round and flat-oval ducts and fittings.
4. Double-wall round and flat-oval ducts and fittings.
5. Sheet metal materials.
6. Duct liner.
7. Sealants and gaskets.
8. Hangers and supports.

B. Related Sections:

1. Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing requirements for metal ducts.
2. Division 23 Section "Air Duct Accessories" for dampers, sound-control devices, duct-mounting access doors and panels, turning vanes, and flexible ducts.

1.3 PERFORMANCE REQUIREMENTS

A. Delegated Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and performance requirements and design criteria indicated in "Duct Schedule" Article.

B. Structural Performance: Duct hangers and supports shall withstand the effects of gravity loads and stresses within limits and under conditions described in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and ASCE/SEI 7.

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

1.4 SUBMITTALS

A. Product Data: For each type of the following products:

1. Liners and adhesives.
2. Sealants and gaskets.

B. LEED V4 BD+C Submittals:
1. Sustainable Design Documentation Submittals: Refer to section 01 81 13.14 “Sustainable Design Requirements – LEED V4 BD+C”.
a. Product Data for Metal Ductwork: Documentation for Leadership Extraction Practices in the following:
1. Leadership Extraction Practices for Recycled Content
2. Provide material cost breakout for this scope of work

C. Shop Drawings:

1. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
2. Factory- and shop-fabricated ducts and fittings.
3. Duct layout indicating sizes, configuration, liner material, and static-pressure classes.
4. Elevation of top and bottom of ducts.
5. Dimensions of main duct runs from building grid lines.
6. Fittings.
7. Reinforcement and spacing.
8. Seam and joint construction.
9. Penetrations through fire-rated and other partitions.
10. Equipment installation based on equipment being used on Project.
11. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.
12. Hangers and supports, including methods for duct and building attachment and vibration isolation.

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

1. Duct installation in congested spaces, indicating coordination with general construction, building components, and other building services. Indicate proposed changes to duct layout.
2. Suspended ceiling components.
3. Structural members to which duct will be attached.
4. Size and location of initial access modules for acoustical tile.
5. Penetrations of smoke barriers and fire-rated construction.
6. Items penetrating finished ceiling including the following:

a. Lighting fixtures.
b. Air outlets and inlets.
c. Speakers.

d. Sprinklers.
e. Access panels.
f. Perimeter moldings.

E. Welding certificates.

F. Field quality-control reports.

1.5 QUALITY ASSURANCE

A. Welding Qualifications: Qualify procedures and personnel according to: AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.

B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."

C. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

D. Mockups:

1. Before installing duct systems, build mockups representing static-pressure classes in excess of 3-inch wg. Build mockups to comply with the following requirements, using materials indicated for the completed Work:

    a. Five transverse joints.
    b. One access door(s).
    c. Two typical branch connections, each with at least one elbow.
    d. Two typical flexible duct or flexible-connector connections for each duct and apparatus.
    e. One 90-degree turn(s) with turning vanes.
    f. One fire damper(s).
    g. Perform leakage tests specified in "Field Quality Control" Article. Revise mockup construction and perform additional tests as required to achieve specified minimum acceptable results.

2. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

PART 2 - PRODUCTS

2.1 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

B. Transverse Joints: Select joint types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Longitudinal Seams: Select seam types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 4, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.2 DOUBLE-WALL RECTANGULAR DUCTS AND FITTINGS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following]:

1. McGill AirFlow LLC.
2. Semco Manufacturing, Inc.
3. Sheet Metal Connectors, Inc.

B. Rectangular Ducts: Fabricate ducts with indicated dimensions for the inner duct.

C. Outer Duct: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

D. Transverse Joints: Select joint types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

E. Longitudinal Seams: Select seam types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

F. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

1. Maximum Thermal Conductivity: 0.27 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.
2. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
3. Cover insulation with polyester film complying with UL 181, Class 1.

G. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C 534, Type II for sheet materials, and with NFPA 90A or NFPA 90B.

1. Maximum Thermal Conductivity: 0.25 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.

H. Inner Duct: Minimum 0.028-inch perforated galvanized sheet steel having 3/32-inch-diameter perforations, with overall open area of 23 percent.

I. Formed-on Transverse Joints (Flanges): Select joint types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible (2005)," Figure 2-1, "Rectangular Duct/Traverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

J. Longitudinal Seams: Select seam types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.3 SINGLE-WALL ROUND AND FLAT-OVAL DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Lindab Inc.
b. McGill AirFlow LLC.
c. SEMCO Incorporated.

d. Sheet Metal Connectors, Inc.
e. Spiral Manufacturing Co., Inc.

B. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension).

C. Transverse Joints: Select joint types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

1. Transverse Joints in Ducts Larger Than 60 Inches in Diameter: Flanged.

D. Longitudinal Seams: Select seam types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

1. Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.
2. Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.

E. Tees and Laterals: Select types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.4 DOUBLE-WALL ROUND AND FLAT-OVAL DUCTS AND FITTINGS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Lindab Inc.
2. McGill AirFlow LLC.
3. SEMCO Incorporated.
4. Sheet Metal Connectors, Inc.

B. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension) of the inner duct.

C. Outer Duct: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on static-pressure class unless otherwise indicated.

1. Transverse Joints: Select joint types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

   a. Transverse Joints in Ducts Larger Than 60 Inches in Diameter: Flanged.

2. Longitudinal Seams: Select seam types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

   a. Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.
   b. Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.

3. Tees and Laterals: Select types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible (2005)," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Inner Duct: Minimum 0.028-inch perforated galvanized sheet steel having 3/32-inch-diameter perforations, with overall open area of 23 percent.

E. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

1. Maximum Thermal Conductivity: 0.27 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.
2. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
3. Cover insulation with polyester film complying with UL 181, Class 1.

F. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C 534, Type II for sheet materials, and with NFPA 90A or NFPA 90B.

1. Maximum Thermal Conductivity: 0.25 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.

2.5 FLUSH FLAT SEAM RECTANGULAR DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class, except use sheet metal 2 gauge numbers heavier than required for classification with normal standing seam construction.

B. Transverse Joints: Fabricate joints in accordance with transverse joint detail shown on drawings. Provide all joints and seams, smooth, and alighted with no projections. In other aspects conform to the latest edition of SMACNA’s “HVAC Duct Construction Standards” for applicable sealing requirements, duct-support intervals and other provisions.

C. Longitudinal Seams: Select seam types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible." Install ducts with longitudinal seams at lop of ducts.

D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 2, "Rectangular Duct Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

E. Reinforcing: Install vertical stays for interval reinforcement at transverse joints and at 2 foot intervals along run of duct, as follows:

1. Ducts up to 60 inches wide: Provide 1 vertical stay at mid-point of duct.
2. Ducts 61 inches to 90 inches wide: Provide 2 vertical stays at third points of duct.
3. Ducts over 90 inches wide: Provide 3 vertical stays at quarter points of duct.
4. Vertical Stays: 10 USSG galvanized steel, free of burrs and rough edges, with both ends bent and fastened to the top and bottom of ducts.

2.6 SHEET METAL MATERIALS

A. General Material Requirements: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G90.
2. Finishes for Surfaces Exposed to View: Mill phosphatized.

C. PVC-Coated, Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G90.
2. Minimum Thickness for Factory-Applied PVC Coating: 4 mils on sheet metal surface of ducts and fittings exposed to corrosive conditions, and minimum 1 mil thick on opposite surface.
3. Coating Materials: Acceptable to authorities having jurisdiction for use on ducts listed and labeled by an NRTL for compliance with UL 181, Class 1.

D. Carbon-Steel Sheets: Comply with ASTM A 1008/A 1008M, with oiled, matte finish for exposed ducts.

E. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304 or 316, as indicated in the "Duct Schedule" Article; cold rolled, annealed, sheet. Exposed surface finish shall be No. 2B, No. 2D, No. 3, or No. 4 as indicated in the "Duct Schedule" Article.

F. Aluminum Sheets: Comply with ASTM B 209 Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view.

G. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

1. Where black- and galvanized-steel shapes and plates are used to reinforce aluminum ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials.

H. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

I. Recycled Content of Metal Ductwork : Postconsumer recycled content plus one-half of pre-consumer recycled content not less than 30 percent.

1. Refer to Section 01 81 13.14 “Sustainable Design Requirements - LEED v4 BD+C” for additional information and requirements for recycled content.

2.7 DUCT LINER

A. Fibrous-Glass Duct Liner: Comply with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. CertainTeed Corporation; Insulation Group.
   b. Johns Manville.
   c. Knauf Insulation.
   d. Owens Corning.
   e. Maximum Thermal Conductivity:

1) Type I, Flexible: 0.27 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.
2) Type II, Rigid: 0.23 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.

2.
3. Water-Based Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C 916.

a. For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
b. Adhesive shall comply with the testing and product requirements of the California Department of Public Health (CDPH) Standard Method v1.1 – 2010 and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

B. Flexible Elastomeric Duct Liner: Preformed, cellular, closed-cell, sheet materials complying with ASTM C 534, Type II, Grade 1; and with NFPA 90A or NFPA 90B.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Aeroflex USA Inc.
b. Armacell LLC.
c. Rubatex International, LLC

2. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
3. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

a. For indoor applications, use adhesive that has a VOC content of 30 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
b. Adhesive shall comply with the testing and product requirements of the California Department of Public Health (CDPH) Standard Method v1.1 – 2010 and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

C. Insulation Pins and Washers:

1. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.135-inch- diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.
2. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- thick galvanized steel; with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

D. Shop Application of Duct Liner: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 7-11, "Flexible Duct Liner Installation."

1. Adhere a single layer of indicated thickness of duct liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of duct liner is prohibited.
2. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.
3. Butt transverse joints without gaps, and coat joint with adhesive.
4. Fold and compress liner in corners of rectangular ducts or cut and fit to ensure butted-edge overlapping.
5. Do not apply liner in rectangular ducts with longitudinal joints, except at corners of ducts, unless duct size and dimensions of standard liner make longitudinal joints necessary.
6. Apply adhesive coating on longitudinal seams in ducts with air velocity of 2500 fpm or higher.
7. Secure liner with mechanical fasteners 4 inches from corners and at intervals not exceeding 12 inches transversely; at 3 inches from transverse joints and at intervals not exceeding 18 inches longitudinally.
8. Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or "Z" profiles or are integrally formed from duct wall. Fabricate edge facings at the following locations:

   a. Fan discharges.
   b. Intervals of lined duct preceding unlined duct.
   c. Upstream edges of transverse joints in ducts where air velocities are higher than 2500 fpm or where indicated.

9. Secure insulation between perforated sheet metal inner duct of same thickness as specified for outer shell. Use mechanical fasteners that maintain inner duct at uniform distance from outer shell without compressing insulation.

   a. Sheet Metal Inner Duct Perforations: 3/32-inch diameter, with an overall open area of 23 percent.

10. Terminate inner ducts with buildouts attached to fire-damper sleeves, dampers, turning vane assemblies, or other devices. Fabricated buildouts (metal hat sections) or other buildout means are optional; when used, secure buildouts to duct walls with bolts, screws, rivets, or welds.

2.8 SEALANT AND GASKETS

A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.

B. Two-Part Tape Sealing System:

1. Tape: Woven cotton fiber impregnated with mineral gypsum and modified acrylic/silicone activator to react exothermically with tape to form hard, durable, airtight seal.
2. Tape Width: As per manufacturer’s written instructions.
3. Sealant: Modified styrene acrylic.
4. Water resistant.
5. Mold and mildew resistant.
6. Maximum Static-Pressure Class: 10-inch wg, positive and negative.
7. Service: Indoor and outdoor.
8. Service Temperature: Minus 40 to plus 200 deg F.
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum.
10. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
11. Sealant shall comply with the testing and product requirements of the California Department of Public Health (CDPH) Standard Method v1.1 – 2010 and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers.” Retain one of first two paragraphs below. If retaining second paragraph, verify acceptability with authorities having jurisdiction.

C. Water-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Solids Content: Minimum 65 percent.
3. Shore A Hardness: Minimum 20.
4. Water resistant.
5. Mold and mildew resistant.
6. VOC: Maximum 75 g/L (less water).
7. Maximum Static-Pressure Class: 10-inch wg, positive and negative.
8. Service: Indoor or outdoor.
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

D. Flanged Joint Sealant: Comply with ASTM C 920.

1. General: Single-component, acid-curing, silicone, elastomeric.
2. Type: S.
3. Grade: NS.
4. Class: 25.
5. Use: O.
6. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealant shall comply with the testing and product requirements of the California Department of Public Health (CDPH) Standard Method v1.1 – 2010 and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

E. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

F. Round Duct Joint O-Ring Seals:

1. Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg and shall be rated for 10-inch wg static-pressure class, positive or negative.
2. EPDM O-ring to seal in concave bead in coupling or fitting spigot.
3. Double-lipped, EPDM O-ring seal, mechanically fastened to factory-fabricated couplings and fitting spigots.

2.9 HANGERS AND SUPPORTS

A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.

B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.

C. Strap and Rod Sizes: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct."

D. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A 603.

E. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A 492.

F. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.

G. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

H. Trapeze and Riser Supports:

1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.
2. Supports for Stainless-Steel Ducts: Stainless-steel shapes and plates.
3. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.

B. Install ducts according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.

C. Install round and flat-oval ducts in maximum practical lengths.

D. Install ducts with fewest possible joints.

E. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.

F. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.

G. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

H. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.

I. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.

J. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches.

K. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers. Comply with requirements in Division 23 Section "Air Duct Accessories" for fire and smoke dampers.

L. Protect duct interiors from moisture, construction debris and dust, and other foreign materials. Comply with the latest edition of SMACNA's "Duct Cleanliness for New Construction Guidelines" and in accordance with specification section 01 34 46, which ever is more stringent.

3.2 INSTALLATION OF EXPOSED DUCTWORK

A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.

B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.

C. Grind welds to provide smooth surface free of burrs, sharp edges, and weld splatter. When welding stainless steel with a No. 3 or 4 finish, grind the welds flush, polish the exposed welds, and treat the welds to remove discoloration caused by welding.

D. Maintain consistency, symmetry, and uniformity in the arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.

E. Repair or replace damaged sections and finished work that does not comply with these requirements.

3.3 INSTALLATION OF DUCTS OUTDOORS

A. Ducts shall be made completely watertight.

B. Construct ducts as follows to assure water run-off.

1. Arrange standing seams so as not to act as dams.
2. Erect ducts with longitudinal seams at bottom of duct.
3. Slope entire top of duct down towards side.
4. Provide vertical struts within duct to bow tap panels of duct into convex shape.
5. Erect ducts with mastic sealant within sheet metal joints.

3.4 DUCT SEALING

A. Seal ducts for duct static-pressure, seal classes, and leakage classes specified in "Duct Schedule" Article according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

B. Mastic sealant shall comply with California Department of Public Heath (CDPH) Standard Method v1.1 – 2010, and evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Envirnomental Chambers and VOC requirements.

C. Seal ducts to the following seal classes according to the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible":

1. Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
2. Outdoor, Supply-Air Ducts: Seal Class A.
3. Outdoor, Exhaust Ducts: Seal Class A.
4. Outdoor, Return-Air Ducts: Seal Class A.
5. Unconditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg and Lower: Seal Class A.
6. Unconditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class A.
7. Unconditioned Space, Exhaust Ducts: Seal Class A.
8. Unconditioned Space, Return-Air Ducts: Seal Class A.
9. Conditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg and Lower: Seal Class A.
10. Conditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class A.
11. Conditioned Space, Exhaust Ducts: Seal Class A.
12. Conditioned Space, Return-Air Ducts: Seal Class B.

3.5 HANGER AND SUPPORT INSTALLATION

A. Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."

B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Where practical, install concrete inserts before placing concrete.
2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches thick.
4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.

C. Hanger Spacing: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.

D. Hangers Exposed to View: Threaded rod and angle or channel supports.

E. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at a maximum interval of 16 feet.

F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.6 CONNECTIONS

A. Make connections to equipment with flexible connectors complying with Division 23 Section "Air Duct Accessories."

B. Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.7 PAINTING

A. Paint interior of metal ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Division 09 painting Sections.

3.8 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Leakage Tests:

1. Comply with the latest edition of SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.
2. Test the following systems:

    a. All ducts which are (1) under positive or negative pressure and (2) which are connected to an air moving device (air handling unit, exhaust fan, supply fan or similar air moving equipment) and (3) which convey 1000 cfm or greater through their largest portion.
    b. All ducts which are (1) under positive or negative pressure and (2) which are part of a supply, return, outside and exhaust air system and (3) which are equal to or greater than 25 feet in length and (4) which may or may not be directly connected to an air moving device.
    c. All supply ducts which are (1) connected to an air moving device (air handling unit, exhaust fan, supply fan or similar air moving equipment) and (2) which convey 1000 cfm or greater through their largest portion.
    d. All return ducts which are (1) which are part of a return and outside air system and (2) which are equal to or greater than 25 feet in length and (3) which may or may not be directly connected to an air moving device.
    e. All exhaust ducts which are (1) which are part of a general and toilet room exhaust air system and (2) which are equal to or greater than 25 feet in length and (3) which may or may not be directly connected to an air moving device.
    f. All exhaust ducts which make up a part of the smoke management system including return air ducts for air handling systems which are converted into smoke exhaust ducts.

3. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
4. Test for leaks before applying external insulation.
5. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure.
6. Give seven days' advance notice for testing.

C. Test Procedure:

1. Test at the time of duct installation, prior to installation of any field-applied insulation and prior to any concealment in chases or similar enclosures.
2. Duct entry and outlet openings shall be capped or sealed prior to pressurizing the duct. The seal shall be of adequate strength and thickness to withstand the test pressures.
3. Use a fan having a minimum capacity of 300 cfm or 10 percent of the particular duct system design capacity, whichever is greater and which is capable of producing a static pressure equal to the duct test pressure.

4. Test fan shall be connected to a flow measuring assembly consisting of straightening vanes and an orifice plate mounted in a straight section with appropriately located pressure taps. Orifice assembly shall be calibrated with its own calibration curve. Pressures shall be measured with U-tube manometers and corresponding flow rates shall be obtained from the orifice performance curve.
5. Connect test fan and orifice flow measuring assembly to the duct to be tested with a section of flexible duct.
6. Test for audible leaks as follows:

    a. Close off and seal all openings in the duct section to be tested.
    b. Start the blower with its control damper partially closed.
    c. Gradually open the control damper until the duct pressure reaches the designed duct operating pressure.
    d. Survey all joints for audible leaks. Mark each leak and repair after shutting down blower. Do not apply a retest until sealing has been repaired and allowed to set.

7. After all audible leaks have been sealed, the remaining leakage should be measured with the orifice section of the test apparatus as follows:

    a. Start blower and open damper until the pressure in duct reaches the designed duct operating pressure.
    b. When partial sections (such as supply section, return section, etc.) of the duct system are tested, the summation of the leakage for all sections shall not exceed the total allowable leakage.

8. Correct any duct leaks which are detected either audibly or by touch regardless of whether leakage through duct system is less than allowable test leakage.

D. Duct system will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

3.9 DUCT CLEANING

A. Clean new duct system(s) before testing, adjusting, and balancing. Submit duct cleaning procedures and methodologies for review.

B. Use service openings for entry and inspection.

1. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Provide insulated panels for insulated or lined duct. Patch insulation and liner as recommended by duct liner manufacturer. Comply with Division 23 Section "Air Duct Accessories" for access panels and doors.
2. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.
3. Remove and reinstall ceiling to gain access during the cleaning process.

C. Particulate Collection and Odor Control:

1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
2. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

D. Clean the following components by removing surface contaminants and deposits:

1. Air outlets and inlets (registers, grilles, and diffusers).
2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
4. Coils and related components.
5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
6. Supply-air ducts, dampers, actuators, and turning vanes.
7. Dedicated exhaust and ventilation components and makeup air systems.

E. Mechanical Cleaning Methodology:

1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
6. Provide drainage and cleanup for wash-down procedures.
7. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents according to manufacturer's written instructions after removal of surface deposits and debris.

F. Duct System Cleanliness Tests:

1. Visually inspect duct system to ensure that no visible contaminants are present.
2. Test sections of metal duct system, chosen randomly by Owner, for cleanliness according to "Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."

   a. Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.

b. Submit test results to Owner for review and approval. Any test results failed to comply with Acceptable Cleanliness Level shall be cleaned and retested.

3.10 START UP

A. Air Balance: Comply with requirements in Division 23 Section "Testing, Adjusting, and Balancing for HVAC."

3.11 DUCT SCHEDULE

A. Fabricate ducts with galvanized sheet steel except as otherwise indicated and as follows:

1. Underground Ducts: Concrete-encased PVC-coated, galvanized sheet steel with thicker coating on duct exterior.

2. Ducts serving Agriculture Lab and Bird Quarantine: Rigid aluminum duct.

B. Supply Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units:

a. Pressure Class: Positive 2-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 6.
d. SMACNA Leakage Class for Round and Flat Oval: 3.
e. Provide minimum 2” internal acoustic lining 10 feet downstream of all terminal units. Duct sizes shown on plans are clear inside dimensions.

2. Ducts Connected to Constant-Volume Air-Handling Units and DOAS Units:

a. Pressure Class: Positive 4-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 6.
d. SMACNA Leakage Class for Round and Flat Oval: 3.
e. Provide minimum 2” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

3. Ducts Connected to Variable-Air-Volume Air-Handling Units:

a. Pressure Class: Positive 4-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 3.
d. SMACNA Leakage Class for Round and Flat Oval: 3.
e. Provide minimum 2” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

4. Ducts Connected to Equipment Not Listed Above:

   a. Pressure Class: Positive 4-inch wg.
   b. Minimum SMACNA Seal Class: A.
   c. SMACNA Leakage Class for Rectangular: 3.
   d. SMACNA Leakage Class for Round and Flat Oval: 3.
   e. Provide minimum 2” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

C. Return Ducts and AHU, DOAS Return/Exhaust Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units:

   a. Pressure Class: Positive or negative 2-inch wg.
   b. Minimum SMACNA Seal Class: A.
   c. SMACNA Leakage Class for Rectangular: 6.
   d. SMACNA Leakage Class for Round and Flat Oval: 3.
   e. Provide minimum 1” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

2. Ducts Connected to Air-Handling Units, DOAS units:

   a. Pressure Class: Positive or negative 2-inch wg.
   b. Minimum SMACNA Seal Class: A.
   c. SMACNA Leakage Class for Rectangular: 6.
   d. SMACNA Leakage Class for Round and Flat Oval: 3.
   e. Provide minimum 1” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

3. Ducts Connected to Equipment Not Listed Above:

   a. Pressure Class: Positive or negative 2-inch wg.
   b. Minimum SMACNA Seal Class: A.
   c. SMACNA Leakage Class for Rectangular: 3.
   d. SMACNA Leakage Class for Round and Flat Oval: 3.
   e. Provide minimum 1” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

D. Exhaust Ducts:

1. Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:

   a. Pressure Class: Negative 2-inch wg.
   b. Minimum SMACNA Seal Class: A.
   c. SMACNA Leakage Class for Rectangular: 6.
   d. SMACNA Leakage Class for Round and Flat Oval: 3.

e. Provide minimum 1” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

2. Ducts Connected to Air-Handling Units and DOAS units:

a. Pressure Class: Positive or negative 2-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 3.
d. SMACNA Leakage Class for Round and Flat Oval: 3.
e. Provide minimum 1” internal acoustic lining 20-25 feet downstream and upstream of all supply, return and exhaust fans. Duct sizes shown on plans are clear inside dimensions.

3. Ducts Connected to Commercial Kitchen Hoods: Comply with NFPA 96.

a. Exposed to View: Type 304, stainless-steel sheet, No. 4 finish.
b. Concealed: Type 304, stainless-steel sheet, No. 2D finish.
c. Welded seams and joints.
d. Pressure Class: Positive or negative 4-inch wg.
e. Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.
f. SMACNA Leakage Class: 3.
g. Slope ductwork towards equipment/source.
h. Duct shall be insulated with a field-applied grease duct enclosure in accordance to ASTM E 2336, refer to Section 23 07 19 HVAC Insulation.

4. Ducts Connected to Dishwasher Hoods:

a. Type 304, stainless-steel sheet.
b. Exposed to View: No. 4 finish.
c. Concealed: No. 2D finish.
d. Welded seams and flanged joints with watertight EPDM gaskets.
e. Pressure Class: Positive or negative 4-inch wg.
f. Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.
g. SMACNA Leakage Class: 3.
h. Slope ductwork towards equipment/source.
i. Duct shall be insulated with a field-applied grease duct enclosure in accordance to ASTM E 2336, refer to Section 23 07 19 HVAC Insulation.
j.

5. Ducts Connected to Smoke Exhaust Systems:

a. Pressure Class: Positive or negative 6-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 3.
d. SMACNA Leakage Class for Round: 3.
e. Duct materials and joints shall be capable of withstanding the probable temperatures and pressures to which they are exposed as determined by the IMC. Ducts shall be leak tested to 1.5 times the maximum design temperature. Measured leakage shall not exceed 5 percent of design flow.

6. Ducts Connected to Fans Exhausting Process (ASHRAE 62.1, Class 3 and 4) Air:

    a. Type 316, stainless-steel sheet.
        1) Exposed to View: No. 4 finish.
        2) Concealed: No. 2B finish.

    b. Pressure Class: Positive or negative 3-inch wg (750 Pa).
    c. Minimum SMACNA Seal Class: A, welded seams, joints, and penetrations.
    d. SMACNA Leakage Class: 3.

7. Ducts Connected to Equipment Not Listed Above:

    a. Pressure Class: Positive or negative 2-inch wg.
    b. Minimum SMACNA Seal Class: A.
    c. SMACNA Leakage Class for Rectangular: 6.
    d. SMACNA Leakage Class for Round and Flat Oval: 6.

E. Outdoor-Air (Not Filtered, Heated, or Cooled) Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units:

    a. Pressure Class: Positive or negative 2-inch wg.
    b. Minimum SMACNA Seal Class: A.
    c. SMACNA Leakage Class for Rectangular: 3.
    d. SMACNA Leakage Class for Round and Flat Oval: 3.

2. Ducts Connected to Air-Handling Units:

    a. Pressure Class: Positive or negative 2-inch wg.
    b. Minimum SMACNA Seal Class: A.
    c. SMACNA Leakage Class for Rectangular: 3.
    d. SMACNA Leakage Class for Round and Flat Oval: 3.

3. Ducts Connected to Equipment Not Listed Above:

    a. Pressure Class: Positive or negative 2-inch wg.
    b. Minimum SMACNA Seal Class: A.
    c. SMACNA Leakage Class for Rectangular: 6.
    d. SMACNA Leakage Class for Round and Flat Oval: 6.

F. Intermediate Reinforcement:

1. Galvanized-Steel Ducts: Galvanized steel.
2. PVC-Coated Ducts:

    a. Exposed to Airstream: Match duct material.
    b. Not Exposed to Airstream: Galvanized.

3. Stainless-Steel Ducts:

a. Exposed to Airstream: Match duct material.
b. Not Exposed to Airstream: Match duct material.

4. Aluminum Ducts: Aluminum.

G. Liner:

1. Duct liner shall meet or exceed insulation "R" values. See Specification Section 23 07 19 "HVAC Insulation."

2. Supply Air Ducts: Flexible elastomeric, 2 inches thick.

3. Return Air Ducts: Flexible elastomeric, 1 inches thick.

4. Exhaust Air Ducts: Flexible elastomeric, 1 inch thick.

5. Supply Fan Plenums: Flexible elastomeric, 2 inches thick.

6. Return- and Exhaust-Fan Plenums: Fibrous glass, 2 inches thick.

7. Transfer Ducts: Fibrous glass, Type I, 1 inch thick.

H. Elbow Configuration:

1. Rectangular Duct: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."

a. Velocity 1000 fpm or Lower:

1) Radius Type RE 1 with minimum 0.5 radius-to-diameter ratio.
2) Mitered Type RE 4 without vanes.

b. Velocity 1000 to 1500 fpm:

1) Radius Type RE 1 with minimum 1.0 radius-to-diameter ratio.
2) Radius Type RE 3 with minimum 0.5 radius-to-diameter ratio and two vanes.
3) Mitered Type RE 2 with vanes complying with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

c. Velocity 1500 fpm or Higher:

1) Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
2) Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
3) Mitered Type RE 2 with vanes complying with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible,"

Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

2. Rectangular Duct: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."

   a. Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
   b. Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
   c. Mitered Type RE 2 with vanes complying with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

3. Round Duct: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "Round Duct Elbows."

   a. Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 3-1, "Mitered Elbows." Elbows with less than 90-degree change of direction have proportionately fewer segments.

      1) Velocity 1000 fpm or Lower: 0.5 radius-to-diameter ratio and three segments for 90-degree elbow.
      2) Velocity 1000 to 1500 fpm: 1.0 radius-to-diameter ratio and four segments for 90-degree elbow.
      3) Velocity 1500 fpm or Higher: 1.5 radius-to-diameter ratio and five segments for 90-degree elbow.
      4) Radius-to Diameter Ratio: 1.5.

   b. Round Elbows, 12 Inches and Smaller in Diameter: Stamped or pleated.
   c. Round Elbows, 14 Inches and Larger in Diameter: Standing seam or Welded.

I. Branch Configuration:

1. Rectangular Duct: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-6, "Branch Connection."

   a. Rectangular Main to Rectangular Branch: 45-degree entry.
   b. Rectangular Main to Round Branch: Spin in.

2. Round and Flat Oval: Comply with the latest edition of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees." Saddle taps are permitted in existing duct.

   a. Velocity 1000 fpm or Lower: 90-degree tap.
   b. Velocity 1000 to 1500 fpm: Conical tap.
   c. Velocity 1500 fpm or Higher: 45-degree lateral.

END OF SECTION 23 31 13

SECTION 23 33 00 - AIR DUCT ACCESSORIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. Section Includes:

1. Backdraft dampers.
2. Manual volume dampers.
3. Fire dampers.
4. Smoke dampers.
5. Combination fire and smoke dampers.
6. Turning vanes.
7. Remote damper operators.
8. Duct-mounted access doors.
9. Flexible connectors.
10. Duct security bars.
11. Duct accessory hardware.
12. Wire mesh grilles.

B. Related Sections:

1. Division 23 Section "HVAC Gravity Ventilators" for roof-mounted ventilator caps.
2. Division 28 Section "Fire Detection and Alarm" for duct-mounted fire and smoke detectors.

1.3 SUBMITTALS

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

1. For all accessories specified, include construction details, dimensions, materials, finishes, bearings and compliance with applicable codes.
2. Performance: Show compliance with pressure drops or specific requirements noted.
3. Provide manufacturer’s installation instructions.
4. For duct silencers/sound attenuators, include pressure drop and dynamic insertion loss data. Include breakout noise calculations for high transmission loss casings.

B. LEED V4 BD+C Submittal:
   1. Sustainable Design Documentation Submittals: Refer to section 01 81 13.14 “Sustainable Design Requirements – LEED V4 BD+C”.
      a. Product Data for Metal Ductwork: Documentation for Leadership Extraction Practices in the following:
         1. Leadership Extraction Practices for Recycled Content
         2. Provide detailed material cost data for this scope of work.

C. Shop Drawings: For duct accessories. Include plans, elevations, sections, details and attachments to other work.

   1. Detail duct accessories fabrication and installation in ducts and other construction. Include dimensions, weights, loads, and required clearances; and method of field assembly into duct systems and other construction. Include the following:

      a. Special fittings.
      b. Manual volume damper installations.
      c. Control damper installations.
      d. Fire-damper, smoke-damper, combination fire- and smoke-damper, ceiling, and corridor damper installations, including sleeves; and duct-mounted access doors and remote damper operators.
      e. Duct security bars.
      f. Wiring Diagrams: For power, signal, and control wiring.

D. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which ceiling-mounted access panels and access doors required for access to duct accessories are shown and coordinated with each other, using input from Installers of the items involved.

E. Source quality-control reports.

F. Operation and Maintenance Data: For air duct accessories to include in operation and maintenance manuals.

1.4 QUALITY ASSURANCE

A. All products provided for enhancement of Life Safety shall be UL listed and bear the appropriate label stating compliance.

B. All Products to have a Florida Product Approval Number, as required by the Florida Building Code (FAC 9N-3).

C. All products located in the conditioned air stream or located in return air plenums shall conform to the NFPA 90A Flame/Smoke/Fuel Contribution of 25/50/0 and all other applicable requirements of NFPA 90A.

D. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

E. Comply with AMCA 500-D testing for damper rating.

F. Demonstrate resetting of fire dampers to authorities having jurisdiction and Owner’s representatives.

G. Smoke and Smoke/Fire dampers shall be provided with a 60 month from the date of shipment parts only warranty, including freight for all components, including damper operators.

1.5 EXTRA MATERIALS

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

1. Fusible Links: Furnish quantity equal to 10 percent of amount installed, or a minimum quantity of five of each type installed.

2. Fire Smoke Damper Actuators: Furnish quantity equal to 10 percent of amount installed, or a minimum quantity of five of each type installed.

3. Fire Smoke Dampers: In addition to quantity indicated on drawings furnish ten (10) additional fire smoke dampers 24x24 or equivalent size per each floor in Landside and 10 per each floor In Airside.

4. Fire Dampers: In addition to quantity indicated on drawings furnish ten (10) additional fire dampers 24x24 or equivalent size per each floor in Landside and 10 per each floor In Airside.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G90.
2. Exposed-Surface Finish: Mill phosphatized.

C. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304, and having a No. 2D finish for concealed ducts and a No. 2B finish for exposed ducts.

D. Aluminum Sheets: Comply with ASTM B 209, Alloy 3003, Temper H14; with mill finish for concealed ducts and standard, 1-side bright finish for exposed ducts.

E. Extruded Aluminum: Comply with ASTM B 221, Alloy 6063, Temper T6.

F. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.

G. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.2 BACKDRAFT DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Air Balance Inc.; a division of Mestek, Inc.
2. Duro Dyne Inc.
3. Greenheck Fan Corporation.
4. Ruskin Company.
5. Vent Products Company, Inc.
6. Nailor Industries, Inc.

B. Description: Gravity balanced.

C. Maximum Air Velocity: 2000 fpm.

D. Maximum System Pressure: 1-inch wg.

E. Frame: Minimum 16 gauge (0.064-inch thick) galvanized sheet steel or extruded aluminum, with welded corners and mounting flange.

F. Blades: Multiple single-piece blades, maximum 6-inch width, minimum 16 gauge (0.064-inch thick) galvanized steel or extruded aluminum, with sealed edges.

G. Blade Action: Parallel.

H. Blade Seals: Neoprene, mechanically locked.

I. Blade Axles:

1. Material: Galvanized steel or aluminum.
2. Diameter: 0.20 inch minimum.

J. Tie Bars and Brackets: Aluminum or galvanized steel.

K. Return Spring: Adjustable tension.

L. Bearings: Steel ball or synthetic pivot bushings.

M. Accessories:

1. Adjustment device to permit setting for varying differential static pressure.
2. Counterweights and spring-assist kits for vertical airflow installations.
3. Electric actuators.
4. Chain pulls.
5. Screen Mounting: Front mounted in sleeve.
    a. Sleeve Thickness: 20-gauge minimum.
    b. Sleeve Length: 6 inches minimum.
6. Screen Mounting: Rear mounted.
7. Screen Material: Galvanized steel or aluminum.
8. Screen Type: Bird.
9. 90-degree stops.

2.3 MANUAL VOLUME DAMPERS

A. Standard, Steel, Manual Volume Dampers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    a. Air Balance Inc.; a division of Mestek, Inc.
    b. McGill AirFlow LLC.
    c. Ruskin Company.
    d. Greenheck, Inc.
2. Standard leakage rating, with linkage outside airstream.
3. Suitable for horizontal or vertical applications.
4. Frames:
    a. Hat-shaped, galvanized-steel channels, 0.064-inch minimum thickness.
    b. Mitered and welded corners.
    c. Flanges for attaching to walls and flangeless frames for installing in ducts.
5. Blades:
    a. Single blade up to 6 inches blade width; multiple blades for width over 6 inches.
    b. Opposed-blade design for multiple blades dampers.
    c. Round or oval ducts: butterfly type.
    d. Stiffen damper blades for stability.
    e. Galvanized-steel, 0.064 inch thick.
6. Blade Axles: Galvanized steel.
7. Bearings:
    a. Molded synthetic.
    b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

8. Tie Bars and Brackets: Galvanized steel.

B. Standard, Aluminum, Manual Volume Dampers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Air Balance Inc.; a division of Mestek, Inc.
   b. McGill AirFlow LLC.
   c. Ruskin Company.
   d. Greenheck, Inc.

2. Standard leakage rating, with linkage outside airstream.
3. Suitable for horizontal or vertical applications.
4. Frames: Hat-shaped, 0.10-inch-thick, aluminum sheet channels; frames with flanges for attaching to walls and flangeless frames for installing in ducts.
5. Blades:

   a. Single blade up to 6 inches blade width; multiple blades for width over 6 inches.
   b. Opposed-blade design for multiple blades dampers.
   c. Stiffen damper blades for stability.
   d. Roll-Formed Aluminum Blades: 0.10-inch- thick aluminum sheet.
   e. Extruded-Aluminum Blades: 0.050-inch- thick extruded aluminum.

6. Blade Axles: Nonferrous metal.
7. Bearings:

   a. Molded synthetic.
   b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

8. Tie Bars and Brackets: Aluminum.

C. Low-Leakage, Steel, Manual Volume Dampers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Air Balance Inc.; a division of Mestek, Inc.
   b. McGill AirFlow LLC.
   c. Ruskin Company.
   d. Vent Products Company, Inc.
   e. Greenheck, Inc.

2. Low-leakage rating, with linkage outside airstream, and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.
3. Suitable for horizontal or vertical applications.
4. Frames:

a. Hat, U or Angle shaped.
b. Galvanized-steel channels, 0.064 inch thick.
c. Mitered and welded corners.
d. Flanges for attaching to walls and flangeless frames for installing in ducts.

5. Blades:

a. Single blade up to 6 inches blade width; multiple blades for width over 6 inches.
b. Opposed-blade design for multiple blades dampers.
c. Stiffen damper blades for stability.
d. Galvanized, roll-formed steel, 0.064 inch thick.

6. Blade Axles: Galvanized steel.
7. Bearings:

a. Molded synthetic.
b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

8. Blade Seals: Neoprene.
9. Jamb Seals: Cambered stainless steel.
10. Tie Bars and Brackets: Galvanized steel.
11. Accessories:

a. Include locking device to hold dampers in a fixed position without vibration.

D. Low-Leakage, Aluminum, Manual Volume Dampers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Air Balance Inc.; a division of Mestek, Inc.
b. McGill AirFlow LLC.
c. Ruskin Company.
d. Vent Products Company, Inc.
e. Greenheck, Inc.

2. Low-leakage rating, with linkage outside airstream, and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.
3. Suitable for horizontal or vertical applications.
4. Frames: Hat, U or Angle-shaped, 0.10-inch- thick, aluminum sheet channels; frames with flanges for attaching to walls and flangeless frames for installing in ducts.
5. Blades:

a. Single blade up to 6 inches blade width; multiple blades for width over 6 inches.
b. Opposed-blade design for multiple blades dampers.
c. Roll-Formed Aluminum Blades: 0.10-inch- thick aluminum sheet.

d. Extruded-Aluminum Blades: 0.050-inch- thick extruded aluminum.

6. Blade Axles: Nonferrous metal.
7. Bearings:

   a. Molded synthetic.
   b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

8. Blade Seals: Neoprene.
9. Jamb Seals: Cambered stainless steel.
10. Tie Bars and Brackets: Aluminum.
11. Accessories:

    a. Include locking device to hold dampers in a fixed position without vibration.

E. Jackshaft:

1. Size: 1-inch diameter.
2. Material: Galvanized-steel pipe rotating within pipe-bearing assembly mounted on supports at each mullion and at each end of multiple-damper assemblies.
3. Length and Number of Mountings: As required to connect linkage of each damper in multiple-damper assembly.

F. Damper Hardware:

1. Zinc-plated, die-cast core with quadrant and lever handle made of 3/32-inch- thick zinc-plated steel, and a lockscrew.
2. Include center hole to suit damper operating-rod size.
3. Include elevated platform to clear insulation for insulated duct mounting.

2.4 FIRE DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Air Balance Inc.; a division of Mestek, Inc.
2. Arrow United Industries; a division of Mestek, Inc.
3. McGill AirFlow LLC.
4. Ruskin Company.
5. Greenheck, Inc.
6. Prefco Products, Inc.

B. Type: Dynamic; UL listed and rated and labeled according to UL 555 by an NRTL. Conformance with NFPA 90A and authorities having jurisdiction.

C. Closing rating in ducts up to 4-inch wg static pressure class and minimum 2000-fpm velocity.

D. Fire Rating: 1-1/2 hours (UL approved for installation in 2 hour walls).

E. Frame: Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream; fabricated with roll-formed, 0.034-inch- thick galvanized steel; with mitered and interlocking corners.

F. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel.

1. Minimum Thickness: UL listed minimum gauge galvanized steel with welded construction corners. Rollformed sleeves will not be acceptable unless contractor guarantees in writing to seal voids in sleeve with UL approved sealer to limit air leakage. Length to suit application.
2. Exception: Omit sleeve where damper-frame width permits direct attachment of perimeter mounting angles on each side of wall or floor; thickness of damper frame must comply with sleeve requirements.

G. Mounting Orientation: Dynamic spring closure type, vertical or horizontal as indicated.

H. Blades: Roll-formed, interlocking, 0.034-inch-thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch-thick, galvanized-steel blade connectors. At locations where duct size exceeds fire damper manufacturer's height limit for Type B fire dampers, multiple blades fire dampers with the same ratings and construction requirements shall be used. Where installed in stainless steel or aluminum ductwork, use Type 304 stainless steel.

I. Horizontal Dampers: Include blade lock and stainless-steel closure spring.

J. Heat-Responsive Device: Replaceable, 165 deg F rated, fusible links constructed to UL Standard 33.

K. Heat-Responsive Device: Electric resettable link and switch package, factory installed, 165 deg F rated.

2.5 SMOKE DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Air Balance Inc.; a division of Mestek, Inc.
2. Ruskin Company.
3. Prefco Products, Inc.
4. Greenheck, Inc.

B. General Requirements: Label according to UL 555S by an NRTL.

C. Smoke Detector: Integral, factory wired for single-point connection.

D. Frame: Multiple-blade type; fabricated with roll-formed, 0.034-inch-thick galvanized steel; with mitered and interlocking corners.

E. Blades: Roll-formed, horizontal, interlocking, 0.034-inch-thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch-thick, galvanized-steel blade connectors.

F. Leakage: Class II.

G. Rated pressure and velocity to exceed design airflow conditions.

H. Mounting Sleeve: Factory-installed, 0.052-inch-thick, galvanized sheet steel; length to suit wall or floor application with factory-furnished silicone calking.

I. Damper Motors: Modulating or two-position action as noted.

J. Damper and actuator shall be provided with a 60 month warranty.

K. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. 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.
2. Electric motor actuator to be UL listed with damper assembly. Motor furnished with all connecting linkage and mounting hardware.
3. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 23 Section "Instrumentation and Control for HVAC" and Division 26 Sections.
4. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
5. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.
6. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F.
7. Nonspring-Return Motors: For dampers larger than 25 sq. ft., size motor for running torque rating of 150 in. x lbf and breakaway torque rating of 300 in. x lbf.
8. Electrical Connection: 115 V or 24 V single phase, 60 Hz; or signal from smoke detector alarm circuit as required.

L. Accessories:

1. Auxiliary switches for signaling, fan control or position indication.
2. Test and reset switches, damper or remote mounted as required.

2.6 COMBINATION FIRE AND SMOKE DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Air Balance Inc.; a division of Mestek, Inc.
2. Ruskin Company.
3. Cesco Products.
4. Prefco Products, Inc.

B. Type: Dynamic; rated and labeled according to UL 555 and UL 555S by an NRTL.

C. Closing rating in ducts up to 4-inch wg static pressure class and minimum 4000-fpm velocity.

D. Fire Rating: 1-1/2 hours.

E. Frame: Multiple-blade type; fabricated with roll-formed, 0.064-inch-thick galvanized steel frame; with mitered and interlocking corners.

F. Heat-Responsive Device: Replaceable, 165 deg F rated, fusible links.

G. Heat-Responsive Device: Electric resettable link and switch package, factory installed, rated. Conform to NFPA 90A and NFPA 92A for fire and smoke dampers.

H. Smoke Detector: Integral, factory wired for single-point connection.

I. Blades: 14 gauge true airfoil design constructed of galvanized steel of low leakage non-heat degradable design with friction free inflatable silicone coated fiberglass material to maintain smoke leakage rating to a minimum of 450°F and galvanized steel for flame seal to 1900°F.

J. Leakage: Minimum UL Class II metal to metal, non-degradable, seals rated to minimum of 350°F.

K. Rated pressure and velocity to exceed design airflow conditions.

L. Mounting Sleeve: Factory-installed, 0.052-inch-thick, galvanized sheet steel; length to suit wall or floor application with factory-furnished silicone calking. Operator located exterior of sleeve.

M. Master control panel for use in dynamic smoke-management systems.

N. Damper Motors: Modulating or two-position action as noted.

O. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. 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.
2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 23 Section "Instrumentation and Control for HVAC" and Division 26 Sections.

3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
4. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.
5. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof.
6. Nonspring-Return Motors: For dampers larger than 25 sq. ft., size motor for running torque rating of 150 in. x lbf and breakaway torque rating of 300 in. x lbf.
7. Electrical Connection: 115 V or 24 V single phase, 60 Hz; or signal from smoke detector alarm circuit as required

P. Accessories:

1. Provide two (2) sets of auxiliary switches for monitoring FSD positions for FAS and BMS.
2. Test and reset switches, damper or remote mounted as required.

2.7 TURNING VANES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Ductmate Industries, Inc.
2. Duro Dyne Inc.
3. METALAIRE, Inc.

B. Manufactured Turning Vanes for Metal Ducts: Curved blades of galvanized steel, aluminum or stainless steel sheet, to match duct material; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.

1. Acoustic Turning Vanes: Fabricate airfoil-shaped aluminum extrusions with perforated faces and fibrous-glass fill.

C. General Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; "Vanes and Vane Runners," and "Vane Support in Elbows."

D. Vane Construction: Double wall.

2.8 REMOTE DAMPER OPERATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Ventfabrics, Inc.
2. Young Regulator Company.

B. Description: Cable system designed for remote manual damper adjustment.

C. Tubing: Brass.

D. Cable: Stainless steel.

Wall-Box Mounting: Recessed, 2 inches deep. Wall-Box Cover-Plate Material: Stainless steel.

E. Ceiling Mounting: Concealed ceiling mounting brackets, with cover plate and all necessary hardware for a complete installation. Cover plate finish to match ceiling finish.

1. High security areas: Provide tamper-proof threaded cap.

2.9 DUCT-MOUNTED ACCESS DOORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Ductmate Industries, Inc.
   2. McGill AirFlow LLC.
   3. Ventfabrics, Inc.
   4. Ruskin.

B. Duct-Mounted Access Doors: Fabricate access panels according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; "Duct Access Doors and Panels," and "Access Panels - Round Duct."

   1. Door:
      a. Double wall, rectangular.
      b. Sheet metal, to match duct material, with insulation fill and thickness as indicated for duct pressure class.
      c. Vision panel.
      d. Hinges and Latches: 2-by-2-inch butt or piano hinge and cam latches.
      e. Fabricate doors airtight and suitable for duct pressure class.
      f. Size: Not less than 16 inches by 14 inches. Ducts less than 16 inches in height, install with one dimension 16 inches and other dimension 2 inches less than duct width. Install larger sized doors where required for access.
   2. Frame: Same material as door, with bend-over tabs and foam gaskets.
   3. Number of Hinges and Locks:
      a. Access Doors Less Than 12 Inches Square: No hinges and two sash locks.
      b. Access Doors up to 18 Inches Square: Two hinges and two sash locks.
      c. Access Doors up to 24 by 48 Inches: Three hinges and two compression latches with outside and inside handles.
      d. Access Doors Larger Than 24 by 48 Inches: Four hinges and two compression latches with outside and inside handles.

2.10 DUCT ACCESS PANEL ASSEMBLIES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Ductmate Industries, Inc.
2. Flame Gard, Inc.
3. 3M.

B. Labeled according to UL 1978 by an NRTL.

C. Panel and Frame: Minimum thickness 0.0528-inch carbon or 0.0428-inch stainless steel to match duct.

D. Fasteners: Carbon or Stainless steel to match. Panel fasteners shall not penetrate duct wall.

E. Gasket: Comply with NFPA 96; grease-tight, high-temperature ceramic fiber, rated for minimum 2000 deg F.

F. Minimum Pressure Rating: 10-inch wg, positive or negative.

2.11 FLEXIBLE CONNECTORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Ductmate Industries, Inc.
2. Duro Dyne Inc.
3. Ventfabrics, Inc.

B. Materials: Flame-retardant or noncombustible fabrics.

C. Coatings and Adhesives: Comply with UL 181, Class 1.

D. Metal-Edged Connectors: Factory fabricated with a fabric strip 3-1/2 inches wide for all ducts except those with any size 13” and larger under positive pressure which shall be 5-3/4 inches wide attached to 2 strips of 2-3/4-inch- wide, 0.028-inch-thick, galvanized sheet steel or 0.032-inch-thick aluminum sheets. Provide metal compatible with connected ducts.

E. Indoor System, Flexible Connector Fabric: Glass fabric double coated with neoprene.

1. Minimum Weight: 30 oz./sq. yd.
2. Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
3. Service Temperature: Minus 40 to plus 200 deg F.
4. Pressure: 10” wg positive or negative.

F. Outdoor System, Flexible Connector Fabric: Glass fabric double coated with weatherproof, synthetic rubber resistant to abrasion and damage due to repeated flexing, UV rays and ozone, waterproof and airtight.

1. Minimum Weight: 30 oz./sq. yd..
2. Tensile Strength: 530 lbf/inch in the warp and 440 lbf/inch in the filling.
3. Service Temperature: Minus 50 to plus 250 deg F.

G. High-Temperature System, Flexible Connectors: Glass fabric coated with silicone rubber.

1. Minimum Weight: 16 oz./sq. yd..
2. Tensile Strength: 285 lbf/inch in the warp and 185 lbf/inch in the filling.
3. Service Temperature: Minus 67 to plus 500 deg F.

H. High-Corrosive-Environment System, Flexible Connectors: Glass fabric with chemical-resistant coating.

1. Minimum Weight: 14 oz./sq. yd..
2. Tensile Strength: 450 lbf/inch in the warp and 340 lbf/inch in the filling.
3. Service Temperature: Minus 67 to plus 500 deg F.

I. Thrust Limits: Combination coil spring and elastomeric insert with spring and insert in compression, and with a load stop. Include rod and angle-iron brackets for attaching to fan discharge and duct.

1. Frame: Steel, fabricated for connection to threaded rods and to allow for a maximum of 30 degrees of angular rod misalignment without binding or reducing isolation efficiency.
2. Outdoor Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
3. Minimum Additional Travel: 50 percent of the required deflection at rated load.
4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
6. Elastomeric Element: Molded, oil-resistant rubber or neoprene.
7. Coil Spring: Factory set and field adjustable for a maximum of 1/4-inch movement at start and stop.

2.12 DUCT SECURITY BARS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Carnes.
2. KEES, Inc.
3. Lloyd Industries, Inc.
4. Metal Form Manufacturing, Inc.
5. Price Industries.

B. Description: Factory-fabricated and field-installed duct security bars.

C. Configuration:

1. Frame: 10 gage by 2 inches.
2. Sleeve: 3/16-inch, bent steel frames with 1-by-1-by-3/16-inch angle frame factory welded to 1 end. To be poured in place or set with concrete block or welded or bolted to wall, one side only. Duct connections on both sides.
3. Horizontal Bars: 2 by 1/4 inch.
4. Vertical Bars: 1/2 inch.
5. Bar Spacing: 6 inches.
6. Mounting: Metal deck or roofing. Bolted or welded with masonry anchors. Ductwork or other framing. Poured in place or set with concrete block. Welded or bolted to one wall (one side only).

2.13 WIRE MESH GRILLES

A. Construction: 1/2 inch (12.5 mm) mesh screen with 1 inch (2.5 mm) sheet metal frame, bolted to flanged duct connection.

B. Materials:

1. Screen: Minimum 18 gauge galvanized steel or 14 gauge aluminum.
2. Frame: Minimum 0.040 inch thick galvanized sheet steel or aluminum sheet.

2.14 Bolts and nuts: Indoors, galvanized steel; exposed to weather, stainless steel.DUCT ACCESSORY HARDWARE

A. Instrument Test Holes: Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments and of length to suit duct-insulation thickness.

B. Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

PART 3 - EXECUTION

3.1 GENERAL REQUIREMENTS

A. Install all products in strict accordance with the manufacturer's written installation instructions.

B. Coordinate the installation of products provided within other sections of Division 23 including but not limited to control dampers, airflow measuring stations, etc.

3.2 INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts.

B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.

C. Install backdraft or control dampers at inlet of exhaust fans or exhaust ducts as close as possible to exhaust fan unless otherwise indicated.

D. Install volume dampers at points on supply, return, outside air, and exhaust systems where branches extend from larger ducts and as indicated. Where dampers are installed in ducts having duct liner, install dampers with hat channels of same depth as liner, and terminate liner with nosing at hat channel.

1. Install volume dampers at the following locations:

   a. At all splits, except grease exhaust ducts.
   b. In ducts serving single supply, return, outside air, and exhaust outlets.
   c. In open return ducts above ceiling.
   d. In ducts connecting to a common plenum.
   e. Where indicated on drawings and in details.
   f. Where required for balancing.
2. Install a 24” long yellow strip of material to each damper handle for easy visual location. These strips must be in place prior to Substantial acceptance.
3. Install remote damper operators for volume dampers above ceilings which are non-accessible or without access panels.
4. Install steel volume dampers in steel ducts.
5. Install aluminum volume dampers in aluminum ducts.
6. Do not install volume dampers in grease ducts.

E. Set dampers to fully open position before testing, adjusting, and balancing.

F. Install test holes at fan inlets and outlets and elsewhere as indicated and in ductwork where required for testing and adjusting.

G. Install fire, smoke and combination fire/smoke dampers according to UL listing in ducts and openings in the following:

1. Shaft walls.
2. Floors and ceilings.
3. Fire walls.
4. Fire resistance partitions.
5. Fire rated ceilings.
6. Exit corridor walls.
7. Elsewhere as indicated on drawings.

H. Install duct security bars. Install where indicated on drawings. Provide 12-by-12-inch hinged access panel with cam lock in duct in each side of sleeve.

I. Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:

1. On both sides of duct coils.
2. Upstream and downstream from duct filters.
3. At outdoor-air intakes and mixed-air plenums.
4. At drain pans and seals.
5. Downstream from manual volume dampers, control dampers, backdraft dampers, and equipment.
6. Adjacent to and close enough to fire, smoke or combination fire/smoke dampers, to reset or reinstall fusible links. Access doors for access to fire or smoke dampers having fusible links shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.
7. Upstream from turning vanes.
8. Upstream or downstream from duct silencers.
9. Control devices requiring inspection, including smoke detection heads.
10. At fan bearings enclosed in ducts.
11. Inlet side of each single width centrifugal fan.
12. At inlet and outlet sides of each in-line centrifugal and axial fan.
13. At duct humidifiers.

J. Install access doors with swing against duct static pressure.

K. Access Door Sizes:

1. One-Hand or Inspection Access: 8 by 5 inches.
2. Two-Hand Access: 12 by 6 inches.
3. Head and Hand Access: 18 by 12 inches.
4. Head and Shoulders Access: 21 by 14 inches.
5. Body Access: 25 by 14 inches.
6. Body plus Ladder Access: 25 by 17 inches.

L. Label access doors according to Division 23 Section "Identification for HVAC Piping and Equipment" to indicate the purpose of access door.

M. Install flexible connectors at duct connections to equipment, at building expansion joints, at connections between ducts of dissimilar metals and at penetrations of mechanical equipment room walls.
   1. Install flexible connections with 2 inches slack in fabric and minimum movement of 1 inch.

N. For fans developing static pressures of 5-inch wg and more, cover flexible connectors with loaded vinyl sheet held in place with metal straps.

O. Connect terminal units to supply ducts directly or with maximum 12-inch lengths of flexible duct as detailed on drawings. Do not use flexible ducts to change directions.

P. Connect diffusers or light troffer boots to ducts directly or with maximum 60-inch lengths of flexible duct clamped in place.

Q. Install duct test holes where required for testing and balancing purposes.

R. Install thrust limits at centerline of thrust, symmetrical on both sides of equipment. Attach thrust limits at centerline of thrust and adjust to a maximum of 1/4-inch movement during start and stop of fans.

S. Install wire mesh screen grilles at return air ducts in hung ceilings and in other places where indicated. Bolt grilles to flanged connections or ducts at terminations.

T. Air Flow Measuring Stations

1. Install air flow measuring stations where indicated, or as directed by engineer.
2. Install all interconnecting tubing between measuring station, companion meter and control systems, in accordance with the manufacturer's printed instructions.

3.3 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Operate dampers to verify full range of movement.
2. Inspect locations of access doors and verify that purpose of access door can be performed.
3. Operate fire, smoke, and combination fire and smoke dampers to verify full range of movement and verify that proper heat-response device is installed.
4. Inspect turning vanes for proper and secure installation.
5. Operate remote damper operators to verify full range of movement of operator and damper.

3.4 MANUFACTURER'S FIELD SERVICES

A. Provide services of a testing agency to take noise measurements per section 23 0593. Use meters meeting requirements of ASA 47 (ANSI S1.4).

B. After start-up, and final corrections and balancing of systems, take octave band sound measurements over full audio frequency range in areas adjacent to mechanical equipment rooms, duct and pipe shafts, and other critical locations, as directed.

C. Provide one-third octave band measurements of artificial sound sources in areas indicated as having critical requirements.

D. Submit complete report of test results including sound curves.

END OF SECTION 23 33 00

SECTION 23 34 13 - AXIAL HVAC FANS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes the following:

1. Tubeaxial fans.
2. Vaneaxial fans.
3. Mixed-flow fans.

1.3 PERFORMANCE REQUIREMENTS

A. Project Altitude: Base fan performance ratings on 100 feet above sea level.

B. Operating Limits: Classify according to AMCA 99.

1.4 SUBMITTALS

A. Product Data: Include rated capacities, furnished specialties, and accessories for each type of product indicated and include the following:

1. Certified fan performance curves with system operating conditions clearly plotted and including:

   a. Sound power levels for both fan inlets and outlet at rated capacity.
   b. Manufacturer’s data for adjustable fan blades for at least five (5) blade settings, including maximum.
   c. Minimum “turn down” CFM for controllable pitch fans.

2. Certified fan sound power ratings, including:
   a. Fan manufacturer’s published sound power, level data based on actual test, on the fan sizes being furnished, conducted in accordance with current AMCA standards. Such data is to define sound power levels (PWL) re: 10-12 watts for each of the eights (8) frequency bands.
   b. Manufacturer’s estimated data will not be acceptable.

3. Motor ratings and electrical characteristics, plus motor and electrical accessories.

4. Material thickness and finishes, including color charts.
5. Dampers, including housings, linkages, and operators.
6. Fan speed controllers.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1. Wiring Diagrams: Power, signal, and control wiring.
2. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
3. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.

C. Coordination Drawings: Show fan room layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements.

D. System Effect Calculations: Since all fans are tested in accordance with AMCA standards and data catalogued consists of fans capacity (CFM at external static pressure) while connected to straight inlet and discharge duct conditions the vendor is responsible for calculating the “System Effect” pressure drop of inlet and discharge connections to the ducts shown on the drawings. This static pressure will be added to the external static pressure of the fan and the submitted fan, fan accessories and fan curve shall indicate the rpm, cfm, bhp, top speed and other required capacity data to be cored to account for the “System Effect” pressure drop and for a minimum of 5% or higher belt drive losses based upon the size and number of V-belts required for the fan sheaves in the selection of the actual motor horse power to provide.

E. Field quality-control test reports.

F. Operation and Maintenance Data: For axial fans to include in emergency, operation, and maintenance manuals.

1.5 QUALITY ASSURANCE

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

B. AMCA Compliance: Products shall comply with performance requirements and shall be licensed to use the AMCA-Certified Ratings Seal.

C. NEMA Compliance: Motors and electrical accessories shall comply with NEMA standards.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations, with protective crating and covering.

B. Disassemble and reassemble units, as required for moving to final locations, according to manufacturer's written instructions.

C. Lift and support units with manufacturer's designated lifting or supporting points.

D. Protect motors, shafts, and bearings from weather and construction dust. Comply with manufacturer’s wheel and motor rotation schedule for extended storage.

1.7 COORDINATION

A. Coordinate size and location of structural-steel support members.

B. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

C. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Division 07 Section "Roof Accessories."

1.8 EXTRA MATERIALS

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

1. Belts: One set for each belt-driven unit.

PART 2 - PRODUCTS

2.1 TUBEAXIAL FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Aerovent; a Twin City Fan Company.
2. American Fan Company (Flakt/Woods).
3. Barry Blower Div.; Penn Ventilation Companies, Inc.
4. Greenheck.
5. Loren Cook Co.

B. Description: Fan wheel and housing, factory-mounted motor with belt drive or direct drive, an inlet cone section, and accessories.

C. Housings: Hot rolled steel ASTM A-283, 0.187 inch thick for fans up to 28 inches ID, and 0.250 inch for larger fan ID's.

D. Wheel Assemblies: Cast aluminum with airfoil-shaped blades mounted on cast-iron wheel plate keyed to shaft with solid-steel key.

E. Wheel Assemblies: Fiberglass-reinforced plastic cured under pressure with airfoil-shaped blades keyed to stainless steel shaft.

F. Wheel Assemblies: Cast aluminum, machined and fitted to shaft.

G. Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
3. Fan Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
4. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
5. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
6. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.
7. Motor Mount: Adjustable base.
8. Shaft Bearings: Radial, heavy duty, pillow block type, self-aligning ball or roller bearings.

   a. Ball-Bearing Rating Life: ABMA 9, L10 of 100,000 hours.
   b. Roller-Bearing Rating Life: ABMA 11, L10 of 100,000 hours.
   c. Extend lubrication lines to outside of casing and terminate with grease fittings.

H. Accessories:

1. Companion Flanges: Rolled flanges of same material as housing.
2. Inspection Door: Bolted door allowing limited access to internal parts of fan, of same material as housing.
3. Propeller Access Section Door: Short duct section bolted to fan inlet and outlet allowing access to internal parts of fan for inspection and cleaning, of same material as housing.
4. Swingout Construction: Assembly allowing entire fan section to swing out from duct for cleaning and servicing, of same material as housing.
5. Mounting Clips: Horizontal ceiling or Vertical mounting clips welded to fan housing, of same material as housing.
6. Horizontal Support: Pair of supports bolted to fan housing, of same material as housing.
7. Vertical Support: Short duct section with welded brackets bolted to fan housing, of same material as housing.

8. Inlet and Outlet Screens: Wire-mesh screen on fans not connected to ductwork, of same material as housing.
9. Backdraft Dampers: Ultra-low leakage type, for bolting to the discharge of fan or outlet cone, of same material as housing. Maximum leakage not to exceed 0.07% at 3 inches W.C. static pressure.
10. Shaft Seal: Elastomeric seal and Teflon wear plate, suitable for up to 300 deg F.
11. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.
12. Inlet Vanes: Adjustable; with peripheral control linkage operated from outside of airstream, bronze sleeve bearings on each end of vane support, and provision for manual or automatic operation of same material as housing.
13. Inlet Bell: Curved inlet for when fan is not attached to duct, of same material as housing.
14. Inlet Cones: Round-to-round transition of same material as housing.
15. Outlet Cones: Round-to-round transition of same material as housing.
16. Stack Cap: Vertical discharge assembly with backdraft dampers, of same material as housing.

I. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.
2. Direct-Driven Units: Encase motor in housing outside of airstream, factory wired to disconnect switch located on outside of fan housing.

J. Factory Finishes:

1. Sheet Metal Parts: Prime coat before final assembly.
2. Exterior Surfaces: Baked-enamel finish coat after assembly.
3. Coatings: Powder-baked enamel.

a. Apply to finished housings.
b. Apply to fan wheels.

K. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

2.2 VANEAXIAL FANS

A. Manufacturers: Subject to compliance requirements, provide products by one of the following:

1. Aerovent; a Twin City Fan Company.
2. American Fan Company (Flakt/Woods).
3. Barry Blower Div.; Penn Ventilation Companies, Inc.
4. Greenheck.
5. New York Blower Company (Jay).
6. Loren Cook Co.

B. Description: Fan wheel and housing, straightening vane section, factory-mounted motor with belt drive or direct drive, an inlet cone section, and accessories.

1. Variable-Pitch Fans: Internally mounted electronic actuator

a. Fan blades shall be automatically controllable through full design pitch range to vary volume and pressure characteristics across this range.
b. Each blade to be index marked for various pitch settings and shall be capable of stepless control across the complete pitch range with the motor operating at full speed.
c. Blades in the controllable pitch hub shall be remotely-controlled by an actuator furnished by the fan manufacturer.

C. Housings: Hot rolled steel ASTM A 283, 0.187 inch thick for fans up to 28 inch ID and 0.250 inch for larger fan ID's, continuously welded.

1. Inlet and Outlet Connections: Flanges.
2. Guide Vane Section: At least 8 stationary integral guide vanes, 3/16 inch thick, downstream from fan wheel designed to straighten airflow.

D. Wheel Assemblies: Fiberglass-reinforced plastic cured under pressure with airfoil-shaped blades keyed to stainless steel shaft.

E. Wheel Assemblies: Cast-aluminum hub assembly, machined and fitted with threaded bearing wells to receive blade-bearing assemblies with replaceable, cast-aluminum blades; factory mounted and balanced.

F. Drives for belt driven fans: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size 1.4.
2. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
3. Fan Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
4. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
5. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
6. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.
7. Motor Mount: Adjustable base.
8. Shaft Bearings: Radial, heavy duty, pillow black type, self-aligning ball or roller bearings.

a. Ball-Bearing Rating Life: ABMA 9, L10 of 100,000 hours.
b. Roller-Bearing Rating Life: ABMA 11, L10 of 100,000 hours.
c. Extend lubrication lines to outside of casing and terminate with grease fittings.

G. Direct Motor Driven Fans:

1. Arrangement 4 with motor inside fan housing.
2. Fan rotor assembly attached directly to motor shaft, properly keyed and secured by means of a ball bearing locknut and washer for a positive locking method of securing rotor to fan shaft.
3. Motor Mount: Flange mounted, with motor flange recessed into motor support plate to preclude any shear effect on bold misalignment.
4. Motor Support Plate: Steel plate, 0.75 inch thick, welded to fan housing by means of motor support ring and names.
5. Motor Support Ring: Steel, at least 0.25 inch thick on hub sized up to 17 inch and at least 0.375 inch thick on hub sizes 21 inch and larger. Continuously welded to motor support plate.

H. Accessories:

1. Companion Flanges: Rolled flanges of same material as housing.
2. Inspection Door: Bolted door allowing limited access to internal parts of fan, of same material as housing.
3. Propeller Access Section Door: Short duct section bolted to fan inlet and outlet allowing access to internal parts of fan for inspection and cleaning, of same material as housing.
4. Swingout Construction: Assembly allowing entire fan section to swing out from duct for cleaning and servicing, of same material as housing.
5. Mounting Clips: Horizontal ceiling or Vertical mounting clips welded to fan housing, of same material as housing.
6. Horizontal Support: Pair of supports bolted to fan housing, of same material as housing.
7. Vertical Support: Short duct section with welded brackets bolted to fan housing, of same material as housing.
8. Inlet and Outlet Screens: Wire-mesh screen on fans not connected to ductwork of same material as housing.
9. Backdraft Dampers: Ultra low leakage type for mounting with flexible connection to the discharge of fan or direct mounted to the discharge diffuser section of same material as housing. Maximum leakage not to exceed 0.07% at 3 inches W.C. static pressure.
10. Stall Alarm Probe: Sensing probe capable of detecting fan operation in stall and signaling control devices. Control devices and sequence of operation are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."
11. Flow Measurement Port: Pressure measurement taps installed in the inlet of fan to detect and signal airflow readings to temperature-control systems. Control devices and sequence of operation are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."
12. Shaft Seal: Elastomeric seal and Teflon wear plate, suitable for up to 300 deg F.
13. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.

14. Inlet Vanes: Adjustable; with peripheral control linkage operated from outside of airstream, bronze sleeve bearings on each end of vane support, and provision for manual or automatic operation of same material as housing.
15. Inlet Bell: Curved inlet for when fan is not attached to duct, of same material as housing.
16. Inlet Cones: Round-to-round transition of same material as housing.
17. Outlet Cones: Round-to-round transition of same material as housing.
18. Stack Cap: Vertical discharge assembly with backdraft dampers, of same material as housing.

I. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.
2. Direct-Driven Units: Encase motor in housing outside of airstream.

a. Flange mounted NEMA standard totally enclosed air over, single speed single winding continuous duty variable torque type.
b. High efficiency type with ball bearings AFEMA “PP,” and Class “F” insulation using thermosetting insulating varnish fortified with water repelling silicone ambient.
c. Provide external copper grease leads for lubrication of motor bearings.
d. Suitable for operation in vertical, horizontal or angular position.

J. Factory Finishes:

1. Sheet Metal Parts: Prime coat before final assembly.
2. Exterior Surfaces: Baked-enamel finish coat after assembly.
3. Coatings: Powder-baked enamel.

a. Apply to finished housings.
b. Apply to fan wheels.

4. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

2.3 MIXED-FLOW FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Loren Cook Company.
2. Greenheck.

B. Description: Fan wheel and housing, straightening vane section, factory-mounted motor with belt drive, and accessories.

C. Housings: Galvanized steel.

1. Inlet and Outlet Connections: Outer mounting frame and companion flanges.

2. Guide Vane Section: Integral guide vanes downstream from fan wheel designed to straighten airflow.
3. Mixed-Flow Outlet Connection: Flanged discharge(s) perpendicular to fan inlet.

D. Wheel Assemblies: Cast aluminum with airfoil-shaped blades mounted on cast-iron wheel plate keyed to shaft with solid-steel key.

E. Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
3. Fan Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
4. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
5. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
6. Motor Mount: Adjustable base.
7. Shaft Bearings: Radial, heavy duty, pillow block type, self-aligning ball or roller bearings.

a. Ball-Bearing Rating Life: ABMA 9, L10 of 100,000 hours.
b. Roller-Bearing Rating Life: ABMA 11, L10 of 100,000 hours.
c. Extend lubrication lines to outside of casing and terminate with grease fittings.

F. Accessories:

1. Mounting Clips: Horizontal ceiling or Vertical mounting clips welded to fan housing, of same material as housing.
2. Inlet and Outlet Screens: Wire-mesh screen on fans not connected to ductwork of same material as housing.
3. Backdraft Dampers: Low leakage type for mounting with flexible connection to the discharge of fan or direct mounted to the discharge diffuser section of same material as housing.
4. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.
5. Inlet Bell: Curved inlet for when fan is not attached to duct, of same material as housing.
6. Inlet Cones: Round-to-round transition of same material as housing.
7. Outlet Cones: Round-to-round transition of same material as housing.
8. Stack Cap: Vertical discharge assembly with backdraft dampers, of same material as housing.

G. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.
2. Direct-Driven Units: Encase motor in housing outside of airstream, factory wired to disconnect switch located on outside of fan housing.

H. Factory Finishes:

1. Sheet Metal Parts: Prime coat before final assembly.
2. Exterior Surfaces: Baked-enamel finish coat after assembly.
3. Coatings: Powder-baked enamel.

   a. Apply to finished housings.
   b. Apply to fan wheels.

I. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

2.4 SOURCE QUALITY CONTROL

A. Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.

B. Fan Performance Ratings: Establish flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests and ratings according to AMCA 210, "Laboratory Methods of Testing Fans for Rating."

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install axial fans level and plumb.

B. Support floor-mounting units. Vibration- and seismic-control devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

1. Secure vibration and seismic controls to concrete bases using anchor bolts cast in concrete base.

C. Install floor-mounting units on concrete bases. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

D. Install floor-mounting units on concrete bases designed to withstand, without damage to equipment, the seismic force required by authorities having jurisdiction. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

E. Support suspended units from structure using threaded steel rods. Vibration-control devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

F. Install units with clearances for service and maintenance.

G. Label fans according to requirements specified in Division 23 Section "Identification for HVAC Piping and Equipment."

3.2 CONNECTIONS

A. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Division 23 Section "Air Duct Accessories."

B. Drawings indicate a specific configuration of ductwork at each unit. If configuration of the units furnished differs from that indicated on the drawings (whether or not the units are scheduled units, or of a listed manufacturer, or an acceptable substitute), it shall be the Contractor’s responsibility to modify ductwork, etc., as required to accommodate the actual configuration of the units furnished.

C. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

D. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.3 FIELD QUALITY CONTROL

A. Perform the following field tests and inspections and prepare test reports:

1. Verify that shipping, blocking, and bracing are removed.
2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
3. Verify that cleaning and adjusting are complete.
4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
5. Adjust belt tension.
6. Adjust damper linkages for proper damper operation.
7. Verify lubrication for bearings and other moving parts.
8. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.

9. Disable automatic temperature-control operators, energize motor and confirm proper motor rotation and unit operation, adjust fan to indicated rpm, and measure and record motor voltage and amperage.
10. Shut unit down and reconnect automatic temperature-control operators.
11. Remove and replace malfunctioning units and retest as specified above.

B. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

3.4 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Adjust belt tension.

C. Lubricate bearings.

END OF SECTION 23 34 13

SECTION 23 34 16 - CENTRIFUGAL HVAC FANS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes the following:

1. Airfoil centrifugal fans.
2. Backward-inclined centrifugal fans.
3. Forward-curved centrifugal fans.
4. Tubular and in-line centrifugal fans.
5. Utility/vent sets.
6. Cabinet fans.
7. Plenum fans.
8. Plug fans.

1.3 PERFORMANCE REQUIREMENTS

A. Project Altitude: Base fan performance ratings on 100 feet above sea level.

B. Operating Limits: Classify according to AMCA 99.

1.4 SUBMITTALS

A. Product Data: Include rated capacities, furnished specialties, and accessories for each type of product indicated and include the following:

1. Certified fan performance curves with system operating conditions indicated.
2. Certified fan sound-power ratings, based on actual test on the fan sizes being furnished, and conducted in accordance with current AMCA standards. Data shall define sound-power levels (PWL) re: 10-12 watts for each of the eight (8) frequency bands. Manufacturer's furnishing estimated data will not be accepted.
3. Motor ratings and electrical characteristics, plus motor and electrical accessories.
4. Material thickness and finishes, including color charts.
5. Dampers, including housings, linkages, and operators.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1. Wiring Diagrams: Power, signal, and control wiring.
2. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
3. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.

C. Coordination Drawings: Show fan room layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements.

D. System Effect Calculations: Since all fans are tested in accordance with AMCA standards and data catalogued consists of fans capacity (CFM at external static pressure) while connected to straight inlet and discharge duct conditions the vendor is responsible for calculating the “System Effect” pressure drop of inlet and discharge connections to the ducts shown on the drawings. This static pressure will be added to the external static pressure of the fan and the submitted fan, fan accessories and fan curve shall indicate the rpm, cfm, bhp, tip speed and other required capacity data to be corrected to account for the “System Effect” pressure drop and for a minimum of 5% or higher belt drive losses based upon the size and number of V-belts required for the fan sheaves in the selection of the actual motor horsepower to provide.

E. Field quality-control test reports.

F. Operation and Maintenance Data: Instructions for lubrication, motor and drive replacement, spare parts list and wiring diagrams, for centrifugal fans to include in emergency, operation, and maintenance manuals.

1.5 QUALITY ASSURANCE

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

B. AMCA Compliance: Products shall comply with performance requirements and shall be licensed to use the AMCA-Certified Ratings Seal.

C. AMCA certification in accordance with AMCA Standard 210 and AMCA Standard 2408 for centrifugal fans. Class I, II, or III, as required for operating conditions.

D. Where variable inlet vanes are used, fan performance characteristics must be manufacturer’s published catalog rating data of fan with vanes.

E. NEMA Compliance: Motors and electrical accessories shall comply with NEMA 1.

F. UL/cUL Power Ventilator for Smoke Control Systems.

G. UL/cUL 705, Power Ventilators.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations, with protective crating and covering.

B. Disassemble and reassemble units, as required for moving to the final location, according to manufacturer's written instructions.

C. Lift and support units with manufacturer's designated lifting or supporting points.

D. Protect motors, shafts, and bearings from weather and construction dust. Comply with manufacturer’s wheel and motor rotation schedule for extended storage.

1.7 COORDINATION

A. Coordinate size and location of structural-steel support members.

B. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

C. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Division 07 Section "Roof Accessories."

1.8 EXTRA MATERIALS

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

1. Belts: Two sets for each belt-driven unit.

PART 2 - PRODUCTS

2.1 GENERAL

A. Units furnished shall be complete with all components assembled. All features considered standard by the manufacturer and which are required to complete the system, and to make it functional, shall be included without respect to specified detailing in these specifications.

B. Drawings indicate a specific configuration of ductwork at each unit based on required discharge and intake requirements and taking into account fan rotation. If configuration of the units furnished on the project differs from that indicated on the drawings (whether or not the units furnished are the scheduled units, a listed manufacturer or an acceptable substitute), it shall be the Contractor's responsibility to modify ductwork, etc., as required to accommodate the actual configuration of units furnished on the project.

C. Fan manufacturer shall provide all ultra-low leakage type motorized backdraft dampers of type indicated on drawings.

1. Frames: Galvanized steel, not less than 0.09 inch thick.
2. Blades: Galvanized steel, not less than 0.064 inch thick and not more than 8 inches wide.
3. Bearings: Oiltite, ball bearing or nylon, with 0.50 inch shafts.
4. Side seals: Stainless steel of the tight-seal spring type.
5. Maximum leakage not to exceed 0.07% at static pressure of 3 inches W.C.
6. Submit leakage and flow characteristic date for all backdraft dampers with fan manufacturer's submittals.

D. Spark Resist and Construction for fans as noted.

1. Spark Arrestance Class:

   a. Class A: All parts in contact with air, non-ferrous.
   b. Class B: Fan wheel and rubbing, non-ferrous.
   c. Class C: Inlet cone and rub ring, non-ferrous.

2. Motor: Explosionproof, Class I, Group D, Division 2.
3. Belt Drive: Non-sparking.
4. Fan arrangement with bearings out of air stream.
5. No inlet vanes or outlet dampers.
6. Verify corrosive characteristics of materials being handled, operating temperatures and whether fumes are wet or dry. Fan manufacturer to determine the material, number and thickness of coats, preparation of metal surfaces, baked or air dried, etc.
7. Assure that corrosion resistant construction does not conflict with spark-resistant requirements.

E. Corrosion Resistant Construction for fans as noted.

1. Fan shall be completely corrosion resistant, equipped with fan blades best suited for corrosion protection method.
2. Scroll and Wheel: Type 304, 316 stainless steel.

2.2 AIRFOIL CENTRIFUGAL FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Aerovent; a Twin City Fan Company.

2. Barry Blower Co.
3. Chicago Blower Corporation.
4. Greenheck Fan Corp.
5. Loren Cook Company.

B. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure.

C. Housings: Formed panels to make curved-scroll housings with shaped cutoff, with doors or panels to allow access to internal parts and components.

1. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
2. Horizontally split, bolted-flange housing.
3. Spun inlet cone with flange.
4. Outlet flange.

D. Airfoil Wheels: Single-width-single-inlet and double-width-double-inlet construction with curved inlet flange; heavy backplate; hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate; and cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws**;** and special coating.

E. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
2. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

F. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings for fans smaller than 24" diameter. Fans 24" and larger, bearing housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

G. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing. For fans 24" and larger, bearings housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

H. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.

2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

I. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
3. Motor pulleys: Cast iron or cast steel, companion sheaves to maintain belts parallel.

a. Adjustable pitch diameter:

1) For fans with motors up to 5 hp.
2) For fans with motors from 7 1/2 to 25 hp operating under 1000 rpm.

b. Fixed pitch diameter:

1) Fans with motors 25 hp and larger.
2) Fans with motors 7 1/2 hp and larger operating over 1000 rpm.
3) All fans with variable inlet vanes or variable frequency drives.
4) Supply and install on fixed pitch pulley per fan to balance systems.

c. Select pulleys so pitch adjustment is at the middle of adjustment range at fan design conditions.

4. Belts: Oil resistant non-sparking and non-static matched sets for multiple belt drives.

5. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
6. Motor Mount: Adjustable for belt tensioning.

J. Accessories:

1. Scroll Access Doors: Shaped to conform to scroll, with quick-opening latches and gaskets.
2. Cleanout Door: Quick-opening, latch-type gasketed door allowing access to fan scroll, of same material as housing.
3. Scroll Drain Connection: NPS 1 steel pipe coupling welded to low point of fan scroll.
4. Companion Flanges: Rolled flanges for duct connections of same material as housing.
5. Variable Inlet Vanes: With blades supported at both ends with two permanently lubricated bearings of same material as housing. Variable mechanism terminating in single control lever with control shaft for double-width fans.

6. Discharge Dampers: Assembly with parallel blades constructed of two plates formed around and to shaft, channel frame, and sealed ball bearings; with blades linked outside of air stream to single control lever of same material as housing.
7. Inlet Screens: Grid screen of same material as housing.
8. Outlet Screens: Grid screen of same material as housing, where no connecting ductwork is indicated.
9. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
10. Spark-Resistant Construction: AMCA 99.
11. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
12. Weather Cover: Enameled-steel sheet with ventilation slots, bolted to housing.
13. Bearing Lubrication: Pressure type lubricating fittings, similar to Alemite and pressure relief fittings, similar to Keystone; extended to accessible locations.

K. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.
2. Variable Speed Drive: Inverter rated totally enclosed fan cooled premium plus high efficiency motor, not EPACT standard efficiency.

L. Characteristics:

1. Housing Material: Reinforced steel.
2. Special Housing Coating: Powder-baked enamel.
3. Wheel Material: Steel.
4. Special Wheel Coating: Powder-baked enamel.

M. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

2.3 BACKWARD-INCLINED CENTRIFUGAL FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Aerovent; a Twin City Fan Company.
2. Barry Blower Co.
3. Chicago Blower Corporation.
4. Greenheck Fan Co.
5. Loren Cook Company.

B. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure.

C. Housings: Formed panels to make curved-scroll housings with shaped cutoff; with doors or panels to allow access to internal parts and components.

1. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
2. Horizontally split, bolted-flange housing.
3. Spun inlet cone with flange.
4. Outlet flange.

D. Backward-Inclined Wheels: Single-width-single-inlet and double-width-double-inlet construction with curved inlet flange, backplate, backward-inclined blades welded or riveted to flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.

E. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Turned, ground, and polished hot-rolled steel with keyway. Ship with a protective coating of lubricating oil.
2. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

F. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings for fans smaller than 24" diameter. Fans 24" and larger, bearing housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

G. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, horizontally split, cast-iron housing. For fans 24" and larger, bearings housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

H. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, horizontally split, cast-iron housing. For fans 24" and larger, bearing housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, Ll0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, Ll0 at 120,000 hours.

I. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
3. Motor pulleys: Cast iron or cast steel, companion sheaves to maintain belts parallel.

a. Adjustable pitch diameter:

1) For fans with motors up to 5 hp.
2) For fans with motors from 7 1/2 to 25 hp operating under 1000 rpm.

b. Fixed pitch diameter:

1) Fans with motors 25 hp and larger.
2) Fans with motors 7 1/2 hp and larger operating over 1000 rpm.
3) All fans with variable inlet vanes or variable frequency drives.
4) Supply and install on fixed pitch pulley per fan to balance systems.

c. Select pulleys so pitch adjustment is at the middle of adjustment range at fan design conditions.

4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
5. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
6. Motor Mount: Adjustable for belt tensioning.

J. Accessories:

1. Scroll Access Doors: Shaped to conform to scroll, with quick-opening latches and gaskets.
2. Cleanout Door: Quick-opening, latch-type gasketed door allowing access to fan scroll, of same material as housing.
3. Scroll Drain Connection: NPS 1 steel pipe coupling welded to low point of fan scroll.
4. Companion Flanges: Rolled flanges for duct connections of same material as housing.
5. Variable Inlet Vanes: With blades supported at both ends with two permanently lubricated bearings of same material as housing. Variable mechanism terminating in single control lever with control shaft for double-width fans.
6. Discharge Dampers: Assembly with parallel blades constructed of two plates formed around and to shaft, channel frame, and sealed ball bearings; with blades linked outside of air stream to single control lever of same material as housing.
7. Inlet Screens: Grid screen of same material as housing.
8. Outlet Screens: Grid screen of same material as housing, where no connecting ductwork is indicated.
9. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
10. Spark-Resistant Construction: AMCA 99.
11. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
12. Weather Cover: Enameled-steel sheet with ventilation slots, bolted to housing.

13. Bearing Lubricating: Pressure type lubricating fittings, similar to Alemite and pressure relief fittings, similar to Keystone; extended to accessible locations.

K. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.
2. Variable Speed Drive: Inverter rated totally enclosed fan cooled premium plus high efficiency motor, not EPACT standard efficiency.

L. Capacities And Characteristics:

1. Housing Material: Reinforced steel.
2. Special Housing Coating: Powder-baked enamel.
3. Wheel Material: Steel.
4. Special Wheel Coating: Powder-baked enamel.

M. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

2.4 FORWARD-CURVED CENTRIFUGAL FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Aerovent; a Twin City Fan Company.
2. Barry Blower Co.
3. Chicago Blower Corporation.
4. Greenheck Fan Corp.
5. Loren Cook Company.

B. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure.

C. Housings: Formed panels to make curved-scroll housings with shaped cutoff; with doors or panels to allow access to internal parts and components.

1. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
2. Horizontally split, bolted-flange housing.
3. Spun inlet cone with flange.
4. Outlet flange.

D. Forward-Curved Wheels: Black-enameled or galvanized steel construction with inlet flange, backplate, shallow blades with inlet and tip curved forward in direction of airflow, mechanically secured to flange and backplate; cast-steel hub swaged to backplate and fastened to shaft with set screws.

E. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
2. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

F. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings for fans smaller than 24" diameter. Fans 24" and larger, bearing housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

G. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, horizontally split, cast-iron housing. For fans 24" and larger, bearing housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

H. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, horizontally split cast-iron housing. For fans 24" and larger, bearing housing shall be horizontally split.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

I. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
3. Motor pulleys: Cast iron or cast steel, companion sheaves to maintain belts parallel.

   a. Adjustable pitch diameter:

      1) For fans with motors up to 5 hp.
      2) For fans with motors from 7 1/2 to 25 hp operating under 1000 rpm.

   b. Fixed pitch diameter:

      1) Fans with motors 25 hp and larger.
      2) Fans with motors 7 1/2 hp and larger operating over 1000 rpm.
      3) All fans with variable inlet vanes or variable frequency drives.
      4) Supply and install on fixed pitch pulley per fan to balance systems.

4. Select pulleys so pitch adjustment is at the middle of adjustment range at fan design conditions.

5. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
6. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
7. Motor Mount: Adjustable for belt tensioning.

J. Accessories:

1. Scroll Access Doors: Shaped to conform to scroll, with quick-opening latches and gaskets.
2. Cleanout Door: Quick-opening, latch-type gasketed door allowing access to fan scroll, of same material as housing.
3. Scroll Drain Connection: NPS 1 steel pipe coupling welded to low point of fan scroll.
4. Companion Flanges: Rolled flanges for duct connections of same material as housing.
5. Variable Inlet Vanes: With blades supported at both ends with two permanently lubricated bearings of same material as housing. Variable mechanism terminating in single control lever with control shaft for double-width fans.
6. Discharge Dampers: Assembly with parallel blades constructed of two plates formed around and to shaft, channel frame, and sealed ball bearings; with blades linked outside of air stream to single control lever of same material as housing.
7. Inlet Screens: Grid screen of same material as housing.
8. Outlet screens: Grid screen of same material as housing, where no connecting ductwork is indicated.
9. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
10. Spark-Resistant Construction: AMCA 99.
11. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
12. Weather Cover: Enameled-steel sheet with ventilation slots, bolted to housing.
13. Bearing Lubrication: Pressure type lubricating fittings, similar to Alemite and pressure relief fittings, similar to Keystone; extended to accessible locations.

K. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.
2. Variable Speed Drive: Inverter rated totally enclosed fan cooled premium plus high efficiency motor, not EPACT standard efficiency.

L. Characteristics:

1. Housing Material: Reinforced steel.

2. Special Housing Coating: Powder-baked enamel.
3. Wheel Material: Galvanized steel.
4. Special Wheel Coating: Powder-baked enamel.

M. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

2.5 TUBULAR (INLINE) CENTRIFUGAL FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Aerovent, a Twin City Fan Company.
2. Barry Blower Company.
3. Greenheck Fan Corporation.
4. Loren Cook Company.

B. Description: Factory-fabricatedassembled, tested, and finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure.

C. Housings: Formed steel panels to make tubular housings, continuously welded, with doors or panels to allow access to internal parts and components.

1. Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
2. Spun inlet cone with flange.
3. Inlet and outlet flanges.
4. Straightening Vanes: Downstream from fan wheel designed to straighten airflow.

D. Airfoil Wheels: With curved inlet flange; heavy backplate; hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate; and cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws**;** and special coating.

E. Backward-Inclined Wheels: With curved inlet flange, backplate, backward-inclined blades welded or riveted to flange and backplate; cast-iron or cast steel hub riveted to backplate and fastened to shaft with set screws.

F. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
2. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

G. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings.

1. Ball-Bearing Rating Life: ABMA 9, L10 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, L10 at 120,000 hours.

H. Grease-Lubricated Shaft Bearings: Heavy duty, self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, L10 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, L10 at 120,000 hours.

I. Grease-Lubricated Shaft Bearings: Heavy duty, self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, L10 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, L10 at 120,000 hours.

J. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.
1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
3. Motor pulleys: Cast iron or cast steel, companion sheaves to maintain belts parallel.

    a. Adjustable pitch diameter:

        1) For fans with motors up to 5 hp.
        2) For fans with motors from 7 1/2 to 25 hp operating under 1000 rpm.

    b. Fixed pitch diameter:

        1) Fans with motors 25 hp and larger.
        2) Fans with motors 7 1/2 hp and larger operating over 1000 rpm.
        3) Supply and install on fixed pitch pulley per fan to balance systems.

    c. Select pulleys so pitch adjustment is at the middle of adjustment range at fan design conditions.

4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
5. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
6. Motor Mount: Adjustable for belt tensioning.

K. Accessories:

1. Access Doors: Shaped to conform to housing, with quick-opening latches and gaskets.

2. Cleanout Door: Quick-opening, latch-type gasketed door allowing access to fan housing, of same material as housing.
3. Drain Connection: NPS 1 (DN 25) steel pipe coupling welded to low point of fan housing.
4. Companion Flanges: Rolled flanges for duct connections of same material as housing.
5. Mounting Brackets: For horizontal floor or ceiling mounting and for vertical mounting.
6. Drive chamber and Belt Tube: Isolate belts and drives from air stream, of same material as housing.
7. Inlet and Outlet Screens: Where no connecting ductwork is indicated, grid screen of same material as housing.
8. Shaft Seals: Airtight seals around shaft or drive side, of felt or neoprene.
9. Bearing Lubrication: Pressure type lubricating fittings, similar to Alemite and pressure relief fittings, similar to Keystone, extended to outside of housing.
10. Spark-Resistance Construction: AMCA Type B.

L. Motors: Comply with requirements in Division 23 Section “Common Motor Requirements for HVAC Equipment.”

1. Enclosure Type: Totally enclosed, fan cooled.

M. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

N. Characteristics:

1. Housing Material: Reinforced steel.
2. Special Housing Coating: Powder-baked enamel.
3. Wheel Material: Steel.
4. Special Wheel Coating: Powder-baked enamel.

2.6 UTILITY VENT SETS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Aerovent: a Twin City Fan Company.
2. Chicago Blower Corporation.
3. Greenheck Fan Corp.
4. Loren Cook Company.
5. Trane.

B. Description: Factory-fabricated, -assembled, -tested, and –finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly and common bare structure, with bearing pedestal, in fan arrangement 10.

C. Fans shall be UL listed as "Power Ventilators for Smoke Control Systems" (by maximum temperature for a minimum number of hours of operation) for one of the following:
   1. 500°F (260°C) maximum temperature for a minimum of 4 hours of operation
   2. 572°F (300°C) maximum temperature for a minimum of 2 hours of operation.
   3. 750°F (400°C) maximum temperature for a minimum of 2 hours of operation.
   4. 1000°F (538°C) maximum temperature for a minimum of 15 minutes of operation.
   5. The UL Power Ventilators for Smoke Control sticker shall be fixed to the fan housing

D. Housings: formed panels to make curved-scroll housings with shaped cutoff; with doors or panels to allow access to internal parts and components.

   1. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
   2. Bearing pedestal: Steel angle, integral with fan bracing for mounting bearings. Fan motor mounted under bearing pedestal.
   3. Housings: Field rotatable to standard discharge positions.
   4. Inlet cone.
   5. Outlet and inlet flanges.

E. Fan Wheels:

   1. Under 12 inch (305 mm): Forward curved wheels, steel construction with inlet flange, backplate, shallow blades with inlet and tip curved forward in direction of airflow, mechanically secured to flange and backplate; cast-steel hub swaged to backplate and fastened to shaft with set screws.
   2. 12 inch (305 mm) and larger: Backward inclined wheels, steel construction with curved inlet flange, backplate, backward-inclined blades welded or riveted to flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened shaft with set screws.

F. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

   1. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
   2. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

G. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings.

   1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
   2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

H. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and cast-iron housing.

   1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.

2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

I. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
3. Motor Pulleys: Cast iron or cast steel. Adjustable pitch diameter for use with motors up to 5 hp; fixed pitch diameter for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
5. Belt Guards: Fabricate to comply with OSHA SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use to tachometer with guard in place
6. Motor Mount: Adjustable for belt tensioning.

J. Accessories:

1. Scroll Access Doors: Shaped to conform to scroll, with quick-opening latches and gaskets.
2. Cleanout Door: Quick-opening, latch-type gasketed door allowing access to fan scroll, of same material as housing.
3. Scroll Drain Connection: NPS 1 (DN 25) steel pipe coupling welded to low point of fan scroll.
4. Companion Flanges: Rolled flanges for duct connections of same material as housing.
5. Discharge Dampers: Assembly parallel blades constructed of two plates formed around and to shaft, channel frame, and sealed ball bearings; with blades linked outside of airstream to single control level of same material as housing.
6. Inlet Screens: Grid screen of same material as housing.
7. Outlet Screens: Grid screen of same material as housing, where no connecting ductwork is indicated.
8. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
9. Spark-Resistant Construction: AMCA 99.
10. Shaft Seals: Airtight seals installed around shaft on drive side of fans.
11. Weather Cover: Enameled-steel sheet with ventilation slots, bolted to housing and support base.

K. Motors: Comply with requirements in Division 23 Section “Common Motor Requirements for HVAC Equipment.”

1. Enclosure Type: Totally closed, fan cooled.

L. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

2.7 CABINET FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Greenheck Fan Corporation.
   2. Loren Cook Company.
   3. Penn Ventilator Company.
   4. Trane.

B. Description: Factory-fabricated, -assembled, -tested, and –finished, units, consisting of insulated cabinet containing filter box, fan wheel(s), fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure.

C. Cabinet: Galvanized sheet steel, at least 0.08 inch thick, reinforced and braced with angles, with hinged or bolted access panels to allow access to internal parts and components.

   1. Internal Bracing: Steel angle or channel-iron supports for mounting fan wheels(s), shaft, motor and accessories.
   2. Inlet and outlet duct connection flanges.
   3. Internal Insulation: Coated fiberglass board insulation, NFPA 90 approved, 1 inch thick, 1.5 lb density.

D. Fan Wheels: Galvanized steel construction forward curved in direction of air flow or backward inclined blades mounted on a common shaft and secured with keyways.

E. Shafts: Solid steel selected for continuous operation at maximum rated fan speed and motor horsepower.

   1. Shaft mounted on ball bearings.
   2. Motor and drive frame isolated on shock mounts.

F. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and cast-iron housing.

   1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
   2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

G. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

   1. Service Factor Based on Fan Motor Size: 1.4.
   2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
   3. Motor Pulleys: Cast iron or cast steel. Adjustable pitch diameter for use with motors up to 7 1/2 hp; fixed pitch diameter for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
   4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.

5. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
6. Motor Mount: Adjustable for belt tensioning.

H. Accessories:

1. Access Panels: hinged or bolted gasketed panels allowing access to internal parts and components in cabinet, of same material as cabinet.
2. Companion Flanges: Flanges for duct connections of same material as cabinet.
3. Spark-Resistant Construction: AMCA 99.
4. Bearing Lubrication: Lubricating fittings and pressure relief fittings extended to accessible locations.
5. Discharge Dampers: Assembly with parallel blades constructed of two plates formed around and to shaft, channel frame, and sealed ball bearings; with blades linked outside of airstream to single control lever of same material as housing.

I. Motors: Ball bearing type. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed fan cooled.

J. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

K. Filter Box: Galvanized sheet steel fabricated as specified for cabinet, to mate with fan cabinet, with side access panels for filter replacement.
1. Filters: 2 inch (50 mm) thick throwaway pleated type.

2.8 PLENUM FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Acme Engineering & Mfg. Corp.
2. Aerovent; a Twin City Fan Company.
3. Chicago Blower Corporation.
4. Greenheck Fan Corporation.
5. Loren Cook Company.
6. Trane.
7. Owner approved substitution.

B. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure.

C. Airfoil Wheels: Single-width-single-inlet construction with smooth-curved inlet flange; heavy backplate; hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate; and cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws; and special coating.

D. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
2. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

E. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

F. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

G. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

H. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
3. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
5. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
6. Motor Mount: Adjustable for belt tensioning.

I. Accessories:

1. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
2. Spark-Resistant Construction: AMCA 99.

3. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.

J. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.

K. Characteristics:

1. Wheel Material: Steel.
2. Special Wheel Coating: Powder-baked enamel.

L. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

M. Spark Arrestance Class: A.

2.9 PLUG FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Acme Engineering & Mfg. Corp.
2. Aerovent; a Twin City Fan Company.
3. Chicago Blower Corporation.
4. Loren Cook Company.
5. Trane.

B. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure for installation into a fan plenum or duct.

C. Airfoil Wheels: Single-width-single-inlet construction with smooth-curved inlet flange; heavy backplate; hollow die-formed, airfoil-shaped, backward inclined, blades continuously welded at tip flange and backplate; and cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws; and special coating.

D. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
2. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

E. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

F. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

G. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.

1. Ball-Bearing Rating Life: ABMA 9, LI0 at 120,000 hours.
2. Roller-Bearing Rating Life: ABMA 11, LI0 at 120,000 hours.

H. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
3. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
5. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
6. Motor Mount: Adjustable for belt tensioning.

I. Accessories:

1. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
2. Spark-Resistant Construction: AMCA 99.
3. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
4. Spun inlet cone with flange.
5. Safety Guard: Heavy wire screw cage to enclose moving parts of fan where required for personnel protection.
6. Inlet Vane and Econocone Actuators: with separate access section, minimum 21 inches (530 mm) long, with door for upstream access to vanes.

J. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.

K. Characteristics:

1. Wheel Material: Steel.
2. Special Wheel Coating: Powder-baked enamel.

L. Vibration Isolators: Spring isolators having a static deflection of 1 inch.

M. Spark Arrestance Class: A.

2.10 SOURCE QUALITY CONTROL

A. Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.

B. Fan Performance Ratings: Establish flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests and ratings according to AMCA 210, "Laboratory Methods of Testing Fans for Rating."

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install centrifugal fans level and plumb.

B. Support floor-mounting units using spring isolators having a static deflection of 1 inch. Vibration- and seismic-control devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

1. Secure vibration and seismic controls to concrete bases using anchor bolts cast in concrete base.

C. Install floor-mounting units on concrete bases. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

D. Install floor-mounting units on concrete bases designed to withstand, without damage to equipment, the seismic force required by authorities having jurisdiction. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

E. Support suspended units from structure using threaded steel rods and spring hangers having a static deflection of 1 inch. Vibration-control devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

F. All roof-mounted equipment shall be properly secured to the building structure to withstand local Coastal Windstorm criteria, ie., minimum 115 MPH hurricane force winds.

G. Install units on raised supports where so noted. Furnish platform and all supports and bracing, and provide suitable vibration isolation.

H. Overhead suspended unites and units on raised supports shall be provided with access platforms, railings and ladders.

I. Install units with clearances for service and maintenance.

J. Label fans according to requirements specified in Division 23 Section "Identification for HVAC Piping and Equipment."

3.2 CONNECTIONS

A. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Division 23 Section "Air Duct Accessories."

B. Install ducts adjacent to fans to allow service and maintenance.

C. Install line-sized piping from scroll drain connection, with trap with seal equal to 1.5 times specified static pressure, to nearest floor drain.

D. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

E. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.3 FIELD QUALITY CONTROL

A. Perform the following field tests and inspections and prepare test reports:

1. Verify that shipping, blocking, and bracing are removed.
2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
3. Verify that cleaning, including ductwork, and adjusting are complete.
4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
5. Adjust belt tension.
6. Adjust damper linkages for proper damper operation.
7. Verify lubrication for bearings and other moving parts.
8. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.

9. Refer to Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing procedures.
10. Remove and replace malfunctioning units and retest as specified above.

B. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

3.4 DEMONSTRATION

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

3.5 FINAL CLEANING

A. Refer to Section 01 74 23 for final cleaning.

END OF SECTION 23 34 16

SECTION 23 34 23 - HVAC POWER VENTILATORS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes the following:
1. Centrifugal roof ventilators.
2. Axial roof ventilators.
3. Upblast propeller roof exhaust fans.
4. Centrifugal wall ventilators.
5. Ceiling-mounting ventilators.
6. In-line centrifugal fans.
7. Propeller fans.
8. Wall or column-mounted oscillating fans.

1.3 PERFORMANCE REQUIREMENTS

A. Project Altitude: Base fan-performance ratings on 100 feet above sea level.

B. Operating Limits: Classify according to AMCA 99.

1.4 SUBMITTALS

A. Product Data: Include rated capacities, furnished specialties, and accessories for each type of product indicated and include the following:

1. Certified fan performance curves with system operating conditions indicated.
2. Certified fan sound-power ratings.
3. Motor ratings and electrical characteristics, plus motor and electrical accessories.
4. Material thickness and finishes, including color charts.
5. Dampers, including housings, linkages, and operators.
6. Roof curbs.
7. Fan speed controllers.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1. Wiring Diagrams: Power, signal, and control wiring.
2. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
3. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.

C. Coordination Drawings: Reflected ceiling plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:

1. Roof framing and support members relative to duct penetrations.
2. Ceiling suspension assembly members.
3. Size and location of initial access modules for acoustical tile.
4. Ceiling-mounted items including light fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.

D. System Effect calculations: Since all fans are tested in accordance with AMCA standards and data catalogued consists of fan capacity (CFM at external static pressure) while connected to straight inlet and discharge duct conditions, the vendor is responsible for calculating the “System Effect” pressure drop of inlet and discharge connections to the ducts shown on the drawings. This static pressure will be added to the external static pressure of the fan and the submitted fan, fan accessories and fan curve shall indicate the rpm, cfm, bhp, tip speed and other required capacity data to be corrected to account for the “System Effect” pressure drop and for a minimum 5% or higher belt drive losses based upon the size and number of V-belts required for the fan sheaves in the selection of the actual motor horse power to provide.

E. Field quality-control test reports.

F. Operation and Maintenance Data: For power ventilators to include in emergency, operation, and maintenance manuals.

1.5 QUALITY ASSURANCE

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

B. Sound-Power Level Ratings: Comply with AMCA 301, “Methods for Calculating Fan Sound Ratings from Laboratory Test Data.” Factory test fans according to AMCA 300, “Reverberant Room Method for Sound Testing of Fans.” Label fans with the AMCA-Certified Ratings Seal.

C. AMCA Compliance: Establish flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests and ratings according to AMCA 210, “Laboratory methods of Testing Fans for Rating.” Label fans with the AMCA Certified Ratings Seal...

D. American Society for Testing Materials (ASTM): Standard E84, Surface Burning Characteristics of Building Materials.

E. National Fire Protection Association (NFPA): Standard 255, Test Methods, Surface Burning Characteristics of Building Materials.

F. NEMA Compliance: Motors and electrical accessories shall comply with NEMA standards.

G. UL Standard: Power ventilators shall comply with UL 705.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver fans as factory-assembled unit, to the extent allowable by shipping limitations, with protective crating and covering.

B. Disassemble and reassemble units, as required for moving to final location, according to manufacturer's written instructions.

C. Lift and support units with manufacturer's designated lifting or supporting points.

D. Protect motors, shafts, and bearings from weather and construction dust. Comply with manufacturer’s wheel and motor rotation schedule for extended storage.

1.7 COORDINATION

A. Coordinate size and location of structural-steel support members.

B. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

C. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Division 07 Section "Roof Accessories."

1.8 EXTRA MATERIALS

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

1. Belts: Two sets for each belt-driven unit.

PART 2 - PRODUCTS

2.1 General

A. Units furnished shall be complete with all components assembled. All features considered standard by the manufacturer and which are required to complete the system, and to make it functional, shall be included without respect to specific detailing in these specifications.

B. A specific configuration of the duct at each unit has been indicated on the drawings based on required discharge and intake requirements. If the configuration of the units furnished on the project differs from that indicated on the drawings (whether or not the units furnished are scheduled units, a listed manufacturer or an acceptable substitute), it shall be the Contractor's responsibility to modify duct, etc. as required to accommodate the actual configuration of units furnished on the project.

C. Low leakage motorized backdraft dampers: The fan manufacturer shall provide ultra low leakage type motorized backdraft dampers as indicated on the plans. Frames shall not be less than 0.093 inch thick galvanized steel. Blades must not be over 8 inches wide galvanized steel roll formed with edge seals. Bearing shall be Oiltite, ball bearing or nylon with ½" shafts. Side seals shall be stainless steel of the tight-seal spring type. Dampers and seals shall be suitable for temperature ranges of 40°F to 200°F. Dampers shall be minimum (ultra-low leakage) leakage type to conserve energy and the manufacturer shall submit leakage and flow characteristic data for all backdraft dampers with the fan manufacturer temperature control submitted. Maximum leakage shall be 0.07% at static pressure of 3 inches of WC.

D. Preview safety disconnects shall be mounted on the fans at the fan motor with flexible conduit and shall conform to requirements of specification section 23 05 33. Roof mounted fans with three phase motors shall have NEMA-3R disconnects pre-wired.

E. Three phase motors 1 ½ hp and larger shall be TEFC premium plus high efficiency.

F. Furnish and install curb mounted outside air intake hoods, exhaust fan discharge air hoods, relief hoods, and curb mounted rook exhaust fans on roof curbs where indicated on the drawings.
   1. Openings in roof and supporting miscellaneous steel and structural framing as required for support of all roof mounted outside air intake hoods, roof mounted relief hoods, roof mounted discharge hoods for ceiling exhaust fans, and roof mounted exhaust fans shall be by the General Contractor.
   2. HVAC Contractor must furnish to the General Contractor exact curb outside dimensions, exact roof opening sizes and dimensioned location of roof curbs on roof.
   3. Roof curbs for aluminum fans shall be minimum 18" tall, factory pre-fabricated all welded aluminum construction, factory insulated with built in cant, 1 ½" by 1 ½" wolmanized and fire treated wooded nailer strip, 1 1/2" wide by 1/8" thick neoprene full perimeter curb gasket. Roof curbs shall be furnished with damper trays for ease of mounting damper and duct connection. Roof curbs for galvanized steel fans

shall be same as for aluminum curbs, except factory pre-fabricated all welded galvanized construction.

4. Where fans are installed on sloping roofs, the fan manufacturer shall provide a roof curb that matches the roof slop or curvature to allow the fan to be installed level and shall be responsible for coordination with Architectural drawings for exact roof slop and for flashing and sealing details.
5. Where fans are installed on standing seam metal sloping roofs, the standing seam metal roofing manufacturer shall provide the roof curb.
   a. The standing seam metal roofing manufacturer shall provide a 12” high insulated, welded, galvanized, steel roof curb with 1 ½” by 1 ½” wolmanized and fire treated wooden nailer strip for all roof mounted outside air intake goods, roof mounted discharge hoods for ceiling exhaust fans, roof mounted exhaust fans to match slope and roofing material corrugations and standing seam configuration. Roofing manufacturer must coordinate with Architectural drawings for exact roof slope and for flashing sealing details.
   b. Roofing manufacturer must coordinate with HVAC Contractor for exact curb outside dimensions, exact backdraft damper tray opening and dimensions, and exact roof opening size for fans furnished by the contractor.
   c. General Contractor must install roof curbs in manner as recommended by standing seam metal roofing manufacturer furnished on the project and as detailed by the Architect.

G. Corrosion Resistant Construction: For fans so indicated or specified, entire fan shall be completely corrosion resistant, and shall be provided with a scroll drain, shaft seal and flanged inlet and outlets.
   1. Shaft shall be made of stainless steel.
   2. Scroll and wheel shall be stainless steel.

2.2 CENTRIFUGAL ROOF VENTILATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Carnes Company HVAC.
   2. Greenheck.
   3. Loren Cook Company.
   4. Penn Ventilation.

B. Description: Direct- or belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, curb base, and accessories.

C. Housing: Removable, spun-aluminum, dome top and outlet baffle; square, one-piece, aluminum base with venturi inlet cone.

   1. Upblast Units: Provide spun-aluminum discharge baffle to direct discharge air upward, with rain and snow drains and grease collector.
   2. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.

D. Fan Wheels: Aluminum hub and wheel with backward-inclined blades.

E. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:

1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
2. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
3. Fan and motor isolated from exhaust airstream.
4. Pulleys: Cast-iron, adjustable-pitch motor pulley.
   a. Fan pulley: Fixed pitch diameter.
   b. Motor pulley: Variable pitch diameter for use with motors up to 5 hp; Fixed pitch diameter for larger motors and for fans with solid state speed controllers. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
5. Belts: Oil resistant, non-sparking, non-static, notch grip construction; matched sets for multiple belt drives.

F. Accessories:

1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
2. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted outside fan housing, factory wired through an internal aluminum conduit.
3. Bird Screens: Removable, 1/2-inch mesh, aluminum or brass wire.
4. Dampers: Counterbalanced, rattle free, parallel-blade, backdraft dampers mounted in curb base; factory set to close when fan stops.
5. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.

G. Roof Curbs: Aluminum; mitered and welded corners; 1-1/2-inch-thick, rigid, fiberglass insulation adhered to inside walls, damper tray and 1-1/2-inch wood nailer and neoprene curb sealing gasket. Size as required to suit roof opening and fan base.

1. Configuration: Self-flashing without a cant strip, with mounting flange.
2. Overall Height: 18 inches.
3. Sound Curb: Curb with sound-absorbing insulation matrix.
4. Pitch Mounting: Manufacture curb for roof slope.
5. Metal Liner: Aluminum.
6. Burglar Bars: 1/2-inch- thick steel bars welded in place to form 6-inch squares.
7. Mounting Pedestal: Galvanized steel with removable access panel.
8. Vented Curb: Unlined with louvered vents in vertical sides.

H. Characteristics:
1. Drive Arrangement: Direct or Belt drive as scheduled.
2. Sound: As scheduled.
3. Damper: Yes.

2.3 AXIAL ROOF VENTILATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Aerovent; a Twin City Fan Company.
2. Carnes Company HVAC.
3. Greenheck.
4. Loren Cook Company.
5. Penn Ventilation.

B. Description: Direct- or belt-driven axial fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, curb base, and accessories.

C. Housing: Heavy-gage, removable, spun-aluminum, dome top and outlet baffle; square, one-piece, hinged, aluminum base.

   1. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.

D. Fan Wheel: Aluminum hub and blades.

E. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:

   1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
   2. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
   3. Pulleys: Cast-iron or cast steel.
      a. Fan pulley: Fixed pitch diameter.
      b. Motor pulley: Variable pitch diameter for use with motors up to 5 hp; Fixed pitch diameter for larger motors and for fans with solid state speed controllers. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
   4. Belts: Oil resistant, non-sparking, non-static, notch grip construction; matched sets for multiple belt drives.

F. Accessories:

   1. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted outside fan housing, factory wired through an internal aluminum conduit.
   2. Bird Screens: Removable, 1/2-inch mesh, aluminum or brass wire.
   3. Dampers: Counterbalanced, rattle free, parallel-blade, backdraft dampers mounted in curb base; factory set to close when fan stops.
   4. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.

G. Roof Curbs: Aluminum; mitered and welded corners; 1-1/2-inch-thick, rigid, fiberglass insulation adhered to inside walls, damper tray and 1-1/2-inch wood nailer. Size as required to suit roof opening and fan base.

   1. Configuration: Self-flashing without a cant strip, with mounting flange.
   2. Overall Height: 18 inches.
   3. Sound Curb: Curb with sound-absorbing insulation matrix.
   4. Pitch Mounting: Manufacture curb for roof slope.
   5. Metal Liner: Aluminum.

6. Burglar Bars: 1/2-inch- thick steel bars welded in place to form 6-inch squares.
7. Mounting Pedestal: Galvanized steel with removable access panel.

H. Capacities and Characteristics:
1. Drive Arrangement: Direct or Belt drive as scheduled.
2. Sound: As scheduled.
3. Damper: Yes.

2.4 UPBLAST PROPELLER ROOF EXHAUST FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Carnes Company HVAC.
2. Greenheck.
3. Loren Cook Company.
4. Penn Ventilation.
5. Owner approved substitution.

B. Description: Direct- or belt-driven propeller fans consisting of housing, wheel, butterfly-type discharge damper, fan shaft, bearings, motor and disconnect switch, drive assembly, curb base, and accessories.

C. Wind Band, Fan Housing, and Base: Reinforced and braced galvanized steel, containing galvanized-steel butterfly dampers and rain trough, motor and drive assembly, and fan wheel.

1. Damper Rods: Steel with bronze bearings.
2. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.

D. Fan Wheel: Replaceable, cast or extruded-aluminum, airfoil blades fastened to cast-aluminum hub; factory set pitch angle of blades.

E. Belt-Driven Drive Assembly: Resiliently mounted to housing; weatherproof housing of same material as fan housing with the following features:

1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
2. Shaft Bearings: Prelubricated and sealed, self-aligning, pillow-block-type ball bearings.
3. Pulleys: Cast-iron, adjustable-pitch motor pulley.
   a. Fan pulley: Fixed pitch diameter.
   b. Motor pulley: Variable pitch diameter for use with motors up to 5 hp; Fixed pitch diameter for larger motors and for fans with solid state speed controllers. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
4. Belts: Oil resistant, non-sparking, non-static, notch grip construction; matches, etc. for multiple belt drives.
5. Motor Mount: On outside of fan cabinet, adjustable base for belt tensioning.

F. Roof Curbs: Galvanized steel; mitered and welded corners; 1-1/2-inch-thick, rigid, fiberglass insulation adhered to inside walls, damper tray and 1-1/2-inch wood nailer, and neoprene curb sealing gasket. Size as required to suit roof opening and fan base.

1. Configuration: Self-flashing without a cant strip, with mounting flange.
2. Overall Height: 18 inches.
3. Sound Curb: Curb with sound-absorbing insulation matrix.
4. Pitch Mounting: Manufacture curb for roof slope.
5. Metal Liner: Galvanized steel.
6. Burglar Bars: 1/2-inch-thick steel bars welded in place to form 6-inch squares.
7. Mounting Pedestal: Galvanized steel with removable access panel.

G. Characteristics:
1. Drive Arrangement: Direct or Belt drive as scheduled.
2. Sound: As scheduled.
3. Damper: Yes.

H. Special Applications:
1. Kitchen Exhaust Fans:
    a. Up-blast type centrifugal with non-sparking aluminum wheel and hub.
    b. Stainless steel piano hinge on one side to permit service and maintenance.
    c. Ventilated extended height roof curb to meet NFPA 96 minimum discharge height above roof of 40 inches.
    d. U.L. 762 listed for grease removal.
    e. Grease trough.
    f. Without backdraft damper.
    g. Flexible electrical connector with pre-wired NEMA 3R disconnect switch.
2. Smoke Exhaust Fans:
    a. Up-blast type, all steel construction, with heat slinger wheel and seal.
    b. High temperature bearings and bearing grease.
    c. Motor and belt outside of air stream with insulated belt housing.
    d. Bifurcated housing for direct drive motor outside of air stream.
    e. U.L. 792 listed for high temperature operation and duration, i.e. 1,000°F with minimum operation of 15 minutes and 500°F with 4 hours minimum operation.
    f. Ultra-low leakage motorized back-draft damper.
    g. Inlet bell with debris screen.
    h. Flexible electrical connector with pre-wired NEMA 3R disconnect switch.

2.5 CENTRIFUGAL WALL VENTILATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Carnes Company HVAC.
2. Greenheck.
3. Loren Cook Company.
4. Penn Ventilation.

B. Description: Direct- or belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and accessories.

C. Housing: Heavy-gage, removable, spun-aluminum, dome top and outlet baffle; venturi inlet cone.

D. Fan Wheel: Aluminum hub and wheel with backward-inclined blades.

E. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:

1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
2. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
3. Fan and motor isolated from exhaust airstream.
4. Pulleys: Cast-iron, adjustable-pitch motor pulley.
    a. Fan pulley: Fixed pitch diameter.
    b. Motor pulley: variable pitch diameter for use with motors up to 5 hp; Fixed pitch diameter for larger motors and for fans with solid state speed controllers. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
5. Belts: Oil-resistant, non-sparking, non-static, notch grip construction; matched sets for multiple belt drives.

F. Accessories:

1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
2. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside fan housing, factory wired through internal aluminum conduit.
3. Bird Screens: Removable, 1/2-inch mesh, aluminum or brass wire.
4. Wall Grille: Ring type for flush mounting.
5. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in wall sleeve; factory set to close when fan stops.
6. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.

G. Characteristics:
1. Drive Arrangement: Direct or Belt drive as scheduled.
2. Sound: As scheduled.
3. Damper: Yes.

2.6 CEILING-MOUNTING VENTILATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Broan Mfg. Co., Inc.
2. Carnes Company HVAC.
3. Greenheck.
4. NuTone Inc.

5. Penn Ventilation.
6. Loren Cook Co.
7. Owner approved substitution.

B. Description: Centrifugal fans designed for installing in ceiling or wall or for concealed in-line applications.

C. Housing: Steel, lined with acoustical insulation.

D. Fan Wheel: Centrifugal wheels directly mounted on motor shaft. Fan shrouds, motor, and fan wheel shall be removable for service.

E. Grille: Painted aluminum, louvered grille with flange on intake and thumbscrew attachment to fan housing.

F. Electrical Requirements: Junction box for electrical connection on housing and receptacle for motor plug-in.

G. Accessories:

1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
2. Manual Starter Switch: Single-pole rocker switch assembly with cover and pilot light.
3. Time-Delay Switch: Assembly with single-pole rocker switch, timer, and cover plate.
4. Motion Sensor: Motion detector with adjustable shutoff timer.
5. Ceiling Radiation Damper: Fire-rated assembly with ceramic blanket, stainless-steel springs, and fusible link.
6. Filter: Washable aluminum to fit between fan and grille.
7. Isolation: Rubber-in-shear vibration isolators.
8. Manufacturer's standard roof jack or wall cap, and transition fittings.

2.7 IN-LINE CENTRIFUGAL FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Carnes Company HVAC.
2. Greenheck.
3. Loren Cook Company.
4. Penn Ventilation.
5. Owner approved substitution.

B. Description: In-line, direct or belt-driven (as scheduled) centrifugal fans consisting of housing, wheel, outlet guide vanes, fan shaft, bearings, motor and disconnect switch, drive assembly, mounting brackets, and accessories.

C. Round Housing: Split, spun aluminum with aluminum straightening vanes, inlet and outlet flanges, and support bracket adaptable to floor, side wall, or ceiling mounting.

D. Rectangular and Square Housing: steel with factory applied baked enamel paint on exterior, internally insulated with 1 inch thick, 3 lb. PCF density coated fiberglass insulation secured with welded insulation speed clips. Insulation shall comply with ASTM E84 and NFPA 255 for maximum ratings of flamespread 25 and smoke developed 50. Housing shall have mounting brackets at each corner.

E. Direct-Driven Units: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing with wheel, inlet cone, and motor on swing-out service door.

F. Belt-Driven Units: Motor mounted on adjustable base, with adjustable motor sheaves, enclosure around belts within fan housing, and lubricating tubes from fan bearings extended to outside of fan housing.

G. Fan Wheels: Aluminum, airfoil blades welded to aluminum hub.

H. Accessories:

1. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
2. Volume-Control Damper: Manually operated with quadrant lock, located in fan outlet.
3. Companion Flanges: For inlet and outlet duct connections.
4. Fan Guards: 1/2- by 1-inch mesh of galvanized steel in removable frame. Provide guard for inlet or outlet for units not connected to ductwork.
5. Motor and Drive Cover (Belt Guard): Epoxy-coated steel.

I. Vibration Isolators:
1. Type: Elastomeric Hangers.
2. Static Deflection: 1/4 inch.

J. Spark Arrestance Class: As scheduled.

2.8 PROPELLER FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Aerovent; a Twin City Fan Company.
2. Carnes Company HVAC.
3. Chicago Blower Corporation.
4. Loren Cook Company.
5. Penn Ventilation.
6. Greenheck, Inc.

B. Description: Direct- or belt-driven propeller fans consisting of fan blades, hub, housing, orifice ring, motor, drive assembly, and accessories.

C. Housing: Galvanized-steel sheet with flanged edges and integral orifice ring with baked-enamel finish coat applied after assembly.

D. Steel Fan Wheels: Formed-steel blades riveted to heavy-gage steel spider bolted to cast-iron hub.

E. Fan Wheel: Replaceable, cast or extruded-aluminum, airfoil blades fastened to cast-aluminum hub; factory set pitch angle of blades.

F. Belt-Driven Drive Assembly: Resiliently mounted to housing, statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.4.
2. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
3. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.

   a. Ball-Bearing Rating Life: ABMA 9, L10 of 100,000 hours.

4. Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
5. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
6. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
7. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.

G. Accessories:

1. Gravity Shutters: Aluminum blades in aluminum frame; interlocked blades with nylon bearings.
2. Motor-Side Back Guard: Galvanized steel, complying with OSHA specifications, removable for maintenance.
3. Wall Sleeve: Galvanized steel to match fan and accessory size.
4. Weathershield Hood: Galvanized steel to match fan and accessory size.
5. Weathershield Front Guard: Galvanized steel with expanded metal screen.
6. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
7. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside fan housing, factory wired through an internal aluminum conduit.

H. Vibration Isolators: Refer to Division 23 Section "Vibration and Seismic Control for HVAC Equipment and Piping."

1. Spark Arrestance Class: As scheduled.

2.9 Wall or column-mounted oscillating fans

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Yellow Jacket

2. Owner approved substitution.

B. Description: Direct-driven, oscillating ventilation fans consisting of fan blades, hub, housing, motor, mounting, controller and accessories.

C. Housing: Water resistant, high Density polyethylene housing with vibration dampening. Heavy-gauge steel frame and OSHA-compliant 1/8-inch steel spiral guards.

D. Fan Blades: Replaceable, three-dimensional progressive pitch blades made from high-performmance polyamide nylon.

E. Accessories:

1. Controller: Remotely mounted or onboard speed controller provides on/off function, variable speed and oscillation.

2. Oscillating kit – fully enclosed oscillator assembly with adjustable angle of oscillation to 45, 60 or 90 degrees

3. Mounting Options: Portable base pedestal for adjustable height with I-beam/yoke mount, or wall/column mount. Include all mounting hardware.

2.10 MOTORS

A. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

B. Enclosure Type: Totally enclosed, fan cooled.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install power ventilators level and plumb.

B. Vibration- and seismic-control devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

1. Secure vibration and seismic controls to concrete bases using anchor bolts cast in concrete base.

C. Install floor-mounting units on concrete bases. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

D. Install floor-mounting units on concrete bases designed to withstand, without damage to equipment, the seismic force required by code. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

E. Secure roof-mounting fans to roof curbs with stainless steel hardware. Refer to Division 07 Section "Roof Accessories" for installation of roof curbs.
    1. Contractor shall coordinate all required roof openings with the roof structural plans and shall provide a roof opening shop drawing with the required roof openings dimensioned and sized for the General Contractor to frame out and provide roof openings. Refer to structural plans for required roof opening framing.
    2. Roof curbs shall be furnished and located by the Contractor for the General Contractor's or Owner's bonded roofing contractor to install.
    3. Secure unit curb cap to roof curb with stainless steel or cadmium-plated screws a maximum of 12" on center minimum four per side.
    4. All roof-mounted equipment must be properly secured to the building structure to withstand local Coastal Windstorm criteria, i.e., minimum 145 MPH hurricane force winds and required seismic criteria.

F. Support suspended units from structure using threaded steel rods. Vibration-control devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

G. Install units with clearances for service and maintenance.

H. Label units according to requirements specified in Division 23 Section "Identification for HVAC Piping and Equipment."

I. Install Wall or column-mounted oscillating fans as per manufacturer's instructions with hardware provided by the fan manufacturer.

3.2 CONNECTIONS

A. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Division 23 Section "Air Duct Accessories."

B. Install ducts adjacent to power ventilators to allow service and maintenance.

C. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

D. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.3 FIELD QUALITY CONTROL

A. Perform the following field tests and inspections and prepare test reports:

    1. Verify that shipping, blocking, and bracing are removed.
    2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper

thermal-overload protection is installed in motors, starters, and disconnect switches.

3. Verify that cleaning and adjusting are complete.
4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
5. Adjust belt tension.
6. Adjust damper linkages for proper damper operation.
7. Verify lubrication for bearings and other moving parts.
8. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
9. Disable automatic temperature-control operators, energize motor and adjust fan to indicated rpm, and measure and record motor voltage and amperage.
10. Shut unit down and reconnect automatic temperature-control operators.
11. Remove and replace malfunctioning units and retest as specified above.

B. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

3.4 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Adjust belt tension and align motor belt drive sheaves with fan sheaves.

C. Refer to Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing procedures.

D. Replace fan and motor pulleys as required to achieve design airflow.

E. Lubricate bearings.

END OF SECTION 23 34 23

SECTION 23 34 33 - AIR CURTAINS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes air curtains with electric heat.

1.3 SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, fan curves, discharge nozzle velocity profile, furnished specialties, and accessories for each unit.

B. Shop Drawings: .

1. Design Calculations: Calculate requirements for selecting vibration isolators.
2. Include plans, elevations, sections, details, and attachments to other work.
3. Wiring Diagrams: Power, signal, and control wiring.

C. Coordination Drawings: Plans and details drawn to scale and coordinating penetrations of exterior walls.

D. Samples for Initial Selection: For units with factory-applied color finishes.

E. Operation and Maintenance Data: For air curtains to include in maintenance manuals.

F. Warranties: Special warranties specified in this Section.

1.4 QUALITY ASSURANCE

A. Professional Engineer Qualifications: A professional engineer who is legally qualified to practice in jurisdiction where Project is located and who is experienced in providing engineering services of the kind indicated. Engineering services are defined as those performed for installations of air curtains that are similar to those indicated for this Project in material, design, and extent.

B. Product Options: Drawings indicate size, profiles, and dimensional requirements of air curtains and are based on the specific product indicated. Refer to Division 01 Section "Product Requirements."

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

D. Comply with AMCA 220, "Test Methods for Air Curtain Units," for airflow, outlet velocity, and power consumption.

E. Comply with ARI 410, "Forced-Circulation Air-Cooling and Air-Heating Coils," for components, construction, and rating. Certify coils according to ARI 410

F. Comply with NSF 37, "Air Curtains for Entranceways in Food and Food Service Establishments."

1.5 STORAGE AND HANDLING

A. Protect unites from physical damage by storing in protected areas and leaving factory covers in place.

1.6 COORDINATION

A. Coordinate layout and installation of air curtains and suspension system components with other construction, including light fixtures, fire-suppression-system components, and partition assemblies.

B. Coordinate installation of wall penetrations and louvers. These items are specified in Division 08 Section "Louvers and Vents."

1.7 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of air curtains that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Five years.

1.8 EXTRA MATERIALS

A. Furnish extra materials described below, before construction begins, that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Furnish one set of filters and fan belts for each unit.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers:
1. Berner International Corp.
2. Powered Aire, Inc.
3. Loren Cook Company.
4. Marley Engineered Products.
5. Mars Air Products; Dynaforce Division.
6. MesTec AG; L. J. Wing Division.

2.2 MATERIALS

A. Housing Materials: Heavy-gage, electroplated-zinc steel with welded construction and polyester-coated finish.

1. Mounting Brackets: Steel, for wall or ceiling mounting.

B. Intake Louvers: Integral part of the housing, mechanically field adjustable and capable of reducing air-outlet velocity by 60 percent with louver in totally closed position.

C. Discharge Nozzle: Integral part of the housing, containing adjustable air-directional vanes with 40-degree sweep front to back.

2.3 FANS

A. Fans: Galvanized steel, Centrifugal, forward curved, double width, double inlet, statically and dynamically balanced.

B. Fan Drives: Direct or Belt, equipped with belt guards and adjustable sheaves and pulleys for adjusting air-outlet velocity.

2.4 MOTORS

A. Motor Type: Multispeed, resiliently mounted, continuous duty, open, dripproof, with integral thermal-overload protection.

B. Bearings: Permanently sealed, lifetime, prelubricated, ball bearings.

C. Disconnect: Internal power cord with plug and receptacle for fractional hp motors and toggle disconnect for control power. Provide NEMA 3R disconnect switch for 3 phase motors.

2.5 FILTERS

A. Washable Panel Filters: Removable, stainless-steel, baffle-type filters with spring-loaded fastening; with minimum 0.0781-inch-thick, stainless-steel filter frame.

B. Mounting Frames: Welded, galvanized steel with gaskets and fasteners and suitable for bolting together into built-up filter banks.

2.6 ACCESSORIES

A. Field-Installed Thermostat: Line voltage, factory installed and wired to the junction box on air curtain.

B. Automatic Door Switch: Plunger type installed in door area to activate air curtain when door opens and to deactivate air curtain when door closes.

C. Start-Stop, Push-Button Switch: Manually activates and deactivates air curtain.

D. Time-Delay Relay: Factory installed and adjustable to allow air curtain to operate from 0.5 seconds to 10 hours.

E. Motor-Control Panel: Complete with motor starter, 115-V ac transformer with primary and secondary fuses, terminal strip, and NEMA 250, Type 3R enclosure.

F. Mounting Brackets: Adjustable mounting brackets for drum-type roll-up doors.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions where air curtains will be installed for compliance with requirements for installation tolerances and other conditions affecting performance.

B. Examine roughing-in for electrical systems to verify actual locations of electrical power and controls connections before air-curtain installation.

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

3.2 INSTALLATION

A. Install air curtains with clearance for equipment service and maintenance.

B. Install air curtain discharge nozzle a manufacturer’s recommended height above door opening and properly centered within door width opening.

3.3 CONNECTIONS

A. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

B. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

A. Perform the following field tests and inspections and prepare test reports:

1. After installing air curtains completely, perform visual and mechanical check of individual components.
2. After electrical circuitry has been energized, start unit to confirm motor rotation and unit operation. Certify compliance with test parameters.
3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

B. Repair or replace malfunctioning units and retest as specified above.

3.5 ADJUSTING

A. Adjust belt tension.

B. Adjust motor and fan speed to achieve specified airflow.

C. Adjust discharge louver and dampers to regulate airflow.

D. Adjust air-directional vanes.

3.6 DEMONSTRATION

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

END OF SECTION 23 34 33

SECTION 23 3600 - AIR TERMINAL UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. This Section includes the following:
   1. Fan-powered air terminal units.
   2. Constant volume single-duct air terminal units.
   3. Variable air volume single-duct air terminal units.
   4. Electric heating coils.

1.3 SUBMITTALS

A. Product Data: For each type of product indicated, include rated capacities, furnished specialties, sound-power ratings, and accessories.

B. Include letter with submittal data stating that unit controls have been completely coordinated with controls contractor.

C. Shop Drawings: Detail equipment assemblies and indicate dimensions, required clearances, materials used in fabrication, method of field assembly, components, and location and size of each field connection.

   1. Include a schedule showing unique model designation, room location, model number, size, and accessories furnished.
   2. Wiring Diagrams: Power, signal, and control wiring and differentiate between factory-installed and field-installed wiring.
   3. Include catalog performance ratings which indicate air flow, static pressure and NC designation.
   4. Include a schedule listing discharge and radiated sound power levels, for each unit, of second to sixth octave band at inlet static pressure of 1 to 4 in. w.g. NC data alone will not be acceptable.

D. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:

   1. Ceiling suspension assembly members.

2. Method of attaching hangers to building structure.
3. Size and location of initial access modules for acoustical tile.
4. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.

E. Operation and Maintenance Data: For air terminal units to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include the following:

1. Instructions for resetting minimum and maximum air volumes.
2. Instructions for adjusting software set points.
3. Directions for resetting constant volume regulators.
4. Parts list for each type of air terminal unit and troubleshooting maintenance guide.

1.4 QUALITY ASSURANCE

A. Product Options: Drawings indicate size, profiles, and dimensional requirements of air terminal units and are based on the specific system indicated. Refer to Division 01 Section "Product Requirements."

B. All units shall be the product of a manufacturer regularly engaged in the production of terminal units and all supplied units shall be clearly described by means of published catalog data from the same manufacturer.

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

D. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1-2004, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

E. NFPA Compliance: Install air terminal units according to NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems."

F. Air terminal units shall be certified under AHRI Standard 880-94 certification program and carry the AHRI seal.

G. Air terminal unit lining shall meet UL 181 and NFPA 90A standards. All units shall be suitable for use in a return air plenum. All components within the air stream shall conform to the NFPA 90A Standard for Flame/Smoke/Fire Contribution of 25/50/0.

H. All units shall be capable of maintaining their minimum and maximum set points within a maximum of ±5%.

I. Terminal box insulation and design suitable for 50°F primary air in 75°F, 60% RH ceiling plenum without condensation.

J. Fan-Powered air terminal units:

1. Fan powered boxes to be guaranteed to thoroughly mix 50°F primary air with 75°F recirculated air to produce a maximum of 1-1/2 F temperature differential at any place to the duct 4' downstream of the unit.

2. Manufacturer shall provide proof that the proposed units have been tested under the airflows and static pressures shown on the project schedule, in a certified laboratory as per ANSI S1.31 standard, following AHRI 880, and comply with the maximum sound power levels indicated below.

    a. Maximum radiated sound power level of fan powered boxes shall not be greater than any of the following octave band limits.

Maximum Fan Powered Box Sound Power Levels
Db re: 10^{-12} Watts
Tested in Accordance with AHRI 880

Octave Band: Center Freq. (Hz):	2 125	3 250	4 500	5 1k	6 2k	7 4k
Unit Located Over NC-35 Space:	68	61	57	52	50	44
Unit Located Over NC-40 Space:	72	66	62	57	55	49

1.5 COORDINATION

A. Coordinate layout and installation of air terminal units and suspension system with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.

B. Air terminal units shall be equipped with pressure independent direct digital controls supplied by the Control Contractor and mounted at the factory by the terminal unit manufacturer.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:
    1. Manufacturers: Subject to compliance with requirements, provide products by one of the manufacturers specified.

2.2 FAN-POWERED AIR TERMINAL UNITS

A. Manufacturers:

1. Anemostat; a Mestek Company.
2. Environmental Technologies, Inc.; Enviro-Air Div.
3. Titus.
4. Neptronic
5. Tuttle & Bailey.
6. Price Industries.

B. Configuration: Volume-damper assembly and fan in series or in parallel arrangement, as indicated on Drawings, inside unit casing with control components inside a protective metal shroud.

C. Casing: 0.034-inch galvanized steel.

1. Casing Lining: 1-inch- thick, 1-1/2 lb./cu. ft. density, nylon scrim reinforced foil skin vapor barrier insulation. Insulation shall be dual thermal/acoustical fiberglass insulation meeting NFPA 90A requirements, UL 181 erosion control requirements, meet all requirements of ASTM C1071 (including C665), and carry a 25/50 rating for flame spread/smoke developed per ASTM E-84, UL 723 and have a R-value of 4.2. All cut edges of insulation shall be sealed by a heavy adhesive seal to prevent fibrous material from entering the airstream. A special sheet metal picture frame bracket may be used to enclose the liner of the discharge end to prevent the liner from dislodging under extremely high pressure conditions and to prevent damage during installation.
2. Air Inlets: Round stub connections for duct attachment.
3. Air Outlet: S-slip and drive connections.
4. Access: Removable panels for access to dampers and other parts requiring service, adjustment, or maintenance; with airtight gasket and quarter-turn latches.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2010.

D. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

1. Maximum Damper Leakage: AHRI 880 rated, 2 percent of nominal airflow at 3-inch wg inlet static pressure.
2. Damper Position: Normally open.

E. Fan Section: Acoustically lined, galvanized-steel plenum, with direct-drive, forward-curved fan with air filter and backdraft damper.

1. Motor: ECM. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

   a. Speed Control: Infinitely adjustable with electronic controls.
   b. Fan-Motor Assembly Isolation: Rubber isolators.

2. Air Filter: 1-inch- thick, fiberglass throwaway, MERV 8 according to ASHRAE 52.2.

F. Attenuator Section: 0.034-inch galvanized steel sheet metal.

1. Lining: 1-inch- thick, 1-1/2 lb./cu. ft. density, nylon scrim reinforced foil skin vapor barrier insulation. Insulation shall be dual thermal/acoustical fiberglass insulation meeting NFPA 90A requirements, UL 181 erosion control requirements, meet all requirements of ASTM C1071 (including C665), and carry a 25/50 rating for flame spread/smoke developed per ASTM E-84, UL 723 and have a R-value of 4.2. All cut edges of insulation shall be sealed by a heavy adhesive seal to prevent fibrous material from entering the airstream. A special sheet metal picture frame bracket may be used to enclose the liner of the discharge end to prevent the liner from dislodging under extremely high pressure conditions and to prevent damage during installation. Cover liner with perforated metal.

G. Factory-Mounted and Wired Controls: Electrical components shall be mounted in control box with removable cover. Incorporate single-point electrical connection to power source.

1. Control Transformer: Factory mounted for control voltage on electric and electronic control units with terminal strip in control box for field wiring of thermostat and power source.
2. Wiring Terminations: Fan and controls to terminal strip, and terminal lugs shall match quantities, sizes, and materials of branch-circuit conductors. Enclose terminal lugs in terminal box that is sized according to NFPA 70.
3. Disconnect Switch: Factory-mounted, fused type.

H. Control Panel Enclosure: NEMA 250, Type 1, with access panel sealed from airflow and mounted on side of unit.

I. DDC Controls: Single-package unitary controller and actuator specified in Division 23 Section "Instrumentation and Control for HVAC." BMS shall furnish DDC controller, actuator, flow sensing element, power transformer. Devices factory mounted and wired at terminal unit manufacturer.

2.3 CONSTANT VOLUME SINGLE DUCT AIR TERMINAL UNITS

A. Manufacturers:

1. Anemostat; a Mestek Company.
2. Titus.
3. Neptronic
4. Tuttle & Bailey.
5. Environmental Technologies, Inc.
6. Price Industries.

B. Configuration: Volume-damper assembly inside unit casing with control components located inside a protective metal enclosure.

C. Casing: 0.034-inch galvanized steel.

1. Casing Lining: 1-inch-thick, 1-1/2 lb./cu. ft. density, nylon scrim reinforced foil skin vapor barrier insulation. Insulation shall be dual thermal/acoustical fiberglass insulation meeting NFPA 90A requirements, UL 181 erosion control requirements, meet all requirements of ASTM C1071 (including C665), and carry a 25/50 rating for flame spread/smoke developed per ASTM E-84, UL 723 and have a R-value of 4.2. All cut edges of insulation shall be sealed by a heavy adhesive seal to prevent fibrous material from entering the airstream. A special sheet metal picture frame bracket may be used to enclose the liner of the discharge end to prevent the liner from dislodging under extremely high pressure conditions and to prevent damage during installation.
2. Air Inlets: Round stub connections for duct attachment.
3. Air Outlet: S-slip and drive connections.
4. Access: Removable panels for access to dampers and other parts requiring service, adjustment, or maintenance; with airtight gasket.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2010.

D. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

1. Maximum Damper Leakage: AHRI 880 rated, 2 percent of nominal airflow at 3-inch wg inlet static pressure.
2. Damper Position: Normally open.

E. Attenuator Section: 0.034-inch galvanized steel sheet metal.

1. Lining: 1-inch-thick, 1-1/2 lb./cu. ft. density, nylon scrim reinforced foil skin vapor barrier insulation. Insulation shall be dual thermal/acoustical fiberglass insulation meeting NFPA 90A requirements, UL 181 erosion control requirements, meet all requirements of ASTM C1071 (including C665), and carry a 25/50 rating for flame spread/smoke developed per ASTM E-84, UL 723 and have a R-value of 4.2. All cut edges of insulation shall be sealed by a heavy adhesive seal to prevent fibrous material from entering the airstream. A special sheet metal picture frame bracket may be used to enclose the liner of the discharge end to prevent the liner from dislodging under extremely high pressure conditions and to prevent damage during installation.

F. Multioutlet Attenuator Section: With number and size collars as shown; each with locking butterfly balancing damper.

G. DDC Controls: Single-package unitary controller and actuator specified in Division 23 Section "Instrumentation and Control for HVAC." BMS shall furnish DDC controller, actuator, flow sensing element, power transformer. Devices factory mounted and wired at terminal unit manufacturer.

H. Low Leakage Valves
1. Provide where indicated.

2. Provide low leak seal materials compatible with the severity of service indicated by the particular valve coating that has been specified.

I. Valves connected to fume hood exhaust or where indicated on drawings:
   1. Coat LTAU with minimum 5.0 mil dry film thickness Heresite P403 coating material, applied and baked per coating manufacturer's recommendations.
   2. Shaft, pivot arm and linkage, and other internal metal parts (nuts, bolts, rivets, etc.) shall be stainless steel.
   3. Shaft shall be Teflon coated.

J. Shaft bearing surfaces shall be made of Teflon or polyphenylene sulfide composite.

K. Provide required valve accessories to support the controls contractor.
   1. Phoenix fume hood CVV TAU require corrosion proof 316L stainless steel pressure taps for monitor installation.

2. Siemens fume hood CVV TAU require corrosion proof 316L stainless steel restricting orifices for monitor installation.

2.4 VARIABLE AIR VOLUME SINGLE DUCT AIR TERMINAL UNITS

A. Manufacturers:

   1. Anemostat; a Mestek Company.
   2. Titus.
   3. Tuttle & Bailey.
   4. Environmental Technologies, Inc.
   5. Price Industries.

B. Configuration: Volume-damper assembly inside unit casing with control components located inside a protective metal enclosure.

C. Casing: 0.034-inch galvanized steel.
   1. Casing Lining: 1-inch- thick, 1-1/2 lb./cu. ft. density, nylon scrim reinforced foil skin vapor barrier insulation. Insulation shall be dual thermal/acoustical fiberglass insulation meeting NFPA 90A requirements, UL 181 erosion control requirements, meet all requirements of ASTM C1071 (including C665), and carry a 25/50 rating for flame spread/smoke developed per ASTM E-84, UL 723 and have an R-value of 4.2. All cut edges of insulation shall be sealed by a heavy adhesive seal to prevent fibrous material from entering the airstream. A special sheet metal picture frame bracket may be used to enclose the liner of the discharge end to prevent the liner from dislodging under extremely high pressure conditions and to prevent damage during installation.
   2. Air Inlets: Round stub connections for duct attachments.
   3. Air Outlet: S-slip and drive connections.
   4. Access: Removable panels for access to dampers and other parts requiring service, adjustment, or maintenance; with airtight gasket.

5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2010.

D. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.
  1. Maximum Damper Leakage: ARI 880 rated, 2 percent of nominal airflow at 3-inch wg inlet static pressure.
  2. Damper Position: Normally open.

E. Attenuator Section: 0.034-inch galvanized steel sheet metal.

  1. Lining: 1-inch-thick, 1-1/2 lb./cu. ft. density, nylon scrim reinforced foil skin vapor barrier insulation. Insulation shall be dual thermal/acoustical fiberglass insulation meeting NFPA 90A requirements, UL 181 erosion control requirements, meet all requirements of ASTM C1071 (including C665), and carry a 25/50 rating for flame spread/smoke developed per ASTM E-84, UL 723 and have a R-value of 4.2. All cut edges of insulation shall be sealed by a heavy adhesive seal to prevent fibrous material from entering the airstream. A special sheet metal picture frame bracket may be used to enclose the liner of the discharge end to prevent the liner from dislodging under extremely high pressure conditions and to prevent damage during installation.

F. DDC Controls: Single- package unitary controller and actuator specified in Division 23 Section “Instrumentation and Control for HVAC.” BMS shall furnish DDC controller, actuator, flow sensing element, power transformer. Devices factory mounted and wired at terminal unit manufacturer.

2.5 ELECTRIC HEATING COILS

A. Manufacturers:

  1. Neptronics
  2. Titus
  3. Price Industries

B. As slip-in frame electric duct heater or integral withthe terminal unit assembly, open-coil design with integral NEMA 1 electrical enclosure with single point connection for heater and fan, factory wired and installed. Wiring diagram with specific wiring for each unit included with unit. Tested with the fan terminal in accordance with UL and ETL standards. Meet all NEC requirements. UL Listed. Include the following features:

  1. Automatic reset thermal primary and manual reset secondary overtemperature protection.
  2. Nickel chrome 80/20 open coil heating elements.
  3. Electronic airflow switch to ensure minimum air flow.
  4. Interlocking disconnect switch.
  5. Pressure differential switch
  6. Supply and discharge temperature sensors
  7. Fuses

8. 24 V control transformer.
9. Line and control terminal blocks.
10. SCR controller (silicon controlled rectifier)
11. BACnet MS/TP communication with BMS for remote control and monitoring
12. Provide real-time feedback of heater's output capacity, temperature measurments and power consumption data.
13. DDC Controls: Single- package unitary controller and actuator specified in Division 23 Section "Instrumentation and Control for HVAC."

2.6 SOURCE QUALITY CONTROL

A. Identification: Label each air terminal unit with plan number, nominal airflow, maximum and minimum factory-set airflows, coil type, and AHRI certification seal.

B. Verification of Performance: Rate air terminal units according to AHRI 880.

C. Noise Levels at noted capacities: Units tested in accordance with ASHRAE Standard 36B or ADC, with ratings tabulated for inlet pressure of 3 in, 1 3/4 in, 1 1/2 in, and minimum static pressure.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install in accordance with manufacturer's written installation instructions.

B. Support terminal box independent of ductwork.

C. Install air terminal units level and plumb.

D. Provide sound lining downstream of units for a minimum of 5 ft. or as recommended by unit manufacturer to maintain scheduled NC levels.

E. Maintain sufficient clearance for normal service and maintenance.

F. Coordinate access through ceilings with respective trades.

G. Coordinate the terminal box controls with the building control system contractor to ensure that all miscellaneous accessories required for proper operation are included and that the direct/reverse action normally closed/normally open functions are properly coordinated.

H. Be sure minimum and maximum CFM settings agree with the requirements of the terminal unit schedule.

I. Provide rigid metal straight duct equal to four diameters on inlet of all terminals.

J. Provide flexible duct connection at outlet plus a minimum of 12" and a maximum of 36"of straight flexible duct upstream of rigid duct at inlet.

3.2 CONNECTIONS

A. Connect ducts to air terminal units according to Division 23 Section "Metal Ducts."

B. Ground units with electric heating coils according to Division 26 Section "Grounding and Bonding for Electrical Systems."

C. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

D. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.3 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

B. Perform the following field tests and inspections and prepare test reports:

1. After installing air terminal units and after electrical circuitry has been energized, test for compliance with requirements.
2. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. All equipment and materials shall be protected from damages, exposure to moisture and weather from the time of delivery to job site until date of substantial completion.

D. Remove and replace malfunctioning units, controls and equipment, and retest as specified above.

3.4 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 and do the following:

a. Verify that inlet duct connections are as recommended by air terminal unit manufacturer to achieve proper performance.
b. Verify that controls and control enclosure are accessible.
c. Verify that control connections are complete.
d. Verify that nameplate and identification tag are visible.
e. Verify that controls respond to inputs as specified.

3.5 DEMONSTRATION

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

END OF SECTION 23 36 00

SECTION 23 37 13 - DIFFUSERS, REGISTERS, AND GRILLES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Rectangular and square ceiling diffusers.
2. Linear slot diffusers.
3. Registers and Grilles.
4. Perforated diffusers.
5. Nozzle diffusers
6. Security Grille
7. Security Diffuser
8. Security Return Grille
9. Security Exhaust Grille
10. VAV Diffuser

B. Related Sections:

1. Division 08 Section "Louvers and Vents" for fixed and adjustable louvers and wall vents, whether or not they are connected to ducts.
2. Division 23 Section "Air Duct Accessories" for fire and smoke dampers and volume-control dampers not integral to diffusers, registers, and grilles.

1.3 SUBMITTALS

A. Product Data: For each type of product indicated, include the following:

1. Data Sheet: Indicate materials of construction, finish, end cap and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
2. Diffuser, Register, and Grille Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.
3. Samples for Initial Selection: For diffusers, registers, and grilles with factory-applied color finishes.
4. Samples for Verification: For diffusers, registers, and grilles, in manufacturer's standard sizes to verify color selected.

B. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:

1. Ceiling suspension assembly members.
2. Method of attaching hangers to building structure.
3. Size and location of initial access modules for acoustical tile.
4. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
5. Duct access panels.

C. Source quality-control reports.

PART 2 - PRODUCTS

2.1 GENERAL

A. Manufacturer shall examine application of each air inlet and outlet and guarantee that each will provide comfort space conditions without drafts or noise at noted capacities.

B. Noise Level: Noise levels at rated capacities shall not exceed criteria specifies under 1.4 “Quality Assurance.”

C. All outlets shall be suitable for operation at 5 percent more and at 25 percent less than noted capacities.

D. Air inlets and outlets for surface mounting shall have a concealed mounting frame, with no mounting screws visible in face frame of outlet and/or plastic frame, unless otherwise noted.

E. Scheduled air outlets shall be as manufactured by the listed manufacturer and shall, to the greatest extent possible, all be manufactured by the same manufacturer.

F. The contractor and vender shall be jointly responsible for all quantity and neck size take-offs and coordination of mounting details with the ceiling, wall, or floor mounting in which it is installed.

G. Air distribution devices shall have unit mounted opposed blade volume dampers operable from the face of the air distribution devices.

H. Diffusers in the same room shall all be the same size and type, except as otherwise indicated.

I. Contractor shall provide all required blank offs for directional pattern throws.

2.2 CEILING DIFFUSERS

A. Rectangular and Square Ceiling Diffusers:

1. Manufacturers: Subject to compliance with requirements:

   a. Krueger.
   b. METALAIRE, Inc.
   c. Price Industries.
   d. Titus.

2. Material: Aluminum.
3. Finish: Refer to border and finish shown on Architectual drawings and subject to approval of submitted samples.
4. Face Size: As scheduled on drawings.
5. Face Style: Plaque.

6. Mounting: Surface and T-bar.
7. Pattern: Fixed and Two position.
8. Dampers: Supplied at the takeoff of run-out ductwork.

B. Perforated Diffuser

1. Manufacturers:

   a. Krueger.
   b. METALAIRE, Inc.
   c. Price Industries.
   d. Titus.

2. Material: Steel backpan and pattern controllers, with steel face.
3. Finish: Refer to border and finish shown on Architectual drawings and subject to approval of submitted samples.Face Size: As scheduled on drawings.
4. Face Style: Flush.
5. Mounting: Surface and T-bar
6. Pattern: Adjustable with louvered pattern modules at inlet
7. Dampers: Supplied at the takeoff of run-out ductwork.

C. Louver Face Diffuser:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Price Industries
   b. Anemostat Products; a Mestek company
   c. Kruger
   d. Titus
2. Material: Steel
3. Finish: Refer to border and finish shown on Architectual drawings and subject to approval of submitted samples.
4. Face Size: As scheduled on drawings
5. Mounting: Coordinate with architectural reflected ceiling plans
6. Pattern: Adjustable core style

7. Dampers: Supplied at the takeoff of run-out ductwork

2.3 CEILING LINEAR SLOT OUTLETS

A. Linear Slot Diffuser:

1. Manufacturers: Subject to compliance with requirements:

   a. Krueger.
   b. METALAIRE, Inc.
   c. Price Industries.
   d. Titus.

2. Material - Shell: Aluminum.
3. Material - Pattern Controller and Tees: Aluminum.
4. Finish - Face and Shell: Refer to border and finish shown on Architectual drawings and subject to approval of submitted samples.
5. Finish - Pattern Controller: Refer to border and finish shown on Architectual drawings and subject to approval of submitted samples.
6. Finish - Tees: Baked enamel, black.
7. Slot Width: As scheduled on drawings.
8. Number of Slots: One and two slots, as shown on drawings..
9. Length: See schedule and plans for lengths.
10. Accessories: Plaster frame.

B. Mounting: Coordinate with architectural reflected ceiling plans Linear Bar Diffuser:

1. Manufacturers: Subject to compliance with requirements:

   a. Krueger.
   b. METALAIRE, Inc.
   c. Price Industries.
   d. Titus.

2. Devices shall be specifically designed for variable-air-volume flows.
3. Material: Aluminum.
4. Finish: Coordinate finish with Architect and subject to approval of submitted samples.
5. Narrow Core Spacing Arrangement: 1/8-inch bar spaced 1/2 inch spacing, zero - degree deflection.
6. Frame: 1 inch wide.
7. Contractor shall coordinate with architectural drawings.

2.4 REGISTERS AND GRILLES

A. Fixed Face Grille:

1. Material: Aluminum.
2. Finish: Coordinate border and finish with Architect and subject to approval of submitted samples.
3. Face Arrangement: 1/2-by-1/2-by-1/2-inch grid core.
4. Core Construction: Integral.
5. Frame: 1 inch wide.
6. Mounting: Countersunk screw.

B. Fixed Face Security Grille:

1. Manufacturers: Subject to compliance with requirements:
    a. Krueger.
    b. METALAIRE, Inc.
    c. Price Industries.
    d. Titus.
2. Material: 12 gauge hot rolled steel.
3. Finish: Baked enamel, white and subject to approval of submitted samples
4. Face Arrangement: 45° 1/4-by-1/4-by-1-inch fixed louver blades.
5. Core Construction: Integral.
6. Frame: 1 inch wide.
7. Mounting: Attached to a wall sleeve of 3 /16 in. hot rolled steel with a rear mounting frame for a concealed and secure fastening.

2.5 Nozzle Diffusers:

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Price Industries
2. Anemostat Products; a Mestek company
3. Krueger
4. Titus
5. Seiho
6. Air Concepts

B. Throw: Extended distance for airflow rates

C. Material: Aluminum

D. Nozzles per Unit: One

E. Finish: Coordinate finish with Architect and subject to approval of submitted samples Border: 1/2-inch width with countersunk screw holes

F. Nozzles:
1. ±35 degree deflection
2. 360 degree rotation

G. Accessory: Aperture style damper

2.6 Security Grille

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Price Industries
2. Anemostat Products; a Mestek company
3. Krueger
4. Titus

B. Security grille sizes and mounting types shall be shown on the plans and outlet schedule.

C. Grilles shall have a 3/16" thick steel face with 5/16" diameter holes on 7/16" staggered centers. The sleeve shall be 3/16" thick and shall be stitch welded to the face and along the entire length of all sleeve seams. Grilles should include 1½" x 1½" x 3/16" steel angle mill finished iron frames shipped loose for field welding to grille sleeve at back of wall penetration.

D. Air balancing volume damper serving each grille shall be accessible in ductwork location outside of the holding room.

E. Finish: white and subject to approval of submitted samples.

F. The manufacturer shall provide published airflow and sound performance data for the grille.

G. Shall be tested in accordance with ANSI/ASHRAE Standard 70.

2.7 Security diffuser

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Price Industries
2. Anemostat Products; a Mestek company
3. Krueger
4. Titus

B. Security diffusers shall consist of an outer frame assembly of the sizes and mounting types shown on the plans and outlet schedule.

C. A square inlet shall be an integral part of the frame assembly and a transition piece shall be available to facilitate attachment of round duct. An inner core assembly consisting of fixed deflection louvers shall be available in 1-, 2-, 3-, or 4-way horizontal discharge patterns. The inner core assembly shall be removable in the field without tools for easy installation, cleaning, or damper adjustment.

D. All units shall be constructed of heavy gauge steel. All units shall be covered with a 12-gauge steel face with 13/16" square holes on 1" centers. All units will be provided with screw holes in the face for surface mounting. Tamper proof screws should be provided according to structural requirements.

E. Finish: white and subject to approval of submitted samples.

F. The manufacturer shall provide published airflow and sound performance data for the grille. The grille shall be tested in accordance with ANSI/ASHRAE Standard 70.

2.8 Security Return Grille

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Price Industries
   2. Anemostat Products; a Mestek company
   3. Krueger
   4. Titus

B. Contractors shall provide security grille of sizes and mounting type shown on the plans and outlet schedule.

C. Grilles shall have a 3/16" thick steel face with 5/16" diameter holes on 7/16" staggered centers. The sleeve shall be 3/16" thick and shall be stitch welded to the face and along the entire length of all sleeve seams. Grilles shall include 1½" x 1½" x 3/16" steel angle mill finished iron frame shipped loose for field welding to grille sleeve at back of wall penetration.

D. Air balancing volume damper serving each grille shall be accessible in ductwork location outside of holding room.

E. Finish: White and subject to approval of submitted samples

F. The manufacturer shall provide published airflow and sound performance data for the grille. The grille shall be tested in accordance with ANSI/ASHRAE Standard 70.

2.9 Security Exhaust Grille

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Price Industries
   2. Anemostat Products; a Mestek company
   3. Krueger
   4. Titus

B. Security exhaust grilles shall be have 12-gauge steel lattice faces with 13/16" square holes on 1" centers. Lattice face shall be white baked on enamel. Units shall be mounted to the exhaust duct flange and the ceiling using tamper proof security screws to meet structural requirements. Grill face shall be white baked enamel.

C. VAV Diffusers (CBP rooms in Airside building):

1. Variable air volume diffusers shall be plaque type ceiling diffusers. The diffuser size shall be nominal 24” x 24”, with a minimum 18” square appearance panel. The horizontal air discharge pattern shall be 360° type.
2. The diffusers shall be self-contained, and not require any external electrical or pneumatic connections. The damper shall consist of a spun, round aluminum disk that moves to change the effective free area of the diffuser to modulate flow. The damper shall include a perimeter seal. Each VAV diffuser shall incorporate one or more thermo-powered sensing elements that modulate the diffuser damper in response to the room temperature as sensed by the induced flow across the sensing element(s). The setpoints shall be factory pre-set at 74° F, but shall be field adjustable from 72°-78° F.
3. The diffusers shall be constructed of steel, and shall be designed to integrate with the specified ceiling system type. The diffuser shall consist of a back pan and a removable, heavy gauge appearance panel attached to the back pan. Room temperature setpoint adjustments shall be made by removing the panel, and rotating the appropriate thermo-powered sensor. No tools shall be required.
4. The appearance panel shall have aerodynamic, rigid, hemmed edges around the perimeter and shall be a single piece construction. The panel shall be flat, smooth, and shall be free of any welding or forming blemishes. Holes or plug buttons in the panel are not acceptable.
5. Diffuser finish shall be color as selected by the Architect and subject to approval of submitted samples.
6. Each diffuser shall be free from defects in material and workmanship, and shall carry a manufacturer’s warranty of 10 years.

2.10 SOURCE QUALITY CONTROL

A. Verification of Performance: Rate diffusers, registers, and grilles according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas where diffusers, registers, and grilles are to be installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.

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

3.2 INSTALLATION

A. Install diffusers, registers, and grilles level and plumb.

B. Ceiling-Mounted Outlets and Inlets: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify Architect for a determination of final location.

C. Install diffusers, registers, and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

D. Carefully install all ceiling mounted air distribution devices back pan insulation and vapor barrier. Where pre-molded insulation and vapor barrier is not furnished as an accessory to the air distribution device by the manufacturer the Contractor is responsible for field installation of insulation and vapor barrier for ceiling air distribution device back pans.

E. All visible interior surfaces of all grilles and air device accessories and components visible through the face of the outlet shall be factory painted flat black.

F. Install a manual volume damper in the branch duct to the air distribution device or at the conical bell-mouth spin-in fitting for connection of round duct to the rectangular duct for balancing purposes.

G. Provide all required blank off for directional pattern.

H. Diffusers Utilizing a Plenum Box: Provide plenum box fabricated of 24 USBG galvanized steel, with internal surfaces lined with minimum 1-1/2 inch thick duct liner for R-6 insulating valve as specified under Division 23 Section “Metal Ducts.”

I. Install return and exhaust registers with blades oriented to prevent sight though outlets.

J. Transfer Grilles: Provide 2 grilles, one on each side of wall with connecting sheet metal collar.

K. Transfer Ducts: Provide 2 grilles, one at each end of duct.

3.3 ADJUSTING

A. After installation, adjust diffusers, registers, and grilles to air patterns indicated, or as directed, before starting air balancing.

END OF SECTION 23 37 13

SECTION 23 41 00 - PARTICULATE AIR FILTRATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section Includes:

1. Factory-fabricated air-filter devices and media used to remove particulate matter from air for HVAC applications.
2. Air Filter Gauges.

1.3 DEFINITIONS

A. DOP: Dioctyl phthalate or bis-(2-ethylhexyl) phthalate.

B. HEPA: High-efficiency particulate air.

C. ULPA: Ultra low penetration air.

1.4 SUBMITTALS

A. Product Data: Include dimensions; operating characteristics; required clearances and access; rated flow capacity, including initial and final pressure drop at rated airflow; efficiency and test method; fire classification; furnished specialties; and accessories for each model indicated.

B. Shop Drawings: Include plans, elevations, sections, and details to illustrate component assemblies and attachments.

1. Show filter rack assembly, dimensions, materials, and methods of assembly of components.
2. Include setting drawings, templates, and requirements for installing anchor bolts and anchorages.
3. Wiring Diagrams: Power, signal, and control wiring.

C. Samples: Submit 2 samples of replacement media of each type and filter frame.

D. Operation and Maintenance Data: For each type of filter and rack to include in emergency, operation, and maintenance manuals.

1.5 QUALITY ASSURANCE

A. Product Options: Drawings indicate size, profiles, and dimensional requirements of air filters and are based on the specific system indicated. Refer to Division 01 Section "Product Requirements."

B. Filter Media: ANSI/UL 900 listed, Class I or Class II as noted.

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

D. Comply with AHRI 850.

E. Comply with ASHRAE 52.1 and ASHRAE 52.2 for method of testing and rating air-filter units.

F. Comply with NFPA 70 for installing electrical components.

G. Comply with NFPA 90A and NFPA 90B.

H. Provide all filters as product of one manufacturer.

1.6 COORDINATION

A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

1.7 EXTRA MATERIALS

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

1. Provide 1 complete set of filters for each filter bank. If system includes pre-filters, provide only 1 complete sets of pre-filters and final filters.
2. Provide one container of red oil for inclined manometer filter gage.
3. Provide one complete set of UV-C lamps for each photocatalytic air cleaner.

PART 2 - PRODUCTS

2.1 GENERAL

A. Filters shall be UL listed Class 2, unless otherwise specified Class 1.

B. Arrestance and efficiencies noted are minimum average.

C. Design air flow not to exceed catalogued capacity.

D. Initial and final resistances not to exceed scheduled values.

E. Service access as indicated on drawings.

2.2 FILTER TYPES, PROVIDE AS FOLLOWS:

A. Flat panel, replaceable - Type A.

B. Extended surface, high efficiency - Type B.

C. Catalytic Air Cleaner System - Type C.

D. Terminal, high efficiency - Type D.

2.3 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Air Filters, Electrostatic Air Cleaners, and Filter-Holding Systems:

    a. AAF International.
    b. Farr Co.
    c. Flanders Filters, Inc.
    d. Cam/Farr Company.
    e. Bioclimatic Air System, Inc.

2. Filter Gages:

    a. Airguard Industries, Inc.
    b. Dwyer Instruments, Inc.
    c. Owner approved substitution.

2.4 DISPOSABLE PANEL FILTERS – TYPE A

A. Description: Factory-fabricated, viscous-coated, flat-panel-type, disposable air filters with holding frames.

B. Media: Interlaced glass fibers sprayed with nonflammable adhesive and anti-microbial agent. Arrestance:

1. 1 inch thick: 60 percent.
2. 2 inch thick: 70 percent.

C. Frame: Cardboard frame with perforated metal retainer.

D. Duct-Mounting Frames: Welded, galvanized steel with gaskets and fasteners and suitable for bolting together into built-up filter banks.

2.5 EXTENDED-SURFACE, DISPOSABLE PANEL FILTERS – TYPE A-2

A. Description: Factory-fabricated, dry, extended-surface filters with holding frames.

B. Media: Fibrous material or cotton cellulose, UL Class II, MERV 8 formed into deep-V-shaped pleats with anti-microbial agent and held by self-supporting wire grid.

C. Filter Thickness: 1 inch, 2 inch, or 4 inch as indicated.

D. Media and Media-Grid Frame: Nonflammable cardboard.

E. Duct-Mounting Frames: Welded, galvanized steel with gaskets and fasteners, and suitable for bolting together into built-up filter banks.

2.6 EXTENDED SURFACE, HIGH-EFFICIENCY FINAL FILTER - TYPE B

A. Description: Factory-fabricated 90-95 percent DOP per ASHRAE Standard 52.1 filters with holding casing. Classified by UL to Class 1, UL Standard 900 (MERV 14).

B. Media: Fibrous glass, water resistant, constructed of continuous sheets with closely spaced pleats with aluminum separators.

C. Frame Material: Aluminized steel, or galvanized steel. Depth per filter schedule.

D. Media to Frame Side Bond: Mechanical and chemical bond.

E. Face Gasket: Neoprene expanded rubber. Material must comply with NFPA 90A and 90B and flame spread and smoke development ratings.

F. Headers: Filters shall be double sided headers, continuously attached, suitable for use in frames by various manufacturers.

G. Duct-Mounting Frames: Construct downstream corners of holding device with cushion pads to protect media. Provide bolted filter-sealing mechanism to mount and continuously seal each individual filter.

H. Initial pressure drop shall not exceed 0.56” w.g. when operating at rated cfm and a face velocity of 500 fpm, and shall be capable of reaching 1.5” w.g. without unloading or collapsing. The air leaving side of the filter shall have metal bracing or a metal mesh guard.

2.7 PHOTOCATALYTIC AIR CLEANERS - TYPE C

A. Description: A factory-engineered and factory-installed photocatalytic air cleaner shall be supplied by the air handler manufacturer or installed in a cassette that shall be installed on site in the air handler manufacturer catalytic filter section. Field-installed fixtures shall not be allowed. Air cleaner frames shall be capable of accepting specified air cleaner/MERV 14 filter assembly.

B. Catalytic air cleaner system shall be a three part integral assembly for treatment of air by: 1) High efficiency particle filtration (MERV 14 or higher upstream of catalytic system), 2) Ultraviolet Germicidal Irradiation (UVGI) using UV-C lamps and fixtures; and 3) Photocatalytic Oxidation (PCO) catalyst media using titanium dioxide (TiO_2).

C. Catalyst Media:

D. Electrical Characteristics:
1. UV-C lamps and ballasts designed specifically to provide type-C ultraviolet light with a wavelength at or near 2537 Angstroms and shall not produce any ozone.
2. Lamps shall be Teflon-coated to reduce breakage.
3. Sufficient lamps shall be provided and positioned center point through the media equidistant from edges so as to achieve a minimum overage of 9.5 milliwatts per square inch of UVC light, upstream and downstream, across all exposed surfaces of the PCO media.
4. Lamp UVC output shall not drop below 9.5 milliwatts per square inch over their usable 10000 hr life.
5. Emitters shall include safety switches.
6. Provide a viewport in the access door servicing the UV section in order to confirm UV operation without the need to open the access door.
7. The catalyst media shall consist of six-inch deep (direction of airflow) grid with face area to match casing opening, one pleat per inch (nominal), and coated with 40-200 nanometer TiO_2.
8. The complete PCO media bank assembly shall be housed in a galvanized or stainless steel casing and placed in the air handler perpendicular to the airflow. Assemble shall be capable of withstanding 750 fpm face velocity with no structural damage.
9. Media shall have an internal mechanism to eliminate the silica produced by the oxidation of ethanol.
10. All UV lamps and PCO media shall be removable from outside the AHU casing through a side access door for maintenance purposes.

11. The substrate on which the TiO2 is bonded shall not deteriorate when exposed to UVC light.
12. PCO media shall be washable without affecting its air cleaning efficiency.
13. UV lamps shall be independently replaceable without the need to replace the fixture or remove the PCO media.
14. The catalytic air cleaner system will be configured to operate with 460 Volt / 1 Phase electrical power.
15. All systems shall have an independent single point external power connection.
16. Electrical fixtures shall meet the UL drip proof design criteria. Component enclosures shall be constructed of galvanized steel or stainless steel to resist corrosion.
17. Fixtures shall have been tested and recognized by UL/C-UL under Category Code ABQK (Accessories, Air Duct Mounted), UL Standards 1995.
18. For line voltage options, the photocatalytic air cleaners shall be provided with a UL 508 listed panel for power distribution and over-current protection.

E. All polymeric materials that come into direct or indirect (reflected) contact with UV-C light shall be tested and certified as UV-C tolerant. Any non-conforming construction materials or components within the exposure zone shall be completely shielded from the UV-C light using a certified UV-C tolerant material. UV-C tolerance is defined as being capable of performing its intended duty for a minimum of 20 years.

F. Access Doors:
1. Access doors shall be provided at the location of catalytic air cleaner system as indicated on the plans and schedule. All access doors were there is direct or indirect contact with the UV-C lights shall have a mechanical safety interlock switch that disconnects the UV-C power upon opening.
2. Each catalytic air cleaning system shall be equipped with a factory installed, externally mounted electrical disconnect switch for maintenance purposes, with lock-out capability to prevent unwanted operation.
3. A window shall be provided on each air handler to allow visual inspection of the catalytic air cleaner system during operation. The viewing window shall be guaranteed to block UV-C light emissions below the threshold limits specified by NIOSH and/or ACGIH.
4. Units shall have a safety warning label applied to the exterior of each section containing UV-C lights.

2.8 HIGH-EFFICIENCY FILTERS – TYPE D

A. Terminal type high efficiency filter, Type D: Cells, media shall be minimum of 180 sq ft continuous sheet glass material having pleats separated by corrugated aluminum inserts. Media enclosure shall be self-supporting galvanized steel cell sides with glass packing sealant. Provide 24-inch x 24-inch x 11-1/2-inch-deep cells, UL Class II. Provide galvanized steel flanged header, having sealed and mitered corners, and corner angle supports.

1. Rated capacity shall be 1000 cfm. Dioctyl-phthalate efficiency at rated capacity shall be minimum 95 percent on 0.3 micron particles (MERV 16). Initial resistance

at rated capacity shall be 0.45 inch w.g. Filter shall be suitable for 100 percent relative humidity. Provide type similar to American Air Filter Biocel Type I.

2. Extruded aluminum framing modules shall be continuously factory welded into major sub-assembly with spring loaded retainers. Factory welded framing system shall be designed to receive HEPA filters. Each filter shall be retained with a minimum of four (4) 1 1/2 in. wide clamps, captive springs and visual control bolts. Provide framing system similar to American Air Filter Bevel Seal Grid.
3. Factory fabricated in-line housing for terminal filters: Housing shall be 18 gauge aluminum with access door for filter changing and spring loaded retainers. The door shall be constructed of No.12 gauge aluminum with permanently mounted, quarter turn cam fasteners and neoprene rubber gaskets. Housing shall be riveted and sealed air tight and non-directional with respect to air flow. Provide 1-1/2 inch wide flanges at each end and welded aluminum filter retainer with bevel seal profile. Spring loaded retainers shall be minimum 1-1/2 inch wide clamps, minimum of four clamps per filter cell, calibrated for visual determination of proper compression with captive springs. Steel parts shall be cadmium or zinc plated. Provide type similar to American Air Filter Biocel Type I Filter.

2.9 FRONT- AND REAR-ACCESS FILTER FRAMES

A. Framing System: Aluminum framing members with access for either upstream (front) or downstream (rear) filter servicing, cut to size and pre-punched for assembly into modules. Vertically support filters prevent deflection of horizontal members without interfering with either filter installation or operation.

B. Pre-filters: Incorporate a separate track, removable from front or back.

C. Sealing: Factory-installed, positive-sealing device for each row of filters to ensure seal between gasketed filter elements to prevent bypass of unfiltered air.

2.10 SIDE-SERVICE HOUSINGS

A. Description: Factory-assembled, side-service housings, constructed of galvanized steel, with flanges to connect to duct system.

B. Pre-filters: Integral tracks to accommodate 2-inch disposable or washable filters.

C. Access Doors: Continuous gaskets on perimeter and positive-locking devices. Arrange so filter cartridges can be loaded from either access door.

D. Sealing: Incorporate positive-sealing gasket material on channels to seal top and bottom of filter cartridge frames to prevent bypass of unfiltered air.

2.11 FILTER GAGES

A. Description: Diaphragm type with dial and pointer in metal case, vent valves, black figures on white background, and front recalibration adjustment.

1. Diameter: 4-1/2 inches.
2. Range: 0- to 0.5-inch wg, 0- to 1.0-inch wg, 0- to 2.0-inch wg, 0- to 3.0-inch wg, or 0- to 4.0-inch wg as required for application.

B. Manometer-Type Filter Gage: Molded plastic with epoxy-coated aluminum scale, logarithmic-curve tube gage with integral leveling gage, graduated to read from 0- to 3.0-inch wg, and accurate within 3 percent of full scale range.

C. Accessories:

1. Static-pressure tips, tubing, vent valves, gage connections, and mounting bracket.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install filter frames according to manufacturer's written instructions.

B. Position each filter unit with clearance for normal service and maintenance. Anchor filter holding frames to substrate.

C. Install filters in position to prevent passage of unfiltered air. Do not operate fan system connected to filter bank until all filters (temporary pre-filters and specified filters) are in place.

D. Erect holding frames leak tight and structurally sound to preclude breathing action.

1. Filter banks 3 filters high or more reinforced with 3 inch wide steel stiffeners between each vertical row of filters.
2. Before joining frames caulk with DAP “Butyl Gutter and Lap Sealer” or its equivalent. Caulk leading edge joint gaps after installation.
3. Tape joints on downstream side of filter bank with 1 inch duct tape.

E. Install filter gage for each filter bank, pre-filter and after filter.

F. Install filter gage static-pressure tips upstream and downstream from filters to measure pressure drop through filter. Mount filter gages on outside of filter housing or filter plenum in an accessible position. Adjust and level inclined gages.

G. Coordinate filter installations with duct and air-handling unit installations.

H. Electrical wiring and connections are specified in Division 26 Sections.

I. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

3.2 TEMPORARY PRE-FILTERS FOR CONSTRUCTION

A. Protect all filters upstream of air handling units during construction with blankets of 2" fiberglass filter media or 2" disposable panel filters. UL Class II listed. Replace temporary pre-filters if final pressure is reached during construction or test and balance.

B. Prior to final acceptance of systems or operation of systems by Owner, replace temporary filters as follows:

1. For each pre-filter and final filter assembly, provide one temporary filter bank, equivalent to the specified prefilter. Before balancing and before final acceptance or turning over to owner, replace temporary filters with new prefilters and new final filters. When turning over to Owner, provide new prefilter and replace final filter with space set if air friction is greater than or equal to 0.8 inch w.g.
2. Notify Architect and/or Engineer in writing no less than 7 days before systems are operated for beneficial use of owner and temporary filters used during balancing period are replaced. In absence of such notice, filters shall be replaced on or after starting date of guaranteed period.

3.3 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components, filter and filter-frame installation, and electrical wiring, and to assist in field testing. Report results in writing.

B. HEPA Filters: Pressurize housing to a minimum of 3.0-inch wg or to designed operating pressure, whichever is higher; and test housing joints, door seals, and sealing edges of filter with soapy water to check for air leaks.

3.4 CLEANING

A. After completing system installation and testing, adjusting, balancing and commissioning air-handling and air-distribution systems, clean filter housings and install new filter media.

END OF SECTION 23 41 00

SECTION 23 72 00 - AIR-TO-AIR ENERGY RECOVERY EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. Section Includes:

1. Heat wheels.

1.3 PERFORMANCE REQUIREMENTS

A. Delegated Design: Design vibration isolation details, using performance requirements and design criteria indicated.

1.4 SUBMITTALS

A. Product Data: For each type of product indicated. Include rated capacities, furnished specialties, and accessories.

B. LEED V4 BD+C Submittals:

1. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
2. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1-2010, Section 5 - "Systems and Equipment."

C. Shop Drawings: For air-to-air energy recovery equipment. Include plans, elevations, sections, details, and attachments to other work.

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

3. Detail fabrication and assembly of air-to-air energy recovery equipment.
4. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.

5. Design Calculations: Calculate requirements for selecting vibration isolators and for designing vibration isolation bases.

D. Coordination Drawings: Plans, elevations, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:

1. Suspended ceiling components.
2. Structural members to which equipment or suspension systems will be attached.

E. Field quality-control reports.

F. Operation and Maintenance Data: For air-to-air energy recovery equipment to include in maintenance manuals.

1.5 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. AHRI Compliance: Capacity ratings for air-to-air energy recovery equipment shall comply with AHRI 1060, "Rating Air-to-Air Energy Recovery Equipment."

C. ASHRAE Compliance:

1. Applicable requirements in ASHRAE 62.1-2010, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
2. Capacity ratings for air-to-air energy recovery equipment shall comply with ASHRAE 84, "Method of Testing Air-to-Air Heat Exchangers."

D. NRCA Compliance: Roof curbs for roof-mounted equipment shall be constructed according to recommendations of NRCA.

E. UL Compliance: Packaged heat recovery ventilators shall comply with requirements in UL 1812, "Ducted Heat Recovery Ventilators"; or UL 1815, "Nonducted Heat Recovery Ventilators."

1.6 COORDINATION

A. Coordinate layout and installation of air-to-air energy recovery equipment and support system with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.

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

C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.7 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of air-to-air energy recovery equipment that fail in materials or workmanship within specified warranty period.

1. Warranty Period for Packaged Energy Recovery Units: Two years.
2. Warranty Period for Fixed-Plate Total Heat Exchangers: 10 years.

PART 2 - PRODUCTS

2.1 HEAT WHEELS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. TRANE.
2. Advanced Thermal Technologies.
3. Airxchange.
4. American Energy Exchange, Inc.
5. Loren Cook Company.
6. SEMCO Incorporated

B. The air handling unit shall be certified by AHRI to contain a rotary energy recovery wheel certified to ANSI/AHRI Standard 1060 and bears the AHRI 1060 label. Performance characteristics of the energy wheel shall be provided as defined by AHRI 1060 definitions. The energy wheel shall be a total energy wheel, with the sensible and latent effectiveness reported and within 5% of each other. The calculated total net effectiveness of the recovery wheel shall not be less than 70% when the specified ventilation flow rate equals the exhaust flow rate. The energy wheel's EATR shall be less than the value indicated in the schedule and drawings. Wheel face velocity and pressure drop shall not exceed performance as defined on schedule. The energy recovery cassette shall be an Underwriters Laboratories (UL) Recognized Component certified for mechanical, electrical, and fire safety in accordance with UL Standard 1812.

C. Casing: .

1. Steel with standard factory-painted finish

2. Integral purge section limiting carryover of exhaust air to between 0.05 percent at 1.6-inch wg and 0.20 percent at 4-inch wg differential pressure.

3. Casing seals on periphery of rotor and on duct divider and purge section. Perimeter seals shall be self-adjusting; diameter seals shall be adjustable. Rim shall be continuous rolled stainless steel to form an even concentric circle to prevent leakage around rim and to minimize wear of components

4. Support vertical rotors on grease-lubricated ball bearings having extended grease fittings or permanently lubricated bearings. Support horizontal rotors on tapered roller bearing. Permanently sealed and lubricated wheel bearings shall have minimum L-10 life of 400,000 hours.

5. Wheel casing to be removable to allow for servicing of heat wheel

6. Provide air bypass to allow for airside economizer.

7. Wheel drive motor shall be thermally protected and UL Component Recognized

D. Rotor: Polymer segmented wheel strengthened with radial spokes impregnated with nonmigrating, water-selective, molecular-sieve desiccant coating.

1. Maximum Solid Size for Media to Pass: 800 micrometer

2. Incorporate desiccant without the use of binders or adhesives

3. The absorbent shall not be applied as a glued on surface coating and not susceptible to erosion, abrasion, or delamination

4. Coated segments shall be washable using standard detergent or alkaline-based coil cleaners

5. The absorbent shall be selected for its high affinity for water vapor and shall not dissolve or deliquesce in the presence of water or high humidity

E. Bearing: Wheel bearings shall be permanently sealed and lubricated and have a minimum L-10 life of 400,000 hours.

F. Drive: Fractional horsepower motor and gear reducer and self-adjusting multilink belt around outside of rotor.

1. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment”.

2. 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

3. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 26 Sections.

4. Drive belts shall not require belt tensioner

G. Controls:

1. Basis of design: Starting relay, factory mounted and wired, and manual motor starter for field wiring.

2. Energy recovery wheels shall be designed with variable effectiveness control, to vary the wheel's recovery capacity. Variable effective control shall be done by an internal bypass damper provided by the AHU Manufacturer. The wheel's variable effectiveness control shall have the ability to modulate the total energy recovery ability down to at least 40% of the initial recovery capacity. Variable frequency speed control is not an acceptable method for controlling variable effectiveness.

3. Pilot-Light Indicator: Display rotor rotation and speed.

4. Speed Settings: Adjustable settings for maximum and minimum rotor speed limits

H. Frost Protection: Frost prevention shall be achieved by outside air bypass, return air preheat, or outside air preheat, depending upon design conditions. Frost set point temperatures based on the scheduled design air conditions shall be provided by the AHU Manufacturer. Variable frequency speed control is not an acceptable method of frost control. Winter design supply and exhaust air conditions leaving the energy wheel shall be provided by the AHU Manufacturer and shall include any de-rate in performance due to frost prevention measures.

I. Control of energy wheels shall be incorporated and an integral part of the DOAS control systems and shall be as described under the DOAS control diagrams and control sequences shown on the BMS drawings. Secondary independent wheel controllers are not acceptable.

J. Access doors: Access doors shall be provided on all air entering and air leaving sides of wheel to allow for wheel maintenance, belt, bearing, or motor removal

2.2 CAPACITIES AND CHARACTERISTICS

A. As scheduled on drawings.

PART 3 - EXECUTION

3.1 EXAMINATION

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

B. Examine casing insulation materials and filter media before air-to-air energy recovery equipment installation. Reject insulation materials and filter media that are wet, moisture damaged, or mold damaged.

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

3.2 INSTALLATION

A. Install heat wheels so supply and exhaust airstreams flow in opposite directions and rotation is away from exhaust side to purge section to supply side.

1. Install access doors in both supply and exhaust ducts, both upstream and downstream, for access to wheel surfaces, drive motor, and seals.

B. Install units with clearances for service and maintenance.

C. Install new filters at completion of equipment installation and before testing, adjusting, and balancing.

D. Pipe drains from units and drain pans as shown, same size as condensate drain connection.

3.3 FIELD QUALITY CONTROL

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

3.4 DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain air-to-air energy recovery units.

END OF SECTION 23 72 00

SECTION 23 73 13 - MODULAR INDOOR CENTRAL-STATION AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

B. Basic Requirements: Provisions of Section 23 00 10, Basic HVAC Requirements are part of this Section.

1.2 SUMMARY

A. Section Includes:

1. Constant-air-volume, single-zone air-handling units.
2. Variable-air-volume, single-zone air-handling units.

1.3 PERFORMANCE REQUIREMENTS

A. Structural Performance: Casing panels shall be self-supporting and capable of withstanding 133 percent of internal static pressures indicated, without panel joints exceeding a deflection of L/240 where "L" is the unsupported span length within completed casings.

1.4 SUBMITTALS

A. Product Data: Manufacturer’s literature for each air-handling unit indicated.

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

   a. Certified fan-performance curves with system operating conditions indicated.
   b. Certified fan-sound power ratings.
   c. Fan construction and accessories.
   d. Motor ratings, electrical characteristics, and motor accessories.

4. Certified coil-performance ratings with system operating conditions indicated.

5. Coil description, rows and fins per inch and face velocity.
6. Airflow and airside pressure drop at design conditions.
7. Dampers, including housings, linkages, and operators.

8. Filters with performance characteristics.
9. Scaled drawings of unit assembly with construction details, field connection details and required clearances.
10. Wiring diagrams for interlock and control wiring, clearly indicating factory installed and field installed wiring.

B. Sustainable Design Documentation Submittals: Refer to section 01 81 13.14 “Sustainable Design Requirements – LEED V4 BD+C”.

1. Product Data: Documentation for Filter Media/Filter Log in accordance with specification Section 01 35 46.

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

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

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

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

E. Source quality-control reports.

F. Field quality-control reports.

G. Installation instructions: Manufacturer’s printed instructions for the assembly and installation of each air handling unit including copies shipped with the equipment.

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

1. Catalog cuts of equipment and all components.
2. Instructions for lubrication, filter replacement, motor and drive replacement.
3. Spare parts list.
4. Wiring diagrams.

I. CLOSEOUT SUBMITTALS: See Section 01 78 00 – Closeout Submittals for requirements.

J. MAINTENANCE MATERIAL SUBMITTALS: See Section 01 78 00 – Closeout Submittals for requirements.

1.5 QUALITY ASSURANCE

A. General: All equipment, material, accessories, methods of construction and reinforcement, finish quality, workmanship and installation shall be in compliance with Section 23 00 10.

B. 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.

C. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components. All materials and adhesives used shall conform to the requirements of NFPA 90A and NFPA 255 with flame spread not exceeding 25 and smoke developed ratings not exceeding 50.

D. ARI Certification: Air-handling units and their components shall be factory tested according to ARI 430, "Central-Station Air-Handling Units," and shall be listed and labeled by ARI.

E. ARI Certification: Coil capacities, pressure drops and selection procedure shall be certified in accordance with ARI Standard 410.

F. ASHRAE Compliance: Applicable requirements in the latest edition of ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

G. ASHRAE/IESNA 90.1 Latest Edition Compliance: Applicable requirements in the latest edition of ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

H. Comply with NFPA 70.

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 EXTRA MATERIALS

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

1. Filters: One set for each air-handling unit.
2. Gaskets: One set for each access door.

3. Fan Belts: One set for each air-handling unit fan.
4. Belt Pulleys: One fixed pitch pulley for each air-handling unit fan.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide product by one of the following:
 1. Carrier Corporation; a member of the United Technologies Corporation Family.
 2. Daikin Applied
 3. Temptrol
 4. Trane; American Standard Inc.
 5. YORK International Corporation.

2.2 UNIT CASINGS

A. General Fabrication Requirements for Casings:
 1. Casing Joints: Sheet metal screws or pop rivets.
 2. Casings: Double wall insulated panel construction.
  a. Panels and access doors shall be constructed as a 2-inch (50-mm) nominal thick; thermal broke double wall assembly, injected with foam insulation for an R-value of not less than R-13.
  b. Outer wall: Galvanized or phosphatized cold rolled steel, reinforced and braced with angles.
  c. Internal wall: Galvanized steel panel over 2 inch (50 mm) thick fibrous glass board insulation 1.5 lb/cu. ft. (24 kg./cu. m.) density, NFPA approved. Fan section internal wall shall be perforated galvanized steel in lieu of solid panel.
  d. Factory finish for galvanized steel casing shall consist of factory applied standard two coat, baked on enamel finish consisting of prime coat and thermostting Casing finished to meet ASTM B117 500-hour salt-spray test.
 3. Sealing: Seal all joints with permanently applied bulb-type gasket. Shipped loose gasketing is not allowed.
 4. The casing leakage rate shall not exceed ASHRAE 111 CL 6 at design pressure up to positive or negative 8 inches, where casing leakage (cfm/100 ft2 of casing surface are) = CL × P0.65.
 5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in the latest edition of ASHRAE 62.1.
 6. Panel deflection shall not exceed L/240 ratio at 133% of design static pressure, maximum positive or negative 8 inches of static pressure. Deflection shall be measured at the midpoint of the panel height.
 7. Module to module assembly shall be accomplished with an overlapping, full perimeter, insulated, internal splice joint sealed with bulb type gasketing on both mating modules.

B. Flooring :

1. Units shall have a 0.044” aluminum tread plate floor on access sections.

C. Inspection and Access Panels and Access Doors:

1. Panel and Door Fabrication: Formed and reinforced, double-wall and insulated panels of same materials and thicknesses as casing. Doors shall be flush mounted to cabinetry.
2. Inspection and Access Panels:

a. Fasteners: Two or more camlock type for panel lift-out operation. Arrangement shall allow panels to be opened against air-pressure differential.
b. Gasket: Neoprene, applied around entire perimeters of panel frames.
c. Size: Large enough to allow inspection and maintenance of air-handling unit's internal components.

3. Access Doors:

a. Hinges: A minimum of two stainless-steel hinges and two wedge-lever-type latches, operable from outside. Latches shall be non self-latching. Arrange doors to be opened against air-pressure differential.
b. Gasket: Neoprene, applied around entire perimeters of panel frames.
c. Fabricate windows in fan section doors of double-glazed, safety glass with an air space between panes and sealed with interior and exterior rubber seals. Windows shall be shatterproof capable of withstanding unit operating pressures.
d. Size: At least 18 inches wide by full height of unit casing up to a maximum height of 60 inches.
e. View Port:

1) View Port: view port shall be provided and installed at the UVGI section. View port shall be constructed of anodized aluminum framework and 1/4” thick laminated glass. Viewing area shall be 3” x 12”. Air handling unit insulation rating shall not be compromised. View port shall be constructed to prevent condensation from forming on the view port and access door.
2) Caution sign (7” x 10”) shall be provided and installed on all access to UVGI section. Sign shall be caution yellow with bold black lettering.

f. Door Safety Sensor:

1) System shall incorporate sensor device on the UVGI compartment access door to disconnect power when access is required. Device shall consist of coded magnet and shall be tamper-resistant to prevent by-passing.
2) Sensor shall be shock resistant to 30g/11ms and vibration resistant, 10 to 55 Hz, amplitude 1 mm and conform to CE, UL, CSA, VDE and

3) IEC Standards as well as safety EN954-1, Category 1 with provided safety controller.

4. Locations and Applications:

a. Fan Section: Doors - Access door shall be 20” minimum for this section only.
b. Access Section: Doors.
c. Coil Section: Access doors before and After Coil Section(s) on both sides of the unit – Access door shall be 20” minimum for this section only.
d. Damper Section: Doors.
e. Filter Section: Doors large enough to allow periodic removal and installation of filters.
f. Mixing Section: Doors.
g. Humidifier Section: Doors.

5. Service Light: Provide marine light and GFI receptacle in fan section mounted and wired to a junction box and on-off switch mounted on the outside of the cabinet. Provide marine light in filter section wired to a junction box and on-off switch mounted on the outside of the cabinet.

D. Condensate Drain Pans:

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

a. Length: Extend drain pan downstream from leaving face to comply with ASHRAE 62.1.
b. Depth: A minimum of 2 inches deep.

2. Formed sections or Integral part of floor plating.
3. Double-wall, stainless-steel sheet with space between walls filled with foam insulation and moisture-tight seal.
4. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Drain connection centerline shall be a minimum of 3" above the base rail to aid in proper condensate trapping. Drain connections that protrude from the base rail are not acceptable.
5. Terminate with stainless-steel threaded nipple on one end of pan.
6. Minimum Connection Size: NPS 1.
7. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil, and piped to lowest drain pan.

E. Air-Handling-Unit Mounting Frame: Formed galvanized-steel, designed for low deflection, welded with integral lifting lugs to provide true thermal break

2.3 FAN, DRIVE, AND MOTOR SECTION

A. Fan and Drive Assemblies: Statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower.

1. Shafts: Designed for continuous operation at maximum-rated fan speed and motor horsepower, and with field-adjustable alignment. Multiple fans shall be mounted on a common shaft.

    a. Turned, ground, and polished hot-rolled steel with keyway. Ship with a protective coating of lubricating oil.
    b. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

B. Centrifugal Fan Housings: Formed- and reinforced-steel panels to form curved scroll housings with shaped cutoff and spun-metal inlet bell.

1. Bracing: Steel angle or channel supports for mounting and supporting fan scroll, wheel, motor, and accessories.
2. Horizontal-Flanged, Split Housing: Bolted construction.
3. Housing for Supply Fan: Attach housing to fan-section casing with metal-edged flexible duct connector.
4. Flexible Connector: Factory fabricated with a fabric strip 3-1/2 inches or 5-3/4 inches wide attached to 2 strips of 2-3/4-inch-wide, 0.028-inch-thick, galvanized-steel sheet or 0.032-inch-thick aluminum sheets; select metal compatible with casing.

    a. Flexible Connector Fabric: Glass fabric, double coated with neoprene. Fabrics, coatings, and adhesives shall comply with UL 181, Class 1.

        1) Fabric Minimum Weight: 26 oz./sq. yd..
        2) Fabric Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
        3) Fabric Service Temperature: Minus 40 to plus 200 deg F.

C. Plenum Fan Housings: Steel frame and panel; fabricated without fan scroll and volute housing.

D. Backward-Inclined, Centrifugal Fan Wheels: Single-width-single-inlet and double-width-double-inlet construction with curved inlet flange, backplate, backward-inclined blades welded or riveted to flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.

E. Airfoil, Centrifugal Fan Wheels: Single-width – single-inlet and double-width – double-inlet construction with smooth-curved inlet flange, backplate, and hollow die-formed airfoil-shaped blades continuously welded at tip flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.

F. Direct-drive airfoil plenum supply fan(s):

1. See construction schedules for the number of fans located in the unit. Unit shall have 9 or 12 blade airfoil type, direct-drive class II fans with 2" spring isolation.
2. Fan and motor shall be mounted internally on a steel base. Provide access to motor, drive, and bearings through hinged access door.
3. Fans wheels shall be constructed of all aluminum.

4. Provide inlet safety screen.
5. Provide fan safety screen.
6. Manual block-off damper mounted upstream of fan for isolation of individual fans shall be provided for units with multiple fans.

G. Fan Shaft Bearings:

1. Prelubricated and Sealed, Ball Bearings: Self-aligning, pillow-block type with a rated L-50 life of 500,000 hours according to ABMA 9.
2. Grease-Lubricated, Tapered-Roller Bearings: Self-aligning, pillow-block type with double-locking collars and 2-piece, cast-iron housing with grease lines extended to outside unit and a rated L-50 life of 500,000 hours according to ABMA 11.
3. Grease-Lubricated Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing with grease lines extended to outside unit and a rated L-50 life of 500,000 hours according to ABMA 11.

H. Belt Drives: Factory mounted, with adjustable alignment and belt tensioning, and with 1.5 service factor based on fan motor, allow for one drive change on fan to attain desired flow rates for air balance.

1. Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
2. Motor pulleys:

    a. Adjustable pitch type for use with fans up to 7.5 hp motors and smaller and for fans 10 to 25 hp under 1000 rpm, except fans with variable inlet vanes or variable frequency drives.
    b. Fixed pitch type for use with fans larger than 10 hp to 25 hp and larger, and fans with variable inlet vanes or variable frequency drives.
    c. Select pulley sizes so pitch adjustment is at the middle of adjustment range at fan design conditions.

3. Belts: Oil resistant, nonsparking, and nonstatic; in matched sets for multiple-belt drives. Companion sheaves to maintain belts parallel.
4. Belt Guards: Comply with requirements specified by OSHA and fabricate according to SMACNA's "HVAC Duct Construction Standards"; 0.1046-inch- thick, 3/4-inch diamond-mesh wire screen, welded to steel angle frame; prime coated.

I. Internal Vibration Isolation: Fans shall be factory mounted with manufacturer's standard vibration isolation mounting devices. For deflection, see schedule.

J. Motor: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Open Drip-Proof (ODP) or totally enclosed, fan cooled.
2. NEMA Premium (TM) 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 Division 26 Sections.
5. Motors must be “matched” with variable frequency drives, one (1) VFD per fan. Motors and fans shall be selected and furnished by the air-handling unit manufacturer to meet specified performance requirements. All VFD’s for equipment under this specifications shall be sourced from one single VFD manufacturer.
6. Each VFD shall come with integral disconnect. Provide separate unit service disconnect switch upstream of VFD(s).
7. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.

K. Variable Frequency Controllers: See Section 23 05 14 "Variable Frequency Motor Controllers."
1. VFD for Modular Air Handling Units’ supply fans specified under this section shall be furnished without bypass controller.

2.4 ELECTRICAL

A. General Requirements for Electrical:

1. The air handling units shall be ETL or UL listed, as an entire assembly. Component listing is not an acceptable alternate. ETL-C is not an acceptable alternative.
2. Units shall conform to ANSI/UL Standard 1995/CSA Standard C22.2 No.236.

B. Wiring Termination:

1. Provide terminal lugs to match branch circuit conductor quantities, sizes and materials indicated. Enclosed terminal lugs in terminal box shall comply with NFPA 70.
2. Air Handling Unit manufacturer shall provide and mount conduit and wiring from each fan motor terminated at an exterior junction box.
3. Air handling unit manufacturer shall provide electrical connections as scheduled.

2.5 COIL SECTION

A. General Requirements for Coil Section:

1. Comply with ARI 410. Coil shall bear the AHRI label.
2. Manufacturer of coil shall be ISO 9002 certified.
3. Fabricate coil section to allow removal and replacement of coil for maintenance and to allow in-place access for service and maintenance of coil(s).
4. For multizone units, provide air deflectors and air baffles to balance airflow across coils.
5. Coils shall not act as structural component of unit.
6. Provide access to coils from both sides of unit for service and cleaning.

7. Cooling and heating coils, including headers and return bends, shall be totally enclosed within the unit casing.
8. Unit shall be provided with coil connections that extend a minimum of 5" beyond unit casing for ease of installation.
9. Drain and vent connections shall be provided exterior to unit casing. Coil connections must be factory sealed with grommets on interior and exterior and gasket sleeve between outer wall and liner where each pipe extends through the unit casing to minimize air leakage and condensation inside panel assembly.
10. Headers shall consist of seamless copper tubing to assure compatibility with primary surface. Headers to have intruded tube holes to provide maximum brazing surface for tube to header joint, strength, and inherent flexibility. Header diameter should vary with fluid flow requirements.
11. Fins shall have a minimum thickness of 0.0075" of aluminum plate construction for mixed air units. Fins shall have a minimum thickness of 0.0075” of copper plate construction for 100% outside air units.

    a. Fins shall have full drawn collars to provide a continuous surface cover over the entire tube for maximum heat transfer.
    b. Tubes shall be mechanically expanded into the fins to provide a continuous primary to secondary compression bond over the entire finned length for maximum heat transfer rates. Bare copper tubes shall not be visible between fins.

12. Coil tubes shall be 5/8 inch OD seamless copper, 0.020" nominal tube wall thickness, expanded into fins, brazed at joints. Soldered U-bends shall be provided to minimize the effects of erosion and premature failure having a minimum tube wall thickness of 0.025".Coil connections shall be O.D. sweat copper with connection size to be determined by manufacturer based upon the most efficient coil circuiting. Vent and drain fittings shall be furnished on the connections, exterior to the air handler. Vent connections provided at the highest point to assure proper venting. Drain connections shall be provided at the lowest point to insure complete drainage.
13. Cooling Coil casings shall be a formed channel frame of stainless steel and slide into a pitched track for fluid drainage.
14. Air Velocities:

    a. Units shall have a face velocity below 500 FPM on mixed air unit.
    b. Units shall have a face velocity below 400 FPM on 100% O.A. unit.

15. Cooling coil maximum height shall be 42 inches (10.5 cm). For units that require coils higher than 42 inches (10.5 cm), provide multiple coil sections of equal heights. Provide intermediate condensate drain pans and drain line to lower drain pan.
16. Provide factory installed electric resistance heat for unit. Unit shall include field-replaceable heat sections. All heat sections are to be sub-fused.
17. Electric resistance heaters shall be factory-installed, nichrome element type, open wire coils, insulated with ceramic bushings, and include operating and safety controls. Coil ends shall be staked and welded to terminal screw slots.
18. Heat sections shall feature multiple stage capacity.
19. Safety Features: All heat sections for said unit shall feature factory installed.

a. Automatic discharge air limit Control.
b. Air proving pressure switch.
c. Color coded wiring and matching terminal blocks.
d. Circuit breaker protected transformers.

2.6 AIR FILTRATION SECTION

A. General Requirements for Air Filtration Section: See Division 23 "Particulate Air Filtration."

1. Comply with NFPA 90A.
2. Provide minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
3. Filter media shall be UL 900 listed, Class I or Class II.
4. Provide filter holding frames arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lifted out from access plenum.
5. Provide filter gauges for each filter type.

B. PHOTOCATALYTIC AIR CLEANER:

1. General Requirements: Photocatalytic air cleaner section shall be provided by air handling unit manufacturer as integral part of unit.
2. See Division 23, Section "Particulate Air Filtration" for specific requirements.
3. Air handling unit manufacturer shall coordinate with photocatalytic air cleaner system manufacturer to determine length of section required for proper installation and operation of the system. Section length shown on drawings is minimum length required.
4. Provide access doors. Coordinate with photocatalytic air cleaner system manufacturer for door placement within the section to not interfere with air cleaner installation or operation.

2.7 DAMPERS

A. Dampers: See Division 23 Section "Instrumentation and Control for HVAC."

B. General Requirements for Dampers: Leakage rate, according to AMCA 500, "Laboratory Methods for Testing Dampers for Rating," shall not exceed 2 percent of air quantity at 2000-fpm face velocity through damper and 4-inch wg differential pressure.

C. Damper Operators: Comply with requirements in Division 23 Section "Instrumentation and Control for HVAC."

D. Mixing Section: Multiple-blade, air-mixer assembly located immediately downstream of mixing section.

E. Combination Filter and Mixing Section:

1. Cabinet support members shall hold 2-inch-thick, pleated, flat, permanent or throwaway filters.
2. Multiple-blade, air-mixer assembly shall mix air to prevent stratification, located immediately downstream of mixing box.

2.8 AIR-TO-AIR ENERGY RECOVERY

A. General Requirements: The air-to-air energy recovery section shall be provided by air handling unit manufacturer as integral part of unit.

B. See Division 23, Section "Air-to-Air Energy Recovery Equipment" for specific requirements.

C. Air handling unit manufacturer shall coordinate with energy recovery system manufacturer to determine length of section required for proper installation and operation of the system. Section length shown on drawings is minimum length required.

D. Provide access doors. Coordinate with energy recovery system manufacturer for door placement within the section to not interfere with air cleaner installation or operation.

2.9 AIRFLOW MEASURING SYSTEMS

A. See Division 23 “Instrumentation and Control for HVAC” for airflow measuring devices.

B. Airflow measuring devices shall be furnished and installed by BMS Contractor and shall be integral to the AHU.

2.10 CAPACITIES AND CHARACTERISTICS

A. See Mechanical Drawings and Schedules.

2.11 CONTROLS

A. Controls shall be provided by control contractor.

B. For control devices and operational sequences refer to Division 23 Sections "Instrumentation and Control for HVAC" and see the BMS drawings for the "Sequence of Operations for HVAC Controls.”

2.12 SOURCE QUALITY CONTROL

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

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

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

PART 3 - EXECUTION

3.1 EXAMINATION

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

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

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

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

3.2 INSTALLATION

A. Equipment Mounting: Install air-handling units on concrete bases using elastomeric pads. Secure units to anchor bolts installed in concrete bases. Comply with requirements for concrete bases specified in Division 03 Section "Cast-in-Place Concrete." Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration Controls for HVAC."

1. Install stainless-steel plate to equally distribute weight over elastomeric pad.
2. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.
3. Install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
4. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
5. Install anchor bolts to elevations required for proper attachment to supported equipment.

B. Elevate units by means of structural channels or I-beams where necessary to accommodate cooling coil condensate drainage requirements as detailed. See details on drawings for minimum drain trap.

C. Suspended Units: Suspend and brace units from structural-steel support frame using threaded steel rods and spring hangers. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration Controls for HVAC."

D. Arrange installation of units to provide access space around air-handling units for service and maintenance.

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

F. Install filter-gage, static-pressure taps upstream and downstream of filters. Mount filter gages on outside of filter housing or filter plenum in accessible position. Provide filter gages on filter banks, installed with separate static-pressure taps upstream and downstream of filters.

3.3 CONNECTIONS

A. Comply with requirements for piping specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

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

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

D. Connect condensate drain pans using NPS 1-1/4, ASTM B 88, Type M copper tubing. Extend to nearest equipment or floor drain. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

E. Chilled-Water Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping." Install shutoff valve and union or flange at each coil supply connection. Install balancing valve and union or flange at each coil return connection.

F. Connect duct to air-handling units with flexible connections. Comply with requirements in Division 23 Section "Air Duct Accessories."

3.4 FIELD QUALITY CONTROL

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

B. Perform tests and inspections.

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

2. Do not operate units for any purpose, temporary or permanent , until ductwork is clean, filters are in place, bearings lubricated, and fan as been test run under observation.
3. If operation is required before premises are thoroughly clean, cover all return and exhaust outlets with temporary filter pads.

C. Tests and Inspections:

1. Leak Test: After installation, fill water coils with water, and test coils and connections for leaks.
2. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
3. Photocatalyctic air cleaner operational tests: Pressurize housing to a minimum of 3-inch w.g. or to design operating pressure, whichever is higher, and test housing joints, door seals, and sealing edges of filter with soapy water to check for air leaks.
4. Final-Filter Operational Test: Pressurize housing to a minimum of 3-inch wg or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter with soapy water to check for air leaks.
5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
6. Charge heat pipes with refrigerant and test for leaks.

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

E. Prepare test and inspection reports.

3.5 STARTUP SERVICE

A. Perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
6. Verify that zone dampers fully open and close for each zone.
7. Verify that face-and-bypass dampers provide full face flow.
8. Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.
9. Comb coil fins for parallel orientation.
10. Verify that proper thermal-overload protection is installed for electric coils.
11. Install new, clean filters.

12. 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.

3.6 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Comply with requirements in Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.

3.7 CLEANING

A. After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems and after completing startup service, clean air-handling units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new, clean filters. Refer to Section 01 74 23 for final cleaning requirements.

3.8 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain air-handling units. Provide one 8-hour training session at site with equipment fully operational. Refer to Division 1 Section 01 91 13 for additional requirements.

END OF SECTION 23 73 13

SECTION 23 74 33 - DEDICATED OUTDOOR AIR UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

B. Basic Requirements: Provisions of Section 23 00 10, Basic HVAC Requirements are part of this Section.

1.2 SUMMARY

A. Section Includes:

1. Variable-air-volume, multizone air-handling units.

1.3 PERFORMANCE REQUIREMENTS

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

1.4 SUBMITTALS

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

1. Unit dimensions and weight.
2. Cabinet material, metal thickness, finishes, insulation, and accessories.
3. Fans:
   a. Certified fan-performance curves with system operating conditions indicated.
   b. Certified fan-sound power ratings.
   c. Fan construction and accessories.
   d. Motor ratings, electrical characteristics, and motor accessories.
4. Certified coil-performance ratings with system operating conditions indicated.
5. Dampers, including housings, linkages, and operators.
6. Filters with performance characteristics.
7. Scaled drawings of unit assembly with construction details, field connection details and required clearances.
8. Wiring diagrams for interlock and control wiring, clearly indicating factory installed and field installed wiring.
9. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
10. Design Calculations: Calculate requirements for selecting vibration isolators and for designing vibration isolation bases.

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

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

C. Source quality-control reports.

D. Field quality-control reports.

E. Operation and Maintenance Data: The contractor is to provide a copy of the Installation, Operations, and Maintenance (IOM) manual following approval of the submittal. IOM is to be delivered to the CM within 2 weeks, this manual shall be used in the finalizing of Cx start up, and pre-functional testing check lists. For air-handling units to include in emergency, operation, and maintenance manuals, including:

1. Catalog cuts of equipment and all components.
2. Instructions for lubrication, filter replacement, motor and drive replacement.
3. Spare parts list.
4. Wiring diagrams.

1.5 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

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

C. AHRI Certification: Air-handling units and their components shall be factory tested according to ARI 430, "Central-Station Air-Handling Units," and shall be listed and labeled by AHRI.

D. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1-2010, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Systems Startup."

E. ASHRAE/IESNA 90.1-2010 Compliance: Applicable requirements in ASHRAE/IESNA 90.1-2010, Section 6 - "Heating, Ventilating, and Air-Conditioning."

F. Comply with NFPA 70.

1.6 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement and formwork requirements are specified in Division 3.

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

1.7 EXTRA MATERIALS

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

1. Filters: Two sets for each air-handling unit.
2. Gaskets: Two sets for each access door.
3. Fan Belts: Two sets for each air-handling unit fan.
4. Belt Pulleys: Two sets for each air handling unit fan.

1.8 WARRANTY

A. AHU manufacturer shall provide a parts and labor warranty that covers a period of two years from unit start-up or 30 months from shipment, whichever occurs first. This warrants that all products are free from defects in material and workmanship and shall meet the capacities and ratings set forth in the equipment manufacturer's catalog and bulletins.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Air Handling Units:
   a. Trane. (Custom)
   b. Buffalo Air Handling
   c. HAAKON
   d. MAFNA
   e. Temtrol
   f. Ventrol
   g. Daikin

2.2 UNIT CASING

A. Casing Performance

1. Unit air leakage shall not exceed 0.5% of design cfm at +12.0" w.g. in all positive-pressure sections and -12.0" w.g. in all negative-pressure sections. Leakage shall be calculated by totaling all leakage either in to or out of the unit
2. Casing deflection shall not exceed L/250 at +12.0" w.g. in all positive-pressure sections and -12.0" w.g. in all negative-pressure sections, where L is defined as the panel span.
3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2010.
4. Under scheduled supply air temperature and design conditions on the exterior of the unit of 77°F dry bulb and 72°F wet bulb, condensation shall not form on the casing exterior. The AHU Manufacturer shall provide tested casing thermal performance for the scheduled supply air temperature plotted on a psychrometric chart. The design condition on the exterior of the unit shall also be plotted on the chart. If tested casing thermal data is not available, AHU Manufacturer shall

provide, in writing, a guarantee against condensation forming on the unit exterior under the scheduled supply air temperature and design conditions on the exterior of the unit of 77°F dry bulb and 72°F wet bulb. The guarantee shall note that the AHU Manufacturer will cover all expenses associated with modifying units in the field should external condensate form on them. Copies of the guarantee shall be provided to the Engineer and the Owner.

5. Class “A” thermal break shall be provided throughout the entire casing assembly, including all door assemblies downstream of the cooling coil. A Class “A” thermal break shall be defined as a thermal break that ensures no member on the exterior of the unit, including fasteners, has through metal contact with any member on the interior of the unit, including fasteners.
6. Insulation that meets a minimum R-value of 18.8 shall be provided throughout all unit wall assemblies. Insulation shall be injected foam. Foam shall be closed cell to prevent wicking of moisture. If fiberglass insulation is provided, it shall be completely wrapped with long-strand fiberglass cloth to limit the entrainment of moisture into the insulation. The long-strand fiberglass cloth shall also incorporate an anti-microbial coating to suppress microbial growth. Insulation shall completely fill the panel cavity in all directions so that no voids exist and settling of insulation is prevented. Wall assemblies shall comply with NFPA 90 A. To ensure injected closed-cell foam is properly engineered for rigidity and thermal performance, is amply applied to fill all cavities within each assembly, and is correctly cured to yield strong adhesion to casing members, the AHU Manufacturer shall have experience using injected closed-cell foam as an insulation in AHUs for no less than 10 years.
7. Factory finish for galvanized steel casing shall consist of factory applied standard two coat, baked on enamel finish consisting of prime coat and thermosetting Casing finished to meet ASTM B117 500-hour salt-spray test.

B. Bases & Floors

1. Base shall be constructed of welded structural steel channels around the perimeter and welded structural steel cross members. Formed steel channels are not acceptable. The structural steel base shall be shot blasted, fully welded and then painted. The maximum cross-member spacing shall be 24" on center with members located adequately to support fan, coils, and other large components. The height of each base channel shall be no less than the height indicated in the drawings. Each shipping section shall be provided with removable lifting lugs. Structural framework shall fully support the unit casing and all components during installation such that no section deflects more than L/1000 during rigging of that section, where L is defined as the distance between lifting lugs.
2. Floor shall be double bottom construction, inner floor shall be a minimum of 10 ga, outer floor shall be a minimum of 16 ga galvanized steel, with 4” fiberglass or 2” foam insulation. The floor surface shall be continuously welded with 2” turned up lip around the base perimeter and all floor penetrations. Caulk is not an acceptable sealing method for the floor. Floor deflection shall not exceed L/350 under a point load of 350 pounds, where L is defined as the floor span. Insulation shall completely fill the panel cavity in all directions so that no voids exist. Base assemblies shall comply with NFPA 90 A.

3. Safety grates that provide a walking surface shall be provided across all bottom air openings. Safety grates shall support a minimum 300-pound load. Safety grates shall be made of Type IWA welded rod with a cross flow pattern of 1.1875" x 4". Grating shall be galvanized steel construction for units with galvanized or painted steel floors and shall be aluminum construction for units with aluminum floors. Safety grates shall be removable to ensure adequate access to the ductwork below

C. Walls

1. Wall and roof assemblies shall be double-wall construction with minimum 16ga galvanized steel solid exterior and 16ga galvanized steel interior. The entire unit shall have a solid wall liner on the interior. All spaces and joints of wall assemblies shall be completely sealed. Wall shall meet the casing deflection limits contained herein.
2. A Class "A" thermal break shall be provided throughout the entire wall assembly.
3. Minimum 2" fiberglass or foam insulation shall be provided throughout all unit wall assemblies. Insulation that meets a minimum installed R-value of 18.8 shall be provided throughout all assemblies. Insulation shall completely fill the panel cavity in all directions so that no voids exist and settling of insulation is prevented. Wall assemblies shall comply with NFPA 90 A.
4. Removable wall access panels shall be provided in coil sections for service removal of components. A Class "A" thermal break shall be provided throughout all removal wall access panels. Removable panels shall match the surrounding casing construction

D. Access Doors

1. Access doors shall be provided throughout units as indicated on the schedules and drawings. Access doors shall be double wall construction. Interior door panels shall be min 18 ga. and exterior door panels shall be of the same construction as the exterior wall panels.
2. A Class "A" thermal break shall be provided on all door assemblies throughout the unit.
3. Insulation that meets a minimum installed R-value of 18.8 shall be provided throughout all door assemblies. Insulation shall match casing insulation. Insulation shall completely fill the panel cavity in all directions so that no voids exist and settling of insulation is prevented. Door assemblies shall comply with NFPA 90 A.
4. All doors shall be a minimum of 60" high if sufficient height is available, or the maximum height allowed by the unit height. All doors shall open against pressure to ensure an airtight seal and to prevent a safety hazard. Access doors in fan sections that must open with internal pressure shall be provided with door safety stops.
5. Door test ports shall be provided by the AHU Manufacturer as indicated on the schedule and drawings. Test ports shall be designed to allow the test and balance contractor to validate pressure losses using a hand held instrument. Test ports shall have a removable cover that completely seals the door penetration when testing and balancing is not being conducted

6. Door hinges shall be stainless steel type. Door handles shall be Allegis design for minimized leakage and to provide a Class “A” thermal break. Handles shall fasten against the door frame with a roller cam to eliminate wear of the door frame. On indoor units, if Allegis handles are not provided, Ventlok 310 handles shall be provided on all doors to ensure positive seal of the door and to avoid wear of the door frame. All door handles shall be operable from both the unit exterior and interior. Access doors shall be provided with two securing latches, operable from inside and outside the unit.
7. Windows shall be provided in all access doors. Windows shall be mounted in a metal frame and shall be a minimum of 8” x 8”, with wire-reinforced safety glass. For any instance where a window cannot fit in a door, a narrower window 8” tall may be provided. Windows in doors with a thermal break shall be thermal, double-pane type

E. Condensate Drain Pans:

1. Fabricated pans with slopes in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and to direct water toward drain connection.
    a. Length: Extend drain pan downstream from leaving face to comply with ASHRAE 62.1-2010. Condensate drain pan shall extend min. 18 inches downstream from leaving face.
    b. Depth: A minimum of 2 inches deep.
2. Formed sections.
3. Double-wall, 18 ga 304 stainless steel with space between walls filled with foam insulation and moisture-tight seal.
4. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on both ends of pan.
5. Pan-Top Surface Coating: Asphaltic waterproofing compound.
6. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.

2.3 FAN, DRIVE, AND MOTOR SECTION

A. Fan and Drive Assemblies: Statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower.

1. Shafts: Designed for continuous operation at maximum-rated fan speed and motor horsepower, and with field-adjustable alignment.
    a. Turned, ground, and polished hot-rolled steel with keyway. Ship with a protective coating of lubricating oil.
    b. Designed to operate at no more than 75 percent of first critical speed at top of fan's speed range.

B. All fans shall have airfoil blades. Backward inclined and forward curved fans are not acceptable.

C. All fans shall be selected to provide a maximum fan rpm of 2000.

D. Plenum Fan Housings: Steel frame and panel; fabricated without fan scroll and volute housing.

E. Direct-Drive Plenum Fan: The fan type shall be provided as required for stable operations and optimum energy efficiency. The fan shall be single-width, single-inlet, multiblade-type. Plenum fans shall be equipped with self-aligning, antifriction, pillow-block bearings with an L-50 life of 200,000 hours as calculated per ANSI/AFBMA Standard 9. For any bearing requirement liberation, the great line shall be extended to the fan support bracket on the drive side. The fan blades shall be backward-inclined airflow. Fan sections shall be provided with an expanded-metal guard screen for the access door, mounted on the door opening, to deter unauthorized entry and incidental contact with rotating components.

F. Fan Shaft Bearings:

1. Grease-Lubricated Bearings: Self-aligning, anti-friction bearings selected for L-50 200,000-hour average life per ANSI/AFBMA Standard 9. Lubrication lines for both bearings shall be extended to the drive side of the AHU and rigidly attached to support bracket with zerk fittings. Lubrication lines shall be a clear, high pressure, polymer to aid in visual inspection.

G. Internal Vibration Isolation: Fans and motor shall be factory internally mounted on the same isolation base with spring vibration isolation devices having a minimum static deflection of 1 inch. See Specification Section 23 05 48.13 “Vibration Control for HVAC” for specific requirements.

H. Motor: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.
2. NEMA Premium (TM) 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 Division 26 Sections.
5. Mount unit-mounted disconnect switches on exterior interior of unit.
6. Motors must be “matched” with variable frequency drives, one (1) VFD per fan. Motors and fans shall be selected and furnished by the air-handling unit manufacturer to meet specified performance requirements. All VFD’s for equipment under this specifications shall be sourced from one single VFD manufacturer.
7. Each VFD shall come with integral disconnect. Provide separate unit service disconnect switch upstream of VFD(s).
8. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.

I. The fan section shall be provided with a convenience outlet (120V/1Ø), housekeeping drain, and marine grade light with guard. Convenience outlet shall be on separate circuit.

J. Outdoor air section shall be provided with a housekeeping drain and marine grade light with guard.

K. Variable Frequency Drives: See Section 23 05 14 "Variable Frequency Motor Controllers."

1. Fan VFD for Dedicated Outdoor Air Units specified under this section shall be furnished without bypass controller.

L. Fans shall be tested, rated and certified in accordance with ANSI/AMCA Standard 210 for air delivery and in accordance with AMCA Standard 300 for sound power levels and shall bear the AMCA seal. The fan balancing process, including vibration limits and documentation, shall be performed in accordance with ANSI/AMCA Standard 204.

2.4 COIL SECTION

A. General Requirements for Coil Section:

1.

2. Comply with AHRI 410. Coil shall bear the AHRI label.

3. Manufacturer of coil shall be ISO 9002 certified.

4. Fabricate coil section to allow removal and replacement of coil for maintenance and to allow in-place access for service and maintenance of coil(s).

5. Coils shall not act as structural component of unit.

6. Provide access to coils from both sides of unit for service and cleaning.

7. Cooling coils, including headers and return bends shall be totally enclosed in casing.

8. Unit shall be provided with coil connections that extend a minimum of 5" beyond unit casing for ease of installation.

9. Drain and vent connections shall be provided exterior to unit casing. Coil connections must be factory sealed with grommets on interior and exterior and gasket sleeve between outer wall and liner where each pipe extends through the unit casing to minimize air leakage and condensation inside panel assembly.

10. Headers shall consist of seamless copper tubing to assure compatibility with primary surface. Headers to have intruded tube holes to provide maximum brazing surface for tube to header joint, strength, and inherent flexibility. Header diameter should vary with fluid flow requirements.

11. Fins shall have a minimum thickness of 0.0075" of copper plate construction for 100% outside air units

    a. Fins shall have full drawn collars to provide a continuous surface cover over the entire tube for maximum heat transfer.

    b. Tubes shall be mechanically expanded into the fins to provide a continuous primary to secondary compression bond over the entire finned length for maximum heat transfer rates. Bare copper tubes shall not be visible between fins

12. Cooling coil maximum height shall be 42 inches. For units that require coils higher than 42 inches, provide multiple coil sections of equal heights. Provide intermediate condensate drain pans and drain line to lower drain pan.

13. Cooling Coil casings shall be a formed channel frame of stainless steel and slide into a pitched track for fluid drainage.

14. Air Velocities: Units shall have a face velocity below 400 FPM on 100% O.A. unit.

2.5 AIR FILTRATION SECTION

A. General Requirements for Air Filtration Section. See Division 23 “Particulate Air Filtration.”

1. Comply with NFPA 90A and NFPA 90B.
2. Provide minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) greater than 13, according to ASHRAE 52.2.
3. Provide filter holding frames arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lifted out from access plenum.
4. Provide filter gauges for each filter type.

B. ULTRAVIOLET LIGHT GERMICIDAL IRRADIATION (UVGI) SECTION General Requirements:

1. The UVGI surface irradiation system shall consist of heavy duty, factory assembled and tested light fixtures that emit short wave UVC light (200 nm –270 nm).

2. Constructed and tested for HVAC environments: UL listed at 55°F to 135°F with airflow velocities up to 1000 FPM. Independently tested to verify output and performance. UVGI system shall have UL Approval per Category Code ABQK (Accessories, Air Duct Mounted) UL Standards: UL153, UL1598 & UL1995.

3. Assembly shall consist of double ended UVC florescent lamp and housing, power source and sockets shall be UL Drip proof construction.

4. The enclosure shall be made of drip-proof construction from galvanized steel. The ballast shall be a self-contained electronic type. The enclosure shall include safety mechanical interlocks which do not allow the UV assembly to light unless installed on its track. The multiple UV assemblies shall connect via interlock.

5. UVC Lamp shall be a standard output hot cathode, low pressure T8, double ended UVC lamp. Lamps shall be constructed with a thick wall glass of soda barium UV transparent glass with a base of metal. Lamps shall have 5.5 milligrams or less of mercury.

6. Lamps shall produce adequate UV output and operate in environments of temperatures between 55°F to 135°F. Lamps shall produce a minimum of 80% of initial UV output at end of life (9000 hours minimum).

7. Power source shall be 120 VAC 60hz. Power connections shall be via a provided j-box or line cord from one end of the UV fixture. UV fixtures shall electrically connect via interlocks.

8. Installation shall be such that the cumulative sum length of UV fixtures end-to-end shall equal the coil width +/- three (3) inches. Modular coil system shall be installed and wired so that the entire surface of the coil and drain pan is bathed by UVC. System shall be installed using “tracks” to allow UV fixture to slide into place, for ease of access during installation and annual maintenance. System shall be installed 8"-20" (14" ideal) from coil surface. System shall be installed utilizing one row of lamps for every 48" of coil height. System shall incorporate safety “cut-off” switches on access doors

9. Manufacturer to provide and mount ultraviolet lights on the leaving air side of the cooling coil(s) and over the drain pan to meet GSA 2003 Facilities Standard - 5.9 HVAC Systems and Components and agency approved to UL category Code ABQK specification, HVAC Accessories, Air Duct Mounted

2.6 DAMPERS (PROVIDED BY AHU MANUFACTURER)

A. Dampers: See Division 23 Section “Instrumentation and Control for HVAC.”

B. For Damper Operators: Provided by BMS Contractor and specified in Division 23 Section "Instrumentation and Control for HVAC."

C. Dampers shall be provided by AHU manufacturer and shall be integral to AHU.

2.7 AIR-TO-AIR ENERGY RECOVERY

A. General Requirements: The air-to-air energy recovery section shall be provided by air handling unit manufacturer as integral part of unit.

B. See Division 23, Section "Air-to-Air Energy Recovery Equipment" for specific requirements.

C. Air handling unit manufacturer shall coordinate with energy recovery system manufacturer to determine length of section required for proper installation and operation of the system. Section length shown on drawings is minimum length required.

D. Provide access doors. Coordinate with energy recovery system manufacturer for door placement within the section to not interfere with air cleaner installation or operation.

2.8 AIRFLOW MEASURING SYSTEMS

A. See Division 23 “Instrumentation and Control for HVAC” for airflow measuring device specification.

B. Airflow measuring devices shall be furnished by BMS Contractor and installed by the air handling unit manufacturer and shall be integral to the AHU.

2.9 CAPACITIES AND CHARACTERISTICS

A. See mechanical drawings and schedule.

2.10 CONTROLS

A. Controls shall be provided by BMS Contractor.

B. For control devices and operational sequences refer to Division 23 Sections "Instrumentation and Control for HVAC" and BMS drawings for the "Sequence of Operations for HVAC Controls."

2.11 SOURCE QUALITY CONTROL

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

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

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

PART 3 - EXECUTION

3.1 EXAMINATION

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

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

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

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

3.2 INSTALLATION

A. Equipment Mounting: Install air-handling units on 4-inch high concrete bases with additional steel framing to allow for cooling coil drain pipe trap assembly. Secure units to anchor bolts installed in concrete bases. Comply with requirements for concrete bases specified in Division 03 Section "Cast-in-Place Concrete." Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration Controls for HVAC.”

1. Minimum Deflection: 2 inches.
2. Install galvanized-steel plate to equally distribute weight over elastomeric pad.
3. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.
4. Install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
5. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
6. Install anchor bolts to elevations required for proper attachment to supported equipment.

B. Suspended Units: Suspend and brace units from structural-steel support frame using threaded steel rods and spring hangers. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration Controls for HVAC."

C. Arrange installation of units to provide access space around air-handling units for service and maintenance.

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

E. Install filter-gage, static-pressure taps upstream and downstream of filters. Mount filter gages on outside of filter housing or filter plenum in accessible position. Provide filter gages on all filter banks, installed with separate static-pressure taps upstream and downstream of filters.

3.3 CONNECTIONS

A. Comply with requirements for piping specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

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

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

D. Connect condensate drain pans using minimum NPS 1½, ASTM B 88, Type M copper tubing. See details on drawings and extend to nearest equipment or floor drain. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

E. Hot- and Chilled-Water Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping." Install shutoff valve and union or flange at each coil supply connection. Install balancing valve and union or flange at each coil return connection.

F. Connect duct to air-handling units with flexible connections. Comply with requirements in Division 23 Section "Air Duct Accessories."

3.4 FIELD QUALITY CONTROL

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

B. Perform tests and inspections.

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

C. Tests and Inspections:

1. Air Leak Test: The leakage test shall be done by the manufacturer, onsite, after the units are fully assembled.

2. Water Leak Test: After installation, fill water coils with water, and test coils and connections for leaks.

3. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

4. Photocatalytic Air Cleaner Operational Test: Pressurize housing to a minimum of 3-inch wg or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter with soapy water to check for air leaks.

5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

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

E. Prepare test and inspection reports.

3.5 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 shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
6. Verify that zone dampers fully open and close for each zone.
7. Verify that face-and-bypass dampers provide full face flow.
8. Verify that outdoor- and exhaust-air dampers open and close, and maintain minimum outdoor-air setting.
9. Comb coil fins for parallel orientation.
10. Verify that proper thermal-overload protection is installed for electric coils.
11. Install new, clean filters.
12. 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.

3.6 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Comply with requirements in Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.

3.7 CLEANING

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

3.8 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain air-handling units. Refer to General and Supplemental General Requirements Section "Demonstration and Training."

3.9 COMMISSIONING

A. Comply with commissioning process procedures and requirements as specified in Division 23 08 00 “HVAC System Commissioning,” and Division 01 General Requirements, in addition to the commissioning requirements in each section.

END OF SECTION 23 7433

SECTION 23 81 23 - COMPUTER-ROOM AIR-CONDITIONERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. Section Includes:

1. Floor-mounted computer-room air conditioners, 6 tons and larger.
2. Floor-mounted computer-room air conditioners, 5 tons and smaller.
3. Ceiling-mounted computer-room air conditioners.
4. Console computer-room air conditioners.
5. Water detection system.

1.3 DEFINITION

A. BMS: Building management system.

1.4 SUBMITTALS

A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

B. LEED V4 BD+C Submittals:

1. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
2. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with the latest edition of ASHRAE 62.1, Section 5 - "Systems and Equipment."

C. Shop Drawings: For computer-room air conditioners. Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Wiring Diagrams: For power, signal, safety, and control wiring.
3. Provide list of all BACnet points, functions and alarms available via integration with BMS.

D. Color Samples: For unit cabinet, discharge grille, and exterior louver and for each color and texture specified.

E. Coordination Drawings: Plans, elevations, and other details, drawn to scale, using input from Installers of the items involved.

F. Seismic Qualification Certificates: For computer-room air conditioners, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

G. Field quality-control reports.

H. Operation and Maintenance Data: For computer-room air conditioners to include in emergency, operation, and maintenance manuals.

I. Warranty: Sample of special warranty.

1.5 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. ASHRAE Compliance:

1. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Standard for Refrigeration Systems."
2. ASHRAE Compliance: Applicable requirements in the latest edition of ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Ventilation Rate Procedures," and Section 7 - "Construction and Startup."

C. ASHRAE/IESNA Compliance: Applicable requirements in the latest edition of ASHRAE/IESNA 90.1.

D. ASME Compliance: Fabricate and label water-cooled condenser shell to comply with ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels," Division 1.

E. Sound Ratings: Based on AHRI 270 Standard

F. Performance based on AHRI 210/240 test conditions.

G. UL, CSA approved.

1.6 COORDINATION

A. Coordinate layout and installation of computer-room air conditioners and suspension system with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.

B. Coordinate installation of computer-room air conditioners with computer-room access flooring Installer.

C. Coordinate in-row computer room air conditioners with computer room rack installer.

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

E. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.7 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of computer-room air conditioners that fail in materials or workmanship within specified warranty period.

1. Warranty Period for Compressors: Manufacturer's standard, but not less than five years from date of Substantial Completion.
2. Warranty Period for Humidifiers: Manufacturer's standard, but not less than three years from date of Substantial Completion.
3. Warranty Period for Control Boards: Manufacturer's standard, but not less than three years from date of Substantial Completion.

1.8 EXTRA MATERIALS

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

1. Fan Belts: One set for each belt-driven fan.
2. Filters: One set of filters for each unit.

PART 2 - PRODUCTS

2.1 FLOOR-MOUNTED UNITS 6 TONS AND LARGER

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Liebert Corporation.
2. Stulz-ATS.

B. Description: Packaged, factory assembled, prewired, and prepiped; consisting of cabinet, fans, filters, humidifier, and controls. Units arranged for Down flow or Up flow configuration as scheduled or shown.

C. Cabinet and Frame: Welded tubular steel with corrosion inhibitor, braced for rigidity, and supporting compressors and other mechanical equipment and fittings.

1. Doors and Access Panels: Galvanized steel with polyurethane gaskets, hinges, and concealed fastening devices.
2. Insulation: Thermally and acoustically insulate cabinet interior with minimum 1-inch-thick duct liner.
3. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in the latest edition of ASHRAE 62.1.
4. Finish of Exterior Surfaces: Baked-on, textured vinyl enamel; color as selected from manufacturer's standard colors.
5. Floor Stand: Welded tubular steel, with adjustable legs and vibration isolation pads.

D. Supply-Air Fan(s):

1. Electronically commutated (EC) motor.

E. Refrigeration System:

1. Compressors: Semihermetic reciprocating; with suction-gas-cooled, 1750-rpm motors; thermal overloads; oil sight glass; suction-line strainer; and reversible oil pumps; with oil strainer, internal motor overload protection, resilient suspension system, crankcase heater, manual-reset high-pressure switch, and pump-down low-pressure switch.
2. Compressors: Hermetic reciprocating; with oil strainer, internal motor overload protection, resilient suspension system, crankcase heater, manual-reset high-pressure switch, and pump-down low-pressure switch.
3. Compressors: Hermetic scroll; with oil strainer, internal motor overload protection, resilient suspension system, crankcase heater, manual-reset high-pressure switch, and pump-down low-pressure switch.
4. Refrigeration Circuits: Two; each with hot-gas mufflers, thermal-expansion valve with external equalizer, liquid-line solenoid valve, liquid-line filter-dryer, sight glass with moisture indicator, service shutoff valves, charging valves, and charge of refrigerant.
5. Refrigerant: R-407C or R-410A.
6. Refrigerant Evaporator Coil: Alternate-row or split-face-circuit, direct-expansion coil of seamless copper tubes expanded into aluminum fins.

    a. Mount coil assembly over stainless-steel drain pan complying with the latest edition of ASHRAE 62.1 and having a condensate pump unit with integral float switch, pump-motor assembly, condensate reservoir, check valve and minimum 20 ft head.

    b. Dual float for condensate pump to alarm on high water level.

7. Integral, Water-Cooled Refrigerant Condenser: Shell-and-tube type fabricated and labeled according to ASME Boiler and Pressure Vessel Code: Section VIII. Single pass, counter flow brazed plate heat exchanger, with integral subcooler, 316 stainless steel, 450 psig working pressure with liquid-line stop valve and head-pressure-actuated, two-way regulating valve (minimum 150 psi working pressure). Terminate fluid connections outside cabinet. Cooling Medium: Water.

8. Insulated piping.

F. Hydronic Cooling Coil: Seamless copper tubes (0.020" minimum thickness) expanded into aluminum fins with modulating two-way control valve. Certified as per ARI Standard 410.

1. Cooling Medium: Water.
2. Control Valve: 150 lb rating.

    a. Maximum Pressure Drop: 5 psig at design flow rate.
    b. Close-Off (Differential) Pressure Rating: 100 percent of pressure differential across valve or 100 percent of total system (pump) head.

3. Mount coil assembly over stainless-steel drain pan complying with the latest edition of ASHRAE 62.1 and having a condensate pump unit with integral float switch, pump-motor assembly, condensate reservoir, check valve and minimum 20 ft head capability. Dual float for condensate pump to alarm on high water level.

4. AHRI certified per current Standard 410.

G. Electric-Resistance Heating Coil: Enclosed finned-tube electric elements arranged for SCR, with thermal safety switches, manual-reset overload protection, and branch-circuit overcurrent protection.

H. Extended-Surface, Disposable, Panel Filter: Pleated, lofted, nonwoven, reinforced cotton fabric; supported and bonded to welded-wire grid; enclosed in cardboard frame.

1. Thickness: 4 inches.
2. MERV (ASHRAE 52.2): 8.

I. Infrared Humidifier: High-intensity quartz lamps mounted above stainless-steel evaporator pan, serviceable without disconnecting water, drain, or electrical connections; prepiped and located in bypass airstream; with flush-cycle timer and solenoid drain valve.

J. Integral Electrical Controls: Unit-mounted electrical enclosure with piano-hinged door, grounding lug, combination magnetic starters with overload relays, circuit breakers and cover interlock, and fusible control-circuit transformer.

K. Independent Disconnect Switches: Non-locking type, unit mounted, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.

L. Electronic-Control System: Solid state, with start button, stop button, temporary loss of power indicator, manual-reset circuit breakers, temperature control, humidity control, and monitor panel.

1. Monitor Panel: Backlighted, with no visible indicator lights until operating function is activated; indicators include cooling, humidification, loss of airflow, change filters, high temperature, low temperature, high humidity, low humidity, high head pressure (each compressor), and low suction pressure (each compressor).
2. Temperature- and Humidity-Control Modules: Solid state, plug-in; with adjustable set point, push-to-test calibration check button, and built-in visual indicators to show mode of operation.
3. Location: Behind hinged door in front of unit; isolated from conditioned airstream to allow service while system is operating.

M. Microprocessor-Control System: Continuously monitors operation of process cooling system; continuously displays room temperature and room relative humidity; sounds alarm on system malfunction and simultaneously displays problem. If more than one malfunction occurs, system displays fault in sequence with room temperature and continues to display fault when malfunction is cleared until system is reset.

1. Malfunctions:

a. Power loss.
b. Loss of airflow.
c. Clogged air filter.
d. High room temperature.
e. Low room temperature.
f. High humidity.
g. Low humidity.
h. Smoke/fire.
i. Water under floor.
j. Supply fan overload.
k. Compressor No. 1 - Overload.
l. Compressor No. 1 - Low Pressure.
m. Compressor No. 1 - High Pressure.
n. Compressor No. 2 - Overload.
o. Compressor No. 2 - Low Pressure.
p. Compressor No. 2 - High Pressure.

2. Digital Display:

a. Control power on.
b. Humidifying.
c. Dehumidifying.
d. Compressor No. 1 - Operating.
e. Compressor No. 2 - Operating.

f. Heat operating.
g. Economy cooling.

3. Push buttons shall stop and start process cooling system, silence audible alarm, test indicators, and display room's relative humidity.
4. BMS Interface: Factory-installed hardware and software to enable the BMS to monitor, control, and display unit status and alarms.

a. Hardwired Points:

1) Monitoring: On-off status, common trouble alarm space temperature space relative humidity.
2) Control: On-off operation, space temperature set-point adjustment space relative humidity set-point adjustment.

b. Communication interface with the BMS shall enable the BMS operator to remotely control and monitor the unit from an operator workstation. Control features and monitoring points displayed locally at unit control panel shall be available through the BMS via BACnet integration protocol.

N. Added Control and Safety Functions: Integrated into unit control systems.

1. Automatic restart after power sags or outages to include programmable time delay on restart.
2. Smoke detector shall immediately shutdown units with local alarm dry contacts.
3. Firestat should immediately shutdown systems on high temperature alarm conditions.
4. Common Alarm terminals: Two sets to be wired to automatic switchover panel
5. Remote shutdown terminals: Two sets to be wired to automatic switchover panel and BMS.
6. Furnish leak detection for field installation hardwired to factory mounted controller with spare contacts for interface with BMS.

2.2 FLOOR-MOUNTED UNITS 5 TONS AND SMALLER

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following**:**
1. Liebert Corporation.
2. Stulz-ATS.

B. Description: Self-contained, factory assembled, prewired, and prepiped; consisting of cabinet, fan, filters, and controls; for vertical floor mounting in upflow or downflow configuration.

C. Cabinet and Frame: Welded tubular-steel frame with removable steel panels with baked-enamel finish, insulated with 1-inch-thick duct liner.

1. Floor Stand: Welded tubular steel, with adjustable legs and vibration isolation pads.

2. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in the latest edition of ASHRAE 62.1.

D. Supply-Air Fan:

1. Electronically commutated (EC) motor.

E. Refrigeration System:

1. Compressor: Hermetic, with oil strainer, internal motor overload protection, resilient suspension system, and crankcase heater.
2. Refrigeration Circuit: Low-pressure switch, manual-reset high-pressure switch, thermal-expansion valve with external equalizer, sight glass with moisture indicator, service shutoff valves, charging valves, and charge of refrigerant.
3. Refrigerant: R-407C or R-410A.
4. Refrigerant Evaporator Coil: Direct-expansion coil of seamless copper tubes expanded into aluminum fins, with two circuits, each with solenoid valve.

a. Mount coil assembly over stainless-steel drain pan complying with the latest edition of ASHRAE 62.1 and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir. Dual float for condensate pump to alarm on high water level.

5. Integral, Water-Cooled Refrigerant Condenser: Shell-and-tube type fabricated and labeled according to ASME Boiler and Pressure Vessel Code: Section VIII. Single pass, counter flow brazed plate heat exchanger, with integral subcooler, 316 stainless steel, 450 psig working pressure with liquid-line stop valve and head-pressure-actuated, two-way regulating valve (minimum 150 psi working pressure). Terminate fluid connections outside cabinet.
6. . Cooling Medium: Water

F. Hydronic Cooling Coil: Seamless copper tubes expanded into aluminum fins with modulating three-way control valve.

1. Cooling Medium: Water.

2. Mount coil assembly over stainless-steel drain pan complying with the latest edition of ASHRAE 62.1 and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir. Dual float for condensate pump to alarm on high water level.

3. Control Valve: 150 lb rating.

G. Electric-Resistance Heating Coil: Finned-tube electric elements with contactor and high-temperature-limit switches SCR controller.

H. Filter: 2-inch-thick, disposable, glass-fiber media.

1. MERV (ASHRAE 52.2): 8.

I. Infrared Humidifier: High-intensity quartz lamps mounted above stainless-steel evaporator pan, serviceable without disconnecting water, drain, or electrical connections; prepiped and located in bypass airstream; with flush-cycle timer and solenoid drain valve.

J. Disconnect Switch: Automatic, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.

K. Control System: Unit-mounted panel with main fan contactor, compressor contactor, compressor start capacitor, control transformer with circuit breaker, solid-state temperature and humidity control modules, time-delay relay, heating contactor, and high-temperature thermostat. Provide solid-state, wall-mounted control panel with start-stop switch**,** adjustable humidity set point**,** and adjustable temperature set point.

L. BMS Interface: Factory installed hardware and software to enable BMS to monitor, control and display unit status and alarms.

a. Hardwired Points Monitoring: On-off status, common trouble alarm space temperature and space humidity.

b. Control: On-off operation, space temperature set-point adjustment, space relative humidity set-point adjustment.

M. Communication interface with BMS shall enable the BMS operator to remotely control and monitor the unit from an operator workstation. Control features and monitoring points displayed locally at unit control panel shall be available through the BMS via BACnet integration protocol.

N. Furnish leak detection for field installation hardwired to factory mounted controller with spare contacts for interface with BMS.

2.3 CEILING-MOUNTED UNITS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following**:**
1. Liebert Corporation.
2. Stulz-ATS.

B. Description: Self-contained, factory assembled, prewired, and prepiped; consisting of cabinet, fan, filters, and controls; for horizontal ceiling mounting to fit T-bar ceiling opening of 24 by 48 inches.

C. Cabinet: Galvanized steel with baked-enamel finish, insulated with 1/2-inch-thick duct liner.

1. Integral factory-supplied aluminum supply and return grille to fit ceiling grid kit of 24 by 48 inches, with filter.
2. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in the latest edition of ASHRAE 62.1.

D. Supply-Air Fan: Forward curved, centrifugal, and directly driven by two-speed motor.

E. Refrigeration System:

1. Compressor: Hermetic, with oil strainer, internal motor overload protection, resilient suspension system, force feed lubrication, and crankcase heater.
2. Refrigeration Circuit: Low-pressure switch, manual-reset high-pressure switch, thermal-expansion valve with external equalizer, sight glass with moisture indicator, service shutoff valves, charging valves, and charge of refrigerant.
3. Refrigerant: R-407C or R-410A.
4. Refrigerant Evaporator Coil: Direct-expansion coil of seamless copper tubes expanded into aluminum fins.

    a. Mount coil assembly over stainless-steel drain pan complying with the latest edition of ASHRAE 62.1 and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir. Dual float for condensate pump to alarm on high water level.

5. Remote Air-Cooled Refrigerant Condenser: Integral, copper-tube aluminum-fin coil with propeller fan, direct driven.
6. Split system shall have suction- and liquid-line compatible fittings and refrigerant piping for field interconnection.

F. Hydronic Cooling Coil: Seamless copper tubes expanded into aluminum fins with two-way control valve.

1. Cooling Medium: Water.

2. Mount coil assembly over stainless-steel drain pan complying with the latest edition of ASHRAE 62.1 and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir. Dual float for condensate pump to alarm on high water level.

3. Control Valve: 150 lb rating.

G. Electric-Resistance Heating Coil: Finned-tube electric elements with contactor, dehumidification relay, and high-temperature-limit switches.

H. Filter: 2-inch-thick, disposable, glass-fiber media.

1. MERV (ASHRAE 52.2): 8.

I. Electrode Steam Humidifier: Self-contained, microprocessor-controlled unit with disposable, polypropylene-plastic cylinders, and having field-adjustable steel electrodes and stainless-steel steam dispersion tube.

1. Plumbing Components and Valve Bodies: Plastic, linked by flexible rubber hosing, with water fill with air gap and solenoid valve incorporating built-in strainer, pressure-reducing and flow-regulating orifice, and drain with integral air gap.

2. Control: Fully modulating to provide gradual 0 to 100 percent capacity with field-adjustable maximum capacity; with high-water probe.
3. Drain Cycle: Field-adjustable drain duration and drain interval.

J. Disconnect Switch: Nonautomatic, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.

K. Control System: Unit-mounted panel with main fan contactor, compressor contactor, compressor start capacitor, control transformer with circuit breaker, solid-state temperature and humidity control modules, humidity contactor, time-delay relay, heating contactor, and high-temperature thermostat. Provide solid-state, wall-mounted control panel with start-stop switch, adjustable humidity set point, and adjustable temperature set point.

L. Communication interface with BMS shall be via BACnet protocol.

M. Furnish leak detection for field installation hardwired to factory mounted controller with spare contacts for interface with BMS.

2.4 CONSOLE UNITS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Liebert Corporation.
2. Stulz-ATS.

B. Description: Split system consisting of evaporator section for floor or wall mounting and remote condensing section.

C. Evaporator Cabinet: Furniture-grade steel with baked-enamel finish; with front access and containing direct-drive centrifugal fans and two-speed motor.

1. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in the latest edition of ASHRAE 62.1.

D. Condenser Cabinet: Steel with baked-enamel finish and containing compressor and condenser.

E. Refrigeration System:

1. Compressor: Hermetic, with oil strainer, internal motor overload protection, resilient suspension system, and crankcase heater.
2. Refrigeration Circuit: Filter/dryer, manual-reset high-pressure switch, thermal-expansion valve with external equalizer, sight glass with moisture indicator, service shutoff valves, charging valves, and charge of refrigerant.
3. Refrigerant: R-407C or R-410A.
4. Refrigerant Evaporator Coil: Direct-expansion coil of seamless copper tubes expanded into aluminum fins.

5. Mount coil assembly over stainless-steel drain pan complying with the latest edition of ASHRAE 62.1 and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir. Dual float for condensate pump to alarm on high water level.
6. Remote Air-Cooled Refrigerant Condenser: Integral, copper-tube aluminum-fin coil with propeller fan, direct driven.
7. Split system shall have suction- and liquid-line compatible fittings and refrigerant piping for field interconnection.

F. Hydronic Cooling Coil: Seamless copper tubes expanded into aluminum fins with modulating control valve.

1. Cooling Medium: Water.
2. Mount coil assembly over stainless-steel drain pan complying with the latest edition of ASHRAE 62.1 and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir. Dual float for condensate pump to alarm on high water level.

3. Control Valve: 150 lb rating.

G. Electric-Resistance Heating Coil: Finned-tube electric elements with contactor and high-temperature-limit switches.

H. Filter: 1-inch-thick, disposable, glass-fiber media.

1. MERV (ASHRAE 52.2): 8.

I. Electrode Steam Humidifier: Self-contained and microprocessor controlled; with replaceable cylinder.

J. Disconnect Switch: Nonautomatic, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.

K. Control System: Unit-mounted panel with contactors, control transformer with circuit breaker, and solid-state temperature and humidity control modules. Provide solid-state, unit-mounted control panel with start-stop switch, adjustable humidity set point, and adjustable temperature set point.

L. Communication interface with BMS shall be via BACnet Protocol.

M. Furnish leak detectors for field installation hardwired to factory mounted controller with spare contacts for interface with BMS.

2.5 FAN MOTORS

A. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. 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.
2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 26 Sections.

2.6 WATER DETECTION SYSTEM

A. Basics of Design Product: Subject to compliance with requirements, provide a Liebert Corporation water detection system or an equivalent product by the manufacturer of the units being supplied.

B. Description: Complete water detection location and alarm system and display into its location and sound audible alarm.

C. Cable: plenum rated water detection cable installed below raised floor of computer room area. Include end cap terminator to complete circuit.

1. No single section of detection cable shall exceed 50 feet for ease of installation, or replacement if necessary.
2. Provide hold-down clips, attached to cables and installed 6 feet apart.

D. Display Panel: Wall mounted digital display panel, powered by 120 volts AC, with relay output activated on detection of water or cable fault.

1. Detect Water leak and/or cable fault and display its location and sound alarm (1 foot increments) up to 2000 feet away form start of cable run
2. Provide leader cable from display panel to first water detection cable segment with connector.

E. Site Location Map: Provide a graphic reference map showing actual cable layout with distance indications and room landmarks from beginning point of water detection cable run.

1. Indicate icon location points and distance increments.
2. Maps shall be made after actual testing for distance reading is completed
3. Map shall be framed under glass or otherwise enclosed and secured alongside display panel

F. Enter water detection system installation shall be serviced by the installing contractor for a period of one year from date of recorded startup.

2.7 CAPACITIES AND CHARACTERISTICS

A. As scheduled on drawings

PART 3 - EXECUTION

3.1 EXAMINATION

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

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

C. Examine walls, floors, and roofs for suitable conditions where computer-room air conditioners will be installed.

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

3.2 INSTALLATION

A. Install computer-room air conditioners level and plumb, maintaining manufacturer's recommended clearances. Install according to AHRI Guideline B.

B. Computer-Room Air-Conditioner Mounting: Install using elastomeric pads. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

C. Suspended Computer-Room Air Conditioners: Install using continuous-thread hanger rods and spring hangers with vertical-limit stop of size required to support weight of computer-room air conditioner.

1. Comply with requirements for vibration isolation devices specified in Section 23 05 48 "Vibration Controls for HVAC." Fabricate brackets or supports as required.
2. Comply with requirements for hangers and supports specified in Section 23 05 29 "Hangers and Supports for HVAC Piping and Equipment.
3. Coordinate installation with ceiling construction."

D. Air-Cooled Refrigerant Condenser Mounting: Install using elastomeric mounts. Comply with requirements for vibration isolation devices specified in Section 23 05 48 "Vibration Controls for HVAC."

1. Minimum Deflection: 1/4 inch.

E. Install water detection system cables below raised floor of computer room area in accordance with the manufacturer’s recommendations.

F. Install water detection system display panel where indicated on drawings or where directed by the Architect / Engineer.

3.3 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to machine to allow service and maintenance.

C. Water and Drainage Connections: Comply with applicable requirements in Division 22 Sections. Provide adequate connections for water-cooled units, condensate drain, and humidifier flushing system.

D. Chilled water Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping." Provide shutoff valves in water inlet and outlet piping on water-cooled units.

E. Refrigerant Piping: Comply with applicable requirements in Division 23 Section "Refrigerant Piping." Provide shutoff valves and piping.

3.4 FIELD QUALITY CONTROL

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

B. Perform tests and inspections.

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

C. Tests and Inspections:

1. Inspect for and remove shipping bolts, blocks, and tie-down straps.
2. After installing computer-room air conditioners and after electrical circuitry has been energized, test for compliance with requirements.
3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. Computer-room air conditioners will be considered defective if they do not pass tests and inspections.

E. Prepare test and inspection reports.

F. After startup service and performance test, change filters and flush humidifier.

G. Water Detection System: Perform a complete functional test of the system after installation.

1. Ascertain that equipment has suffered no impairment of performances since tested in factory and that installation is in accordance with the manufacturer's specifications.
2. Tests shall include manufacturer's routine site acceptance tests.
3. The manufacturer shall be responsible for any damage to equipment resulting from his own testing.
4. Engage Factory-authorized technicians for sufficient time to carry out component acceptance, start-up, on-site testing and one (1) day of operational training. Training shall be scheduled at the owner's convenience at any time after acceptance of the equipment.

3.5 ADJUSTING

A. Adjust initial temperature and humidity set points.

B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

C. Occupancy Adjustments: When requested within 12 months of 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.

3.6 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain computer-room air conditioners.

3.7 RELATED WORK TO BE INCLUDED BY VENDOR FOR A.C. EQUIPMENT

A. The Commissioning Specifications contain additional vendor and contractor requirements regarding factory and on-site testing, warrantees, submittals, operation and maintenance manuals, start-up responsibilities and operator training. If there is a discrepancy, the more stringent requirement shall apply.

END OF SECTION 23 81 23

SECTION 23 81 26 - SPLIT SYSTEM AIR CONDITIONERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Basic Requirements: Provisions of Section 23 00 10, “Basic HVAC Requirements” are part of this Section.

1.2 WORK INCLUDED

A. Packaged Split System Air Conditioning Unit, Air Cooled.

1.3 QUALITY ASSURANCE

A. All electrical components shall be UL listed or labeled.

B. All direct expansion coils shall be ARI certified.

C. All components in the air stream shall conform to the NFPA 90A Flame/Smoke/Fire contribution of 25/50/0.

D. All electrical devices shall conform to NEMA standards.

E. All wiring shall conform to the NEC.

F. After installation, the manufacturer's representative of all equipment provided in this section shall certify in writing to the Owner's representative that the equipment has been assembled and installed within the guidelines of the manufacturer's written installation instructions and that its performance meets or exceeds the operating characteristics specified and/or scheduled.

G. Starting of Mechanical Systems:

1. Provide material and labor to perform start-up of each respective item of equipment and system prior to beginning of test, adjust and balance procedures.
2. Provide labor to assist the Owner's Representative in acceptance review.

3. Provide point by point system check-out. Submit results in tabulated form by system. Include this data as part of Operation and Maintenance Manuals.
4. Provide information and assistance and cooperate with test, adjust and balance services.
5. Comply strictly with manufacturer's recommended procedures in starting up mechanical systems.
6. Provide such periodic continuing adjustment services as necessary to ensure proper functioning of mechanical systems until acceptance and up to 1 full year after date of Owner acceptance.

1.4 SUBMITTALS

A. Submit dimension drawings, performance and product data for acceptance. Include fan curves with the system design point plotted, and clearly indicate fan efficiency.

B. Product data, along with installation operation and maintenance instructions, shall be included in the operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Packaged Split System Air Conditioning Unit, Air Cooled:

1. Carrier
2. Daikin Applied
3. Lennox

2.2 EQUIPMENT

A. Packaged Split System Air Conditioning Unit, Air Cooled:

1. Provide an air-to-air electric condensing unit (outdoor unit) in combination with a direct expansion fan coil (indoor unit), fully piped, wired and operational. Condensing unit shall be designed, tested, and fully charged for use with R-410A refrigerant. The system shall have a minimum SEER rating of 16. Combination unit shall be designed certified by UL and ARI, and complete package to have one (1) year limited parts warranty and compressor to have a ten (10) year extended parts warranty.
2. Outdoor Section:

a. Cabinet shall be constructed of commercial grade galvanized steel, primed and painted to manufacturer's standard color. Access doors with neoprene gaskets shall be provided to allow access to coil, fan, motor and controls. Mounting legs shall be provided.
b. Compressor shall be high efficiency hermetic reciprocating type or scroll type equipped with a crankcase heater, automatically reversible oil pump, internal high pressure protection, and internal vibration isolation. Compressor motor shall have both thermal and current sensitive overload protection.
c. Outdoor coil shall be constructed of copper tubing with mechanically bonded aluminum fins having all joints brazed, factory installed coil refrigerant metering device to be mounted on unit liquid service valve, with device internal components to be removable for cleaning or replacement. Coil to be protected by a vinyl coated grille.
d. Outdoor fan shall be propeller type, direct driven, balanced statically and dynamically, and arranged for vertical air discharge. Fan shall be weatherproofed and approved for outdoor use. Fan motor shall be factory lubricated and internally protected.
e. Controls shall provide compressor short cycle protection and shall prevent compressor restart for a minimum of five minutes after shutdown. Liquid line low pressure switch, suction line accumulator with positive oil return, pressure relief switch and a loss of pressure indicator shall be provided.
f. Unit shall be equipped with filter drier, schrader access valves, refrigerant check valves in the refrigerant line, hot gas piping connection and valving, and expansion devices with interconnecting tubing to provide proper refrigerant flow control.
g. Low refrigerant and high refrigerant cut-outs to be arranged in lock out circuit for manual reset. Control wiring terminal board and 24 volt control circuit transformer to be provided. Terminal board shall be designed to match indoor unit terminal board and furnished complete with factory wiring from board to all internal components and accessory thermostat terminals for standardized point-to-point connectors.
h. Units with multiple compressors shall have independent refrigerant circuiting.
i. Comply with the latest edition of ASHRAE/IESNA 90.1, "Energy Standard for Buildings except Low-Rise Residential Buildings."

3. Indoor Section:

a. Cabinet shall be constructed of commercial grade galvanized steel, primed and painted to manufacturer's standard color, and insulated with fireproof, permanent, odorless glass fiber material. Access to be all components shall be provided with neoprene gasketed access panel(s).
b. Indoor coil shall be constructed of copper tubing with mechanically bonded aluminum fins having all joints brazed. Factory installed refrigerant metering device, refrigerant line fittings which permit mechanical connection on the liquid line and female sweat or mechanical connection on the gas line, and condensate pan with primary and auxiliary drain connections shall be

provided. Unit shall also be equipped with hot gas reheat coil installed in the unit.

c. Fan shall be forward curved, centrifugal type, driven by factory lubricated single speed, three phase fan motor complete with internal overload protection, and resiliently mounted. Fan shall have horizontal air discharge or vertical air discharge as shown on the Contract Documents.

d. Unit shall be provided with factory installed electric heater for supplemental heating to mount in discharge air passage. Elements to be of heavy duty nichrome internally delta-connected on three phase. Heater to have line break high limit controls.

e. Certain units require multiple power connections for energy management purposes and are indicated on the schedules. Coordinate this requirement.

f. Unit shall be provided with 1 inch medium efficiency throwaway filters. Initial and one replacement set to be provided with unit. Filter retaining rack to be arranged for removal and replacement in space allotted.

4. Unit Accessories:

a. Control equipment and sequence of operation are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."

b. Thermostat: Low voltage with subbase to control compressor and evaporator fan.

c. Automatic-reset timer to prevent rapid cycling of compressor.

d. Refer to Schedules shown on the Contract Documents.

PART 3 - EXECUTION

3.1 GENERAL

A. Packaged Split System Air Conditioning Unit, Air Cooled:

1. Install in accordance with manufacturer's recommendations.
2. All openings made in walls or the roof the piping/electrical shall be patched and sealed completely, using materials of similar to existing type construction, to the Owner's satisfaction.
3. All refrigerant piping shall follow refrigerant piping techniques.

4. Condensate traps shall be minimum 4 inches deep and shall be field installed. Install plug in condensate drain on opposite side of unit from traps. Condensate drain connection shall be not less than 3/4".
5. All wiring shall comply with applicable local and national codes. Final connections shall be made with Liquid-tight Flexible Metal Conduit (LFMC) for ease in removal.
6. Maintain necessary access space for filter change and normal maintenance. Piping and electrical connections shall be so located as to eliminate any interference with removal and replacement of filter.
7. Maintain space clearances around heat pump per manufacturer's recommendation.
8. After installation of unit, all interconnecting piping, controls and wiring, check each unit for satisfactory operation of fan on continuous and automatic control setting, unit operation on cooling, change over and heating and so indicate on tag pasted on unit indicating: "Checked for proper operation on __Date___ by __Name__."
9. Insert installation and maintenance instructions and parts lists in a one inch ring binder marked "OPERATION AND MAINTENANCE INSTRUCTIONS" and furnish to Owner. (See Section 01 78 00 – Closeout Submittals for other requirements.)
10. Manufacturer shall review the drawings for piping distances. Contractor shall provide pipe sizes and any necessary accessories required by the Manufacturer as the result of their review.

END OF SECTION 23 81 26

SECTION 23 82 16 - AIR COILS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Basic Requirements: Provisions of Section 23 00 10, Basic HVAC Requirements are part of this Section.

1.2 SUMMARY

A. Section includes electric resistance air coils, also referred as electric duct heaters.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for each air coil.
2. Include rated capacities, operating characteristics, and pressure drops for each air coil.

B. Shop Drawings: Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which coil location and ceiling-mounted access panels are shown and coordinated with each other.

B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air coils to include in operation and maintenance manuals.

PART 2 – PRODUCTS

2.1 DESCRIPTION

A. ASHRAE Compliance: Comply with applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

2.2 ELECTRIC RESISTANCE AIR COILS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Neptronic
2. Brasch Manufacturing Co., Inc.
3. Chromalox.
4. Indeeco.

B. Testing Agency Listing and Labeling: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Coil Assembly: Comply with UL 1995.

D. Heating Elements: Open coil type, coiled resistance wire of 80 percent nickel and 20 percent chromium.

E. High-Temperature Coil Protection: Disk-type, automatically reset, thermal-cutout, safety device; serviceable through terminal box without removing heater from duct or casing.

1. Secondary Protection: Load-carrying, manually reset or manually replaceable, thermal cutouts; factory wired in series with each heater stage.

F. Frames: Galvanized-steel channel frame, minimum 0.064 inch thick for slip-in mounting.

G. Control Panel: Unit mounted with disconnecting means and overcurrent protection. Include the following controls:

1. BACnet/Modbus controller
    a. Select MAC address
    b. Remote monitoring (status, alarms, diagnostics and trending)
    c. Realtime feedback of heater’s output capacity
    d. Real-time temperature measures and power consumption data
2. Magnetic contactor.
3. SCR controller
4. Stage fuse
5. Supply and discharge temperature sensors
6. Contact delay
7. Electronic airflow sensor
8. Control fuse
9. Disconnect switch
10. NEMA 1 Control Panel
11. Pressure differential switch
12. Transformer

H. Heater to be controlled by designated remote thermostat via the building management system (BMS).

I. Capacities and Characteristics:

1. See schedule on Drawings.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine ducts, plenums, and casings to receive air coils for compliance with requirements for installation tolerances and other conditions affecting coil performance.

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

3.2 INSTALLATION

A. Install coils level and plumb.

B. Install coils in ducts according to SMACNA's "Ducted Electric Heat Guide for Air-Handling Systems and strict manufacturer’s instructions

C. Maintain manufacturer’s recommended minimum distance to avoid flow obstruction and maintain clearance to access control panel.

D. Install coils in metal ducts and casings constructed according to SMACNA's "HVAC Duct Construction Standards, Metal and Flexible."

E. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

3.3 CONNECTIONS

A. Ground equipment according to Section 26 05 26 "Grounding and Bonding."

B. Connect wiring according to Section 26 05 19 "Building Wire and Cable."

3.3 FIELD QUALITY CONTROL

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

1. Operational Test: After electrical circuitry has been energized, operate electric coils to confirm proper unit operation.

2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

B. Prepare test and inspection reports.

END OF SECTION 23 82 16

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SECTION 23 82 19 - FAN COIL UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. This Section includes fan-coil units and accessories.

1.3 ABBREVIATIONS

A. BAS: Building automation system.

1.4 SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories.

B. LEED V4 BD+C Submittals:

1. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment complies.
2. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1-2004, Section 5 - "Systems and Equipment."

C. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection and associated values.

1. Wiring Diagrams: Power, signal, and control wiring.

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

1. Ceiling suspension components.
2. Structural members to which fan-coil units will be attached.
3. Method of attaching hangers to building structure.
4. Size and location of initial access modules for acoustical tile.

5. Items penetrating finished ceiling, including the following:

    a. Lighting fixtures.
    b. Air outlets and inlets.
    c. Speakers.
    d. Sprinklers.
    e. Access panels.

6. Perimeter moldings for exposed or partially exposed cabinets.

E. Samples for Initial Selection: For units with factory-applied color finishes.

F. Samples for Verification: For each type of fan-coil unit indicated.

G. Field quality-control test reports.

H. Operation and Maintenance Data: For fan-coil units to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include the following:

1. Maintenance schedules and repair part lists for motors, coils, integral controls, and filters.

I. Warranty: Special warranty specified in this Section.

1.5 QUALITY ASSURANCE

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

B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1-2010, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

C. ASHRAE/IESNA 90.1-2010 Compliance: Applicable requirements in ASHRAE/IESNA 90.1-2010, Section 6 - "Heating, Ventilating, and Air-Conditioning."

D. AHRI Compliance: Rated and tested in accordance with AHRI Standard 440 “Room Fan Coil Units.”

E. UL listed and labeled in accordance with ANSI/UL Standard 880- “Safety Standard for Fan Coil Units.”

1.6 COORDINATION

A. Coordinate layout and installation of fan-coil units and suspension system components with other construction that penetrates or is supported by ceilings, including light fixtures, HVAC equipment, fire-suppression-system components, and partition assemblies.

B. Coordinate size and location of wall sleeves for outdoor-air intake.

C. Specific configuration of the supply and return ductwork and piping at each unit has been indicated on the drawings. If the configuration of the units furnished on the project differs from that indicated on the drawings (whether or not the units furnished are the specific units or an acceptable substitute), it shall be the contractor's responsibility to modify ductwork, piping, etc., as required to accommodate the actual the actual configuration of units furnished on the project.

1.7 WARRANTY

A. Warranty Period: One year from date of Substantial Completion.

1.8 EXTRA MATERIALS

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

1. Fan-Coil-Unit Filters: Furnish one spare filter for each filter installed.
2. Fan Belts: Furnish one spare set of fan belts for each unit installed.

PART 2 - PRODUCTS

2.1 GENERAL

A. Manufacturer shall be responsible for examining applications of each type of unit to assure that each will operate properly in the intended application.

B. Unit sizes are shown as selected in accordance with the principles set worth in the ASHRAE Guide and Manufacturer's literature.

C. All items of a given type shall be the products of the same manufacturer.

2.2 MANUFACTURERS

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

B. In the Fan-Coil-Unit Schedule where titles below are column or row headings that introduce lists, the following requirements apply to product selection:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the manufacturers specified.

2.3 FAN-COIL UNITS

A. Manufacturers:

1. Airtherm; a Mestek Company.
2. Carrier Corporation.
3. Environmental Technologies, Inc.
4. McQuay International.
5. Trane.
6. USA Coil & Air.
7. YORK International Corporation.
8. IEC

B. Description: Factory-packaged, completely assembled and -tested units rated according to AHRI 440, ASHRAE 33, and UL 1995.

C. Coil Section Insulation: 1/2-inch thick, 1-1/2 lb density coated glass fiber complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916.

1. Fire-Hazard Classification: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.
2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2010.

D. Main and Auxiliary Drain Pans: Plastic, Insulated Stainless or galvanized steel with plastic liner. Fabricate pans and drain connections to comply with ASHRAE 62.1-2010. Drain pans shall be removable.

E. Chassis: Galvanized steel where exposed to moisture. Floor-mounting units shall have leveling screws.

F. Cabinet: Steel with baked-enamel finish in manufacturer's standard paint color as selected by Architect.

1. Vertical Unit Front Panels: Removable, steel, with integral stamped steel discharge grille and channel-formed edges, cam fasteners, and insulation on back of panel.
2. Horizontal Unit Bottom Panels: Fastened to unit with cam fasteners and hinge and attached with safety chain; with integral stamped steel or cast-aluminum discharge grilles.
3. Stack Unit Discharge and Return Grille: Aluminum double-deflection discharge grille, and louvered- or panel-type return grille; color as selected by Architect from manufacturer's standard colors. Return grille shall provide maintenance access to fan-coil unit.
4. Steel recessing flanges for recessing fan-coil units into ceiling or wall.

G. Outdoor-Air Wall Box: Minimum 0.1265-inch-thick, aluminum, rain-resistant louver and box with integral eliminators and bird screen.

1. Louver Configuration: Horizontal, rain-resistant louver.
2. Louver Material: Aluminum.
3. Bird Screen: 1/2-inch mesh screen on interior side of louver.
4. Decorative Grille: On outside of intake.
5. Finish: Anodized aluminum, Baked enamel, color as selected by Architect from manufacturer's standard colors.

H. Outdoor-Air Damper: Galvanized-steel blades with edge and end seals and nylon bearings; with electronic modulating actuators.

I. Filters: Minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

1. Pleated Cotton-Polyester Media: 7 MERV.

J. Hydronic Coils: 3/8 in. diameter, copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain valve.

K. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in galvanized-steel housing; with fuses in terminal box for overcurrent protection and limit controls for high-temperature protection. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

1. Provided with automatic reset high limit control operating through heating element contactors.

2. U.L. listed and equipped with unit mounted disconnect switch.

3. Provide mercury contactor to provide scheduled steps of heating.

L. Fan and Motor Board: Removable.

1. Fan: Forward curved, double width, centrifugal; directly connected to motor. Thermoplastic or painted-steel wheels, and aluminum, painted-steel, or galvanized-steel fan scrolls.
2. Motor: Permanently lubricated, multispeed; resiliently mounted on motor board. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."
3. Wiring Termination: Connect motor to chassis wiring with twist lock plug connection.

M. Unit Control Box: Integral unit cabinet to include:

1. Fan starter and electric heating coil circuit breakers.
2. Disconnect switches
3. Control circuit transformer for 24-volt control circuit, fused on primary and secondary sides.
4. Single point power entry

5. Numbered Terminal strips.

N. Control devices are specified in Division 23 Sections "Instrumentation and Control for HVAC". Control sequences as indicated on the Drawings.

O. Electrical Connection: Factory wire motors and controls for a single electrical connection.

P. Capacities and Characteristics: As scheduled on drawings.

2.4 DUCTED FAN-COIL UNITS

A. Manufacturers:

1. Carrier Corporation.
2. Environmental Technologies, Inc.
3. McQuay International.
4. Trane.
5. USA Coil & Air.
6. YORK International Corporation.

B. Description: Factory-packaged, completely assembled and -tested units rated according to AHRI 440, ASHRAE 33, and UL 1995.

C. Coil Section Insulation: 1/2-inch thick coated glass fiber complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916.

1. Fire-Hazard Classification: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.
2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2010.

D. Drain Pans: Plastic, Insulated Stainless or galvanized steel with plastic liner. Fabricate pans and drain connections to comply with ASHRAE 62.1-2010.

E. Chassis: Galvanized steel, with baked-enamel finish and removable access panels.

F. Cabinets: Steel with baked-enamel finish in manufacturer's standard paint color.

1. Supply-Air Plenum: Sheet metal plenum finished and insulated to match the chassis with mill-finish, aluminum, double-deflection grille.
2. Return-Air Plenum: Sheet metal plenum finished to match the chassis.
3. Mixing Plenum: Sheet metal plenum finished and insulated to match the chassis with outdoor- and return-air, formed-steel dampers.
4. Dampers: Galvanized steel with extruded-vinyl blade seals, flexible-metal jamb seals, and interlocking linkage.

G. Filters: Minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

1. Pleated Cotton-Polyester Media: 7 MERV.

H. Hydronic Coils: 3/8 in. diameter copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain.

I. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with fuses in terminal box for overcurrent protection and limit controls for high-temperature protection of heaters. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

1. Provided with automatic reset high limit control operating through heating element contractors.

2. UL listed and equipped with unit and mounted disconnect switch.

3. Provide mercury contractor to provide scheduled steps of heating.

J. Direct-Driven Fans: Double width, forward curved, centrifugal; with permanently lubricated, multispeed motor resiliently mounted in the fan inlet. Aluminum or painted-steel wheels, and painted-steel or galvanized-steel fan scrolls.

K. Belt-Driven Fans: Double width, forward curved, centrifugal; with permanently lubricated, single-speed motor installed on an adjustable fan base resiliently mounted in the cabinet. Aluminum or painted-steel wheels, and painted-steel or galvanized-steel fan scrolls.

1. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

L. Control devices and operational sequence are specified in Division 23 Section 23 09 00 "Instrumentation and Control for HVAC

M. Electrical Connection: Factory wire motors and controls for a single electrical connection.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas to receive fan-coil units for compliance with requirements for installation tolerances and other conditions affecting performance.

B. Examine roughing-in for piping and electrical connections to verify actual locations before fan-coil-unit installation.

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

3.2 STORAGE AND HANDLING

A. Comply with manufacturer's installation instructions for rigging, unloading and transporting units.

B. All fan coil units shall be received and stored on the job site with the wooden shipping skids in place. Under no condition shall the units be stored on such a way that metal components are in direct contact with the ground.

C. Unit delivery shall be coordinated with building construction and units shall be delivered to the job site just prior to their installation. Cover air handling units stored on the job site with 6 mil polyethylene sheet, taped in place, to protect the units from damage and the weather. Units that receive water damage due to improper handling or storage shall be removed from the site and new ones furnished at no additional charge to the Owner.

3.3 INSTALLATION

A. Install fan-coil units level and plumb.

B. Install fan-coil units to comply with NFPA 90A.

C. Suspend fan-coil units from structure with elastomeric hangers and at least four 3/8 inch galvanized threaded support rods. Vibration isolators are specified in Division 23 Section "Vibration Controls for HVAC."

D. Verify locations of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation. Install devices 48 inches above finished floor.

E. Install new filters in each fan-coil unit within two weeks after Substantial Completion.

3.4 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties. Specific connection requirements are as follows:

1. Install piping adjacent to machine to allow service and maintenance.
2. Connect piping to fan-coil-unit factory hydronic piping package. Install piping package if shipped loose.
3. Connect condensate drain to full size but not less than 3/4 inch indirect waste.

   a. Install condensate trap of adequate depth to seal against the pressure of fan. Install cleanouts in piping at changes of direction.

B. Connect supply and return ducts to fan-coil units with flexible duct connectors specified in Division 23 Section "Air Duct Accessories." Comply with safety requirements in UL 1995 for duct connections.

C. Ground equipment according to Division 26 Section 26 05 26 "Grounding and Bonding."

D. Connect wiring according to Division 26 Section 26 05 19 "Building Wire and Cable."

3.5 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

B. Perform the following field tests and inspections and prepare test reports:

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
2. Operate electric heating elements through each stage to verify proper operation and electrical connections.
3. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.

C. Remove and replace malfunctioning units and retest as specified above.

3.6 ADJUSTING

A. Adjust initial temperature and humidity set points.

B. Occupancy Adjustments: When requested within 12 months of 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.

3.7 DEMONSTRATION

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

END OF SECTION 23 82 19

SECTION 238239 - UNIT HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Requirements Division 01, Division 23 Specification Sections, and Common Work Requirements for HVAC apply to the work specified in this Section.

1.2 SUMMARY

A. Section Includes:

1. Propeller unit heater with electric-resistance heating coils.

1.3 DEFINITIONS

A. BAS: Building automation system.

B. CWP: Cold working pressure.

C. PTFE: Polytetrafluoroethylene plastic.

D. TFE: Tetrafluoroethylene plastic.

1.4 SUBMITTALS

A. Product Data: Include rated capacities, dimensions, materials, operating characteristics, furnished specialties, and accessories for each product indicated.

B. LEED V4 BD+C Submittals:

1. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment complies.
2. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1-2004, Section 5 - "Systems and Equipment."

C. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1. Plans, elevations, sections, and details.
2. Location and size of each field connection.
3. Details of anchorages and attachments to structure and to supported equipment.

4. Equipment schedules to include rated capacities, operating characteristics, furnished specialties, and accessories.
5. Location and arrangement of integral controls.
6. Wiring Diagrams: Power, signal, and control wiring.

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

1. Suspended ceiling components.
2. Structural members to which unit heaters will be attached.
3. Method of attaching hangers to building structure.
4. Size and location of initial access modules for acoustical tile.
5. Items penetrating finished ceiling, including the following:

   a. Lighting fixtures.
   b. Air outlets and inlets.
   c. Speakers.
   d. Sprinklers.
   e. Access panels.

6. Perimeter moldings for exposed or partially exposed cabinets.

E. Samples for Initial Selection: Finish colors for units with factory-applied color finishes.

F. Samples for Verification: Finish colors for each type of cabinet unit heater and wall and ceiling heaters indicated with factory-applied color finishes.

G. Manufacturer Seismic Qualification Certification: Submit certification that cabinet unit heaters, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment." Include the following:

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

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

2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

H. Field quality-control test reports.

I. Operation and Maintenance Data: For cabinet unit heaters to include in emergency, operation, and maintenance manuals.

1.5 QUALITY ASSURANCE

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

B. ASHRAE Compliance: Applicable requirements in the latest edition of ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

C. ASHRAE/IESNA 90.1 Latest Edition Compliance: Applicable requirements in the latest edition of ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

PART 2 - PRODUCTS

2.1 PROPELLER UNIT HEATERS

A. Manufacturers:

1. McQuay International.
2. Markel Products; a Division of TPI Corporation.
3. Modine Manufacturing Company
4. Sterling Heating Products
5. Trane.

B. Description: An assembly including casing, heating coil, fan, and motor in horizontal discharge configuration with adjustable discharge louvers.

C. Comply with UL 2021.

D. Comply with UL 823.

E. Cabinet: Removable panels for maintenance access to controls.

F. Cabinet Finish: Manufacturer's standard baked enamel applied to factory-assembled and -tested propeller unit heater before shipping.

G. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in the latest edition of ASHRAE 62.1.

H. Electric-Resistance Heating Elements: Nickel-chromium heating wire, free from expansion noise and 60-Hz hum, embedded in magnesium oxide refractory and sealed in steel or corrosion-resistant metallic sheath with fins no closer than 0.16 inch. Element ends shall be enclosed in terminal box. Fin surface temperature shall not exceed 550 deg F at any point during normal operation. Provide stages of electric control as required.

1. Circuit Protection: One-time fuses in terminal box for overcurrent protection and limit controls for high-temperature protection of heaters.
2. Wiring Terminations: Stainless-steel or corrosion-resistant material.

I. Fan: Propeller type with aluminum wheel directly mounted on motor shaft in the fan venturi. Provide fan guard.

J. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Motor Type: Permanently lubricated.

K. Control Devices:

1. Unit-mounted thermostat.

L. Capacities and Characteristics

1. As scheduled on drawings:

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas to receive unit heaters for compliance with requirements for installation tolerances and other conditions affecting performance.

B. Examine roughing-in for electrical connections to verify actual locations before unit heater installation.

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

3.2 INSTALLATION

A. Install cabinet unit heaters to comply with NFPA 90A. Coordinate to assure correct size openings for recessed units.

B. Install propeller unit heaters level and plumb. Mount as high as possible to maintain maximum headroom.

C. Suspend propeller unit heaters from structure with all-thread hanger rods and spring hangers with vertical-limit stop. Hanger rods and attachments to structure are specified in Division 23 Section "Vibration Controls for HVAC." Vibration hangers are specified in Division 23 Section "Vibration Controls for HVAC."

D. After construction, including painting is completed, clean exposed surfaces of units. Vacuum clean coils and inside of cabinets prior to running the equipment.

E. Touch-ups marred or scratched surfaces of factory finished cabinets, using finish materials furnished by the manufacturer.

3.3 CONNECTIONS

A. Ground equipment according to Division 26 Section 260526 "Grounding and Bonding”.

B. Connect wiring according to Division 26 Section 260519 "Building Wire and Cable."

3.4 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

B. Perform the following field tests and inspections and prepare test reports:

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
2. Operate electric heating elements through each stage to verify proper operation and electrical connections.
3. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.

C. Remove and replace malfunctioning units and retest as specified above.

3.5 ADJUSTING

A. Adjust initial temperature set points.

B. Occupancy Adjustments: When requested within 12 months of 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.

3.6 DEMONSTRATION

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

END OF SECTION 238239

SECTION 23 90 00 – PRE-CONDITIONED AIR UNITS AND SPECIALTIES

PART 1 - GENERAL

1.1 GENERAL DESCRIPTION

A. This section of the specifications covers the following components:
   1. Preconditioned Air Handling Units (PCA AHU).
      a. Mounting brackets for PC Air units – rotunda and ground.
      b. Telescoping Air Duct (TAD), rigid and flexible air duct at passenger boarding bridges.
      c. Supports, on-board controls, sensors and other appurtenances associated with the PC Air units.
   2. Passenger Boarding Bridge Rooftop Units (PBB RTU)
   3. Bridge Utility Transport Unit

1.2 REFERENCES

A. Applicable Standards:
   1. Anti-Friction Bearing Manufacturers Association (AFBMA).
   2. Air-Conditioning and Refrigeration Institute (ARI).
   3. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).
   4. National Fire Protection Associated (NAPA).
   5. National Electrical Manufacturer's Association (NEMA).
   6. Occupational Safety and Health Act (OSHA).
   7. Underwriters Laboratories (UL).
   8. Florida Building Code (FBC).

B. Related Sections:
   1. Section 01 91 13 – Commissioning
   2. Section 05 50 00 – Metal Fabrications
   3. Section 23 00 10 – Basic Mechanical Requirements
   4. Section 23 05 13 – Common Motor Requirements for Mechanical Equipment
   5. Section 23 05 14 – Variable Frequency Motor Controllers
   6. Section 23 05 23 – Valves for PCA Piping
   7. Section 23 05 29 – Hangers and Supports
   8. Section 23 05 48 – Mechanical Sound, Vibration Controls
   9. Section 23 05 53 – Mechanical Identification
   10. Section 23 05 93 – Testing, Adjusting and Balancing for HVAC
   11. Section 23 07 19.13 – PCA System Insulation
   12. Section 23 05 23 – General Duty Valves for HVAC Piping
   13. Section 23 08 00 – HVAC Commissioning
   14. Section 23 09 23 – Instrumentation and Controls for HVAC
   15. Section 23 21 13 – Hydronic Piping
   16. Section 23 21 16 – Piping Specialties
   17. Section 23 25 00.01 – PCA Water Treatment
   18. Section 23 74 16.13 - Packaged Rooftop Air-Conditioning Units
   19. Division 26 – Electrical

20. Drawings – Plans, Sections, Details, Sequence of Operation, Controls, Schedules, etc.

1.3 SUBMITTALS

A. General:
   1. The Contractor shall submit product data for selected AHU models and the utility transport units, including specialties, and accessories.
   2. Shop drawings from manufacturer detailing equipment assemblies and indicating dimensions, weights, required clearances, components, and location and size of field connections.
   3. Wiring diagrams that detail power, signal, and control wiring. Differentiate between manufacturer-installed wiring and field installed wiring. Troubleshooting guide.
   4. Maintenance data for complete air-handling units with controllers for inclusion in Operating and Maintenance Manual.

1.4 QUALITY ASSURANCE

A. It is the intent of this contract that the aircraft and the PBB air-handler units, be supplied and installed by a single source contractor. The contractor shall have a minimum of 5 years of experience in all areas of preconditioned air equipment design, manufacturing, supply and installation, aircraft cooling system design and analysis by in-house engineering and programming, development and installation of complete integrated monitoring and control systems. The contractor shall have a minimum of three (3) prior installations at other airports of size, climate and complexity similar to the proposed Greater Orlando International Airport project. This experience shall include systems where the contractor has had turn-key responsibility direct to the Owner for system analysis, design, and supply of all major equipment, installation, programming, testing, system start-up and training.

B. The Contractor shall submit with the bid documents a record of experience for successfully completed and operating systems that provide sub-freezing air to aircraft utilizing central ethylene glycol systems. The experience list shall include a summary of that contractor's experience, including system location, Owner, major subcontractors and equipment suppliers used, on-line date and contact name and telephone number. The summary shall also name the individual engineers and programmers on the contractor's staff to be involved in the project, their assignments and responsibilities for the three prior projects and their employment dates with the contractor.

C. The Contractor shall be responsible to directly supervise the installation of all bridge mounted equipment and controls. Such supervisor shall be in the direct employ of the contractor. This supervision effort shall not be subcontracted to a third party.

D. The Contractor shall coordinate all work with the Owner's Authorized Representatives as required during the installation to ensure that the resulting installed system functions as specified in all respects. This coordination shall cover installation of equipment as well as interfaces with piping, power and controls.

E. Temperature control systems shall be warranted to be new and free of defects in material and workmanship under normal service and use for a period of 12 months from the date of acceptance. If, within this period, any equipment proves defective, it shall be repaired or replaced at no additional cost to GOAA.

F. Equipment and material shall be catalogued products of manufacturers regularly engaged in the production of temperature control systems. Products shall be manufacturer's latest standard design and must have been tested and proven in actual use for low temperature systems.

G. It is the intention that certain items of major equipment, air-handler units, process instrumentation and control valves be standardized throughout all parts of the system. The Contractor shall include in the equipment and material submittals evidence of such coordination between major equipment suppliers.

H. AMCA 500: Provide materials that are labeled as complying with “Laboratory Methods for Testing Dampers for Rating”

I. AHRI Certification: Air-handling units and their components shall be factory tested according to ARI 260, “Sound Rating of Ducted Air Moving and Conditioning Equipment,” and shall be listed and labeled by ARI.

J. AHRI Certification: Air-handling units and their components shall be factory tested according to ARI 430, “Central-Station Air-Handling Units,” and shall be listed and labeled by ARI.

K. ARI Compliance: Air filter equipment shall comply with ARI 850.

L. ASHRAE Compliance: Air filters shall comply with ASHRAE Standard 52 for method of testing, and for recording and calculating air flow rates.

M. NFPA Compliance:
   1. Comply with applicable portions of NFPA 70 Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use for components and installation of air-handling units.
   2. NFPA 417, Standard on Construction and Protection of Aircraft Loading Walkways.
   3. Indoor air-handling units and components shall be designed, fabricated, and installed in compliance with NFPA 90A, “Installation of Air Conditioning and Ventilating Systems.”

N. NEMA Compliance: Motors, enclosures and electrical accessories shall comply with NEMA Standards.

O. UL Compliance: Air-handler units shall be UL-listed and labeled.

P. Comply with the current Florida Building Code.

Q. OSHA: The installation of all PC AIR system equipment to comply with all the requirements of OSHA.

R. Inasmuch as possible, all work related to attaching support brackets, members, etc. to passenger loading bridges shall be done at the loading bridge factory. All of this work, which must be field retrofitted, has to be strictly coordinated with and performed under the direct supervision of the bridge manufacturer, who shall provide field supervision for this work.

1.5 WARRANTY

A. Provide manufacturers one year warranty on all equipment, controls and appurtenances.

1.6 DELIVERY, STORAGE AND HANDLING

A. Lift and support unit with the manufacturer suggested lifting supporting point. Replace any existing supports that are damaged or rusted.

B. Provide unit which do not require any disassembly and reassembly for movement into the final location following manufacturer's written instruction.

C. Deliver unit as a factory-assembled unit to the extent allowable by shipping limitation, with protective crating and covering.

D. Store all equipment and material in suitable weather tight bonded warehouse facilities until delivery and acceptance by the Owner’s Authorized Representative.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. All Manufacturers are subject to compliance with the requirements of these specifications.
   1. Aircraft Pre-conditioned Air-handling Units:
      a. JBT
      b. Cavotec INET US, Inc.
      c. Owner approved substitution
   2. Air Filters:
      a. American Air Filter Company
      b. Farr Company
      c. Eco Air
   3. PBB rooftop units:
      a. Carrier (as coordinated by Bridge Manufacturer)
      b. Owner approved substitution

2.2 PRE-CONDITIONED AIR HANDLING UNIT (PCA AIR Unit)

A. Provide compact, lightweight, and low-noise insulated glycol air-handling units that can be mounted as shown at the passenger loading bridge such that the operational characteristics of the bridge are unrestricted and the bridge's structural integrity is uncompromised. It is the Owner's intent to have the air-handling units hung underneath the bridge. Refer to drawings for specific mounting locations.

B. The new air-handling units shall have a minimum of two distinct assemblies:
    1. A control assembly which contains the low voltage (Class II) logic and control circuits and,
    2. A blower/coil unit containing a blower, variable frequency drive (for PCA AHU), cooling coil, filters, complete motor starting equipment, outlet plenum and condensate drain pan to provide the required cooled air to maintain the aircraft cabin and PBB temperature specified.

C. The PCA air-handling units shall have the capacity required to sufficiently cool the largest designed aircraft, parked at each gate, as designated on the drawings. Units serving jumbo/wide-body gates shall also operate properly when serving a narrow-body aircraft at the same gate. All air-handling units shall be capable of a 45-minute "pull down" for their respective heat "soaked" aircraft from a temperature of 100 deg F to 80 deg F.

D. The PCA and PBB unit blowers shall be centrifugal type and sized for the appropriate volume airflow requirements. The unit size shall be selected so that the fan brake horsepower does not exceed the maximum required over the design operating range of the unit at the total static pressure.

E. The PCA and PBB unit external static pressure shall be defined as the gauge pressure measured at the outlet of the air-handling unit. The Contractor shall present the gauge pressure the PCA air-handling unit can produce at the outlet of the air-handling unit and at the aircraft connection through 100 feet of hose and with an aircraft adapter nozzle in his submittal.

F. The PCA and PBB unit horsepower shall be selected based on the equipment which affects the external resistance of the system. Contractor shall furnish the fan motor and unit size adequate for final total static pressure and maximum brake horsepower requirements.

G. The Contractor shall review and field verify existing conditions at each of the gates.

H. The construction of the PCA and PBB units shall be of a material sufficient to provide adequate structural rigidity for frame and enclosure; of a non-corrosive nature; and provided with thermal insulation for conditions encountered in normal usage. Equipment exterior shall be primed and painted to match bridge color. Equipment interior shall be manufacturer's standard.

I. The maximum sound level for the PCA and PBB air-handling units at maximum cooling shall not exceed 91 dBA at a distance of 15 feet from the unit. Sound power level radiated by the unit outlet and at the unit inlet when the unit is operated at the designated capacity shall be furnished with the submittal.

J. The PCA and PBB air-handling units are required to provide discharge air temperatures as stated in the corresponding equipment schedules on the drawings.

K. Capacity control and defrost control shall be identified and explained in submittals.

L. Return air to the units shall not be utilized.

M. The PCA and PBB air-handling units' enclosure shall provide access doors of the hinged and insulated type. Located as required for proper access to the following:
   1. Blower and VFD (PCA unit only)
   2. Filters
   3. Coils

N. Each PCA air-handling unit shall have a condensate pump and drain pan. The condensate pump shall be lightweight, self-priming, and capable of running dry. Minimum pump rating shall be 1/5 hp or as required by the specific bridge configuration. Position the drain pan under the coil section. Drain pan shall be stainless steel. Condensate pump shall be provided with a summer/winter switch or internal float switch actuated assembly.

O. Each PBB air-handling unit shall have a condensate pump and drain pan. The condensate pump shall be lightweight, self-priming, and capable of running dry. Minimum pump rating shall be 1/50 hp or as required by the specific bridge configuration. Position the drain pan under the coil section. Drain pan shall be stainless steel. Condensate pump shall be provided with a summer/winter switch or internal float switch actuated assembly.

P. All air-handling units shall be prepared with all necessary rails and mounting assemblies to be hung from the underside of the bridges.

Q. All air handling units shall be provided with photoelectric smoke detectors located in such a manner to sense the presence of smoke in the discharge air plenum. All smoke sensing lines from the plenum to the detector shall be furnished in such a manner as to prevent condensation at the smoke detector from cold discharge air.

R. Provide new modulating valves, actuators, control and power wiring for each PCA and PBB unit.

2.3 PCA AND PBB AHU CONTROL ASSEMBLY

The controller assembly for the new air-handler unit shall be designed for mounting directly onto the blower/coil unit or for mounting remote from the blower/coil unit. For the PBB unit, the controller shall be located at the entrance to the bridge.

A. The air-handler controller shall contain the following door mounted controls and displays:
   1. ON and OFF push buttons, lighted. The ON push button shall be operable in the AHU manual mode only.
   2. Summary FAULT indicator (overload).
   3. "Change Filter" light.

B. The PBB AHU shall also include an illuminated remote push button start with green light to indicate "on", timer off and manual override off, mounted inside the entrance to

PBB at rotunda end. Push button shall be of robust construction (not plastic) and include a stainless steel cover plate.

C. The controller shall contain the following operator controls located within the controller cabinet.
   1. Auto/Manual Mode Switch.
   2. Manual override controls (dials or keypad) to manually vary the outlet air temperature and air flow.
   3. PCA units only shall have manual secondary hose damper switch to open or close the second hose damper (Nominal 90 ton air-handler units only).
   4. Connections for remote on/off push-button, aircraft type selector switch, cabin temperature sensor and remote monitoring system for PCA units and connections for remote on/off push-button, bridge temperature and remote monitoring system for PBB AHU.
   5. Connection for shutdown and display of smoke alarm indication.

D. The air handling unit controller shall be direct digital control (DDC) using microprocessor technology for all control, regulation, modulation, alarm shut-down, and response to/from remote signals.

E. The controller shall automatically control the AHU outlet air temperature in response to the temperature as sensed by the companion cabin temperature sensor or bridge thermostat, as applicable.

E. The PCA AHU controller shall automatically sense a failure of the cabin temperature sensor and automatically begin outlet air temperature control based upon sensed inlet ambient temperature. During this backup mode of automatic temperature control, the remote monitoring system shall be supplied with a signal indicating the failure of the cabin temperature sensor.

F. The controller shall, in addition to the above functions, provide for local data display and program updates with laptop computer connected directly to the controller. In addition, the controller shall provide full networking capabilities and built-in control and monitoring communication means with remote devices including, as a minimum, the following points:
   1. Air-handler ON and OFF status and SUMMARY ALARM.
   2. Designation of each alarm condition, by type.
   3. Air outlet and ambient temperatures.
   4. Position of gate GW modulating valve.
   5. Motor speed as % of full rated speed if VFD.
   6. Totalized AHU running time.
   7. Running time since last air filter change-out.
   8. Readout of, and control of, cabin temperature set point or bridge temperature set point, as applicable.
   9. Readout of actual cabin temperature as measured by cabin temperature probe used by the controller logic.
   10. Signal to prohibit starting the AHU (enable/disable).
   11. Readout of and control of mode changeover points and slope versus ambient temperature (backup temperature control in event of cabin temperature sensor failure).

12. Control of auto filter alarm timer set point.
13. Second hose status (open/closed) – Nominal 90 ton gates only.
14. Nighttime cabin temperature set-up mode control including on/off control, set-up temperature set point, mode automatic start and stop times and remote override capabilities to adjust start and stop times.
15. Coil freeze up.
16. Return GW temperature.
17. Controls to be BACnet compatible and connected to nearest building automation system panel.

G. The AHU controller shall contain an internal read-time clock with battery of minimum 30-day life. The battery shall be capable of being changed without losing any internal history, such as total running time or time since last filter change.

H. The controller shall be capable of stand-alone automatic operation in the event of failure of the data/control network.

I. The controller assembly shall be housed in NEMA 3R gasketed enclosed and be suitable for direct mounting on the blower/coil unit or remote mounted.

2.4 CABIN TEMPERATURE CONTROL

A. Each gate shall be equipped with controls to automatically maintain the set PCA cabin temperature within $\pm$ 2 deg F at the sensing point. This shall be by use of a small temperature probe connected to the system by way of a small cable and jack in the bridge cab.

B. The PCA Cabin Temperature Sensor assembly shall consist of a cord mounted sensor element mounted in a Delrin Plastic housing and a mating wall receptacle design for mounting in the cab of a passenger boarding bridge.
   1. The sensor element shall be rated for ambient temperatures listed on ASHRAE Climatic Region Tables most stringent column, be an RTD or solid state element type and be fully compatible with the specified AHU controller.
   2. The sensor shall be housed in the Delrin plastic housing and provide full sealing of the sensor against all weather conditions. The upper end of the housing shall provide openings sufficient to provide necessary air flow across the sensor element while protecting the element from damage when in use or being stored. The sensor shall be connected to a neoprene retractable cable. The cable length shall be approximately four feet retracted and twenty feet extended and be retrained to the sensor housing by a screw-on type waterproof strain relief with O-ring seat.
   3. The receptacle mating end of the cable shall be terminated with 90 deg angle, waterproof type plug with a screw cap for securing to the wall receptacle. The mating receptacle shall be mounted on a stainless steel cover plate. A bracket shall be provided in the bridge cab next to the cover plate for easy storage of the sensor assembly when not in use.

C. Each PBB shall be equipped with a low profile recessed temperature sensor and housing, equal to Veris Industries TS series, mounted on the same side as the ductwork in the PBB.

2.5 PCA AHU BLOWER/COIL UNIT COMPONENTS

A. Casing: Manufacturer's standard casing construction, having corrosion protection coating, and exterior finish. Where the air-handler unit is provided as a utilized enclosure construction, casing shall have removable panels or access doors for inspection and access to internal parts; provide manufacturer's standard thermal insulation, knockouts for electrical and exterior condensate drain connection, and lifting provisions.

B. Blower:
1. General: Provide blower that is factory fabricated and assembled, factory tested and factory finished, with required capacities and characteristics.
2. Blower and Shafts: Statically and dynamically balanced and designed for continuous operation at the maximum rated fan speed and motor horsepower. Blower Shaft: Turned, ground and polished steel designed to operate at no more than 70% of the first critical speed at the top of the speed range of the fan's class.
3. Shaft Bearings: Provide bearings having a median life "Rating Life" (AFBMA L50) of 200,000 calculated in accordance with AFBMA 9 for ball bearings or AFBMA 11 for roller bearings.
4. Factory Finish:
   a. Exterior Sheet Metal Parts: Prime coating prior to final assembly. Final color to match bridge color, color chip to be provided to the manufacturer by the Owner.
   b. Interior Surface: Manufacturer's standard finish is acceptable.
5. Blower: Forward-curved, centrifugal, direct drive fans; and permanently lubricated motor bearings where bearings are not more accessible for greasing.

C. Coils:
1. Aluminum plate fins and seamless copper tube type, minimum 5/8 inch O.D for PCA units and ½ inch O.D for PBB units. Fins shall have collar drawn, belled and firmly bonded to the tubes by means of mechanical or hydraulic-expansion of the tubes.
2. No soldering or tinning shall be used in the bonding process. Coils shall have a galvanized steel casing. Coils shall be mounted on the coil casing with same end connections accessible for service. Coils shall be removable from the unit. Coil section shall be completely insulated.
3. The number of tubes and fin spacing shall be submitted on coil selections made. Coils shall be constructed and tested in general accordance with ASHRE 15 and ARI 410.
4. Coils shall be proof tested at 400 psig and leak tested at 250 psig tested with air pressure under water.

D. Ethylene glycol/water, potable water and condensate drain flexible hoses, for utility transport unit application and connections to rigid piping, shall be of reinforced tube with minimum design operating pressure of 300 psi. Hoses shall be of high-tensile polyester cord spiral with a layer of natural rubber resistant to abrasion, weathering, sun-checking, and water-absorption. Hoses shall maintain a bending radius of 4 inches for 1-1/2 to 2 inch hose and 5 inches for 2-1/2-inch hose. Potable water hoses shall be rated for potable water service.

1. Glycol Hose shall be insulated with a minimum 2" elastomeric insulation per specification Section 23 07 00.01 with finish coating.
2. Flange or union connections to be provided in the supply and return connections at the wall isolation valves.
3. Isolation valves are to be per Section 23 05 23.01.

E. Airflow Control: Airflow control shall be by variable frequency drive control for the PCA air handling units.

F. Inlet Air Filters: Provide medium efficiency pleated disposable air filters suitable for installation in holding frames; two-inch thick minimum for nominal 45 ton PCA units and PBB units, four-inch thick minimum for nominal 90 ton PCA units; constructed of non-woven cotton fabric type. The enclosing frame shall be constructed of rigid, heavy duty, high wet-strength beverage board to the filter pack materials. The filter media internal support shall have welded wire grid. Holding frames shall be fabricated metal construction complete. For WB and NB units, provide filter with rated face velocity of 500 fpm, initial resistance of not greater than 0.30 inches water gauge, final rated resistance of 0.50 inches water gauge and average arrestance of 80%. For jumbo units, provide filters with rated face velocity of 600 fpm. The holding frame and filters shall be sized such that the rate face velocity of the filters shall be sized such that the rated face velocity of the filters is not exceeded at specified AHU mass flow and design inlet ambient temperature conditions.

G. CONDENSATE AND EQUIPMENT DRAIN:
1. Pipe and Fittings:
   a. Type D hard drawn copper inside unit.
   b. Flexible Tubing to be added to any drains from the outside of the unit to within 1'-0" of apron pavement.
2. Insulation: Elastomeric. Refer to Section 23 07 19.13 – Cellular Glass Insulation.

2.6 BRIDGE DELIVERY EQUIPMENT

A. Each bridge with the AHU at the cab end shall be provided with a utility transport unit. Each unit shall carry services like 400 Hz cables, potable water, power to air-handler, data/communication control, etc., to bridge end in a single, low profile package. Refer to Section 2.7, Bridge Utility Transport Unit for further specifications.

B. Moving parts within enclosed utility transport units shall be minimized. Cables and pulleys are not allowed in the operation of the enclosed units. The units shall be designed to allow easy access for maintenance and inspection.

2.7 BRIDGE UTILITY TRANSPORT UNIT

A. The utility transport unit shall meet the mechanical and electrical requirements for an across the bridge utility delivery designed for side mounting on a two- or three-tunnel telescoping ramp drive passenger loading bridge.

B. The general design and construction of the utility transport unit shall be in conformance with sound engineering practices and all equipment and material shall be new.

C. Enclosed units shall not have cables and pulleys used in the operation of the device. Non-enclosed units, such as pantographs, may have cables and pulleys. The unit shall be mounted on the side of the Passenger boarding bridge.

D. The complete utility transport unit shall be fully operational under the logical combinations of the following conditions:
   1. Blowing winds up to 60 MPH in the operation mode and 186 MPH in the non-operational mode.
   2. Ambient temperature range: 32 degF to 120 degF.
   3. All components and connections shall be designed according to FBC (latest and ASCE - 7 latest).

E. The unit shall be capable of containing, protecting and transporting across the telescoping tunnels of the bridge factory-installed GW and potable water hoses, AHU power cable HZ power cable AHU condensate drain hose, network cable and control cable.

F. An enclosed assembly shall consist of two (for 3-tunnel bridges) identical sliding tubes within a main box, designed to mount at three (3) tunnel passenger loading bridge. Both enclosed and non-enclosed units shall extend and retract in synchronism with the movements of the passenger loading bridge.

G. When installed on the bridge, the unit shall permit the bridge to fully extend and react (within normal operating limits) without limiting or restricting bridge movement or imposing excessive loads on the bridge structure.

H. Enclosed Units:
   1. The main box and sliding tube shall be constructed of aluminum.
   2. The main box shall have a three-piece top cover. The top shall be made of aluminum sheet. The top shall be removable for ease of access to interior components.
   3. Each sliding tube shall have sealed ball bearings mounted under the inboard side of the tube to allow for smooth movement.

I. Non-Enclosed Units:
   1. The main tubing shall be constructed of aluminum.
   2. The knuckles or joints shall be aluminum.

J. The brackets that support the unit shall be designed to be welded or bolted to the structural members of each tunnel.

K. The unit shall be supplied complete with mounting brackets, support assemblies and hardware to secure to the passenger loading bridge, either in the field or at the bridge factory. Each bolted joint shall be provided with washers and lock nuts.

L. The exterior surfaces of the unit shall be painted to the color as specified by the Owner.

M. PCA AHU Power Cable
   1. The air-handler power cable shall be compatible with the size and

configuration of the AHU, design ambient temperature conditions and local codes. Cable to be Type W Round with EP insulation, neoprene jacket rated 600/2000 volt, UL listed and 4 conductor #1/0 AWG max.

2. The cable shall be continuous from a junction box at the building to a junction box at the aircraft end of the passenger loading bridge.

N. 400 Hertz Power Cable

1. The 400-Hertz power cable shall be compatible with the size and configuration of the 400-Hertz central system power, design ambient temperature conditions and local codes. Cable to be Type W round with EP insulation, neoprene jacket and rated 600/2000 volt, 4 conductor #2 /0 AWG max.
2. The cable shall be continuous from a junction box at the building to the Aircraft Service Cabinet at the aircraft end of the passenger loading bridge.

O. Network Cable

1. A cable shall be provided for system monitoring of the Pre-Conditioned Air System and PPB AHU units. The cable shall consist of three (3) twisted shielded pair single jacket daisy chain installed in conduit (where existing cable tray is not available). Conduit size one (1") minimum (larger diameter where required). The cable shall be Belden 9773-18/3TSP. Provide Belden 9774 18/4 TSP or as listed on drawings from J -Box to utility transport unit. All cables to be UL recognized.
2. The cable shall be continuous from the network terminal box at the building (or nearest building automation system panel) to a terminal box or AHU controller located at the rotunda end for the PBB AHU and aircraft end of the passenger loading bridge for the PCA unit.

P. Control Cable

1. A single control cable shall be provided to provide for control of components located external to the AHU and control valves. The cable shall provide the required number and type of conductors to provide of those devices where specified.

2.8 SUPPLY AIR DELIVERY SYSTEM

A. General: Each gate to be equipped with necessary accessories to conduct the ethylene glycol and hot water to the PC Air Unit and the supply air from the PC Air Unit to a point at the end of the bridge suitable for connection to the flexible aircraft service hose. All bridges are to be movable.

B. All gates with WB or NB air-handler units shall be provided with a single primary air delivery hose. All gates with jumbo air-handler units shall be provided with a primary and secondary hose. Each hose end shall be provided with an aircraft PCA connection nozzle, Milo mini-adapter, or equal, approved for use by the Owner's Authorized Representative.

C. Telescoping Air Duct (TAD):

1. General: The telescoping air duct shall be a complete assembly of rigid insulated tubing sections, air seals or gaskets, guide bearings, brackets and other mounting and alignment devices. It shall be designed to extend and

retract during the full range of motion of a telescoping passenger loading bridge to which it is attached. It shall be proven in service to withstand thousands of bridge motion cycles while carrying air at the specified conditions from a fixed-mounted air handler at the terminal end of a loading bridge to a connection of flexible duct at the aircraft-end of the bridge.

2. Manufacturer Experience: The telescoping air duct shall be the regularly manufactured product of a company who has designed and manufactured no less than 20 units that are currently in service. The full-retract and full-extend lengths shall be as required to install on the loading bridges as defined in the bid documents or other bridge definition documents.
3. Ratings: The TAD shall be rated to carry pressurized air at up to 40 inches column of H2O at temperatures between 20°F and +150°F. In order to accommodate the required airflows within acceptable pressure drop limits, the inner diameter of the smallest section of duct shall be at least 13.5 inches.
4. In addition, the construction shall allow extension and retraction of the duct assembly while mounted on the bridge, for a minimum of 50,000 full cycles or ten years, without requiring inspection or any scheduled maintenance.
5. Materials and Construction: Telescoping air duct shall be rigid cross-bridge, shall be foam core fiber glass with minimum 1/8" inner and outer fiberglass layer for rigid construction. Polyurethane insulation core shall be flame retardant. Fireproof and smoke proof, as tested and demonstrated according to approved NFPA procedures, with records of such successful testing on existing products previously installed to be submitted as requested by the Port. Telescoping section shall have Teflon bearings and foam seals to minimize air leaks. Seals shall be provided as necessary to limit air leakage during operation to less than 1% under the above rated air pressure conditions. The number of telescoping sections shall match the number of tunnels of the passenger loading bridge at each gate. Provide no hindrance or resistance to bridge retraction or extension in excess of 50kg of force opposing the bridge motion. Cause no limitation of bridge retraction or extension limits be reason of its mounting method beyond a small amount and only as approved by the Port.
6. Furnish telescoping duct with all brackets and supports as recommended by the manufacturer's installation requirements.
7. Mounting: Each telescoping duct assembly shall be provided with a full set of mounting clamps and brackets to attach to the bridge in a manner and coordinated with each bridge manufacturer during the shop drawing submittal process. It is the responsibility of the PC Air Installer to mount TAD brackets.
8. Shipping: Each telescoping duct assembly shall be shipped complete, as an assembly, with all sections retracted into one another. Each assembly shall be marked on the outside of its wrapping with bridge or gate number ID, along with its mounting bracket kit.
9. Drawings and coordination: The manufacturer shall provide mounting installation guide and adequate information to the coordination process with the PC Air Installer. Following complete coordination, the manufacturer shall provide full set of installation drawings and process description, matched gate-by-gate for each bridge.
10. Units with dual hoses shall include tight shut-off dampers with stainless steel exterior locking operators.

D. Flexible Hose:
   1. Air flexible hose shall be of the lightweight insulated type, maximum thermal conductance of 1.28 BTU/Hr /Ft /deg F, pressure rated for 50 inches of water maximum.
   2. Provide helical wire reinforced insulated flexible hose from the end of the telescoping duct to the transition down to the hose basket. The flexible hose is to have inner and outer coverings of polyurethane-coated nylon. The outer covering to be protected with wireless scuff rings constructed of high-profile polyvinylchloride.
   3. Flat insulated extension hoses of a minimum length of 65 feet (3-15 feet, 1-20 feet in length) with quick connect fittings to be furnished for each gate. Hose is to be supplied in sections of no more than 25 feet in length, connected by a closed nylon zipper device, or Velcro connectors with a 14-inch to 8-inch diameter reducing adapter on the end section. The flexible air delivery hoses to be of sufficient length to reach the air conditioning connection for the type of parked aircraft as indicated for each gate. The flexible hose to be connected to the wire-reinforced hose at the transition to the hose basket at the bridge cab. The hose to be a minimum of 14 inches in diameter, lightweight, insulated, with weather-proof outer cover, which is flat when not in use for storage by one person in the hose storage basket mounted at each gate. Air hose overall length shall not exceed 10 feet beyond furthest aircraft connection.
   4. Flexible hoses shall be used from the rigid pipe termination at each gate to connect to the equipment and the utility transport unit. The length of the flexible connections shall provide for full bridge movement and be provided with additional mid-span supports as necessary to ensure that hoses do not interfere with other equipment at the bridge support column.
   5. Color: Standard safety yellow.
   6. Manufacturer:
      a. JBT
      b. Flex-fab
      c. Air Tech, Inc.
      d. Owner approved substitution

E. Fittings and Connections: Provide a high strength plastic or nylon aircraft connector – not subject to damage or deformity when dropped with a flexible hose adapter and stainless steel hardware with coated handles for each gate. Flexible hose is to be provided with a connecting device to allow easy coupling of the adapter without special tools.
   1. Manufacturer:
      a. JBT
      b. Owner approved substitution

F. Storage Basket: A dual compartment storage basket (wheel type) with open front to be provided for storage of the flexible ductwork and aircraft nozzle. The basket at each gate shall be suitable to hold the specified length of flexible hose and is to be mounted to the bridge support mechanism and accessible from the apron level. The mounting of the basket is to not interfere with the operation of the bridge apron-drive and the installation to be acceptable to the bridge manufacturer. The basket is to be reinforced as necessary to move with the bridge without binding or bending. The basket shall be constructed of steel frame with rounded top edges and corners, with sheet steel or expanded steel sides and an open framework or expanded steel bottom. The top front edge (toward hose deployment direction) shall have a minimum radius of 1 inch. On apron drive bridges, the basket shall be mounted to the bridge support mechanism, as directed by the engineer accessible on the air side. The basket shall be painted and primed in accordance with the Painting paragraph of this Section. The basket connection shall be constructed such that it can be readily removed and reconnected. All gates shall be equipped with dual compartment hose baskets for storage of dual hoses as required. Hose baskets shall be adequately sized for storage of all hose assemblies required for servicing the gate, including MD80 extension hoses.

2.9 Passenger Boarding Bridge Rooftop Units (PBB RTU)

A. Refer to specification section 23 74 16.13 - Packaged Rooftop Air-Conditioning Units.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of air-handling units.

B. Do not proceed until unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

A. Furnish all necessary support, brackets, guard posts, safety rails, etc. for proper installation of all air-handling units.

B. The air-handling units shall be properly aligned, adjusted and lubricated and field-tested before final acceptance.

C. Perform water and air system testing and balancing.

3.3 CONNECTIONS

A. Connect new unit to existing Glycol Water Piping, and condensate drain piping.

B. Connect new unit to existing electrical power wiring.

C. Connect new unit to existing control system.

D. Coordinate location of outside air louvers with bridge stairs prior to ordering and installing PCA units. On 3-tunnel bridges outside air intake shall be opposite to bridge stairs.

E. Provide (2) hose bands at the outlet of the PCA unit connection to flex hose, and (2) hose bands at the fiberglass TAD connection. Do not use screws to secure flex hose.

3.4 PRE-CONDITIONED AIR HANDLING UNIT

A. General: The PC Air Manufacturer and Installer are responsible for coordinating the entire installation of the PC Air system with the existing loading bridges. All PC Air equipment on installed on JBT loading bridges shall be approved by the loading bridge manufacturer.

B. Rotunda Mounting: The PC Air Unit is to be mounted as high as possible at the rotunda end of the bridge. Suitable protection is to be provided to prevent accidental head injuries. See drawings and specifications.

C. Servicing: The PC Air Unit, power distribution box, PC Air Unit control cabinet, and the air delivery system ductwork is to be installed in such a manner that each item has sufficient service area without interfering with the service area of any one of the other items or existing equipment in the field. Flexible hose shall also be installed in such a manner that it will not interfere with equipment access on or near rotunda column.

D. Field Assembly: Provide field assembly of components shipped loose with this system. The PC Air Unit including controllers, VFD, fan and other integral devices shall be factory-assembled and tested; field installation of these items is not acceptable.

E. Vibration of Air Handling Equipment and Fan Units: Field vibration levels will not be acceptable for PC Air Unit equipment if the maximum vibration velocity or displacement measurement exceeds the following values (when measurements are taken at the bearing supports using a vibration analyzer with the filter set at the operating fan speed):

F. TABLE - MAXIMUM ALLOWABLE FAN VIBRATION

Fan Speed (RPM)	Maximum Vibration Level
800 or less	5 mils (0.127 mm) max. displacement
801 and greater	0.20 in/sec. (5mm/s) max. velocity

3.5 PIPING

A. General: Refer to Sections 23 21 13 Hydronic Piping, 23 05 23 General Duty Valves for HVAC Piping, 23 05 29 Hangers and Supports, 23 21 16 Piping Specialties and 23 05 48 Mechanical Vibration and Seismic Control.

3.6 SUPPLY AIR DELIVERY SYSTEM

A. General: The installation of the PC Air Unit and supply air delivery system is to in no way restrict the movement of the bridge or the apron drive.

B. Rigid Ductwork: Rigid over-the-bridge telescoping ductwork is to be located above the bottom of the loading bridge on the left side while facing the cab end. Provide and secure all mounting brackets for attachment of the ductwork to the structural members of the bridge. Coordinate the installation with the existing loading bridges. The fiberglass ductwork is to have pigmented resin to match the color of the bridge.

C. Condensate Drain Piping: The condensate drain discharge is to be discharged on to the apron. Flexible tubing is to be used from the outside of the unit to within 1'-0" of the apron.

3.7 ETHYLENE GLYCOL-WATER MAKE-UP SYSTEM

A. 25% ethylene glycol shall be provided for PCA chilled water loop.

3.8 FITTING COVERS AND PIPE JACKETS

A. General: Fitting covers and pipe jackets are to be installed in compliance with the manufacturer's written instructions.

3.9 IDENTIFICATION MARKERS

A. Piping: All PC Air piping is to have identification markers as specified in Section 23 05 53 – Mechanical Identification.

B. Equipment: Equipment identification is compliant with Section 23 05 53 – Mechanical Identification.

C. Labels are to be permanent for outdoor exposure.

3.10 OPERATING AND MAINTENANCE INSTRUCTIONS:

A. Requirement: Refer to Section 01 78 23.13 – Aviation Operations and Maintenance Documentation.

3.11 TESTS

A. Leakage Testing and Balancing: Test and Balance and leakage testing of the entire air delivery system shall be performed by the T&B Agency. See Section 23 05 93 "Testing, Adjusting and Balancing".

3.12 MANUFACTURER'S CHECKOUT:

3.13 TRAINING

A. Refer to Section 23 00 10 – Basic Mechanical Requirements – General and Section 01 79 00 – Training - for specific requirements and durations.

3.14 FIELD QUALITY CONTROL

A. Certified Representatives: Provide at least 1 factory trained representatives of PC Air Unit and Unit controller manufacturers for checkout and startup service. The air handler controller service representative and air handler service representative is to inspect installation and all units installation including piping, wiring and control adjustments prior to startup. After certifying correctness of the electrical installation, the service representatives are to jointly perform initial startup, checkout, calibrate all controls, perform adjustments to insure optimum performance and efficiency. Provide a written report of all data for each individual PC Air Unit. The factory representatives are to assist leak testing of the supply Air delivery system and the PC Air Unit performance testing.

B. Manufacturer's Field Inspection: Arrange and pay for a factory authorized service representative to perform the following:
   i. Inspect the field assembly of components and installation of air-handling units including ductwork and electrical connections.
   ii. Prepare a written report on findings and recommended corrective actions.

3.15 ADJUSTING, CLEANING, AND PROTECTING

A. Comply with Division 01.

B. Clean unit cabinet interiors to remove foreign material and construction dirt and dust. Vacuum-clean fan wheel and cabinet.

C. Provide factory paint touch kits and remove any surface rust and re-finish as required to prevent corrosion and rust.

D. Insulate unit cabinet to prevent condensation.

E. Check and adjust condensate float switch. Check hose is not obstructed in anyway.

3.16 COMMISSIONING

A. Refer to Section 01 91 00 – Commissioning and 23 08 00 HVAC Commissioning.

B. Final checks before start-up shall include but not be limited to:
   1. Remove shipping, blocking and bracing.
   2. Verify unit is secure on mountings and supporting devices and that connections for piping, ductwork, and electrical wiring are complete. Verify proper thermal overload protection is installed in motors, starters and disconnects.
   3. Perform cleaning and adjusting.
   4. Lubricate bearings and other moving parts with factory-recommended lubricants.
   5. Fan is free to turn.

C. Commissioning Procedures for PCA and PBB RTUs shall include but not be limited to:
   1. Functional PCA Unit:
      1) Energize motor: verify proper operation of motor, drive system, and blower wheel. Replace blower and motor as required to achieve design conditions.
      2) Measure and record motor electrical value for voltage and amperage.
      3) Check and demonstrate automatic operation of smoke detectors.

4) Check and demonstrate variable frequency drive operation for wide body and narrow body aircrafts.
5) Check and demonstrate operation of controls, including valves, dampers and sensors.

2. Functional testing of Controls:
   1) Auto-Level interface
   2) Push button station function – Verify lbs./min. of air is provided as listed in equipment submittal at each setting for heating and cooling.
   3) Bridge retraction, extension, lift limit devices coordinated with telescoping duct and PC Air unit equipment
   4) Temperature sensors and other control devices
   5) Building Automation System Control interface, communications and graphics
   6) Defrost coil control
   7) Vibration
   8) Sound level
   9) Fire alarm shutdown through BAS
3. Calibration of:
   1) Temperature sensors
   2) Pressure sensors
   3) VFD and interface to BAS
   4) Sequence of Operation including, but not limited to:
   5) VFD speed associated with position switch at push button station
   6) Heating and cooling coil control valve
   7) Defrost coil control
   8) RTD cabin temperature sensor
   9) Use of ambient temperature control as selected by the Authority.
4. Seasonal Testing:
   1) Contractor shall test equipment modes in appropriate seasons to ensure all equipment is performing per Contract Documents.
   2) Winter testing shall occur between November and February.
   3) Summer testing shall be performed between July and September.

3.17 DEMONSTRATION AND TRAINING

A. Contractor shall arrange and pay for a factory-authorized service representative to train Owner's maintenance personnel per Division 01.

END OF SECTION 23 90 00

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