SECTION 230500
COMMON WORK RESULTS FOR HVAC

GENERAL

RELATED DOCUMENTS

Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

SUMMARY

This Section includes the following:

Piping materials and installation instructions common to most piping systems.
Dielectric fittings.
Mechanical sleeve seals.
Sleeves.
Penetration sealing.
Escutcheons.
Grout.
HVAC demolition.
Equipment installation requirements common to equipment sections.
Painting and finishing.
Concrete bases.
Supports and anchorages.
Roof curbs.
Equipment supports.

DEFINITIONS

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.

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

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

Concealed, Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above solid ceilings and within chases.

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.

The following are industry abbreviations for plastic materials:

CPVC: Chlorinated polyvinyl chloride plastic.
PE: Polyethylene plastic.
PVC: Polyvinyl chloride plastic.

The following are industry abbreviations for rubber materials:

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

SUBMITTALS

Product Data: For the following:

Dielectric fittings.
Mechanical sleeve seals.
Escutcheons.
Supports and anchorages.
Roof curbs.
Equipment supports.

Operations Manual: Include the following:

Final processed submittals of all Division 23 specification sections.
Subcontractor contact list including name, phone number and e-mail contact information.
Valve tag charts.
Field reports, including ductwork leakage testing and piping pressure testing.
Startup reports for all mechanical equipment.
Certifications of piping systems, equipment or systems if specified in the individual specification section.
Testing, adjusting and balancing reports.
ASME Stamp Certification and Reports: “A”, “S”, or “PP” stamp certificates of authorization.
Operations and maintenance information for all equipment.

Processing Time: Allow enough time for submittal review, including time for resubmittals, as follows. Time for review shall commence on Engineer’s receipt of submittal.

Initial review: Allow 15 days for initial review of each submittal. Allow additional time if processing must be delayed to permit coordination with subsequent submittals. Engineer will advise Contractor when a submittal must be delayed for coordination.
Concurrent review: Where concurrent review of submittals by Architect/Engineer’s Consultants, Owner or other parties is required, allow 21 days for initial review of each submittal.

Submittal Schedule:

Contractor shall submit all submittals to the Engineer for initial review within 30 days of award of contract, or within the first 10% of the duration of the project, whichever is less. Submittals which require processing completion prior to 45 days after award of contract shall be scheduled with the Engineer at least 14 days in advance of their requested due date.

QUALITY ASSURANCE

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

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

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

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.

Roofing Standards: Comply with the following:

SMACNA's "Architectural Sheet Metal Manual" details for fabrication including flanges and cap flashing to coordinate with type of roofing indicated.
NRCA's "Roofing and Waterproof Manual" details for installing units.
Existing roofs: Maintain existing roof warranty.

DELIVERY, STORAGE, AND HANDLING

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 into the pipe.

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

Deliver, store and install materials and equipment (including supports and hangers) such that they are maintaining "as-new" condition (e.g. no rust) upon installation and up through the date of Substantial Completion. Account for environmental conditions of the construction site and schedule work accordingly.

Do not allow any materials nor equipment to be stored in standing water from a rainstorm.

COORDINATION

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

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

Coordinate requirements with all trades for the location and size of access doors and frames necessary to gain access to HVAC items. Coordinate these requirements for all HVAC items that are concealed behind finished surfaces. See Division 08.

Existing Utilities: Do not interrupt utilities serving facilities occupied or partially occupied by the Owner or others unless specifically allowed under the following conditions and then only after arranging to provide temporary utility services according to requirements indicated.

Notify Owner at least seven days in advance of proposed utility interruptions. Identify extent and duration of utility interruptions.
Indicate method of proposed utility interruptions in detail.
Do not proceed with proposed utility interruptions without Owner's permission.
All air handling units, rooftop units, exhaust fans, pumps, chillers, refrigeration equipment, boilers, heat exchangers, fan coil units, cabinet unit heaters, fin tube radiation, steam system components and unit heaters are to remain disabled and off unless TAB personnel are on-site actively testing that particular piece of equipment.
Utilization of the permanent installed HVAC systems to condition or pressurize the construction area is not allowed without prior specific written authorization from the Owner listing which equipment may be operated and under what limiting conditions along with written agreement to compensate the Owner for utility usage. Limiting conditions shall include specific written listing of all of these features: filtration requirements for all airstreams; fire alarm/smoke detection for all air streams; schedule for preventative maintenance for bearings, seals and other operated equipment features; hours of operation and which hours will be supervised by contractor personnel on site; written confirmation of operability of all equipment control sequences safeties and alarms; and written maintenance recordkeeping at a minimum.

New Equipment:

All air handling units, rooftop units, exhaust fans, pumps, chillers, refrigeration equipment, boilers, heat exchangers, fan coil units, cabinet unit heaters, fin tube radiation, steam system components and unit heaters are to remain disabled and off unless TAB personnel are on-site actively testing that particular piece of equipment.
Utilization of the permanent installed HVAC systems to condition or pressurize the construction area is not allowed without prior specific written authorization from the Owner listing which equipment may be operated and under what limiting conditions along with written agreement to compensate the Owner for utility usage. Limiting conditions shall include specific written listing of all of these features: filtration requirements for all airstreams; fire alarm/smoke detection for all air streams; schedule for preventative maintenance for bearings, seals and other operated equipment features; hours of operation and which hours will be supervised by contractor personnel on site; written confirmation of operability of all equipment control sequences safeties and alarms; and written maintenance recordkeeping at a minimum.

Coordinate new installations with the existing installations which will remain in place and be reutilized or those that are abandoned in place. Provide transitions and fittings in ductwork and piping as well as extra lengths of ductwork and piping as required to route around these existing installations. Illustrate all such ductwork fittings on the sheet metal duct shop drawing submittal. Existing installations include plumbing, piping, electrical and other building systems components including, but not limited to, roof drain piping, sanitary piping, plumbing piping, fire protection piping, fire protection heads, heating and cooling water piping, condensate drains, steam and condensate return piping, conduit, cable tray, electrical pull boxes, projectors, booms, etc. Coordinate installation of above ceiling components and devices such that maintenance access is achieved at the completion of the project when all ceiling mounted components are installed. Coordinate with all trades. Ultimate responsibility for any rework required to achieve maintenance access is the responsibility of the Contractor responsible for coordination as noted in Division 1 Sections. The required maintenance access is defined here for this contract:

A person with a 24" arm length can stand on a folding ladder which rests on the finished floor and which does not extend through the ceiling grid. All lights and diffusers remain in the grid when defining maintenance access. Ceiling tiles with sprinkler heads, smoke detectors, fire alarm devices and other system devices remain in the grid when defining maintenance access. Light fixtures and diffusers/grilles remain in the ceiling grid when defining maintenance access.

While standing on a step of this ladder which is rated for standing upon and while not leaning against the ceiling grid, this person can touch the following items with both hands at the same time:

Terminal unit/terminal box damper actuators.
Terminal unit/terminal box reheat valve actuators.
Terminal unit/terminal box airflow controller.
Terminal unit/terminal box transformers, EP switches, temperature sensor, and all other control components.
Terminal box discharge low pressure volume dampers on diffuser runouts.
Terminal unit/terminal box piped accessories – strainer, PT ports, air vents, drains, shutoff valves, unions and calibrated balance valves.
Piped hydronic system shutoff valves, calibrated balance valves, control valves, vents, and drains.
Steam system traps, control valves, humidifier components and humidifier control components.
Fire damper and fire/smoke damper duct access doors.
Fire damper and fire/smoke damper fusible links.

Locate buried utility and distribution services within the project area.

Provide temporary connections to maintain existing systems in service during the construction. This may include ductwork, piping, power, controls, water, as well as other connections as required.

Provide the Owner a schedule prior to the start of demolition with phased selected demolition identified by system and by floor. Identify required outages on the schedule and any temporary measures required to maintain existing systems in service.

Coordinate the HVAC demolition with all aspects of demolition and temporary construction (including dust barriers) by other trades.

CONTRACT DOCUMENTS

The drawings indicate the general arrangement and scope of the systems and shall be followed insofar as possible. If deviations from the layout are necessitated by field conditions, detailed layouts of the proposed departures shall be submitted in writing to the Engineer for approval before proceeding with the Work.

The drawings are not intended to show every vertical offset or horizontal offset that may be necessary to complete the system or clear obstructions and/or the Work of other Contractors and other trades. Contractors shall anticipate during bidding that additional offsets may be required and include same in their proposals.

The Drawings, Schedules and Specifications shall be considered to be cooperative and anything appearing in the Specifications that may not be indicated on the Drawings or vice-versa, shall be considered as part of the Contract and must be executed by the Contractor the same as though indicated by both. Clarify conflicting statements with the Engineer prior to submitting a bid.

Measurements: Contractor shall make all his own measurements in the field and shall be responsible for correct fitting. He shall coordinate this Work with all other branches and trades in such a manner as to cause a minimum of conflict or delay. The Contractor shall coordinate

his work in advance with all other trades and report immediately any difficulty which can be anticipated and propose solutions to resolve the potential difficulty.

Adjustments to Work in the Field:

The Engineer reserves the right to make minor adjustments (maximum of 10'-0") in location of sensors, valving, ductwork, dampers, conduit, drains, piping, hangers and/or equipment at no additional charge if so directed prior to their installation.
Where the Drawings show equipment, casework, structure, fire rated construction, or the like, Contractors shall lay out the work to avoid conflicts.
Where offsets in piping, additional fittings, necessary drains, minor valves, traps and devices are required to complete the installation, to clear obstructions, or for the proper operation of the system (including air vents and drains), these shall be deemed to be included in the Contract and shall be furnished and installed complete by the Contractor at no additional charge.
Where offsets in ductwork, additional fittings, necessary transitions, minor fittings, dampers, accessories and devices are required to complete the installation, to clear obstructions, or for the proper operation of the system, these shall be deemed to be included in the Contract and shall be furnished and installed complete by the Contractor at no additional charge.

Clearances: All installations shall be made to maintain maximum headroom and clearance around equipment. When space and/or headroom appear inadequate, the Contractor shall notify the Engineer prior to proceeding with the installation. No claims for additional compensation will be approved for failure on the part of the Contractor or his Subcontractor to comply with this requirement.

RECORD DRAWINGS

Contractor shall provide owner with a complete set of accurate Record Drawings for all work performed under this contract.

Record Drawings shall include all approved change orders and pertinent RFI responses.
Include actual dimensions of equipment furnished under this contractor where shown on the floor plans.
Record Drawings shall include work performed by all sub-contractors retained.
Record Drawings shall include the words "RECORD DRAWING" on each sheet.
Record Drawings shall be completed using **[AutoCAD] [REVIT]** and in a version as directed by the owner.

Submission:

Submit one set of record Drawings for review by Engineer prior to submission of closeout documents. Record Drawings shall be submitted using the established submittal process.
Upon satisfactory review of the Record Drawing submittals by Engineer, provide three (3) printed sets of the Record Drawings and three (3) copies in electronic format with closeout documents
Paper Record Drawings shall be printed full size using the same sheet size as the construction documents issued to the contractor with the contractor's title block.
Electronic Record Drawings shall include **[AutoCAD] [a REVIT]** compatible **[files] [model]** and **[individual PDF files named by sheet and organized in folders by disciplines] [multi-sheet PDF files combined and named by discipline]**.

PRODUCTS

MANUFACTURERS

In other Part 2 articles where subparagraph titles below introduce lists, the following requirements apply for product selection:

Manufacturers: Subject to compliance with requirements, provide products by the manufacturers specified.

Provide all materials necessary for demolition work to occur, including cutting, capping, removing walls for access, and repairing finishes.

PIPE, TUBE, AND FITTINGS

Refer to individual Division 23 piping Sections for pipe, tube, and fitting materials and joining methods.

Pipe Threads: ASME B1.20.1 for factory-threaded pipe and pipe fittings.

Hex bushings, face bushings, and plugs are not acceptable in any Division 23 piping system.

JOINING MATERIALS

Refer to individual Division 23 piping Sections for special joining materials not listed below.

Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.

Steam service: ASME B16.20, spiral wound gasket with stainless steel metal winding strip, flat, asbestos-free graphite filler, 1/8-inch (3.2-mm) maximum thickness unless thickness or specific material is indicated. Suitable for pressure class of service and a minimum operating temperature of 600 deg F. Similar to Flexitallic Style CG.
All other services: Thermoseal C-4401, 1/16” thick.
Do not apply compounds, adhesives, or anti-stick lubricants to gasket surface.

Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.

Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer, unless otherwise indicated.

Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.

Brazing Filler Metals: AWS A5.8, BCuP Series, copper-phosphorus alloys for general-duty brazing, unless otherwise indicated; and AWS A5.8, BAg1, silver alloy for refrigerant piping, unless otherwise indicated.

Welding Filler Metals: Comply with AWS D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

Solvent Cements for Joining Plastic Piping:

CPVC Piping: ASTM F 493.
PVC Piping: ASTM D 2564. Include primer according to ASTM F 656.

Fiberglass Pipe Adhesive: As furnished or recommended by pipe manufacturer.

DIELECTRIC FITTINGS

Description: Combination fitting of copper alloy and ferrous materials with threaded, solder-joint, plain, or weld-neck end connections that match piping system materials.

Insulating Material: Suitable for system fluid, pressure, and temperature.

Dielectric Unions: Factory-fabricated, union assembly, for 250-psig (1725-kPa) minimum working pressure at 225 deg F. Minimum 400 volts dielectric resistance, insulated against galvanic corrosion, threaded ends, O-ring.

Manufacturers:

Capitol Manufacturing Co.
Central Plastics Company.
Eclipse, Inc.
Epco Sales, Inc.
Hart Industries, International, Inc.
Watts Industries, Inc.; Water Products Div.
Zurn Industries, Inc.; Wilkins Div.

Dielectric Flanges: Factory-fabricated, companion-flange assembly, for 150- or 300-psig (1035- or 2070-kPa) minimum working pressure as required to suit system pressures.

Manufacturers:

Capitol Manufacturing Co.
Central Plastics Company.
Drake Specialties.
Epco Sales, Inc.
Watts Industries, Inc.; Water Products Div.

Dielectric-Flange Kits: Companion-flange assembly for field assembly. Include flanges, full-face- or ring-type neoprene or phenolic gasket, phenolic or polyethylene bolt sleeves, phenolic washers, and steel backing washers.

Manufacturers:

Advance Products & Systems, Inc.
Calpico, Inc.
Central Plastics Company.
Drake Specialties.
Pipeline Seal and Insulator, Inc.

Separate companion flanges and steel bolts and nuts shall have 150- or 300-psig (1035- or 2070-kPa) minimum working pressure where required to suit system pressures.

Dielectric Couplings: Galvanized-steel coupling with inert and non-corrosive, thermoplastic lining; threaded ends; and 300-psig (2070-kPa) minimum working pressure at 225 deg F (107 deg C).

Manufacturers:

Calpico, Inc.
Lochinvar Corp.

Dielectric Nipples: Electroplated steel nipple with inert and non-corrosive, thermoplastic lining; plain, threaded, or grooved ends; and 300-psig (2070-kPa) minimum working pressure at 225 deg F (107 deg C).

Manufacturers:

Perfection Corp., Clearflow Dielectric Fittings.
Precision Plumbing Products, Inc.
Sioux Chief Manufacturing Co., Inc.
Victaulic Co. of America.

MECHANICAL SLEEVE SEALS

Description: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.

Manufacturers:

Advance Products & Systems, Inc.
Calpico, Inc.
Metraflex Co.
GPT/Pipeline Seal and Insulator/Link-Seal/Enpro Industries.

Sealing Elements: EPDM interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
Pressure Plates: Glass reinforced nylon polymer or stainless steel. Include two for each sealing element.
Connecting Bolts and Nuts: Stainless steel of length required to secure pressure plates to sealing elements. Include one for each sealing element.

SLEEVES

Galvanized-Steel Sheet: 0.0239-inch (0.6-mm) minimum thickness; round tube closed with welded longitudinal joint.

Steel Pipe: ASTM A 53, Type E, Grade B, Schedule 40 up to 10” NPS, standard weight for 12” NPS and larger, galvanized, plain ends, fabricated with 2” integral seal welded waterstop. Touch up cut ends of galvanized pipe sleeves with zinc-rich coating prior to installation.

Cast Iron: Cast or fabricated "wall pipe" equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.

Manufacturers:

Calpico, Inc.

Stack Sleeve Fittings: Manufactured, cast-iron sleeve with integral clamping flange. Include clamping ring and bolts and nuts for membrane flashing.

Underdeck Clamp: Clamping ring with set screws.

Stainless Steel Sheet: Fabricated 304L stainless steel, 0.078” minimum thickness, round tube closed with welded longitudinal joint, fabricated with 2” integral seal welded waterstop.

PENETRATION SEALING

Penetrations in Horizontal Assemblies:

Annular space fill:

Resists the free passage of flame and the products of combustion.
Approved non-combustible material.

Penetration firestopping:

Fill, void or cavity material that is tested and classified for use in through penetration firestop systems.

ESCUTCHEONS

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.

One-Piece, Cast-Brass Type: With set screw.

Finish: Polished chrome-plated.

Split-Casting, Cast-Brass Type: With concealed hinge and set screw.

Finish: Polished chrome-plated.

One-Piece, Stamped-Steel Type: With set screw or spring clips and chrome-plated finish.

GROUT

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

Characteristics: Post-hardening, volume-adjusting, non-staining, non-corrosive, nongaseous, and recommended for interior and exterior applications.
Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.
Packaging: Premixed and factory packaged.

ROOF CURBS

General: If not specified in individual Division 23 specification sections, provide roof curbs capable of supporting superimposed live and dead loads, including equipment loads and other

construction to be supported on roof curbs. Coordinate dimensions with rough-in information or shop drawings of equipment to be supported.

Manufacturers: Subject to compliance with requirements, provide products by the manufacturers specified:

Creative Metals, Inc.
Custom Curb, Inc.
Greenheck.
Pate Co. (The).
Thybar Corporation.

Fabrication: Unless otherwise indicated or required for strength, fabricate units from minimum 0.0747 inch (1.9 mm) thick, structural quality, hot dip galvanized or aluminum zinc alloy coated steel sheet, factory primed and prepared for painting with welded or sealed mechanical corner joints.

Provide fire retardant treated wood nailers at tops of curbs and formed flanges at perimeter bottom for mounting to roof.
On ribbed or fluted metal roofs, form flange at perimeter bottom to conform to roof profile.
Provide manufacturer's standard rigid or semi-rigid insulation and metal liners.
Provide formed cants and base profile coordinated with roof insulation thickness.
Fabricate units to minimum height of 16 inches (400 mm) unless otherwise indicated.
Sloping roofs: Where slop of roof deck exceeds 1/4-inch per foot (1:48) fabricate curb units with water diverter or cricket and with height tapered to match slope to level tops of units.
Provide curbs suitable for equipment dead weight, wind loads, seismic lifting, and anchoring forces as required.
Provide anchoring instructions.

EQUIPMENT SUPPORTS

General: If not specified in individual Division 23 specification sections, provide equipment supports capable of supporting superimposed live and dead loads, including equipment loads and other construction to be supported. Coordinate dimensions with rough-in information or shop drawings of equipment to be supported.

Fabricate exterior supports from galvanized or stainless materials which are compatible with the equipment, piping and ductwork being supported.

Manufacturers: Subject to compliance with requirements, provide products by the manufacturers specified.

Custom Curb, Inc.
Pate Co. (The).
ThyCurb, Inc.

Fabrication: Unless otherwise indicated or required for strength, fabricate units from minimum 0.0747 inch (1.9 mm) thick, structural quality, hot dip galvanized or aluminum zinc alloy coated steel sheet; factory primed and prepared for painting with welded or sealed mechanical corner joints.

Provide fire retardant treated wood nailers at tops of curbs and formed flanged at perimeter bottom for mounting to roof.
On ribbed or fluted metal roofs, form flange at perimeter bottom to conform to roof profile.

Fabricate units to minimum height of 12 inches (300 mm), unless otherwise indicated.
Sloping roofs: Where slope of roof deck exceeds 1/4-inch per foot (1:48), fabricate support units with water diverters and height tapered to match slope to level tops of units.
Provide supports suitable for equipment dead weight, wind loads, seismic lifting, and anchoring forces as required.
Provide anchoring instructions.

EXECUTION

HVAC DEMOLITION

Refer to Division 1 Section "Cutting and Patching" and Division 2 Section "Selective Structure Demolition" for general demolition requirements and procedures.

Disconnect, demolish, and remove HVAC systems, equipment, and components indicated to be removed. No equipment or components shall be abandoned in place unless specifically noted on the drawings.

Piping to Be Removed: Remove portion of piping indicated to be removed and cap remaining piping with same or compatible piping material.
Piping to Be Abandoned in Place: Drain piping and cap piping with same or compatible piping material.
Ducts to Be Removed: Remove portion of ducts indicated to be removed and cap remaining ducts with same or compatible ductwork material. Seal remaining ductwork to seal Class C. Duct tape is not permitted.
Ducts to Be Abandoned in Place: Cap ducts with same or compatible ductwork material.
Equipment to Be Removed: Disconnect and remove services and remove equipment. Cap piping and ductwork as required.
Equipment to Be Removed and Reinstalled: Disconnect and cap services and remove, clean, store equipment and protect in a safe location during construction to prevent damage; when appropriate, reinstall, reconnect, and make equipment operational.
Equipment Piping and Ductwork to Be Removed and Salvaged: Disconnect and cap services and remove equipment. Owner shall be given first right of refusal to all items removed from the Owner's facility or property. Deliver salvaged items to Owner at location requested by Owner.
When removing piping and ductwork components, all accessories, hangers, insulation and hanger rods shall be removed also.
Provide temporary hangers for any pipe or duct to remain which has had hangers removed such that hanger spacing does not exceed 10'-0".
Provide temporary hangers for any pipe or duct which was supported by a wall which was removed.
Locate and identify mechanical systems passing through the affected demolition area which serves other areas outside the demolition limits. Provide information to the Engineer directly of any questionable items.
Systems serving areas outside the work limits shall remain uninterrupted unless specifically authorized in writing by the Owner.

If pipe, insulation, or equipment is damaged in appearance or is unserviceable due to demolition work, remove damaged or unserviceable portions and replace with new products of equal capacity and quality.

All caps installed shall be installed and located such that the pipe or duct may be reconnected to and extended without relocation of other components while utilizing standard fittings.

Coordinate with all trades such that any existing, temporary or new installations by other trades does not block access to caps.

Confirm with the Owner, which if any, supply, return or exhaust air openings associated with systems which serve the project area may remain in use during construction. Cover all supply, return and exhaust air openings with synthetic air filter media, 1-inch thick, with non-oily tackified surface, with a dust holding capacity of at least 250 grams per square yard, an average dust spot arrestance of at least 85 percent, and a MERV rating of at least 6. Allow in the bid to replace the air filter media at least once per month and more often as required for proper operation of the fan systems.

Removal of portions of systems which are energized or will be energized at any point during the construction project shall be accomplished by skilled trades who will be contractually engaged in connecting new work (piping, ductwork or caps thereof) to these same systems.

PIPING SYSTEMS - COMMON REQUIREMENTS

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

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.

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

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.

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

Install piping to permit valve servicing.

Install piping at indicated slopes.

Install piping free of sags and bends.

Install fittings for changes in direction and branch connections. Utilize tee fittings for branch connections that have all three connection sizes of NPS 1-1/2” and larger. It is acceptable to utilize threadolet fittings with dielectric nipples on carbon steel piping of NPS 2-1/2” and larger when the branch connection size is NPS 1” or less and a bronze body ball valve is installed on the other end of the dielectric nipple.

Install piping and ductwork to allow application of insulation.

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

Install escutcheons for penetrations of walls, barriers, ceilings, and floors in exposed areas. In Dietary, Kitchen, Cafeteria, Sterile Processing, Sterilizer, Sub-Sterile, Animal Holding,

Operating Rooms, Procedure Rooms and other sterile areas do not install escutcheons, but seal pipe penetrations airtight with clear food grade silicone.

New concrete floors, walls, and roof penetrations are required to have sleeves cast-in-place (no core drilling is allowed unless specifically noted on the drawings).

Core drilling in buildings that are occupied up to two floors above the construction area or two floors below the construction area or are occupied on the same floor within 100 linear feet shall be accomplished with wet core drilling machines with slurry extraction to reduce noise.

Install sleeves for pipes passing through concrete and masonry walls, gypsum-board partitions, and concrete floor and roof slabs. It is the contractors requirement to coordinate fine sleeve placement and size.

Cut sleeves to length for mounting flush with both surfaces.

Exception: Extend top of sleeves installed in all floors (including mechanical equipment areas) and penthouses 2 inches (50 mm) above finished floor level. Waterstop shall be entirely contained within concrete with approximately 1-1/2-inch of concrete cover. Extend cast-iron sleeve fittings below floor slab as required to secure clamping ring if ring is specified.

Install sleeves in new walls and slabs as new walls and slabs are constructed.
Install sleeves that are large enough to provide 1/4-inch (6.4-mm) annular clear space between sleeve and pipe or pipe insulation. Use the following sleeve materials:

Steel pipe sleeves, cast iron pipe sleeves or stainless steel sheet sleeves for all pipes penetrating other than gypsum board partitions or walls.
Galvanized Steel Sheet Sleeves: For pipes and larger, penetrating gypsum-board partitions or walls.
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 7 Section "Joint Sealants" for materials and installation.

Aboveground, Exterior-Wall Pipe Penetrations: Seal penetrations using sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.

Install steel pipe for sleeves smaller than 6 inches (150 mm) in diameter.
Install cast-iron "wall pipes" for sleeves 6 inches (150 mm) and larger in diameter.
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.

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 (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.

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.

Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, barriers, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Refer to Division 7 Section "Firestopping" for materials.

Verify final equipment locations for roughing-in.

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

Install piping, hangers and equipment so that they do not interfere with fully opening the access panels on any part of the structure, any contractor installed access panels, nor access panels on any equipment (either contract provided or Owner provided or Owner installed equipment).

Install piping, hangers and equipment so that they do not interfere with personnel movement. Components shall be a minimum of 7'-6" above finished floor unless specifically noted to be installed lower. Provide personnel protection on components located less than 6'-6" above finished floor (elastomeric insulation, caution markings).

PIPING JOINT CONSTRUCTION

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

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

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

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.

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

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:

Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
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.

Welded Joints:

Construct carbon steel joints according to AWS D10.12, using qualified processes and welding operators according to Part 1 "Quality Assurance" Article.
Construct stainless steel joints according to AWS D10.4, using qualified processes and welding operators according to Part 1 "Quality Assurance" Article.
Construct aluminum joints according to AWS D10.7, using qualified processes and welding operators according to Part 1 "Quality Assurance" Article.

Utilize AWS D10.11 Guide for Root Pass Welding of Pipe without Backing for all Welding Operations. Purge as required to obtain a smooth root surface.

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

Plastic Piping Solvent-Cement Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:

Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.
CPVC Piping: Join according to ASTM D 2846/D 2846M Appendix.
PVC Pressure Piping: Join schedule number ASTM D 1785, 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.
PVC Non-pressure Piping: Join according to ASTM D 2855.

Plastic Pressure Piping Gasketed Joints: Join according to ASTM D 3139.

Plastic Non-pressure Piping Gasketed Joints: Join according to ASTM D 3212.

PE Piping Heat-Fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657.

Plain-End Pipe and Fittings: Use butt fusion.
Plain-End Pipe and Socket Fittings: Use socket fusion.

Fiberglass Bonded Joints: Prepare pipe ends and fittings, apply adhesive, and join according to pipe manufacturer's written instructions.

PIPING CONNECTIONS

Make connections according to the following, unless otherwise indicated:

Install unions, in piping NPS 2 (DN 50) and smaller, adjacent to each valve and at final connection to each piece of equipment.
Install flanges, in piping NPS 2-1/2 (DN 65) and larger, adjacent to flanged valves and at final connection to each piece of equipment.
Dry Piping Systems: Install dielectric unions and flanges to connect piping materials of dissimilar metals.
Wet Piping Systems: Install dielectric coupling and dielectric nipple fittings to connect piping materials of dissimilar metals. Do not utilize dielectric unions with O-rings on wet piping systems.

EQUIPMENT INSTALLATION - COMMON REQUIREMENTS

Install equipment to allow maximum possible headroom unless specific mounting heights are not indicated. Provide a minimum of 7’-2” headroom under all exposed equipment.

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

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.

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

Comply with the equipment manufacturer's written installation instructions.

Provide access platforms on the side of equipment where the access level is more than 30 inches above the roof or floor. Provide handrail guards that extend 42" above the platform in accordance with the International Building Code. Provide a permanent ladder or stairs to access the platform. All platforms, guards and stair/ladder materials shall be non-corrosive. Handrails shall be readily removable for removal of equipment components.

PAINTING

Painting of HVAC systems, equipment, and components is specified in Division 9 Sections.

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

CONCRETE BASES

Concrete Bases: Anchor equipment to concrete base according to equipment manufacturer's written instructions and according to seismic codes at Project. If concrete bases are not detailed on the drawings, then furnish:

Construct concrete bases of dimensions indicated, not less than 3.5 inches thick and not less than 4 inches (100 mm) larger in both directions than supported unit.
Install bonding agent to connect concrete base to concrete floor. Apply to 100% of the contact area between base and floor.
Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.
Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
Install anchor bolts to elevations required for proper attachment to supported equipment.
Install anchor bolts according to anchor-bolt manufacturer's written instructions.
Use 3000-psi (20.7-MPa), 28-day compressive-strength concrete and reinforcement as specified in Division 3 Section. If not specified, utilize #4 reinforcing at 12" on center each way with #4 around the perimeter.

ERECTION OF METAL SUPPORTS AND ANCHORAGES

Refer to Division 5 Section "Metal Fabrications" for structural steel.

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

Field Welding: Comply with AWS D1.1.

ERECTION OF WOOD SUPPORTS AND ANCHORAGES

Cut, fit, and place wood grounds, nailers, blocking, and anchorages to support, and anchor HVAC materials and equipment.

Select fastener sizes that will not penetrate members if opposite side will be exposed to view or will receive finish materials. Tighten connections between members. Install fasteners without splitting wood members.

Attach to substrates as required to support applied loads.

GROUTING

Mix and install grout for HVAC equipment base bearing surfaces, pump and other equipment base plates, and anchors.

Clean surfaces that will come into contact with grout.

Provide forms as required for placement of grout.

Avoid air entrapment during placement of grout.

Place grout, completely filling equipment bases. Obtain pump manufacturer's written installation instructions.

Place grout on concrete bases and provide smooth bearing surface for equipment.

Place grout around anchors.

Cure placed grout.

ROOF CURBS AND EQUIPMENT AND PIPE SUPPORTS

General: Comply with manufacturer's written instructions. Coordinate installation of roof accessories with installation of roof deck, roof insulation, flashing, roofing membranes, penetrations, equipment, and other construction involving roof accessories to ensure that each element of the work performs properly and that combined elements are waterproof and weathertight. Anchor roof accessories securely to support structural substrates so they are capable of withstanding lateral and thermal stresses, and inward and outward loading pressures.

All roof repairs shall be completed by a roofing contractor that is certified by the manufacturer of the existing and new roofing systems. All roof repairs shall be completed with materials and workmanship that is fully compatible with the roofing system and in full accordance with the roofing manufacturer's written installation requirements to maintain the roof warranty.

Install roof accessory items according to construction details of NRCA's "Roofing and Waterproofing Manual" unless otherwise indicated.

Separation: Separate metal from incompatible metal or corrosive substrates, including wood, by coating concealed surfaces or at locations of contact, with bituminous coating or providing other permanent separation.

Flange Seals: Unless otherwise indicated, set flanges of accessory units with a thick bed of roofing cement to form a seal.

Cap Flashing: Where required as component of accessory, install cap flashing to provide waterproof overlap with roofing or roof flashing (as counterflashing). Seal overlap with thick bead of mastic sealant.

CUTTING AND PATCHING

Refer to Division 2 for general cutting and patching requirements and procedures.

Cut, channel and drill floors, walls, partitions, shafts, ceiling sand other surfaces required to permit electrical installations and demolition. Perform cutting by skilled mechanics of trades involved.

Repair and refinish disturbed finish materials and other surfaces to match adjacent undisturbed surfaces. Install new fireproofing where existing firestopping has been disturbed. Repair and refinish materials and other surfaces by skilled mechanics of trades involved.

FIRESTOPPING

Apply firestopping to penetrations of fire-rated floor and wall assemblies for all installations to restore original fire-resistance rating of assembly. Apply firestopping to structure where demolition exposes the structure. Firestopping materials and installation requirements are specified in Division 7 Section “Firestopping”.

Apply firestopping as indicated to seal penetrations in Paragraph “Penetration Sealing”.

Apply firestopping to all penetrations of smoke barriers. Provide an approved through penetration firestop system installed and tested in accordance with the requirements of UL 1479 for air leakage. The L rating for each firestop system shall not exceed 5.0 cfm per square foot at 0.30 inches of water in both ambient and elevated temperature tests.

PENETRATION SEALING

Horizontal assembly penetrations of all floors, floor/ceiling assemblies and ceiling membranes of roof/ceiling assemblies shall be sealed as follows:

Non-fire resistance rated assemblies with non-combustible penetrating items shall utilize annular space fill or penetration firestopping.
Fire resistance rated assemblies shall utilize penetration firestopping.

All Penthouse floor penetrations shall be sealed.

All attic floor penetrations shall be sealed.

All enclosed spaces which house HVAC equipment shall have all penetrations of the horizontal and vertical membranes which separate the space from occupied and unoccupied building spaces sealed.

Penetrations to be sealed shall include, at a minimum, all piping, ductwork, flues, vents, chimneys, conduit and cabling penetrations installed.

CLEANING AND PROTECTION

On completion of installation, inspect exposed finish. Remove burrs, dirt, paint spots and construction debris. This requirement applies for components including piping and ductwork which are located above lay-in and hard ceilings, especially their upper surfaces prone to collect dust and debris.

Protect equipment and installations and maintain conditions to ensure that coatings, finishes, and cabinets are without damage or deterioration at time of Substantial Completion. Repair all coatings, finishes and cabinets to “as-new” conditions prior to Substantial Completion.

Remove all un-utilized construction materials from the project area.

Trim rod hangers to a maximum exposed threaded length of 1” below the bottom nut.

Protect all Owner provided spare parts. Obtain written receipt of Owner acceptance of spare parts denoting the quantities and storage location.

END OF SECTION

SECTION 230513
COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. This Section includes basic requirements for factory-installed motors.

1.3 DEFINITIONS

A. Factory-Installed Motor: A motor installed by motorized-equipment manufacturer as a component of equipment.

1.4 SUBMITTALS

A. Product Data for Installed Motors: For each type and size of motor, provide:

1. Nameplate data and ratings (hp; full load amps; rpm; voltage; power factor; temperature rise class; insulation class; service factor; enclosure type, frame material of construction).
2. Shipping weights.
3. Four pole, nominal 1,800 rpm, full load, nominal efficiency.

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. Comply with NFPA 70.

1.6 COORDINATION

A. Coordinate features of motors, installed units, and accessory devices. Provide motors that are:

1. Compatible with the following:

a. Magnetic controllers.
b. Multi-speed controllers.

c. Reduced-voltage controllers.
d. Variable frequency controllers:

1) Cable distance.
2) Operation of the variable frequency controller at up to 90 Hz.

2. Matched to torque, speed and horsepower requirements of the load.
3. Matched to ratings and characteristics of supply circuit and required control sequence.
4. Matched to ambient and environmental conditions at installation location.

B. Motors shall not operate in service factor range.

C. Coordinate motor support with requirements for driven load; access for maintenance and motor replacement; installation of accessories, belts, belt guards; and adjustment of sliding rails for belt tensioning.

D. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 3 Section.

PART 2 - PRODUCTS

2.1 MOTOR REQUIREMENTS

A. Motor requirements apply to all motors except when starter requirements, performance or characteristics for a motor are specified in another section or on the drawings.

2.2 MOTOR CHARACTERISTICS

A. Motors 3 HP and Larger: Three phase.

B. Motors Smaller Than 3 HP:
1. Single or three phase as identified on the construction documents.
2. Shall utilize an Electrically Commutated Motor

C. Frequency Rating: 60 Hz.

D. Voltage Rating: Matched to voltage of supply circuit.

E. Service Factor: 1.35 for 1/3 HP and below; 1.25 above 1/3 HP to 3/4 HP; 1.15 above 3/4 HP.

F. Duty: Continuous duty at ambient temperature of 105 deg F (40 deg C) and at altitude of 3300 feet (1005 m) above sea level.

G. Capacity and Torque Characteristics: NEMA Standards MG1; 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.

H. Enclosure: Open drip-proof unless noted otherwise in specific equipment specification or on the drawings. Motor enclosures in hazardous areas shall be of the proper UL Class and group for the atmosphere in which they are located.

2.3 POLYPHASE MOTORS

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

B. Nominal Efficiency: Four-pole, full load, minimum nominal efficiency and minimum power factor at nominal 1,800 rpm and nominal 460 VAC:

HP	MINIMUM EFFICIENCY PERCENT	MINIMUM POWER FACTOR
1	85.5	75
1.5	86.5	75
2	86.5	75
3	87.5	75
5	89.5	75
7.5	91.0	75
10	91.7	80
15	93.0	80
20	93.0	80
25	93.6	85
30	94.1	85
40	94.1	85
50	94.5	85
60	95.0	85
75	95.0	85
100	95.4	85
125	95.4	85
150	95.8	85
200	95.8	85

C. Service Factor: Minimum 1.15.

D. Stator: Copper windings, unless otherwise indicated.

1. Multi-speed motors shall have separate winding for each speed.

E. Rotor: Squirrel cage, unless otherwise indicated.

F. Bearings: Double-shielded, prelubricated ball bearings less than 40 HP, regreasable 40 HP and larger, suitable for radial and thrust loading.

G. Temperature Rise: Class B at 1.0 service factor, unless noted otherwise.

H. Insulation: Class F, unless otherwise indicated.

I. Code Letter Designation: NEMA code letters for AC motors normally started on full voltage. NEMA starting code for Code G for motors 15 Hp and larger.

J. Enclosure Material: Cast iron for motors 10 HP and larger; rolled steel for motors smaller than 10 HP.

2.4 POLYPHASE MOTORS WITH ADDITIONAL REQUIREMENTS

A. Motors Used with Reduced-Inrush Controllers: Match wiring connection requirements for controller with required motor leads. Provide terminals and/or leads 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. Designed and labeled for inverter duty per NEMA MG-1, Part 31 in its entirety and suitable for use throughout 20% to 150% motor base speed range in a variable torque application without overheating.

1. Designed with critical vibration frequencies outside operating range of controller output.
2. Temperature Rise: Class F.
3. Insulation: Class H IEEE Standard 117. Designed to resist transient spikes, high frequencies and short time pulses.
4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.
5. Provide a factory installed, maintenance free, circumferential shaft grounding ring to discharge shaft currents to ground. Grounding ring shall be installed at the motor manufacturer’s factory on the drive end of the motor.

C. Severe-Duty Motors: Totally enclosed, with 1.15 minimum service factor, greased bearings, integral condensate drains, and capped relief vents. Windings insulated with non-hygroscopic material. Comply with IEEE 841.

1. Finish: Chemical-resistant paint over corrosion-resistant primer.

2.5 SINGLE-PHASE MOTORS

A. Type: One of the following, to suit starting torque and requirements of specific motor application:

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

B. Shaded-Pole or Permanent Split Capacitor Motors: For motors 1/20 hp and smaller only.

C. Motors that are 1/12 HP or greater and less than 1 HP shall be electronically commutated motors with a minimum efficiency of 70 percent when rated in accordance with DOE 10 CFR 431.

D. 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.

E. Bearings: Ball type for belt-connected motors and other motors with high radial forces on motor shaft; sealed, prelubricated-sleeve type for other single-phase motors.

F. Source Quality Control: Perform the following tests on each motor according to NEMA Standards MG 1:

1. Measure winding resistance.
2. Read no-load current and speed at rated voltage and frequency.
3. Measure locked rotor current at rated frequency.

G. Electronically Commutated Motor Speed Controller: Integral with the motor, sized and matched for motor by the motor manufacturer, capable of at least a 20% speed adjustment increase and 50% speed decrease via a manual potentiometer. Provide all transformers and wiring factory mounted for a completely functional unit. Furnish controller analog input or two speed input as required to meet the control sequence. Coordinate with Building Automation System submittals.

2.6 ELECTRONICALLY COMMMUTATED MOTOR

A. Motor shall be an electronic commutated (EC) motor specifically designed for fan applications.

B. Motor shall be speed controllable down to 20% of full speed. Speed shall be controlled either by a potentionmeter dial mounted on the motor or by a 0-10 VDC signal.

C. Motor shall be 80% efficient at all speeds rated in accordance with NEMA Standard MG 1-2006

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas to receive motors for compliance with requirements, installation tolerances, and other conditions affecting performance.

B. Examine roughing-in of conduit systems to verify actual locations of conduit connections before motor installation.

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

D. For each electronically commutated motor furnished, provide an electronically commutated motor speed controller.

3.2 MOTOR INSTALLATION

A. Anchor each motor assembly to base, adjustable rails, or other support, arranged and sized according to manufacturer's written instructions. Attach by bolting. Level and align with load transfer link.

B. Comply with mounting and anchoring requirements specified in Division 23 Section "HVAC Vibration and Seismic Controls."

3.3 FIELD QUALITY CONTROL

A. Prepare for acceptance tests as follows:

1. Run each motor with its controller. Demonstrate correct rotation, alignment, and speed at motor design load.
2. Test interlocks and control features for proper operation.
3. Verify that current in each phase is within nameplate rating.

B. Testing: Perform the following field quality-control testing:

1. Perform each electrical test and visual and mechanical inspection stated in NETA ATS, Section 7.15.1. Certify compliance with test parameters.
2. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

C. Manufacturer's Field Service: Engage a factory-authorized service representative to perform the following:

1. Inspect field-assembled components, equipment installation, and piping and electrical connections for compliance with requirements.
2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
3. Verify bearing lubrication.
4. Verify proper motor rotation.
5. Test Reports: Prepare a written report to record the following:

    a. Test procedures used.
    b. Test results that comply with requirements.
    c. Test results that do not comply with requirements and corrective action taken to achieve compliance.

3.4 ADJUSTING

A. Align motors, bases, shafts, pulleys and belts. Tension belts according to manufacturer's written instructions.

3.5 CLEANING

A. After completing equipment installation, inspect unit components. Remove paint splatters and other spots, dirt, and debris. Repair damaged finish to match original finish.

B. Clean motors and nameplates, on completion of installation, according to manufacturer's written instructions.

END OF SECTION

SECTION 230529
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 and Supplementary Conditions and Division 1 Specification Sections, apply to 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 5 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" and "Nonmetal 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 seismic-restraint hangers and supports for piping and equipment.

1.5 SUBMITTALS

A. Product Data: For the following:

1. Steel pipe hangers and supports. Include piping system schedule delineating which piping systems receive roller hangers.
2. Thermal-hanger shield inserts.
3. Powder-actuated fastener systems.
4. Spring hangers utilized at pumps and other locations.

B. 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.

1.6 QUALITY ASSURANCE

A. Welding: Qualify procedures and personnel according to the following as applicable:

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.

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. B-Line Systems, Inc.; a division of Cooper Industries.
2. Carpenter & Paterson, Inc.
3. ERICO/Michigan Hanger Co.
4. Anvil International, Inc.
5. National Pipe Hanger Corporation.
6. PHD Manufacturing, Inc.
7. PHS Industries, Inc.
8. Piping Technology & Products, Inc.
9. Tolco Inc.

C. Galvanized, Metallic Coatings: Pregalvanized or hot dipped.

D. Nonmetallic Coatings: Plastic coating, jacket, or liner.

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. Power-Strut Div.; Tyco International, Ltd.
4. Thomas & Betts Corporation.
5. Tolco Inc.
6. 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 SHIELDS

A. Description: Carbon steel, galvanized finish, shield. For use with Clevis hangers with ribs to keep shield centered in hanger. MSS-SP-69 Type 40.

2.6 THERMAL-HANGER SHIELD INSERTS

A. Description: 100-psig- (690-kPa-) 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: Water-repellent treated, ASTM C 552, Type II cellular glass with vapor barrier.

D. Insulation-Insert Material for Hot Piping: Water-repellent treated, ASTM C 533, Type I calcium silicate or ASTM C 552, Type II cellular glass.

E. For Trapeze and Clamped Systems: Insert and shield shall cover entire circumference of pipe.

F. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.

G. Insert Length: Extend 2 inches (50 mm) beyond sheet metal shield for piping operating below ambient air temperature.

2.7 FASTENER SYSTEMS

A. Mechanical-Expansion Anchors: Insert-wedge-type zinc-coated or stainless 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.

2.8 PIPE STAND FABRICATION

A. Pipe Stands, General: Shop or field-fabricated assemblies made of manufactured corrosion-resistant components to support piping.

B. Compact Pipe Stand: One-piece UV-inhibited plastic unit with integral-rod-roller, pipe clamps, or V-shaped cradle to support pipe, for roof installation without membrane penetration, complete with seismic restraints. All metal components shall be hot dipped galvanized in accordance with ASTM A123 after fabrication.

1. Manufacturers:

a. ERICO/Michigan Hanger Co.
b. MIRO Industries.
c. Portable Pipe Hangers.

C. 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.

2.9 EQUIPMENT SUPPORTS

A. Description: Welded, shop- or field-fabricated equipment support made from structural-steel shapes.

2.10 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, non-shrink and nonmetallic grout; suitable for interior and exterior applications.

1. Properties: Non-staining, non-corrosive, and nongaseous.
2. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.

PART 3 - EXECUTION

3.1 HANGER AND SUPPORT APPLICATIONS

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 come into direct contact with galvanized piping.

D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.

E. Use pre-galvanized (hot dipped galvanized not required) or plain finish for indoor steel pipe hangers unless otherwise indicated.

F. 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 non-insulated or insulated stationary pipes, NPS 1/2 to NPS 30 (DN 15 to DN 750). Install second upper locknut on hanger rod and tighten.
2. Adjustable, Swivel-Ring Band Hangers (MSS Type 10): For suspension of non-insulated stationary pipes, NPS 1/2 to NPS 2 (DN 15 to DN 50).

3. U-Bolts (MSS Type 24): For support of heavy pipes, NPS 1/2 to NPS 30 (DN 15 to DN 750).
4. Pipe Stanchion Saddles (MSS Type 37): For support of pipes, NPS 4 to NPS 36 (DN 100 to DN 900), with steel pipe base stanchion support and cast-iron floor flange and with U-bolt to retain pipe.
5. Adjustable, Pipe Saddle Supports (MSS Type 38): For stanchion-type support for pipes, NPS 2-1/2 to NPS 36 (DN 65 to DN 900), if vertical adjustment is required, with steel pipe base stanchion support and cast-iron floor flange.
6. Single Pipe Rolls (MSS Type 41): For suspension of pipes, NPS 1 to NPS 30 (DN 25 to DN 750), from 2 rods if longitudinal movement caused by expansion and contraction might occur.
7. Adjustable Roller Hangers (MSS Type 43): For suspension of pipes, NPS 2-1/2 to NPS 20 (DN 65 to DN 500), from single rod if horizontal movement caused by expansion and contraction might occur.
8. Complete Pipe Rolls (MSS Type 44): For support of pipes, NPS 2 to NPS 42 (DN 50 to DN 1050), if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is not necessary.
9. Adjustable Pipe Roll and Base Units (MSS Type 46): For support of pipes, NPS 2 to NPS 30 (DN 50 to DN 750), if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.

G. 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 12.
2. Carbon- or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers, NPS 14 to NPS 20, if longer ends are required for riser clamps.

H. 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 (150 mm) for heavy loads.
2. Steel Weldless Eye Nuts (MSS Type 17): For 120 to 450 deg F (49 to 232 deg C) piping installations.

I. 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. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.
4. C-Clamps (MSS Type 23): For structural shapes.
5. Top-Beam Clamps (MSS Type 25): For top of beams if hanger rod is required tangent to flange edge.
6. Side-Beam Clamps (MSS Type 27): For bottom of steel I-beams.
7. Steel-Beam Clamps with Eye Nuts (MSS Type 28): For attaching to bottom of steel I-beams for heavy loads.
8. Linked-Steel Clamps with Eye Nuts (MSS Type 29): For attaching to bottom of steel I-beams for heavy loads, with link extensions.

9. Malleable Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.
10. 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 (340 kg).
    b. Medium (MSS Type 32): 1500 lb (680 kg).
    c. Heavy (MSS Type 33): 3000 lb (1360 kg).

11. Horizontal Travelers (MSS Type 58): For supporting piping systems subject to linear horizontal movement where headroom is limited.

12. For building attachments other than those indicated (such as Z purlins), install appropriate attachments directly to building or install unistrut to structure and hang from the unistrut. Clarify with the Structural Engineer as required

J. 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.

K. 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 (32 mm).
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.

L. Comply with MSS SP-69 for trapeze pipe hanger selections and applications that are not specified in piping system Sections.

M. Comply with MFMA-102 for metal framing system selections and applications that are not specified in piping system Sections. Utilize powder coated channel for all channel exposed to view in occupied spaces and mechanical spaces.

N. Use mechanical-expansion anchors instead of building attachments where required in concrete construction. Do not utilize powder-actuated fasteners.

3.2 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. 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 fabricated 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:

1. Arrange for grouping of parallel runs of piping and support together on field-assembled metal framing systems.
2. Provide vinyl frame caps on the ends of framing members which are located less than 8’-0” above finished floor.

D. Thermal-Hanger Shield Installation: Install in pipe hanger or shield for insulated piping.

E. Fastener System Installation:

1. 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. Curb-Mounting-Type Pipe Stands: Assemble components or fabricate pipe stand and mount on permanent, stationary roof curb. Refer to Division 7 Section "Roof Accessories" for curbs.
2. Insulate pipe stands which come in direct contact with piping or piping system components which operate below 50 deg F.

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 4 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 (DN 100) 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 (DN 100) 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 (DN 8 to DN 90): 12 inches (305 mm) long and 0.048 inch (1.22 mm) thick.
    b. NPS 4 (DN 100): 12 inches (305 mm) long and 0.06 inch (1.52 mm) thick.
    c. NPS 5 and NPS 6 (DN 125 and DN 150): 18 inches (457 mm) long and 0.06 inch (1.52 mm) thick.

d. NPS 8 to NPS 14 (DN 200 to DN 350): 24 inches (610 mm) long and 0.075 inch (1.91 mm) thick.
e. NPS 16 to NPS 24 (DN 400 to DN 600): 24 inches (610 mm) long and 0.105 inch (2.67 mm) thick.

5. Pipes NPS 8 (DN 200) and Larger: Include wood inserts.
6. Insert Material: Length at least as long as protective shield.
7. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.
8. Pipe Spacing: Arrange piping so that a minimum of 2-1/2" of clear space exists between the outer surface of the pipe insulation on parallel piping.
9. Spaces with no ceiling: Attach protective insulation shield to hanger utilizing tack weld such that shield cannot be dislodged from the hanger.

3.3 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.

D. Paint interior supports with corrosion resistant paint.

E. Insulate supports which come in direct contact with equipment or piping which operates below 50 deg F.

F. Fabricate exterior supports from galvanized or stainless materials which are compatible with the equipment, piping and ductwork being supported.

3.4 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 D1.1 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.

D. Provide brush-on galvanizing touch-up for all bare metal exposed during installation or assembly. Galvanizing touch-up shall be compatible with original galvanized material.

3.5 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 1-1/2 inches (40 mm).

3.6 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 (0.05 mm).

B. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

END OF SECTION

SECTION 230549
VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawing and general provisions of the contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes vibration isolation controls for HVAC components. This section includes restraints for equipment, piping, and ductwork.

B. This Section includes the following:

1. Elastomeric isolation pads.
2. Restrained elastomeric isolation mounts.
3. Freestanding and restrained spring isolators.
4. Housed spring mounts.
5. Elastomeric hangers.
6. Spring hangers with vertical-limit stops.
7. Pipe riser resilient supports.
8. Resilient pipe guides.
9. Restrained vibration isolation roof-curb rails.
10. Snubbers.
11. Steel and inertia, vibration isolation equipment bases.
12. Anchor bolts.

1.3 DEFINITIONS

A. OSHPD: Office of Statewide Health Planning & Development for the State of California.

B. SMACNA: Sheet Metal and Air Conditioning Contractors National Association, Inc.

C. NFPA: National Fire Protection Association.

D. IBC: International Building Code.

1.4 PERFORMANCE REQUIREMENTS

A. Equipment Restraint:

1. Design Spectral Acceleration, Short Period: [**0.XXX.**]

B. Seismic restraint shall be provided in accordance with requirements of the applicable Building Code and Mechanical Code and other locally enforced codes.

C. Wind Restraint Loading:

1. Basic Wind Speed and Building Classification: See structural drawings.
2. Minimum 10 lb/sq. ft. multiplied by the maximum area of the HVAC component projected on a vertical plane that is normal to the wind direction and 45 degrees either side of normal.

1.5 SUBMITTALS

A. Product Data: Include load deflection curves rated load and overload capacity for each vibration isolation device.

B. Equipment Shop Drawings: Signed and sealed by a qualified professional engineer. Include the following:

1. Vibration Isolation Base Details: Detail fabrication, 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. Include equipment and motor location template on concrete inertia base submittals to confirm overall size of inertia base and arrangement of items on top of inertia base.
2. Restraint Details: Detail fabrication and attachment of restraints and snubbers. Show anchorage details and indicate material, strength, finish, quantity, diameter, depth of penetration of anchors, and required anchor edge distances.

C. Wind Restraint Details: Detail fabrication and attachment of restraints. Show anchorage details and indicate quantity, diameter, and depth of penetration of anchors. Submit calculations showing wind forces and compliance with all state and local codes.

1.6 QUALITY ASSURANCE

A. Restraint devices shall have horizontal and vertical load testing and analysis performed according to OSHPD and shall bear anchorage preapproval "OPA" number, from OSHPD or another agency acceptable to authorities having jurisdiction, showing maximum seismic-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.

B. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code--Steel."

C. HVAC equipment mounted outside the building shall be anchored to building structure in compliance with lateral load requirements of the locally enforced building code.

1.7 COORDINATION

A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into base. Concrete, reinforcement, and formwork requirements are specified in Division 3.

B. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Division 7 Section "Roof Accessories."

C. Coordinate with all trades the locations of restraints for HVAC piping and equipment with all other systems and equipment in the vicinity.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Amber/Booth Company, Inc., A VMC Group Company.
2. Kinetics Noise Control, Inc.
3. Mason Industries, Inc.
4. Vibration Eliminator Company, Inc.
5. Vibro-Acoustics.
6. Vibration Mountings and Controls, Inc.

2.2 VIBRATION ISOLATORS

A. Elastomeric Isolator Pads: Oil and water resistant neoprene arranged in single or multiple layers, molded with non-slip pattern and galvanized steel baseplates of sufficient stiffness for uniform loading over pad area and factory cut to sizes that match requirements of supported equipment.

1. Material: Standard neoprene.

B. Spring Isolators: Freestanding, laterally stable, open spring isolators.

1. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
2. Minimum Additional Travel: 50 percent of the required deflection at rated load.
3. Lateral Stiffness: More than 80 percent of the rated vertical stiffness.
4. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
5. Baseplates: Factory drilled for bolting to structure and bonded to 1/4-inch- (6-mm-) thick, rubber isolator pad attached to baseplate underside. Baseplates shall limit floor load to 100 psig (690 kPa).
6. Top Plate and Adjustment Bolt: Threaded top plate with adjustment bolt and cap screw to fasten and level equipment.

C. Restrained Spring Isolators: Freestanding, steel, open spring isolators with seismic restraint.

1. Housing: Steel with resilient vertical-limit stops to prevent spring extension due to wind loads or if weight is removed; factory-drilled baseplate bonded to 1/4-inch- (6-mm-) thick, elastomeric isolator pad attached to baseplate underside;

and adjustable equipment mounting and leveling bolt that acts as blocking during installation.
2. Outside 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 the rated vertical stiffness.
5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
6. Restraint: Snubber and stop as required for equipment and authorities having jurisdiction.

D. Elastomeric Hangers: Double deflection type, with molded, oil resistant rubber or neoprene isolator elements, steel housings with threaded connections for hanger rods. Color coded or otherwise identified to indicate capacity range.

E. Spring Hangers: Combination coil-spring and elastomeric-insert hanger with spring and insert in compression.

1. Frame: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.
2. Outside 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 the 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. Steel-washer-reinforced cup to support spring and bushing projecting through bottom of frame or other method which puts the neoprene in series with the spring.
7. Self-centering hanger rod cap to ensure concentricity between hanger rod and support spring coil.

F. Spring Hangers with Vertical-Limit Stop: Combination coil-spring and elastomeric-insert hanger with spring and insert in compression and with a vertical-limit stop.

1. Frame: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.
2. Outside 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 the 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. Adjustable Vertical Stop: Steel washer with neoprene washer "up-stop" on lower threaded rod.
8. Self-centering hanger rod cap to ensure concentricity between hanger rod and support spring coil.

G. Pipe Riser Resilient Support: All-directional, acoustical pipe anchor consisting of 2 steel tubes separated by a minimum of 1/2-inch- (13-mm-) thick neoprene. Include steel and neoprene vertical-limit stops arranged to prevent vertical travel in both

directions. Design support for a maximum load on the isolation material of 500 psig (3.45 MPa) and for equal resistance in all directions.

H. Resilient Pipe Guides: Telescopic arrangement of 2 steel tubes separated by a minimum of 1/2-inch- (13-mm-) thick, neoprene. Factory set guide height with a shear pin to allow vertical motion due to pipe expansion and contraction. Shear pin shall be removable and reinsertable to allow for selection of pipe movement. Guides shall be capable of motion to meet location requirements.

2.3 RESTRAINED VIBRATION ISOLATION ROOF-CURB RAILS

A. Description: Factory-assembled, fully enclosed, insulated, air- and watertight curb rail designed to resiliently support equipment and to withstand seismic and wind forces. Wind forces shall be a minimum of 125-mph (56-m/s) wind impinging laterally against side of equipment.

B. Lower Support Assembly: Sheet-metal "Z" section containing adjustable and removable steel springs that support upper floating frame. Upper frame shall provide continuous support for equipment and shall be captive to resiliently resist wind and seismic forces. Lower support assembly shall have a means for attaching to building structure and a wood nailer for attaching roof materials, and shall be insulated with a minimum of 2 inches (50 mm) of rigid, glass-fiber insulation on inside of assembly.

C. Spring Isolators: Adjustable, restrained spring isolators shall be mounted on 1/4-inch- (6-mm-) thick, elastomeric vibration isolation pads and shall have access ports, for level adjustment, with removable waterproof covers at all isolator locations. Isolators shall be located so they are accessible for adjustment at any time during the life of the installation without interfering with the integrity of the roof.

1. Restrained Spring Isolators: Freestanding, steel, open-spring isolators with seismic and/or wind restraint.

    a. Housing: Steel with resilient vertical-limit stops and adjustable equipment mounting and leveling bolt.
    b. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
    c. Minimum Additional Travel: 50 percent of the required deflection at rated load.
    d. Lateral Stiffness: More than 80 percent of the rated vertical stiffness.
    e. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

2. Elastomeric Isolator Pads: Oil- and water-resistant elastomer or natural rubber, arranged in single or multiple layers, molded with a non-slip pattern and galvanized steel baseplates of sufficient stiffness for uniform loading over pad area, and factory cut to sizes that match requirements of supported equipment.

    a. Material: Standard neoprene.

D. Snubber Bushings: All-directional, elastomeric snubber bushings at least 1/4 inch (6 mm) thick.

E. Water Seal: Galvanized sheet metal with EPDM seals at corners, attached to upper support frame, extending down past wood nailer of lower support assembly, and counterflashed over roof materials.

2.4 RESTRAINT DEVICES

A. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least four times the maximum seismic forces to which they will be subjected.

B. Resilient Isolation Washers and Bushings: 1-piece, molded, neoprene having a durometer of 40 - 60, plus or minus 5, with a flat washer face.

C. Snubbers: Factory fabricated using welded structural-steel shapes and plates, anchor bolts, and replaceable resilient isolation washers and bushings.

1. Anchor bolts for attaching to concrete shall be seismic-rated, drill-in, and stud-wedge or female-wedge type.
2. Resilient Isolation Washers and Bushings: 1-piece, molded, bridge-bearing neoprene complying with AASHTO M 251 and having a durometer of 40 - 60, plus or minus 5.
3. Maximum 1/4-inch air gap and minimum 1/4-inch thick resilient cushion.

D. Hanger Rod Stiffener: Steel tube or steel slotted support system sleeve with internally bolted connections or reinforcing steel angle clamped to hanger rod.

E. Anchor Bolts: Seismic-rated, drill-in, and stud-wedge or female-wedge type suitable for seismic use in accordance with ACI 355. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488/E 488M. Provide adhesive anchor bolts for non-isolated equipment in excess of 10 HP.

F. Channel Support System: MFMA-3 shop or field fabricated support assembly made of slotted steel channels rated in tension, compressor, and torsion forces and with accessories for attachment to braced component at one end and to building structure at the other end.

2.5 VIBRATION ISOLATION EQUIPMENT BASES

A. Steel Base: Factory-fabricated, welded, structural-steel bases and rails.

1. Design Requirements: Lowest possible mounting height with not less than 1-inch (25-mm) clearance above the floor and not more than 1-1/2 inch clearance. Include equipment anchor bolts and auxiliary motor slide bases or rails. Include supports for suction and discharge elbows for pumps.
2. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. Bases shall have shape to accommodate supported equipment.
3. Support Brackets: Factory-welded steel angles on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.

B. Inertia Base Factory-fabricated, welded, structural-steel bases and rails ready for field-applied, cast-in-place concrete.

1. Design Requirements: Lowest possible mounting height with not less than 1-inch (25-mm) clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails. Include supports for suction and discharge elbows for pumps.
2. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. Bases shall have shape to accommodate supported equipment. Prime and paint all steel.
3. Support Brackets: Factory-welded steel angles on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.
4. Fabrication: Fabricate steel templates to hold equipment anchor-bolt sleeves and anchors in place during placement of concrete. Obtain anchor-bolt templates from supported equipment manufacturer.
5. Bottom pan with stiffener supports welded to the steel frame.
6. Cast-in-place anchor templates for supported equipment.
7. Rebar for concrete, sized and located as required.

2.6 FACTORY FINISHES

A. 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 electro-galvanized. Hot-dip galvanized metal components for exterior use.
3. Baked enamel for metal components on isolators for interior use.
4. Color-code or otherwise mark vibration isolation and seismic-control devices to indicate capacity range.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and equipment to receive vibration isolation and wind control devices for compliance with requirements, 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 INSTALLATION

A. Install roof curbs, equipment supports, and roof penetrations as specified in Division 7 Section "Roof Accessories" and in accordance with applicable codes as required by the authorities having jurisdiction.

B. Install thrust limits at centerline of thrust, symmetrical on either side of equipment.

C. Install snubbers or restrained springs on isolated equipment. Locate snubbers as close as possible to vibration isolators and bolt to equipment base and supporting structure.

D. Install restraining cables steel angles or channel for hanging equipment as specified herein. Install cables so they do not bend across sharp edges of adjacent equipment or building structure. Do not weld angles to threaded rods.

E. Install resilient bolt isolation washers on equipment anchor bolts.

F. Install hanger rod stiffeners where required to prevent buckling of hanger rods due to forces.

G. Multiple Pipe Supports: Secure pipes to trapeze member with clamps approved for application by ICC-ES, OSHPD or another agency acceptable to authorities having jurisdiction.

H. Attachment to Structure: Anchor bracing to structure at flange of beams, at upper chord of truss or at concrete members.

I. Drilled in Anchors:

1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage reinforced steel and embedded items. Locate and avoid all items.
2. Do not drill holes until concrete has achieved full design strength.
3. Set anchors to manufacturer’s recommended torque, using a torque wrench.
4. Install zinc coated anchors for interior and stainless steel anchors for exterior applications.

J. Field installed identification means on each actual restraint which is cross-referenced to the submittal drawing.

K. Fill concrete inertia bases, after installing base frame, with 3000-psi (20.7-MPa) concrete; trowel to a smooth finish.

1. Cast-in-place concrete materials and placement requirements as specified in Division 3.

3.3 EQUIPMENT BASES

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

B. Positively anchor concrete base to concrete floor. Unless otherwise indicated, install #3 with 6" hook dowel rods, 6" from edge of base, minimum four per base, on 18-inch (457-mm) centers around the full perimeter of the base.

1. Place and secure anchorage devices a minimum of 6" from edge of base. Use Setting Drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
2. Install anchor bolts to elevations required for proper attachment to supported equipment.

3. Install anchor bolts according to anchor-bolt manufacturer's written instructions.
4. Cast-in-place concrete materials and placement requirements are specified in Division 3.

3.4 ACCOMMODATION OF DIFFERENTIAL BUILDING MOTION

A. Install flexible connections in piping where they cross building joints, where adjacent sections or branches are supported by different structural elements, and where the connections terminate with connection to equipment that is anchored to a different structural element from the one supporting the connections as they approach equipment. Comply with requirements in Division 23 Section "Hydronic Piping" for piping flexible connections.

3.5 ADJUSTING

A. Adjust isolators after piping systems have been filled and equipment 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. Attach thrust limits at centerline of thrust and adjust to a maximum of 1/4-inch (6-mm) movement during start and stop.

D. Adjust active height of spring isolators.

E. Adjust snubbers according to manufacturer's written recommendations.

F. Adjust restraints to permit free movement of equipment within normal mode of operation.

G. Torque anchor bolts according to equipment manufacturer's written recommendations to resist seismic forces.

3.6 CLEANING

A. After completing equipment installation, inspect vibration isolation and seismic-control devices. Remove paint splatters and other spots, dirt, and debris, leaving equipment free to move on isolation supports.

3.7 EQUIPMENT VIBRATION ISOLATION AND RESTRAINT

A. Manufacturer shall design and provide vibration isolation and restraints to meet the requirements of this specification and as indicated on the Drawings.

B. Restraints shall be designed and provided for all equipment.

C. All floor mounted equipment whether vibration isolated or not shall be anchored, bolted or welded to the structure to comply with the required design forces.

D. All roof mounted equipment whether vibration isolated or not, shall be anchored, bolted or welded to its equipment support. All equipment supports shall be anchored, bolted or welded to the building structure to comply with required design forces.

E. Suspended equipment shall be two rigid restraint or four point cables independently braced.

END OF SECTION

SECTION 230553
IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes the following mechanical identification materials and their installation:

1. Equipment labels.
2. Access panel and door labels.
3. Pipe labels.
4. Duct labels.
5. Stencils.
6. Valve tags.
7. Valve schedules.
8. Ceiling and thermostat labels.
9. Access flooring labels.
10. Raceway identification materials.
11. Control cable identification materials.

1.3 SUBMITTALS

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

B. Valve Tag Schedules: For each piping system. Include a listing of all valves to be labeled with proposed content for each label. Include valve numbering scheme. Furnish extra copies (in addition to mounted copies) to include in maintenance manuals.

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

1.4 QUALITY ASSURANCE

A. ASME Compliance: Comply with ASME A13.1, "Scheme for the Identification of Piping Systems," for letter size, length of color field, colors, and viewing angles of identification devices for piping.

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 location of access panels and doors.

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

D. Coordinate identifying devices to be consistent in appearance in all exposed locations.

PART 2 - PRODUCTS

2.1 EQUIPMENT IDENTIFICATION DEVICES

A. Equipment Labels: Engraved, color-coded, multi-layer, multi-color laminated plastic for mechanical engraving. Include contact-type, permanent adhesive suitable for surface temperature of equipment.

1. Terminology: Match Owner's numbering scheme or drawing schedules with unique equipment number.
2. Size: Length and width vary for required label content, but not less than 4-1/2 by 6 inches (115 by 150 mm) for equipment, 1/8 inch thick.
3. Letters: 1/2 inch minimum.

B. Access Panel and Door Labels: 1/16-inch- (1.6-mm-) thick, engraved laminated plastic, with abbreviated terms and numbers corresponding to identification. Provide 1/8-inch (3.2-mm) center hole for attachment.

1. Terminology: Match Owner’s labeling scheme.
2. Fasteners: Self-tapping, stainless-steel screws or contact-type, permanent adhesive.

2.2 PIPING IDENTIFICATION DEVICES

A. Manufactured Pipe Labels, General: Preprinted, color-coded, with lettering indicating service, and an arrow showing direction of flow.

1. Colors: ASME A13.1 or Owner's current color scheme.
2. Lettering:

Refrigerant Suction	RS
Refrigerant Liquid	RL
Refrigerant Hot Gas Bypass	RHGB
Condensate Drain	CD

3. Pipes with OD, Including Insulation, Less Than 6 Inches (150 mm): Full-band pipe markers extending 360 degrees around pipe at each location.
4. Pipes with OD, Including Insulation, 6 Inches (150 mm) and Larger: Either full-band or strip-type pipe markers at least three times letter height and of length required for label.
5. Arrows: Integral with piping system service lettering to accommodate both directions; or as separate unit on each pipe marker to indicate direction of material flow in piping.

B. Pretensioned Pipe Labels: Precoiled semi-rigid plastic formed to cover full circumference of pipe and to attach to pipe without adhesive.

C. Self-Adhesive Plastic Tape Pipe Labels: Continuously printed, vinyl tape at least 3 mils (0.08 mm) thick with pressure-sensitive, permanent-type, self-adhesive back.

D. Pipe Label Contents: Include identification of piping service using same designations or abbreviations used on drawings and an arrow indicating flow direction. Provide lettering size at least 1-1/2 inches high.

2.3 DUCT IDENTIFICATION DEVICES

A. Duct Labels: Preprinted, color-coded with lettering indicating service. Include direction of airflow and duct service (such as supply, return, and exhaust). Include contact-type, permanent adhesive.

2.4 DUCT AND ACCESS DOOR STENCILS

A. Stencils: Prepared with letter sizes according to ASME A13.1; 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 markers and similar operational instructions.

1. Stencil Paint: Exterior, gloss, acrylic enamel black, unless otherwise indicated. Paint may be in pressurized spray-can form.
2. Identification Paint: Exterior, acrylic enamel in colors according to ASME A13.1, unless otherwise indicated.

2.5 VALVE TAGS

A. Valve Tags: Stamped with 1/4-inch (6.4-mm) letters for piping system abbreviation and 1/2-inch (13-mm) numbers, with numbering scheme approved by Owner. Provide 5/32-inch (4-mm) hole for fastener.

1. Material: 0.032-inch- (0.8-mm-) thick brass.
2. Valve-Tag Fasteners: Brass S-hook.
3. Lettering: Black filled.
4. Size: Minimum 1-1/2”, larger as required for labeling scheme.

2.6 VALVE SCHEDULES

A. Valve Schedules: For each piping system, on standard-size 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-Schedule Frames: Glazed display frame for removable mounting on masonry walls for each page of valve schedule. Include mounting screws.
2. Frame: Extruded aluminum.
3. Glazing: ASTM C 1036, Type I, Class 1, Glazing Quality B, 2.5-mm, single-thickness glass.

2.7 CEILING LABELS

A. Description: 1/2-inch wide clear extra strength tape with 1/4-inch high black letters. Extra strength adhesive suitable for use on rough, textured, or uneven surfaces, as well as painted and powder coated surfaces.

2.8 TEMPERATURE SENSOR LABELS

A. Description: 1/4-inch wide clear extra strength tape with 1/8-inch high black letters. Extra strength adhesive for use on rough textured or uneven surfaces, as well as painted or powder coated surfaces.

2.9 ACCESS FLOORING LABELS

A. Description: Minimum 4-inch tall permanent marker lettering on the upper surface of the access floor tile indicating components located below that tile.

2.10 RACEWAY (EMT AND CONDUIT) IDENTIFICATION MATERIALS

A. Comply with ANSI A13.1 for minimum size of letters for legend and for minimum length of color field for each raceway and cable size.

B. Color for Printed Legend:

1. Control circuits:

   a. Temperature controls: Black letters on a white field.
2. Legend: Indicate system or service. Indicate voltage.

C. Self-Adhesive Vinyl Labels: Preprinted, flexible label laminated with a clear, weather and chemical resistant coating and matching wraparound adhesive tape for securing ends of legend label.

2.11 CONTROL CABLE IDENTIFICATION MATERIALS

A. Color-Coding Conductor Tape: Colored, self-adhesive vinyl tape not less than 3 mils (0.08 mm) thick by 1 to 2 inches (25 to 50 mm) wide.

B. Marker Tapes: Vinyl or vinyl-cloth, self-adhesive wraparound type with circuit identification legend machine printed by thermal transfer or equivalent process.

C. Aluminum Wraparound Marker Labels: Cut from 0.014-inch (0.35-mm) thick aluminum sheet with stamped, embossed or scribed legend and fitted with tabs and matching slots for permanently securing around wire or cable jacket or around groups of conductors.

D. Metal Tags: Brass or aluminum, 2 by 2 by 0.05 inch (50 by 50 by 1.3 mm), with stamped legend, punched for use with self-locking nylon tie fastener.

PART 3 - EXECUTION

3.1 APPLICATIONS, GENERAL

A. Products specified are for applications referenced in other Division 23 Sections. If more than single-type material, device, or label is specified for listed applications, selection is Installer's option.

3.2 EQUIPMENT IDENTIFICATION

A. Install equipment labels with permanent adhesive on or near each item of mechanical equipment.

1. Letter Size: Minimum 3/4-inch (19 mm) for name of units and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
2. Data: Distinguish among multiple units, indicate operational requirements, indicate safety and emergency precautions, warn of hazards and improper operations, and identify units.
3. Locate labels where accessible and visible. Include labels for each piece of mechanical equipment and for the following general categories of equipment:

    a. Fuel-burning units, including boilers, furnaces, heaters, stills, and absorption units.
    b. Pumps, compressors, chillers, condensers, and similar motor-driven units.
    c. Heat exchangers, built-up coil banks, evaporators, cooling towers, heat recovery units, and similar equipment.
    d. Fans, blowers, primary balancing dampers, and mixing boxes.
    e. Packaged HVAC central-station and zone-type units.
    f. Tanks and pressure vessels.
    g. Filters, humidifiers and water-treatment systems.
    h. Fire dampers and fire/smoke dampers.
    i. Humidifiers and pressure reducing valves.
    j. Terminal units (supply air terminal boxes, exhaust air valves): For terminal units located above ceiling, locate equipment label on the bottom or side of the terminal unit where it will be visible from the designated ceiling access panel/tile. If utilizing manufacturer’s labels, lettering shall be at least 1” tall. Permanent marker handwritten labels with 2” tall letters are also acceptable. Do not paint over manufacturer provided labels.

B. Install access panel and door labels on equipment and shaft access panels.

3.3 PIPING IDENTIFICATION

A. Install manufactured pipe label indicating service on each piping system. Install with flow indication arrows showing direction of material flow in piping.

1. Pipes with OD, Including Insulation, Less Than 6 Inches (150 mm): Pretensioned pipe labels. Use size to ensure a tight fit.
2. Pipes with OD, Including Insulation, Less Than 6 Inches (150 mm): Self-adhesive pipe labels. Use color-coded, self-adhesive plastic tape, covering full circumference of pipe.
3. Pipes with OD, Including Insulation, 6 Inches (150 mm) and Larger: Self-adhesive pipe labels. Use color-coded, self-adhesive plastic tape, at least 1-1/2 inches (38 mm) wide, lapped at least 3 inches (75 mm) at both ends of pipe label, and covering full circumference of pipe.

B. Locate pipe labels as follows:

1. Near (within 24” of) each valve and control device.
2. Near each branch connection, excluding short takeoffs less than ten feet long for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
3. Each side of penetrations through walls, floors, ceilings, and non-accessible 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 15 feet (4.5 m) along each run.
7. At a minimum of once over each room for each piping system present over that room. Center the label in the pipe run over the room. If pipe length over the room is less than 15 feet than install labels at each wall penetration.

3.4 DUCT IDENTIFICATION

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

1. Green: For cold-air supply ducts.
2. Yellow: For hot-air supply ducts.
3. Blue: For exhaust-, outside-, relief-, return-, and mixed-air ducts.
4. Red: For bio-hazard and isolation room exhaust ducts.
5. ASME A13.1 Colors and Designs: For hazardous material exhaust.
6. Letter Size: Minimum 1-inch (26 mm) and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

B. Stenciled Duct Option: Stenciled labels, showing service and direction of flow, may be provided instead of laminated-plastic duct labels, 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 15 feet (4.5 m) in each space where ducts are exposed or concealed by removable ceiling system.

D. Duct marker identification shall indicate the associated fan system (e.g., “EF-3 exhaust”).

3.5 VALVE-TAG INSTALLATION

A. Install tags on valves and control devices in piping systems, except check valves; valves within factory-fabricated equipment units; faucets; convenience hose connections; at HVAC terminal devices and at similar roughing-in connections of end-use fixtures and units. List tagged valves in a valve schedule.

3.6 VALVE-SCHEDULE INSTALLATION

A. Mount valve schedules on a wall in an accessible location in each major equipment room.

3.7 CEILING LABEL AND TEMPERATURE SENSOR LABEL INSTALLATION

A. Provide ceiling labels to locate items above T-bar type lay-in panel ceilings. Locate at corner of T-Bar grid closest to equipment. Items which are scheduled on the drawings shall have labels which indicate their scheduled tag (e.g. “TB-201”). Items which are not scheduled on the drawings shall have labels which indicate their name (e.g. “Fire damper”). Provide ceiling labels for the following:

1. HVAC terminal units (terminal boxes, fan powered terminal boxes, fan coil units, reheat coils, etc.).
2. Fire dampers and fire/smoke dampers. Utilize ceiling tags “fire damper”, “fire/smoke damper” etc. if not provided individual tag names by the Owner.
3. Steam traps, humidifiers and steam pressure reducing valves. Utilize ceiling tags “steam trap”, “humidifier”, etc.
4. Controls components: Control panels, duct static pressure sensors, humidifier sensors, control valves, control dampers, control air reducing valves, etc. Utilize ceiling tags “control panel”, “pressure sensor”, etc.
5. Duct smoke detectors. Utilize ceiling tag “duct detector”.
6. Each valve which receives a valve tag. Utilize valve tag nomenclature for ceiling tag (e.g. “CHWP-7”).

B. Provide thermostat labels on the inside cover of all thermostats with removable covers. For other sensors, install label on top exterior surface. Label shall indicate equipment tag of controlled device (e.g., TB-311). Clarify location of label with controls submittal.

3.8 ACCESS FLOOR TILE LABEL INSTALLATION

A. Provide access floor tile labels to locate items below raised access floor. Locate on upper surface of access tile. Provide access floor labels for the following:

1. HVAC terminal units (terminal boxes, reheat coils, etc.).
2. Fire dampers and fire/smoke dampers.
3. Controls components: Control panels, duct static pressure sensors, humidifier sensors, control valves, control dampers and control air reducing valves, etc.
4. Duct smoke detectors.

5. Each valve which receives a valve tag.

3.9 WARNING LABEL INSTALLATION

A. Write required message on and attach warning labels to equipment and other items (e.g., hazardous ductwork systems) where required.

3.10 ADJUSTING

A. Relocate mechanical identification materials and devices that have become visually blocked by other work.

3.11 CLEANING

A. Clean faces of mechanical identification devices and glass frames of valve schedules.

3.12 TEMPERATURE CONTROL LABEL INSTALLATION

A. Control panels shall receive equipment labels where the number of the panel matches that on the controls submittal.

B. All control raceways and junction boxes shall be identified with preprinted self-adhesive vinyl labels.

C. All cables not located within raceways shall be identified at maximum 25 foot intervals.

D. Control raceways shall be identified at maximum 15 foot intervals within rooms with no ceiling and at a minimum once over each room the raceway passes through.

END OF SECTION

SECTION 230593
TESTING, ADJUSTING AND BALACING FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes testing, adjusting and balancing HVAC systems to produce design objectives, including the following:

1. Balancing airflow and water flow within distribution systems, including submains, branches and terminals, to indicated quantities according to specified tolerances.
2. Adjusting total HVAC systems to provide indicated quantities.
3. Measuring electrical performance of HVAC equipment.
4. Setting quantitative performance of HVAC equipment.
5. Verifying that automatic control devices are functioning properly.
6. Reporting results of the activities and procedures specified in this Section.

1.3 DEFINITIONS

A. AABC: Associated Air Balance Council.

B. NEBB: National Environmental Balancing Bureau.

C. TAB: Testing, adjusting, and balancing.

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

1.4 SUBMITTALS

A. LEED Submittal:

1. Air-Balance Report for LEED Prerequisite EQ 1: Documentation of work performed for ASHRAE 62.1-2004, Section 7.2.2, "Air Balancing."

B. Qualification Data: Within 30 days of Contractor's Notice To Proceed, submit documentation that the TAB Contractor and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article. This documentation shall include the following:

1. A list of the names of all individual on-site Field Supervisors and TAB Technicians who may be assigned to the project.

2. A statement that each of the individual listed on-site Field Supervisors and TAB Technicians has met the experience and certification requirements of the specification.
3. A statement that each of the individual listed on-site Field Supervisors and TAB Technicians has received the required training from the selected Controls Supplier.
4. A statement noting that apprentice labor may be utilized for lesser skilled tasks if under the direct supervision of one of the listed individual on-site Field Supervisors and TAB Technicians who is on-site at all times the apprentice is working.

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

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

E. Pencil-copy initial TAB reports, sent directly to the Engineer, as system TAB progresses.

F. Certified TAB reports.

G. Instrument calibration reports, to include the following:

1. Instrument type and make.
2. Serial number.
3. Application.
4. Dates of use.
5. Dates of calibration. Calibration dates shall be within a period of six months prior to the first recorded measurements on the project site.

H. Additional testing reports with verified conditions noted, description of adjustments made and outstanding corrective action items required by other trades.

1.5 QUALITY ASSURANCE

A. TAB Contractor Qualifications: Shall meet the following minimum requirements:

1. TAB Contractor shall be either:

a. A current certified member of AABC, registered in the state of the project site.
b. A current certified member of NEBB, registered in the state of the project site.
c. A registered Professional Engineer licensed in the state of the project site that specialized in the testing, adjusting and balancing of systems with a minimum of ten years of documented experience.

2. Testing, adjusting and balancing shall be completed under the direct field supervision of the TAB Field Supervisor. The TAB Field Supervisor shall be either:

a. A direct employee of the TAB Contractor who is currently certified as an AABC Test and Balance Engineer with at least ten years of demonstrated working experience in the testing, adjusting and balancing of building HVAC systems.
b. A direct employee of the TAB Contractor who is currently certified as NEBB Qualified TAB Supervisor with at least ten years of demonstrated working experience in the testing, adjusting and balancing of building HVAC systems.
c. A registered Professional Engineer that specialized in the testing, adjusting and balancing of systems with a minimum of ten years of documented experience.

3. All testing, adjusting and balancing work shall be completed by a TAB technician. The TAB technician shall be either:

a. An employee of the TAB Contractor and who is certified by AABC as a test and balance technician.
b. An employee of the TAB Contractor and who is certified by NEBB as a qualified TAB technician.
c. A registered Professional Engineer that specialized in the testing, adjusting and balancing of systems with a minimum of ten years of documented experience.

4. In addition to the technical capabilities described herein, the TAB Contractor demonstrates a production capability to plan, control, and integrate manpower and other resources necessary for successful contract completion.
5. TAB Contractor shall have received software training from the selected Controls Supplier applicable to the software and hardware which will be provided for this project.
6. TAB Contractor shall have on the project site all required software and hardware necessary from the selected Controls Supplier to perform testing, adjusting and balancing required tasks.
7. TAB Contractor shall be listed on the Bid Form on bid day.
8. [TAB Contractor shall not be owned by any of the following contractors nor subcontractors on this project:]

a. [General Contractor.]
b. [Mechanical Contractor.]
c. [Electrical Contractor.]
d. [Temperature Controls Contractor.]

9. TAB Contractor shall have at least five years documented experience in the testing, adjusting and balancing of commercial DDC controls. The Owner may ask to verify the qualifications and experience for all field installation technicians assigned to the project prior to the approval of the TAB Contractor.
10. TAB Contractor shall submit a statement acknowledging agreement with the applicable manufacturer's design guidelines covering the installation of controls and the subsequent requirements of the TAB Contractor.
11. TAB Contractor shall attend a one hour familiarization session immediately following the project preconstruction meeting.

B. TAB Conference: Meet with Engineer, Owner, Construction Manager, and Commissioning Authority on approval of the TAB strategies and procedures plan to develop a mutual understanding of the details. Require the participation of the TAB

field supervisor and technicians. Provide seven days' advance notice of scheduled meeting time and location.

1. Agenda Items:

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

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

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

D. TAB Report Forms: Use standard TAB contractor's forms.

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

1.6 PROJECT CONDITIONS

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

1.7 COORDINATION

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

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

C. The TAB Agent shall telephone the Engineer while on-site TAB work is being undertaken. Provide pencil copy handwritten data directly to the Engineer via fax while on-site TAB work is being undertaken.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 TAB SPECIALISTS

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

1. Central Indiana:

    a. Fulton Air Balance.

b. Midwest Balance and Service.

2. Chicago:

a. Mechanical Test and Balance, Crown Point, Indiana.
b. Independent Testing and Balancing, Wheaton, Illinois.
c. Controlled Environmental Testing and Balancing, Schaumburg, Illinois.
d. International Test and Balance, Inc., Des Plaines, Illinois.

3. Northwest Indiana:

a. Fluid Dynamics, Inc., Fort Wayne, Indiana.
b. Mechanical Test and Balance, Crown Point, Indiana.
c. Independent Testing and Balancing, Wheaton, Illinois.
d. Circle 'R' Mechanical

4. Northeastern/ South Bend

a. Fluid Dynamics, Inc., Fort Wayne, Indiana.

5. Evansville, Indiana:

a. Flo-Tech.
b. Midwest Roofing and Sheet Metal.

6. Charleston, West Virginia:

a. Kahoe Air Balance.

7. Springfield, Illinois:

a. IL Certified Testing, Inc., 500 Juniper Drive, Petersburg, Illinois 62675, (217) 632-3479.
b. Thermodynamic Balance, Inc., 25218 North 2175 East Road, Lexington, Illinois 61753, (309) 365-2520.
c. System Testing and Analysis, 11730 Old Ballas Road, Creve Coeur, Missouri 63141, (314) 567-6011.

8. Central Texas:

a. TAB Technologies
b. Campos Engineering.
c. Engineered Air Balance (EAB).

3.2 EXAMINATION

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

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

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

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

E. Examine ceiling plenums and underfloor air plenums used for supply, return, or relief air to verify that they meet the leakage class of connected ducts as specified in Division 23 Section "Metal Ducts" and are properly separated from adjacent areas. Verify that penetrations in plenum walls are sealed and fire-stopped if required.

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

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

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

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

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

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

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

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

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

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

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

P. Examine automatic temperature system components to verify the following:

1. Dampers, valves and other controlled devices operate 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 position. This includes dampers in multi-zone units, mixing boxes and variable air volume terminals.
4. Automatic modulating and shutoff valves, including 2-way valves and 3-way mixing and diverting valves, are properly connected.

5. Thermostats and humidistats are located to avoid adverse affects 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 setpoints are set at design values. Observe and record system reactions to changes in conditions. Record default setpoints if different from design values.
9. Interlocked systems are operating.
10. Changeover from heating to cooling mode occurs according to design values.

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

3.3 PREPARATION

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

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

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

3.4 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in AABC's "National Standards for Total System Balance," ASHRAE 111 NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems," SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing," and in this Section.

1. Comply with requirements in ASHRAE 62.1-2004, Section 7.2.2, "Air Balancing."

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

1. After testing and balancing, patch probe holes in ducts with same material and thickness as used to construct ducts.
2. After testing and balancing, install test ports and duct access doors that comply with requirements in Division 23 Section "Air Duct Accessories."
3. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Division 23 Section "HVAC Insulation."

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

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

3.5 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

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

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

C. For variable-air-volume systems, develop a plan to simulate diversity. Submit this plan to all contractors to verify phasing and occupancy concerns. Submit plan to the Engineer prior to execution.

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

E. Check airflow patterns from the outdoor-air louvers and dampers and the return- and exhaust-air dampers through the supply-fan discharge and mixing dampers. Communicate concerns about potential stratification directly to the Engineer.

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

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

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

I. Check for airflow blockages.

J. Check condensate drains for proper connections and functioning.

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

L. Verify that air duct system is sealed as specified in Division 23 Section "Metal Ducts."

M. Measure and record for each terminal unit the static air pressure and the damper position (% open) when recording the maximum airflow readings for the space.

3.6 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

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

1. Measure total airflow.

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

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

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

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

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

4. Measure static pressures entering and leaving other devices, such as sound traps, heat-recovery equipment, and air washers, under final balanced conditions.
5. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.
6. Obtain approval from Engineer for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in Division 23 Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
7. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.
8. Replace sheaves and belts as required to deliver the necessary airflow through the system accounting for all system losses. Coordinate final belt and sheave sizes with unit manufacturers. Refer to individual Division 23 specifications for additional information.

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

1. Measure airflow of submain and branch ducts.

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

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

C. Measure air outlets and inlets without making adjustments.

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

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

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

3.7 PROCEDURES FOR MULTIZONE SYSTEMS

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

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

3.8 PROCEDURES FOR MOTORS

A. Motors: Test at final balanced conditions and record the following data:

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

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

3.9 PROCEDURES FOR CONDENSING UNITS

A. Verify proper rotation of fans.

B. Measure entering- and leaving-air temperatures.

C. Record compressor data.

3.10 TEMPERATURE CONTROL VERIFICATION

A. Verify that controllers are calibrated and commissioned.

B. Check transmitter and controller locations and note conditions that would adversely affect control functions.

C. Record controller settings and note variances between setpoints, controller readings and actual measurements.

D. Verify operation of limiting controllers (i.e., high and low temperature controllers).

E. Verify free travel and proper operation of control devices such as damper and valve operators.

F. Verify sequence of operation of control devices. Note air pressures and device positions and correlate with airflow and water flow measurements. Note the speed of response to input changes.

G. Confirm interaction of electrically operated switch transducers.

H. Confirm interaction of interlock and lockout systems.

I. Verify main control supply air pressure and observe compressor and dryer operations.

J. Record voltages of power supply and controller output. Determine if the system operates on a ground or non-grounded power supply.

K. Note operation of electric actuators using spring return for proper fail safe operations.

L. For each system with airflow measuring station, record the calibration data, actual airflow and measured sensor process variable at minimum airflow, maximum airflow, and halfway between minimum and maximum airflow settings.

M. With each piece of equipment in operation under the fully automatic control of the Building Automation System, perform the following test:

1. Throw the disconnect to the off position. For equipment driven by a variable frequency drive, switch the breaker feeding the drive to the “off” position. Simultaneously remove power from the Building Automation System controller which controls that piece of equipment.
2. Remain in the un-energized condition for eight seconds.
3. Return disconnect and breaker to their normal “on” position. Return power to controls.
4. Document normal operation of the equipment after power interruption (normal speed, normal position, normal pressure, etc.).

N. Measure and record the discharge air temperature from each terminal unit, fan coil unit and induction unit. Cooling and heating systems shall be operational during this test. Report all cooling discharge air temperatures that are above 55 deg. F to the proper contractors for remediation. Report all heating discharge air temperatures that are less than 90 deg. F to the proper contractor for remediation.

O. Report all results in writing for all verification activities.

3.11 FULL AIRFLOW TESTING

A. Prior to performing building pressurization testing, perform full airflow testing on each floor, one floor at a time, to be witnessed by the Mechanical Engineer.

B. Adjust diffuser throws prior to full airflow testing.

C. In fully automatic control, reset each supply terminal unit temperature control setpoint to 55 deg F and verify maximum simultaneous flow at all terminal units. Record

percentage open position of the five most hydraulically remote terminal units while simultaneously measuring static pressure at each of the five terminal units and at all the system static pressure sensors. Measure supply air temperature at the DDC sensor and compare to sensor reading. Investigate temperatures which indicate reheat valve is not fully closed. Adjust static pressure sensor setpoint such that the most hydraulically remote terminal box is 85 percent open. Rerecord percentage open position at the five most hydraulically remote terminal units while simultaneously measuring static pressure at each of the five terminal units and at the system static pressure sensors. With the floor still in full airflow and with the final static pressure setpoint in operation, identify acoustic issues for investigation by the Mechanical Engineer. Measure supply air by duct traverse in locations suitable to confirm airflow serving the floor.

D. Report all results in writing.

3.12 BUILDING PRESSURIZATION

A. Measure building pressurizations across doors at all existing buildings and exterior doors in full automatic occupied mode.

B. Adjust corridor and other constant volume terminal boxes and exhaust valves as clarified by Engineer.

C. Repeat testing in full automatic unoccupied mode.

D. Remeasure differential pressure across doors and readjust as clarified.

E. Report all results in writing.

3.13 SPECIAL SYSTEMS

A. Special systems include isolation rooms, protective environment rooms, operating rooms, clean rooms and pharmacies. Special systems include all spaces equipped with a pressure monitor or pressure indicating device. Special systems also include animal housing spaces.

B. Initial Tests:

1. Measure static pressure differential across all door undercuts with systems operating in full automatic control.
2. Adjust airflows at all exhaust, return and supply boxes as clarified by the Engineer.
3. Remeasure static pressure differential across all door undercuts with systems operating in full automatic control. Record damper positions.
4. Readjust airflows as clarified by Engineer. Adjust system pressure settings as clarified by Engineer.
5. Coordinate with cleanroom certifier for BSC testing and adjusting.

C. Final Tests:

1. After receiving clarification of initial tests and with BSC setup by certifier complete, adjust airflows as clarified by Engineer.

2. Assist TCC in calibrating pressure transmitters. Record all pressures measured with TAB equipment while simultaneously recording the readings at the Owner's operating workstation. Provide a sketch with doors and room numbers, pressures and flows for each special system. Report all results in writing.
3. Measure static pressure differential across all door undercuts. Measure percentage open of each control valve.
4. Re-perform static pressure readings in presence of the Owner and Engineer. Adjust as required. Record all pressures measured with TAB equipment while simultaneously recording the readings at the Owner's operating workstation. Provide a sketch with doors and room numbers, pressures and flows for each special system. Report all results in writing.

3.14 KITCHEN EXHAUST HOODS

A. Determine total airflow into the room where the hood is located and balance systems to ensure adequate air supply to all hoods.

1. Energize the exhaust fan and adjust airflow to provide the required air volume.
2. Measure exhaust airflow volume by measuring airflow at hood opening.
3. Measure air velocity using Pitot-tube traverse method.
4. Record each face velocity measurement taken at 4- to 6-inch (100- to 150-mm) increments over the entire hood opening.
5. Calculate the average face velocity by averaging all velocity measurements.
6. Calculate the airflow volume of exhaust hood face velocity by multiplying the calculated average face velocity by the opening area. Compare this quantity with exhaust volume at exhaust fan and report duct leakage.
7. Measure airflow volume supplied by makeup fan. Verify that the makeup system supplies the proper amount of air to keep the space at the indicated pressure with the exhaust systems in all operating conditions.
8. Retest for average face velocity. Adjust fan drives and other parts of the system to provide the indicated average face velocity and the indicated auxiliary air supply percentages.
9. Retest and adjust the systems until hood performance complies with Contract Documents.
10. Report all results in writing.

3.15 TOLERANCES

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

1. Supply, Return, and Exhaust Fans and Equipment with Fans: Zero to plus 10 percent.
2. Air Outlets and Inlets: Plus or minus 5 percent.
3. Heating-Water Flow Rate: Zero to plus 5 percent.
4. Cooling-Water Flow Rate: Zero to plus 5 percent.

3.16 REPORTING

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

balancing devices to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.

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

3.17 FINAL REPORT

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

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

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

1. Pump curves.
2. Fan curves.
3. Manufacturers' test data.
4. Field test reports prepared by system and equipment installers.
5. Other information relative to equipment performance; do not include Shop Drawings and product data.

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

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

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

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

    a. Settings for outdoor-, return-, and exhaust-air dampers.

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

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

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

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

1. Unit Data:

a. Unit identification.
b. Location.
c. Make and type.
d. Model number and unit size.
e. Manufacturer's serial number.
f. Unit arrangement and class.
g. Discharge arrangement.
h. Sheave make, size in inches (mm), and bore.
i. Center-to-center dimensions of sheave, and amount of adjustments in inches (mm).
j. Number, make, and size of belts.
k. Number, type, and size of filters.

2. Motor Data:

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

3. Test Data (Indicated and Actual Values):

a. Total air flow rate in cfm (L/s).
b. Total system static pressure in inches wg (Pa).
c. Fan rpm.
d. Discharge static pressure in inches wg (Pa).
e. Filter static-pressure differential in inches wg (Pa).

f. Preheat-coil static-pressure differential in inches wg (Pa).
g. Cooling-coil static-pressure differential in inches wg (Pa).
h. Heating-coil static-pressure differential in inches wg (Pa).
i. Outdoor airflow in cfm (L/s).
j. Return airflow in cfm (L/s).
k. Outdoor-air damper position.
l. Return-air damper position.
m. Vortex damper position.

F. Apparatus-Coil Test Reports:

1. Coil Data:

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

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm (L/s).
b. Average face velocity in fpm (m/s).
c. Air pressure drop in inches wg (Pa).
d. Outdoor-air, wet- and dry-bulb temperatures in deg F (deg C).
e. Return-air, wet- and dry-bulb temperatures in deg F (deg C).
f. Entering-air, wet- and dry-bulb temperatures in deg F (deg C).
g. Leaving-air, wet- and dry-bulb temperatures in deg F (deg C).
h. Water flow rate in gpm (L/s).
i. Water pressure differential in feet of head or psig (kPa).
j. Entering-water temperature in deg F (deg C).
k. Leaving-water temperature in deg F (deg C).
l. Refrigerant expansion valve and refrigerant types.
m. Refrigerant suction pressure in psig (kPa).
n. Refrigerant suction temperature in deg F (deg C).
o. Inlet steam pressure in psig (kPa).

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

1. Unit Data:

a. System identification.
b. Location.
c. Make and type.
d. Model number and unit size.
e. Manufacturer's serial number.
f. Fuel type in input data.
g. Output capacity in Btu/h (kW).
h. Ignition type.

i. Burner-control types.
j. Motor horsepower and rpm.
k. Motor volts, phase, and hertz.
l. Motor full-load amperage and service factor.
m. Sheave make, size in inches (mm), and bore.
n. Center-to-center dimensions of sheave, and amount of adjustments in inches (mm).

2. Test Data (Indicated and Actual Values):

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

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

1. Unit Data:

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

2. Test Data (Indicated and Actual Values):

a. Heat output in Btu/h (kW).
b. Air flow rate in cfm (L/s).
c. Air velocity in fpm (m/s).
d. Entering-air temperature in deg F (deg C).
e. Leaving-air temperature in deg F (deg C).
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 (mm), and bore.
h. Center-to-center dimensions of sheave, and amount of adjustments in inches (mm).

2. Motor Data:

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

3. Test Data (Indicated and Actual Values):

a. Total airflow rate in cfm (L/s).
b. Total system static pressure in inches wg (Pa).
c. Fan rpm.
d. Discharge static pressure in inches wg (Pa).
e. Suction static pressure in inches wg (Pa).
f. System leakage data. Report on system leakage as the difference between the airflows measured at the fan inlet traverse and the summation of airflows measured at the spaces served. Measure fan airflows while the space airflows are all simultaneously at their maximum airflow settings. For leakage rates greater than 3%, perform branch traverse airflow readings to identify locations of leakage.

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 (deg C).
d. Duct static pressure in inches wg (Pa).
e. Duct size in inches (mm).
f. Duct area in sq. ft. (sq. m).
g. Indicated air flow rate in cfm (L/s).
h. Indicated velocity in fpm (m/s).
i. Actual air flow rate in cfm (L/s).
j. Actual average velocity in fpm (m/s).
k. Barometric pressure in psig (Pa).

K. Air-Terminal-Device Reports:

1. Unit Data:

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

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm (L/s).
b. Air velocity in fpm (m/s).
c. Preliminary air flow rate as needed in cfm (L/s).
d. Preliminary velocity as needed in fpm (m/s).
e. Final air flow rate in cfm (L/s).
f. Final velocity in fpm (m/s).
g. Space temperature in deg F (deg C).
h. Static pressure at the terminal unit when the terminal is flowing the maximum airflow setting.
i. Damper position (% open) when the terminal is flowing the maximum airflow setting.

L. System-Coil Reports: For terminal heating and cooling hydronic coils at terminal units, include the following:

1. Unit Data:

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

2. Test Data (Indicated and Actual Values):

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

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: Include the following:

a. Unit identification.
b. Location.
c. Unit make and model number.
d. Manufacturer's compressor serial numbers.
e. Compressor make.

f. Compressor model and serial numbers.
g. Refrigerant weight in lb (kg).
h. Low ambient temperature cutoff in deg F (deg C).

2. Test Data: Include design and actual values for the following:

a. Inlet-duct static pressure in inches wg (Pa).
b. Outlet-duct static pressure in inches wg (Pa).
c. Entering-air, dry-bulb temperature in deg F (deg C).
d. Leaving-air, dry-bulb temperature in deg F (deg C).
e. Condenser entering-water temperature in deg F (deg C).
f. Condenser leaving-water temperature in deg F (deg C).
g. Condenser water temperature differential in deg F (deg C).
h. Condenser entering-water pressure in feet of head or psig (kPa).
i. Condenser leaving-water pressure in feet of head or psig (kPa).
j. Condenser water pressure differential in feet of head or psig (kPa).
k. Control settings.
l. Unloader set points.
m. Low-pressure-cutout set point in psig (kPa).
n. High-pressure-cutout set point in psig (kPa).
o. Suction pressure in psig (kPa).
p. Suction temperature in deg F (deg C).
q. Condenser refrigerant pressure in psig (kPa).
r. Condenser refrigerant temperature in deg F (deg C).
s. Oil pressure in psig (kPa).
t. Oil temperature in deg F (deg C).
u. Voltage at each connection.
v. Amperage for each phase.
w. The kW input.
x. Crankcase heater kW.
y. Number of fans.
z. Condenser fan rpm.
aa. Condenser fan airflow rate in cfm (L/s).
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. Instrument Calibration Reports:

1. Report Data:

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

O. System and Functional Test Reports: For each system test, include the following:

1. Condition of controls (fully automatic or not).
2. Variable frequency drive Hertz.
3. All conditions denoted in the Procedures Section.
4. System static pressures at building automation sensors, both physical readings and controller readouts.

3.18 INSPECTIONS

A. Initial Inspection:

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

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

B. Final Inspection:

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

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

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

D. Prepare test and inspection reports.

3.19 ADDITIONAL TESTS

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

B. Seasonal Periods: If initial TAB procedures for equipment were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions. Additional tests shall be performed as follows:

1. Cooling season: With outdoor air temperature at least 80 deg. F, index the unit to 100% outdoor air and reset space setpoints such that all zones are simultaneously at maximum cooling airflow. Test cooling coil performance both airside (including wet bulb readings) and tube side and record data, including cooling systems equipment operation, overall flow rates and system temperatures.
2. Heating season: With outdoor air temperature no greater than 30 deg. F., reset space setpoints such that all zones are simultaneously at maximum heating. Adjust outdoor air control to load the heating coil at its maximum scheduled capacity. Test heating coil performance both air side and tube side and record data, including heating system equipment in operation, overall flow rates and system temperatures.

END OF SECTION

SECTION 230700
HVAC INSULATION

GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Insulation Materials:

a. Calcium silicate.
b. Cellular glass.
c. Flexible elastomeric.
d. Mineral fiber.

2. Fire-rated insulation systems.
3. Insulating cements.
4. Adhesives.
5. Mastics.
6. Sealants.
7. Factory-applied jackets.
8. Field-applied fabric-reinforcing mesh.
9. Field-applied cloths.
10. Field-applied jackets.
11. Tapes.
12. Securements.
13. Corner angles.

B. Related Sections:

1. Division 22 Section "Plumbing Insulation."
2. Division 23 Section "Metal Ducts" for duct liners.
3. Division 33 Section "Underground Hydronic Energy Distribution" for loose-fill pipe insulation in underground piping outside the building.
4. Division 33 Section "Underground Steam and Condensate Distribution Piping" for loose-fill pipe insulation in underground piping outside the building.

1.3 SUBMITTALS

A. Product Data: For each type of product indicated. Include thermal conductivity, thickness, and jackets (both factory and field applied, if any). Provide a scheduled listing in the submittal of each type of pipe service, duct service or equipment type that insulates with the thickness and jacket noted for each service and type.

B. LEED Submittal (if required):

1. Product Data for Credit EQ 4.1: For adhesives and sealants, including printed statement of VOC content.

C. Shop Drawings:

1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
2. Detail insulation application at pipe expansion joints for each type of insulation.
3. Detail insulation application at elbows, fittings, flanges, valves, and specialties for each type of insulation.
4. Detail removable insulation at piping specialties, equipment connections, and access panels.
5. Detail application of field-applied jackets.
6. Detail application at linkages of control devices.
7. Detail field application for each equipment type.

D. Field quality-control reports.

1.4 QUALITY ASSURANCE

A. Fire-Test-Response Characteristics: Insulation and related materials shall have fire-test-response characteristics indicated, as determined by testing identical products per 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 and inspecting 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.

B. 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 (3-m) section of NPS 2 (DN 50) 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 (DN 50) or smaller valve, and one NPS 2-1/2 (DN 65) 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 pressure temperature tap.
h. One mechanical coupling.

2. Ductwork Mockups:

a. One 10-foot (3-m) 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. Four support hangers for round and rectangular ductwork.

3. Equipment Mockups:

a. One chilled-water pump.
b. One tank or vessel.

4. For each mockup, fabricate cutaway sections to allow observation of application details for insulation materials, adhesives, mastics, attachments, and jackets.
5. Notify Engineer seven days in advance of dates and times when mockups will be constructed.
6. Obtain Engineer'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 Engineer 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. Storage: Insulation material shall be stored to prevent dirt and moisture contamination.

1.6 COORDINATION

A. Coordinate size and location of supports, hangers, and insulation shields specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."

B. Coordinate clearance requirements with piping Installer for piping insulation application, duct Installer for duct insulation application, and equipment Installer for equipment insulation application. Before preparing piping and ductwork Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

1.7 SCHEDULING

A. Schedule insulation application after satisfactory pressure testing systems and, where required, after installing and testing heat tracing.

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 Part 3 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 materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.

E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.

F. 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 (The); Thermo-12 Gold.

2. 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.
3. 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. 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.

G. 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. Cell-U-Foam Corporation; Ultra-CUF.
   b. Pittsburgh Corning Corporation; Foamglass Super K.

2. Block Insulation: ASTM C 552, Type I.
3. Special-Shaped Insulation: ASTM C 552, Type III.
4. Board Insulation: ASTM C 552, Type IV.
5. Preformed Pipe Insulation with Factory-Applied ASJ or ASJ-SSL: Comply with ASTM C 552, Type II, Class 2.
6. Factory fabricated shapes according to ASTM C 450 and ASTM C 585.

H. Flexible Elastomeric: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type I for tubular materials and Type II for sheet materials.

1. Products: Subject to compliance with requirements, provide one of the following:

   a. Aeroflex USA Inc.; Aerocel and Aerocel (EPDM).
   b. Armacell LLC; AP Armaflex and UT Solaflex (EPDM).
   c. K-Flex USA; Insul-Sheet, K-Flex and Kflex HT (EPDM).

2. Where flexible elastomeric (EPDM) is required, it shall be suitable for continuous operation up to at least 250 deg. F and down to at least -40 deg. F and be U.V. resistant in accordance with ASTM G7/G90.

I. 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 [**II with factory-applied vinyl jacket**] [**III with factory-applied FSK jacket**] [**III with factory-applied FSP jacket**]. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Products: Subject to compliance with requirements, provide one of the following:

   a. CertainTeed Corp.; Duct Wrap.
   b. Johns Manville; Microlite.
   c. Knauf Insulation; Duct Wrap.
   d. Manson Insulation Inc.; Alley Wrap.
   e. Owens Corning; All-Service Duct Wrap.

J. Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type IA or Type IB. For duct and plenum applications, provide insulation with factory-applied FSK jacket. For equipment applications, provide insulation with factory-applied ASJ. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Products: Subject to compliance with requirements, provide one of the following:

   a. CertainTeed Corp.; Commercial Board.
   b. Fibrex Insulations Inc.; FBX.
   c. Johns Manville; 800 Series Spin-Glas.
   d. Knauf Insulation; Insulation Board.
   e. Manson Insulation Inc.; AK Board.
   f. Owens Corning; Fiberglas 700 Series.

K. Mineral-Fiber, Preformed Pipe Insulation:

1. Products: Subject to compliance with requirements, provide one of the following:

a. Fibrex Insulations Inc.; Coreplus 1200.
b. Johns Manville; Micro-Lok.
c. Knauf Insulation; Earthwool 1000.
d. Manson Insulation Inc.; Alley-K.
e. Owens Corning; Fiberglas Pipe Insulation.

2. Type I, 850 deg F (454 deg C) Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A, with factory-applied ASJ or with factory-applied ASJ-SSL. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

L. Mineral-Fiber, Pipe and Tank Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semi-rigid 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. (40 kg/cu. m) or more. Thermal conductivity (k-value) at 100 deg F (55 deg C) is 0.29 Btu x in./h x sq. ft. x deg F (0.042 W/m x K) or less. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Products: Subject to compliance with requirements, provide one of 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.

2.2 FIRE-RATED INSULATION SYSTEMS

A. Fire-Rated Blanket: High-temperature, flexible, blanket insulation with fully encased FSK jacket that is tested and certified to provide a 2-hour fire rating by a NRTL acceptable to authority having jurisdiction.

1. Products: Subject to compliance with requirements, provide one of the following:

a. CertainTeed Corp.; FlameChek.
b. Johns Manville; Firetemp Wrap.
c. Morgan Thermal Ceramics; FireMaster Duct Wrap or Fastwrap XL.
d. 3M; Fire Barrier Wrap Products.
e. Unifrax Corporation; FyreWrap.
f. Vesuvius; PYROSCAT FP FASTR Duct Wrap.

B. Performance:

1. Zero inch clearance required to combustible construction at all points along the ductwork (including insulation joints).
2. Continuous product model and rating markups on foil face for identification.
3. Blanket shall be UL classified non-combustible with a flame spread of 0, smoke development of 0 and fuel construction of 0.

4. Suitable for continuous use to 300 deg F; four hour operation at 500 deg F.
5. Provide UL listed terminations at shaft construction with firestopping details as required by the authority having jurisdiction.
6. Accommodate duct access doors with easily removable sections of insulation.

C. Air Duct Application:

1. Single layer application to achieve required rating.
2. Minimum 1-1/2” thickness.

D. Grease Duct Application:

1. Double layer application to achieve required rating.
2. Minimum 1-1/2” thickness per layer.
3. Installation in compliance with all sections of ASTM E2336. Provide 2” thick layers as required.

2.3 INSULATING CEMENTS

A. Mineral-Fiber Insulating Cement: Comply with ASTM C 195.

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. Insulco, Division of MFS, Inc.; Triple I.
b. P. K. Insulation Mfg. Co., Inc.; Super-Stik.

2.4 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. Calcium Silicate Adhesive: Fibrous, sodium-silicate-based adhesive with a service temperature range of 50 to 800 deg F (10 to 427 deg C).

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 Products, Division of ITW; CP-97.
b. Foster Products Corporation, H. B. Fuller Company; 81-27/81-93.
c. Marathon Industries, Inc.; 290.
d. Mon-Eco Industries, Inc.; 22-30.
e. Vimasco Corporation; 760.

2. 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).

C. Cellular-Glass 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 products that may be incorporated into the Work include, but are not limited to, the following:

a. Childers Products, Division of ITW; CP-96.
b. Foster Products Corporation, H. B. Fuller Company; 81-33.

2. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

D. Flexible Elastomeric and Polyolefin Adhesive: Comply with MIL-A-24179A, Type II, Class I.

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. Aeroflex USA Inc.; Aeroseal.
b. Armacell LCC; 520 Adhesive.
c. Foster Products Corporation, H. B. Fuller Company; 85-75.
d. K-Flex USA.
e. RBX Corporation; Rubatex Contact Adhesive.

2. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

E. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.

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 Products, Division of ITW; CP-82.
b. Foster Products Corporation, H. B. Fuller Company; 85-20.
c. ITW TACC, Division of Illinois Tool Works; S-90/80.
d. Marathon Industries, Inc.; 225.
e. Mon-Eco Industries, Inc.; 22-25.

2. 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).

F. 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 products that may be incorporated into the Work include, but are not limited to, the following:

a. Childers Products, Division of ITW; CP-82.
b. Foster Products Corporation, H. B. Fuller Company; 85-20.
c. ITW TACC, Division of Illinois Tool Works; S-90/80.
d. Marathon Industries, Inc.; 225.
e. Mon-Eco Industries, Inc.; 22-25.

2. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

G. PVC Jacket Adhesive: Compatible with PVC 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. Dow Chemical Company (The); 739, Dow Silicone.
b. Johns-Manville; Zeston Perma-Weld, CEEL-TITE Solvent Welding Adhesive.
c. P.I.C. Plastics, Inc.; Welding Adhesive.
d. Speedline Corporation; Speedline Vinyl Adhesive.

2. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

2.5 MASTICS

A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-C-19565C, Type II.

B. Vapor-Barrier Mastic: Water based; suitable for indoor and outdoor use on below ambient services.
1. Products: Subject to compliance with requirements, provide one of the following:

a. Childers Products, Division of ITW; CP-35.
b. Foster Products Corporation, H. B. Fuller Company; 30-90.
c. ITW TACC, Division of Illinois Tool Works; CB-50.
d. Marathon Industries, Inc.; 590.
e. Mon-Eco Industries, Inc.; 55-40.
f. Vimasco Corporation; 749.

2. Water-Vapor Permeance: ASTM E 96, Procedure B, 0.013 perm (0.009 metric perm) at 43-mil (1.09-mm) dry film thickness.
3. Service Temperature Range: Minus 20 to plus 180 deg F (Minus 29 to plus 82 deg C).
4. Solids Content: ASTM D 1644, 59 percent by volume and 71 percent by weight.
5. Color: White.

2.6 SEALANTS

A. Joint Sealants:

1. Joint Sealants for Cellular-Glass, 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 Products, Division of ITW; CP-76.
b. Foster Products Corporation, H. B. Fuller Company; 30-45.
c. Marathon Industries, Inc.; 405.
d. Mon-Eco Industries, Inc.; 44-05.
e. Pittsburgh Corning Corporation; Pittseal 444.
f. Vimasco Corporation; 750.

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.
6. For indoor applications, use sealants that have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

B. FSK and Metal Jacket Flashing Sealants:

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 Products, Division of ITW; CP-76-8.
   b. Foster Products Corporation, H. B. Fuller Company; 95-44.
   c. Marathon Industries, Inc.; 405.
   d. Mon-Eco Industries, Inc.; 44-05.
   e. Vimasco Corporation; 750.

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 (Minus 40 to plus 121 deg C).
5. Color: Aluminum.
6. For indoor applications, use sealants that have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

C. ASJ Flashing Sealants, and Vinyl, PVDC, and PVC Jacket Flashing Sealants:

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 Products, Division of ITW; CP-76.

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 (Minus 40 to plus 121 deg C).
5. Color: White.
6. For indoor applications, use sealants that have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

2.7 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. Vinyl Jacket: White vinyl with a permeance of 1.3 perms (0.86 metric perms) when tested according to ASTM E 96, Procedure A, and complying with NFPA 90A and NFPA 90B.

2.8 FIELD-APPLIED FABRIC-REINFORCING MESH

A. Woven Glass-Fiber Fabric for Pipe Insulation: Approximately 2 oz./sq. yd. (68 g/sq. m) with a thread count of 10 strands by 10 strands/sq. inch (4 strands by 4 strands/sq. mm) 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. Vimasco Corporation; Elastafab 894.

B. Woven Glass-Fiber Fabric for Duct and Equipment Insulation: Approximately 6 oz./sq. yd. (203 g/sq. m) with a thread count of 5 strands by 5 strands/sq. inch (2 strands by 2 strands/sq. mm) for covering equipment.

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 Products, Division of ITW; Chil-Glas No. 5.

C. Woven Polyester Fabric: Approximately 1 oz./sq. yd. (34 g/sq. m) with a thread count of 10 strands by 10 strands/sq. inch (4 strands by 4 strands/sq. mm), in a Leno weave, for duct, equipment, and pipe.

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. Foster Products Corporation, H. B. Fuller Company; Mast-A-Fab.
b. Vimasco Corporation; Elastafab 894.

2.9 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. (271 g/sq. m).

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.

2.10 FIELD-APPLIED JACKETS

A. Field-applied jackets shall comply with ASTM C 921, Type I, unless otherwise indicated.

B. 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. Flame spread of 25 or less and smoke developed rating of 50 or less per ASTM E84.

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; Zeston.
    b. P.I.C. Plastics, Inc.; FG Series.
    c. Proto PVC Corporation; LoSmoke.
    d. Speedline Corporation; SmokeSafe.

2. Adhesive: As recommended by jacket material manufacturer.
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.

5. Factory-fabricated tank heads and tank side panels.

C. 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 Products, Division of ITW; Metal Jacketing Systems.
    b. PABCO Metals Corporation; Surefit.
    c. RPR Products, Inc.; Insul-Mate.

2. Aluminum Jacket: Comply with ASTM B 209 (ASTM B 209M), Alloy 3003, 3005, 3105 or 5005, Temper H-14.

    a. Finish and thickness are indicated in field-applied jacket schedules.
    b. Moisture Barrier for Indoor Applications: 3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper or 2.5-mil- (0.063-mm-) thick Polysurlyn.
    c. Moisture Barrier for Outdoor Applications: 3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper or 2.5-mil- (0.063-mm-) thick Polysurlyn.
    d. 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.

3. Stainless-Steel Jacket: ASTM A 167 or ASTM A 240/A 240M.

    a. Material, finish, and thickness are indicated in field-applied jacket schedules.
    b. Moisture Barrier for Indoor Applications: 3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper or 2.5-mil- (0.063-mm-) thick Polysurlyn.
    c. Moisture Barrier for Outdoor Applications: 3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper or 2.5-mil- (0.063-mm-) thick Polysurlyn.
    d. 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 fabricated fitting covers only if factory-fabricated fitting covers are not available.

D. 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 cross-laminated 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; Alumaguard 60.

2.11 TAPES

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with pressure sensitive 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. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0836.
    b. Compac Corp.; 104 and 105.
    c. Ideal Tape Co., Inc., an American Biltrite Company; 428 AWF ASJ.
    d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ.

2. Minimum width: 3 inches (75 mm).
3. Thickness: 11.5 mils (0.29 mm).
4. Adhesion: 45 ounces force/inch (1.0 N/mm) in width.
5. Elongation: 2 percent.
6. Tensile strength: 40 lbf/inch (7.2 N/mm) in width.
7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.
8. WVTR: 0.02 perms per ASTM E96.

B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic pressure sensitive 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. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0827.
    b. Compac Corp.; 110 and 111.
    c. Ideal Tape Co., Inc., an American Biltrite Company; 491 AWF FSK.
    d. Venture Tape; 1525 CW, 1528 CW, and 1528 CW/SQ.
2. Minimum width: 3 inches.
3. Minimum thickness: 6.5 mils.
4. Minimum adhesion: 40 ounces force/inch in width.
5. Elongation: 2 percent.
6. Minimum tensile strength: 40 lbf/inch (7.2 N/mm) in width.
7. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.
8. WVTR: 0.02 perms per ASTM E96.

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. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0555.
    b. Compac Corp.; 130.
    c. Ideal Tape Co., Inc., an American Biltrite Company; 370 White PVC tape.
    d. Venture Tape; 1506 CW NS.

2. Width: 2 inches (50 mm).
3. Thickness: 6 mils (0.15 mm).
4. Adhesion: 64 ounces force/inch (0.7 N/mm) in width.
5. Elongation: 500 percent.
6. Tensile Strength: 18 lbf/inch (3.3 N/mm) 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. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0800.
    b. Compac Corp.; 120.
    c. Ideal Tape Co., Inc., an American Biltrite Company; 488 AWF.
    d. Venture Tape; 3520 CW.

2. Width: 2 inches (50 mm).
3. Thickness: 3.7 mils (0.093 mm).
4. Adhesion: 100 ounces force/inch (1.1 N/mm) in width.
5. Elongation: 5 percent.
6. Tensile Strength: 34 lbf/inch (6.2 N/mm) in width.

E. 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. Childers Products; Bands.
b. PABCO Metals Corporation; Bands.
c. RPR Products, Inc.; Bands.

2. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, Type 304 or Type 316; 0.015 inch (0.38 mm) thick, 3/4 inch (19 mm) wide with wing seal .
3. Aluminum: ASTM B 209 (ASTM B 209M), Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch (0.51 mm) thick, 3/4 inch (19 mm) wide with wing seal .

F. Insulation Pins and Hangers:

1. Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin (or other material as required for stainless or aluminum ductwork), fully annealed for capacitor-discharge welding, 0.135-inch- (3.5-mm-) diameter shank, length to suit depth of insulation indicated.

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.; CWP-1.
2) GEMCO; CD.
3) Midwest Fasteners, Inc.; CD.
4) Nelson Stud Welding; TPA, TPC, and TPS.

2. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin (or other material as required for stainless steel or aluminum duct), fully annealed for capacitor-discharge welding, 0.135-inch- (3.5-mm-) diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch (38-mm) 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.; CWP-1.
2) GEMCO; Cupped Head Weld Pin.
3) Midwest Fasteners, Inc.; Cupped Head.
4) Nelson Stud Welding; CHP.

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 Insul-Hangers, Series T.
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: Fully annealed, 0.106-inch- (2.6-mm-) diameter shank, length to suit depth of insulation indicated.
d. Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

4. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- (0.41-mm) thick, 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) 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.

5. 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.

G. Staples: Outward-clinching insulation staples, nominal 3/4-inch- (19-mm-) wide, stainless steel or Monel.

H. 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.
b. Childers Products.
c. PABCO Metals Corporation.
d. RPR Products, Inc.

2.12 CORNER ANGLES

A. Aluminum Corner Angles: 0.040 inch (1.0 mm) thick, minimum 1 by 1 inch (25 by 25 mm), aluminum according to ASTM B 209 (ASTM B 209M), Alloy 3003, 3005, 3105 or 5005; Temper H-14.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation and other conditions affecting performance of insulation application.

1. Verify that systems and equipment to be insulated have been tested and are free of defects.
2. Verify that surfaces to be insulated are clean and dry.
3. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

B. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless-steel surfaces, use demineralized water.

C. Surface Preparation: Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:

1. Carbon steel: Coat carbon steel operating at a service temperature below 60 deg F with an epoxy coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.

3.3 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of equipment, ducts and fittings, and piping including fittings, valves, and specialties.

B. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item of equipment, duct system, and pipe system as specified in insulation system schedules.

C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

D. Install insulation with longitudinal seams at top and bottom of horizontal runs.

E. Install multiple layers of insulation with longitudinal and end seams staggered.

F. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.

G. Keep insulation materials dry during application and finishing.

H. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.

I. Install insulation with least number of joints practical.

J. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

1. Install insulation continuously through hangers and around anchor attachments.
2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.

K. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.

L. Install insulation with factory-applied jackets as follows:

1. Draw jacket tight and smooth.
2. Cover circumferential joints with 3-inch- (75-mm-) wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches (100 mm) o.c.
3. Overlap jacket longitudinal seams at least 1-1/2 inches (38 mm). Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 2 inches (50 mm) o.c.

    a. For below ambient services, apply vapor-barrier mastic over staples.

4. Cover joints and seams with tape as recommended by insulation material manufacturer to maintain vapor seal.
5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct and pipe flanges and fittings.

M. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.

N. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

O. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches (100 mm) beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

P. For above ambient services, do not install insulation to the following:

1. Vibration-control devices.
2. Testing agency labels and stamps.
3. Nameplates and data plates.
4. Manholes.
5. Handholes.
6. Cleanouts.

3.4 PENETRATIONS

A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.

1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
3. Extend jacket of outdoor insulation outside roof flashing at least 2 inches (50 mm) below top of roof flashing.
4. Seal jacket to roof flashing with flashing sealant.

B. Insulation Installation at Underground Exterior Wall Penetrations: Terminate insulation flush with sleeve seal. Seal terminations with flashing sealant.

C. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.

1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant. Fabricate a cellular glass "box" around the pump which is removable. Utilize flexible elastomeric at penetrations and seal with silicone. Allow for removal of suction diffuser screen if a suction diffuser is installed.
3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches (50 mm).
4. Seal jacket to wall flashing with flashing sealant.

D. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.

E. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions. Terminate insulation at fire damper sleeves for fire-rated wall and partition penetrations. Externally insulate damper sleeves to match adjacent insulation and overlap duct insulation at least 2 inches (50 mm).

1. Comply with requirements in Division 7 Section "Firestopping" and fire-resistive joint sealers.

F. Insulation Installation at Floor Penetrations:

1. Duct: Install insulation continuously through floor penetrations that are not fire rated. For penetrations through fire-rated assemblies, terminate insulation at fire damper sleeves and externally insulate damper sleeve beyond floor to match adjacent duct insulation. Overlap damper sleeve and duct insulation at least 2 inches (50 mm).
2. Pipe: Install insulation continuously through floor penetrations.
3. Seal penetrations through fire-rated assemblies. Comply with requirements in Division 7 Section "Firestopping."

3.5 EQUIPMENT, TANK, AND VESSEL INSULATION INSTALLATION

A. Mineral Fiber, Pipe and Tank Insulation Installation for Tanks and Vessels: Secure insulation with adhesive and anchor pins and speed washers.

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for minimum 50 percent coverage of tank and vessel surfaces.
2. Groove and score insulation materials to fit as closely as possible to equipment, including contours. Bevel insulation edges for cylindrical surfaces for tight joints. Stagger end joints.
3. Protect exposed corners with secured corner angles.
4. Install adhesively attached or self-sticking insulation hangers and speed washers on sides of tanks and vessels as follows:

    a. Do not weld anchor pins to ASME-labeled pressure vessels.
    b. Select insulation hangers and adhesive that are compatible with service temperature and with substrate.
    c. On tanks and vessels, maximum anchor-pin spacing is 3 inches (75 mm) from insulation end joints, and 16 inches (400 mm) o.c. in both directions.
    d. Do not overcompress insulation during installation.
    e. Cut and miter insulation segments to fit curved sides and domed heads of tanks and vessels.
    f. Impale insulation over anchor pins and attach speed washers.
    g. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

5. Secure each layer of insulation with stainless-steel or aluminum bands. Select band material compatible with insulation materials.
6. Where insulation hangers on equipment and vessels are not permitted or practical and where insulation support rings are not provided, install a girdle network for securing insulation. Stretch prestressed aircraft cable around the diameter of vessel and make taut with clamps, turnbuckles, or breather springs. Place one circumferential girdle around equipment approximately 6 inches (150 mm) from each end. Install wire or cable between two circumferential girdles 12 inches (300 mm) o.c. Install a wire ring around each end and around outer periphery of center openings, and stretch prestressed aircraft cable radially from the wire ring to nearest circumferential girdle. Install additional

circumferential girdles along the body of equipment or tank at a minimum spacing of 48 inches (1200 mm) o.c. Use this network for securing insulation with tie wire or bands.
7. Stagger joints between insulation layers at least 3 inches (75 mm).
8. Install insulation in removable segments on equipment access doors, manholes, handholes, and other elements that require frequent removal for service and inspection.
9. Bevel and seal insulation ends around manholes, handholes, ASME stamps, and nameplates.
10. For equipment with surface temperatures below ambient, apply mastic to open ends, joints, seams, breaks, and punctures in insulation.

B. Flexible Elastomeric Thermal Insulation Installation for Tanks and Vessels: Install insulation over entire surface of tanks and vessels.

1. Apply 100 percent coverage of adhesive to surface with manufacturer's recommended adhesive.
2. Seal longitudinal seams and end joints.

C. Insulation Installation on Pumps:

1. Fabricate custom fitted insulation pieces. Fit pieces around pumps and coincide joints with splits in pump casings. Fabricate joints with outward bolted flanges. Secure box sections together using a latching mechanism for easy removal of sections to maintain pump.
2. For below ambient services, install a vapor barrier at seams, joints, and penetrations. Seal between flanges with replaceable gasket material to form a vapor barrier. Fabricate a cellular glass “box” around the pump which is removable. Utilize flexible elastomeric at penetrations and seal with silicone. Allow for removal of suction diffuser screen if a suction diffuser is installed.

3.6 GENERAL PIPE INSULATION INSTALLATION

A. Requirements in this article generally apply to all insulation materials except where more specific requirements are specified in various pipe insulation material installation articles.

B. Insulation Installation on Fittings, Valves, Strainers, Flanges, and Unions:

1. Install insulation over fittings, valves, strainers, flanges, unions, and other specialties with continuous thermal and vapor-retarder integrity, unless otherwise indicated.

2. Insulate pipe elbows using preformed fitting insulation or mitered fittings made from same material and density as adjacent pipe insulation. Each piece shall be butted tightly against adjoining piece and bonded with adhesive. Fill joints, seams, voids, and irregular surfaces with insulating cement finished to a smooth, hard, and uniform contour that is uniform with adjoining pipe insulation.
3. Insulate tee fittings with preformed fitting insulation or sectional pipe insulation of same material and thickness as used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.

4. Insulate valves using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For valves, insulate up to and including the gate valve bonnets, valve stuffing-box studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement.
5. Insulate steam safety relief valves up to the bottom base and provide the minimum clearance to the nuts and bolts to remove the flanged safety relief valve.
6. Insulate strainers using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers so strainer basket flange or plug can be easily removed and replaced without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below ambient services, provide a design that maintains vapor barrier.
7. Insulate flanges and unions using a section of oversized preformed pipe insulation. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker.
8. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below ambient services and a breather mastic for above ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.
9. For services not specified to receive a field-applied jacket except for flexible elastomeric and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing using PVC tape.
10. Stencil or label the outside insulation jacket of each union with the word "UNION." Match size and color of pipe labels.
11. Install insulation at coil connection piping not required to have a continuous vapor barrier such that the maximum length of uninsulated piping does not exceed 3” in length.

C. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and transmitters on insulated pipes, vessels, and equipment. Shape insulation at these connections by tapering it to and around the connection with insulating cement and finish with finishing cement, mastic, and flashing sealant.

D. Install removable insulation covers at locations indicated. Installation shall conform to the following:

1. Make removable flange and union insulation from sectional pipe insulation of same thickness as that on adjoining pipe. Install same insulation jacket as adjoining pipe insulation.
2. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union long at least two times the insulation thickness over adjacent pipe insulation on each side of flange or union. Secure flange cover in place with stainless-steel or aluminum bands. Select band material compatible with insulation and jacket.
3. Construct removable valve insulation covers in same manner as for flanges except divide the two-part section on the vertical center line of valve body.
4. When covers are made from block insulation, make two halves, each consisting of mitered blocks wired to stainless-steel fabric. Secure this wire frame, with

its attached insulation, to flanges with tie wire. Extend insulation at least 2 inches (50 mm) over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.

5. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

3.7 CALCIUM SILICATE INSULATION INSTALLATION

A. Insulation Installation on Boiler Breechings and Ducts:

1. Secure single-layer insulation with stainless-steel bands at 12-inch (300-mm) intervals and tighten bands without deforming insulation material.
2. Install 2-layer insulation with joints tightly butted and staggered at least 3 inches (75 mm). Secure inner layer with wire spaced at 12-inch (300-mm) intervals. Secure outer layer with stainless-steel bands at 12-inch (300-mm) intervals.
3. On exposed applications without metal jacket, finish insulation surface with a skim coat of mineral-fiber, hydraulic-setting cement. When cement is dry, apply flood coat of lagging adhesive and press on one layer of glass cloth. Overlap edges at least 1 inch (25 mm). Apply finish coat of lagging adhesive over glass cloth. Thin finish coat to achieve smooth, uniform finish.

B. Insulation Installation on Straight Pipes and Tubes:

1. Secure single-layer insulation with stainless-steel bands at 12-inch (300-mm) intervals and tighten bands without deforming insulation materials.
2. Install 2-layer insulation with joints tightly butted and staggered at least 3 inches (75 mm). Secure inner layer with wire spaced at 12-inch (300-mm) intervals. Secure outer layer with stainless-steel bands at 12-inch (300-mm) intervals.
3. Apply a skim coat of mineral-fiber, hydraulic-setting cement to insulation surface. When cement is dry, apply flood coat of lagging adhesive and press on one layer of glass cloth or tape. Overlap edges at least 1 inch (25 mm). Apply finish coat of lagging adhesive over glass cloth or tape. Thin finish coat to achieve smooth, uniform finish.

C. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of block insulation of same material and thickness as pipe insulation.
4. Finish flange insulation same as pipe insulation.

D. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.

2. When preformed insulation sections of insulation are not available, install mitered sections of calcium silicate insulation. Secure insulation materials with wire or bands.
3. Finish fittings insulation same as pipe insulation.

E. Insulation Installation on Valves and Pipe Specialties:

1. Install mitered segments of calcium silicate insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
2. Install insulation to flanges as specified for flange insulation application.
3. Finish valve and specialty insulation same as pipe insulation.

3.8 CELLULAR-GLASS INSULATION INSTALLATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation to pipe with wire or bands and tighten bands without deforming insulation materials.
2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
3. For interior insulation with factory-applied jackets on above ambient services, secure laps with outward clinched staples at 6 inches (150 mm) o.c.
4. For insulation with factory-applied jackets on below ambient services, do not staple longitudinal tabs but secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant. Seal all insulation terminations with vapor seal mastic. Provide minimum 3” wide ASJ butt strip at joints to maintain the vapor barrier.
5. For exterior insulation, utilize manufacturer’s standard weather barrier mastic under the jacketing.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of cellular-glass block insulation of same thickness as pipe insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch (25 mm), and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.
2. When preformed sections of insulation are not available, install mitered sections of cellular-glass insulation. Factory miter and tar together with a minimum of three segments for elbows. Secure insulation materials with wire or bands.
3. Secure fittings with 1/2” wide filament tape as recommended by the manufacturer.

4. Coat fittings with vapor seal with fab cloth embedded in it.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of cellular-glass insulation to valve body.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.

3.9 FLEXIBLE ELASTOMERIC INSULATION INSTALLATION

A. Seal longitudinal seams and end joints with manufacturers' recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

B. Insulation Installation on Pipe Flanges:

1. Install pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of sheet insulation of same thickness as pipe insulation.
4. Secure insulation to flanges and seal seams with manufacturers' recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install mitered sections of pipe insulation.
2. Secure insulation materials and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed valve covers manufactured of same material as pipe insulation when available.
2. When preformed valve covers are not available, install cut sections of pipe and sheet insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.
4. Secure insulation to valves and specialties and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.10 MINERAL-FIBER INSULATION INSTALLATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of preformed pipe insulation to pipe with wire or bands and tighten bands without deforming insulation materials.

2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
3. For insulation with factory-applied jackets on above ambient surfaces, secure laps with outward clinched staples at 6 inches (150 mm) o.c.
4. For insulation with factory-applied jackets on below ambient surfaces, do not staple longitudinal tabs but secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with mineral-fiber blanket insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch (25 mm), and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation when available.
2. When preformed insulation elbows and fittings are not available, install mitered sections of pipe insulation, to a thickness equal to adjoining pipe insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of same material as straight segments of pipe insulation when available.
2. When preformed sections are not available, install mitered sections of pipe insulation to valve body.
3. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
4. Install insulation to flanges as specified for flange insulation application.

E. Blanket Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

1. Apply adhesives according to manufacturer's written recommended coverage rates.
2. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

    a. On exposed ductwork where no ceiling is installed, on all duct sizes greater than 12 inch span, place pins along longitudinal centerline of duct on both duct sides and on the duct bottom. Space pins 3 inches (75 mm) maximum from insulation section joints, and maximum 16 inches (400 mm) on center each way from other pins.
    b. On concealed ductwork, on duct with dimensions larger than 24 inches, place pins at a maximum of 16 inches (400 mm) on center each way from other pins and 3 inches (75 mm) maximum from insulation section joints.

Install pins on any side or the bottom with dimension greater than 24". Install additional pins to hold insulation tightly against the duct surface at structural steel cross bracing.

c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
d. Do not overcompress insulation during installation.
e. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing. Tape shall extend at least 2 inches in all directions from the pin.

3. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches (50 mm) from 1 edge and 1 end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch (13-mm) outward-clinching staples installed at a maximum of 3 inches on center between staples. Install vapor barrier tape at each joint. Vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant may be used at joints, seams, and protrusions in lieu of vapor barrier tape.

   a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
   b. Install vapor stops for ductwork and plenums operating below 50 deg F (10 deg C) at 18-foot (5.5-m) intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to 2 times the insulation thickness but not less than 3 inches (75 mm).

4. Overlap unfaced blankets a minimum of 2 inches (50 mm) on longitudinal seams and end joints. At end joints, secure with steel bands spaced a maximum of 18 inches (450 mm) o.c.
5. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
6. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch- (150-mm-) wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches (150 mm) o.c.
7. Insulate duct mounted coils located within terminal units (terminal boxes, supply air valves, fan coil units) by extending external duct insulation over the terminal unit a minimum of two inches. Insulate over return bends.
8. Insulate the external side of diffusers as noted on the details.

F. Board Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for minimum 50 percent coverage of duct and plenum surfaces.
2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.

3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

    a. On duct sides with dimensions 18 inches (450 mm) and smaller, place pins along longitudinal centerline of duct. Space 3 inches (75 mm) maximum from insulation end joints, and 16 inches (400 mm) o.c.
    b. On duct sides with dimensions larger than 18 inches (450 mm), space pins 16 inches (400 mm) o.c. each way, and 3 inches (75 mm) maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
    c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
    d. Do not overcompress insulation during installation.
    e. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches (50 mm) from 1 edge and 1 end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch (13-mm) outward-clinching staples, 1 inch (25 mm) o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.

    a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
    b. Install vapor stops for ductwork and plenums operating below 50 deg F (10 deg C) at 18-foot (5.5-m) intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to 2 times the insulation thickness but not less than 3 inches (75 mm).

5. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Groove and score insulation to fit as closely as possible to outside and inside radius of elbows. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
6. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch- (150-mm-) wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches (150 mm) o.c.

3.11 FIELD-APPLIED JACKET INSTALLATION

A. Where glass-cloth jackets are indicated, install directly over bare insulation or insulation with factory-applied jackets.

1. Draw jacket smooth and tight to surface with 2-inch (50-mm) overlap at seams and joints.
2. Embed glass cloth between two 0.062-inch- (1.6-mm-) thick coats of lagging adhesive.
3. Completely encapsulate insulation with coating, leaving no exposed insulation.

B. Where FSK jackets are indicated, install as follows:

1. Draw jacket material smooth and tight.
2. Install lap or joint strips with same material as jacket.
3. Secure jacket to insulation with manufacturer's recommended adhesive.
4. Install jacket with 1-1/2-inch (38-mm) laps at longitudinal seams and 3-inch-(75-mm-) wide joint strips at end joints.
5. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.

C. Where PVC jackets are indicated, install with 1-inch (25-mm) overlap at longitudinal seams and end joints; for horizontal applications, install with longitudinal seams along top and bottom of tanks and vessels. Seal with manufacturer's recommended adhesive.

1. Apply two continuous beads of adhesive to seams and joints, one bead under lap and the finish bead along seam and joint edge.

D. Where metal jackets are indicated, install with 2-inch (50-mm) overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless-steel bands 12 inches (300 mm) o.c. and at end joints.

3.12 FIRE-RATED INSULATION SYSTEM INSTALLATION

A. Where fire-rated insulation system is indicated, secure system to ducts and duct hangers and supports to maintain a continuous fire rating.

B. Insulate duct access panels and doors to achieve same fire rating as duct.

C. Install firestopping at penetrations through fire-rated assemblies. Fire-stop systems are specified in Division 7 Section "Firestopping."

3.13 FINISHES

A. Duct, Equipment, and Pipe Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Division 9 painting Sections.

1. Flat Acrylic Finish: Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.

a. Finish Coat Material: Interior, flat, latex-emulsion size.

B. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.

C. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.

D. Do not field paint aluminum or stainless-steel jackets.

3.14 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

3.15 DUCT INSULATION SCHEDULE, GENERAL

A. Comply with the requirements in “Indoor Duct and Plenum Insulation Schedule” and “Aboveground, Outdoor Duct and Plenum Insulation Schedule” Articles for where insulating materials shall be applied.

B. Items Not Insulated:

1. Fibrous-glass ducts.
2. Factory-insulated flexible ducts.
3. Factory-insulated plenums and casings.
4. Flexible connectors.
5. Vibration-control devices.
6. Factory-insulated access panels and doors.

C. Products shall not contain asbestos, lead, mercury or mercury compounds.

D. Products that come into contact with stainless steel shall be qualified as acceptable according to ASTM C795.

3.16 INDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. Concealed, rectangular, round and flat oval, supply air duct insulation shall be the following:

1. Mineral-Fiber Blanket: 2 inches minimum thick and 1.0-lb/cu. ft. nominal density to achieve a minimum installed (at 25% compression) R value of 6.0 at 75 deg F. mean temperature.

B. Concealed, rectangular, round and flat oval, return air duct insulation shall be the following:

1. Mineral-Fiber Blanket: 1-1/2 inches minimum thick and 0.75-lb/cu. ft. nominal density to achieve a minimum installed R value of 3.5 at 75 deg F mean temperature.

C. Concealed, rectangular, round and flat-oval, outdoor-air duct and energy recovery device discharge air duct insulation shall be the following:

1. Mineral-Fiber Blanket: 2 inches (50 mm) minimum thick and 1.0-lb/cu. ft. nominal density to achieve a minimum installed R value of 6.0 at 75 deg F mean temperature.
2. Insulate energy recovery device discharge air duct from the outlet of the energy recovery device to the penetration of the building exterior.

D. Concealed and exposed rectangular and round, exhaust-air and relief air duct insulation between isolation damper and penetration of building exterior shall be the following:

1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.0-lb/cu. ft. nominal density.

E. Concealed and Exposed, Type I, Commercial, Kitchen Hood Exhaust Duct and Plenum Insulation: Fire-rated blanket insulating system; thickness as required to achieve 2-hour fire rating.

F. Exposed, supply-air duct, relief air duct, return air duct, outdoor air duct and energy recovery device discharge air duct insulation shall be the following:

1. Flexible Elastomeric: 1 inch (25 mm) thick on edges, corners, and flanges of ductwork which are less than 6'-6" above finished floor with space below them for personal access.
2. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.0-lb/cu. ft. nominal density on surfaces which are more than 8'-0" above finished floor.
3. Mineral-Fiber Board: 2 inches (50 mm) thick and 6-lb/cu. ft. nominal density for ductwork which is less than 8'-0" above finished floor.

G. Concealed and exposed ductwork with fire rated blanket insulating system: Fire rated blanket insulating system thickness as required to achieve 2-hour fire rating.

H. Concealed and exposed oven and warewash exhaust duct insulation shall be the following: 2 inches minimum thick and 1.0 lb/cu.ft. nominal density to achieve a minimum installed (at 25% compression) R value of 6.0 at 75 deg F mean temperature.

3.17 ABOVEGROUND, OUTDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. Insulation materials and thicknesses are identified below. If more than one material is listed for a duct system, selection from materials listed is Contractor's option.

B. Concealed, and exposed, rectangular, round and flat-oval, [**supply-air,**] [**return air**] and [**exhaust air**] duct insulation shall be the following:

1. Mineral-Fiber Board: 4 inches minimum thick, 6-lb/cu. ft. (96-kg/cu. m) nominal density to achieve a minimum R value of 17.0 at 75 deg F. mean temperature.
2. Elastomeric (EPDM): 4 inches minimum thick with additional UV resistant coating furnished by the insulation manufacturer.

3.18 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 in paragraphs below that is not factory insulated.

C. Fans located on the discharge of heat recovery devices shall be the following:

1. Mineral fiber board: 2-inches thick.

3.19 PIPING INSULATION SCHEDULE, GENERAL

A. Acceptable preformed pipe and tubular insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from the materials listed is at the Contractor's option.

B. Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:

1. Drainage piping located in crawl spaces.
2. Underground piping.
3. Chrome-plated pipes and fittings unless there is a potential for personnel injury.

C. Products shall not contain asbestos, lead, mercury or mercury compounds.

D. Products that come into contact with stainless steel shall be qualified as acceptable according to ASTM C795.

3.20 INDOOR PIPING INSULATION SCHEDULE

A. Condensate and Equipment Drain Water below 60 Deg F (16 Deg C):

1. All Pipe Sizes: Insulation shall be the following:

a. Flexible Elastomeric: 3/4 inch (19 mm) thick.

B. Refrigerant Suction, Liquid, and Hot-Gas Piping and Tubing:

1. NPS 1-1/2 and Smaller: Insulation shall be the following:

a. Cellular glass: 1 inch (25 mm) thick.
b. Flexible elastomeric: 1 inch (25 mm) thick.

2. NPS 1-5/8 and Larger:

a. Cellular glass: 1-1/2 inches thick.
b. Flexible elastomeric: 1-1/2 inches thick.

C. Hot Service Drains (including boiler blowdown):

1. All Pipe Sizes: Insulation shall be the following:

a. Mineral-Fiber, Preformed Pipe, Type I or II: 1 inch (25 mm) thick.

D. Hot Service Vents (including steam vents):

1. All Pipe Sizes: Insulation shall be the following:

a. Mineral-Fiber, Preformed Pipe, Type I or II: 1 inch (25 mm) thick.

E. Cold Service Vents (including MRI quench vents):

1. All Pipe Sizes: Insulation shall be the following:

a. Flexible elastomeric: 1 inches thick.

3.21 OUTDOOR, ABOVEGROUND PIPING INSULATION SCHEDULE

A. Refrigerant Suction and Hot-Gas Piping and Tubing:

1. All Pipe Sizes: Insulation shall be the following:

a. Flexible Elastomeric (EPDM): 2 inches (50 mm) thick.

3.22 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. Piping, Exposed; within finished occupied spaces; below 8’-0” above finished floor:

1. PVC: 20 mils (0.5 mm) thick.

D. Piping exposed, within mechanical rooms [**and within rooftop pipe enclosures at AHU’s**] [**below 8’-0” above finished floor**][**all chilled water piping within the space][shall be suitably installed for washdown service utilizing a standard water spray nozzle and building water pressure**].

1. PVC: 20 mils (0.5 mm) thick.

3.23 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. Confirm that the vapor barrier of the insulation is 100% intact and repair as necessary prior to applying jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Ducts and Plenums, Exposed:

1. Aluminum, Stucco Embossed: 0.024 inch (0.61 mm) thick.
2. Field applied fabric reinforcing mesh with vapor barrier mastic.

D. Piping, Exposed:

1. Aluminum, Stucco Embossed: 0.032 inch (0.81 mm) thick.

END OF SECTION

SECTION 230900
ENVIRONMENTAL CONTROL SYSTEM

I. WORK DESCRIPTION

A. Scope of Work:

1. The Environmental Control Contractor (ECC) shall furnish, install complete, program, and place in totally acceptable operation an environmental control system as shown or implied on the Contract Documents.

B. Work Included:

1. Furnish and install electric, and direct digital control temperature, humidity and pressure controls, and accessories as required to provide a complete operable system to obtain the operational sequence described.
2. All control and interlock wiring by ECC to be in full compliance with all sections of electrical specifications.
3. ECC shall prepare electric wiring diagram on all controls, starters, and mechanical equipment detailing all terminals in each component.
4. Any relays or auxiliary contacts required, but not furnished by suppliers of mechanical equipment or starters shall be furnished by ECC.
5. Note that schematic control diagrams on drawings are presented to show the intent of all control loops and to illustrate the operational sequences described. The electric signals are diagrammatic only and each bidder shall be required to furnish such cabling and air lines as required to meet their specific equipment. ECC is directed to building drawings and all schedules for complete coordination of project requirements.
6. All standards of quality and operation shown, described, and implied are to be fully met. Any questions relative to deviations to be submitted in writing to the Architect/Engineer at least 14 days prior to bid date.
7. The ECC is responsible for coordinating data integration with third party equipment/systems shown on the Contract Documents to be integrated with the ECC's Building Automation System. This coordination includes verifying communication protocol compatibility with each equipment/system manufacturer and/or supplier and verifying the list of available points through the integration/interface. Refer to related specification sections below for project specific integration requirements.

    a) Section 22 11 13 – Facility Fuel Oil System.
    b) Section 22 11 23 – Packaged Booster Pumps.
    c) Section 22 11 24 – Variable Speed Packaged Booster Pumps.
    d) Section 22 13 29 – Sewage Pumps.
    e) Section 22 14 29 – Sump Pumps.
    f) Section 22 15 19 – General Service Compressed Air Equipment.
    g) Section 22 31 16 – Water Softeners.
    h) Section 22 34 00 – Fuel Fired Domestic Water Heaters.
    i) Section 22 67 19 – RO/Deionized Water Equipment.
    j) Section 23 25 00 – HVAC Water Treatment.

k) Section 23 33 00 – Air Duct Acessories
l) Section 23 52 16 – Condensing Boilers.
m) Section 23 52 33 – Water Tube Boilers.
n) Section 23 52 39 – Fire Tube Boilers.
o) Section 23 53 16 – Deaerators, Surge Tanks and Blowdown Separators.
p) Section 23 64 16 – Centrifugal Water Chillers.
q) Section 23 64 26 – Rotary Screw Air-Cooled Water Chillers.
r) Section 23 65 00 – Cooling Towers.
s) Section 23 72 00 – Air-To-Air Energy Recovery Equipment.
t) Section 23 81 19 – Self-Contained Air Conditioners
u) Section 23 81 23 – Computer Room Air Conditioners.
v) Section 23 84 13 – Humidifiers.
w) Section 26 09 13 – Electrical Power Monitoring and Control.
x) Section 26 09 43 – Network Lighting Controls.
y) Section 26 11 16 – Secondary Unit Substations.
z) Section 26 12 00 – Medium Voltage Transformers.
aa) Section 26 23 13 – Paralleling Low Voltage Switchgear.
bb) Section 26 24 13 – Switchboards.
cc) Section 26 24 19 – Motor Control Centers.
dd) Section 26 27 13 – Electricity Metering.
ee) Section 26 29 23 – Variable Frequency Controllers.
ff) Section 26 32 13 – Engine Generators.
gg) Section 26 33 53 – Static Uninterruptible Power Supply.
hh) Section 26 36 00 – Transfer Switches.
ii) Section 26 56 00 – Exterior Lighting.

2. This Contractor/Supplier is directed to all General Conditions of the Contract.

B. Work Not Included:

C. Electrical Contractor shall provide all power wiring to and from all motor starters, variable frequency controllers, and motor control centers.

D. Electrical Contractor to provide 120/60 power to all Direct Digital Controllers.

E. Additional 120 Volt power wiring and conduit that is required beyond that which the Electrical Contractor provides shall be furnished and installed by the Environmental Control Supplier/Engineering Contractor.

F. Sheet Metal Contractor shall install motorized dampers and duct mounted airflow measuring stations furnished by the Environmental Control Contractor.

G. Mechanical Contractor to install all temperature sensing wells and control valves furnished by the Environmental Control Contractor.

H. Related Work Specified Elsewhere:

1. Basic mechanical materials and methods.
2. Hangers and supports.
3. Mechanical identification.
4. Testing, adjusting and balancing.
5. Enclosed switches and circuit breakers.
6. Enclosed controllers.

7. Motor control centers.

II. QUALITY ASSURANCE

A. Acceptable Supervisory Level Control Manufacturer
1. Johnson Controls, Inc.
2. Siemens Building Technologies,
3. Schneider Electric I/A Series,
4. Automated Logic.
5. Tridium – Niagra 4 Framework, Latest Version

B. Acceptable Building Level Control Manufacturer
1. Johnson Controls
2. Siemens Building Technologies
3. Schneider Electric
4. Automated Logic
5. Alerton

C. Acceptable Installation and Service Contractor:
1. Indianapolis
   a) Johnson Controls, Inc.,
   b) Siemens Building Technologies,
   c) Precision Control Systems of Indianapolis,
   d) Automated Logic Indiana.
   e) Open Control Systems
   f) Conserve
2. Chicago
   a) Precision Control System of Chicago
   b) Automated Logic of Chicago
   c) Open Control Systems

D. The entire electric, electronic, and direct digital control system shall be approved and listed by Underwriters Laboratories, Inc. All equipment shall bear the appropriate UL listing marking to insure compliance. In addition to the UL listing requirement, all work shall conform to the following codes and standards as applicable:

1. National Fire Protection Agency (NFPA) Standards.
2. National Electrical Code (NEC) and applicable local electrical codes.
3. UL 268 Smoke Detectors.
4. UL 916 Energy Management.
5. NFPA 70 – National Electrical Code.
6. NFPA 90A – Standard for the Installation of Air Conditioning and Ventilating Systems.
7. American National Standards Institute (ANSI).
8. National Electrical Manufacturer's Association (NEMA).
9. American Society of Mechanical Engineers (ASME).
10. ASHRAE.
11. Air Movement and Control Association (AMCA).
12. American Standard Code for Information Interchange (ASCII).
13. Institute of Electrical and Electronic Engineers (IEEE).
14. Electronic Industries Associates (EIA).
15. Occupational Safety and Health Administration (OSHA).
16. American Society of Testing and Materials (ASTM).
17. Federal Communications Commission (FCC).
18. American Disability Act (ADA).
19. ANSI/EIA 909.1-A-1999 (Lon Works).

20. ANSI/ASHRAE Standard 195-2008 (BACnet).
21. UL 864 UUKL Smoke Control.
22. NFPA 92A and 92B – Smoke Purge/Control Equipment.

E. Except where certain controls are specified by manufacturer and product numbers (and no substitute is permitted in those cases), all products shall be of a common manufacturer and no mixing of manufacturers is permitted. It should be noted that all quality requirements noted in this specification shall be equally met; any variance shall be submitted in writing 14 days prior to bidding and, if approved, notice will be given in writing. Failure to meet the 14-day requirement will negate any consideration of variance.

F. All engineering, project management, system programming, system checkout and project commissioning (if required) shall be performed by experienced full-time professional employees of the Control Supplier/Engineering Contractor. Installation of all electric, electronic, and DDC controls including all electric wiring shall be the responsibility of the ECC. Installation may be subcontracted at the Contractor's discretion, but full and complete responsibility for the quality and workmanship rests with the ECC. Where work is subcontracted, the ECC shall make a complete inspection before the system is placed in operation to insure that all sections of Part 3 - Execution are met and such documentation shall be made a part of the final operation and maintenance manuals.

G. The Control Supplier/Engineering Contractor shall have a minimum of 15 years of experience in the design and installation of Environmental Control Systems equal in scope and size to that herein specified and shall be prepared to provide documented proof of such history. Contractor to be full factory branch or provide written proof that control manufacturer assumes full liability for any product fault or defect.

H. Service and installation personnel to be permanently located within 100 miles of job site and to be available 24 hours each day and respond on-site within 4 hours' notice. Contractors who rely on third party vendors for maintenance/service staff and expertise on any major component are not acceptable.

I. Installer Qualifications:

1. Licensed contractor with at least five years of working experience in the installation of Building Automation Systems.
2. Demonstrated specific experience shall include cabling systems and pathways of electrical and telecommunications systems.
3. Demonstrated expertise in the installation, functional checkout, point to point verification, calibration, troubleshooting and startup of Building Automation Systems.
4. In addition to the technical capabilities described herein, demonstrate a production capability to plan, control and integrate manpower and other resources necessary for successful contract completion.
5. The Owner may ask to verify the qualifications and experience for all field installation technicians and installation contractors assigned to the project prior to the installation work commencing.
6. Installation personnel working this specific project shall attend a one hour familiarization session with the Owner’s control system personnel immediately following the project preconstruction meeting. This meeting shall include the ECC’s assigned Project Manager.

J. SYSTEM PERFORMANCE

1. Comply with the following performance requirements:

a) Graphic display: Display graphic with minimum 20 dynamic points with current data within 10 seconds.
b) Graphic refresh: Update graphic with minimum 20 dynamic points with current data within 8 seconds.
c) Object command: Reaction time of less than two seconds between operator command of a binary object and device reaction.
d) Object scan: Transmit change of state and change of analog values to control units or workstation within six seconds.
e) Alarm response time: Annunciate alarm at workstation within 45 seconds. Multiple workstations must receive alarms within five seconds of each other.
f) Program execution frequency: Run capability of applications as often as five seconds, but selected consistent with mechanical process under control.
g) Performance: Programmable controllers shall execute DDC PID control loops, and scan and update process values and outputs at least once per second.
h) Reporting accuracy and stability of control: Report values and maintain measured variables within tolerances as follows:

(1) Water temperature: Plus or minus 1 deg F.
(2) Water flow: Plus or minus 5 percent of full scale.
(3) Water pressure: Plus or minus 2 percent of full scale.
(4) Space temperature: Plus or minus 1 deg F.
(5) Ducted air temperature: Plus or minus 1 deg F.
(6) Outside air temperature: Plus or minus 2 deg F.
(7) Dew point temperature: Plus or minus 3 deg F.
(8) Temperature differential: Plus or minus 0.25 deg F.
(9) Relative humidity: Plus or minus 5 percent.
(10) Airflow (pressurized spaces): Plus or minus 3 percent of full scale.
(11) Airflow (measuring stations): Plus or minus 5 percent of full scale.
(12) Airflow (terminal): Plus or minus 10 percent of full scale.
(13) Air pressure (space): Plus or minus 0.01-inch wg.
(14) Air pressure (ducts): Plus or minus 0.1-inch wg.
(15) Carbon monoxide: Plus or minus 5 percent of reading.
(16) Carbon dioxide: Plus or minus 50 ppm.
(17) Electrical: Plus or minus 5 percent of reading.

K. PRELIMINARY SUBMITTAL PACKAGE

1. The Environmental Control Contractor (ECC) shall submit, at, or before, the time of bid, a comprehensive Preliminary Submittal Package including all items listed below. Failure to submit the required documentation at the designated time will be grounds for rejection of the Environmental Control Contractor bid. The ECC contract shall be awarded based on a combination of price, completeness of bid (per review of Preliminary Submittal Package), and presentation/interview with the client and their design team.

2. The following documentation shall be provided, at a minimum, as part of the Preliminary Submittal Package:

3. Network diagram(s) showing the correct number of Network Controllers, Operator Interface devices, and Servers as required for the type and size of the BAS system and the communication network connecting all anticipated field level panels/controllers. Clearly identify the responsibilities of connecting the BAS system to the client's IT network (as applicable).
4. Flow diagrams specific for each mechanical system (whether DDC-controlled or locally controlled) schematically showing all control devices intended and required to properly control said system. NOTE: The ECC shall generate the flow diagrams using their standard engineering tool(s). It is not acceptable to directly copy the control schematics included in the bid documents generated by TRC Worldwide to meet this requirement.
5. Sequence of operations written out for each mechanical system (whether DDC-controlled or locally controlled) covering all modes of operation for each piece of equipment. NOTE: The ECC shall generate the sequence of operations using their standard engineering tool(s). It is not acceptable to directly copy the sequence of operation verbiage included in the bid documents to meet this requirement.
6. Point schedules for all equipment that is DDC-controlled. Point nomenclature shall match between the flow diagram and associated point schedule. NOTE: The ECC shall generate the point schedules using their standard engineering tool(s). It is not acceptable to directly copy the point schedules included in the bid documents generated by TRC Worldwide to meet this requirement.
7. Product data sheets for each control device shown on the control schematics.
8. Sample graphic print outs of systems similar to those utilized on this specific project.
9. Resumes of execution/delivery team including project manager(s), field technicians, programmers, engineers, etc.
10. Customer training plan.
11. Detailed drawing, sequence and description of corridor lighting control.

12. Coordinate delivery of the Preliminary Submittal Package per the following scenarios:

14. Direct Bid to Owner as Prime Contractor: Deliver a minimum of two complete hard copies of the Preliminary Submittal Package in appropriately sized 3-ring binders to the designated Owner's representative. All documents should be compiled into the minimum amount of Acrobat pdf files as possible. It is not desired to deliver each document individually. Electronic copies of the entire submittal package shall also be sent to the designated Owner's representative, the General Contractor/Construction Manager, and the Architect/Engineer. *<u>NOTE: All pricing and corresponding proposals are to be sent directly to the designated Owner's representative – not to the HVAC/Mechanical Contractors. See Bid Form for details.</u>

15. Acceptable electronic formats are:

    a) E-mail attachment(s) (beware of size restrictions).

b) On-line file storage service (box.net or equal. Provide applicable access codes, passwords, etc.).
c) FTP file sharing site (provide applicable access codes, passwords, etc.).
d) USB mass storage device(s).
e) CD/DVD media.

16. Prime or direct bid to Construction Manager (CM). Deliver the Preliminary Submittal Package electronically to the designated Construction Manager's representative. All documents should be compiled into the minimum amount of Acrobat pdf files as possible. It is not desired to deliver each separate document. ECC must copy Architect/Engineer indicating the ECC has satisfied the requirement of transmitting the Preliminary Submittal Package. *NOTE: All pricing and corresponding proposals are to be sent to the Construction Manager, not to the Owner's representative.

17. Acceptable electronic formats are:

a) E-mail attachment(s) (beware of size restrictions).
b) On-line file storage service (box.net or equal. Provide applicable access codes, passwords, etc.).
c) FTP file sharing site (provide applicable access codes, passwords, etc.).
d) USB mass storage device(s).
e) CD/DVD media.

18. Bid to General Contractor (GC) as subcontractor. Deliver the Preliminary Submittal Package electronically to each designated General Contractor's Representative. All documents should be compiled into the minimum amount of Acrobat pdf files as possible. It is not desired to deliver each separate document. ECC must copy Architect/Engineer indicating the ECC has satisfied the requirement of transmitting the Preliminary Submittal Package. *NOTE: All pricing and corresponding proposals are to be sent to the General Contractors, not to the Owner's representative.

19. Acceptable electronic formats are:

a) E-mail attachment(s) (beware of size restrictions).
b) On-line file storage service (box.net or equal. Provide applicable access codes, passwords, etc.).
c) FTP file sharing site (provide applicable access codes, passwords, etc.).
d) USB mass storage device(s).
e) CD/DVD media.

20. Bid to Mechanical Contractor (MC) as subcontractor: Deliver the Preliminary Submittal Package electronically to the designated Owner's representative. All documents should be compiled into the minimum amount of Acrobat pdf files as possible. It is not desired to deliver each separate document. ECC must copy each Mechanical Contractor bidding this project indicating the ECC has satisfied the requirement of transmitting the Preliminary Submittal Package. *NOTE: All pricing and corresponding proposals are to be sent to the Mechanical Contractors, not to the Owner's representative.

21. Acceptable electronic formats are:

a) E-mail attachment(s) (beware of size restrictions).
b) On-line file storage service (box.net or equal. Provide applicable access codes, passwords, etc.).
c) FTP file sharing site (provide applicable access codes, passwords, etc.).
d) USB mass storage device(s).
e) CD/DVD media.

L. PRICING AGREEMENT

1. In addition to the Preliminary Submittal Package, the Environmental Control Contractor (ECC) shall submit at or before the time of bid, a Pricing Agreement document for review by the Owner, the Construction Manager and the Project Design Team. The terms and structure of the Pricing Agreement will be considered in the process of selecting and awarding the Environmental Control System Contract.

2. The Pricing Agreement shall include, at a minimum, the following four (4) sections with pricing detailed specifically for this project.

3. Manufacturer's material, equipment and devices: Show total material list price, proposed discount from the list price and final total estimated material price for this project. ECC should be prepared to break this pricing down further per area of building or per system.
4. Third party material, equipment and devices: Show total cost of third party material, proposed overhead and markup structure for the third party material and total estimated price for third party material for this project. Again, the ECC should be prepared to break this pricing down further per area of building or per system.
5. Subcontract labor cost: Show total cost of proposed subcontracted labor (per labor type), proposed overhead and makeup structure for the subcontracted labor and total estimated price for this labor. The ECC should receive competitive bids for each type of subcontracted labor (preferably 3 or more per labor type) and be prepared to share the subcontract quotes with the Owner, Construction Manager and Project Design Team for analysis.
6. Self-performed labor cost: Show cost for each category of self-performed labor, including, but not limited to, project management, project engineering, technician/programming, clerical, training, general conditions, travel and expense. List estimated time (in hours), proposed hourly billing rate and total estimated cost for each category.

M. SUBMITTALS

1. Product:

2. Submit descriptive literature and shop drawings in accordance with Section 01 33 00.
3. Submittals shall include the following data:

4. Dimensions and electrical characteristics.
5. Installation instructions.
6. Product description, operational capacities, and accuracies.

7. For each component located within the occupant's space provide dimensions, colors, and scaled drawings of the faceplate with each feature identified. Provide this information for all space sensors, pressure monitors, carbon dioxide sensors, and humidity sensors.
8. For each terminal controller, floor level controller, network controller and operators workstation (hardware and software) type, provide the following:

a) Date introduced on the market.
b) Expected date which product will cease to be produced.
c) Expected date that successor product is expected to be available.
d) Expected date that support of the product will end.

9. Shop Drawings:

10. Submit shop drawings to the Architect/Engineer which completely illustrate:

a) Full schematic presentation of all systems with location of all sensors, relays, dampers, valves, and actuators. All components to be designated to a code similar to Engineer's design on HPE drawings.
b) Full wiring diagrams with point to point designation. Number, size, and type of wiring with designation as to exact enclosure and support to be clearly noted.
c) All DDC analog and binary points to be cross referenced to the same code designation (AI-X, AO-X, BI-X, and BO-X) shown on Engineer's HPE drawings.
d) All operating systems shall include the sequence of operation that will be employed. This will parallel, as a minimum, the sequence detailed on Engineer's HPE drawings and shall include any virtual points, timers, lookup tables, startup and shutdown sequences, and other control means required. This sequence shall be written in sentence format on the shop drawings similar to that noted on the HPE drawings.
e) All pneumatic sensing and activating air lines to be clearly denoted with sizing and reference to specified installation standards.
f) Hydronic and steam valve schedules with flowrate, design differential pressure at the design flowrate, valve body maximum pressure rating, maximum working differential pressure at which control can be maintained.
g) Damper schedule including design maximum and minimum flowrates, opposed/parallel blade configuration, insulation, and leakage characteristics.
h) Building control system architecture illustrating each DDC controller; the type of communication between each DDC controller; all 120V power requirements; network, phone, fiber and internet connections; and operator's workstations and printer locations.
i) Color graphic samples shall be included in initial submittal package. Floor plan graphics and system graphics depicting mechanical, electrical and plumbing systems similar to those utilized in this project shall be included.
j) Data Communication Protocol Certificates: Certify that each proposed DDC system component complies with ASHRAE 135 (BACNet).

11. ECC to schedule a presubmittal presentation of all proposed formal submittal diagrams and data with A/E prior to said formal submittal. This meeting shall be scheduled and conducted at TRC Worldwide.

12. Maintenance Manuals:

13. Submit maintenance and operating manuals in accordance with Section 01 78 23.
14. Submit software and firmware operating and upgrade manuals.
15. Submit program backup software on compact disc, complete with data files.
16. Device address list.
17. Software license required by and installed for DDC workstations and internet access.

18. Owner Instruction and Training Report:

19. Submit the written "Owner Instruction and Training Report" in accordance with this specification section.

20. Field Quality Control Test Reports:

21. Submit the written "Owner Instruction and Training Report" in accordance with this specification section.

N. PRE-INSTALLATION COORDINATION MEETING

1. A pre-installation coordination meeting shall be held after submittal approval and before installation of the control system beings. The location of this meeting will be determined at a later date and will be appropriate for all parties participating. The following people/roles are required attendees at this meeting:

a) Owner: Director of Facilities/Engineering/Maintenance or equivalent role, key users/operators of the controls/BAS system as designated by the Director of Facilities/Engineer/Maintenance.
b) TRC Worldwide: Project Manager
c) ECC: Project Manager, Lead Field Technician, Design Engineer and Sales Engineer.
d) Construction Manager/General Contractor: Project Manager and MEP Coordinator.

2. The intent of the pre-installation coordination meeting is to address, discuss and resolve controls/BAS items with all key parties in attendance that historically have caused conflict and delays during the closeout/completion phase of projects.

O. DEFINITIONS

1. BAS System: An automatic, programmable building automation system that consists of an open framework Supervisory Level and a system of BACnet compliant Building Level Controllers. The system architecture shall use an IP based Supervisory Level system that connects to the internet and is web based

for ease of access while the Building Level network shall be MSTP, twisted pair network integrating with the Supervisory Level through BACnet protocol and open framework drivers.

a) Supervisory Level: an open framework platform utilizing Tridium Niagara that provides a web based operator graphical interface for supervision, data logging, trending, alarming, scheduling, and network management of all Building Level controllers.

b) Building Level: BACnet compliant, programmable controllers located at terminal devices and systems. The Building Level is connected through a MSTP, twisted pair network.

P. SEQUENCE OF OPERATION

1. Note that all operational sequences are noted on the Drawings.

PRODUCTS

III. FIELD EQUIPMENT

A. Control Instruments:

1. All control instruments, unless otherwise specified, shall be fully proportioning with adjustable sensitivity. Note that P, PI, and PID loops shall be required wherever necessary to afford final stable control within acceptable parameters to satisfaction of Architect/Engineer.

B. Thermostat:

1. Low limit thermostats:

2. Low limit safety thermostats shall be manually reset, line voltage with maximum 23'-0" flexible sensing elements responsible to lowest temperature along entire length. Furnish minimum two (2) wired in series on the discharge side of the first hydronic coils (i.e., a 4-section coil requires eight low limit thermostats wired in series). Contractor to note that the operating head of such instruments shall be shielded from conditions whereby it could be activated by low temperature. Clarify location of low limits with the Engineer during submittal review if HPE Sheets illustrate a location other than the discharge side of the first hydronic coil.
3. All flexible averaging sensors shall be attached by wire ties to a suspended wire or insulated cable to prevent sensor contact with metal or other unit components.
4. Install flexible sensors across all coils at a maximum of 6” from the bottom of the bottom coil and a minimum of 7” diameter to turn the sensor. Install the detector with a maximum free distance of 12” between each pass.
5. Staggered coils shall utilize multiple sensors. Each sensor shall cover one section of the staggered coil. Sensing elements shall be a minimum of 17’ long.
6. All flexible sensors shall be protected at point of penetration of unit via a section of poly tubing to prevent contact of the sensor and the unit.

7. Mount detector within 6” of the face of the coil unless noted otherwise. For staggered coil banks, this requirement applies for each half of the bank
8. ECC to note that when any low limit controls are above an elevation 7'-0" above floor level or otherwise inaccessible, they shall employ automatic reset and shall be wired to an auxiliary control panel of a 5'-0" elevation. The control panel with piano hinged door shall utilize a latching reset relay for each individual low limit control which insures that the fan is de-energized even as the low limit resets automatically. The panel face shall utilize a red alarm pilot light that remains lit until the 10 second time delay reset relay momentary contact switch is activated. An LED inside the panel shall indicate which of low limits has signaled the alarm.

C. Temperature Sensors:

1. Duct sensors for critical spaces shall utilize averaging elements, 1000 OHM platinum Resistance Temperature Detectors (RTD) having an accuracy of ±0.5 deg F.
2. Duct sensors for non-critical spaces may utilize 10,000 OHM or 20,000 OHM thermistor having an accuracy of ±1.0 deg F. 1000 OHM RTDs are also acceptable for non-critical applications.
3. Immersion sensors to be furnished with companion wells separable stainless steel. Well pressure rating shall be consistent with and extend the system pressure it will be immersed in. Wells shall withstand pipe design flow velocities.
4. Outdoor sensors to utilize Vaisala DTR 503A shields.

D. Space Sensors:

1. Space sensors located in private offices, conference rooms, other areas deemed “non-public” and as noted on the drawings shall have exposed external set-point adjustment and digital LCD display capable of displaying setpoint and actual sensed temperature.
2. In areas deemed “public” or where indicated on the drawings, space sensors shall have exposed external setpoint adjustment, but be without LCD displays.
3. Set-point adjustment to be a maximum plus and minus 4 degrees from the null setpoint programmed through the DDC system.
4. Space sensors may be (RTD) 1,000 Ohm platinum with an accuracy of ±0.5 deg F or 10,000 OHM thermistor with accuracy of ±0.5 deg. F for all spaces unless noted otherwise on the HPE Drawings.
5. Space sensor shall be of a neutral color (white, beige or other customer approved color) unless noted otherwise on the HPE Drawings.
6. Provide insulating bases for all sensors located on exterior walls and on exterior column wraps. Foam seal cavity and junction box prior to installing insulating base.
7. Provide locking, ventilated guards where indicated on the HPE Drawings. It is the ECC’s responsibility to coordinate color of all space sensors with the Owner prior to installation of same.
8. Provide washdown resistant sensors where indicated on the HPE Drawings and for all wet locations.
9. Provide occupancy override button on face of space sensor where indicated on the sequence and on the HPE Drawings.
10. Space sensors with occupant set-point adjustment shall be adjustable from the operator’s work station as to the deadband of adjustability allowed to the occupants.

E. Electronic Actuators:

1. Manufactured, brand labeled or distributed by Belimo or Johnson Controls, Inc. or Siemens.
2. Size for torque required for damper seal at load conditions.
3. Coupling: V-bolt dual nut clamp with a V-shaped, toothed cradle.
4. Mounting: Actuators shall be direct shaft mount type. Actuators shall be capable of being mechanically and electrically paralleled to increase torque if required.
5. Overload protected electronically throughout rotation.
6. Fail safe operation: Mechanical, spring return mechanism. [**Electronic fail safe shall incorporate a visual indication of the fail safe status on the face of the actuator. The power fail position shall be field adjustable between 0 to 100% in 10 deg. F increments. The electronic fail safe shall have a 2 second (adjustable) operational delay.**]
7. Power requirements (spring return): 24 VAC, maximum 15 VA at 24 VAC or 8 W at 24 VDC.
8. Proportional actuators shall be fully programmable through an EEPROM without the use of actuator mounted switches.
9. Temperature rating: -22 deg. F to +122 deg. F.
10. Housing: Minimum requirement NEMA Type 2/IP54 mounted in any orientation. NEMA 4/4X (IP67) required for outdoor applications.
11. Agency listings: ISO 9001 or UL.
12. The manufacturer shall warrant all components for a period of 5 years from the date of production with the first two years unconditional.
13. All damper actuators used on equipment introducing outdoor air shall be furnished with mechanical spring return mechanism as indicated in “fail safe operation” above.
14. All actuators shall have external adjustable stops to limit the travel in either direction and a gear release to allow manual positioning.
15. Actuators shall be provided with position feedback signal (2-10 VDC or 4-20 mA) where indicated on HPE drawings. Feedback signal shall be independent of the input signal and shall provide true position indication.

F. Industrial Actuators (Only to be used with Butterfly Valves – Resilient Seat and Butterfly Valves – High Performance):

1. Manufacturer, brand labeled or distributed by Belimo or Johnson Controls, Inc. or Siemens.
2. The combination of valve and actuator shall meet the close-off requirements as specified in the “Butterfly Valves” portion of this Specification.
3. Coupling: ISO 5211 mounting standards.
4. Overload protection: A self-resetting thermal switch embedded in the motor.
5. Manual override: Actuator shall be equipped with a hand wheel or shaft for manual override to permit operation of the actuator in the event of an electrical power failure.
6. Power requirements: [**24 VAC**][**120 VAC**] 1 PH.
7. Auxiliary switches: 2 SPDT rated 3A at 250 VAC.
8. Temperature rating: -22 deg. F to +150 deg. F.
9. Housing: Minimum requirement NEMA Type 4X/IP67 with an industrial quality coating. Actuator shall have an internal heater to prevent condensation within the housing. A visual indication beacon shall indicate position status of the device.
10. Agency listing: ISO, UL.

11. The manufacturer shall warrant for 2 years from the date of production.

G. Control Valves:

1. Manufacturer: Manufactured, brand labeled or distributed by Belimo or Johnson Controls, Inc. or Siemens.
2. Control valve actuators:

a) Size for valve close off at 150 percent of total system (head) pressure for two-way valves and 100 percent of pressure differential across the valve or 100 percent of total system (pump) head differential pressure for three-way valves.
b) Coupling: Directly couple and mount to valve stem and shaft ISO style direct-coupled mounting pad.
c) Shall meet all the requirements of 2.1.E Electronic Actuators.

3. Control valves:

a) Factory fabricated of type, body material and pressure class based on maximum pressure and temperature rating of piping system unless otherwise indicated.
b) Sizing:

(1) Two-position: Line size or size using a pressure differential of 1 psi.
(2) Two-way modulating: 5 psid or twice the load pressure drop, whichever is more.
(3) Three-way modulating: Twice the load pressure drop, but not more than 5 psid.

c) Sizing (steam):

(1) Two-position: Line size or sized using 10% of inlet gauge pressure.

(2) Modulating: 15 psig or less inlet steam pressure, the pressure drop shall be 80% of inlet gauge pressure. Higher than 15 psig inlet steam pressure, the pressure drop shall be 42% of the inlet absolute pressure.

d) Close-off pressure rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of total system head pressure for two-way valves and 150 percent of the design pressure differential across the three-way valves. Combination of actuator and trim shall provide minimum close-off pressure rating of 100 psid.
e) The control valve assembly shall be provided and delivered from a single manufacturer as a complete assembly.

4. The manufacturer shall warrant all components for a period of 5 years from the date of production with the first two years unconditioned (except as noted).

H. Pressure independent control valves:

1. NPS 2 and smaller: Forged brass body rated at no less than 400 psi, chrome plated brass ball and stem, female NPT union ends, dual EPDM lubricated O-rings and a brass Tefzel characterizing disc.
2. NPS 2-1/2 through 6: GG25 cast iron body according to ANSI Class 125, Standard Class B, stainless steel ball and blowout proof stem, flange to match ANSI 125 with a dual EPDM O-ring packing design, PTFE seats and a stainless steel flow characterizing disc.
3. Accuracy: The control valves shall accurately control the flow from 0 to 100% full rated flow with an operating pressure differential range of 5 to 50 psi differential across the valve with a valve body accuracy of ±5% variance due to different pressure fluctuation or ±10% total assembly error incorporating differential pressure fluctuation, manufacturing tolerances and valve hysteresis.
4. Flow characteristics: Equal percentage characteristics.
5. All actuators shall be capable of being electronically programmed in the field by use of external computer software or a dedicated handheld tool for the adjustment of flow. Programming using actuator mounted switches or multi-turn actuators are not acceptable.
6. Coil optimization 2-1/2" through 6" shall be accomplished by utilizing a pressure independent control valve assembly; two temperature sensors providing feedback of coil inlet water temperature and coil outlet water temperature and a magnetic flow meter to provide analog flow feedback. Software shall control the valve to avoid the coil differential temperature from falling below a programmed setpoint. Independent trend logs data shall be available by means of BACnet MS/TP trending data to include, but not be limited to, inlet and outlet coil water temperatures, valve position, absolute flow, absolute valve position, absolute power and heating/cooling energy in BTU/hr.
7. The manufacturer shall provide a published commissioning procedure following the guidelines of the National Environmental Balancing Bureau (NEBB) and the Testing Adjusting Balance Bureau (TABB).
8. The control valve shall require no maintenance and shall not include replaceable cartridges.
9. NPS 2" and smaller pressure independent control valves for individual coil control shall be provided as part of a pipe package supplied by the valve manufacturer. The supply side of the coil shall contain an integrated isolation ball valve/manual air vent [**strainer**/**shut-off valve**/**drain**] with a P/T port. The return side shall contain a union fitting with a P/T port, pressure independent control valve, an integrated isolation ball valve/manual air vent with a P/T port. Shutoff valves as an integrated part of the pressure independent control valve are prohibited.

I. Characterized control valves:

1. NPS 2 and smaller: Nickel plated forged brass body rated at no less than 400 psi, stainless steel ball and blowout proof stem may be female NPT, sweat connection or pressure connect end fittings with a dual EPDM O-ring packing design, fiberglass reinforced Teflon seat or graphite reinforced PTFE seats and a flow characterizing disc.
2. NPS 2-1/2 through 3: GG25 cast iron body according to ANSI Class 125, Standard Class B, stainless steel ball and blowout proof stem, flange to match ANSI 125 with a dual EPDM O-ring package design, PTFE seats and a stainless steel flow characterizing disc.
3. For steam applications, NPS 1 and smaller: Nickel plated forged brass body rated at no less than 600 psi, stainless steel ball and blowout proof stem, female NPT end fittings with a dual EPDM O-ring packing design,

fiberglass reinforced PTFE Teflon seats and a PTFE Teflon flow characterizing disc.

4. Flow characteristics: Equal percentage characteristics.

5. Six-way control valves shall have the following characteristics:

6. NPS ½" and ¾": Nickel plated forged brass body rated at no less than 600 psi, dual chrome plated brass ball and blowout proof stems and female NPT end fittings. Each three-way portion of the 6-way valve body shall have EPDM O-ring packing design, fiberglass reinforced Teflon seats and a flow characterizing disc.
7. The six-way control valve shall be controlled by a rotary actuator for managing two media in a switching application. The valve shall be closed to flow at mid-rotation.

8. Globe valves shall have the following characteristics:

   a) NSP 2 and smaller: ANSI Class 250 bronze body, stainless steel stem, brass plug, bronze seat and a TFE packing.
   b) NPS 2-1/2 and larger: ANSI Class [**125**][**250**] cast iron body, stainless steel stem, bronze plug, bronze seat and a TFE V-ring packing.
   c) Flow characteristics: Two-way valves shall have equal percentage characteristics. Three-way valves shall have linear characteristics.
   d) Two and three way globe valves shall be used only if characterized control valves do not fit the sizing criteria or application.

9. Butterfly valves – resilient seat:

   a) NPS 2 and 12: Valve body shall be full lugged cast iron 200 psig body with a 304 stainless steel disc, EPDM seat, extended neck and shall meet ANSI Class 125/150 flange standards. Disc-to-stem connection shall utilize an internal spine. The shaft shall be supported at four locations by RPTFE bushings.
   b) NPS 14 and larger: Valve body shall be full lugged cast iron 150 psig body with a 304 stainless steel disc, EPDM seat, extended neck and shall meet ANSI Class 125/150 flange standards. Disc-to-stem connection shall utilize a dual pin method to prevent the disc from settling onto the linear. The shaft shall be supported at four locations by RPTFE bushings.
   c) Sizing:

      (1) Two position: Line size or size using a pressure differential of 1 psi.
      (2) Modulating: 5 psig or twice the load pressure drop, whichever is more. Size for the design flow with the disc in a 60 degree open position and a design velocity not-to-exceed 12 feet per second.

   d) Close off pressure rating:

      (1) NPS 2-12" 200 psi bubble tight shutoff.
      (2) NPS 14 and larger: 150 psi bubble tight shutoff.

J. Butterfly valves – high performance:

1. Valve body shall be full lugged carbon steel ANSI Class [**150**][**300**] body with a 316 stainless steel disc without a nylon coating, RTFE seat and be ANSI Class 150/300 flange standards. Blowout proof shaft shall be 17-4 ph stainless steel and shall be supported at four locations by glass backed TFE bushings. Valve packing shall be Chevron TFE and shall include fully adjustable packing flange and separable packing gland. Valve body shall have long stem design to allow for 2" insulation (minimum). Valve face-to-face dimensions shall comply with API 609 and MSS-SP-68. Valve assembly shall be completely assembled and tested, ready for installation.
2. Sizing:

3. Two position: Line size or size using a pressure differential of 1 psi.
4. Modulating: 5 psig or twice the load pressure drop, whichever is more. Size for the design flow with the disc in a 60 degree open position and a design velocity not-to-exceed 12 feet per second.

5. Flow characteristics: Modified equal percentage, unidirectional.
6. Close off pressure rating: [**150**][**285**] psi bubble tight shutoff.
7. Media temperature range: ANSI Class [**150**][**300**] limitations.
8. Max differential pressure: 285 psi at 100 deg. F for ANSI 150 (725 psi at 100 deg. F. for ANSI 300).

K. Zone valves (on/off two position applications):

1. NPS 1 and smaller: Forged brass body rated at no less than 300 psi, stainless steel stems, female, NPT union or sweat with a stainless steel stem or EPDM seals.
2. The manufacturer shall warrant all components for a period of 2 years from the date of production.

L. Dampers:

1. All automatic dampers furnished by this Contractor for modulating control shall be of the proportioning type with opposed or parallel blades depending on the application or as shown on the drawings. Dampers for two position action shall be of the opposed blade type for all applications except those located immediately at the inlet of fans and as noted otherwise on the drawings. Dampers for generator radiator fan exhaust shall be opposed blade type.
2. All dampers for outdoor air service and exhaust air service to be equal to TAMCO Series 9000 aluminum and have the following features:

    a) Frames shall be 4" deep X 1" and no less than .080" in thickness, mill finish extruded aluminum 6063-T5 with mounting flanges on both sides of the frame. Frame to be assembled using plated steel mounting fasteners.
    b) Entire frame shall be thermally broken by means of two polyurethane resin pockets complete with thermal cuts.
    c) Blades shall be extruded aluminum 6063-T5, mill finish air foil profiles, internally insulated with expanded polyurethane foam and shall be thermally broken.
    d) Blade and frame seals shall be of extruded silicone and shall be secured in an integral slot within the aluminum extrusions. Blade and frame seals are to be mechanically fastened to eliminate

shrinkage and movement over the life of the damper. Adhesive or clip on type blade seals shall not be approved.

e) Maintenance free bearings are to be composed of an inner bearing fixed to a 7/16" aluminum hexagon blade pivot pin, rotating within a polycarbonate outer bearing inserted into the frame. There shall be no metal-to-metal or metal-to-plastic contact.

f) Adjustable 7/16" hexagonal drive rod, U-bolt fastener and hexagonal retaining nuts shall be corrosion resistant, zinc plated steel to provide positive connection to blades and linkage.

g) Linkage hardware shall be installed in the frame side. All linkage crank arm and rod hardware parts shall be constructed of mill finished aluminum, complete with corrosion resistant, zinc plated trunnions and cup point trunnion screws for a slip-proof grip.

h) Dampers are to be designed for operation in temperatures ranging between -40 deg. F (-40 deg. C) and 212 deg. F (100 deg. C).

i) Dampers shall be rated Leakage Class 1A at 1 in. w.g. (0.25 kPa) static pressure differential. Standard air leakage data shall be certified under the AMCA Certified Ratings Program.

j) Dampers shall be made to size required without blanking off free area.

k) Dampers shall be available as "flanged to duct" mounting type.

l) Installation of dampers must be in accordance with manufacturer's installation guidelines provided with each damper shipment.

m) Intermediate or tubular steel structural support is required to resist applied pressure loads for dampers that consist of two or more sections in both height and width. (See manufacturer's installation guidelines).

3. Dampers for all other applications to be equal to TAMCO Series 1500 Ultra Low Leakage Air Foil Aluminum and have the following features:

a) Frames shall be 4" deep X 1" and no less than .080" in thickness, mill finish extruded aluminum 6063-T5 with mounting flanges on both sides of the frame. Frame to be assembled using plated steel mounting fasteners.

b) Entire frame shall be thermally broken by means of two polyurethane resin pockets complete with thermal cuts.

c) Blades shall be extruded aluminum 6063-T5, mill finish air foil profiles, internally insulated with expanded polyurethane foam and shall be thermally broken.

d) Blade and frame seals shall be of extruded silicone and shall be secured in an integral slot within the aluminum extrusions. Blade and frame seals are to be mechanically fastened to eliminate shrinkage and movement over the life of the damper. Adhesive or clip on type blade seals shall not be approved.

e) Maintenance free bearings are to be composed of an inner bearing fixed to a 7/16" aluminum hexagon blade pivot pin, rotating within a polycarbonate outer bearing inserted into the frame. There shall be no metal-to-metal or metal-to-plastic contact.

f) Adjustable 7/16" hexagonal drive rod, U-bolt fastener and hexagonal retaining nuts shall be corrosion resistant, zinc plated steel to provide positive connection to blades and linkage.

g) Linkage hardware shall be installed in the frame side. All linkage crank arm and rod hardware parts shall be constructed of mill finished

aluminum, complete with corrosion resistant, zinc plated trunnions and cup point trunnion screws for a slip-proof grip.

h) Dampers are to be designed for operation in temperatures ranging between -40 deg. F (-40 deg. C) and 212 deg. F (100 deg. C).

i) Dampers shall be rated Leakage Class 1A at 1 in. w.g. (0.25 kPa) static pressure differential. Standard air leakage data shall be certified under the AMCA Certified Ratings Program.

j) Dampers shall be made to size required without blanking off free area.

k) Dampers shall be available with either opposed blade action or parallel blade action.

l) Dampers shall be available as “flanged to duct” mounting type.

m) Installation of dampers must be in accordance with manufacturer’s installation guidelines provided with each damper shipment.

n) Intermediate or tubular steel structural support is required to resist applied pressure loads for dampers that consist of two or more sections in both height and width. (See manufacturer’s installation guidelines).

4. Automatic dampers (modulating) shall be designed for face velocity that varies from 1,200 fpm to 2,000 fpm in most cases as approved by the design engineer. Dampers to be selected by the supplier with blade shaft lengths that prevent torsion that will create a leakage of more than 2 percent of the rated leakage capacity. Beyond that point, the dampers shall be broken into multiple sections. Field supplied mullions are required on large dampers exceeding 200 square feet.
5. Individual damper section actuators are preferred unless access to actuators is difficult and then jack shafting is acceptable. ECC to note that drive shafts between dampers of different air paths (i.e., outdoor air and return air or return air and exhaust air) is not acceptable. Jack shafting between sections is permitted when such shafting is designed to accommodate and eliminate the effects of torsion.
6. ECC to note that free access to all actuators is the responsibility of the ECC.
7. Each damper shall be equipped with an individual damper operator of the size and style required for the service intended.
8. Actuators to be designed for modulating control with spring return to the fail "safe" position. Actuators to be low voltage with 100% surplus torque (submittals to incorporate calculations to prove 100 percent closure under 4.0" wg status pressure differential for modulating service and 2.0" wg for two position application).
9. Terminal box/AFCV damper actuators to be low voltage, non-spring return and incremental control with 200 percent torque. All control actuators to utilize auto zero program to insure total accuracy of damper actuator. The feature to be activated during periods of low or no occupancy.
10. Pneumatic damper actuators to be piston type of the size and style to meet application. All modulating dampers to be equipped with pilot positioners to make the full power of the actuator available as well as to allow the operating range and starting point of the actuator to be field adjusted.
11. Smoke Damper and Combination Fire Smoke Dampers full open and full closed status signal shall be displayed at the operators work station, generate a report of this status and generate an alarm when they are not in the open (normal) position.

M. Humidity Sensors:

1. Space and duct humidity sensors to utilize this film capacitor structure on glass substrate element to operate with an accuracy of ±2% within a range of 20 and 95% RH. Sensitivity to be 0.1% RH, repeatability 0.5% RH with hysteresis less than 1%.
2. Sensors to be Vaisala.

    a) Space sensors: HMW80 Series.
    b) Duct sensors: HMD 60 U.

3. Outdoor sensors (temperature and humidity) to be Vaisala Model HMP 60 Series with DTR500 radiation shield.

N. Carbon Dioxide Sensors:

1. Units to be capable of sensing carbon dioxide from 0 to 2000 ppm with an accuracy of ±2% of range plus 2% of reading. Output to be 4-20 ma.
2. The unit shall be guaranteed to maintain accuracy of ±5% of range for 60 months before requiring recalibration.
3. Sensors:

    a) Space: Vaisala GMW 20 (GMW 21 includes temperature sensor option).
    b) Duct: Vaisala GMD 20 (GMD 21 includes temperature sensor option).

O. Control Panels:

1. Control panels for electric and electronic controls shall be located as detailed on drawings or otherwise adjacent to air handling units, heat exchangers, or other mechanical systems served. Panels shall utilize unistrut support from floor brackets such that the center of the panel is at a 48" height.
2. Panel frames shall be extruded alloy with fluted surfaces. All corners to be securely riveted and supported by an internal angle bracket. The door shall be hinged the entire length of the cabinet with key locking latch. The panels shall contain all thermostats, regulators, relays, etc., with all instruments associated with each unit mounted on a common panel inside panel. All thermometers and gages shall be arranged for flush mounting on panel face. Furnish descriptive nameplates below each item on equipment. All instrument capillaries shall be installed in protective channels. Detailed drawings shall be submitted for each panel before beginning construction.

P. Insertion Turbine Flow Meters for Chilled Water (CHW), Heating Hot Water (HHW) and Closed Loop Condenser Water (CW):

1. Provide dual turbine flow meter complete with all installation hardware necessary to enable insertion and removal of the meter without system shutdown. The flow meter shall be hand insertable up to 400 psi. The flow meter shall have two contra-rotating axial turbines, with electronic impedance-based sensing and an averaging circuit to reduce measurement errors due to swirl and flow profile distortion.

2. The flow meter shall be installed in accordance with the manufacturer's installation guide including meter orientation and straight pipe recommendations.
3. Wetted metal components shall be nickel-plated brass for applications operating below 250 degrees F, 316L SS construction for DW applications, HTHW applications operating over 250 degrees F, and for any application in non-metallic pipe. The maximum operating temperature shall be 280 degrees F, 300 F peak.
4. Each flow meter shall be individually wet-calibrated against a primary volumetric standard that is accurate to within 0.1% and traceable to NIST. The manufacturer's certificate of calibration shall be provided with each flow meter.
5. Accuracy shall be within ± 0.5% of rate at the calibrated velocity, within ± 1% of rate over a 10:1 turndown (3.0 to 30 ft/s) and within ± 2% of rate over a 50:1 turndown (from 0.4 to 20 ft/s).
6. The flow meter shall include integral analog output(s), 4-20 mA, 0-10V, or 0-5V, and a high resolution frequency output for use with peripheral devices (remote display or BTU Meter). FB-1210 for Bi-directional applications shall include an isolated contact closure output for direction.
7. The flow meter shall be covered by the manufacturer's two year warranty.
8. Turbine meter shall be ONICON Incorporated Model F-1210 Dual Turbine, or as approved by the Engineer.

Q. Insertion Electromagnetic Flow Meters for Hydronic Measurements Including CHW, HHW and Open Loop CW:

1. Provide Insertion Electromagnetic Flow Meter complete with all installation hardware necessary to enable insertion and removal of the meter without system shutdown. The flow meter shall be hand-insertable up to 400 psi. The flow meter shall average velocity readings from two sets of diametrically opposed electrodes.
2. The flow meter shall be installed in accordance with the manufacturer's installation guide including meter orientation and straight pipe recommendations.
3. The flow meter shall be installed either in the supply or return pipe of the system to be measured following the manufacturer's instructions. For installations in non-metallic pipe, install grounding rings or grounding probes.
4. Materials of construction for wetted metal components shall be 316 SS. The maximum operating temperature shall be 250 degrees F.
5. Each flow meter shall be individually wet-calibrated against a primary volumetric standard that is accurate to within 0.1% and traceable to NIST. A certificate of calibration shall be provided with each flow meter.
6. Accuracy shall be within ± 1% of rate from 2-20 ft/s. Overall turndown shall exceed 80:1.
7. The flow meter shall be covered by the manufacturer's two year warranty.
8. Insertion electromagnetic flow meter shall be Onicon Incorporated, Model F-3500 or as approved by the Engineer.

R. In-Line Flanged Electromagnetic Flow Meters for Hydronic Measurements including CHW, HHW, CW, DW, Makeup and Blowdown:

1. Provide an In-line flanged Electromagnetic Flow Meter complete with integral or remote electronics module. The electronics module shall

include a backlit graphic display and external keypad. The principle of operation shall be based of Faraday's Law of Electromagnetic Induction.

2. The flow meter shall be installed in accordance with the manufacturer's installation guide including meter orientation and straight pipe recommendations. Connections to the piping shall be ANSI class 150 flanges *(ANSI class 300 where required)*. For installations in non-metallic pipe, install grounding rings between flanges. The installing contractor is responsible for providing suitable mating flanges and any required reducer/expander.
3. The flow tube shall be epoxy coated steel; the sensing electrodes shall be 316SS; the liner shall be polypropylene or ebonite for low temperature service, PFTE for hot water service (266 F maximum).
4. Each flow meter shall be individually wet-calibrated and accurate to within ±0.2% of reading from 1.6 to 33 feet per second velocity. A certificate of calibration shall be provided with each flow meter.
5. Output signals shall be 4-20 mA and programmable pulse. The flow meter shall be capable of measuring bi-directional flow. Each flow meter shall be factory programmed for its specific application, and shall be re-programmable using the integral keypad on the electronics module (no special interface device or computer required).
6. Each flow meter shall be covered by the manufacturer's two-year warranty.
7. In-line flanged Electromagnetic Flow Meter shall be ONICON Incorporated Model F-3200, or as approved by the Engineer.

S. Clamp-On Ultrasonic Flow Meters for Hydronic Measurements:

1. Provide clamp-on transit time ultrasonic flow meter, complete with matched transducers, all necessary installation hardware and coaxial transducer cables. The flow meter shall be installed without making any openings in the pipe wall and shall utilize non-wetted ultrasonic transducers that may be located up to 300 ft from the meter.
2. Installation hardware shall support the transducers independent of the pipe clamping mechanism and provide precise spacing with an integral calibrated scale.
3. The flow meter shall be installed in accordance with the manufacturer's installation guide including meter orientation and straight pipe recommendations.
4. Multiple-frequency axial beam transducers provided must be optimized for the specific pipe & process conditions for each application and the transducer frequency shall be automatically matched to the resonant frequency of the pipe at start-up. The use of single frequency transducer technology or shear mode detection technology shall not be acceptable.
5. An integral auto-zero function shall be provided for zero precision. The flow meter shall be capable of measuring bi-directional flow.
6. Accuracy shall be within ± 1% of rate from 1 to 40 ft/sec and ± 0.01 ft/sec for velocities below 1 ft/sec. Overall turndown shall exceed 400:1.
7. Each flow meter shall be covered by the manufacturer's two-year warranty.
8. Clamp-on ultrasonic flow meter shall be ONICON Incorporated Model F-4200, or as approved by the Engineer.

T. Differential Pressure Transmitter:

1. Liquid: Furnish field mounted differential pressure transmitters as indicated on plans for measuring differential pressure and transmitting an isolated 4 to 20 mA dc output linear with differential pressure. The unit

shall be accurate to ±0.2% of calibrated span. It shall withstand static pressures of 2000 psig with negligible change in output. The flanges shall be made of stainless steel with stainless steel wetted sensing components. A 3-valve bypass manifold shall be utilized for easier on-site equalization and calibration. Unit shall be protected against radio frequency interference and shall have a watertight (NEMA Type 4) electrical enclosure with 1/2" NPT conduit connection. The transmitter shall be a standard process grade transmitter as manufactured by Rosemount.

2. Air: Furnish field mounted differential pressure transmitters using a 4-20 mA (or 0-10 Vdc) output linear with measured differential pressure. Accuracy shall be ±0.8% of calibrated span. Response time shall be 250 milliseconds. Transmitter shall be in a standard grade transmitter manufactured by Ashcroft.

U. Airflow Measuring Stations:

1. All air flow measuring stations to be furnished under this contract as shown on control schematics and as scheduled.

a) Approved manufacturers are Tek-Air Systems, Air Monitor, Paragon, Ebtron, and Farr, providing they have approved representation within 100 miles of job site.

2. Duct-mounted stations shall be installed by the Sheet Metal Contractor while fan inlet station installation responsibility shall be by this Contractor.
3. Sizing and physical location of stations shall be the responsibility of this Contractor. ECC to insure that sufficient distance is available both upstream and downstream such that turbulence is not a factor in the velocity pressure measurement. Sizing shall insure that the minimum velocity across the station affords accuracy of measurement and the design engineer shall be notified within 30 days of contract award if any modifications are required to the field ductwork.
4. ECC to insure that a proper access door upstream of the station is provided in the ductwork such that the inlet face of the unit may be cleaned as necessary.
5. Duct-mounted air flow measuring stations:

a) Furnish and install air flow measuring stations constructed of 16 gage sheet metal casing and a copper velocity pressure traverse section.

b) The velocity pressure traverse section shall consist of air straightening tubes, total pressure sensors and static pressure sensors, all interconnected to form a traverse by copper manifolds which shall equalize and integrate each type sensor measurement into one (1) total pressure and one (1) static pressure metering port. There shall be one static pressure sensor for each total pressure sensor.

c) A minimum of one static and one total pressure sensor shall be used for every 16 square feet in cross section. For larger ducts, a minimum of one static and one total pressure sensor shall be used for every 36" of duct cross sectional area up to a maximum as recommended by ASHRAE guide for traverse measurement.

d) Identification: Each air flow measuring station shall have a nameplate with the following information:

(1) Unit size.

(2) Unit designation.
(3) Design air quantity.
(4) Direction of air flow.
(5) Design air velocity.

6. Fan inlet air flow sensing (non-intrusive piezometer type):

a) Accuracy: Within 2% throughout the velocity range of 600 fpm and over, when installed in accordance with published recommendations
b) Temperature: 350 deg F continuous operation; 400 deg F intermittent operation
c) Humidity: 0-100% continuous operation
d) Corrosion resistance: Good salt air and mild acid resistance, excellent solvent and aromatic hydrocarbon resistance
e) Material: 6063-T5 anodized aluminum, galvanized mounting brackets

V. Thermal Dispersion Air Flow Measurement:

1. Air volume measurement system to consist of multiple sensors designed to average velocity using thermal dispersion principles. System to be designed to be totally independent of temperature, density, and humidity. Tek-Air or Ebtron.
2. The quantity of sensing tubes shall conform to manufacturer's requirements for spacing based on the specified accuracy and the actual inlet and outlet conditions.
3. Unit to be accurate to 1.5% between 50 fpm and 6000 fpm. Output to be 4-20 mA.
4. All software by ECC.

W. Carbon Monoxide Alarm: Single or multichannel, dual-level detectors using solid-state plug-in sensors with a 3-year minimum life; suitable over a temperature range of 32 to 104 deg F with 2 factory-calibrated alarm levels at 50 and 100 ppm.

X. Refrigerant Alarm:

1. The unit shall meet or exceed all requirements of ANSI/ASHRAE 15 plus all local, state, and national codes.
2. The refrigerant monitor shall be housed in a NEMA-4 wall mount enclosure as assembled by manufacturer. Detection of refrigerant vapor concentration shall be refrigerant specific and include circulation of ambient air through a non-dispersing infrared energy cell. Electro-chemical sensing technology employing depletion sensors or short term life sensors, which deplete as a normal part of their operation or storage shelf life, shall not be acceptable.
3. Unit range of sensing shall be 0-100 parts per million (ppm) for refrigerant R-123 and/or 0-1000 ppm for all other refrigerants. Concentrations of refrigerant in the ambient air space will be displayed as PPM on the face of the monitor. The monitoring device shall indicate threshold violation via a status panel readout and remote alarm signaling.
4. Sequential sampling and multi-point monitoring shall be employed where airflow currents and/or room size prohibit a representative sample from one sensing point. The system shall have add-on sample point expansion modules available for present configuration and future expansion.

5. Unit to utilize three levels of dry contact alarms to afford the following:

6. Level 1: 25 percent contamination (to energize local strobe light and audible alarm).
7. Level 2: 50 percent contamination (to energize remote alarms and area ventilating process).
8. Level 3: 100 percent contamination (to shut down all chillers in Chiller Room).

9. The monitor shall incorporate dry contact relays for each alarm level and a malfunction relay. An analog 4-20ma signal, and an RS-485 digital output shall also be standard equipment. The specifier is to determine the desirable output mode.
10. Unit to be SAM-I from General Analysis Corp. or approved equal. (The Chill Co., Inc. – Indianapolis, Indiana).

Y. Status Sensors:

1. Status inputs for pumps: Differential-pressure switch with pilot-duty rating and with adjustable pressure-differential range of 8 to 60 psig (55 to 414 kPa), piped across pump.
2. Voltage transmitter (100- to 600-V ac): Comply with ISA 50.00.01, single-loop, self-powered transmitter, adjustable, with suitable range and 1 percent full-scale accuracy.
3. Power monitor: 3-phase type with disconnect/shorting switch assembly, listed voltage and current transformers, with pulse kilowatt hour output and 4- to 20-mA kW output, with maximum 2 percent error at 1.0 power factor and 2.5 percent error at 0.5 power factor.
4. Water-flow switches: Bellows-actuated mercury or snap-acting type with pilot-duty rating, stainless-steel or bronze paddle, with appropriate range and differential adjustment, in NEMA 250, Type 1 enclosure.

Z. Miscellaneous Controls and Relays:

1. High and low limit static pressure safety pressure differential switches to be equal to elevated AFS-460 (0.5 – 12.0 in wc field adjustable) with manual reset. All devices to be mounted so as to allow full access to reset mechanism while standing on the floor.
2. Current sensing controls to be equal to Hawkeye H708 to operate between -15 and 85□C. Trip set point to be adjustable ±1% of scale, amperage 1-135A, N.O. solid state, output rating 0.5A at 30VDC.
3. Liquid level alarm switch to be equal to Dwyer Flotect Model L6 with stainless steel flow lever arm and float. Switch to be sensitive to level change of 0.5".
4. Damper end switches: End switches for dampers to be MicroSwitch BZ-2RW863-A2 with a 3PAI enclosure unit to be totally field adjustable.
5. Water sensors to be equal to Ademco No. 470.
6. Occupancy sensors to be equal to Watt Stopper CI-24 passive infrared model having N.O. and N.C. contacts and having proper power pack. Units to incorporate field adjustable time delay (adjustable from 30 seconds to 30 minutes) that allows the area being monitored to remain on Occupied Mode. Unit to also allow the sensitivity to be field adjusted.

AA. Room Pressure Monitor:

1. General:

a) The room pressure monitor shall be CRC-RPM model as manufactured by Critical Room Control (CRC), Setra Model SCRM or TSI Pressura Model RPM20.

b) The room pressure monitor shall be capable of monitoring up to two (2) differential pressure relationships. Each monitor shall have its own controller capable of standalone operation. Each monitor is capable of both visual and audible alarms. Each monitor will use direct pressure measurement utilizing industrial quality differential pressure transducer technology. Pressure sensing technology shall be a dead ended non-metallic silicon diaphragm that does not allow air/gas to pass from controlled space to reference. The monitor shall be capable of displaying pressure to 0.0001" WC.

c) Each monitor shall have an easy to navigate microprocessor based controller with full color touch screen interface. Minimum touch screen size to be 4.0". Screen shall be capable of displaying multiple colors at the same time. Monitor shall not be limited to single screen size and shall be available in multiple sizes depending on application. All settings and programming shall be made via simple touch screen or communication network. The monitor shall have a full color LED TFT/WQVGA touch screen with a minimum resolution of 480 X 272 (WQVGA), 16 bit (65,535) color depth and sunlight viewable. Panel shall have a minimum brightness rating of 350 cdm for clear indication in all lighting environments. Each monitor shall incorporate a high speed microprocessor based controller, designed for critical environment control applications.

d) The monitor shall have easy to navigate screens that clearly give the user description of any changes that are being made.

(1) Displays that simply change the back lighting for color or use LED indicators are not acceptable.

(2) Monitors that use keypads and layered menus are not acceptable.

e) Display shall be user programmable with graphics and verbiage included with monitor. Monitor shall store all settings in a non-volatile memory. Monitor will allow user to continually display or hide room differential pressure. Main screen shall be solely reserved for critical information and not display programming or menu information. Monitor settings shall be accessed via dual password protected touch screen. Main display shall allow user to select from at least three (3) colors. Monitor shall include automated room changeover including timed clearing and cleaning modes. The monitor shall display the values and setpoints of at least eight (8) auxiliary points in addition to differential pressure. The monitor shall include both visual and audible alarming of both differential pressure and auxiliary points. The monitor shall be field configurable to allow or not allow user to make adjustments setpoints.

f) The monitor shall include at least five (5) modes. Modes shall allow for user to enter customizable naming. Monitor shall display user defined precautions. Precautions shall be field customizable.

g) Monitor shall be recess or surface mounted. Supply voltage shall be 24 VDC.

(1) Monitors using single or multiple line LCD alphanumeric character displays, LED indicators or backlit screens are not acceptable. Touch pads and layered programming menus are not acceptable.

h) Screen is capable of wipe down cleaning and water spray and dust resistant meeting (IP-54).

2. Mounting:

a) Monitors shall be mounted outside of controlled space at locations shown on the prints. The monitors shall be mounted in locations that are easily visible and accessible by staff.
b) The room monitor shall be available in both recessed and surface mounting configurations.
c) The monitors shall not require penetration into the wall for mounting. The monitor shall not extend more than 0.75" from the wall.
d) Monitors that require differential pressure lines to be run down the wall to monitor must be copper or stainless steel to eliminate kinking.

3. Room monitor:

a) The monitor shall use clear unambiguous screen and verbiage to indicate monitor modes and alarms. The main display shall clearly indicate the current status of up to two (2) pressure relationships. The main screen shall allow user to display or not display actual differential pressure. The ability to show and hide actual differential pressure readout shall be accessed from the main screen without having to reconfigure monitor. The monitor shall display the current user defined precautions without having to reconfigure monitor. The monitor shall display current user defined precautions for entering the space. All pressure relationships and associated differential pressure relationships must be clearly displayed at all times.
b) Monitor shall allow the user to select the background color for the main screen.

c) The monitors that change main screen or scroll to display additional relationships are not acceptable. Actual pressure readout must be able to be accessed from the main screen without having to reconfigure monitor.

4. Modes:

a) The monitor shall have a minimum of five (5) user defined modes. Each mode shall be capable of field configuration and naming. The monitor shall include automated sequences and timing features for procedures and room changeover.
b) Naming of the modes shall be field configurable through the touch screen interface. The modes shall include functionality associated with:

(1) Isolation/pressure controlled.

(2) Isolation alarming.
(3) Occupied non-isolation.
(4) Clearing of space.
(5) And cleaning.

c) Mode change shall include optional password protection.
d) All modes shall be capable of automating proper procedures. The modes shall include user selectable timed procedures and staff interaction functions.

(1) Monitors that allow users to select from fixed verbiage or banners that are not coupled to proper sequencing or logic are not acceptable. All mode changes shall be able to be password protected. Each mode will have unique parameters and screen graphics clearly indicating changed status. Mode and condition of space shall be made with single user change and not require user to make changes to multiple parameters.
(2) Monitors that do not offer automated function of clearing, cleaning and room changeover are not acceptable.

5. Precautions:

a) The monitor/controller shall include precautions that can be displayed during occupied modes. Precautions shall be selected and automated with modes. The user selected precaution shall be clearly shown on the main screen. The monitor shall be capable of not showing any precautions if current conditions do not require any special safety requirements. Precautions shall be automated with current mode selected.
b) Changes to precautions shall include optional password protection.

(1) Monitors that do not integrate and/or automate displaying precautions with mode selection or require user to reconfigure or manual key in verbiage are not acceptable.

6. More information:

a) Each monitor shall have a dedicated screen capable of displaying up to eight (8) network points. The “more information” screen shall be accessible from the main screen.
b) Each point shall be field configurable for type/name i.e. “temperature, humidity, air change rate, etc.” Each point shall be field configurable to engineering units i.e. ℉, ℃, WC, etc.”
c) Each point shall allow user to select the appropriate resolution to be displayed. Each point shall:

(1) Display status of point.
(2) Include audible and visual alarming of point.
(3) Display or not display set point.
(4) Allow or not allow user to make set point change.

7. Pressure sensing:

a) The room pressure monitor shall be capable of monitoring up to two (2) differential pressure relationships. The monitor pressure

sensing shall continuously monitor bi-directional room pressure and the associated referenced space. Each monitor will use direct pressure measurement utilizing industrial quality differential pressure transducer technology. Pressure sensing technology shall be a dead ended non-metallic diaphragm that does not allow air/gas to pass from controlled space to reference space. Pressure measurement shall use a variable capacitance sensor. Each sensor shall be digitally compensated using an application specific integrated circuit (ASIC).

b) Pressure sensor shall not be limited to monitor and field removable. The pressure sensor shall be capable of replacement without removing monitor. The pressure sensor shall be capable of changing ranges without removing monitor. Pressure sensing operation shall be indicated by integral LED power/status light.

c) Pressure sensor shall be individually calibrated for installed and scheduled range.

d) The room pressure sensing shall be factory calibrated with NIST traceable standards.

(1) Implied pressure measurement systems utilizing thermal hot wire, thermal mass air velocity measurement, metallic diaphragm or non-dead ended are not acceptable.
(2) Pressure sensors that catalogue accuracy based on larger transducer ranges will not be accepted.
(3) Monitor suppliers with pressure sensing integral to monitor shall include one (1) monitor/sensor for every five (5) monitors required for project.

8. Accuracy:

a) Sensing accuracy shall be ±0.4% full scale including the effects of non-linearity, non-repeatability, and hysteresis, zero offset and span setting errors.

(1) All monitors must supply differential pressure sensor accuracy statements that include the effects of non-linearity, hysteresis, non-repeatability, zero offset and span setting errors.
(2) Accuracy statement sand claims that use the (RSS) root sum squares of non-linearity (BFSL), non-repeatability and hysteresis or exclude zero offset and span setting errors are not acceptable.

b) Stability: Stability per year shall ≤0.25% per year.
c) Overpressure limits: Minimum proof pressure of 15 psi and minimum.
d) Burst pressure limits: Minimum burst pressure of 25 psi.
e) Available pressure ranges: The monitor shall support the following pressure ranges:

(1) 0/0.1, 0/0.25, 0/0.5, 0/0.75, 0/1.0, 0/2.0, 0/2.5, 0/3.0, 0/5.0, 0/10.0, 25.0.
(2) Compound: ±0.1, ±0.25, ±0.5, ±1.0, ±2.0, ±5.0, ±10.0.

9. Pressure sensor setup:

a) The monitor shall be field configurable to accept multiple signal inputs. The monitor shall accept a hardwired analog signal or network signal.
b) The monitor shall be field configurable to accept multiple pressure ranges. The monitor shall be capable of accepting multiple input signals of (4-20mA, 0-5V or 0-10V). The monitor shall allow the users to zero calibrate pressure without removing monitor or accessing pressure transducer. Zero function shall be accomplished via room monitor touch screen. The monitor shall display offset of zero calibration. The offset shall be directly field configurable without calibration function.
c) The monitor shall be able to display in inches of water (“WC) or Pascal’s (pa).

10. Alarms (audible and visual0:

a) Audible alarms:

(1) The monitor shall include at least three (3) distinct alarm sounds. Alarms shall include:

(a) Pressure alarm.
(b) Remote alarm.
(c) More info auxiliary alarm.

(2) Pressure: The monitor shall include both high and low alarms. Both high and low alarms shall be individually configurable. The monitor shall allow for disabling the audible alarm. The monitor shall allow for programmable audible alarm time delay. The monitor shall be capable of locally and remotely acknowledging the audible alarm. The monitor shall include an acknowledgement time out feature. The acknowledgement time out features silences the audible alarm for user defined time, if alarm condition is not cleared after acknowledgement time period has expired the audible alarm will rest. The acknowledge time out feature shall allow for field configurable time delay or can be disabled. Audible alarm shall be indicated with unique icon appearing on the screen. The alarm icon shall also indicate when alarm has been acknowledged.
(3) More information: Audible alarms shall be configurable for each of the eight (8) “more info” points. Alarms shall be able to be locally and remotely silenced. When silenced, the monitor shall visually indicate that the alarm has been silenced. When point being displayed does not have any alarm parameters, the indicator shall be grey. When audible alarm has been acknowledged, the indicator will show that alarm has been acknowledged.

b) Visual alarms:

c) Pressure: The monitor shall at all times display current condition and alarm status of all pressure relationships being monitored. If monitor is configured for two pressure relationships, both relationships must be clearly displayed at all times. All pressure alarms must be clearly displayed whenever in pressurized mode. When pressure is not

being maintained and inside the timed audible delay period, the monitor screen shall display “loss of pressure” and change indication to amber. The monitor shall include a unique “loss of pressure” icon and verbiage indicating that the differential pressure is outside of designated pressure ranges. When pressure is outside of alarm pressure range and audible delay is not active or delay has elapsed, the monitor shall display “pressure alarm” and change indication to red. The monitor shall include a unique alarm icon and verbiage indicating that the differential pressure is outside of designated pressure ranges. Whenever “loss of pressure” or “pressure alarm” conditions are present, the monitor shall also prompt user to check door.

(1) Monitors that change main screen or scroll to display additional relationships and alarms are not acceptable.
(2) Monitor/controllers that do not specifically indicate status or rely on ambiguous verbiage similar to “caution” are not acceptable.

d) More information: Each point shown on the “More Info” screen shall have individual indication for current point status. When no alarm is present, the status indicator shall be green. When in alarm status, indicator shall be red. When point being displayed does not have any alarm parameters, the indicator shall be grey. When audible alarm has been acknowledged, the indicator shall show that alarm has been acknowledged.

11. Door contact (optional):

a) The monitor shall be capable of supporting multiple door contacts. The door contact shall be stand alone or integral to pressure control logic and sequencing.
b) The monitor shall support surface mount, recessed mount, overhead door, plunger, disconnect and magnet style door contacts.
c) Door contact shall be field configurable to allow the user option to “freeze” the monitor pressure control PI loop.
d) Door control logic to include:

(1) Door closed and pressure is lost: Monitor to bypass “loss of pressure” mode and go directly “pressure alarm” mode.
(2) Door open and pressure is lost: Monitor indicates “loss of pressure” mode for alarm delay period. When alarm delay has timed out the monitor will go to “pressure alarm” mode.

12. Monitor inputs and outputs:

a) The monitor shall have minimum of the following inputs and outputs:

(1) Analog inputs: Four (4) analog inputs.
(2) Analog outputs: Four (4) analog outputs.
(3) Digital inputs: Four (4) digital inputs.
(4) Digital contacts: Four (4) digital contacts (relay).

b) The monitor shall include onboard power isolation.

c) The monitor shall include LED light indicators that monitor is powered and working properly.
d) The monitor shall include on board power supply including:

(1) 10 VDC.
(2) 5 VDC.
(3) Power circuit for 4-20mA.

13. Power isolation:

a) The monitor shall be powered by 24 VAC. The pressure monitor shall be internally isolated and not require external isolation transformers.

b) Monitors that require isolated power supplies shall be responsible for providing proper isolation transformers with hinged enclosure and manual disconnect. The cost for installing isolated power supplies shall be included in monitor price.

14. Network communication:

a) The monitor shall have an RS-485 serial network interface that supports native BACnet MS/TP. The monitor shall also support Modbus, N2 and Lon with optional card.
b) All network configurations shall be made without removing monitor from the wall or mounting location.
c) All network parameters shall be digitally set via touch screen interface. The monitor network shall be field configurable from the touch screen administrative menu.
d) The monitor shall support baud rates of 9600, 19200, 38400, 56200, 76800 and 115200.
e) The monitor shall support instance ID's of a minimum 1-4,000,000.

BB. Analog communication:

1. The monitor shall be capable of communicating via non-network analog points.
2. A minimum of four (4) relays shall be available for pressure alarm indication.
3. The monitor shall be able to send analog signal of mode change between multiple monitors without the use of a communication network.
4. The monitor shall be able to send and receive analog differential pressures between unlimited monitor/controllers in a daisy chain configuration without the use of a communication network.
5. The monitor shall be able to send analog signal and/or relay contacts for communication with remote monitoring station without the use of a communication network.

6. Monitors that require differential pressure and alarms to be passed to remote monitor and between multiple monitors shall be required to run redundant independent communication networks.

CC. Password protection:

1. Monitor shall have at least two layers of passwords:

    a) Staff password shall allow access to daily functions and mode selection.
    b) Administrative password shall allow access to engineering and monitor configuration screens.

2. The staff password shall be able to be deactivated.
3. Staff password shall be able to be changed from the administrative menu.
4. The monitor shall have a unique password for staff use and a separate unique password for the accessing the administrative menu.

    a) Monitors that give access to menus while unit is in operation or do not offer separate passwords for staff and administrative functions will not be accepted.
    b) All menus shall be hidden from view and only appear when screen is touched. Monitors that only use a single level of password protection are not acceptable.

5. Time out feature:

    a) The monitor shall have a time out feature. This feature shall return the monitor to the main screen after inactivity (field configurable).

6. Watchdog function:

    a) The monitor shall continuously monitor its own operation to ensure that it is operating properly. The monitor shall be capable of resetting itself to clear any errors before notification.

DD. Diagnostic screen:

1. The monitor shall graphically show all analog and digital inputs and outputs.
2. Analog inputs shall be shown on a bar indicating 0-100% of full signal.
3. The diagnostic screen shall allow for testing of parameters and system checkout without removal of monitor.
4. Digital inputs shall be indicated as red or green as follows:

    a) Open verbiage with green indication.
    b) Shut verbiage with red indication.

5. Analog outputs shall be able to be controlled from this screen. The user shall be able to move the outputs from 0-100% signal. The monitor shall send same signal of field components.
6. Allows the user to open and close controller relays as follows:

    a) Open verbiage with gray indication.
    b) Shut verbiage with red indication.
    c) Monitors that do not have I/O diagnostics shall include costs for factory representative on site for any troubleshooting that may be related to I/O for installed locations.

EE. User Interface Touch Screen Display:

1. General:

   a) The room user interface shall be CRC-Multi-view Model as manufactured by Critical Room Control (CRC).
   b) The Multi-view shall be capable of displaying up to six (6) fully configurable environmental point values, room status or mode selection graphical ions. Graphical icons shall be displayed in up to seven (7) different arrangements. Each icon shall be configurable to include the point's title, current value, set point, status and/or mode. Multi-view shall be able to display any combination of graphical icons on the same screen.
   c) The multi-view points shall include individual alarm parameters for each point. The Multi-view shall be capable of displaying current point values, set points, point status, mode and alarm parameters. Multi-view shall allow for user to make set point, status or mode changes. Each monitor is capable of both visual and audible alarms. Each Multi-view monitor will support direct and network capabilities. The Multi-view graphical icons shall be individually color configurable.
   d) Each Multi-view shall have an easy to navigate microprocessor based controller with full color touch screen interface. Minimum touch screen size to be 7.0". Screen shall be capable of displaying multiple colors at the same time. Monitor/controller shall not be limited to single screen size and shall be available in multiple sizes depending on application. All settings and programming shall be made via simple touch screen or communication network. All settings and programming shall be made via simple touch screen or communication network. The monitor shall have a full color LED TFT / WQVGA touch display with a minimum resolution of 800 X 480 (WVGA), 18 bit (262,144) color depth, and sunlight viewable. Panel shall have a minimum brightness rating of 400cdm for clear indication in all lighting environments. Each Monitor shall incorporate a high speed microprocessor based controller, designed for critical environment control applications.
   e) Each monitor shall be capable of accepting point information via direct analog signal or from network communication.
   f) The monitor shall have easy to navigate screens that clearly give the user description of any changes that are being made:

      (1) Displays that simply change the back lighting for color or use LED indicators are not acceptable.
      (2) Monitors that use keypads and layered menus are not acceptable.

2. Display shall be user programmable with graphics and verbiage included with monitor. The Multi-view shall store all settings in non volatile memory. The Multi-view shall allow the user to continually display up to six (6) user configurable point values, point status or modes. Main screen shall be solely reserved for critical information and not display programming or menu information. Multi-view shall be accessed via optional password protected touch screen. The Multi-view shall include both visual and audible alarming. The Multi-view shall be field configurable to allow or not allow user to make adjustments set points, current status and mode change.
3. Monitor shall be recess or surface mounted. Supply voltage shall be 24 VAC/DC.

4. Monitor shall be recess or surface mounted. Supply voltage shall be 24 VAC/DC.

FF. Mounting:

1. The Multi-view shall be mounted at locations shown on the prints. The Multi-view shall be mounted in locations that are easily visible and accessible by staff.
2. The Multi-view shall be available in both recessed and surface mounting configurations.
3. The Multi-view shall not require penetration into the wall for mounting. The monitor shall not extend more than 0.75" from the wall.
4. Controller shall be mounted remote from the monitor. All control wiring shall be connected to the controller located remote from monitor.

GG. Multi-view value points:

1. The Multi-view shall use clear unambiguous screen and verbiage to indicate current values and alarms. The main screen shall display up to six (6) graphical icons. The monitor shall be field configurable to support between 1-6 graphical icons. Each point on the main screen shall display points and associated set points. Each point shall be configurable to allow or not allow user to adjust set point. Each point's status shall be indicated by color background. If a room goes into alarm, its background will turn red, an audible alarm will sound, and a alarm icon will appear. A user can silence the audible alarm by via a "Silence Alarm" button located on each graphical icon. If a user acknowledges / silences a room's audible alarm, that room's background will remain red until the alarm condition changes to normal. Each value point shall be configurable as an analog or network input/output.

HH. Multi-view list/status points:

1. The Multi-view shall use clear and unambiguous screen and verbiage to indicate a list of user selectable status points. The main screen shall display up to six (6) graphical icons. The monitor shall be field configurable to support between 1-6 graphical icons. Points shall be fully configurable to change modes, indicate alarms, perform control sequencing etc. The Multi-view shall be configurable for up to thirty (30) status points. Each graphical icon list shall allow the user to indicate visual and audible alarms based on selection. A user can silence the audible alarm by via a "Silence Alarm" button located on each graphical icon. Each list point shall color configurable. Each value point shall be configurable as an analog or network input/output.

II. Multi-view mode points:

1. The Multi-view shall use clear and unambiguous screen and verbiage to indicate a list of user selectable status points. Each graphical icon shall be field configurable to allow up to 1-5 user defined modes. The Multi-view shall be configurable for up to thirty (30) modes. Points shall indicate alarms, perform control sequencing etc. Each graphical icon list shall allow the user to indicate visual and audible alarms based on selection. A user can silence the audible alarm via a "Silence Alarm" button located on each graphical icon. Each mode shall be color coded and field configurable. Each mode point shall be configurable as an analog or network input/output.

JJ. Alarms:

1. The Multi-view shall have both audible and visual alarm thresholds:

    a) Alarm range high and low shall be active when point values exceed the alarm parameters. The background color of the point shall change and indicate alarm condition. A user can silence the audible alarm by via a “silence alarm” button located on each graphical icon.

2. The Multi-view shall include both high and low alarms. Both high and low alarms shall be individually configurable.
3. The Multi-view shall allow for disabling the audible alarm. The Multi-view shall allow for programmable audible alarm time delay. The Multi-view shall be capable of locally and remotely acknowledging the audible alarm. Audible alarm shall be indicated with unique icon appearing on the main screen graphical icon. The alarm Icon shall also indicate when alarm has been acknowledged.
4. The Multi-view shall allow user to set up both audible and visual alarms based on point status. Status alarms shall be field configurable for both color and alarm.
5. The Multi-view shall allow user to set up both audible and visual alarms based on point mode. Status alarms shall be field configurable for both color and alarm.

KK. Multi-view set point change:

1. The Multi-view shall be field configurable to display current set point and allow access to make local changes to set point. Set point change shall be accessed from the main screen graphical icon.

LL. Multi-view status change:

1. The Multi-view shall be field configurable to display current status and allow access to make local changes to status point. Status change shall be accessed from the main screen graphical icon.

MM. Multi-view mode change:

1. The Multi-view shall be field configurable to display current mode and allow access to make local changes to modes. Mode change shall be accessed from the main screen graphical icon.

NN. Controller inputs and outputs:

1. The monitor/controller shall have minimum of the following inputs and outputs:

    a) Analog inputs: Four (4) analog inputs.
    b) Analog outputs: Four (4) analog outputs.
    c) Digital inputs: Four (4) digital inputs.
    d) Digital outputs: Four (4) digital outputs.

2. The controller shall include on board power isolation.
3. The controller shall include LED light indicators that controller is powered and working properly.

4. The controller shall include on board power supply including:

   a) 10 VDC.
   b) 5 VDC.
   c) Power circuit for 4-20 mA.

OO. Power isolation:

1. The monitor shall be powered by 24VAC/DC. The pressure monitor/controller shall be internally isolated and not require external isolation transformers.

2. Monitors that require isolated power supplies shall be responsible for providing proper isolation transformers with hinged enclosure and manual disconnect. The cost for installing isolated power supplies shall be included in monitor price.

PP. Network communication:

1. The Multi-view shall have an RS-485 serial network interface that supports native BACnet MS/TP. The monitor/controller shall also support Modbus, N2 and Lon with optional card.
2. All network configurations shall be made without removing controller from the wall or mounting location.
3. All network parameters shall be digitally set via touch screen interface. The monitor/controller network shall be field configurable from the touch screen administrative menu.
4. The controller/monitor shall support baud rates of 9600, 19200, 38400, 56200 76800 and 115200. The controller/monitor shall support instance ID's of a minimum of 1-4,000,000.

QQ. Analog communication:

1. The monitor/controller shall be capable of communicating via non-network analog points. The monitor/controller shall send analog signals mirroring associated analog inputs.
2. A minimum of four (4) relays shall be available for alarm, status or mode indication.
3. A minimum of four (4) analog outputs shall be configurable for relaying inputs, communicating set point, status or modes.
4. A minimum of four (4) configurable analog inputs. Inputs shall support analog signals from remote sensors and controllers. Inputs can be configured as a value, mode or status input. The inputs shall be configurable to accept multiple voltage inputs.
5. A minimum of four (4) digital inputs shall be available for alarms, status and mode changes from other monitors, relays or controllers.
6. The monitor/controller shall be able send analog signal and/or relay contacts for communication with remote monitoring station without the use of a communication network.

RR. Password protection:

1. Monitor/Controller shall have at least one (1) password. The password shall be field configurable. User shall be able to activate or deactivate password protection.

2. The monitor shall have a time out feature. This feature shall return the monitor to the main screen after inactivity (field configurable). After timeout screen will require user to re-enter password to make changes.

3. Monitors that give access to menus while unit is in operation or do not offer separate passwords for staff and administrative functions will not be accepted.

4. All menus shall be hidden from view and only appear when screen is touched.

SS. Watchdog function:

1. The Monitor/controller shall continuously monitor its own operation to ensure that it is operating properly. The monitor/controller shall be capable of resetting itself to clear any errors before notification.

TT. Diagnostic screen:

1. The monitor/controller shall graphically show all analog and digital inputs and outputs.
2. Analog inputs shall be shown on a bar indicating 0-100% of full signal.
3. The diagnostic screen shall allow for testing of parameters and system checkout without removal of monitor/controller.
4. Digital inputs shall be indicated as red or green as follows:

    a) Open verbiage with green indication.
    b) Shut verbiage with red indication.

5. Analog outputs shall be able to be controlled from this screen. The user shall be able to move the outputs from 0-100% signal. The controller shall send same signal to field components.
6. Allows the user to open and close controller relays as follows:

    a) Open verbiage with gray indication.
    b) Shut verbiage with red indication.

UU. Differential Pressure Monitor:

1. Differential pressure monitor for space pressure differentials in Surgeries, Isolation Rooms, etc., to be TSI Pressura Model #8630-PM with adjustable update to negate rapid alarm change.
2. Unit to include alphanumeric digital display of room pressure differential in inches water gage.
3. Alarm to be initiated with an adjustable 20-600 second delay any time the room pressure differential is less than 0.01" wg.
4. The monitor system shall include sensor, digital interface module, transformer, cables, and a Mute menu key to manually deactivate the audible alarm for 5-minute intervals and then require reset for additional deactivation period.
5. Differential Pressure Room Pressure Switch equal to TSI Model #8694-7 with Negative-Neutral key switch and alarm status lights. The key switch will deactivate all alarms when in the Neutral position. All alarms will be active when the key switch is in the Negative position.

VV. Pneumatic Tubing:

1. Pneumatic tubing:

2. Polyethylene tubing shall be manufactured from virgin stock and shall meet the following specifications:

a) Density: 0.92 grams/cc.
b) Melt index: 0.30 decigrams/min.
c) Stress check resistance: 2000 hours minimum per ASTM-D 1693.
d) Tensile strength: 2200 psi.
e) Fire resistancy: “FR” type.

3. Fitting connections for low pressure tubing (25 psig or less) may be made with barbed push-on fittings. For high pressure tubing (more than 25 psig), the connections shall be made with compression fittings.
4. Polyethylene tubing shall be installed using the following rules:

a) Single polyethylene tubing may be run exposed for lengths 18” or less. For lengths which exceed 18”, the lines shall be run concealed in EMT, ¾” size and this tube carrier system shall be installed in a workmanlike manner, parallel to building lines, adequately supported, etc. All connections, except for terminal connections to valves, damper operators, etc. shall be made inside trough junction boxes or control cabinets. Support entry 6 feet to building structure. Accessible ceiling tubing may be bundled neatly and mechanically attached to and parallel with building structure.
b) No fitting connections shall be made within the inaccessible area.
c) All connections shall be tight and secure.
d) 25 psig lines shall be 3/8” minimum poly, 80 psig lines shall be in copper.

IV. NETWORK EQUIPMENT

A. General:

1. The controls systems shall consist of multiple network supervisory controllers and associated equipment connected by industry standard digital and communication network arrangements.
2. The operator user interface devices, servers, and principal network computer equipment shall be standard products of recognized major manufacturers available through normal PC and computer vendor channels. ("Clones" assembled by a third-party subcontractor are not acceptable.)
3. Provide licenses for all software residing on and used by the controls systems and transfer these licenses to the Owner prior to completion.
4. The networks shall, at minimum, comprise, as necessary, the following:

a) Data servers: Where network capacity, concurrent users and data storage requirements deem necessary.
b) Operator’s user interface devices: Fixed and portable as required by the specifications.
c) Network computer processing, data storage, and communication equipment including servers and digital data processors.
d) Routers, bridges, switches, hubs, modems, interfaces and the like communication equipment. Verify hardware and configuration requirements with Owner’s IT/IS Department.

e) Network supervisory controllers including programmable field panels and controllers together with their power supplies and associated equipment.
f) Configurable and application specific field-level controllers including power supplies, enclosures and associated equipment.
g) Local display devices.
h) Addressable elements, sensors, transducers, and end devices.
i) Third-party equipment interfaces as required by the Contract Documents.
j) Other components required for a complete and working control systems as specified.

5. The specifications for the individual elements and component subsystems shall be minimum requirements and shall be augmented as necessary by the Contractor to achieve both compliance with all applicable codes, standards, the requirements of the authority having jurisdiction (AHJ) at the site and to meet all requirements of the Contract Documents.
6. The system shall be modular in nature and shall permit expansion of both capacity and functionality through addition of sensors, actuators, controllers and operator devices while reusing existing controls equipment.
7. The system shall comply with the following NFPA Codes and Standards as applicable:

a) NFPA 70 National Electrical Code.
b) NFPA 72 National Fire Alarm Code.
c) NFPA 101 Life Safety Code.
d) NFPA 90A Standard for the Installation of Air Conditioning and Ventilation Systems.
e) NFPA 92B Guide for Smoke Management Systems in Malls, Atria and Large Areas.
f) UL 864 (UUKL) Ninth Edition Smoke Control Listing including the UL 864 Ninth Edition Standard for Controls Units and Accessories for Fire Alarm Systems.

8. The system shall comply with the following International Code Council (ICC) Codes:

a) Building Officials and Code Administrators International (BOMA) Model Code.
b) Southern Building Code Congress International (SBCCI) Regulations.

B. SUPERVISORY LEVEL
1. Open framework Tridium Niagara 4 system consisting of JACE 8000 controllers.
a) Niagara Software Licenses for the Supervisory Level shall be open to the owner to allow access from any provider and any associated programming tool set and manufacturer specific devices and controllers.
2. JACE 8000 controllers:
a) TI AM3352; 1000MHZ ARM Cortex-A8, 1GB DDR3 SDRAM, Wi-Fi capable, real time clock, battery less.
b) Provide expansion modules for each JACE 8000 as required to provide necessary networks or IO modules.
3. DEVICE/POINT CAPACITY:

a) Provide JACE 8000 with device and point license capacity as required for each installation
b) OR
c) Provide JACE 8000 with a minimum license capacity of:
d) --- Devices, --- Points
e) MAINTENANCE AGREEMENT:
f) Provide JACE 8000 with a standard 18 month service agreement
g) OR
h) Provide JACE 8000 with a **(3year)(5year)** service agreement
i) Niagara 4 Supervisor:
j) Provide a Supervisor license for installations with more than one JACE

4. MAINTENANCE AGREEMENT:
   a) Provide Niagara Supervisor with a standard 18 month service agreement
   b) OR
   c) Provide Niagara Supervisor with a **(3year)(5year)** service agreement
   d) Provide a Supervisor license with Niagara Network connections as required
   e) OR
   f) Provide a Supervisor license with **(1)(2)(3)(10)(100)(UNL)** Niagara Network connections
   g) Provide Niagara Supervisor license with add on to allow for running Niagara AX (3.8 & up) in addition to the Niagara 4 platform

C. Automation Network:

1. The automation network shall be based on a PC industry standard of Ethernet TCP/IP. Where used, LAN controller cards shall be standard “off the shelf” products available through normal PC vendor channels.
2. The BMS shall network multiple user interface clients, automation engines, system controllers and application specific controllers. Provide application and data server(s) as required for systems operation, data storage and required number of concurrent users.
3. All BMS devices on the automation network shall be capable of operating at a communication speed of 100 Mbps with full peer-to-peer network communication.
4. Network supervisory controllers and operator user interfaces.
5. The automation network will be compatible with other enterprise-wide networks. Where indicated, the automation network shall be connected to the enterprise network and share resources with it by way of standard networking devices and practices.

D. Control Network:

1. Network supervisory controllers (NSC) shall provide supervisory control over the control network and shall support all three (3) of the following communication protocols:

   a) BACnet Standard MS/TP Bus Protocol ASHRAE SSPC-135, Clause 9.

(1) The NSC shall be BACnet Testing Labs (BTL) certified and carry the BTL label.
(2) The NSC shall be tested and certified as BACnet Building Controller (B-BC).

b) LonWorks enabled devices using the Free Topology Transceiver (FTT-10a).
c) Legacy manufacturer's proprietary field bus [**Johnson Control N2.**][**Siemens P1.**]

2. Control networks shall provide either "peer-to-peer", master slave or supervised token passing communications and shall operate at a minimum communication speed of 9600 baud.
3. DDC controllers shall reside on the control network.
4. Control network communication protocol shall be BACnet Standard MS/TP Bus Protocol ASHRAE SSPC-135.
5. A BACnet Protocol Implementation Conformance Statement (PICS) shall be provided for each controller device (master or slave) that will communicate on the BACnet MS/TP Bus.
6. The PICS shall be submitted 10 days prior to bidding.

E. Integration:

1. Hardwired:

a) Analog and digital signal values shall be passed from one system to another via hardwired connections.
b) There will be one separate physical point on each system for each point to be integrated between the systems.

2. Direct protocol (integrator panel):

a) The BAS system shall include appropriate hardware equipment and software to allow bi-directional data communications between the system and the third party manufacturer's control panels. The BAS shall receive, react to and return information from multiple building systems, including, but not limited to, chillers, boilers, variable frequency drives, power monitoring system and medical gas.
b) All data required by the application shall be mapped into the automation engine'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 BAS software features such as control software, energy management, custom process programming, alarm management, historical data and trend analysis, totalization and local area network communications.

3. BACnet Protocol Integration – BACnet:

a) The neutral protocol used between systems will be BACnet over Ethernet and comply with the ASHRAE BACnet Standard 135-2008.
b) A complete Protocol Implementation Conformance Statement (PICS) shall be provided for all BACnet system devices.
c) The ability to command, share point object data, change of state (COS) data and schedules between the host and BACnet systems shall be provided.

F. Dedicated Web Based User Interface:

1. Where indicated on plans, the ECC Contractor shall provide and install a personal computer for command entry, information management, network alarm management and database management functions. All real-time control functions, including scheduling, history collection and alarming, shall be resident in the network supervisory controllers to facilitate greater fault tolerance and reliability.
2. Dedicated user interface architecture: The architecture of the computer shall be implemented to conform to industry standards so that it can accommodate applications provided by the ECC Contractor and by other third party applications suppliers, including but not limited to, Microsoft Office applications. Specifically, it must be implemented to conform to the following interface standards.

a) Microsoft Internet Explorer for user interface functions.
b) Microsoft Office Professional for creation, modification and maintenance of reports and sequences of other necessary building management functions.
c) Microsoft Outlook or other e-mail program for supplemental alarm functionality and communication of system events and reports.
d) Required network operating system for exchange of data and network functions such as printing of reports, trends and specific system summaries.

3. PC hardware: The personal computer(s) shall be configured as follows:

a) Memory: 1 GB (minimum).
b) CPU: Pentium 4 processor, 2.8 GHz clock speed (minimum).
c) Hard drive: 100 GB free hard drive space (minimum).
d) Hard drive backup system: CD/RW, DVD/RW or network backup software provided by IT Department.
e) CD ROM Drive: 32X performance.
f) Ports: Two (2) serial, one (1) parallel and two (2) USB ports.
g) Keyboard: 101 keyboard and 2 button mouse.
h) CRT configuration: 1-2 CRTs as follows:

(1) Each display: 19” flat panel monitor (minimum), 1280 X 1024 resolution minimum.
(2) Display card with multiple monitor support.

i) LAN communications: Ethernet communications boards; 3Comm or equal.

4. Operating system software:

a) Windows Windows 7 (32 bit) or 10.
b) Where user interface is not provided via browser, provide complete operator workstation software package, including any hardware or software keys. Include the original installation disks and licenses for all included software, device drivers and peripherals.
c) Provide software registration cards to the Owner for all included software.

G. Distributed Web Based User Interface:

1. All features and functions of the dedicated user interface previously defined in this document shall be available on any computer connected directly or via a wide area or virtual private network (WAN/VPN) to the automation network and conforming to the following specifications.
2. The software shall run on the Microsoft Internet Explorer (10.0 or higher) browser supporting the following functions:

    a) Configuration.
    b) Commissioning.
    c) Data archiving.
    d) Monitoring.
    e) Commanding.
    f) System diagnostics.

3. Minimum hardware requirements:

    a) 1GB RAM.
    b) 2.8 GHz clock speed, Pentium 4 microprocessor.
    c) 500 GB hard drive.
    d) 1 keyboard with 83 keys (minimum).
    e) SVGA 1280 X 1024 resolution display with 64K colors and 16 bit color depth.
    f) Mouse or other pointing device.

V. DDC SYSTEMS EQUIPMENT

A. Tier 1 – Network Supervisory Controller (NSC):

1. The NSC shall be designed, packaged, installed, programmed, and commissioned in consideration of their specific service and prevailing operating conditions. They shall be proven standard product of their original manufacturer and not a custom product for this project.
2. The NSC shall support a minimum of 200% of the project's installed field points together for fully functional distributed processing operations.
3. The controls systems shall be designed and implemented entirely for use and for operation on the Internet and the Owner's Intranet. This functionality for operational access shall extend down to the field panel and field point level.
4. The primary controls systems nodes (NSC) shall be fully IT compatible nodes operating over the industry standard IT infrastructure provided for the project. The Controls Contractor shall coordinate with the IT infrastructure support staff or trade contractors to ensure compatibility and performance of the operation of the controls systems over the LAN/WAN made available for its shared use.
5. The controls systems Tier 1 network shall be configured on IT industry standard off-the-shelf technologies compatible with other building systems and project network arrangements.
6. The primary NSC shall manage and direct all information traffic on the Tier 1 network, between the Tier 1 and Tier 2 networks and to the server(s). The NSC shall monitor the network of application specific, configurable and programmable field level controllers. Provide global strategy and direction and communicate on a peer-to-peer basis with the other NSCs on the Tier 1 network.

7. All NSC on the Tier 1 network shall be equipped with all software and functionality necessary to operate the complete user interface, including graphics, via a browser connected to the node on the network or directly via a local port on the NSC.
8. A failure at a primary NSC shall not cause failures or non-normal operation at any other system NSC other than the possible loss of active real-time information from the failed NSC.
9. Tier 1 primary NSC shall maintain all programming in non-volatile or battery backed memory and shall automatically resume normal monitoring and control following the restoration of stable electrical power after a power outage. ECC to supply uninterruptible power supplies (UPS) on all NSC where noted. UPS to allow a minimum of 12 minutes of full operation before the emergency power is in full operation. Software shall allow an orderly shutdown to save all data in the event power is not restored before the battery is fully discharged.
10. All communication between controls application nodes shall be digital.
11. All controls systems application facilities and features shall be accessible via Intranet and Internet browser with user ID or password access control for user access.
12. The primary NSC shall be capable of direct connection to multiple field busses using different protocols simultaneously as indicated below. Should the NSC not support multiple field busses then install multiple NSC in parallel to achieve this functionality.

    a) BACnet Standard MS/TP Protocol ASHRAE SSPC-135.
    b) A LON field bus for supervision and control of LON based controllers that conform to the LonTalk standard.
13. Manufacturer's legacy proprietary field bus if adding to existing legacy network [**Johnson Controls N2.**][**Siemens P1.**]

14. The NSC shall integrate data from all field busses into a common and conformal object structure. Data from all field busses shall appear in common displays throughout the Operator Interface in the same format. Conformal formatting shall be provided for each type of data not dependent on the type of field bus from which the data originated.
15. The controls systems application shall support auto-dial/auto-answer communications to allow controls systems nodes to communicate with other remote controls systems nodes via standard telephone lines.
16. Downloading and Uploading:

    a) Provide the capability to generate and modify the controls systems application software-based sequences, database elements, associated operational definition information and user-required revisions to same at any designated workstation together with the means to download same to the associated NSC.
    b) The controls systems application software tool provided for the generation of custom and database definitions shall be resident in both the NSC and controls systems application server(s).
    c) Provide the capability to upload controls systems application operating software information, database items, sequences, and alarms to designated server(s).
    d) The functions of this Part shall be governed by the codes, approvals, and regulations applying to this controls systems application as provided.

17. ASHRAE 135 Compliance: Control units shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) datalink/physical layer protocol.
18. LonWorks Compliance: Control units shall use LonTalk protocol and communicate using EIA/CEA 709.1 datalink/physical layer protocol.

B. Tier 2 – HVAC System Specific Application Node (AN):

1. Tier 2 HVAC system AN shall provide both standalone and networked direct digital control of mechanical and electrical building systems as required by the system design.
2. A dedicated HVAC system AN shall be configured and provided for each primary HVAC system (air handler, chiller, boiler, etc.). At the ECC's option, the AN for primary HVAC system(s) may reside on the Tier 1 network, however, it is the ECC's responsibility to coordinate the additional network "drops" and associated IP addressing with the Owner's IT Department. The ECC will also be responsible for any costs necessary to compensate the Owner, or Subcontractor hired by the Owner to provide and install the additional network connections not shown on construction documents.

a) The system AN shall have a built-in panel interface that allows the user to monitor status as well as adjust setpoints locally, in addition to the ability to temporarily override input and output points for troubleshooting and maintenance.
b) The system AN shall have expandable point capacity with multiple configurations allowing for 25% future analog and binary input/output points. Additional points shall be eligible for use in any control strategy that resides in the AN.
c) Local Display on all Primary AHU systems plus primary hot water and chilled water systems:

(1) The display shall allow the user to view and change set points, modes of operation and parameters of all binary and analog points associated with respective AN.
(2) A local display terminal that allows for multiple lines of text and graphical representation of the equipment being controlled by the AN including actual data from all points residing on the system controller.
(3) The display terminal shall have the ability to view an alarm summary for current alarms as well as alarm history.

3. A dedicated HVAC system AN shall be configured and provided for each terminal HVAC system (unit heater, fan coil unit, cabinet heater, heat pump, chilled beam, etc.).

a) The terminal AN shall have a library of control strategies capable of performing sequences specified.
b) The terminal AN shall support a connection directly at the node or its associated temperature sensor for a portable user interface.

4. A dedicated HVAC system AN shall be configured and provided for each terminal box (VAV, CAV, F/P, and AFCV) application.

a) The terminal box AN shall include an integral pressure transducer and damper actuator and the entire assembly shall be mounted or removed as one piece.
b) The damper actuator shall be capable of stroking 90 degrees in 30 seconds.
c) The terminal box AN shall have the auto zero ability to automatically calibrate the flow sensor to eliminate pressure transducer offset error due to ambient temperature and humidity effects.

5. Each HVAC system AN shall retain program, control algorithms, and setpoint information for at least 72 hours in the event of a power failure and shall return to normal operation upon stable restoration of normal line power.
6. Each HVAC system AN (AHU, hot water, chilled water, terminal box, etc.) shall monitor and report its communication status to the controls system application. The controls systems shall provide a system advisory upon communication failure and restoration.
7. Provide a means to prevent unauthorized personnel from accessing setpoint adjustments and equipment control definitions at the HVAC system AN.
8. The HVAC system AN shall perform the functional monitoring of all controls application variables, both from real hardware points, software variables, and controller parameters such as setpoints.
9. A failure at an HVAC AN shall not cause failures or non-normal operation at any other system AN other than the possible loss of active real-time information from the failed AN.
10. ASHRAE 135 Compliance: Communicate using read (execute and initiate) and write (execute and initiate) property services defined in ASHRAE 135. Reside on network using MS/TP datalink/physical layer protocol and have service communication port for connection to diagnostic terminal unit.
11. LonWorks Compliance: Communicate using EIA/CEA 709.1 datalink/physical layer protocol using LonTalk protocol.
12. Enclosure: Dustproof rated for operation at 32 to 120 deg F.

C. Servers:

1. As required for the functional operation of the control systems, the Controls Contractor shall provide all necessary digital processor programmable server(s). These server(s) shall be utilized for controls systems application configuration, for archiving, reporting, and trending of data, for operator transaction archiving and reporting, for network information management, for alarm annunciation, for operator interface tasks, for controls application management and the like. These server(s) shall utilize IT industry standard data base platforms such as Microsoft SQL server and Microsoft data engine (MSDE) or approved equal.
2. Provide controls systems application server(s) to archive historical data including trends, alarm, and event histories and transaction logs.
3. Equip these server(s) with the same software tool set that is located in the primary controls systems application nodes for system configuration and custom logic definition.
4. Equip these server(s) with the same software tool set that is located in the primary application nodes for color graphic configuration.
5. Access to all information on the control systems server(s) shall be through the same operator interface functionality used to access individual nodes. When logged onto a server, the Operator will be able to also interact with any of the primary nodes on the controls systems application.

6. Server disc shall have capacity to store all programmed trends, alarm history, user graphics, etc., for a minimum of 18 months minimum. The server shall allow a hard copy printout of all alarms as they occur.

D. Time Clock: Solid-state, programmable time control with 8 separate programs each with up to 100 on-off operations; 1-second resolution; lithium battery backup; keyboard interface and manual override; individual on-off-auto switches for each program; 365-day calendar with 20 programmable holidays; choice of fail-safe operation for each program; system fault alarm; and communications package allowing networking of time controls and programming from PC.

E. Operator Interface:

1. The Operator Interface provided shall include the functionality to selectively combine data and information from any system element or component in the controls systems application on a single browser window display panel at the operator's option. This shall include both current information and historical data stored on the server(s).
2. All aspects of the controls systems operator interface shall be provided to operate through an IT industry standard web browsers such as Internet Explorer or Chrome or approved equivalent.
3. The web browser based operator interface provided shall incorporate complete tool sets, operational information displays, multi-window displays, and other interactive aids to assist interpretation and ease of use. Simple HTML based web page displays are not acceptable; all values must be dynamic such that they are constantly changing.
4. The web browser based operator interface provided shall not require the procurement or licensing of any special or proprietary software from the Controls Contractor or its suppliers for the controls systems OWS.
5. The controls systems application OWS shall operate on Microsoft Windows 2000/XP or other approved platform.
6. Each controls systems application fixed and portable OWS shall be on-line configurable for specific functionalities and associated groups of system points and elements.
7. The controls systems application portable OWS shall operate identically and have equal functionality to the fixed OWS. All Operator access into the controls systems from portable OWS shall be the same browser format and functionality as provided for the fixed OWS.
8. File and system management display (navigation trees):

    a) The operator interface shall include the ability to display system names in a hierarchal (navigation tree) format that allows logical grouping of systems and point names. This hierarchal organization shall represent the logical system network layout.
    b) Provide the capability to display multiple navigation trees that aid the operator in navigating throughout all systems and points connected. At minimum provide a tree that identifies all systems on the controls systems networks.
    c) Provide the capability for the Operator to add custom trees. The Operator shall be able to define any logical grouping of systems or points and arrange them on the tree in any selected order. Provide the capability to nest groups within other groups. Provide at minimum for 5 levels of nesting.
    d) The navigation trees shall be "dockable" to other displays in the operator interface including graphic displays. The tees shall

appear as part of the display and may be individually detached and minimized to the Windows task bar or closed. Provide for a single keystroke to reattach the navigation tree to a primary display.

9. Divisible display windows:

a) Provide for the operator to divide the display area within a single browser window into multiple display panels. The content of each display panel can be any of the standard summaries and graphics provided in the controls systems application.
b) Provide each display panel with minimize, maximize, and close icons.

10. Alarms:

a) Alarms shall be routed directly from primary controls systems application nodes to OWS and server(s). Provide for specific alarms from specific points to be routed to selectable OWS and server(s). The alarm management portion of the controls systems software shall, at minimum, provide the following functions:

(1) Log date and time of alarm occurrence.
(2) Generate a "Pop-Up" window on the browser display panel, with audible alarm, informing the operator that an alarm has been received.
(3) Allow an operator, with the appropriate password, to acknowledge, temporarily silence or cancel an alarm.
(4) Provide an audit trail on hard drive for alarms by recording user acknowledgement, deletion, or canceling of an alarm. The audit trail shall include the ID of the user, the alarm, the action taken on the alarm and a time/date stamp.
(5) Provide the ability to direct alarms to an e-mail address or alpha-numeric pager. This must be provided in addition to the pop-up window described herein. Controls systems that use e-mail and pagers as the exclusive means of annunciating alarms are not acceptable.
(6) Provide for any attribute of any object in the controls systems to be designated to report as an alarm.

b) The controls systems application shall annunciate systems diagnostic alarms indicating system failures and non-normal operating conditions.
c) The controls systems application shall annunciate controls alarms at minimum as required by Part 3.
d) Provide the on-line means to display alarms within the browser windows by date/time of occurrence, priority class, point designation, value, or other defined text keywords.

11. Operator transaction archiving:

a) Provide the means to automatically archive all operator activities on the controls systems application and for the recall of same for reporting.
b) Provide the means to sort and report archived activities by operator, date/time, activity type and system area.

c) Provide access protection to preclude the unauthorized removal or tampering with archived records.
d) Provide management support facilities for the deletion and reinitializing of archived record logs under master password control or equal means.

12. Reports:

a) Reports shall be generated and directed to one or more of the following: User interface displays, printers archived at the Owner's defined option. As a minimum, the controls systems application shall provide the following reports:

(1) All points in the controls systems application.
(2) All points in a specific controls systems AN.
(3) All points in a user-defined group of points.
(4) All points currently in alarm.
(5) All points locked out.
(6) All controls systems application schedules.
(7) All user defined and adjustable variables, schedules, interlocks, diagnostics, systems status reports, and the like.

b) Provide all applicable original manufacturer's standard reports for the controls systems.
c) Provide any custom report as specified.

13. Dynamic Color Graphics:

a) Provide for any number of real-time color graphic displays shall be able to be generated and displayed in the controls systems application limited only by memory data storage capacity.
b) Graphics shall be based on Scalar Vector Graphics (SVG) technology.
c) Values of real-time attributes displayed on the graphics shall be dynamic and updated on the displays.
d) The graphic displays shall be able to display and provide animation based on real-time data that is acquired, derived, or entered into the operating controls systems.
e) Provide for the Owner to be able to change values (setpoints) and states in system controlled equipment directly from the graphic display.
f) Provide a graphic editing tool that allows for the creation and editing of graphic files. It shall be possible to edit the graphics directly while they are on line, or at an off line location for later downloading to the AN.
g) Provide a complete user expandable symbol library containing all of the basic symbols used to represent components of a typical system. Implementing these symbols in a graphic shall involve dragging and dropping them from the library to the graphic.
h) ECC Project Manager and/or programmer/technician shall meet with the Owner’s Maintenance and Facility Staff prior to graphic development. Graphics shall not be installed on BAS system until the Owner’s Staff has reviewed, commented and approved graphic appearances, layouts, etc. including floor plan graphics.

14. Schedules:

a) Provide multiple schedule input forms for automatic time-of-day scheduling and override scheduling of operations. At a minimum, the following spreadsheet types shall be accommodated:

(1) Weekly schedules.
(2) Temporary override schedules.
(3) Special "Only Active If Today Is A Holiday" schedules.
(4) Monthly schedules.

b) Schedules shall be provided for each group, system, and sub-system in the controls systems application. It shall be possible to include all of any commandable points residing within the controls systems in any custom schedule. Each point shall 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.
c) Multiple 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.

15. Historical trending and data collection:

a) Trend and store point history data for all actual and virtual (software) points and values as required by the Owner.
b) The trend data shall be stored in a manner that allows custom queries and reports using industry-standard software tools.
c) At a minimum, provide the capability to perform statistical functions on the historical database:

(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.

16. Operator access security (combined password and user ID):

a) Provide for Operator access into the controls systems via the use of on-line Owner defined software password and user identification (ID) pairs, unique for each operator and unique throughout the controls systems application, to supplement standard password access control.
b) Stored password/user ID definitions shall be stored in encrypted formats whether at the controls server or at the AN.
c) Password logins shall not be echoed on any screen or printer except during master password definition processes. An operator defining a password shall be required to re-enter to confirm authenticity.

d) Operator access privileges shall be definable in terms of functions and project areas.
e) As part of the access privileges definition for each user the Owner shall be able to define at minimum the following:

(1) Access times by day.
(2) Permanent or temporary, with expire date, password.
(3) Number of incorrect access attempts allowed before the password is disabled.
(4) Whether or not the operator is able to redefine their own password.
(5) A field for the operator's e-mail address.
(6) A field for the operator's contact phone number.
(7) Definition of the operator's access privilege functionalities including viewing only, fully control, selected functions, etc.

17. Primary DDC Issues:

a) All analog and binary signaling to be wired and piped to DDC panels as detailed on plans. Bidder to verify total of points scheduled. Global communication trunk LAN to allow sharing of data between individual panels.
b) DDC controllers to have points as scheduled on plans as a minimum. ECC to note that additional analog and binary points may be required to achieve the operating sequence of operation or as dictated by standards and codes.
c) A separate application node controller shall be required for each individual air-handling unit unless detailed to the contrary.
d) Miscellaneous requirements:

(1) All analog points to have applicable high and low alarm points programmed to identify operation out of acceptable ranges.
(2) Status of all motors to be programmed to consider programmed off cycle as non-alarm. Normal status of all motors to be shown.
(3) Flow sensing for BTU calculations to be performed with turbine meters or magnetic inductive transmitter as detailed.
(4) All safety thermostats and pressure switches to have manual reset requiring manual rest on restart.
(5) Each DDC controller of each type shall be equipped with an integral "ON-OFF" switch that disconnects it from the primary electrical service.

e) The entire DDC system shall employ capability for compatibility to BAC net technology.
f) Where specifically called for and where detailed in the unit specification, this Contractor to furnish gateways that allow for the integration of data into the BAS system.
g) Furnish to Owner at project completion a CD incorporating the entire software system.
h) The operating system requires that the operator shall have access to all analog and binary data points through the global LAN. This shall include all points contained in all application node controllers,

and such other points as are integral in auxiliary mechanical and electrical components. Access to be accomplished through integral network terminals or separate laptop computers. The resulting communication network shall allow the ability to read and adjust all binary and analog points throughout the entire network through any interface. Refer to architecture detailed on HPE drawings.

EXECUTION

VI. INSTALLATION

A. Instrumentation Mounting:

1. All sensing capillaries on coils shall be rigidly supported as directed by the Architect/Engineer to prevent capillary vibration and to accurately sense coil temperature.
2. All sensors except where installed in finished areas shall have bakelite plates identifying their function keyed to control schematics.
3. All sensors where duct or unit housing 30" or more in width or height shall utilize flexible averaging bulb elements installed to sense average temperature. Element to cover entire coil surface with multiple passes to insure accurate average. Multiple sensors to be utilized as required. Elements to be mounted on field fabricated frame or cable support with nylon tie wraps.
4. Room thermostats, humidistats, and other space sensors shall be installed where shown on the Drawings. These components shall not be installed between a light switch and doorway when they are co-located on the Drawings. These components shall be installed at a height of 46" above finished floor to the center of the component, unless indicated otherwise.
5. Sensors located in fire-resistance rated walls shall be installed within steel electrical boxes. Boxes shall be protected with listed firestop putty pads if located less than 24” from other electrical boxes on the opposite side of the wall. Install putty pads on all boxes (existing or by other trades) within 24” of the box with the sensor.
6. This Contractor shall be responsible for exact field location of all airflow measuring stations, water flow turbine meters, vortex shedding sensors, pitot tubes, airflow sensors, thermal sensors, humidity sensors, pressure sensors, and any other variables required as a part of the environmental control system. This Contractor shall coordinate the sensors with devices furnished and installed under other sections of the project. Any conflicts to be brought to Architect/Engineer prior to installation.
7. All controllers, alarms, and sensors, except in finished areas, shall carry plastic laminate identifying tags describing their function and keyed to automation diagrams.
8. Vortex shedding sensors to be field installed by ECC.
9. All controllers and control panels shall utilize mounting support that insures no vibration from the structure or mechanical equipment. Back boxes or backing panels are required as appropriate. Where walls are plaster or drywall, channels shall be utilized screwed to studs with laminated panel facing to support instruments or control panels; all such assemblies to be crafted to present easy access to controls. Proper engraved identification nameplates are required.
10. ECC is responsible to coordinate with Mechanical, Sheet Metal, and Electrical Contractors the proper location of all air, water, and steam

measurements and control components to insure that sizing and locations meet all manufacturer's standards for maximum accuracy of sensing and control. Instances where piping or duct sizing and location need be modified from what is shown on drawings to achieve required accuracy shall be brought to designer's attention prior to bidding; failure to so notify designer requires ECC to accommodate required field modifications.

11. Instrument operating assemblies located within finished spaces intended to be accessed by personnel shall be installed at a height of 46" above finished floor to the center of the assembly. This applies for all controllers, readout components, pressure monitors, and safety devices.

12. Within mechanical rooms, all instrument operating assemblies for all controllers, readout components, and safety devices shall be installed in locations that are easily accessible to maintenance and operating personnel. Locations such as those on remote sides of air handling units or other mechanical systems are not acceptable.

B. Electrical Wiring:

1. Under this division, furnish and install interlock, LAN, sensor, and actuator wiring. Connect controls in accordance with approved wiring diagrams. Install wiring inside panels to terminal strips.

2. Configure LAN as either a bus, star, or combination of the two. Use twisted pair, coax, or fiberoptic cable to meet noise immunity and/or distance requirements. Design system for data transfer rate of no less than 1 megabaud. LAN wiring requires shielded cable or shall be cable certified for LON or BAC net. All LAN wiring must meet supplier's standards of operation and quality.

a) Use Belden No. 22 gage or larger Beldfoil or equal for runs up to 250 feet.

b) Use Belden No. 18 gage or larger Beldfoil or equal for runs 250 feet to 500 feet.

c) All input/output wiring shall have sufficient strength to meet all operational requirements.

3. Sensor wiring over 50 feet, where run in a common conduit or near inductive loads, shall be shielded cable.

a) Use Belden No. 24 gage or larger Beldfoil or equal for runs up to 100 feet.

b) Use Belden No. 18 gage or larger Beldfoil or equal for runs up to 500 feet.

c) All input/output wiring shall have sufficient strength to meet all operational requirements.

4. Power Wiring for 24volt power trunk shall be minimum two conductor No. 14 gage plenum rated wiring.

5. Install all control and interlock wiring in addition to low voltage sensor and LAN wiring in accordance with local requirements, the National Electrical Code and Division 26 of project specifications.

6. Installation minimum requirements:

a) Mechanical and service areas plus any areas without finished ceilings: All wiring including cables in EMT.

b) Space sensors and alarms: All wiring and cables in EMT within wall construction.
c) Ceiling returns (accessible or drop ceilings - ducted returns): Approved non-plenum cable.
d) Ceilings (open returns): Approved plenum-rated cable.
e) Ceiling returns (non-accessible): EMT or code compliant equal solid conduit.
f) Inside air handling units: All wiring including cables in EMT or code compliant equal solid conduit.
g) Note that the use of cable is limited to low voltage service less than 24 volt only.
h) In no case shall cables be allowed to lay on ceiling grid.
i) Note that all conduit junctions and terminations shall utilize compression fittings.
j) Installation of all cabling in ceilings and walls shall be run in a professional workmanlike fashion acceptable to Architect/Engineer. Cables to be supported with tie wraps such that droop and sag is within acceptable degrees and shall be securely fastened to fixed members of the building structure at sufficient points to avoid excessive freedom of movement.

7. Grounding:

a) Provide suitable grounding for all digital equipment.
b) Install a separate ground to earth using existing water piping or a copper rod driven into the ground as indicated by the equipment manufacturer. In no situation may the ground be connected to the building neutral conductors, either at the breaker or at the main feeder entrance to the building (no exceptions).

8. Transient protection:

a) All electronic equipment including processors, relays, monitoring devices, temperature sensors, and other non-computerized solid state equipment will be adequately protected against power line transients or RFI interference. All components to meet IEEE/ANSI standards.
b) Equipment that fails to operate properly due to transient or other electrical interference, in the opinion of the Engineer, will be required to be retrofitted with the appropriate protection device(s).
c) Provide an isolation transformer as a separate component, on the 110 VAC power supply to the digital controllers to protect all controllers to manufacturer's requirements.

d) All control wiring that must be routed in EMT shall be separate from any power feed wiring.
e) The sizing type and provision of cable, conduit, cable trays, and trunking shall be the design responsibility of the ECC. If complications arise, however, due to the incorrect selection of cable, cable trays, trunking, and/or conduit by the ECC, the Contractor shall be responsible for all costs incurred in replacing the selected components.
f) Note that any disconnect switches between variable frequency drives and operating motors shall be interlocked such that drive inverter returns to zero position when motor is disconnected. Interlock wiring

between disconnect and VFD by EC. Refer to VFD Specifications Section.

9. General:

a) Any penetration of an air handling unit enclosure for passage of tubing, conduit, or sensing elements shall be sealed with an appropriate grommet and caulked.
b) Contractor to insure that all instruments requiring reset or field adjustment are mounted with the operating heads located on the exterior of air handling units in positions of ready access. In instances of rooftop assemblies, all such devices to be inside unit enclosures with access via manufacturer's access panels.

C. DEMOLITION

1. Existing controls systems to be demolished shall be physically removed complete by the ECC. Reuse of existing conduits and raceways is permitted, if they do not interfere with the work of other trades.

2. The ECC shall install temporary measures as required for phasing and temporary operating conditions. The ECC shall examine the complete document set and verify phasing with other subcontractors prior to submitting a bid. These measures may include temporary wiring to maintain floor level networks.

a) Any pneumatic lines cut during demolition must be checked and refed as required to keep the existing equipment in operation.
b) Any pneumatic lines removed must be plugged and capped immediately to avoid excessive compressor run time.

D. FIELD QUALITY CONTROL

1. 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.

2. Perform the following field tests and inspections and prepare test reports:

a) Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
b) Test and adjust controls and safeties.
c) Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
e) Pressure test high-pressure control air piping at 150 psig and low-pressure control air piping at 30 psig for 2 hours, with maximum 1-psig loss.
f) Test calibration of pneumatic and electronic controllers by disconnecting input sensors and stimulating operation with compatible signal generator.

g) Test each point through its full operating range to verify that safety and operating control set points are as required.
h) Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions.
i) Test each system for compliance with sequence of operation.
j) Test software and hardware interlocks.

3. DDC Verification:

a) Verify that instruments are installed before calibration, testing, and loop or leak checks.
b) Check instruments for proper location and accessibility.
c) Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.
d) Check instrument tubing for proper fittings, slope, material, and support.
e) Check installation of air supply for each instrument.
f) Check flow instruments. Inspect tag number and line and bore size, and verify that inlet side is identified and that meters are installed correctly.
g) Check pressure instruments, piping slope, installation of valve manifold, and self-contained pressure regulators.
h) Check temperature instruments and material and length of sensing elements.
i) Check control valves. Verify that they are in correct direction.
j) Check air-operated dampers. Verify that pressure gages are provided and that proper blade alignment, either parallel or opposed, has been provided.
k) Check DDC system as follows:

l) Verify that DDC controller power supply is from emergency power supply, if applicable.
m) Verify that wires at control panels are tagged with their service designation and approved tagging system.
n) Verify that spare I/O capacity has been provided.
o) Verify that DDC controllers are protected from power supply surges.
p) Verify all supervisory and application controllers are operating on the latest version of software/firmware. If newer versions of software and/or firmware are released during the project's duration, the ECC shall upgrade/update those controllers to the newer version at no additional cost to the Owner. The ECC shall submit a spreadsheet as part of the project closeout documents listing the software version of each controller.

4. Replace damaged or malfunctioning controls and equipment and repeat testing procedures.

E. ADJUSTING

1. Calibrating and Adjusting:

2. Calibrate instruments.

3. Make three-point calibration test for both linearity and accuracy for each analog instrument.
4. Calibrate equipment and procedures using manufacturer's written recommendations and instruction manuals. Use test equipment with accuracy at least double that of instrument being calibrated.
5. Control System Inputs and Outputs:

    a) Check analog inputs at 0, 50, and 100 percent of span.
    b) Check analog outputs using milliampere meter at 0, 50, and 100 percent output.
    c) Check digital inputs using jumper wire.
    d) Check digital outputs using ohmmeter to test for contact making or breaking.
    e) Check resistance temperature inputs at 0, 50, and 100 percent of span using a precision-resistant source.

6. Flow:

    a) Set differential pressure flow transmitters for 0 and 100 percent values with 3-point calibration accomplished at 50, 90, and 100 percent of span.
    b) Manually operate flow switches to verify that they make or break contact.

7. Pressure:

    a) Calibrate pressure transmitters at 0, 50, and 100 percent of span.
    b) Calibrate pressure switches to make or break contacts, with adjustable differential set at minimum.

8. Temperature:

    a) Calibrate resistance temperature transmitters at 0, 50, and 100 percent of span using a precision-resistance source.
    b) Calibrate temperature switches to make or break contacts.

9. Stroke and adjust control valves and dampers without positioners, following the manufacturer's recommended procedure, so that valve or damper is 100 percent open and closed.
10. Stroke and adjust control valves and dampers with positioners, following manufacturer's recommended procedure, so that valve and damper is 0, 50, and 100 percent closed.
11. Provide diagnostic and test instruments for calibration and adjustment of system.
12. Provide written description of procedures and equipment for calibrating each type of instrument. Submit procedures review and approval before initiating startup procedures.

13. Adjust initial temperature and humidity set points.

14. 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 three visits to Project during other than normal occupancy hours for this purpose.

F. DEMONSTRATION

1. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC instrumentation and controls. Refer to Section 017900 "Demonstration and Training."

2. When the project encompasses a formal commissioning process, this Environmental Control Contractor shall furnish, as a requirement of the contract, the services of an approved Engineer/Technician who will demonstrate the complete operation of the Environmental Control Installation including all hardware and software in the presence of the Commissioning Agent.

a) The services of a qualified representative of the Control Contractor shall be provided to demonstrate the installation, startup of system and instruct the Owner's maintenance personnel in the care and proper operation of the system. This shall require the Contractor to demonstrate the installed accuracy of all controlled variables as herein detailed, i.e.,

b) All temperature, pressure, humidity and flow sensors, controllers, alarms, relays, and safety devices.
c) All actuators functioning with control loops. All actuators to be demonstrated for complete travel from full open to full closure; all actuators to have 200% power for intended functionality.
d) All hardware and software of all DDC controllers and BAS control loops.
e) Current sensors to be field calibrated to insure alarm status on loss of electrical power or loss of drive sheaves or belts.
f) Other control features installed as part of the contract and as requested by Design Engineer.
g) Provide an override report indicating that all controls are fully automatic.
h) The installation and Service Contractor shall provide the Owner with 40 hours of instruction and training. This shall be done as follows:

(1) Job completion – 24 hours.
(2) 30 days later – 4 hours.
(3) 3 months later – 4 hours.
(4) The remaining 8 hours as requested by Owner.

H. WARRANTY

1. At completion of final test of installation and acceptance by Owner, provide any service incidental to proper performance for a period of 24 months beginning with the project's last, final Certificate of Substantial Completion which has been signed by the Owner. This final Certificate of Substantial Completion utilized for the start of the warranty period shall not contain an attached list of punch list items which includes any items for the Environmental Control System.
2. Warrant equipment for 24 months for defects in workmanship and material under normal use and service. During warranty period, replace or repair, free of charge, equipment proven to be defective in workmanship or material.

3. Certain electronic devices not manufactured by the Environmental Control Supplier, such as computers, printers, and CRTs display, shall carry the same warranty as above. Pass any registration and warranty documents and warranty rights to the Owner.
4. All valve and damper actuators to carry a warranty of 60 months after project acceptance. Warranty to cover both labor and material without exception.
5. Control Supplier/Engineering Contractor to provide written documentation of availability of repair parts for all material installed under this contract for a period of 60 months after project acceptance. In the event a component is obsolete, it shall be replaced with the new generation at no cost to the Owner.

I. SERVICE CONTRACT

1. In addition to the contractually required Quality Checks, Adjustments and Demonstrations and Warranty, this Contractor shall include a full service maintenance contract for a period of 18 months from the Date of Substantial Completion.

2. This Contract shall include, but not be limited to:
   a) Monthly tests of entire Environmental Control System with reprogramming of DDC controllers as required to achieve maximum efficiency and comfort
   c) All safety thermostats, switches, and devices to be exercised on a monthly basis.

3. At the conclusion of this 18-month service contract, the Owner shall be given a proposal to continue the service on an annual basis. Contractor to spend no less than 8 hours on the job site for each monthly system test.
4. A written report shall be submitted to the Architect/Engineer Project Engineer detailing condition and operation of Environmental Control System after each service visit.

END OF SECTION

SECTION 232213
STEAM AND CONDENSATE PIPING

GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes steam and condensate piping and specialties for systems up to 100 psig (688 kPa), inside the building.

1.3 DEFINITIONS

A. MP Systems: Medium pressure systems operating at 16 psig up to 100 psig.

B. LP Systems: Low-pressure systems operating at or less than 15 psig.

1.4 PERFORMANCE REQUIREMENTS

A. Components and installation shall be capable of withstanding the following minimum working pressures and temperatures:

1. MP Steam Piping: 150 psig (365 deg F saturated steam).
2. LP Steam Piping: 125 psig (353 deg F saturated steam).
3. Condensate Piping: 125 psig at 250 deg F.
4. Steam Vent Piping: 125 psig at 250 deg. F.
5. Makeup Water Piping: 125 psig at 225 deg F.
6. Blowdown Drain Piping: Equal to pressure of the piping system to which it is attached.
7. Air Vent and Vacuum Breaker Piping: Equal to pressure of the piping system to which it is attached.
8. Safety Valve Inlet and Outlet Piping: Equal to pressure of the piping system to which it is attached.

1.5 SUBMITTALS

A. Product Data:

1. For each type of pressure reducing valve, safety relief valve and other special-duty valve and steam trap indicated, including rated capacities and accessories. Identify safety relief valves which are “UV” labeled and utilized on hydronic components.

2. For each type of piping system including pipe type, grade and schedule, fitting types, flexible connectors, gaskets, nuts and bolts.

3. Strainers, flash tanks, air vents, and vacuum breakers for steam coils and heat exchangers.
4. Identify MPR drip leg traps. Identify LPR drip leg traps.

B. Shop Drawings: Detail flash tank assemblies and fabrication of pipe anchors, hangers, special pipe support assemblies, alignment guides, and expansion joints and loops and their attachment to the building structure. Include dimensions, weights, loadings, required clearances, method of field assembly, components, and location and size of each field connection.

C. Field Test Reports: Written reports of tests specified in Part 3 of this Section. Include the following:

1. Test procedures used.
2. Test results that comply with requirements.
3. Failed test results and corrective action taken to achieve requirements.

D. Maintenance Data: For pressure reducing valves, safety valve, other special duty valves, steam traps, vacuum breakers, and meters to include in maintenance manuals specified in Division 1.

1.6 QUALITY ASSURANCE

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

B. ASME Compliance: Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation. Safety valves and pressure vessels shall bear the appropriate ASME label. Fabricate and stamp flash tanks to comply with the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 unless denoted to be non-stamped.

1.7 COORDINATION

A. Coordinate layout and installation of steam and condensate piping and suspension system components with other construction, including light fixtures, hydronic piping, fire-suppression-system components, and partition assemblies.

B. Coordinate closely all gravity condensate lines that cannot lift condensate (due to control valve modulation) such that these pipes are installed in the ceiling space prior to all other piping, ductwork, conduit, ceilings, or other components.

C. Coordinate pipe sleeve installation for foundation wall penetrations.

D. Coordinate piping installation with roof curbs, equipment supports, and roof penetrations.

E. Coordinate pipe fitting pressure classes with products specified in related Sections.

F. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases.

G. Coordinate installation of pipe sleeves for penetrations through exterior walls and floor assemblies. Coordinate with requirements for firestopping specified in Division 7 Section "Firestopping" for fire and smoke wall and floor assemblies.

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. Supply one end of main steam trap assembly with shutoff valves, strainer, piping and pipe fittings and insulation required to install steam trap assembly.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Safety Valves:

a. Armstrong International, Inc.
b. Kunkle Valve; a Tyco International Co.
c. Spirax Sarco, Inc.
d. Watts Industries, Inc.; Watts Regulators.

2. Pressure-Reducing Valves:

a. Armstrong International, Inc.
b. Fisher.
c. ITT Hoffman; ITT Fluid Technology Corp.
d. Leslie Controls, Inc.
e. Spence Engineering Company, Inc.
f. Spirax Sarco, Inc.
g. Watson McDaniel.

3. Steam Traps:

a. Armstrong International, Inc.
b. Best-O-Bell.
c. Fisher.
d. ITT Hoffman; ITT Fluid Technology Corp.
e. MEPCO.
f. Mueller.
g. Spirax Sarco, Inc.
h. Sterling, Inc.
i. Watson McDaniel.

4. Air Vents and Vacuum Breakers:

a. Armstrong International, Inc.
b. ITT Hoffman; ITT Fluid Technology Corp.

c. Johnson Corp. (The).
d. Spirax Sarco, Inc.
e. Watson McDaniel.

2.2 PIPING MATERIALS

A. General: Refer to Part 3 piping application articles for applications of pipe and fitting materials.

2.3 STEEL PIPE AND FITTINGS

A. Steel Pipe, NPS 2 (DN 50) and Smaller: ASTM A 53/A 53M or ASTM A106, Type S (seamless) Grade B, Schedules 40 and 80, black steel, plain ends.

B. Steel Pipe, NPS 2-1/2 through NPS 10 (DN 65 through DN 250): ASTM A 53/A 53M or ASTM A106, Type E (electric-resistance welded), Grade B, Schedules 40 and 80, black steel, plain ends.

C. Steel Pipe, NPS 12 through NPS 20 (DN 300 through DN 500): ASTM A 53 or ASTM A106, Type E (electric-resistance welded), Grade B, standard weight, black steel, plain ends.

1. Steel Pipe Nipples: ASTM A 733, made of ASTM A 53, Schedules 40 and 80, black steel; seamless for NPS 2 (DN 50) and smaller and electric-resistance welded for NPS 2-1/2 (DN 65) and larger.

D. Cast Iron Threaded Fittings: ASME B16.4; Classes 125 and 300.

E. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300; female pattern; ground joint brass-to-iron seat.

F. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.

G. Wrought-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. Weld neck flanges.
3. Facings: Raised face.
4. Bolt holes: Spot faced.
5. Wall thickness: Same as pipe in which installed.

H. Flexible Connectors: Stainless-steel bellows with woven, flexible, bronze, wire-reinforcing protective jacket; 150-psig (1035-kPa) minimum working pressure and 250 deg F (121 deg C) maximum operating temperature. Connectors shall have flanged or threaded-end connections to match equipment connected and shall be capable of 3/4-inch (20-mm) misalignment.

I. Welding Materials: Comply with Section II, Part C, of the ASME Boiler and Pressure Vessel Code for welding materials appropriate for wall thickness and for chemical analysis of pipe being welded.

J. Gasket Material:

1. ASME B16.20, spiral wound gasket with stainless steel metal winding strip flat, asbestos-free graphite filler, 1/8-inch (3.2-mm) maximum thickness unless thickness or specific material is indicated. Suitable for pressure class of service and a minimum operating temperature of 400 deg. F. Similar to Flexitallic Style CG.
2. Do not apply compounds, adhesives, or anti-stick lubricants to gaskets surface.

K. Flange Bolts and Nuts:

1. ASME B18.2.1, carbon steel, unless otherwise indicated.
2. Medium pressure steam systems shall utilize the following at all locations where the operating pressure is greater than 30 psig:

   a. Use alloy steel heavy hex bolts per ASTM A193, Grade B7 with alloy steel heavy hex nuts per ASTM A194, Grade 4 or 7.
   b. Bolts shall be marked B7.

2.4 VALVES

A. Gate, globe, and check valves are specified in Division 23 Section "General Duty Valves for HVAC Piping."

2.5 SAFETY VALVES

A. Size and Capacity: As required for equipment according to the ASME Boiler and Pressure Vessel Code.

B. Cast-Iron Safety Valves (1-1/2" NPT inlet and larger): Class 250; forged copper-alloy disc with bronze nozzle; fully enclosed, cadmium-plated steel spring with adjustable pressure range and positive shutoff, factory set and sealed; raised-face flanged inlet and threaded outlet connections; factory set and sealed.

C. Bronze Safety Valves (1-1/4" NPT inlet and smaller): Class 250, bronze trim and nozzle, fully enclosed, stainless steel spring with adjustable pressure range and positive shutoff, factory set and sealed, open lever assembly, threaded inlet and outlet connections.

D. Drip Pan Elbow: Cast iron and having threaded inlet and outlet with threads complying with ASME B1.20.1.

E. Stop-Check Valves: Class 250, malleable-iron body and bonnet, cylindrical disc, removable liner and machined seat, brass-alloy stem, outside screw and yoke, polytetrafluoroethylene-impregnated packing with 2-piece packing gland assembly, flanged end connections, and cast-iron handwheel.

2.6 PRESSURE-REDUCING VALVES

A. Size, Capacity, and Pressure Rating: Factory set for inlet and outlet pressures indicated.

B. Valve Characteristics: Pilot-actuated, diaphragm type, with adjustable pressure range and positive shutoff. Valves shall have cast-iron body with threaded connections for valves NPS 1-1/2 and smaller and flanged connections for valves

NPS 2 and larger; and hardened stainless-steel trim, replaceable head and seat, main head stem guide fitted with flushing and pressure-arresting device, cover over pilot diaphragm, and non-asbestos gaskets, 125 psig minimum working steam pressure, regulation accuracy from required capacity down to 5% of rated maximum capacity. Provide minimum scheduled valve body sizes with reduced ports as required.

C. Delivery Pressure Control Accuracy: Delivery pressures greater than 30 psig = ±1 psig. Delivery pressures less than or equal to 30 psig = ±0. 5 psig.

D. Acoustic Mufflers and Orifice Plates: Manufacturer's standard construction to meet specified acoustic performance.

E. Insulating Blanket:

1. Custom fit thermal/acoustic insulating jacket by PRV manufacturer or secondary supplier such as Insultech (Shannon Enterprises)
2. Inner and outer PTFE impregnated fiberglass cloth jackets over needled fiberglass mat.
3. 2" thick insulation.
4. Sewn seams with velcro fasteners.
5. Blankets shall be removable, reusable, and rated to 450°F.

2.7 STEAM TRAPS

A. Float and Thermostatic Traps: ASTM A 126, Class 30 cast-iron body and bolted cap; renewable, replaceable, stainless-steel float mechanism with renewable, hardened stainless-steel head and seat; maximum operating pressure of 125 psig (860 kPa); balanced-pressure, stainless-steel or monel thermostatic bellow element.

1. Thermostatic air vent capable of withstanding 45 deg F (25 deg C) of superheat and resisting water hammer without sustaining damage.

B. Inverted Bucket Traps: ASTM A-278 Class 30 cast-iron body and cap, pressure rated for 250 psig (1725 kPa); stainless-steel head and seat; stainless-steel valve retainer, lever, and guide pin assembly; and brass or stainless-steel bucket.

1. Air Vent: Stainless-steel thermostatic vent.

2.8 VACUUM BREAKERS

A. Vacuum Breakers: 150-psig (1035-kPa) steam working pressure, 365 deg F (185 deg C) maximum operating temperature, brass or stainless-steel body, and stainless-steel retainer, spring, and ball; with plain or threaded outlet.

2.9 THERMOSTATIC AIR VENTS

A. Thermostatic Air Vents: 125 psig steam working pressure, stainless steel body, threaded ends, stainless steel float, valve, and seat.

2.10 STRAINERS

A. Y-Pattern Strainers:

1. Threaded Connections: 250-psig (1725-kPa) working steam pressure; ASTM A 126, Class B cast-iron body; stainless-steel screen, No. 30 mesh (1/50" openings) for NPS 2 (DN 50) and smaller; tapped blowoff plug. Threaded connections for strainers NPS 2 (DN 50) and smaller.
2. Flanged Connections: 125-psig (860-kPa) working steam pressure; ASTM A126, Class B cast iron body, stainless steel screen, 3/64" perforations, tapped blowoff plug, bolted cover flange with tapered seats.
3. Utilize stainless steel strainer body construction where noted on drawings.

B. Basket Strainers: 250-psig (1725-kPa) working steam pressure; ASTM A 126, Class B cast-iron body; stainless-steel screen bolted cover; threaded connections for strainers NPS 2 (DN 50) and smaller and flanged connections for strainers NPS 2-1/2 (DN 65) and larger.

2.11 FLASH TANKS

A. Shop or factory fabricated of welded steel according to the ASME Boiler and Pressure Vessel Code, for 150-psig (1035-kPa) rating. Fabricate with tappings for vents, low-pressure steam and condensate outlets, high-pressure condensate inlet, air vent, safety valve, and legs. Flash tanks vented to atmosphere shall not bear the ASME "UV" label. Flash tanks not vented to atmosphere without any intervening valves shall bear the ASME "UV" label.

PART 3 - EXECUTION

3.1 LP STEAM PIPING APPLICATIONS

A. Steam Piping and Steam Vent Piping, NPS 2 (DN 50) and Smaller: Schedule 40 steel pipe, with threaded joints using Class 125 cast iron fittings.

B. Steam Piping and Steam Vent Piping, NPS 2-1/2 through NPS 10 (DN 65 through DN 250): Schedule 40 steel pipe, with welded joints using Schedule 40 wrought-steel welding fittings and Class 150 wrought-steel flanges.

C. Steam piping for atmospheric steam between the humidifier evaporator and the humidifier dispersion grid shall be Schedule 10 stainless steel or brazed copper as noted on the Drawings.

D. Steam Piping, NPS 12 through NPS 20 (DN 300 through DN 500): Standard weight steel pipe, with welded joints using standard weight wrought-steel welding fittings and Class 150 wrought-steel flanges.

E. Condensate Piping, NPS 2 (DN 50) and Smaller: Schedule 80 type S (seamless) steel pipe, with threaded joints using Class 125 cast iron fittings.

F. Condensate Piping, NPS 2-1/2 through NPS 12 (DN 65 through DN 300): Schedule 80 steel pipe, with welded joints using Schedule 80 wrought-steel welding fittings and Class 150 wrought-steel flanges.

G. Boiler Blowdown, Chemical Feed, Steam System Sampling Piping, and Boiler Feedwater Piping: Schedule 80 steel pipe.

H. Air Vent Piping:

1. Inlet: Same as service where installed.
2. Outlet: Type K (A) annealed-temper copper tubing with brazed joints.

I. Vacuum Breaker Piping: Inlet and outlet, same as service where installed.

J. Safety Valve Inlet and Outlet Piping: Same materials and joining methods as for piping specified for the service in which safety valve is installed.

3.2 MP STEAM PIPING APPLICATIONS

A. Steam Piping and Steam Vent Piping, NPS 2 (DN 50) and Smaller: Schedule 40 steel pipe, with threaded joints using Class 300 malleable-iron fittings.

B. Steam Piping and Steam Vent Piping, NPS 2-1/2 through NPS 10 (DN 65 through DN 250): Schedule 40 steel pipe, with welded joints using Schedule 40 wrought-steel welding fittings and Class 150 wrought-steel flanges.

C. Steam Piping, NPS 12 through NPS 20 (DN 300 through DN 500): Standard weight steel pipe, with welded joints using standard weight wrought-steel welding fittings and Class 150 wrought-steel flanges.

D. Condensate Piping, NPS 2 (DN 50) and Smaller: Schedule 80 Type S (seamless) steel pipe, with threaded joints using Class 150 malleable-iron fittings.

E. Condensate Piping, NPS 2-1/2 through NPS 12 (DN 65 through DN 300): Schedule 80 steel pipe, with welded joints using Schedule 80 wrought-steel welding fittings and Class 150 wrought-steel flanges.

F. Safety Valve Inlet and Outlet Piping: Same materials and joining methods as for piping specified for the service in which safety valve is installed.

3.3 VALVE APPLICATIONS

A. General-Duty Valve Applications: Unless otherwise indicated, use the following valve types:

1. Shutoff Duty: Gate valves.
2. Throttling Duty: Globe valves.

B. Install shutoff-duty valves at each branch connection to supply and return mains, at inlet connection to each steam trap, and elsewhere as indicated.

C. Valves shall be installed with the valve stem at or above the center of the pipe. All valves shall be installed to be easily accessible.

D. Provide chain wheel operators on all valves in Equipment Rooms over 4” size which are installed at a height of 84” or higher above finished floor.

3.4 LP STEAM-TRAP APPLICATIONS

A. Float and Thermostatic Traps: Steam main and riser drip legs, laundry equipment, kitchen equipment, heat exchangers, and heating coils. Size for a minimum three times the load at one psig pressure differential.

3.5 MP STEAM-TRAP APPLICATIONS

A. Inverted Bucket Traps: Steam main drip legs, end of main drip legs, riser drip legs, and laundry equipment. Size for a minimum four times the load at 5 psig pressure differential.

B. Float and Thermostatic Traps: Kitchen equipment, heat exchangers, heat tracer lines, and heating coils. Size for minimum three times the load at one psig pressure differential.

3.6 PIPING INSTALLATIONS

A. Refer to Division 23 Section "Common Work Results for HVAC" for basic piping installation requirements.

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

C. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

D. Install drains, consisting of a tee fitting, NPS 3/4 (DN 20) ball valve, and short NPS 3/4 (DN 20) threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.

E. Install steam supply piping at a uniform grade of 1” in 40’-0” downward in direction of steam flow.

F. Install condensate return piping at a uniform grade of 2” in 40’-0” downward in direction of condensate flow.

G. Reduce pipe sizes using eccentric reducer fitting installed with level side down.

H. Unless otherwise indicated, install branch connections to steam mains using 45-degree fittings in main pipe, with the takeoff coming out the top of the main pipe. Use of 90-degree tee fittings is permissible if 45-degree fittings are impractical. If length of branch takeoff is less than 10 feet (3 m), pitch branch line down toward mains at a 0.4 percent grade.

I. Install unions in piping NPS 2 (DN 50) and smaller adjacent to each valve, at final connections of each piece of equipment, and elsewhere as indicated.

J. Install flanges in piping NPS 2-1/2 (DN 65) and larger at final connections of each piece of equipment and elsewhere as indicated.

K. Install strainers on supply side of each control valve, pressure-reducing valve, solenoid valve, traps, and elsewhere as indicated. Install NPS 3/4 (DN 20) nipple and gate valve in blowdown connection of strainers NPS 2 (DN 50) and larger. Match size of strainer blowoff connection for strainers smaller than NPS 2 (DN 50). Extend valve blow-off to nearest equipment drain. Lay strainers upstream of control valves and pressure reducing valves on their side to minimize accumulation of condensate.

L. Install unions adjacent to each threaded valve, at the final threaded connection to each piece of equipment, in equipment connections as required to perform major maintenance or removal and where shown on the Drawings. Insulating (dielectric) fittings shall be used wherever two dissimilar metals are joined.

M. Anchor piping for proper direction of expansion and contraction. Provide expansion loops as shown on the Drawings.

N. Install drip legs at low points and natural drainage points such as ends of mains, bottoms of risers, and ahead of pressure regulators, control valves, isolation valves, pipe bends, and expansion joints.

1. On straight runs with no natural drainage points, install drip legs at intervals not exceeding 300 feet (90 m) where pipe is pitched down in direction of steam flow and a maximum of 150 feet (45 m) where pipe is pitched up in direction of steam flow.
2. Size drip legs at vertical risers same size as pipe and extend beyond rise. Size drip legs at other locations same diameter as main. In steam mains NPS 6 (DN 150) and larger, dirt leg size can be reduced, but to no less than NPS 4 (DN 100).
3. Install gate valve at drip legs, dirt pockets, and strainer blowdowns to allow removal of dirt and scale.
4. Install steam traps close to drip legs.

O. Install flexible connectors for inlet and discharge connections to pumps and other vibration producing equipment.

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

Q. Install piping to permit valve servicing.

R. Install piping free of sags and bends.

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

T. Install piping to allow application of insulation.

U. Install expansion loops, expansion joints, anchors, and pipe alignment guides.

V. Identify piping as specified in Division 23 “Identification for HVAC Piping and Equipment.”

3.7 STEAM-TRAP INSTALLATION

A. Install steam traps in accessible locations as close as possible to connected equipment, but not more than 48 inches (1200 mm) from connected equipment.

1. Unless otherwise indicated, install gate valve, strainer, and union upstream from trap; install union, check valve, and gate valve downstream from trap.

B. Install trap assemblies in all piping runs as required to eliminate build-up of condensate.

C. Install extra steam trap assembly at low point of steam piping as required to remove condensate from low points of piping. Provide extra steam trap assemblies at all low points created by the installing contractor's piping arrangement.

3.8 PRESSURE-REDUCING VALVE INSTALLATION

A. Install pressure-reducing valves in readily accessible location for maintenance and inspection.

B. Install bypass piping around each pressure-reducing valve, with globe valve equal in size to area of largest pressure-reducing valve seat ring, unless otherwise indicated.

C. Install gate valves on the inlet and outlet of each pressure-reducing valve.

D. Install unions on the inlet and outlet of each pressure-reducing valve having threaded-end connections.

E. Install pressure gages on low-pressure side of each pressure-reducing valve and ahead of shutoff valve. Install pressure gages downstream from globe valve on pressure-reducing valve bypass.

1. On two-stage pressure-reducing stations, install drip trap and pressure gage upstream from second stage pressure-reducing valve.

F. Install strainers upstream for each pressure-reducing valve.

G. Install safety valves downstream from each pressure-reducing valve station.

H. Set-up for Multiple Parallel PRVs:

1. Obtain manufacturer's written recommendations for setpoints on PRVs such that the smaller sized PRV controls low flows.
2. Submit manufacturer's setpoint recommendation and setup procedure to Architect/Engineer.

I. Install safety valves on pressure reducing stations and elsewhere as required by ASME Boiler and Pressure Vessel Code. Install safety valve discharge piping, without valves, to nearest floor drain or as indicated on Drawings. Comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, for installation requirements.

J. Install insulating blanket after all adjustments are complete.

3.9 STEAM METER INSTALLATION

A. Install lengths of straight pipe upstream and downstream from meters according to steam meter manufacturer's instructions. Confirm requirements with manufacturer's written installation instructions prior to installing any steam piping.

3.10 SAFETY VALVE INSTALLATIONS

A. Install safety valves according to ASME B31.1. Pipe safety valve discharge without any intervening valves to atmosphere outside building. Install drip-pan elbow fitting adjacent to safety valve and pipe drain connection to nearest floor drain.

3.11 HANGERS AND SUPPORTS

A. Hanger, support, and anchor devices are specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."

B. Seismic restraints are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

C. Install the following pipe attachments:

1. Adjustable steel clevis hangers for all sizes of individual horizontal branch piping less than 20 feet (6 m) long.
2. Adjustable steel clevis hangers for condensate piping up to 3” NPS for individual horizontal branch piping less than 60 feet long.
3. Adjustable roller hangers for individual horizontal piping 20 feet (6 m) or longer.
4. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet (6 m) or longer, regardless of size, supported on a trapeze.
5. Spring hangers to support vertical runs.

D. Install hangers with the following maximum spacing and minimum rod sizes:

1. NPS 3/4 (DN 20) – NPS 1 (DN 25): Maximum span, 9 feet (2.7 m); minimum rod size, 1/4 inch (6.4 mm).
2. NPS 1-1/2 – NPS 3 (DN 80) (DN 40): Maximum span, 10 feet (3 m); minimum rod size, 3/8 inch (10 mm).
3. NPS 4 (DN 100) NPS 6 (DN 150): Maximum span, 10 feet (3 m); minimum rod size, 1/2 inch (13 mm).
4. NPS 8 (DN 200): Maximum span, 10 feet (3 m); minimum rod size, 5/8 inch (16 mm).
5. NPS 10 (DN 250): Maximum span, 10 feet (3 m); minimum rod size, 3/4 inch (19 mm).
6. NPS 12 (DN 300): Maximum span, 10 feet (3 m); minimum rod size, 7/8 inch (22 mm).
7. NPS 14 (DN 350) NPS 16 (DN 400): Maximum span, 10 feet (3 m); minimum rod size, 1 inch (25 mm)
8. NPS 18 (DN 450) NPS 20 (DN 500): Maximum span, 10 feet (3 m); minimum rod size, 1-1/4 inches (32 mm).

E. Support vertical runs at roof and at each floor and at 10 foot intervals between floors.

3.12 PIPE JOINT CONSTRUCTION

A. Refer to Division 23 Section "Common Work Results for HVAC" for joint construction requirements for threaded, welded, and flanged joints.

3.13 TERMINAL EQUIPMENT CONNECTIONS

A. Size for supply and return piping connections shall be same as for equipment connections.

B. Install traps and control valves in accessible locations close to connected equipment.

C. Install bypass piping with globe valve around control valve. If multiple, parallel control valves are installed, only one bypass is required.

D. Install vacuum breaker downstream from control valve and bypass and close to coil inlet connection. Install thermostatic air vent adjacent to vacuum breaker to let the air back out.

E. Install ports for pressure and temperature gages at coil inlet connections.

F. Install a drip leg at coil outlet.

G. Install shutoff gate valve at each piping connection to the equipment.

3.14 FIELD QUALITY CONTROL

A. Prepare steam and condensate piping according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.
2. Flush system with clean water. Clean strainers.
3. 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.
4. 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. Perform the following tests on steam and condensate 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 trapped air. Use drip legs installed at low points for complete draining of liquid.
3. Flush steam and condensate piping with clean water. Remove and clean or replace strainer screens.
4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the design pressure. Design pressure shall be 100 psig for LP systems and 125 psig for MP systems. 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 either 90 percent of specified minimum yield strength or 1.7 times "SE" value in Appendix A of 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.

3.15 ADJUSTING AND CHECKOUT

A. Mark calibrated nameplates of condensate pump discharge valves after steam and condensate system balancing has been completed, to permanently indicate final balanced position.

B. Perform these tests and adjustments before operating the system in an unsupervised mode:

1. Open valves to fully open position. Close coil bypass valves.
2. Set temperature controls so all coils are calling for full flow.
3. Check operation of automatic bypass valves.
4. Verify pressure settings of pressure reducing stations during operation.
5. Verify safety relief valve discharge and reseating.
6. Confirm vacuum breakers and thermostatic air vents are operational.
7. Operate the system for a minimum of four hours with maximum flow rates, then shutdown and remove and clean and replace all strainers.
8. Confirm that all ASME data sheets are provided to the Owner's Maintenance Staff.

3.16 CLEANING

A. Flush steam and condensate piping with clean water. Remove and clean or replace strainer screens.

END OF SECTION

SECTION 232923
VARIABLE FREQUENCY CONTROLLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes solid-state, PWM, VFC's for speed control of three-phase, squirrel-cage induction motors.

B. Related Sections include the following:

1. Division 26 Section "Transient Voltage Suppression" for low-voltage power, control, and communication surge suppressors.

1.3 DEFINITIONS

A. BMS: Building management system.

B. IGBT: Integrated gate bipolar transistor.

C. LAN: Local area network.

D. PID: Control action, proportional plus integral plus derivative.

E. PWM: Pulse-width modulated.

F. VFC: Variable frequency controller.

1.4 SUBMITTALS

A. Product Data: For each type of VFC. Include dimensions, mounting arrangements, location for conduit entries, shipping and operating weights, and manufacturer's technical data on features, performance, electrical ratings, characteristics, and finishes.

B. Shop Drawings: For each VFC.

1. Include dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment. Show tabulations of installed devices, equipment features, and ratings. Include the following:

a. Each installed unit's type and details.

b. Nameplate legends.
c. Fully rated, short-circuit current rating of integrated unit.

2. Wiring Diagrams: Power, signal, and control wiring for VFC's. Provide schematic wiring diagram for each type of VFC.
3. Manufacturer's complete parameter list including default settings on the VFC.

C. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout, required working clearances, and required area above and around VFC's where pipe and ducts are prohibited. Show VFC layout and relationships between electrical components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.

D. Field quality-control test reports.

E. Operation and Maintenance Data: For VFC's, all installed devices, and components to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 1 Section "Operation and Maintenance Data," include the following:

1. Routine maintenance requirements for VFC's and all installed components.
2. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.

F. Load-Current and List of Settings of Adjustable Overload Relays: Solid state, adjustable, Class 20, compile after motors have been installed and arrange to demonstrate that settings for motor running overload protection suit actual motor to be protected.

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

1. The VFC manufacturer shall provide calculations, specific to this installation, showing total harmonic voltage distortion is less than 5% at the point of common coupling. Input line filters shall be sized and provided as required by the VFC manufacturer to ensure compliance with IEEE Standard 519.

1.5 QUALITY ASSURANCE

A. Manufacturer Qualifications: A qualified manufacturer. Maintain, within 100 miles of Project site, a service center capable of providing training, parts, startup, all warranty work, and emergency maintenance and repairs. Emergency maintenance and repair shall be available from this service center such that a service technician will be on the project site within 24 hours after the service center has been contacted.

B. Source Limitations: Obtain VFC's of a single type through one source from a single 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. Comply with NFPA 70.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Store VFC's indoors in clean, dry space with uniform temperature to prevent condensation. Protect VFC's from exposure to dirt, fumes, water, corrosive substances, and physical damage.

B. If stored in areas subject to weather, cover VFC's to protect them from weather, dirt, dust, corrosive substances, and physical damage. Remove loose packing and flammable materials from inside controllers; install electric heating of sufficient wattage to prevent condensation.

1.7 PROJECT CONDITIONS

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

1. Ambient Temperature: 0 to 40 deg C.
2. Humidity: Less than 90 percent (non-condensing).
3. Altitude: Not exceeding 3300 feet (1005 m).

B. Product Selection for Restricted Space: Drawings indicate maximum dimensions for VFC's, including clearances between VFC's, and adjacent surfaces and other items. Comply with indicated maximum dimensions.

1.8 COORDINATION

A. Coordinate layout and installation of VFC's with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

B. Coordinate features of VFC's, installed units, and accessory devices with pilot devices and control circuits to which they connect.

C. Coordinate features, accessories, and functions of each VFC and each installed unit with ratings and characteristics of supply circuit, motor, required control sequence, and duty cycle of motor and load.

1.9 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of variable frequency controllers and associated auxiliary components that fail in materials or workmanship within specified warranty period.

1. Warranty period: 36 months from the date of certified start-up.
2. The warranty shall include all parts, labor, travel time, and expenses, including readjustments and startup necessary for acceptable controls system functionality.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. ABB Power Distribution (Design reference: Model ACH550 with E-Clipse bypass, circuit breaker disconnect, and VFD service switch.).
2. Eaton (Design reference: HVX 9000 Series with input line fuses, manual HOA bypass controller, dynamic braking).
3. Toshiba (Design reference: Q9 series).

2.2 VARIABLE FREQUENCY CONTROLLERS

A. Description: NEMA ICS 2, IGBT, PWM, VFC; UL listed and labeled as a complete unit and arranged to provide variable speed of an NEMA MG 1, Design B, 3-phase induction motor by adjusting output voltage and frequency.

B. Design and Rating: Match load type such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.

C. Output Rating: 3-phase; 6 to 60 Hz, with voltage proportional to frequency throughout voltage range.

D. Unit Operating Requirements:

1. Input ac voltage tolerance of plus or minus 10 percent.
2. Input frequency tolerance of 50/60 Hz, plus or minus 5 percent.
3. Minimum Efficiency: 96 percent at 60 Hz, full load.
4. Minimum Displacement Primary-Side Power Factor: 96 percent.
5. Overload Capability: 1.1 times the base load current for 60 seconds; 1.3 times the base load current for 3 seconds.
6. Starting Torque: 100 percent of rated torque or as indicated.
7. Speed Regulation: Plus or minus 1 percent.
8. Power loss ride through of 2 seconds.
9. The drive shall include password protection against parameter changes.
10. The minimum full load current rating shall meet or exceed the value in the N.E.C. Table 430-150 for 4-pole motors.

E. Isolated control interface to allow controller to follow control signal over an 11:1 speed range.

1. Electrical Signal: 4 to 20 mA at 24 V.

F. Internal Adjustability Capabilities:

1. Minimum Speed: 5 to 25 percent of maximum rpm.
2. Maximum Speed: 80 to 100 percent of maximum rpm.
3. Acceleration: 0.1 to a minimum of 999 seconds.
4. Deceleration: 0.1 to a minimum of 999 seconds.
5. Current Limit: 50 to a minimum of 110 percent of maximum rating.

G. Self-Protection and Reliability Features:

1. Input transient protection by means of surge suppressors. Surge suppression shall consist of 4-120 Joule rated MOV (phase to phase and phase to ground) and capacitor clamping. Include snubber network to protect against malfunction.
2. Under- and overvoltage trips; inverter overtemperature, overload, and overcurrent trips.
3. Motor Overload Relay: Solid state, adjustable and capable of NEMA ICS 2, Class 20 performance.
4. Notch filter to prevent operation of the controller-motor-load combination at a natural frequency of the combination. Include minimum of three (3) settings.
5. Instantaneous line-to-line and line-to-ground overcurrent trips.
6. Loss-of-phase protection.
7. Reverse-phase protection.
8. Short-circuit protection.
9. Motor overtemperature fault.
10. Drive overtemperature/overload.
11. Ground fault.
12. CPU error.

H. Automatic Reset/Restart: Attempts three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Bidirectional autospeed search shall be capable of starting into rotating loads spinning in either direction and returning motor to set speed in proper direction, without damage to controller, motor, or load.

I. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.

J. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.

K. Input Line Conditioning: 5% input line reactor to reduce the total harmonic distortion to the power line voltage and to add protection from AC line transient per IEEE 519.

L. Output Line Conditioning: Provide output line filter for all installations where the cable length distance between the VFC and the motor exceeds 75 feet.

M. LCD display with key pad (HMI): Back lit LCD display; time clock with battery backup, selector switch, mounted flush in controller door and connected to indicate and control of the following controller parameters:

1. Output frequency (Hz).
2. Motor speed (rpm).
3. Motor status (running, stop, fault).
4. Motor current (amperes).
5. Motor torque (percent).
6. Fault or alarming status (code).
7. PID feedback signal (percent).
8. DC-link voltage (VDC).
9. Set-point frequency (Hz).
10. Motor output voltage (V).

11. Power on, operating condition.
12. Automatic/manual selection.
13. Run or operating hours.
14. Control location (local/remote/hand/auto).
15. Manual speed control in local mode.
16. Running log of total power versus time.
17. Total run time.
18. Fault log, maintaining last four faults with time and date stamp for each.

N. Control Signal Interface:

1. Electric Input Signal Interface: A minimum of 2 analog inputs (0 to 10 V or 0/4-20 mA) and 6 programmable digital inputs.
2. Remote Signal Inputs: Capability to accept any of the following input signals from the BMS or other control systems:

    a. Speed signal: 0 to 10-V dc.
    b. Remote start.
    c. Digital programmable input – minimum of 6.
    d. Fixed frequencies using digital inputs.
    e. RS485.
    f. Keypad display for local hand operation.
    g. Analog programmable input – minimum of 2.
3. Run permissive circuit to accept a system ready signal to ensure VFC does not start until auxiliary equipment is in the proper state.
4. Run permissive output signal suitable for use as a start command to auxiliary equipment where the auxiliary equipment must be started prior to allowing the VFC to start.
5. Output Signal Interface:

    a. A minimum of 1 analog output signal (4-20 mA), which can be programmed to any of the following:

        1) Output frequency (Hz).
        2) Output current (load).
        3) DC-link voltage (VDC).
        4) Motor torque (percent).
        5) Motor speed (rpm).
        6) Set-point frequency (Hz).

6. Remote Indication Interface: A minimum of 2 dry circuit relay outputs (120-V ac, 1 A) for remote indication of the following:

    a. Motor running.
    b. Power on.
    c. Fault and warning indication (overtemperature or overcurrent).
    d. Terminate each dry contact at a terminal strip for use by Building Controls.

O. Communications:

1. Communication capabilities shall include, but not be limited to, run-stop control, and speed set adjustment.

P. EMI/RFI Filters:

1. All VFC's shall include EMI/RFI filters. The onboard filters shall allow the VFC assembly to be CE marked and the VFC shall meet product standard EN 61800-3 for the First Environment restricted level.

Q. Manual Bypass: Arrange magnetic contactor to safely transfer motor between controller output and bypass controller circuit when motor is at zero speed. Unit shall be capable of stable operation (starting, stopping, and running), with motor completely disconnected from controller, and allowing the controller to be completely disconnected from the power. Three-contactor bypass scheme or two contactor with fast acting fuse bypass scheme.

1. The drive/bypass shall include the following:

   a. On/off switch.
   b. Local/Automatic switch. Hand (local) operation speed control may be manually varied from manual speed control.
   c. Drive mode/bypass mode selector switches (Inverter/Bypass), and bypass fault reset.
   d. Test mode on/off selector switch.
   e. Indicator (LED) for power-on, bypass mode selector, bypass fault, safety open and automatic transfer to bypass.
   f. Form C relay output(s) for system started, system running bypass, override enabled, bypass fault.
   g. Bypass Controller: Full-voltage, non-reversing controller with across-the-line starting capability in manual-bypass mode. Solid state, Class 20 selectable motor overload protection with phase loss/phase reversal under both modes of operation with control logic that allows common start-stop capability in either mode.
   h. Door interlocked main fused disconnect padlockable in the OFF position.
   i. In Test position the motor is operated at full speed from the AC line power while power is applied to the input of the VFC. This allows the VFC to be given an operational test while continuing to run the motor at full speed in bypass.
   j. Provide for a normally closed dry contact to be able to stop the motor whether in drive mode or bypass mode.
   k. Bypass shall allow user to operate motor with failed electronic control.

R. Integral Disconnecting Means: NEMA KS 1, heavy-duty fusible switch. Service personnel shall be able to defeat the main power disconnect and open the bypass enclosure without disconnecting power while still meeting all local and national code requirements for safety. Safety/services switch shall be provided integral with each VFC.

S. The VFC shall include the following:

1. A "run permissive circuit" that will provide a fail open contact for use by the Building Automation System. Whenever a run command is provided (local or remote start command in VFC or bypass mode) the run permissive circuit is closed. When the VFC system safety interlock (fire detector, freezestat, high static pressure switch, etc.) opens, the motor shall coast to a stop and the run permissive contact shall open, thereby closing the damper or valve.
2. Internal switch to select manual or automatic bypass. Set switch to manual.
3. An adjustable current sensing circuit for the bypass to provide loss of load indication (broken belt) when in the bypass mode.

T. VFC short circuit withstand rating shall be minimum of 65 KAIC.

2.3 ENCLOSURES

A. NEMA 1 or 12, UL listed.

B. Provide an air cooling fan with filter.

2.4 ACCESSORIES

A. Devices shall be factory installed in controller enclosure, unless otherwise indicated.

B. Push-Button Stations, LED Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.

2.5 FACTORY FINISHES

A. Finish: Manufacturer's standard paint applied to factory-assembled and tested VFC's before shipping.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas, surfaces, and substrates to receive VFC's for compliance with requirements, installation tolerances, and other conditions affecting performance.

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

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

3.2 APPLICATIONS

A. Select features of each VFC to coordinate with ratings and characteristics of supply circuit and motor; required control sequence; and duty cycle of motor, controller, and load.

B. Select horsepower rating of controllers to suit motor controlled.

3.3 INSTALLATION

A. Install VFC with tops at uniform height and with disconnect operating handles not higher than 72 inches above finished floor, unless otherwise indicated.

B. Install wall-mounted VFC by bolting units to lightweight structural-steel channels which are bolted to the structural wall of the building.

C. Install VFC not located on walls with floor-mounted freestanding racks complying with Section 260529 "Hangers and Supports for Electrical Systems." Do not attach channels to air handling unit panels, casings, or any other HVAC component. Do not utilize channels attached to HVAC plenum wall panels. Utilize freestanding floor-mounted racks when VFC are located adjacent to HVAC air handling units and plenum wall panels.

D. Anchor each VFC channel support assembly to floor-mounted or wall-mounted steel-channel sills arranged and sized according to manufacturer's written instructions. Attach by bolting. Level and grout sills flush with floor-mounting surface.

E. Comply with mounting and anchoring requirements specified in Division 26 Section "Hangers and Supports for Electrical Systems".

3.4 IDENTIFICATION

A. Identification is provided by Division 23. Utilize Division 26 Section "Electrical Identification of Electrical System for detailed requirements. Identify VFC's, components, and control wiring.

1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
2. Label each VFC with engraved nameplate.
3. Label each enclosure-mounted control and pilot device.

3.5 CONTROL WIRING INSTALLATION

A. Install control wiring between VFC's and remote devices according to Division 26 Section "Low Voltage Electrical Power Conductors and Cables."

B. Install control wiring within EMT.

C. Connect hand-off-automatic switch and other control devices where applicable.

1. Connect selector switches to bypass only manual- and automatic-control devices that have no safety functions when switch is in hand position.
2. Connect selector switches with control circuit in both hand and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.
3. Provide control wiring between VFC and remote safety switch (disconnect).

3.6 CONNECTIONS

A. Power conduit installation requirements are specified and provided in Division 26 Sections. Drawings indicate general arrangement of VFC, fittings, and specialties. Line wiring and load wiring shall reside within separate conduits. Verify location and routing of conduit with installing Tradesmen.

B. Grounding of equipment is furnished and provided according to Division 26 "Grounding and Bonding."

C. 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.

3.7 FIELD QUALITY CONTROL

A. Prepare for acceptance tests as follows:

1. Test insulation resistance for each enclosed controller element, bus, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.
3. Verify that voltages at VFC locations are within 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify Electrical Engineer of Record before starting the motor(s).
4. Test each motor for proper phase rotation.
5. Perform tests according to the Inspection and Test Procedures for Adjustable Speed Drives stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
6. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

B. Manufacturer's Startup Service: Startup personnel shall not be employees of the installing contractor nor tradesmen temporarily employed by the installing contractor. Startup personnel shall have completed the most current factory training and certifications for the specific model of the VFC being installed. Startup service shall be included in the Project by the VFC manufacturer via the VFC manufacturer's authorized representative. Engage a factory-authorized service representative to perform the following:

1. Inspect controllers, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.
2. Assist in field testing of equipment including pretesting and adjusting of solid-state controllers.
3. Perform the following field tests, inspections, demonstrations and training, and prepare test reports:

    a. Perform each electrical test and visual and mechanical inspection, as follows. Certify compliance with test parameters.
        1) Compare equipment nameplate data with drawings and specifications.
        2) Inspect physical and mechanical condition.
        3) Inspect anchorage, alignment, and grounding.
        4) Verify the unit is clean.
        5) Ensure vent path openings are free from debris and that heat transfer surfaces are clean.
        6) Verify correct connections of circuit boards, wiring, disconnects and ribbon cables.
        7) Motor running protection:
            a) Verify drive overcurrent setpoints are correct for their application.
            b) If drive is used to operate multiple motors, verify individual overload element ratings are correct for their application.

c) Apply minimum and maximum speed setpoints. Verify setpoints are within limitations of the load coupled to the motor

8) Inspect bolted electrical connections for high resistance using calibrated torque wrench method.

9) Test for the following parameters as recommended by the manufacturer:
   a) Input phase loss protection.
   b) Input overvoltage protection.
   c) Output phase rotation.
   d) Overtemperature protection.
   e) DC overvoltage protection.
   f) Overfrequency protection.
   g) Drive overload protection.
   h) Fault alarm outputs.

10) Perform startup of drive in accordance with manufacturer's published data. Calibrate drive to the system's minimum and maximum speed control signals.

11) Perform operational tests by initiating control devices:
   a) Slowly vary drive speed between minimum and maximum. Observe motor and load for unusual noise or vibration.
   b) Verify operation of drive from remote start/stop and speed control signals.

b. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

4. Program microprocessors for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to Substantial Completion.
5. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.
6. Adjust the trip settings of instantaneous-only circuit breakers and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements. Initially adjust to 6 times the motor nameplate full-load amperes and attempt to start motors several times, allowing for motor cool-down between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed 8 times the motor full-load amperes. Where these maximum settings do not allow starting of a motor, notify Electrical Engineer of Record before increasing settings.
7. Set field-adjustable circuit-breaker trip ranges as specified in Section 260573.16 "Overcurrent Protective Device Coordination Study."
8. Identify in writing every single input setting that is adjustable (controller settings and physical settings such as knobs and dipswitches). Differentiate settings available by level of controller access.
9. Report all results in writing directly to the Mechanical Engineer of Record within 12 hours of the each measurement being taken. Telephone and fax the written results directly to the Mechanical Engineer of Record.
10. The startup technician shall directly telephone the Mechanical Engineer of Record while on the Project Site to verbally report on any issues.
11. Prepare formal written startup report for submission to Owner during Training.
12. Failure to contact the Engineer of Record as required shall negate any startup work performed. Repeat of negated work shall be included at no additional cost nor schedule delay.
13. Said startup service shall not be less than 4 hours total time on job site for each VFC installed and shall continue until such time as the Engineer of Record determines that the equipment operation and startup is satisfactory.

14. Coordinate startup service closely with the Controls Installation Contractor, Electrical Contractor, Owner's Energy Management personnel, and the responsible coordinating Mechanical Contractor.
15. Test Reports: Prepare a written report to record the following:

    a. Test procedures used.
    b. Test results that comply with requirements.
    c. Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.
    d. Final operational parameter list of all VFD settings.

3.8 CLEANING

A. Clean VFC's internally, on completion of installation, according to manufacturer's written instructions. Vacuum dirt and debris; do not use compressed air to assist in cleaning.

3.9 DEMONSTRATION AND TRAINING

A. Engage a factory-authorized service representative to train Owner's maintenance personnel as specified below:

1. Adjust, operate, and maintain variable frequency controllers. Operate driven equipment, including accessories and controls, to demonstrate compliance with requirements.
2. Train Owner's maintenance personnel on procedures and schedules related to startup and shutdown, troubleshooting, servicing, and preventive maintenance.
3. Review data in the maintenance manuals.
4. Demonstrate to the Owner's maintenance personnel the procedures and settings required to start, stop, troubleshoot, service and maintain the VFC. Review data in maintenance manual. Allow for a six hour training session on-site for all the VFC associated with this project. Specifically review a pump VFC, a fan VFC and each VFC which differ from the typical pump and fan.
5. Provide a written summary programming and settings to the Owner as required for the proper operation of the specific mechanical equipment.
6. Schedule training with Owner with at least 4 days' advance notice. Provide written startup report to Owner with at least 4 day's advance notice.
7. Said demonstration service shall not be less than 4 hours total time on job site and shall continue until such time as the Owner determines that the equipment operation and training is satisfactory.

3.10 OCCUPANCY ADJUSTMENTS

A. When requested by the Owner or the Engineer of Record, within 18 months of Substantial Completion, provide on-site assistance adjusting the system to suit actual occupied conditions. Provide up to three visits to the project site for this purpose. Project site visits for occupancy adjustment shall commence within 72 hours of when requested and shall be staffed appropriately such that they are fully completed within 24 hours of arrival on the Project site.

B. The above on-site occupancy adjustment assistance shall be performed by direct factory employees of the VFC manufacturer unless otherwise requested in writing by

the Engineer of Record. The VFC shall be “restarted up” at the end of each of the visits with all new complete written documentation of setpoints and operability provided prior to the technician leaving the project site.

C. The factory technician shall directly telephone the Engineer of Record 24 hours prior to arrival at the Project Site and once every day while on the Project Site to verbally report on the status and issues. Failure to contact the Engineer of Record as required shall negate any startup work performed. Repeat of negated work shall be included at no additional cost nor schedule delay.

END OF SECTION

SECTION 233113
METAL DUCTS

GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes metal ducts for supply, return, outside, and exhaust air-distribution systems in pressure classes from minus 2- to plus 10-inch wg. Metal ducts include the following:

1. Rectangular ducts and fittings.
2. Single-wall, round and flat-oval spiral-seam ducts and formed fittings.
3. Double-wall, round and flat-oval spiral-seam ducts and formed fittings.
4. Sheet metal materials.
5. Sealants and gaskets.
6. Hangers and supports.
7. Seismic restraint devices.
8. Duct liner.

B. Related Sections include the following:

1. Division 23 Section "Nonmetal Ducts" for fibrous-glass ducts, thermoset FRP ducts, thermoplastic ducts, PVC ducts, and concrete ducts.
2. Division 23 Section "HVAC Casings" for factory- and field-fabricated casings for mechanical equipment.
3. Division 23 Section "Duct Accessories" for dampers, sound-control devices, duct-mounting access doors and panels, turning vanes, and flexible ducts.
4. Division 23 Section “Testing, Adjusting and Balancing for HVAC” for testing, adjusting and balancing requirements for metal ducts.
5. Division 23 Section “Vibration and Seismic Controls for HVAC Piping and Equipment” for seismic hazard levels.

1.3 SYSTEM DESCRIPTION

A. Duct system design, as indicated, has been used to select size and type of air-moving and -distribution equipment and other air system components. Changes to layout or configuration of duct system must be specifically approved in writing by Architect. Accompany requests for layout modifications with calculations showing that proposed layout will provide original design results without increasing system total pressure.

B. Structural Performance: Duct hangers and supports and seismic restraints shall withstand the effects of gravity and seismic loads and stresses within limits and under

conditions described in SMACNA's "HVAC Duct Construction Standards – Metal and Flexible" and SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."

C. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.

1.4 SUBMITTALS

A. Product Data: For each type of the following products:

1. Liners and adhesives.
2. Sealants and gaskets.
3. Seismic restraint devices.

B. LEED Submittals:

1. Product Data for Prerequisite EQ 1: Documentation indicating that duct systems comply with ASHRAE 62.1-2004, Section 5 – "Systems and Equipment."
2. Product Data for Prerequisite EA 2: Documentation indicating that duct systems comply with ASHRAE/IESNA 90.1-2004, Section 6.4.4 – "HVAC System Construction and Insulation."
3. Leakage Test Report for Prerequisite EA 2: Documentation of work performed for compliance with ASHRAE/IESNA 90.1-2004, Section 6.4.4.2.2 – "Duct Leakage Tests."
4. Duct Cleaning Test Report for Prerequisite EQ 1: Documentation of work performed for compliance with ASHRAE 62.1-2004, Section 7.2.4 – "Ventilation System Startup."

C. Shop Drawings: CAD-generated and drawn at minimum 1/4" = 1'-0" scale. Shop drawings shall include the following:

1. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
2. Duct layout indicating sizes and pressure classes.
3. Elevations of top and bottom of all duct and terminal units along with applicable elevations of structural elements.
4. Dimensions of main duct runs from building grid lines.
5. Fittings, including details of construction and turning vanes.
6. Reinforcement and spacing.
7. Duct gauge thickness by pressure class.
8. Seam and joint construction.
9. Duct material type and coatings.
10. Penetrations through fire-rated barriers and partitions and smoke barriers.
11. Equipment installation based on equipment being utilized on this Project.
12. Duct accessories, including access doors and panels, volume dampers, fire dampers, smoke dampers and flexible connectors.
13. Length of application of acoustic duct liner where it will be applied.
14. Hangers and supports, including methods for duct and building attachment, vibration isolation, and seismic restraints.
15. Ceiling suspension assembly members.
16. Other systems installed in the same space as ducts where order of installation effects access.

17. Ceiling and wall-mounting access doors and panels required to provide access to dampers and other operating devices.
18. Ceiling-mounting items, including lighting fixtures, diffusers, grilles, speakers, smoke detectors, sprinklers, access panels, and special moldings.
19. On each drawing, include a tabular listing of each fan system's ductwork represented on that drawing and the total square foot surface area of each fan's duct system illustrated on that drawing.
20. Duct riser elevations/sections which detail duct passing through structure, shaft construction and shaft bottom construction. Illustrate fire damper high hats, duct takeoff, boot taps and other pertinent features.
21. Shop drawings shall be submitted prior to the fabrication or installation of the ductwork and serve as the foundation for coordination between the various trades to maintain required ceiling heights.

D. Field Test Reports: Written reports of tests specified in Part 3 of this Section. Include the following:

1. Test procedures used.
2. Test results that comply with requirements.
3. Failed test results and corrective action taken to achieve requirements.

E. Coordination Drawings: Plans, drawn to scale, on which the following items are illustrated 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. Include plumbing, piping, electrical, and other building systems components including, but not limited to, roof drain piping, sanitary piping, plumbing piping, fire protection piping, heating and cooling water piping, condensate drains, steam and condensate return piping, conduit cable tray, electrical pull boxes, etc.
2. Suspended ceiling components (projectors, booms, partitions, etc).
3. Structural members size (depth) and location to which duct will be attached.
4. Size and location of access through acoustical ceiling tile. Denote which tiles are reserved for access to HVAC components above ceiling.
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. Sprinkler heads.
    e. Access panels/access doors.
    f. Perimeter moldings and bulkheads.
    g. Occupancy/vacancy sensors.
    h. Smoke detectors.
    i. Strobe lights.
    j. Exit signage.
    k. Security cameras.
    l. Wireless access nodes.
    m. Projectors.
    n. Projector screens.
    o. Safety showers.
    p. Casework which penetrates the ceiling.

7. Coordination drawing final submission and sheet metal shop drawing final submission shall occur simultaneously.

F. Leak Testing Documentation: Contractor shall submit a written report to the authorities having jurisdiction which documents that 100% of the ducts designed at static pressures in excess of 3” wg. has been leak tested and that the air leakage class is less than 6.0 (see Energy Code). Provide duplicate submittal to the Owner and the Engineer.

G. Grease duct light test documentation.

H. Mockups: Of architecturally exposed ductwork installations including duct, hangers, connectors and sealant.

1.5 QUALITY ASSURANCE

A. NFPA Compliance:

1. NFPA 90A, "Installation of Air Conditioning and Ventilating Systems."
2. NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

B. Comply with NFPA 96, "Ventilation Control and Fire Protection of Commercial Cooking Operations," Ch. 3, "Duct System," for range hood ducts, unless otherwise indicated.

C. 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.

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

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports.
3. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.

E. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1-2004, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."

F. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1-2004, Section 6.4.4 - "HVAC System Construction and Insulation."

1.6 DELIVERY, STORAGE, AND HANDLING

A. Store all ductwork and associated ductwork components to prevent damage and to prevent entrance of dirt, debris, and moisture.

B. Support all ductwork and associated ductwork components to prevent sagging or bending.

C. Provide temporary storage, delivery and handling in accordance with the SMACNA Duct Cleanliness Standard level specified herein.

PART 2 - PRODUCTS

2.1 SINGLE WALL RECTANGULAR DUCTS AND FITTINGS

A. Fabricate ducts, elbows, transitions, offsets, branch connections, and other construction according to SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" and complying with requirements for metal thickness, reinforcing types and intervals, tie-rod applications, and joint types and intervals.

1. Lengths: Fabricate rectangular ducts in lengths appropriate to reinforcement and rigidity class required for pressure class.
2. Deflection: Duct systems shall not exceed deflection limits according to SMACNA's "HVAC Duct Construction Standards--Metal and Flexible."
3. Minimum sheet metal gage shall be 24.
4. Utilize radius elbows with centerline radius equal to 1.5 times the width unless specifically shown otherwise on the drawings.
5. Square throat elbows where specifically shown on the drawings shall include turning vanes for all applications (supply, return, exhaust, relief, outdoor air, etc.) except grease hood duct.
6. Utilize SMACNA Figure 4-6, 45 degree entry branch connections with a minimum “L” dimension of six inches or one quarter of “W” whichever is greater.

B. Transverse Joints: Prefabricated slide-on joints and components constructed using manufacturer's guidelines for material thickness, reinforcement size and spacing, and joint reinforcement, or roll formed flange connection system TDC or TDF according to “SMACNA HVAC Duct Construction Standards – Metal and Flexible” maximum 24” long duct section whenever any side exceeds 96 inches.

1. Manufacturers:

   a. Ductmate Industries, Inc.
   b. Nexus Inc.
   c. Ward Industries, Inc.

C. Formed-On Flanges: Construct according to SMACNA's "HVAC Duct Construction Standards--Metal and Flexible," Figure 1-4, using corner, bolt, cleat, and gasket details.

1. Manufacturers:

   a. Ductmate Industries, Inc.
   b. Lockformer.

2. Duct Size: Maximum 30 inches wide and up to 2-inch wg pressure class.
3. Longitudinal Seams: Pittsburgh lock sealed with non-curing polymer sealant.

D. Cross Breaking or Cross Beading: Cross break or cross bead duct sides 19 inches and larger and 0.0359 inch thick or less, with more than 10 sq. ft. of non-braced panel area unless ducts are lined. Cross break or cross bead all pressure class duct even where SMACNA Figure 2-9 says you do not need to.

2.2 SINGLE WALL, ROUND AND FLAT-OVAL, SPIRAL-SEAM DUCTS AND FORMED FITTINGS

A. Diameter as applied to flat-oval ducts in this Article is the diameter of a round duct with a circumference equal to the perimeter of a given size of flat-oval duct.

B. Round, Spiral Lock-Seam Ducts: Fabricate supply ducts of galvanized steel according to SMACNA's "HVAC DUCT Construction Standards – Metal and Flexible."

1. Minimum sheet metal gage shall be 24.
2. Mechanically fasten ducts by means of at least three sheet metal screws spaced in approximately uniform intervals along the circumference of the ducts.

C. Flat-Oval, Spiral Lock-Seam Ducts: Fabricate supply ducts according to SMACNA's "HVAC Duct Construction Standards—Metal and Flexible." Fabricate ducts larger than 72 inches in diameter with butt-welded longitudinal seams.

1. Manufacturers:

a. Eastern Sheet Metal.
b. Foremost.
c. JTD Spiral.
d. LaPine.
e. Lindab, Inc.
f. McGill Airflow LLC.
g. SEMCO Incorporated.

D. Duct Joints:

1. Ducts up to 20 Inches in Diameter: Interior, center-beaded slip coupling at least two gages heavier than duct wall, sealed before and after fastening, attached with sheet metal screws.
2. Ducts 21 to 72 Inches in diameter: Three-piece, gasketed, flanged joint consisting of two internal flanges with sealant and one external closure band with gasket which compresses the gasket between the internal flanges.
3. Ducts larger than 72 inches in diameter: Companion angle flanged joints per SMACNA "HVAC Duct Construction Standards—Metal and Flexible," Figure 3-1. Refer to manual for proper sizing and construction details.
4. Round ducts (Optional): Prefabricated connection system consisting of double-lipped, EPDM rubber gasket. Manufacture ducts according to connection system manufacturer's tolerances.

a. Manufacturers:

1) Ductmate Industries, Inc.
2) Lindab Inc.

5. Flat-Oval Ducts: Prefabricated connection system consisting of two flanges and one synthetic rubber gasket.

a. Manufacturers:

1) Ductmate Industries, Inc.
2) Lindab, Inc.
3) McGill Airflow LLC

4) SEMCO.

E. Conical Tees, 90-Degree Tees, 45-Degree Laterals, Bellmouths and 45-Degree Entry Tees: Fabricate to comply with SMACNA's "HVAC Duct Construction Standards—Metal and Flexible," with metal thicknesses specified for longitudinal-seam straight ducts.

F. Diverging-Flow Fittings: Fabricate with reduced entrance to branch taps and with no excess material projecting from fitting onto branch tap entrance.

G. Fabricate elbows using die-formed, gored, pleated, or mitered construction. Centerline bend radius of die-formed, gored, and pleated elbows shall be 1-1/2 times duct diameter. Unless elbow construction type is indicated, fabricate elbows as follows:

1. Mitered-Elbow Radius and Number of Pieces: Welded construction complying with SMACNA's "HVAC Duct Construction Standards—Metal and Flexible," unless otherwise indicated.
2. Round Mitered Elbows: Welded construction with the following metal thickness for pressure classes from 2- to 10-inch wg.

    a. Ducts 3 to 26 Inches in Diameter: 0.034 inch.
    b. Ducts 27 to 50 Inches in Diameter: 0.040 inch.
    c. Ducts 52 to 60 Inches in Diameter: 0.052 inch.
    d. Ducts 62 to 84 Inches in Diameter: 0.064 inch.

3. Flat-Oval Mitered Elbows: Welded construction with same metal thickness as longitudinal-seam flat-oval duct.
4. 90-Degree, 2-Piece, Mitered Elbows: Use only for supply systems or for material-handling Class A or B exhaust systems and only where space restrictions do not permit using radius elbows. Fabricate with single-thickness turning vanes.
5. Round Elbows 8 Inches and Less in Diameter: Fabricate die-formed elbows for 45- and 90-degree elbows and pleated elbows for 30, 45, 60, and 90 degrees only. Fabricate nonstandard bend-angle configurations or nonstandard diameter elbows with gored construction.
6. Round Elbows 9 through 14 Inches in Diameter: Fabricate gored or pleated elbows for 30, 40, 45, 60, and 90 degrees unless space restrictions require mitered elbows. Fabricate nonstandard bend-angle configurations or nonstandard diameter elbows with gored construction.
7. Round Elbows Larger than 14 Inches in Diameter and All Flat-Oval Elbows: Fabricate gored elbows unless space restrictions require mitered elbows.
8. Die-Formed Elbows for Sizes through 8 Inches in Diameter and All Pressures 0.040 inch thick with 2-piece welded construction.
9. Round Gored-Elbow Metal Thickness: Same as non-elbow fittings specified above.
10. Flat-Oval Elbow Metal Thickness: Same as longitudinal-seam flat-oval duct specified above.
11. Pleated Elbows for Sizes through 14 Inches in Diameter and Pressures through 10-Inch wg: 0.022 inch.

H. PVC-Coated Elbows and Fittings: Fabricate elbows and fittings as follows:

1. Round Elbows 4 to 8 Inches in Diameter: Two piece, die stamped, with longitudinal seams spot welded, bonded, and painted with PVC aerosol spray.

2. Round Elbows 9 to 26 Inches in Diameter: Standing-seam construction.
3. Round Elbows 28 to 60 Inches in Diameter: Standard gored construction, riveted and bonded.
4. Other Fittings: Riveted and bonded joints.
5. Couplings: Slip-joint construction with a minimum 2-inch insertion length.

2.3 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. Sheet Metal Connectors, Inc.

B. Rectangular Ducts: Fabricate ducts with indicated dimensions for the inner duct.

C. Outer Duct: Comply with 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 SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-4, "Transverse (Girth) Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

E. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-5, "Longitudinal Seams - Rectangular Ducts," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

F. Formed-on Transverse Joints (Flanges): Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-4, "Traverse (Girth) Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

G. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-5, "Longitudinal Seams - Rectangular Ducts," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

H. Interstitial Insulation: Fibrous-glass liner complying with ASTM C1071, NFPA 90A, and with NAIMA AH124, "Fibrous Glass Duct Liner Standard." Cover insulation with polyester film complying with UL 181, Class 1.

2.4 DOUBLE-WALL DUCT, ROUND AND FLAT-OVAL SPIRAL SEAM DUCTS AND FORMED FITTINGS

A. Manufacturers:

1. Eastern Sheet Metal.

2. Foremost.
3. Lindab Inc.
4. McGill AirFlow LLC.
5. SEMCO Incorporated.

B. Ducts: Fabricate double-wall (insulated) ducts with an outer shell and an inner duct. Dimensions indicated are for inner ducts.

1. Outer Shell: Base metal thickness on outer-shell dimensions. Provide spiral lock seam (without standing ribs). Fabricate outer-shell lengths 2 inches longer than inner duct and insulation and in metal thickness specified for single-wall duct.
2. Insulation: [**1-inch thick**][**2-inch thick**] fibrous glass, unless otherwise indicated. Terminate insulation where double-wall duct connects to single-wall duct or uninsulated components, and reduce outer shell diameter to inner duct diameter.

    a. Minimum installed R value of [**3.5**][**6.0**][**8.0**] mean temperature.
    b. Minimum 1.0 lb/cubic feet nominal density.

3. Solid Inner Ducts: Use the following minimum sheet metal thicknesses and seam construction:

    a. Ducts 3 to 8 Inches in Diameter: 0.019 inch with standard spiral-seam construction.
    b. Ducts 9 to 42 Inches in Diameter: 0.019 inch with single-rib spiral-seam construction.
    c. Ducts 44 to 60 Inches in Diameter: 0.022 inch with single-rib spiral-seam construction.
    d. Ducts 62 to 88 Inches in Diameter: 0.034 inch with standard spiral-seam construction.

4. Perforated Inner Ducts: Fabricate with 0.028-inch thick sheet metal having 3/32-inch-diameter perforations, with overall open area of 23 percent.
5. Maintain concentricity of inner duct to outer shell by mechanical means. Prevent dislocation of insulation by mechanical means.
6. Connections: use connections suitable for architecturally exposed ductwork systems. Do not provide raised flanges (e.g. AccuFlange, Econoflange) which extend from the outer surface of the duct more than 1”. Spiralmate closure pieces shall be located on top of the duct and in a non-visible location.

C. Fittings: Fabricate double-wall (insulated) fittings with an outer shell and an inner duct.

1. Solid inner ducts: Use the following minimum sheet metal thicknesses:

    a. Ducts 3 to 34 inches in diameter: 0.028 inches.
    b. Ducts 35 to 58 inches in diameter: 0.034 inches.
    c. Ducts 60 to 88 Inches in Diameter: 0.040 inch.

2. Solid outer shells: Use the following minimum sheet metal thicknesses:

    a. Ducts 3 to 34 inches in diameter: 0.028 inches.
    b. Ducts 35 to 58 inches in diameter: 0.034 inches.
    c. Ducts 60 to 88 inches in diameter: 0.040 inches.

3. Perforated inner ducts: Fabricate with 0.028-inch thick sheet metal having 3/32-inch-diameter perforations, with overall open area of 23 percent.
4. Construction: Provide solid welded fittings, fabricated without fasteners or sealant. Insulation type and thickness shall match adjoining ductwork. Inner duct liners shall be solid.

D. Materials:

1. Provide paintable galvanized steel outer duct suitable for Direct to Metal paint products. Remove all surface contaminants and protective oils from the manufacturing process and dirt due to installation prior to applying paint. Comply with direct to metal paint manufacturer's written requirements.
2. All ductwork, fittings and hangers shall be fabricated and installed suitable for visibility by the public and shall be considered "architecturally exposed".
3. Provide [**G90 galvanized**][**stainless steel**] outer liner for exterior mounted duct.

E. Mockup: Provide a mockup of the duct hanger, duct connector and duct sealant prior to fabricating any ductwork. Make all revisions requested by the Owner and the Architect based upon mockup review. Implement the mockup (with revisions) for the actual installation.

2.5 SHEET METAL 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: Lock-forming quality; complying with ASTM A 653/A 653M and having G60 coating designation (G90, if exterior duct); ducts shall have mill-phosphatized finish for surfaces exposed to view.

C. PVC-Coated Galvanized Steel: Acceptable by authorities having jurisdiction for use in fabricating ducts with UL 181, Class 1 listing. Lock-forming-quality, galvanized sheet steel complying with ASTM A 653/A 653M and having G90 coating designation. Factory-applied PVC coatings shall be 4 mils thick on sheet metal surfaces of ducts and fittings exposed to corrosive conditions and 1 mil thick on opposite surfaces.

D. Polyamide Epoxy Coated Galvanized Steel: Acceptable by authorities having jurisdiction for use in fabricating ducts with UL 181, Class 1 listing. Lock forming quality, galvanized sheet steel complying with ASTM A 653/A 653M and having G90 coating designation. Shop applied and cured coating prior to delivery to job site. Two coats of Tnemec Series 66 high build epoxoline polyamide. The epoxy shall be approximately 4 mils per layer. Aggregate dry film thickness total of both layers shall be 6-8 mils. All surface prep, primers, etc. shall be in accordance with coating manufacturer's written instructions. Solvent clean ductwork prior to coating per SSPC-SPI procedure.

E. Carbon-Steel Sheets: ASTM A 1008/A, 1008/M; commercial quality; with oiled, matte finish for exposed ducts.

F. Stainless Steel: ASTM A 480/A 480M, Type 304 or 304L and having a No. 2D finish for concealed ducts and No. 3 finish for exposed ducts.

G. Aluminum Sheets: ASTM B 209 (ASTM 209M), alloy 3003, temper H14; with mill finish for concealed ducts and standard, one side bright finish for duct surfaces exposed to view.

H. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts. Aluminum reinforcement where installed on aluminum ducts.

I. 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. Aluminum material for aluminum ducts.

2.6 SEALANT AND GASKETS

A. Joint and Seam Sealants, General: The term "sealant" is not limited to materials of adhesive or mastic nature but includes tapes and combinations of open-weave fabric strips and mastics.

B. Water-Based Joint and Seam Sealant: Flexible, adhesive sealant, resistant to UV light when cured, UL 723 listed, and complying with NFPA requirements for Class 1 ducts.

C. Solvent-Based Joint and Seam Sealant: One-part, non-sag, solvent-release-curing, polymerized butyl sealant formulated with a minimum of 75 percent solids.

D. For indoor applications, use sealant that has a VOC content of 75 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

E. Exterior duct sealants shall be marketed specifically as forming a positive air and watertight seal, bonding well to the metal, remaining flexible with metal movement, having a service temperature range of -30 deg F to 175 deg F, be ultraviolet ray and ozone resistant.

F. Flanged Joint Sealant: Single component, acid-curing, silicone, elastomeric joint sealant complying with ASTM C 920, Type S, Grade NS, Class 25, use O.

G. Flange Gaskets: Butyl rubber, neoprene or EPDM polymer with polyisobutylene plasticizer.

H. Round Duct Joint O-Ring Seals:

1. Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg (0.14 L/s per sq. m at 250 Pa) and shall be rated for 10-inch wg (2500-Pa) 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.
4. Provide additional sealant applied to the entire exterior of the circumferential joint for ductwork of 2” wg pressure class or greater.
5. Install screw attachments, 12” on center at gasketed joints.

2.7 HANGERS AND SUPPORTS

A. Building Attachments: Concrete inserts or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Do not use powder-actuated concrete fasteners.

B. Hanger Rods for Non-Corrosive Environments: Cadmium plated steel rods and nuts.

C. Hanger Rods for Corrosive Environments: Electro-galvanized, all thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.

D. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards – Metal and Flexible," Table 4-1 (Table 4-1M), "Rectangular Duct Hangers Minimum Size," and Table 4-2, "Minimum Hanger Sizes for Round Duct."

E. Steel Cables for Galvanized Steel Ducts: Galvanized steel complying with ASTM A 603.

F. Steel Cables For Stainless Steel Ducts: Stainless steel complying with ASTM A 492.

G. Steel Cable End Connections: Cadmium plated steel assemblies with brackets, swivel, and bolts designed for duct hanger services with an automatic locking and clamping device.

H. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

I. Trapeze and Riser Supports: Steel shapes complying with ASTM A 36/A 36M.

1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.
2. Supports for Stainless-Steel Ducts: Stainless-steel support materials.
3. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.
4. Strut type trapeze supports shall be minimum 14 gauge.

J. 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.

2. Antimicrobial Erosion-Resistant Coating: Apply to the surface of the liner that will form the interior surface of the duct to act as a moisture repellent and erosion-resistant coating. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
3. Solvent or Water Based Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C916.

a. For indoor application, 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).

4. Liner must have a noise reduction coefficient of at least 0.65.
5. Polyester liner must be able to withstand a constant internal temperature up to 150 deg. F and contain zero VOCs per ASTM D5116. Comply with ASTM E84, ASTM C518, ASTM G-21, NFPA 90A and 90B and UL 181.
6. Polyester duct liner must be pinned and attached using a non-flammable low VOC water based adhesive. Provide edge coating and metal nosing on all edges perpendicular to the airstream direction.

K. Flexible Elastomeric Duct Liner: Preformed, cellular, closed cell, sheet materials complying with ASTM C534, Type II, Grade 1 and with NFPA 90A or NFPA 90B.

1. Manufacturers: Subject to compliance with requirements, provide products by one fo 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.
4. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
5. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers".

L. 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 (3.5-mm) diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch (38-mm) galvanized carbon steel washer.
2. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch (0.41-mm) thick aluminum with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches (38 mm) in diameter.

M. Shop Application of Duct Liner: Comply with SMACNA's "HVAC Duct Construction Standards – Metal and Flexible," Figure 2-19, "Flexible Duct Liner Installation."

1. Adhere a single layer of indicated thickness of the 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 joints with adhesive.
4. Fold and compress liner in corners of rectangular ducts or cut and it 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. Secure liner with mechanical fasteners 4 inches (100 mm) from corners and at intervals not exceeding 12 inches (300 mm) transversely; at 3 inches (75 mm) from transverse joints and at intervals not exceeding 18 inches (450 mm) longitudinally.
7. Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or “Z” profiles or are internally formed from duct wall. Fabricate edge facings at the following locations:

    a. Fan discharge and fan inlets.
    b. Intervals of lined duct preceding unlined duct.
    c. Upstream edges of transverse joints in ducts where air velocities are higher than 2500 fpm (12.7 m/s) or where indicated.

8. Terminate inner ducts with build-outs attached to fire damper sleeves, dampers, turning vane assemblies, or other devices. Fabricated build-outs (metal hat sections) or other build-out means are optional; when used, secure build-outs to duct walls with bolts, screws, rivets or welds.

PART 3 - EXECUTION

3.1 DUCT APPLICATIONS

A. Static-Pressure Classes: Unless otherwise indicated, construct ducts according to the following:

1. Supply Ducts (before Air Terminal Units): 4-inch wg.
2. Supply Ducts (after Air Terminal Units): 1-inch wg.
3. Supply Ducts (in Mechanical Equipment Rooms and inside shafts): 6-inch wg.
4. Return and Outside Air Ducts (in Mechanical Equipment Rooms and inside shafts) (Negative Pressure): 4-inch wg.
5. Return Ducts (above ceiling): 2-inch wg.
6. General Exhaust Ducts (Negative Pressure): 2-inch wg.
7. Laboratory and Pharmacy Exhaust Ducts (Negative Pressure): 6-inch wg.
8. Relief Ducts (Positive Pressure): 4-inch wg.
9. Isolation Room Exhaust Ducts (Negative Pressure): 6-inch wg.

B. All ducts shall be galvanized steel except as follows:

1. Grease Exhaust Ducts

    a. Type 1 (Grease) Field fabricated or manufactured ductwork
    b. Concealed: Carbon-steel sheet, 16 gage.
    c. Exposed: Type 304, stainless steel with finish to match kitchen equipment and range hood.
    d. Continuous liquid-tight welds on external duct surface.
    e. Access doors shall be grease-tight, hinged and self-closing. Gasket shall be suitable for 1,500 deg F.

2. Dishwasher Hood Exhaust Ducts:

a. Type II (Dishwasher), stainless steel with finish to match kitchen equipment and range hood. Weld all seams and joints.

3. Corrosion-Resistant (Fume-Handling) Ducts [**for the entire EF-X system**]: [**Type 316 stainless steel sheet with No. 3 finish.**][**PVC coated galvanized steel with thicker coating on duct interior.**][**Polyamide epoxy coated galvanized steel.**]
4. Fully welded stainless steel ducts as noted on plans.

a. Type 304, weld all seams and joints.
b. Utilize wet air exhaust ductwork system requirements.

5. MRI Exam Rooms: All aluminum construction, duct, hangers, fasteners, etc.

6. Exhaust air ducts: **[Fibrous glass], [Elastomeric]**, Type I, 2 inches thick. Liner only included to the extent specifically noted on the plans and details and herein. Clarify as required during bidding.
7. Return air ducts: FSK lined polyester, Type I, 2 inches thick. Liner only included to the extent specifically noted on the plans and details and herein. Clarify with the Engineer as required during bidding.

8. Exposed supply air, relief air, exhaust air and outdoor air ductwork in occupied areas and as noted on the drawings shall be double wall with paintable surfaces. Duct size indicated on drawings shall be the inner duct size.

3.2 WET AIR EXHAUST DUCTWORK SYSTEM

A. Duct material shall be constructed of no lighter than 18 gage, 304 stainless steel. Construction shall be -6” wg minimum.

B. All seams and joints shall be continuously welded externally with 304L welding rod and ground smooth. Spiral pipe is not acceptable. Butt weld all connections.

C. Where ducts are not self-draining back to the equipment, provide low point drain pocket with polypropylene drain pipe to sanitary sewer. Drain pocket is not to accumulate more than one gallon. Provide access doors or panels for duct cleaning inside of horizontal duct at drain pockets at 20 foot intervals and at each change of direction.

D. Volume dampers frames, damper blades, and shafts shall be 304 stainless steel. Dampers shall be mounted inside with horizontal penetrating shaft.

E. Hang ductwork so as to not penetrate the duct with any screws. Utilize trapeze on rectangular. Utilize straps which hug the circumference on round duct.

F. Ductwork, which is exposed to an occupied space, shall be polished to a uniform satin (#3) finish.

3.3 STAINLESS STEEL CANOPY HOODS

A. Type 302 or Type 304 stainless steel shall be used for all hood components including exposed trim and connection flanges.

B. Exposed surfaces inside the hood and on the exterior of the hood exposed below the ceiling shall be polished to a uniform satin (#3) finish. If original finish is disturbed, polish to match original finish.

C. Hem all edges. Include drip lip turned up.

D. Exposed external corners shall be tightly welded, ground smooth and polished.

E. Minimum 18 gage construction, thicker as required for adequate stiffness.

F. One piece construction with all seams and corners welded.

G. Support separately from structure and kick brace so no sway.

H. Thoroughly clean all surfaces prior to above ceiling inspection.

3.4 DUCT INSTALLATION

A. Construct and install ducts according to SMACNA's "HVAC Duct Construction Standards--Metal and Flexible," unless otherwise indicated.

B. Install round and flat-oval ducts in lengths not less than 12 feet unless interrupted by fittings.

C. Install ducts with fewest possible joints.

D. Cable hangers may only be used on low pressure (2" wg construction and lower) round spiral ductwork which is not insulated and has a diameter of 10" or less. Utilize the double lock method such that the lower loop is cinched tight to the ductwork and the cable is vertical. Utilize manufacturer's top attachment device.

E. Install fabricated fittings for changes in directions, size, and shape and for connections.

F. Install couplings tight to duct wall surface with a minimum of projections into duct. Secure couplings with sheet metal screws. Install screws at maximum intervals of 12 inches, with a minimum of 3 screws in each round metallic duct coupling.

G. Install ducts, unless otherwise indicated, vertically and horizontally and parallel and perpendicular to building lines; avoid diagonal runs.

H. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

I. Install ducts with a minimum clearance of 2 inches, plus allowance for insulation thickness, to all components.

J. Install ductwork takeoffs at smoke dampers such that there is a minimum of 24" between the damper and the start of the first takeoff.

K. Low pressure ductwork shall extend a minimum of 9 inches beyond last diffuser takeoff.

L. Conceal ducts from view in finished spaces. Do not encase horizontal runs in solid partitions unless specifically indicated.

M. Do not penetrate ducts with conduit or piping. Provide SMACNA Figure E obstruction fitting where structural members are shown penetrating ductwork.

N. Coordinate layout with suspended ceiling, fire- and smoke-control dampers, lighting layouts, smoke partition rated walls and similar finished work allowing for proper maintenance and installation.

O. Seal all joints and seams. Apply sealant to male end connectors before insertion, and afterward to cover entire joint and sheet metal screws.

P. Electrical Equipment Spaces: Route ducts to avoid passing through transformer vaults and electrical equipment spaces and enclosures. Do not route duct over motor control centers or panelboard.

Q. Non-Fire-Rated Partition Penetrations: Where ducts pass through interior partitions and exterior walls and are exposed to view, conceal spaces between construction openings and ducts or duct insulation with sheet metal flanges of same metal thickness as ducts. Overlap openings on 4 sides by at least 1-1/2 inches.

R. Fire-Rated Partition Penetrations: Where ducts pass through interior partitions and exterior walls, install appropriately rated fire dampers, sleeves, and firestopping sealant. Fire and smoke dampers are specified in Division 23 Section "Duct Accessories." Firestopping materials and installation methods are specified in Division 7 Section "Firestopping."

S. Install ducts with hangers and braces designed to withstand, without damage to equipment, seismic force required by applicable building codes. Refer to SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."

T. Protect duct interiors from the elements and foreign materials until the building envelope is fully enclosed and all dust producing activities are complete. Follow SMACNA's "Duct Cleanliness for New Construction," [**intermediate**] level for [**all AHU systems**].

3.5 CLOTHES DRYER EXHAUST DUCTS, SPECIAL INSTALLATION REQUIREMENTS

A. Ducts shall not be connected or installed with sheet metal screws or other fasteners that will obstruct the exhaust flow.

B. Male ends of ducts at overlapped duct joints shall extend in the direction of airflow.

C. Clothes dryer transition ducts used to connect the appliance to the exhaust duct system shall be limited to single lengths not-to-exceed 8 feet in length and shall be listed and labeled for the application.

D. Each vertical riser shall be provided with a cleanout or other means for cleaning the interior of the duct.

E. Install permanent labels in an observable location on all clothes dryer exhaust duct indicating the developed length of the exhaust duct system. The developed length shall include 2.5 feet for each 45 degree elbow and 5 feet for each 90 degree elbow unless indicated otherwise.

3.6 TYPE I GREASE HOOD EXHAUST DUCTS, SPECIAL INSTALLATION REQUIREMENTS

A. Install ducts to allow for thermal expansion through 2000 deg. F temperature range.

B. Install ducts without dips or traps that may collect residues unless traps have continuous or automatic residue removal.

C. Install access openings at each change in direction and at intervals defined by NFPA 96 maximum 20 foot intervals; locate on sides of duct a minimum of 1-1/2 inches from bottom; and fit with grease-tight covers of same material as duct.

D. Do not penetrate fire-rated assemblies except as permitted by applicable building codes.

E. Perform light test of entire ductwork run and submit results.

F. Install an access door at every change in direction.

G. Install an access door every twelve feet.

H. Install an access door at each floor.

I. Mount access doors at a minimum of 2” from bottom of duct.

J. Fasteners for access doors shall not penetrate ductwork.

K. Label each access door with signage reading: “Access Panel Do Not Obstruct.”

L. Slope ductwork ¼” per foot back to the grease hood. Do not create any low spots in ductwork.

M. Provide 6” minimum to 12” maximum clearance from rated shaft walls.

N. Provide at least 18” clearance to combustible materials and at least 3” clearance to limited combustible materials.

O. Support duct such that hangers and attachments can support weight of duct plus 800 pounds at any point.

P. Provide ductwork inspection by a certified company acceptable to the authority having jurisdiction.

Q. Coordinate with all trades such that a minimum of 4” clearance is provided between ductwork and limited combustible materials such as gypboard, fiberglass insulation, etc.

3.7 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. Rotate spiral seams to align with the seams of adjoining duct section or adjoining fittings prior to joining sections together.

E. Repair or replace damaged sections and finished work that does not comply with these requirements.

F. For painted architecturally exposed ductwork, clean the outer duct prior to installation to remove oils. Clean the outer duct after installation to remove construction dirt just prior to painting.

3.8 SEAM AND JOINT SEALING

A. Seal duct seams and joints of all ductwork according to SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" to meet seal Class A requirements. Supply ducts after terminal units shall be sealed to meet seal Class B requirements.

B. Seal ducts before external insulation is applied.

C. Do not utilize pressure sensitive tapes to externally seal ductwork.

D. Seal round duct couplers continuously around both ends of the coupler prior to assembling and then again after fastening.

3.9 EXTERIOR STACK GUYING AND BRACING MATERIALS INSTALLATION

A. Cable: Four stainless stranded wires of the following thickness:

1. Minimize size: 1/4 inch (6 mm) in diameter.
2. For ID sizes 4 to 15 inches (100 to 381 mm): 5/16 inch (8 mm).
3. For ID sizes 18 to 24 inches (457 to 610 mm): 3/8 inch (9.5 mm).
4. For ID sizes 27 to 30 inches (685 to 762 mm): 7/16 inch (11 mm).
5. For ID sizes 33 to 36 inches (838 to 915 mm): 1/2 inch (13 mm).
6. For ID sizes 39 to 48 inches (990 to 1220 mm): 9/16 inch (14.3 mm).
7. For ID sizes 51 to 60 inches (1295 to 1524 mm): 5/8 inch (16 mm).

B. Cable Encasement: 2” diameter, white Schedule 40 PVC pipe (ASTM D1784) and white Schedule 40 fittings (ASTM D2466, Type 1, Grade 1). Pipe and fittings shall be painted white with a water based latex paint suitable for exterior use. Provide Guy wire cable encasement on only the portion of the guy wire cables which are less than 7’-0” above the finished roof surface. Portions of the guy wires above 7’-0” shall not be encased.

C. Install stack on exhaust fan discharge as required. Provide stacks constructed of stainless materials unless noted otherwise. Utilize stainless fasteners.

D. Erect stacks plumb to finished tolerance of no more than 1 inch out of plumb from top to bottom. Install guy wires and cable encasement.

3.10 HANGING AND SUPPORTING

A. Support horizontal ducts within 24 inches of each elbow and within 48 inches of each branch intersection.

B. Support vertical ducts at maximum intervals of 16 feet and at each floor.

C. Utilize trapeze hangers for all ductwork greater than 48” in width.

D. Install upper attachments to structures with an allowable load not exceeding one-fourth of failure (proof-test) load.

E. Install concrete inserts before placing concrete.

F. Install powder-actuated concrete fasteners after concrete is placed and completely cured.

1. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.

G. Install flexible duct hanger at least once per segment such that each flexible duct is supported a minimum of three times, counting the two end connections. Support at intervals no greater than 5 feet. Maximum permissible sag is 0.5 inch per foot of spacing between supports. A connection to another duct or to equipment at each end is considered a support point. Flexible duct hangers shall be at least 1.0” wide.

3.11 SEISMIC-RESTRAINT-DEVICE INSTALLATION

A. Seismic restraints are specified in Division 23 Section “Vibration and Seismic Controls for HVAC Piping and Equipment.”

B. Install ducts with hangers and braces designed to support the duct and to restrain against seismic forces required by applicable building codes. Comply with SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems." Requirements of the Seismic Restraint Manual may require closer spacing than the maximums described here.

1. Space lateral supports a maximum of 40 feet (12 m) o.c., and longitudinal supports a maximum of 80 feet (24 m) o.c.
2. Brace a change of direction longer than 12 feet (3.7 m).

C. Select seismic-restraint devices with capacities adequate to carry present and future static and seismic loads.

D. Install cables so they do not bend across edges of adjacent equipment or building structure.

E. Install cable restraints on ducts that are suspended with vibration isolators.

F. Install seismic-restraint devices using methods approved by an agency acceptable to authorities having jurisdiction.

G. Attachment to Structure: If specific attachment is not indicated, anchor bracing and restraints to structure, to flanges of beams, to upper truss chords of bar joists, or to concrete members.

H. Drilling for and Setting Anchors:

1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify the Architect if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid pre-stressed 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. Set anchors to manufacturer's recommended torque, using a torque wrench.
5. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

3.12 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 9 painting Sections.

B. Paint exteriors of architecturally exposed metal ducts. Paint materials and application requirements are specified in Division 09.

3.13 CONNECTIONS

A. Make connections to equipment with flexible connectors according to Division 23 Section "Duct Accessories."

B. Comply with SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.14 FIELD QUALITY CONTROL

A. Perform the following field tests and inspections according to SMACNA's "HVAC Air Duct Leakage Test Manual" and prepare test reports:

1. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
2. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If pressure classes are not indicated, test entire system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure. Give two days' advance notice for testing to the Owner’s maintenance staff, the commissioning agent (if applicable) and the Owner’s project management staff. [**All tests shall be witnessed by personnel other than the Contractor.**]
3. All supply ductwork from fan or AHU outlet to the inlet of every terminal unit or reheat coil shall be tested. The terminal unit and all ductwork downstream of the terminal unit shall not be tested. All return and exhaust ductwork shall be

tested from the fan to the end of the branch to every grille. Do not test flexible ductwork.

4. Maximum Allowable Leakage:

    a. In accordance with the following total leakage quantity limitations, provide a leakage per square foot of ductwork for each fan or AHU to meet the following requirements:

        1) Allowable Leakage, Supply Duct: 1.0 percent of total scheduled supply fan design airflow.
        2) Allowable Leakage, Return, Outside Air and Relief Air Duct: 5.0 percent of total scheduled applicable fan design airflow.
        3) Allowable Leakage, General Exhaust Duct: 5.0 percent of total scheduled general exhaust fan design airflow.
        4) Allowable Leakage, Laboratory Exhaust Duct: 2.0 percent of total lab exhaust scheduled fan design airflow. Do not include redundant fan airflow capacity in system total.
        5) Allowable Leakage, Welded Duct: No measureable leakage.
        6) Contractor shall identify fan or AHU total scheduled fan airflow, surface area of ductwork to be tested, total duct surface area of the fan or AHU system and location of ductwork prior to testing. All testing shall be witnessed, documented, and submitted by persons other than the Sheet Metal Contractor. Document individual test sections, test pressure, orifice size, pressure drop across orifice, surface area of ductwork to be tested, and measured leakage for each section tested. Summarize total leakage by fan or AHU system.
        7) Submit handwritten field test reports within two business days of the individual test date. Do not proceed with insulating ductwork until the test report demonstrating acceptable leakage has been submitted and processed by the Architect. Include a running total leakage summary on each individual test submission that includes total system surface area, total system leakage allowed, individual test surface area and individual test measured results.
        8) Concurrent with the leakage pressurization test, perform an acoustic pressure cycling test. Pressurize the ductwork in the direction of normal operation (supply positive pressure, return/exhaust negative pressure) to a pressure 0.5” less than the design static pressure class duct construction. Remove the pressure and identify areas with duct flexure noise. Reapply the pressure and identify areas with duct flexure noise. Externally reinforce the ductwork such that flexure noise is removed. Repeat pressure testing and add reinforcement until noise is removed and is acceptable to these witnessing the test.

B. 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 and/or the Engineer, 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.

C. Duct system will be considered defective if it does not pass leakage and cleanliness tests and inspections.

D. Prepare test and inspection reports.

3.15 CLEANING EXISTING SYSTEMS

A. Use service openings, as required, for physical and mechanical entry and for inspection.

1. Use existing service openings where possible.
2. Create other openings to comply with duct standards.
3. Disconnect flexible ducts as needed for cleaning and inspection.
4. Reseal rigid fiberglass duct systems according to NAIMA recommended practices.
5. Remove and reinstall ceiling sections to gain access during the cleaning process.

B. Mark position of dampers and air-directional mechanical devices before cleaning, and restore to their marked position on completion.

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 the outside, use filtration to contain debris removed from HVAC system and locate exhaust down wind and away from air intakes and other points of entry into building.

D. Clean the following metal duct systems 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, and actuators 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 all duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace all 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 operative drainage system for washdown procedures.
7. Biocidal Agents and Coatings: Apply biocidal agents if fungus is present. Apply biocidal agents according to manufacturer's written instructions after removal of surface deposits and debris.

F. Cleanliness Verification:

1. Verify cleanliness after mechanical cleaning and before application of treatment, including biocidal agents and protective coatings.
2. Visually inspect metal ducts for contaminants.
3. Where contaminants are discovered, re-clean and reinspect ducts.

G. Gravimetric Analysis: At discretion and expense of Owner, sections of metal duct system, chosen randomly by Owner and/or the Engineer, may be tested for cleanliness according to NADCA vacuum test gravimetric analysis.

1. If analysis determines that levels of debris are equal to or lower than suitable levels, system shall have passed cleanliness verification.
2. If analysis determines that levels of debris exceed suitable levels, system cleanliness verification will have failed and metal duct system shall be re-cleaned and re-verified.

H. Verification of Coil Cleaning: Cleaning must restore coil pressure drop to within 10 percent of pressure drop measured when coil was first installed. If original pressure drop is not known, coil will be considered clean only if it is free of foreign matter and chemical residue, based on thorough visual inspection.

END OF SECTION

SECTION 233300
AIR DUCT 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.

1.2 SUMMARY

A. Section Includes:

1. Backdraft dampers.
2. Pressure relief doors.
3. Manual volume dampers.
4. Fire dampers.
5. Ceiling dampers.
6. Smoke dampers.
7. Combination fire and smoke dampers.
8. Duct silencers.
9. Turning vanes.
10. Duct access panel assemblies.
11. Flexible connectors.
12. Flexible ducts.
13. Duct accessory hardware.

B. Related Sections:

1. Division 23 Section "HVAC Gravity Ventilators" for roof-mounted ventilator caps.

2. Division 23 Environmental Control System
3. 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 duct silencers, include pressure drop and dynamic insertion loss data. Include breakout noise calculations for high transmission loss casings.
2. For fire dampers, smoke dampers and fire/smoke dampers, provide pressure drop at 1000 fpm, 1500 fpm and at 2000 fpm.
3. For flexible air ducts, indicate R value.

B. LEED Submittal:

1. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1-2004, Section 5 - "Systems and Equipment."

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.

2. Detailed fire damper, smoke damper, combination fire and smoke damper installation requirements which incorporate manufacturer's and UL listing requirements for opening size, stud construction, opening framing and other required construction features. Provide detailed drawings for the penetrations of all floor assemblies.

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.

G. Acceptance Test Reports: Perform and submit NFPA 90A acceptance test reports for each fire damper and fire/smoke damper. Acceptance test demonstrating removal and reinstallation of fusible links shall be completed after all above ceiling installations are complete to confirm acceptable access. Submit acceptance test report prior to occupancy of the building.

1.4 QUALITY ASSURANCE

A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

B. Comply with AMCA 500-D testing for damper rating.

C. Perform NFPA 90A acceptance tests and document results. Replace fusible links at the completion of acceptance tests.

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.

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 (Z275).
2. Exposed-Surface Finish: Mill phosphatized.

C. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304, and having a No. 2 finish for concealed ducts and No. 3 finish for exposed ducts.

D. Aluminum Sheets: Comply with ASTM B 209 (ASTM B 209M), 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 (ASTM B 221M), 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 (6-mm) minimum diameter for lengths 36 inches (900 mm) or less; 3/8-inch (10-mm) minimum diameter for lengths longer than 36 inches (900 mm).

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. American Warming and Ventilating; a division of Mestek, Inc.
3. Cesco Products; a division of Mestek, Inc.
4. Greenheck Fan Corporation.
5. Nailor Industries Inc.
6. NCA Manufacturing, Inc.
7. Pottorff; a division of PCI Industries, Inc.
8. Ruskin Company.
9. SEMCO Incorporated.

10. Vent Products Company, Inc.

B. Description: Gravity balanced.

C. Maximum Air Velocity: 2500 fpm.

D. Maximum System Pressure: Matching ductwork design pressure.

E. Frame: 0.063-inch- (1.6-mm-) thick extruded aluminum, with welded corners and mounting flange.

F. Blades: Multiple single-piece blades, maximum 6-inch (150-mm) width, 0.025-inch- (0.6-mm-) thick, roll-formed aluminum with sealed edges.

G. Blade Action: Parallel.

H. Blade Seals: Extruded vinyl, mechanically locked.

I. Blade Axles:

1. Material: Non-ferrous metal.
2. Diameter: 0.20 inch (5 mm).

J. Tie Bars and Brackets: Aluminum.

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. Chain pulls.
4. Screen Mounting: Front mounted in sleeve.

a. Sleeve Thickness: 20-gage (1.0-mm) minimum.
b. Sleeve Length: 6 inches (152 mm) minimum.

5. Screen Material: Aluminum.
6. Screen Type: Insect.
7. 90-degree stops.

2.3 PRESSURE RELIEF DOORS

A. Manufacturers:

1. A.J. Manufacturing.
2. American Warming and Ventilating; a Division of Mestek.
3. Greenheck.
4. Pottorff.

5. Ruskin.
6. United Enertech.

B. Frame: 0.063 inch thick aluminum extrusion.

C. Door: Minimum 24 gage solid double wall door galvanized steel with 1" thick insulation. Fully hinged.

D. Trim Flange: Minimum 1" width.

E. Seal: Polyurethane, PVC or neoprene gasket. Gasket shall cover the entire perimeter of the flange.

F. Mechanism:

1. Cable assembly: Cable limits door opening past 90 degrees. Components located outside of airstream.
2. Outward opening door in positive pressure ductwork. Inward opening door in negative pressure ductwork.

G. Latch: Adjustable magnet assembly, factory set at desired relief pressure. Field adjustable relief pressure settings.

H. Leakage: Not-to-exceed 0.6 cfm/ft.^{2} at 12 inches w.g.

2.4 MANUAL VOLUME DAMPERS

A. Small, Low Pressure, 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. American Warming and Ventilating; a division of Mestek, Inc.
c. Cesco.
d. Greenheck.
e. Lindab.
f. Metalaire, Inc.
g. Nailor Industries Inc.
h. Pottorff; a division of PCI Industries, Inc.
i. Ruskin Company.
j. Vent Products Company, Inc.

2. Standard leakage rating, with linkage outside airstream.
3. Suitable for horizontal or vertical applications.
4. Frames:

a. Hat-shaped, galvanized-steel channels, 0.052-inch minimum thickness.
b. Mitered and welded corners.
c. Flanges for attaching to walls and flangeless frames for installing in ducts.
d. Maximum size 12" X 12".

e. Suitable for 2 inch w.g. pressure class construction.

5. Blades:

   a. Multiple or single blade.
   b. Parallel- or opposed-blade design.
   c. Stiffen damper blades for stability.
   d. Galvanized-steel, 0.040-inch thick.
   e. Locking hand quadrant and 2” standoff mounting bracket for all insulated ductwork applications.

6. Blade Axles: Galvanized steel.
7. Bearings:

   a. Molded synthetic.
   b. Dampers in ducts with pressure classes of 3-inch wg (750 Pa) 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.
9. Provide stainless and aluminum dampers to match ductwork construction where dampers are shown in stainless or aluminum ductwork.

B. Larger Size or Higher Pressure, Steel, Manual Volume Dampers:

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

   a. Air Balance, Inc., a division of Mestek, Inc.
   b. American Warming and Ventilating; a division of Mestek, Inc.
   c. Cesco.
   d. Greenheck.
   e. Lindab.
   f. Metalaire, Inc.
   g. Nailor Industries, Inc.
   h. Pottorff; a division of PCI Industries, Inc.
   i. Ruskin Company.
   j. Vent Products Company, Inc.

2. Pressure classes of 3-inch w.g. or higher or 14” X 14” and larger duct size:

   a. Multiple opposed blade design.
   b. End bearings or other seals for ducts with axles full length of damper blades and bearings at both ends of operating shaft.
   c. Suitable for 2000 fpm velocity at the width and height required.
   d. Jackshaft to operate multi-section dampers from one side.
   e. Locking hand quadrant and 2” stand-off mounting bracket.
   f. Minimum 16 gauge frame thickness.
   g. Linkage out of the airstream.
   h. Flanged frame on both entering and leaving faces.

3. Provide stainless and aluminum dampers to match ductwork construction where dampers are shown in stainless or aluminum ductwork.

C. 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. American Warming and Ventilating; a division of Mestek, Inc.
    c. Greenheck.
    d. Metalaire, Inc.
    e. Nailor Industries Inc.
    f. Pottorff; a division of PCI Industries, Inc.
    g. Ruskin Company.
    h. Vent Products Company, Inc.

2. Standard leakage rating, with linkage outside airstream.
3. Suitable for horizontal or vertical applications.
4. Frames: Hat-shaped, 0.10-inch- (2.5-mm-) thick, aluminum sheet channels; frames with flanges for attaching to walls and flangeless frames for installing in ducts.
5. Blades:

    a. Multiple or single blade.
    b. Parallel- or opposed-blade design.
    c. Stiffen damper blades for stability.
    d. Roll-Formed Aluminum Blades: 0.10-inch- (2.5-mm-) thick aluminum sheet.

6. Blade Axles: Nonferrous metal.
7. Bearings:

    a. Molded synthetic.
    b. Dampers in ducts with pressure classes of 3-inch wg (750 Pa) or greater shall have axles full length of damper blades and bearings at both ends of operating shaft.

8. Tie Bars and Brackets: Aluminum.

D. Jackshaft:

1. Size: 1-inch (25-mm) 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.

E. Damper Hardware:

1. Zinc-plated, die-cast core with dial and handle made of 3/32-inch- (2.4-mm-) thick zinc-plated steel, and a 3/4-inch (19-mm) hexagon locking nut.
2. Include center hole to suit damper operating-rod size.
3. Include elevated platform for insulated duct mounting for all pressure class dampers (including low pressure run-outs to diffusers. No bent handles).

2.5 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. Cesco Products; a division of Mestek, Inc.
3. Greenheck Fan Corporation.
4. Nailor Industries Inc.
5. NCA Manufacturing, Inc.
6. Pottorff; a division of PCI Industries, Inc.
7. Prefco; Perfect Air Control, Inc.
8. Ruskin Company.
9. United Enertech.
10. Vent Products Company, Inc.
11. Ward Industries, Inc.; a division of Hart & Cooley, Inc.

B. Type: Dynamic; rated and labeled according to UL 555 by an NRTL.

C. Closing rating in ducts up to 4-inch wg (1-kPa) static pressure class and minimum 2000 fpm velocity.

D. Fire Rating: 1-1/2 and 3 hours as required.

E. Frame: Curtain type with blades outside airstream; fabricated with roll-formed, 0.034-inch- (0.85-mm-) thick galvanized steel; with mitered and interlocking corners.

F. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel.

1. Minimum Thickness: 0.052 or 0.138 inch (1.3 or 3.5 mm) thick, as indicated, and of 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.
3. Provide non-breakaway style, seal welded sleeve where the ductwork system is welded.

G. Mounting Orientation: Vertical or horizontal as indicated.

H. Blades: Roll-formed, interlocking, 0.034-inch- (0.85-mm-) thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch- (0.85-mm-) thick, galvanized-steel blade connectors.

1. Provide double wall airfoil blades for multiple segment dampers.

I. Horizontal Dampers: Include blade lock and stainless-steel closure spring.

J. Heat-Responsive Device: Replaceable, 165F or 212F rated, fusible links.

K. Provide 304 stainless steel frame, blades, bearings, jamb seals, axle and linkage for dampers installed within stainless steel duct systems.

2.6 CEILING 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. Cesco Products; a division of Mestek, Inc.
3. Greenheck.
4. Nailor Industries Inc.
5. Prefco; Perfect Air Control, Inc.
6. Ruskin Company.
7. United Enertech.
8. Vent Products Company, Inc.
9. Ward Industries, Inc.; a division of Hart & Cooley, Inc.

B. General Requirements:

1. Labeled according to UL 555C by an NRTL.
2. Comply with construction details for tested floor- and roof-ceiling assemblies as indicated in UL's "Fire Resistance Directory."

C. Frame: Galvanized sheet steel, round or rectangular, style to suit ceiling construction.

D. Blades: Galvanized sheet steel with refractory insulation.

E. Heat-Responsive Device: Replaceable, 165 deg F (74 deg C) or 212 deg F (100 deg C) rated, fusible links as required.

F. Fire Rating: 2 or 3 hours as required.

2.7 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. Cesco Products; a division of Mestek, Inc.
3. Greenheck Fan Corporation.
4. Nailor Industries Inc.
5. Pottorff.
6. Ruskin Company.
7. United Enertech.

B. General Requirements: Label according to UL 555S by an NRTL.

C. Smoke Detector: By fire alarm provider, duct mounted.

D. Frame: Multiple-blade type; fabricated with roll-formed, 0.034-inch- (0.85-mm-) thick galvanized steel; with mitered and interlocking corners.

E. Blades: Interlocking, minimum 0.034-inch- (0.85-mm-) thick, galvanized sheet steel.

1. Provide double wall airfoil shaped blades for dampers.
2. Blade edge seals.

F. Leakage: Class I, bi-directional.

G. Rated pressure and velocity to exceed design airflow conditions, minimum 2000 fpm and 4-inch water gauge at 250 degrees F.

H. Mounting Sleeve: Factory-installed, 0.052-inch- (1.3-mm-) thick, galvanized sheet steel; length to suit wall or floor application with factory-furnished UL listed silicone caulking.

I. Damper Motors: Two-position action.

J. 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 to close upon loss of power unless noted otherwise (e.g. for elevator shaft venting). Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 150 in. x lbf (17 N x m).
5. 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 (minus 40 deg C).
6. Electrical Connection: 115 V, single phase, 60 Hz.

K. Pneumatic Actuator:

1. Large enough to properly operate at a differential pressure equal to the ductwork construction in inches.
2. Utilize 20 psig control air.

L. Accessories:

1. Auxiliary switches for position indication with connections for the building automation system.
2. Momentary test switch, damper or remote mounted.

2.8 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. Cesco Products; a division of Mestek, Inc.
3. Greenheck Fan Corporation.
4. Nailor Industries Inc.
5. Pottorff.
6. Ruskin Company.
7. United Enertech.

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 (1-kPa) static pressure class and minimum 2000-fpm velocity.

D. Fire Rating: 1-1/2 and 3 hours as required.

E. Frame: Multiple-blade type; fabricated with roll-formed, 0.034-inch- (0.85-mm-) thick galvanized steel; with mitered and interlocking corners.

F. Heat-Responsive Device: Replaceable, 165 deg F (74 deg C) or 212 deg F (100 deg C) rated, fusible links as required.

G. Heat-Responsive Device: Electric resettable link and switch package, factory installed, rated.

H. Smoke Detector: By fire alarm provider, duct mounted.

I. Blades: Interlocking, minimum 0.034-inch- (0.85-mm-) thick, galvanized sheet steel.

1. Provide double wall airfoil shaped blades.
2. Blade edge seals.

J. Leakage: Class I, bi-directional.

K. Rated pressure and velocity to exceed design airflow conditions, minimum 2000 fpm and 4-inch water gauge at 250 degrees F.

L. Mounting Sleeve: Factory-installed, 0.052-inch- (1.3-mm-) thick, galvanized sheet steel; length to suit wall or floor application with factory-furnished UL listed silicone caulking.

M. Damper Motors: Two-position action.

N. 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 to close upon loss of power. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 150 in. x lbf (17 N x m).
5. 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 (minus 40 deg C).
6. Electrical Connection: 115 V, single phase, 60 Hz.

O. Accessories:

1. Auxiliary switches for position indication
   a. Connection to the building smoke management system
   b. Connection to the building automation system.
2. Momentary test switch, damper or remote mounted.

2.9 DUCT SILENCERS

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

1. Aerosonics.
2. Commercial Acoustics.
3. Industrial Noise Control, Inc.
4. Price Industries.
5. Ruskin Company.
6. SEMCO.
7. VAW Systems.
8. Vibro-Acoustics.

B. General Requirements:

1. Factory fabricated.
2. Fire-Performance Characteristics: Adhesives, sealants, packing materials, and accessory materials shall have flame-spread index not exceeding 25 and smoke-developed index not exceeding 50 when tested according to ASTM E 84.
3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.

C. Shape:

1. Rectangular straight with splitters or baffles.
2. Other shapes as scheduled and shown on the drawings.

D. Rectangular Silencer Outer Casing: ASTM A 653/A 653M, G90 (Z275), galvanized sheet steel, 0.034 inch (0.85 mm) thick.

E. Round Silencer Outer Casing: ASTM A 653/A 653M, G90 (Z275), galvanized sheet steel.

1. Sheet Metal Thickness for Units up to 24 Inches (600 mm) in Diameter: 0.034 inch (0.85 mm) thick.
2. Sheet Metal Thickness for Units 26 through 40 Inches (660 through 1000 mm) in Diameter: 0.040 inch (1.02 mm) thick.
3. Sheet Metal Thickness for Units 42 through 52 Inches (1060 through 1300 mm) in Diameter: 0.052 inch (1.3 mm) thick.
4. Sheet Metal Thickness for Units 54 through 60 Inches (1370 through 1500 mm) in Diameter: 0.064 inch (1.62 mm) thick.

F. Inner Casing and Baffles: ASTM A 653/A 653M, G90 (Z275) galvanized sheet metal, 0.034 inch (0.85 mm) thick, and with 1/8-inch- (3-mm-) diameter perforations.

G. Special Construction:

1. Suitable for outdoor use where located outdoors.

H. Connection Sizes: Match connecting ductwork unless otherwise indicated.

I. Principal Sound-Absorbing Mechanism:

1. No-media type: Controlled impedance membranes and broadly tuned resonators without absorptive media.
2. Film lined type:

   a. Fill material: Inert, moisture-proof fibrous material.
   b. Erosion Barrier: Polymer film bag enclosing fill, and heat sealed before assembly.
   c. Lining: Polymer.

J. Fabricate silencers to form rigid units that will not pulsate, vibrate, rattle, or otherwise react to system pressure variations. Do not use mechanical fasteners for unit assemblies.

1. Lock form and seal or continuously weld joints.
2. Suspended Units: Factory-installed suspension hooks or lugs attached to frame in quantities and spaced to prevent deflection or distortion.
3. Reinforcement: Cross or trapeze angles for rigid suspension.

K. Accessories:

1. Factory-installed end caps to prevent contamination during shipping.

L. Source Quality Control: Test according to ASTM E 477, latest revision.

1. Record acoustic ratings, including dynamic insertion loss and generated-noise power levels with an airflow of at least 2000-fpm (10-m/s) face velocity.
2. Leak Test: Test units for airtightness at 200 percent of associated fan static pressure or 6-inch wg (1500-Pa) static pressure, whichever is greater.

2.10 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.
4. SEMCO Incorporated.
5. Ward Industries, Inc.; a division of Hart & Cooley, Inc.

B. Manufactured Turning Vanes for Metal Ducts: Curved blades of galvanized sheet steel; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.

C. General Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 2-3, "Vanes and Vane Runners," and 2-4, "Vane Support in Elbows."

D. Vane Construction: Double wall.

2.11 DUCT-MOUNTED ACCESS DOORS

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

1. Air Balance.
2. American Warming and Ventilating; a division of Mestek, Inc.
3. Cesco Products; a division of Mestek, Inc.
4. Ductmate Industries, Inc.
5. Flexmaster U.S.A., Inc.
6. Greenheck Fan Corporation.
7. Kees.
8. Nailor Industries Inc.
9. Pottorff; a division of PCI Industries, Inc.
10. Ruskin.
11. Ventfabrics, Inc.
12. Ward Industries, Inc.; a division of Hart & Cooley, Inc.

B. Duct-Mounted Access Doors: Fabricate access panels according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 2-10, "Duct Access Doors and Panels," and 2-11, "Access Panels - Round Duct."

1. Door:

a. Double wall, rectangular.
b. Galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class.
c. Hinges and Latches: Piano hinge and cam latches with safety chain.
d. Fabricate doors airtight and suitable for duct pressure class.
e. Access doors for ductwork pressure class 3-inch or greater shall include a 1” frame flange for duct mounting (access doors for ductwork pressure class 2-inch and less may be bent over tabs and foam gasketing).
f. [**Vision panel.**]

2. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.
3. Number of Hinges and Locks:

    a. Access Doors Less Than 12 Inches (300 mm) Square: One hinge and two sash locks.
    b. Access Doors up to 18 Inches (460 mm) Square: Two hinges and two sash locks.
    c. Access Doors up to 24 by 48 Inches (600 by 1200 mm): Three hinges and two compression latches.
    d. Access Doors Larger Than 24 by 48 Inches (600 by 1200 mm): Four hinges and two compression latches with outside and inside handles.

2.12 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 (1.3-mm) carbon or 0.0428-inch (1.1-mm) stainless steel.

D. Fasteners: Stainless steel. 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 (1093 deg C).

F. Minimum Pressure Rating: 10-inch wg (2500 Pa), positive or negative.

2.13 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 (89 mm) wide attached to 2 strips of 2-3/4-inch- (70-mm-) wide, 0.028-inch- (0.7-mm-) thick, galvanized sheet steel or 0.032-inch- (0.8-mm-) thick aluminum sheets. Provide metal compatible with connected ducts.

E. Indoor System, Flexible Connector Fabric: Glass fabric double coated with neoprene.

1. Minimum Weight: 26 oz./sq. yd. (880 g/sq. m).
2. Tensile Strength: 480 lbf/inch (84 N/mm) in the warp and 360 lbf/inch (63 N/mm) in the filling.
3. Service Temperature: Minus 40 to plus 200 deg F (Minus 40 to plus 93 deg C).

F. Outdoor System, Flexible Connector Fabric: Glass fabric double coated with weatherproof, synthetic rubber (Hypalon) resistant to UV rays and ozone.

1. Minimum Weight: 24 oz./sq. yd. (810 g/sq. m).
2. Tensile Strength: 530 lbf/inch (93 N/mm) in the warp and 440 lbf/inch (77 N/mm) in the filling.
3. Service Temperature: Minus 50 to plus 250 deg F (Minus 45 to plus 121 deg C).

G. High-Corrosive-Environment (Grease Duct) System, Flexible Connectors: Glass fabric with chemical-resistant coating.

1. Minimum Weight: 14 oz./sq. yd. (474 g/sq. m).
2. Tensile Strength: 450 lbf/inch (79 N/mm) in the warp and 340 lbf/inch (60 N/mm) in the filling.
3. Service Temperature: Minus 67 to plus 500 deg F (Minus 55 to plus 260 deg C).

H. 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 (6-mm) movement at start and stop.

2.14 FLEXIBLE DUCTS

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

1. Flexmaster U.S.A., Inc.
2. McGill AirFlow LLC.
3. Ward Industries, Inc.; a division of Hart & Cooley, Inc.

B. Low Pressure Insulated, Flexible Duct: UL 181, Class 1, 2-ply polymer film supported by helically wound, spring galvanized steel wire; fibrous-glass insulation; black polyethylene fire retardant vapor-barrier film.

1. Pressure Rating and Operating Pressure: 4-inch wg positive and 0.5-inch wg negative.
2. Maximum Air Velocity: 4000 fpm.
3. Temperature Range: Minus 20 to plus 175 deg F.
4. Insulation R-value: Comply with ASHRAE/IESNA 90.1, minimum R-6.

C. High Pressure Insulated, Flexible Duct: UL 181, Class 1, 2-ply polymer film supported by helically wound, spring galvanized steel wire; fibrous glass insulation, black polyethylene fire retardant vapor barrier film.

1. Pressure Rating: 10-inch wg positive and 2-inch wg negative.
2. Operating Pressure: 6-inch wg positive pressure and 2-inch wg negative minimum all duct sizes.
3. Maximum Air Velocity: 4000 fpm.
4. Temperature Range: Minus 20 to plus 175 deg. F.
5. Insulation R-Value: Comply with ASHRAE/IESNA 90.1, minimum R-6.

D. Flexible Duct Connectors:

1. Clamps: Nylon strap in sizes 3 through 18 inches (75 through 460 mm), to suit duct size.

2.15 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 INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts and in NAIMA AH116, "Fibrous Glass Duct Construction Standards," for fibrous-glass ducts.

B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel and fibrous-glass ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.

C. Install [**backdraft**] [**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, and exhaust systems where branches extend from larger ducts. 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 steel volume dampers in steel ducts.

   2. Install aluminum volume dampers in aluminum 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.

G. Install fire and smoke dampers according to UL listing written installation instructions. Install manufacturer's UL listed optional sealant around the full perimeter of the angle on both sides of the wall. Install duct sealant for the full perimeter of the breakaway connections in accordance with the manufacturer's written UL listing installation instructions. It is the contractors responsibility to coordinate the penetration of any rated assembly. The contractor shall provide additional detail to floor penetrations and provide the required space between systems in accordance with the manufacturer recommendations.

H. Connect ducts to duct silencers rigidly.

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 control dampers, backdraft dampers, and equipment.
   6. Adjacent to and close enough to fire or smoke dampers, to reset or reinstall fusible links or to clean duct detectors.
   7. Control devices requiring inspection, specifically humidity sensors, airflow sensors and pressure sensors.
   8. Elsewhere as indicated. Note that not all access doors required may be indicated on the drawings. Provide in bid to provide and install access doors as specified in addition to those shown on the drawings.

J. Install access doors with swing against duct static pressure.

K. Install external angle duct reinforcement across the long side of the duct at each access door which is greater than 14" in dimension.

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 to connect ducts to equipment supported by vibration isolators.

N. For fans developing static pressures of 5-inch wg (1250 Pa) 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 (300-mm) lengths of flexible duct. Do not use flexible ducts to change directions.

P. Connect light troffer boots with maximum 60-inch (1500-mm) lengths of flexible duct clamped or strapped in place.

Q. Connect diffusers to ducts with maximum 96-inch lengths of flexible duct clamped or strapped in place unless indicated length differs on drawings.

R. Connect flexible ducts to metal ducts with draw bands.

S. Install flexible duct hangers at least once per segment such that each flexible duct is supported a minimum of three times, counting the two end connections. Support at internals no greater than 5 feet and as required such that flexible duct does not contact the ceiling, ceiling hangers, lighting, lighting hangers or piping. Maximum permissible sag is 0.5 inch per foot of spacing between supports. A connection to another duct or to equipment at each end is considered a support point. Flexible duct hangers shall be at least 1.0” in width where they contact the flexible duct.

T. Install duct test holes where required for testing and balancing purposes.

U. 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 (6-mm) movement during start and stop of fans.

V. Utilize high pressure flexible duct on the inlet of supply terminal units where the use of flexible duct is indicated on the drawings. Utilize high pressure flexible duct on the discharge side of exhaust valves where the use of flexible duct is indicated on the drawings.

3.2 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.
6. Adjust pressure relief doors for relief setting.

B. NFPA 90A Acceptance Testing:

1. Perform NFPA 90A acceptance testing for each fire damper and each fire/smoke damper.
2. Acceptance test demonstrating removal and reinstallation of fusible links shall be completed only after all above ceiling installations are complete to confirm acceptable access. Under no circumstances shall the test demonstrations be undertaken greater than two weeks prior to Substantial Completion award is finalized.
3. Test report contents; for each damper list:

    a. Damper size.
    b. Room number the damper was accessed from.

c. Access means (duct access door or exposed face).
d. Results of link removal and reinstallation.
e. Name of the person testing the damper.
f. Date test was completed.
g. The Substantial Completion Date for the area in which the particular damper is located.
h. Yes check box that the test date is no greater than two weeks prior to the Substantial Completion date.

4. Relocate the work of any trade which does not provide for required maintenance access to fusible links. See Division 23 Section “Common Work Results for HVAC” coordination requirements.
5. Submit acceptance test report results prior to occupancy of the building.

END OF SECTION

SECTION 233416
CENTRIFUGAL HVAC FANS

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. Centrifugal fans.
2. Mixed flow in-line fans.

1.3 PERFORMANCE REQUIREMENTS

A. 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. Dimensional details of motor and fan arrangement on inertia bases which illustrates overall size of inertia base and the relative arrangement of the fan and motor on the inertia base.

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.

C. Operation and Maintenance Data: 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. NEMA Compliance: Motors and electrical accessories shall comply with NEMA 1.

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.

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. Final fan belts: Two (2) sets for each belt driven fan. Field installed and sized by the Testing, Adjusting and Balancing contractor the size as required to deliver the necessary airflow through the system account for all system losses.
2. Final fan sheave: One (1) set for each belt driven fan. Field installed and sized by the Testing, Adjusting and Balancing Contractor. Sized as required to deliver the necessary airflow through the system accounting for all system losses.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

2. Greenheck Fan Corporation.
3. Loren Cook Company.
4. New York Blower.
5. Twin City Fan Company.

2.2 CENTRIFUGAL FANS

A. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor, drive assembly, and support structure.

B. 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.

C. 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; cast-iron or cast-steel hub welded to backplate and fastened to shaft with set screws.

D. Backward Inclined Wheels: Single-width-single-inlet and double-width-double-inlet construction with curved inlet flange, backplate, backward-inclined blades[**welded to flange and backplate; cast-iron or cast-steel hub welded to backplate**] and fastened to shaft with set screws.

E. Mixed Flow Wheels: Mixed flow wheels shall be constructed with a wheel cone, spherical back plate and single thickness cambered blades.

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. 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, Ll0 at 200,000 hours.

H. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.5.
2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.

3. Motor Pulleys: Adjustable pitch for use with other than 3600 rpm motors through 5 hp; fixed pitch for use with larger motors. Fixed pitch for all 3600 rpm motors. Select pulley 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. Fabricated from 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. Access Door: [**Bolted**] [**Quick-opening, latch-type**] [**raised for insulated fans**] gasketed door allowing access to fan scroll, of same material as housing.
2. Scroll Drain Connection: NPS 1 (DN 25) steel pipe coupling welded to low point of fan scroll, with plug.
3. Companion Flanges: Rolled flanges for duct connections of same material as housing.
4. Discharge Dampers: Assembly with [**parallel**] [**opposed**] 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]** [**weight mechanism**] of same material as housing.
5. Inlet Screens: Grid screen of same material as housing.
6. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
7. Spark-Resistant Construction: AMCA 99, Class [**A**][**B**][**C**].
8. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
9. Weather Cover: Enameled-steel sheet with ventilation slots, bolted to housing.
10. Shaft Guard: Enameled steel sheet with ventilation slots, bolted to housing.
11. Plenum fan protective cage guarding fully enclosing four sides of the fan assembly discharge.
12. Special Coating: Coat all airstream surfaces with special coating.

J. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

2.3 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 unit as scheduled on the drawings and as specified in Division 23 Section “Mechanical Vibration and Seismic Controls”.

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 units with clearances for service and maintenance.

E. 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 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. Refer to Division 01 Section "Demonstration and Training."

END OF SECTION

SECTION 233423
HVAC POWER VENTILATORS

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. Utility set fans.
2. Centrifugal roof ventilators.
3. In-line centrifugal fans
4. Propeller fans
5. Ceiling Exhaust Fan

1.3 PERFORMANCE REQUIREMENTS

A. Project Altitude: Base fan-performance ratings on 700 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.

C. Seismic Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.

D. 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.

E. 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.

F. Field quality-control test reports.

G. 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. 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.

D. 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.

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.

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. Final Fan Belts: Two sets for each belt-driven fan. Field installed and sized by the Testing, Adjusting and Balancing Contractor. Sized as required to deliver the necessary airflow through the system accounting for all system losses.
2. Final Fan Sheave: One set for each belt-driven fan. Field installed and sized by the Testing, Adjusting and Balancing Contractor. Sized as required to deliver the necessary airflow through the system accounting for all system losses.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Greenheck.
2. Loren Cook Company.
3. JencoFan; Div. of Breidert Air Products.
4. Penn Barry.
5. Twin City Fan and Blower.

B. Parking Garage Propeller Fan Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Greenheck

C. Residential Style Ceiling Fan Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Delta Breeze

2.2 UTILITY SET FANS

A. Description: [**Direct**] [**Belt**]-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and accessories.

B. Housing: Fabricated of galvanized steel with side sheets fastened with a deep lock seam or welded to scroll sheets.

1. Housing Discharge Arrangement: Adjustable to eight standard positions.

C. Fan Wheels: Single-width, single inlet; welded to cast-iron or cast-steel hub and spun-steel inlet cone, with hub keyed to shaft.

1. Blade Materials: [**Steel**] [**Aluminum**].
2. Blade Type: [**Backward inclined**] [**Forward curved**] [**Airfoil**].

D. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub. Stainless steel where scheduled.

E. Shaft Bearings: Prelubricated and sealed, self-aligning, pillow-block-type ball bearings with ABMA 9, L_{10} of 200,000 hours.

F. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.5.
2. 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.
3. Belts: Oil resistant, non-sparking, and non-static; matched sets for multiple belt drives.
4. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.

G. Accessories: Refer to Fan Schedule on drawings for individual fan requirements.

2.3 CENTRIFUGAL ROOF VENTILATORS

A. Description: Direct- or belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, curb base, and accessories.

B. 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.

C. Fan Wheels: Aluminum hub and wheel with backward-inclined blades.

D. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:

1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub. Stainless steel where scheduled.
2. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
3. Pulleys: Cast-iron, adjustable-pitch motor pulley.
4. Fan and motor isolated from exhaust airstream.

E. Accessories: Refer to Fan Schedule on drawings for individual fan requirements.

F. Roof Curbs: Galvanized steel; mitered and welded corners; 1-1/2-inch thick, rigid, fiberglass insulation adhered to inside walls; and 1-1/2-inch wood nailer. Size as required to suit roof opening and fan base.

1. Overall Height: Minimum 16 inches.
2. Pitch Mounting: Manufacture curb for roof slope.
3. Metal Liner: Galvanized steel.

2.4 IN-LINE CENTRIFUGAL FANS

A. Description: In-line, [**direct**] [**belt**]-driven centrifugal fans consisting of housing, wheel, outlet guide vanes, fan shaft, bearings, motor and disconnect switch, drive assembly, mounting brackets, and accessories.

B. Housing: Split, spun aluminum with aluminum straightening vanes, inlet and outlet flanges, and support bracket adaptable to floor, side wall, or ceiling mounting.

C. 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**].

D. Belt-Driven Units: Motor mounted on adjustable base, with adjustable sheaves, enclosure around belts within fan housing, and lubricating tubes from fan bearings extended to outside of fan housing.

E. Fan Wheels: Aluminum, airfoil blades welded to aluminum hub.

F. Accessories: Refer to Fan Schedule on drawings for individual fan requirements.

2.5 PROPELLER FANS

A. Description: Direct- or belt-driven propeller fans consisting of fan blades, hub, housing, orifice ring, motor, drive assembly, and accessories.

B. Housing: Galvanized-steel sheet with flanged edges and integral orifice ring with baked-enamel finish coat applied after assembly.

C. Steel Fan Wheels: Formed-steel blades riveted to heavy-gage steel spider bolted to cast-iron hub.

D. Fan Wheel: Replaceable, cast-aluminum, airfoil blades fastened to cast-aluminum hub; factory set pitch angle of blades.

E. 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, L_{10} 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, non-sparking, and non-static; matched sets for multiple belt drives.
7. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.

F. Accessories: Refer to Fan Schedule on drawings for individual fan requirements.

1. Disconnect Switch: Non-fusible type, with thermal-overload protection mounted inside fan housing, factory wired through an internal aluminum conduit.
2. Wall housing, wall housing guard (OSHA approved).
3. Damper, damper actuator (factory wired) and end switch with damper guard.

2.6 CEILING EXHAUST FAN

1. Description: Ceiling Mounted Energy Star Qualified exhaust fan. Manufactured in an ISO 9001 Certified Factory. Fan shall have a low sound level (less than 1 Sone)
2. Motor: Brushless DC motor with integral disconnect
3. Options
   a. Ceiling Radiation Damper
   b. Integral LED light with frosted lens.
   c. Integral motion detector
4. Refer to schedule or drawings for capacity.

2.7 MOTORS

A. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

B. Roof Ventilator Direct Drive Fans with Single Phase Motors: Furnish electronically commutated (EC) motor to convert AC power to DC power. Furnish a speed controller matched to the motor which allows for at least a 50% speed reduction adjustment via a manual potentiometer. Provide all transformers and wiring factory mounted for a completely functional unit.

C. Fan Motor Wiring:

1. Each fan shall be wired separately to a non-fused disconnect mounted with thermal overload protection on the exterior of the fan section per NEC requirements.
2. Provide conduit sized for motor conductors routed from the fan motor to the disconnect. Provide power wiring inside the conduit.
3. For fans indicated to be driven by variable frequency controllers (VFC), the disconnect shall incorporate a remote contact connection for the interlock of the variable frequency controller.
4. Penetrations of junction boxes and disconnects shall be sealed watertight inside (around the wires) and outside of the conduit.

2.8 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 power ventilators level and plumb.

B. Support units as scheduled on the drawings and as 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. Secure roof-mounting fans to roof curbs with cadmium-plated hardware. Refer to Division 07 Section "Roof Accessories" for installation of roof curbs.

E. Install units with clearances for service and maintenance.

F. Label units 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 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.

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

SECTION 233713
DIFFUSERS, REGISTERS AND GRILLES

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 ceiling and wall mounted diffusers, registers and grilles.

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 Sheets: Indicate materials of construction, finish, and mounting details; performance data including horizontal throw and vertical drop, total pressure and static-pressure drop, and noise ratings. Include all assumptions utilized for noise ratings. Indicate thermal insulation and acoustic insulation provided with materials information. Indicate mounting type.
2. Diffuser, Register, and Grille Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.
3. Color chips: Where custom colors are required.
4. Techzone compatibility statement: Where Armstrong TechZone ceiling system compatibility is required.

1.4 EXTRA MATERIALS

A. Furnish extra materials that match product installed.

1. Air baffles: Furnish quantity equal to 5 percent of the diffusers installed or a minimum of five.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers:

1. Diffuser Registers and Grilles
   a. Donco.
   b. Metalaire; as manufactured by Metal Industries, Inc.
   c. Nailor Industries Inc.
   d. Price Industries.
   e. Titus
2. Laminar Flow Diffusers
   a. Price
   b. Titus
   c. Nailor
   d. AAF Flanders

B. See drawing schedules, plans and details for required materials, finishes, style, sizes, pattern, performance and accessories.

1. Internal insulation of slot diffuser plenums is not allowed. All slot diffuser plenums shall be externally insulated.

C. Laminar Flow Diffusers
1. Aluminum or Stainless steel construction with continuously welded joints.
2. Dual chamber construction to provide unidirectional, non-aspirating airflow and consistent face velocity. Exterior shall be insulated with ½ inch foil backed insulation.
3. Face operable damper and safety cables.
4. Filter units shall have static pressure port and be factory tested for leaks.
5. Mounting frame to match the ceiling condition identified on the architectural plans.

2.2 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 Engineer 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, fire dampers, terminal units, control valves and other above ceiling components.

D. Do not modify slot diffuser plenums nor penetrate slot diffuser plenums for piping, conduit, cable tray or other interferences.

E. Do not install diffuser neck mounted dampers, except where specifically scheduled as noted as such. Clarify the installation of all neck mounted dampers directly with the Engineer prior to furnishing the submittal.

F. Support all slot diffusers and laminar flow diffusers independently of the ceiling. Support all other diffusers, registers and grilles which weigh more than five pounds independently of the ceiling. Support all components independently of the ceiling if so required by Division 09 ceiling specifications and CISCA recommendations.

3.3 ADJUSTING

A. After installation, adjust diffusers, registers, and grilles to air patterns indicated, or as directed, before starting air balancing.

B. Install air baffles in diffusers identified as being drafty. Confirm individual diffusers to be corrected with the space occupants and coordinate the installation of air baffles with the occupant's schedule. Confirm acceptability of draft reduction forty-eight (48) hours after air baffle installation with the space occupants and report results in writing.

END OF SECTION

SECTION 235523
LOW INTENSITY GAS FIRED RADIANT HEATERS

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 low-intensity, gas-fired, forced-draft radiant heaters.

1.3 GENERAL

1. Condensing System: Design gas-fired radiant systems to operate such that water vapor present in products of combustion will be condensed, and this heat of condensation will be extracted by the system and will be added to the heated space.

2. Vacuum Vented: To preclude the possibility of combustion gases escaping into the building, the entire system must be under a negative pressure at all times and vented to the outside atmosphere.

1.4 CODES AND STANDARDS

1. American National Standard / CSA Standard Gas-Fired Low Intensity Infrared Heaters:

a. Construct and certify gas-fired infrared heaters in accordance with latest edition ANSI Z83.20 / CSA 2.34 "Gas-Fired Low-Intensity Infrared Heaters" including all current supplements.

2. Installation Compliance: United States: Refer to National Fuel Gas Code NFPA 54/ANSI Z223.1 - latest revision.

3. CSA Compliance: Provide CSA Seal affixed to each burner name plate and provide CSA Certification of heater design as vented or unvented infrared heater for indoor installation.

4. National Standard Gas Piping Compliance: Install and connect gas piping to gas fired infrared heaters in accordance with United States: Refer to National Fuel Gas Code NFPA 54/ANSI Z223.1 - latest revision.

5. National Electrical Code Compliance: Install and connect electrical wiring to gas fired infrared heaters in accordance with: 1.) United States: Refer to National Electrical Code®, NFPA 70 - latest revision. Wiring must conform to the most current National Electrical Code®, local ordinances and any special diagrams furnished.

6. Venting: Venting shall be installed in accordance with the requirements within the manufacture installation operation and service manual and in compliance with United States: Refer to National Fuel Gas Code NFPA 54/ANSI Z223.1 – latest revision.

7. Compressed and Liquefied Natural Gas Installation: Installation must comply with Code for Motor Fuel Dispensing Facilities and Repair Garages NFPA 30A – latest revision. Heaters are certified by CSA to meet maximum tube temperature of 750℉ (399℃) in accordance with NFPA 30A (2012 edition) section 7.6.6.

6. National Performance Rating for Gas Fired Infrared Heaters Standard: Radiant output of gas fired infrared

heaters shall be rated in accordance with AHRI Standard 1330. Refer to Performance Rating for Radiant Output of Gas Fired Infrared Heaters Standard CAN/ANSI/AHRI 1330-2015.

1.5 ACTION SUBMITTALS

1 Product Data: For each type of product.

Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

2 Shop Drawings:

1 Signed, sealed, and prepared by or under the supervision of a qualified professional engineer.
2 Include plans, elevations, sections, and mounting details.
3 Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
4 Detail fabrication and assembly of high-intensity, gas-fired, radiant heaters, as well as procedures and diagrams.
5 Include diagrams for power, wiring.

1.6 INFORMATIONAL SUBMITTALS

1 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 Structural members to which equipment will be attached.
2 Gas piping to heater installations
3 Thermostats and wiring to heaters.
4 Heater locations and clearance requirements.
5 Other suspended ceiling components including the following:

a. Lighting fixtures.
b. Air outlets and inlets.
c. Sprinklers.

2 Field quality-control reports.

3 Sample Warranty: For manufacturer's special warranties.

1.7 CLOSEOUT SUBMITTALS

1 Operation and Maintenance Data: For gas-fired, radiant heaters to include in emergency, operation, and maintenance manuals.

1.8 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Igniter: One hot-surface burner igniter(s) for each style of high-intensity, gas-fired, radiant heater furnished.

1.9 WARRANTY

Manufacturer to provide written warranty agreeing to replace/repair, within warranty period, components of gas fired infrared systems furnished by manufacturer, which are defective in either material or workmanship, provided manufacturer's instructions for handling, installing, protecting, and maintaining units have been adhered to during warranty periods as follows:

1. Three (3) year warranty on the burner system from the date of final acceptance of the infrared heaters.
2. Five (5) year warranty from the date of final acceptance of cast iron combustion chambers.
3. Three (3) year warranty from date of final acceptance of all other components including electrical.

1.10 QUALITY ASSURANCE

A. Manufacturer's Qualifications

1. Firms regularly engaged in manufacture of gas fired infrared systems with characteristics, sizes, and capacities required, whose products have been in satisfactory use in similar service for not less than 15 years.

B. Alternate Manufacturers

1. Other low intensity infrared heaters of equal or greater thermal efficiency and with the same or lower burner firing rate capacity and with the infrared distribution pattern shown on drawing while CSA certified to be in compliance with NFPA 30A 7.6.6 (2012 edition) may be acceptable provided they meet the intent of these specifications and prior approval in writing is obtained from the engineer. If such systems are approved, the contractor assumes responsibility for the design, performance and expense of same. The redesigned system, gas piping, and electric wiring shall be done by a registered mechanical engineer. Shop drawings of the entire new system shall be provided by this contractor. The contractor should state the amount to be credited to the owner due to this substitution.

2. Where approved substitutes are used, the contractor assumes all responsibility for physical dimensions and all other resulting changes. This responsibility extends to cover all extra work as necessitated by other trades as a result of the substitutions.

3. The engineer reserves the right to require the contractor to remove and replace any material or equipment which does not meet specifications or does not have any prior approval as a substitute item. Work shall be completed without cost or inconvenience to the owner.

PART 2 - PRODUCTS

2.1 Manufacturers

A. Roberts-Gordon.

B. Dayton

C. Modine

D. Space-ray

E. Approved equal.

2.2 PERFORMANCE REQUIREMENTS

A. CSA certified, with CSA Seal and certification number clearly visible on units indicating compliance with ANSI Z83.20/CSA 2.34.

B. UL listed and labeled, with UL label clearly visible on units indicating compliance with ANSI Z83.20/CSA 2.34.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 Burner Box

A. Natural Gas burner assemblies consisting of heavy-duty cast-iron burner heads. Pre-wired gas controls with direct spark ignition module and combustion air filters. Provide minimum number of burners shown on plans to insure proper radiant heat distribution. Burners shall be designed for firing in tandem without adverse effects from combustion gases from upstream burners. Burners shall be CSA certified to be in compliance NFPA 30A (2012 edition) section 7.6.6.

B. Design firing rate of burners shall be as stated on drawings. Provide manufacturer recommended clearance to combustible surfaces as measured from the tube surface.

C. Premix Gas and Air: Provide burners to totally pre-mix air and gas required for combustion.

D. Constant Air/Gas Ratio: Provide burners designed to maintain constant proportion of fuel gas to filtered combustion air. Introduce both fuel gas and air at atmospheric pressure, and establish flow of both by means

of negative pressure on the downstream side of the flow metering orifices. If combustion air flow is impeded, gas flow rate will decrease in constant proportion to maintain proper gas/air mixture for complete combustion.

2.4 Burner Controls

A. Factory Wired: All burners shall be factory wired for 115 VAC with transformer for 24 VAC DSI operation and supplied with a grounded 24-30 inch (61–76 cm) three wire pigtail located at rear of burner

B. Fail-Safe Controls: To assure a high degree of fail-safe operation, the design shall preclude main flow of gas if any or all of the following abnormal conditions occur:

1. Power fails (Gas valves in burners close in safe position).

2. Main Valve fails in open position

3. Vacuum pump motor fails (Vacuum proving switch cuts power to burners).

B. Ignition Controls: All gas vacuum-firing burner units shall be equipped with a Direct Spark Ignition Module (DSI). The DSI module shall have a 15-second flame safety time per ignition trial before lockout occurs. In addition, the DSI module shall be capable of a minimum of 3 trials for ignition to provide maximum reliability.

2.5 Vacuum Pump (1/3 HP):

A. Outdoor Venting: The system shall vent all products of combustion outdoors by means of the vacuum pump.

B. Motor: Vacuum pump shall be equipped with a 1/3 horsepower, 60 hertz, 120/230 volts AC, 3450 RPM, single phase motor. This motor shall have thermal overload protection, high temperature sealed ball bearings, and shall be constructed in accordance with electric motor industry standards.

C. Housing: The scroll of this pump shall 12-gauge stamped steel construction. The impeller wheel shall be pressure cast 319-alloy aluminum with a minimum metal thickness of approximately 3/32 inch (.24 cm).

D. Pressure Switch: As an additional safety measure, there will be a low voltage (24 VAC) interlock circuit from the pressure switch (located at the inlet to the vacuum pump) to the controller to prove pump operation.

E. High Temperature Acoustical Isolation: The vacuum pump shall be acoustically isolated from the system with a flexible connector with a constant service temperature rating of 350ºF (177ºC) minimum. The connection between the 4” (10 cm) pump inlet and tailpipe is made with acoustic boot and clamps provided. The discharge connection is made with an acoustic boot and

schedule 40 steel pipe or 4 inch (10 cm) ABS schedule 5 pipe and fittings. The motor in the vacuum pump shall be secured with rubber mounts for acoustical isolation.

F. Rotation: Vacuum pump motor requires a grounded circuit 120/230 volts AC, single phase, 60 hertz for a maximum of 4.8/2.4 full load. This motor must have the same rotation to match the direction of the arrow on the fan scroll. If the motor is not rotating in this direction, it must be reversed by interchanging the black and red line leads as shown on the motor nameplate.

2.6 Provide high radiant reflective aluminum reflectors installed over all heat exchangers. Provide reflector joint pieces over heat exchanger fittings such as elbows so reflector covers heat exchanger continuously. In order to maximize radiant output and reduce convective heat losses, reflectors are to extend below the bottom of the heat exchanger tube.

A. Cover Elbow Fittings: Provide reflector joint pieces over heat exchanger elbows so reflector covers heat exchanger continuously.

B. End Cap Fittings: All reflectors at end of the heat exchanger pipe and any elbows joints shall have end caps to prevent convective heat from escaping.

C. Side Reflectors: System to have perimeter side extension reflector in certain areas of layout as shown on plan where specified. Side reflectors permanently attach to side of top reflector and are secured to the pipe by three side reflector supports and two "Z" clips for each 8’ (2.44 m) section of side reflector. To prevent convection losses, tilting of reflectors will not be acceptable.

D. Over Entire pipe Network: Standard reflectors shall be installed on all radiant pipe and tail pipe as indicated on system layout furnished.

2.7 Outside Air

A. Provide fresh outside air to supply each burner and end vent for the support of combustion air as called for on plans. Fresh outside air supply must be installed in accordance with the requirements within the installation operation and service manual.

1. Outside Air Blower: Blower shall be 167 watt, 60 hertz, 120 volts AC, 3000 RPM, single phase motor. Provides system with pressured outside air supply to each burner and end vent for the support of combustion air as called for on plans.

2. Fresh Air Filter Box: System shall be equipped with fresh air filter box providing pre-filtered outside air through 1” thick E-Z Kleen® aluminum mesh filters, or equivalent. Filter box to be constructed of 22-gauage galvanized steel with 8” (20 cm) inlet and outlet as per the manufacture of the infrared system specifications. The fresh air filter box must be installed

in accordance with the requirements within the installation operation and service manual.

2.8 Controls

A. Thermostats: Provide where indicated, low voltage type connected to infrared heater. Mount thermostat as noted on the drawing. All thermostats shall be numbered instead of marked in degrees.

2.9 Infrared Piping – Radiant Piping - Heat Exchanger

A. Radiant Tube: Shall be new schedule 40 ASTM A53 (Latest edition) grade B ERW black steel pipe TNC 4” (10 cm), both ends threaded to 4” (10 cm) NPT conforming to ANSI/ASME B1.20.1 (Latest edition).

B. Tail Pipe Tube: Shall be new schedule 40 ASTM A53 (Latest edition) grade B ERW black steel pipe TNC 4” (10 cm), both ends threaded to 4” (10 cm) NPT conforming to ANSI/ASME B1.20.1 (Latest edition).

C. Radiant Tube Fittings: Shall be 150 lb. malleable black iron 4” (10 cm), both ends threaded to 4” (10 cm) NPT conforming to ANSI/ASME B1.20.1 (Latest edition).

D. Tail Pipe Tube Fittings: Shall be 150 lb. malleable black iron 4” (10 cm), both ends threaded to 4” (10 cm) NPT conforming to ANSI/ASME B1.20.1 (Latest edition). For tubes as described in the installation, operation and service manual.

E. Hanging Materials: All system’s tube must be supported in accordance with best building practices, local codes, seismic requirements, and applicable standards and as shown on plans. Pipe shall pitch down at least ½” in 20’ (1.27 cm in 6.1 m) on radiant lines and 1” in 20’ (1.27 cm in 6.1 m) on tailpipe lines toward the vacuum pump.

F. End Vent Assembly: Each open end combustion chamber shall have an approved end vent with fresh air connected for the support of combustion air and the reflector shall terminate with an end cap, and be installed according to manufacturer’s installation operation and service manual and as shown on plans.

G. Condensate Piping: Above Ground: copper tubing type M hard drawn. Fittings: ANSI/ASME 816.23 cast brass or ANSI/AMSE 816.29, wrought copper. Joints ANSI/ASTM B32, solder, grade 95TA.

H. Condensate Neutralization Tube: Provide and install condensate neutralization tube as per the manufacture instructions in the installation operation and service manual.

PART 3 EXECUTION

3.1 EXAMINATION

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

B. Examine roughing-in for fuel-gas piping to verify actual locations of piping connections before equipment installation.

C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.

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

3.2 INSTALLATION

A. Equipment Installation: Install gas-fired, radiant heaters and associated gas features and systems according to NFPA 54.

B. Suspended Units: Suspend from substrate using chain hanger kits and building attachments.

1. Comply with requirements for hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

C. Maintain manufacturers' recommended clearances for combustibles.

3.3 CONNECTIONS

A. Gas Piping: Comply with Section 231123 "Facility Natural-Gas Piping." Connect gas piping to gas train inlet; provide union with enough clearance for burner removal and service.

B. Gas Connections: Connect gas piping to radiant heaters according to NFPA 54.

C. Where installing piping adjacent to gas-fired, radiant heaters, allow space for service and maintenance.

D. Vent Connections: Comply with Section 233113 "Metal Ducts".

E. Electrical Connections: Comply with applicable requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

F. Install electrical devices furnished with heaters but not specified to be factory mounted.

3.4 FIELD QUALITY CONTROL

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

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

1. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
2. Verify bearing lubrication.
3. Verify proper motor rotation.
4. Test Reports: Prepare a written report to record the following:

A. Test procedures used.
B. Test results that comply with requirements.
C. Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.

C. Gas-fired, radiant heaters will be considered defective if they do not pass tests and inspections.

D. Prepare test and inspection reports.

3.5 ADJUSTING

A. Adjust initial-temperature set points.

B. Adjust burner and other unit components for optimum heating performance and efficiency.

3.6 TRAINING

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain gas-fired, radiant heaters.

END OF SECTION

SECTION 237433
DEDICATED OUTDOOR AIR UNITS

GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes packaged dedicated outdoor air handling units with refrigerant compressors, air-cooled condensers, natural gas heat, electric heat, energy recovery devices and required controls and safeties to provide a complete operational system.

B. Related Sections include the following:
1. Division 23 Section "HVAC Instrumentation and Control for HVAC" for control devices not packaged with units.

1.3 SUBMITTALS

A. Product Data: Include rated capacities, required maintenance clearances, ducted sound power ratings, furnished specialties, and accessories for each type of product indicated.

B. Shop Drawings:

1. Dimensions, weights, method of field assembly, location, and size of field connections.
2. Diagram power, signal, and control wiring.

C. Samples for Initial Selection: For units with factory-applied color finishes.

D. Field quality-control test reports.

E. Operation and Maintenance Data: For self-contained air-conditioners to include in emergency, operation, and maintenance manuals.

F. Warranty: Special warranty specified in this Section.

G. Coordination Drawings: 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. Structural members to which RTU's will be attached.
2. Roof openings.
3. Roof curbs and flashing.
4. Pipe penetrations.
5. Conduit penetrations.

1.4 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 62.1-2004, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

C. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1-2007

D. ARI Certification:

1. Cooling capacity shall be rated in accordance with ARI Standards.
2. Ducted sound power ratings shall be in accordance with ARI Standards.

1.5 COORDINATION

A. Coordinate size and location of concrete bases for units. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork are specified in Division 3 Section "Cast-in-Place Concrete."

1.6 WARRANTY

A. General Warranty: Special warranty specified in this Article shall not deprive Owner of other rights Owner may have under other provisions of the Contract Documents and shall be in addition to, and run concurrent with, other warranties made by Contractor under requirements of the Contract Documents.

B. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of self-contained air-conditioners that fail in materials or workmanship within specified warranty period.

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

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. Filters: One set of filters for each unit.
2. Final fan belts: Two (2) sets for each belt driven fan. Field installed and sized by the Testing, Adjusting, and Balancing Contractor. Sized as required to deliver the necessary airflow through the system accounting for all system losses.
3. Final fan sheave: One (1) set for each belt driven fan. Field installed and sized by the Testing, Adjusting, and Balancing Contractor. Sized as required to deliver the necessary airflow through the system accounting for all system losses.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

a. Carrier Air Conditioning; Div. of Carrier Corporation.
b. Daikin International.
c. Trane Co. (The); North American Commercial Group.
d. JCI York
e. AAON

2.2 GENERAL DESCRIPTION

A. Description: Self-contained, factory-assembled, packaged rooftop dedicated outside air unit consisting of cabinet, compressor, evaporator fan, evaporator coil, air filters, energy recovery device and unit controls; and fully charged with refrigerant and oil.

B. Disconnect Switch: Factory mounted inside control panel.

2.3 CABINET

A. Frame and Panels: Structural-steel frame with double wall galvanized-steel panels with baked- enamel finish in color selected by Architect, and with access doors or panels. Exterior and interior panels shall be constructed of G90 Galvanized steel Provide pitched roof panels and lifting lugs. Cabinet leakage shall not exceed 1% following AHRI Standard 340/360. Exterior paint shall be capable of withstanding at least 2500 hours when tested in accordance with ASTM B 117-95.

B. Insulation: Minimum 2-inch thick to provide a R value of 13 for the assembly. Insulate coils sections. Provide solid metal liner on all surfaces exposed to the airstream.

C. Drain Pan: Stainless steel, complying with ASHRAE 62.1-2010.

D. Isolation: Spring isolators for mounting under base of unit, with minimum static deflection of 1 inch (25 mm).

E. Discharge Plenum: Cabinet extension with directional louvers.

F. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2010.

2.4 FANS

A. Material: Galvanized steel.

B. Configuration: Double-width, double-inlet, backward curved centrifugal fan; statically and dynamically balanced.

C. Drive: Direct, with fan and motor resiliently mounted.

D. Fan Sheaves: Cast-iron or steel sheaves, dynamically balanced, bored to fit shafts and keyed.

E. Motor Sheave: Variable and adjustable pitch selected so required rpm are obtained when set at mid-position.

F. Rating: As recommended by the manufacturer or a minimum of one and one-half times nameplate rating of motor.

G. Bearings: Grease lubricated with grease lines extended to exterior of unit.

H. Variable Air Volume: Variable-frequency motor controller.

I. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

J. Motors: Open-drip-proof type.

1. Special Motor Features: Premium efficiency, as defined in Division 23 Section "Common Motor Requirements for HVAC Equipment."

K. Isolation: Mount fan and motor on common subbase and mount assembly on spring isolators with minimum static deflection of 1 inch (25 mm).

2.5 COMPRESSOR

A. Description: Hermetically sealed, 3600 rpm maximum, and resiliently mounted with positive lubrication and internal motor protection.

B. Compressor Type: Scroll. Internal overcurrent, overtemperature and pressure relief.

2.6 EVAPORATOR COIL

A. Direct-Expansion Coil: Seamless copper tubes expanded into aluminum fins.

B. Refrigerant Circuits: A separate circuit for each compressor, with externally equalized thermal- expansion valve with adjustable superheat, filter-dryer, sight glass, high-pressure relief valve, and charging valves. Coils shall be interfaced such that refrigerant circuit covers the entire coil face which has the total scheduled airflow of the unit/coil bank. All the air passes over an active circuit at all times.

INTEGRAL AIR-COOLED CONDENSER

C. Description: Factory assembled and tested; consisting of condenser coil, fans and motors, and cabinet.

1. Condenser Coil: Aluminum-fin copper tube with integral sub-cooler; leak tested to 425 psig (2930 kPa).
2. Condenser Fan: Direct-drive propeller type with permanently lubricated motor with built- in thermal-overload protection.
3. Low Ambient Control: Cycles fans to permit operation down to 0 deg F (minus 18 deg C).

2.7 REFRIGERATION SYSTEM

A. Description: Factory assembled and tested, and charged with CFC-free refrigerant; consisting of piping and accessories connecting scroll compressor, evaporator coil, and condenser coil, and including the following:

1. Four-way reversing valve and suction-line accumulator.
2. Expansion valve with replaceable thermostatic element.
3. Refrigerant dryer, replaceable core.
4. High-pressure switch.
5. Low-pressure switch.
6. Thermostat for coil freeze-up protection during low ambient temperature operation or loss of air.
7. Low ambient switch.
8. Brass service valves installed in discharge and liquid lines.

B. Provide separate refrigerant circuits for each compressor. Provide a minimum of two refrigerant circuits.

C. Refrigerant: R-32 or R-454B.

D. Provide hot gas bypass on one refrigerant circuit. Factory installed and wire all components.

2.8 HEATING COIL

A. Hot Gas Refrigeration reheat coil shall be provided to maintain system leaving air temperature.

2.9 HEAT EXCHANGER

A. Stainless steel heat exchanger and drain pan construction for natural gas fired burners with the following controls:

1. Redundant single or dual gas valve with manual shutoff.
2. Direct spark pilot ignition.
3. Electronic flame sensor.
4. Induced draft blower interlocked with gas valve.
5. Flame rollout switch.
6. Fully modulating gas valve with turn down ratio of at least 4:1.
7. Electric space heater for gas burner compartment.

B. High Turndown Modulating Natural Gas Furnace shall be equipped with modulating gas valves, adjustable speed combustion blowers, stainless steel tubular heat exchangers, and electronic controller. Combustion blowers and gas valves shall be capable of modulation. Electronic controller includes a factory wired, field installed supply air temperature sensor. Sensor shall be field installed in the supply air ductwork. Supply air temperature setpoint shall be adjustable on the electronic controller within the controls compartment. Gas heater shall be capable of capacity turndown ratio as shown on the unit rating sheet. Heat trace shall be included on the condensate drain

2.10 AIR FILTERS

A. Extended-Surface, Disposable Panel Filters: 12-inch thick, dry, filters with fibrous media material formed into deep-V-shaped pleats and held by self-supporting wire grid holding frames, with nonflammable cardboard media and media-grid frame.

1. Efficiency: ASHRAE 52.2 MERV rating of 7 or higher.

B. Air-Pressure Switch: Indicates dirty filters.

2.11 ENERGY RECOVERY

A. Unit shall contain a factory mounted and tested energy recovery wheel. The energy recovery wheel shall be mounted in a rigid frame containing the wheel drive motor, drive belt, wheel seals and bearings. Frame shall slide out for service and removal from the cabinet.

B. The energy recovery component shall incorporate a rotary wheel in an insulated cassette frame complete with seals, drive motor and drive belt.

C. The energy recovery cassette shall be an Underwriters Laboratories Recognized Component for electrical and fire safety. The wheel drive motor shall be an Underwriters Laboratory Recognized Component and shall be mounted in the cassette frame and supplied with a service connector or junction box. Thermal performance shall be certified

by the manufacturer in accordance with ASHRAE Standard 84, Method of Testing Air-to-Air Heat Exchangers and AHRI Standard 1060, Rating Air-to-Air Energy Recovery Ventilation Equipment. Cassettes shall be listed in the AHRI Certified Products.

D. Unit shall include 2-inch-thick, pleated panel outside air and exhaust air filters with an ASHRAE MERV rating of 8, upstream of the wheels.

E. Hinged service access doors shall allow access to the wheel.

F. Polymer Energy Recovery Wheels

1. Shall be provided with removable energy transfer matrix. Wheel frame construction shall be a welded hub, spoke and rim assembly of stainless, plated and/or coated steel and shall be self-supporting without matrix segments in place. Segments shall be removable without

   the use of tools to facilitate maintenance and cleaning. Wheel bearings shall be selected to provide an L-10 life in excess of 400,000 hours. Rim shall be continuous rolled stainless steel and the wheel shall be connected to the shaft by means of taper locks.

2. All diameter and perimeter seals shall be provided as part of the cassette assembly and shall be factory set. Drive belts of stretch urethane shall be provided for wheel rim drive.
3. Polymer Energy recovery wheel cassette shall carry a 5-year non-prorated warranty, from the date of original equipment shipment from the factory. The first 12 months from the date of equipment startup, or 18 months from the date of original equipment shipment from the factory, whichever is less, shall be covered under the standard AAON limited parts warranty. The remaining period of the warranty shall be covered by Airxchange. The 5- year warranty applies to all parts and components of the cassette, with the exception of the motor, which shall carry an 18-month warranty. Warranty shall cover material and workmanship that prove defective, within the specified warranty period, provided the Airxchange written instructions for installation, operation and maintenance have been followed. Warranty excludes parts associated with routine maintenance, such as belts. Refer to the Airxchange Energy Recovery Cassette Limited Warranty Certificate.
4. Total energy recovery wheels shall be coated with silica gel desiccant permanently bonded by a process without the use of binders or adhesives, which may degrade desiccant performance. The substrate shall be lightweight polymer and shall not degrade nor require additional coatings for application in marine or coastal environments. Coated segments shall be washable with detergent or alkaline coil cleaner and water. Desiccant shall not dissolve nor deliquesce in the presence of water or high humidity.

2.12 CONTROLS

A. Control Package: Factory wired, including contactor, high- and low-pressure cutouts, internal- winding thermostat for compressor, control-circuit transformer, and non-cycling reset relay.

B. Time-Delay Relay: Five-minute delay to prevent compressor cycling for five minutes after a shutdown.

C. Adjustable Thermostat: Unit mounted to control the following:

1. Supply fan.
2. Compressor.
3. Condenser.
4. Hot-water coil valve.
5. Electric heater.

D. System Selector Switch: Off-heat-auto-cool.

E. Low ambient control down to 0 deg F for units without airside economizers.

F. Microprocessor Control Panel: Controls unit functions, including refrigeration and safety controls and the following:

1. Supply fan.
2. Supply-fan motor speed. Constant volume
3. Compressors.
4. Air-cooled condenser.
5. Panel-mounted control switch to operate unit in remote or local control mode, or to stop or reset.
6. Panel-mounted indication and adjustable control of the following:

    a. Operating status.
    b. System diagnostics and safety alarms.
    c. Supply-air temperature set point.
    d. Zone heating-temperature set point.
    e. Supply-air pressure set point.
    f. Economizer minimum position set point.
    g. Supply-air-pressure, high-limit set point.

7. Time-of-day control to cycle unit on and off.
8. Night-heat, morning warm-up cycle.
9. Power interruption restart mode.
10. Unit diagnostics and diagnostic code storage.
11. Dehumidification control with humidistat.
12. Building pressure control.
13. Unoccupied mode temperature setback and set forward with override thermostat.
14. Return air temperature limit.
15. Controller shall have volatile-memory backup.
16. Safety control operation:

    a. Smoke detectors: Stop fan and close outdoor air damper if smoke is detected.
    b. Provide additional contacts for alarm interface to fire alarm control panel.
    c. Fire alarm control panel interface: Provide control interface.
    d. Low discharge temperature: Stop fan and close outdoor air damper if supply air temperature is less than 40 deg F (4 deg. C).
    e. Defrost control for condenser coil: Pressure differential switch to initiate defrost sequence.

    f. Gas furnace operation:

        1) Occupied periods: Modulate burner to maintain discharge temperature.
        2) Unoccupied periods: Cycle burner to maintain setback temperature.

17. Interface requirements for HVAC instrumentation and control system:

    a. Interface relay for scheduled operation.
    b. Interface relay to provide indication of fault at the central workstation and diagnostic code storage.

G. Sequence of Operation:

1. Rooftop unit to be supplied with all operating and safety controls to supply 55 deg F air at all times during occupied cycles. The supply air will be distributed to terminal units which are controlled by space thermostats (controls for terminal units are not provided by the RTU manufacturer).
2. RTU is indexed for occupied to unoccupied from a binary signal generated from the Building Automation System Operator's Work Station and DDC system.
3. Occupied cycle:

    a. The unit and all associated exhaust fans operate continuously
    b. The unit delivers room neutral air 68F (adjustable) to the building.
    c. The unit delivers 55F (adjustable) air to the building and modulates the supply volume in accordance with a pressure sensor 90% through the system. Terminal units regulate the delivery of air to each space.

4. Unoccupied cycle:

    a. The unit is cycled on a fully recirculated basis in the event the space temperature falls below 55 deg F or rises above 85 deg F or in the event the relative humidity exceeds 60 percent RH.
    b. The unit may be returned to occupied cycle through a 0-6 hour manual override switch located in the space.

5. The unit supplier shall be responsible for furnishing, installing, wiring, and adjusting 100 percent off all the controls required for the rooftop unit to perform the operating sequence. The indexing for the programmed occupied-unoccupied cycles shall be coordinated with ECC to receive the external input from the Building Automation System.

H. The Manufacturer/Supplier is responsible for including and providing the following related to data integration with and to the building automation system/environmental control system (Specification Section 23 09 00).

1. All hardware, firmware and software components required to provide the BACnet MS/TP protocol interface necessary to transmit the specified data points to the BAS system. The equipment manufacturer and/or equipment supplier is responsible for identifying and coordinating the required controls protocol with the successful ECC Contractor. The final result of the coordination shall be indicated on the written equipment submittal.
2. On-site technical labor to assist the ECC Contractor with the data integration and to verify the specified data points, including data values, change of state values and units and are communicated properly and completely to the BAS system. On-site technical assistance shall not be less than a minimum of 4 hours total time on the

job site for each piece of equipment installed with this time split over two separate site visits. Allow a minimum of 2 hours to assist the ECC Electrician and coordinate wiring terminations and a minimum of 2 hours to assist the ECC Programmer to confirm data connectivity. On-site technical assistance shall continue beyond these minimum times stated at no cost to the Owner nor revisions to the Contract amount nor schedule until such time as the Engineer of Record determines that the equipment operation, startup and graphics are satisfactory.

3. The equipment submittal shall state whether the equipment manufacturer or the equipment supplier is providing each of these items with personnel names and mobile phone numbers included in the submittal:

   a. On-site technical labor to assist the ECC Electrician.
   b. On-site technical labor to assist the ECC Programmer with data connectivity and graphics.

2.13 OUTDOOR AIR INTAKE

A. Height above roof as required.

B. Designed to resist all rain penetration at 100 percent economizer airflow.

2.14 ELECTRICAL

A. Power Connection: Provide for single connection of power to unit with unit mounted disconnect switch accessible from outside unit and control circuit transformer with built-in circuit breaker.

B. Service Outlets: Two (2) 115-V, GFCI type with weather cover.

C. Unit shall have a minimum interruption rating of 32 KA at 480V.

D. Variable frequency drives shall be provided in accordance with Division 26 sections.

2.15 ROOF CURB

A. Galvanized steel, insulated with metal insulation liner, gasketing and factory installed wood nailer; complying with NRCA standards; minimum height of 18 inches. Secure units to curbs and secure curbs to roof structure.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install units' level and plumb. Install according to ARI Guideline B.

B. Anchor units to structure.

C. Install seismic restraints.

3.2 CONNECTIONS

A. Install piping adjacent to unit to allow service and maintenance.

B. Duct Connections: Duct installation requirements are specified in Division 23 Section "Metal Ducts." Drawings indicate the general arrangement of ducts. Connect supply and return ducts to self-contained air-conditioners with flexible duct connectors. Flexible duct connectors are specified in Division 23 Section "Air Duct Accessories."

C. Provide ductwork connections with 45-degree angle transition beginning from the casing inner surface. Fitting and shall be provided by mechanical contractor. AHU manufacturer to adjust opening to accept fitting and duct.

D. Remove roof decking only as required for passage of ducts. Do not cut out decking under entire roof curb.

E. Terminate return air duct through roof structure and insulate space between roof and bottom of unit with 2-inch- (50-mm) thick, acoustic duct liner.

F. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

G. Electrical Connections: Comply with requirements in Division 26 Sections for power wiring, switches, and motor controls.

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. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
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. Remove and replace malfunctioning units 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.
2. Complete the following:

a. Inspect for visible damage to unit casing.
b. Inspect for visible damage to compressor, air-cooled outside coil and fans.
c. Inspect internal insulation.
d. Verify that labels are clearly visible.
e. Verify that clearances have been provided for servicing.
f. Verify that controls are connected and operable.
g. Verify that filters are installed.
h. Clean outside coil and inspect for construction debris.
i. Inspect for visible damage to furnace combustion chamber.
j. Clean furnace flue and inspect for construction debris.
k. Connect and purge gas line.
l. Adjust vibration isolators.
m. Inspect operation of dampers.
n. Lubricate bearings on fan.
o. Inspect fan wheel rotation for movement in correction direction without vibration and binding.
p. Adjust fan belts to proper alignment and tension.
q. Start unit according to manufacturer's written instructions:

1) Start refrigeration system in summer only.
2) Complete startup sheets and attach copy with Contractor's startup report.

r. Inspect and record performance of interlocks and protective devices; verify sequences.
s. Commission variable frequency drives for ramp settings, over/under voltage settings, auto restart, start on the fly and other settings as available.
t. Operate unit for an initial period as recommended or required by manufacturer.
u. Perform the following operations for both minimum and maximum firing and adjust burner for peak efficiency. Adjust pilot to stable flame.

1) Measure gas pressure on manifold.
2) Measure combustion air temperature at inlet to combustion chamber.
3) Measure flue gas temperature at furnace discharge.
4) Perform flue gas analysis. Measure and record flue gas carbon dioxide and oxygen concentration.
5) Measure supply air temperature and volume when burner is at maximum firing rate and when burner is off. Calculate useful heat to supply air.

v. Calibrate thermostats.
w. Adjust and inspect high temperature limits.
x. Inspect outside air dampers for proper stroke and interlock with return air dampers.
y. Start refrigeration system and measure and record the following:

1) Coil leaving air, dry and wet bulb temperatures.
2) Coil entering air, dry and wet bulb temperatures.
3) Outside air, dry bulb temperature.
4) Outside air coil, discharge air, dry bulb temperature.

z. Inspect controls for correct sequencing of heating, mixing damper, refrigeration and normal and emergency shutdown.

aa. Measure and record the following minimum and maximum airflows. Plot fan volumes on fan curve.

1) Supply air volume.
2) Return air volume.
3) Relief air volume.
4) Outside air intake volume.

bb. Simulate maximum cooling demand and inspect the following:

1) Compressor refrigerant suction and hot gas pressures.
2) Short circuiting of air through outside coil or from outside coil to outside air intake. Seal all coil bypasses.

cc. Verify operation of remote panel, including pilot light operation and failure modes.

Inspect the following:

1) High limit heat exchanger.
2) Warm up for morning cycle.
3) Freezestat operation.
4) Economizer to limited outside air changeover.
5) Alarms.

dd. After startup and performance testing, change filters, vacuum heat exchanger and cooling and outside coils, lubricate bearings, adjust belt tension and inspect operation of power vents.

3.5 ADJUSTING

A. Adjust initial temperature and humidity setpoints, building pressure control, scheduled unoccupied cycles and all other control features.

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 (2) visits to site outside normal occupancy hours for this purpose, without additional cost.

3.6 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain units. Refer to Division 1 Section "Demonstration and Training."

END OF SECTION

SECTION 238110
UNITARY SPLIT HEAT PUMP SYSTEMS

GENERAL

1.1. WORK INCLUDES

A. Summary:

1. Contractor provide:

a. Packaged unitary heat pump condensing units and accessories.
b. Packaged unitary heat pump furnace units and accessories.
c. Control of all components to meet the requirements of control sequences specified.

1.2. RELATED WORK

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

B. Specified elsewhere in the following Sections:

1. Section 23 0100 - Special Mechanical Requirements.
2. Section 23 2300 - Refrigerant Piping Systems.
3. Division 26 - Electrical Work.

1.3. QUALITY ASSURANCE

A. Units factory tested.

1.4. SUBMITTALS

A. Shop Drawings: Not required for Engineer/Architect review.

B. Samples: Not required for Engineer/Architect review.

C. Product data:

1. Provide the following information:

a. Performance data.
   1) Filter data.
   2) Coil data.
   3) Fan data including fan curves.
   4) Fan and casing sound levels.
   5) Electrical data.
   6) Accessories furnished.
b. Catalog information with dimensions, weights, loadings, required clearances, size and location of connections and accessories furnished.
c. Wiring diagrams.
d. Installation instructions.

2. In addition to the printed copies of the submittal, a portable document format (pdf) of the submittal shall be transmitted via email to the Engineer.

D. Project Information: Not required for Engineer/Architect review.

E. Contract Closeout Information:

1. Operating and maintenance data.
2. Owner instruction report.

F. Warranties: Provide one (1) year minimum material and labor warranty on all components from date of substantial completion.

1. Provide five (5) year material and labor warranty on compressors.

PART 2 - PRODUCTS

2.1. UNITARY SPLIT AIR CONDITIONER

A. Acceptable Manufacturers:

1. Outdoor heat pump condensing units:

a. Carrier.
b. Daikon.
c. Lennox.
d. Trane
e. York.

2. Indoor heat pump air handling units:

a. Carrier.
b. Daikon.
c. Lennox.
d. Trane
e. York.

3. Other manufacturers desiring approval comply with Division 1.

2.2. OUTDOOR HEAT PUMP CONDENSING UNIT

A. Condensing Unit: Air-cooled condensing unit, factory assembled, consisting of compressor, condenser coil and fan, and casing.

1. Units: CSA and UL approved; conforming to ARI Standard 210/240.
2. Operating range: 0-115 deg F outdoor with low ambient kits.
3. Factory installed filter drier.
4. Field or factory installed sight glass.
5. Exposed sweat refrigerant connections with re-useable service valves.

B. Compressor: Hermetic, scroll type mounted on rubber vibration isolators.

1. Motor: Wide operating range, dual voltage.
2. Internal spring isolation and 2-stage sound isolation.
3. Winding thermostat and current overload device coupled with pressure limiting valve.
4. Internal protection devices for:

   a. Motor overload.
   b. Locked rotor.
   c. Extreme voltage supply.
   d. Excessive winding temperatures.
   e. Extreme pressures.
   f. Loss of refrigerant charge.
   g. Compressor cycling.

5. Off cycle crankcase heater.

C. Controls: Provide controls in weather-tight control box behind accessible panel. Control circuit shall be 24 V. Microprocessor based defrost control shall initiate defrost cycle only to reduce compressor energy consumption. Provide anti-recycle timer to prevent short cycling. Provide hard start kit and outdoor thermostat.

D. Coil, Condenser: Seamless aluminum tubes, 3/8 IN OD, with aluminum fins mechanically bonded.

1. Two row.
2. Factory pressure and leak tested at 600 PSI.
3. Provide heavy duty protective grille on every side.

E. Fan, Condenser: Aluminum, aerodynamically designed, statically balanced.

1. Motor: Two-speed, single phase, direct drive, heavy duty, permanently lubricated, with built in thermal overload protection.
2. Mount fan and motor support to cabinet top.

3. Provide grille to protect fan.

F. Casing, Condensing Unit: 18 GA galvanized steel.

1. Finish: Phosphatized; epoxy resin primer; acrylic finish coat.
2. Removable end panel for access to components and connections.
3. Standard base size.
4. Mounting rails: Die formed; integral with base.
5. Drain holes in base pan.
6. Electrical and refrigeration connections in same location on units.

G. Accessories.

1. Provide four (4) 6” high equipment supports.

2.3. FURNACE UNIT

A. Casing: Suitable for upflow heat pump applications; consisting of fan, heat exchanger, evaporator coil, filter controls and casing.

1. UL approved as heating units; for installation in confined spaces with reduced clearances to combustible materials.
2. Wiring: Complete at factory.

a. Internal wiring: 105° C rated.
b. Low voltage wiring terminal strip.
c. Low and high voltage connections made from either side.

B. Heat Exchanger (GAS):

1. Condensing type.
2. Primary heat exchanger – aluminized steel construction.
3. Secondary heat exchanger Type 29-4C stainless steel construction.
4. UL approved.

a. Units shall contain a centrifugal power venter and blower fan with PSC motor. Motor shall be open drip-proof blower type with thermal overload protection.

C. Heating elements, (Electric): Open type nickel-chromium alloy.

5. UL approved.
6. Cover 70%, minimum, of air outlet area, minimize bypass air and reduce coil surface temperatures.

D. Heating Controls:

1. Igniter: silicon nitride type with adaptive heat up.

2. Dual solenoid combination gas valve and regulator. Gas valve opens when proper vent flow is sensed.
3. Control transformer: 24-volt.
4. Fan and limit safety controls.

E. Power Venter:

1. Induced draft type, purges heat exchanger before ignition.

F. Fan: Forward curved, centrifugal type, with locked blades.

1. Motor: Direct drive variable speed ECM motor with permanently lubricated bearings and separately isolated motor mounts.
2. Capacity: As required for heating and cooling.
3. Assembly mounted on casing slide rails for access and removal.

G. Filter: Throwaway type, 1" thick, mounted in filter grilles; sized to handle maximum CFM. Provide two additional sets of filters for each filter/grille.

H. Casing: G-90 steel, with cleaned and phosphatized, primed and baked enamel finish coat. Provide 1” thickness foil lined fiberglass insulation with an R value of 4.2.

I. Cooling Coil: Provide a factory tested A-frame coil with hydrophilic coating, complete with corrosion resistant drain pan and bolt on thermal expansion valve.

J. Controls:

1. Thermostat: Non-programmable auto heating/cooling, for remote mounting.
   Cooling: Single Stage

   Heating: Single Stage

2.4. HEAT PUMP AIR HANDLING UNIT

A. AHU: Indoor, packaged draw-thru air-handling unit for use in commercial heat pump split systems. Unit shall have a multi-position design and shall be capable 0f horizontal or vertical installation, on a floor or in a ceiling, with or without ductwork.

1. UL approved as heating units; for installation in confined spaces with reduced clearances to combustible materials.
2. Wiring: Complete at factory.

   a. Internal wiring: 105° C rated.
   b. Low voltage wiring terminal strip.

c. Low and high voltage connections made from either side.
3. All coils shall be designed and tested in accordance with ASHRAE 15 Safety Code for Mechanical Refrigeration, latest edition.
4. Unit insulation and adhesive shall comply with NFPA-90A requirements for flame spread and smoke generation.

B. Heating Elements, Electric: Open type nickel-chromium alloy.

1. UL approved.
2. Cover 70%, minimum, of air outlet area, minimize bypass air and reduce coil surface temperatures.
3. Heater assembly shall include contactors with 24 volt coils, power wiring, 24 volt control wiring terminal blocks, and a hinged access panel.
4. Single-point wiring connection.

C. Fan: Forward curved, centrifugal type, with locked blades.

1. Motor: Belt drive, ECM motor with permanently lubricated, sealed bearings and separately isolated motor mounts.
2. Capacity: As required for heating and cooling.
3. Inherent automatic-reset thermal overload protection.
4. Assembly mounted on casing slide rails for access and removal.

D. Filter: 2" thick, Merv 11, disposable filters mounted in side access racks; sized to handle maximum CFM. Provide one additional sets of filters.

E. Cabinet:

1. Constructed of galvanized steel.
2. Cabinet panels shall be fully insulated with 1” fire-retardant material. Insulation shall have a minimum R-Value of 4.2. Insulation shall contain an EPA-registered immobilized antimicrobial agent to effectively resist the growth 0f bacteria and fungi as proven by tests in accordance with ASTM standards G21 and 22.
3. Unit shall contain a corrosion-free condensate drain pan for both horizontal and vertical applications. Drain pans shall have connections on the right or left sides of unit to facilitate field connection. Drain pans shall have the ability to be sloped toward the right or left side of the unit to prevent standing water form accumulating in the pans.

F. Cooling Coil: Provide a factory tested direct-expansion coil with hydrophilic coating.

1. Copper tube with aluminum fins bonded to the tubes by mechanical expansion.
2. Coils shall have factory-installed thermostatic expansion valves (TXVs) for refrigerant control. The TXVs shall be capable of external adjustment.
3. Coils shall have a factory-installed bypass line and check valve assembly around the TXVs to allow liquid flow from the coil to the outdoor unit during

heating mode.

G. Controls:

1. Thermostat: Programmable multi-stage thermostat with 7-day clock, holiday scheduling, auto heating/cooling, for remote mounting.
2. Cooling: Single stage.
3. Heating: Multi-stage.
4. Heat pump:
   a. Electric – Stage 1.
   b. Electric – Stage 2.

5. Controls and control sequence:
   a. Compressor time guard shall prevent compressor start until it has been off for at least 5 minutes (approximately).
   b. Multi-staging (for heating): Higher stage heat is not enabled until preceding stage has been on for 15 minutes.
      Heating Stage 1: Heat pump operation

      Heating Stage 2: Drop heat pump and enable [Gas Heat] [Electric Heat] – 1

      Heating Stage 3: Add Electric Heat - 2

   c. Lock out electric heat for outdoor air temperature above 35° F (adjustable)

2.5. REFRIGERANT PIPING AND ELECTRICAL WORK

A. Refrigerant piping for quick connect installations: Pre-charged, factory assembled, in standard lengths.

1. Female couplings.
2. Suction line: Elastomeric closed cell insulated.
3. Provide gauge ports at condenser.

B. Refrigerant piping for field assembled piping: See Section 23 23 00.

C. Control wiring: Provide wiring between components for control functions. Provide separate conduits for low voltage (24 V) and line voltage (120/240 V) wiring.

PART 3 - EXECUTION

3.1 INSPECTION

A. Examine areas and conditions under which unitary heat pump condensing units and heat pump air handlers shall be installed.

B. Do not proceed with work until unsatisfactory conditions have been corrected.

3.2 GENERAL

A. Install unitary heat pump condensing units and heat pump air handlers where indicated, in accordance with equipment manufacturer's installation instructions, and with recognized industry practices, to insure that equipment complies with requirements and serves intended purposes.

B. Install unitary heat pump condensing units and heat pump air handlers with recommended clearances provided for service and maintenance.

C. Connect piping, wiring and control wiring.

3.3 ELECTRICAL CONNECTIONS

A. Ensure that HVAC equipment and components are wired properly, with rotation in direction indicated and intended for proper performance.

B. Furnish to Electrical Installer, manufacturer's wiring diagram and electrical requirements for installation of field-wiring required for equipment (including control panels); not work of this section.

3.4 FIELD QUALITY CONTROL

A. Upon completion of installation of HVAC equipment, and after motors have been energized with normal power source, test equipment to demonstrate compliance with requirements.

B. Where possible, field correct malfunctioning equipment, retest to demonstrate compliance. Replace equipment which cannot be satisfactorily corrected.

3.5 INSTALLATION OF UNITARY HEAT PUMP CONDENSING UNITS

A. Install condensing unit on six inch high equipment supports and secure unit and equipment supports to pad with anchor bolts.

B. Provide all necessary refrigerant piping, fittings, valves, etc., to provide a complete installation as indicated and as specified.

C. Provide the control devices furnished by the manufacturer, but not specified to be factory mounted in accordance with the manufacturer's instructions, complete with control wiring.

3.6 INSTALLATION OF UNITARY HEAT PUMP AIR HANDLERS

A. Contractor to coordinate with other work, including ductwork and electrical piping, as necessary to interface installation of equipment.

B. Coordinate the footprint of the unit with architectural, structural and electric components. Coordinate requirements for floor penetrations with other trades.

C. Provide for each direct expansion coil, all necessary refrigerant piping, fittings, valves, etc., to provide a complete installation as indicated and as specified. Install piping to allow service and maintenance.

D. Provide humidity condensate drain with P-trap and route condensate piping to floor drain or as otherwise indicated on the drawings. Trap shall be adequately sized to properly drain condensate.

E. Install remote thermostat and all control wiring.

3.7 INSTALLATION OF UNITARY CONDENSING UNITS

A. Install condensing unit secure unit to pad with anchor bolts.

B. Provide all necessary refrigerant piping, fittings, valves, etc., to provide a complete installation as indicated and as specified.

C. Provide the control devices furnished by the manufacturer, but not specified to be factory mounted in accordance with the manufacturer's instructions, complete with control wiring.

3.8 INSTALLATION OF UNITARY FURNACES

A. Contractor to coordinate with other work, including ductwork and electrical piping, as necessary to interface installation of equipment.

B. Coordinate the footprint of the unit with architectural, structural and electric

components. Coordinate requirements for floor penetrations with other trades.

C. Provide for each direct expansion coil, all necessary refrigerant piping, fittings, valves, etc., to provide a complete installation as indicated and as specified. Install piping to allow service and maintenance.

D. Provide humidity condensate drain with P-trap and route condensate piping to floor drain or as otherwise indicated on the drawings. Trap shall be adequately sized to properly drain condensate.

E. Install remote thermostat and all control wiring.

3.9 INSTALLATION OF UNITARY HEAT PUMP AIR HANDLERS

A. Contractor to coordinate with other work, including ductwork and electrical piping, as necessary to interface installation of equipment.

B. Coordinate the footprint of the unit with architectural, structural and electric components. Coordinate requirements for floor penetrations with other trades.

C. Provide for each direct expansion coil, all necessary refrigerant piping, fittings, valves, etc., to provide a complete installation as indicated and as specified. Install piping to allow service and maintenance.

D. Provide humidity condensate drain with P-trap and route condensate piping to floor drain or as otherwise indicated on the drawings. Trap shall be adequately sized to properly drain condensate.

E. Install remote thermostat and all control wiring.

END SECTION

SECTION 238136
VARIABLE REFRIGERANT VOLUME AIR CONDITIONING

PART 1 - GENERAL

1.1 SUMMARY

A. The variable refrigerant volume (VRV) air conditioning system shall consist of multiple fan coil units, branch controller boxes, piping joints and headers and heat recovery condensing outdoor units all interconnected with a refrigeration distribution system using PID control. The outdoor units are direct expansion (DX), air-cooled heat recovery condensing units with variable speed driven compressors using R-410A refrigerant. All zones are each capable of operating separately with individual temperature control.

1.2 SUBMITTALS

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

B. Shop Drawings: 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. Furnished specialties and accessories.
3. Rated performance including discharge velocities and sound power characteristics and external static pressure capabilities.
4. Electrical power requirements, including voltage, phase and wiring configuration.
5. Electrical characteristics denoting disconnecting means locations.
6. Power diagrams and wiring diagrams (control and power).

C. Operation and maintenance data.

D. Field quality control reports.

E. Warranty: Sample of special warranty.

1.3 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”.

C. ASHRAE/IESNA Compliance: Applicable requirements to ASHRAE/IESNA 90.1-2013.

D. The units shall be listed by Electrical Laboratories (ETL) and bear the cETL label.

E. Performance: The outdoor units must meet or exceed the heating design capacities and cooling design capacities listed in the equipment schedule at the design outdoor ambient temperature and performance must be corrected for defrost.

1.4 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of VRV system that fail in materials or workmanship within specified warranty period.

1. Warranty period:

a. For all parts and labor: One (1) year from the date of Substantial Completion.
b. For compressor: Five (5) years from the date of Substantial Completion parts only warranty after the first year.

1.5 COORDINATION

A. Coordinate size, location and connection details with roof curbs, equipment supports and roof penetrations specified in Division 07 Section "Roof Accessories".

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Daikin AC.
2. LG.
3. Mitsubishi.
4. Trane.

2.2 HEAT RECOVERY CONDENSING UNIJTS

A. The heat recovery condensing units (HRCUs) shall be factory assembled and pre-wired with all necessary electronic and refrigerant controls. The refrigeration circuit of the condensing unit shall consist of scroll compressors, motors, fans, condenser coil, electronic expansion valves, solenoid valves, 4-way valve, distribution headers and capillaries, filters, shutoff valves, oil separators, service ports and refrigerant regulator.

B. The outdoor unit can be wired and piped with outdoor unit access from the left, right, rear or bottom.

C. The sound pressure level standard shall be no greater than 63 dB(A) at a distance of 10 feet on the roof.

D. The system will automatically restart operation after a power failure and will not cause any settings to be lost.

E. The unit shall incorporate an auto-charging feature and a refrigerant charge check function.

F. The following safety devices shall be included on the condensing unit, high pressure switch, control circuit fuses, fusible plug, overload relay, inverter overload protector, thermal protectors for compressor and fan motors, overcurrent protection for the inverter and anti-recycling timers.

G. To ensure the liquid refrigerant does not flash when supplying to the various fan coil units, the circuit shall be provided with a sub-cooling feature.

H. Oil recovery cycle shall be automatic occurring 2 hours after start of operation and then every 8 hours of operation.

I. The outdoor unit shall be capable of heating operation at -10 deg. F dry bulb ambient temperature without additional low ambient controls.

J. Unit Cabinet: The outdoor unit shall be completely weatherproof and corrosion resistant. The unit shall be constructed from rust-proofed mild steel panels coated with a baked enamel finish.

K. Fan:

1. The condensing unit shall consist of one or more propeller type, direct driven fan motors that have multiple speed operation via a digitally commutating inverter.
2. The condensing unit fan motor shall have multiple speed operation of the DC (digitally commutating) inverter type and be of high external static pressure. The fan shall be capable of providing 0.32 in. wg pressure.
3. The fan shall have a vertical discharge configuration.
4. The fan motor shall have inherent protection and permanently lubricated bearings.
5. The fan motor shall be provided with a fan guard to prevent contact with moving parts.

L. Condenser Coil:

1. The condenser coil shall be manufactured from copper tubes expanded into aluminum fins to form a mechanical bond.
2. The heat exchanger coil shall be of a waffle louver fin and rifled bore tube design to ensure high efficiency performance.

M. Compressor:

1. The inverter scroll compressors shall be variable speed controlled which is capable of changing the speed to follow the variations in total cooling and

heating load as determined by the suction gas pressure as measured in the condensing unit. In addition, samplings of evaporator and condenser temperatures shall be made so that the high/low pressures detected are read every 20 seconds and calculated. With each reading, the compressor capacity (INV frequency or STD ON/OFF) shall be controlled to eliminate deviation from target value.

2. The inverter driven compressor in each condensing unit shall be of highly efficient reluctance DC (digitally commutating), hermetically sealed scroll “G-type” with a maximum speed of 6,480 rpm.
3. Neodymium magnets shall be adopted in the rotor construction to yield a higher torque and efficiency in the compressor instead of the normal ferrite magnet type. At complete stop of the compressor, the neodymium magnets will position the rotor into the optimum position for a low torque start.
4. The capacity control range shall be as low as 6% to 100%.
5. Each non-inverter compressor shall also be of the hermetically sealed scroll type.
6. Each compressor shall be equipped with a crank case heater, high pressure safety switch and internal thermal overload protector.
7. Oil separators shall be standard with the equipment together with an intelligent oil management system.
8. The compressor shall be spring mounted to avoid the transmission of vibration.
9. Units sized under 12 tons shall contain a minimum of 1 inverter driven compressor. In the case of multiple condenser modules, conjoined operation hours of the compressors shall be balanced by means of the duty cycling function, ensuring sequential starting of each module at each start/stop cycle, completion of oil return and completion of defrost for every 8 hours.

N. Electrical:

1. The unit electrical power shall be [**208**] [**480**] volt, 3 phase, 60 Hertz.
2. The control voltage between the indoor and outdoor unit shall be 16 VDC shielded, stranded 2 conductor cable.

2.3 BRANCH CONTROLLER BOX

A. Branch controller (BC) boxes shall be factory assembled, wired, piped and run tested.

B. When simultaneously heating and cooling, the units in heating mode shall energize their sub-cooling solenoid valve.

C. Unit Cabinet:

1. These units shall have a galvanized steel plate casing.
2. Each cabinet shall house multiple refrigeration control valves and a liquid gas separator.
3. The cabinet shall contain a tube in the tube heat exchanger.
4. The unit shall have sound absorption thermal insulation material made of flame and heat resistant foamed polyethylene.
5. Nominal sound pressure levels while operating shall be no greater than 43 dB (A).
6. Nominal sound pressure levels while stopping shall be no greater than 32 dB (A).

7. The cabinet shall have a condensate drain connection if required by the manufacturer.

D. Refrigerant Valves:

1. The unit shall be furnished with five (5) electronic expansion valves to control the direction of refrigerant flow.
2. The refrigerant connections must be of the braze type.

E. Electrical:

1. The unit electrical power shall be 208/230 volts, 1 phase, 60 Hertz.
2. The control voltage between the indoor and outdoor unit shall be 16 VDC, non-shielded, 2 conductor cable.

2.4 DUCTED FAN COIL UNITS

A. The unit shall be a ceiling concealed ducted indoor fan coil design that mounts above the ceiling with a 2-position, field adjustable return and a fixed horizontal discharge supply and shall have a modulating linear expansion device. The unit shall support individual control using DDC controllers.

B. The unit shall be factory assembled, wired and run tested. Contained within the unit shall be all factory wiring, piping, electronic modulating linear expansion device, control circuit board and fan motor. The unit shall have a self-diagnostic function, 3-minute time delay mechanism and an auto restart function. Indoor unit and refrigerant pipes shall be charged with dehydrated air before shipment from the factor.

C. Unit Cabinet:

1. The unit shall be ceiling-concealed, ducted.
2. The cabinet panel shall have provisions for a field installed filtered outside air intake.

D. Fan:

1. The unit fan shall be an assembly with a direct driven fan(s) by a single motor. Multiple fans may be used for higher capacity units.
2. The indoor fan shall be statically and dynamically balanced and run on a motor with permanently lubricated bearings.
3. The unit fan shall have capacity for a ducted air outlet system and ducted return air system to be field installed.

E. Filter: Return air shall be filtered by means of a factory installed MERV 5 filter installed at rear of unit.

F. Coil:

1. The indoor coil shall be of non-ferrous construction with smooth plate fins on copper tubing.
2. The tubing shall have inner grooves for high efficiency heat exchanger.
3. All tube joints shall be brazed with phos-copper or silver alloy.
4. The coils shall be pressure tested at the factory.
5. A condensate pan and drain shall be provided under the coil.
6. The condensate shall be pumped with integral condensate pump capable of at least 20” lift.
7. Both refrigerant lines to the units shall be insulated.

G. Electrical: The unit electrical power shall be 208 volt, 1 phase and 60 Hertz.

2.5 CONTROLS

A. Operation of the system shall permit both individual cooling and individual heating of each fan coil simultaneously. Each fan or group of fan coils shall be able to provide set temperature independently via a local remote controller and through a BMS interface.

B. Branch controller (BC) boxes shall be located as shown on the drawings. The BC box shall consist of electronic expansion valves, refrigerant control piping and electronics to facilitate communications between the BC box and main processor and between the BC box and fan coils. The BC box shall control the operational mode of the subordinate fan coils.

1. All indoor units shall maintain the settings for: temperature setpoint, start/stop status, operating mode, fan speed, airflow direction in on-volatile memory each time they are changed. These settings shall not be lost upon a power loss event.
2. All indoor unit settings shall be adjustable through the BMS interface.
3. The entire system shall automatically restart upon a power loss event.
4. All indoor units shall be auto addressing.

C. Control Wiring Requirements:

1. All control wiring shall be done per the control wiring drawings provided on the drawings and in manufacturer’s installation instructions.
2. All control wiring shall be 16 awg, 2 conductor and stranded shielded cable.
3. All control voltage transformers shall be provided by the VRF equipment supplier.

D. Wall Mounted Temperature Sensor:

1. In all spaces, a wall mounted space temperature monitor/controller shall be mounted 46” above the finished floor to the center of the controller.
2. This monitor shall wire to the indoor unit that serves this space. Ducted units shall sense the temperature of the space at the wall sensor. Non-ducted units shall sense the temperature of the space on the fan coil unit return air.

E. Change Operation:

1. Start/stop, operation mode, temperature setting, fan speed and airflow direction.
2. Monitoring: Status, malfunction identification, malfunction code, filter sign, operation mode, temperature setting, fan speed and airflow direction.
3. Disable/enable wall mounted temperature sensors.
4. Allow user to define daily and weekly schedules.
5. Disable/enable contact based on occupied/unoccupied status.

F. BMS Interface: System shall be capable of full integration for all monitoring and setpoint modifications.

2.6 HVAC EQUIPMENT REQUIREMENTS

A. The equipment manufacturers shall bid job intent as described in specifications and drawings. The bid shall include all costs associated with manufacturer specific refrigerant piping, control wiring, electrical wiring and equipment cost. The equipment supplier shall provide to the mechanical engineer for review and to the bidding mechanical contractor a complete equipment data package. This package shall include, but is not limited to, equipment capacities at the design condition, power requirements, indoor units CFM/static pressures, fan curves, installation requirements and physical dimensions. All systems shall meet or exceed the heating and cooling design capacities at the design outdoor ambient temperature. Performance must be corrected for defrost.

B. The equipment supplier shall furnish a complete drawing package to the mechanical contractor prior to bid day for bidding and installation. The HVAC and electrical series design documents will be made available in electronic format for use by the equipment supplier in preparing their drawings. The equipment supplier shall provide all necessary refrigerant piping drawings, control wiring drawings and electrical wiring drawings.

C. The equipment supplier shall draft all piping circuits, components, overall building control schematic, detailed control wiring diagrams, system details and schedules for their system. The drawings shall convey all requirements to successfully install the equipment supplier’s system.

D. The submitted documents shall be complete system designs and show no less information than the HVAC equipment/controls contract bid documents.

PART 3 - EXECUTION

3.1 INSTALLATION

A. The system shall be installed by a factory trainer contractor.

B. Refrigerant piping distribution fittings and headers shall be furnished by the VRV manufacturer for contractor installation.

C. Install units’ level and plumb.

D. Install evaporator fan components using manufacturer's standard mounting devices securely fastened to building structure.

E. Install roof mounted, compressor/condenser components on equipment supports specified in Division 07 Section "Roof Accessories". Anchor units to supports with removable, cadmium-plated fasteners.

F. Install ground mounting, compressor/condenser components on 4-inch (100 mm) thick, reinforced concrete base, 4 inches (100 mm) larger on each side of the unit. Concrete reinforcement and formwork are specified in Division 03 Section "Cast-In-Place Concrete". Coordinate anchor installation with concrete base.

G. Install and connect precharged refrigerant tubing to component's quick connect fittings. Install tubing to allow access to unit.

H. Install seismic restraints.

I. Install fan coil units on restrained, spring isolators with a minimum static deflection of 1 inch (25 mm).

J. High/low pressure gas line, liquid and suction lines must be individually insulated between the outdoor and indoor units.

3.2 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings and specialties.

B. Where piping is installed adjacent to the unit, allow space for service and maintenance of unit.

3.3 FIELD QUALITY CONTROL

A. 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.

B. Tests and Inspections:

1. Leak test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
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. Remove and replace malfunctioning units and retest as specified above.

D. Prepare test and inspection reports.

3.4 DEMONSTRATION

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

1. The manufacturer shall provide 24 hours of on-site Owner training to be scheduled by the Owner. Sixteen hours (16) to be provided at startup and eight (8) hours to be provided 30 days later. The manufacturer shall provide two (2) days of training at the manufacturer's training center. The training shall include system diagnostics and troubleshooting and shall be a hands-on training class using a working system in the training center.

END OF SECTION

SECTION 238219
FAN COIL UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes fan-coil units and accessories.

1.3 DEFINITIONS

A. BAS: Building automation system.

1.4 SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories.

B. LEED 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, 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. Wiring Diagrams: Power, signal, and control wiring. Differentiate between manufacturer installed and field installed wiring.
2. Manufacturer's color charts showing full range of color sections available.

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.
f. Electrical conduit.
g. Smoke detectors, exit signs, security systems and other system components.

6. Perimeter moldings for exposed or partially exposed cabinets.

E. Manufacturer Seismic Qualification Certification: Submit certification that fan-coil units, 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 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.

F. Field quality-control test reports.

G. Operation and Maintenance Data: For fan-coil units to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 1 Section "Operation and Maintenance Data," include the following:

1. Maintenance schedules and repair part lists for motors, coils, integral controls, and filters.

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, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

C. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1-2004, Section 6 - "Heating, Ventilating, and Air-Conditioning."

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.

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. Final fan belts: Two (2) sets for belt-driven fan. Field installed and sized by the Testing, Adjusting, and Balancing Contractor. Sized as required to deliver the necessary airflow through the system accounting for all system losses.
2. Final fan sheave: One (1) set for each belt-driven fan. Field installed and sized by the Testing, Adjusting, and Balancing Contractor. Sized as required to deliver the necessary airflow through the system accounting for all system losses.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Airtherm; a Mestek Company.
2. Carrier Corporation.
3. Environmental Technologies, Inc.
4. Williams
5. International Environmental Corporation.
6. Johnson Controls.
7. Daikin International.
8. Trane.

B. Description: Factory-packaged and -tested units rated according to AHRI 440, ASHRAE 33, and UL 1995.

C. Coil Section and Fan Section Insulation: [**1/2-inch thick, matte finish, closed cell foam**], [**1/2-inch fiberglass with foil faced lining**] complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916. [**Provide solid metal inner lining over all insulation exposed to the airstream.**]

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.

D. Main and Auxiliary Drain Pans: **[Insulated galvanized steel with plastic liner.] [Stainless steel.]**. Fabricate pans and drain connections to comply with ASHRAE 62.1. Include secondary drain connection

E. Chassis: Galvanized steel where exposed to moisture. Floor-mounting units shall have leveling screws.

F. Cabinet: Steel with [**factory prime coating, ready for field painting**] [**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 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- (3.2-mm-) thick, aluminum, rain-resistant louver and box with integral eliminators and bird screen.

1. Louver Configuration: [**Horizontal**] [**Vertical**], rain-resistant louver.
2. Louver Material: Aluminum.
3. Bird Screen: 1/2-inch (13-mm) 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**] [**custom**] colors.

H. Outdoor-Air Damper: Galvanized-steel blades with edge and end seals and nylon bearings; with [**electronic**] [**pneumatic**], [**two-position**] [**modulating**] actuators.

I. Filters: Minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

1. Washable Foam: 70 percent arrestance and 3 MERV.
2. Glass Fiber Treated with Adhesive: 80 percent arrestance and 5 MERV.
3. Pleated Cotton-Polyester Media: 90 percent arrestance and 7 MERV.

J. 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. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

K. 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, multi-speed; 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 plug connection.

L. Control devices and operational sequences are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."

M. BAS Interface Requirements:

1. Interface relay for scheduled operation.
2. Interface relay to provide indication of fault at the central workstation.
3. Provide [**BACnet**] [**or**] [**LonWorks**] interface for central BAS workstation for the following functions:

    a. Adjust set points.
    b. Fan-coil-unit start, stop, and operating status.
    c. Data inquiry, including [**outdoor-air damper position,**]supply- and room-air temperature[**and humidity**].
    d. Occupied and unoccupied schedules.

N. Electrical Connection: Factory wire motors and controls for a single point electrical connection to power source. Mount components within a steel enclosure box with a removable cover.

1. Factory mounted transformer for control voltage on electric and electronic control units with terminal strip in control box for field wiring of thermostat and power source. Minimum 50VA transformer size.
2. Wiring terminations: Fan and controls to terminal strip and terminal lugs to match quantities, sizes, and materials of branch circuit conductors. Enclose terminal lugs in terminal box sized according to NEMA 70.
3. Disconnect switch: Factory mounted, non-fused, disconnect switch. Single point power connection.
4. Refer to Drawings for additional accessories.

5. Fan speed controller: Unit mounted minimum 3 speed control switch with off position.
6. Fan speed controller: Unit mounted adjustable from 60% to 120% of scheduled conditions.

7. Condensate pan high level switch wired to shutdown fan.

O. Ducted Fan Coil Units:

1. Cabinets: Steel with baked-enamel finish in manufacturer's standard paint color.

a. Supply-Air Plenum: Sheet metal plenum finished and insulated to match the chassis[**with mill-finish, aluminum, double-deflection grille**].
b. Return-Air Plenum: Sheet metal plenum finished to match the chassis.

c. Mixing Plenum: Sheet metal plenum finished and insulated to match the chassis with outdoor- and return-air, formed-steel dampers.
d. Dampers: Galvanized steel with extruded-vinyl blade seals, flexible-metal jamb seals, and interlocking linkage.

2. Indoor Refrigerant Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and brazed joints at fittings. Comply with AHRI 210/240, and leak test to minimum 450 psig (3105 kPa) for a minimum 300-psig (2070-kPa) working pressure. Include thermal expansion valve.

3. Direct-Driven Fans: Double width, forward curved, centrifugal; with permanently lubricated, multi-speed motor resiliently mounted in the fan inlet. Aluminum or painted steel wheels and painted steel or galvanized steel fan scrolls.

4. 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. Adjustable sheaves. Aluminum or painted-steel wheels, and painted-steel or galvanized-steel fan scrolls.

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 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][spring]** hangers. Vibration isolators are specified in other Division 23 Sections.

D. Install new filters in each fan-coil unit within two weeks after Substantial Completion.

E. Do not operate fan coil units until Substantial Completion except for test, adjust, and balance. Turn off units after test, adjust, and balance is complete. Drain coils in vestibule units to prevent freezing of coils.

F. Install all fan coil units such that the bottom of the fan coil unit is no more than 12” above the finished ceiling. Maintain access to electrical disconnects. Maintain access to fan motors. Maintain access to filter housings. Do not install utilities below the fan coil unit.

3.3 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.
3. Connect condensate drain to 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 "Grounding and Bonding for Electrical Systems."

D. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

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 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.

3.6 CLEANING

A. After installing units, inspect unit cabinet for damage to finish. Remove paint splatters and other spots, dirt and debris. Repair damaged finish to match original finish.

B. After installing units, clean fan coil units internally according to manufacturer’s written instructions.

3.7 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain fan-coil units. Refer to Division 1 Section "Demonstration and Training."

END OF SECTION

SECTION 238239
UNIT HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Cabinet unit heaters with centrifugal fans [**electric-resistance heating**] coils.
2. Propeller unit heaters with [**electric-resistance heating**] coils.
3. Wall and ceiling heaters with propeller fans and electric-resistance heating coils.
4. Combustion air heaters with steam 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, operating characteristics, furnished specialties, and accessories for each product indicated.

B. LEED Submittal:

1. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, 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 piping valves and specialties.
6. Location and arrangement of integral controls.
7. 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.

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 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 ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

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

1.6 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. Cabinet Unit Heater Filters: Furnish two spare filter(s) for each filter installed.

PART 2 - PRODUCTS

2.1 CABINET UNIT HEATERS

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

1. Electric cabinet heaters:

a. Berko Electric Heating.
b. Chromalox.
c. Indeeco.
d. Markel Products Company.
e. Q-Mark.
f. Trane.

2. Hydronic cabinet heaters:

a. Airtherm.
b. Carrier.
c. International Environmental Corporation.
d. Rosemex.
e. Sigma Products.
f. Sterling.
g. Trane.

B. Description: A factory-assembled and -tested unit complying with AHRI 440.

1. Comply with UL 2021.

C. Coil Section Insulation: ASTM C 1071; surfaces exposed to airstream shall be aluminum-foil facing to prevent erosion of glass fibers.

1. Thickness: 1 inch (25 mm).
2. Thermal Conductivity (k-Value): 0.26 Btu x in./h x sq. ft. at 75 deg F (0.037 W/m x K at 24 deg C) mean temperature.
3. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.
4. Adhesive: Comply with ASTM C 916 and with NFPA 90A or NFPA 90B.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Cabinet: Steel with **[factory prime coating, ready for field painting] [baked-enamel finish with manufacturer's standard paint, in color selected by Architect] [baked-enamel finish with manufacturer's custom paint, in color selected by Architect].**

1. Vertical Unit, Exposed Front Panels: Minimum 0.0528-inch- (1.35-mm-) thick, galvanized, sheet steel, removable panels with channel-formed edges secured with tamperproof cam fasteners. Front grille air inlet and air outlet.
2. Horizontal Unit, Exposed Bottom Panels: Minimum 0.0528-inch- (1.35-mm-) thick, galvanized, sheet steel, removable panels secured with tamperproof cam fasteners and safety chain. Bottom panel grille for air inlet and air outlet.
3. Recessing Flanges: Steel, finished to match cabinet.
4. Control Access Door: Key operated.
5. Airflow configuration:

a. Air inlet: Front of cabinet, lower portion.
b. Air discharge: Front of cabinet, upper portion.

6. Base: Minimum 0.0528-inch- (1.35-mm-) thick steel, finished to match cabinet, 4 inches (100 mm) high with adjustable leveling bolts.

7. Extended Piping Compartment: 8-inch- (200-mm-) wide piping end pocket.
8. False Back: Minimum 0.0428-inch- (1.1-mm-) thick steel, finished to match cabinet.

E. Filters: Minimum arrestance according to ASHRAE 52.1 and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

1. Glass Fiber Treated with Adhesive: 80 percent arrestance and 5 MERV.
2. Pleated: 90 percent arrestance and 7 MERV.
3. Cleanable aluminum mesh media, 1/2-inch thick.

F. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from 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. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

G. Fan and Motor Board: Removable.

1. Fan: Forward curved, [**high static,**] 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, multi-speed; resiliently mounted on motor board. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."
3. Wiring Terminations: Connect motor to chassis wiring with plug connection.
4. Provide motor fusing for fans in units with electric heat.

H. Basic Unit Controls:

1. Control voltage transformer.

2. [**Wall-mounting**] [**Unit-mounted**] thermostat/sensor with the following features.

a. Heat-off switch.
b. Fan on-auto switch.
c. Manual fan speed switch, three speed, unit mounted and wired.
d. Adjustable deadband.
e. Concealed set point.
f. Concealed indication.
g. Deg F (Deg C) indication.
h. Two pole thermostat with an OFF position on the detail.

3. Unoccupied period override push button.

4. Data entry and access port.

a. Input data includes room temperature, and occupied and unoccupied periods.
b. Output data includes room temperature, supply-air temperature, entering-water temperature, operating mode, and status.

I. BAS Interface Requirements:

1. Interface relay for scheduled operation.

2. Interface relay to provide indication of fault at central workstation.

3. Interface shall be compatible for central BAS workstation and include the following functions:

    a. Adjust set points.
    b. Cabinet unit heater start, stop, and operating status.
    c. Data inquiry, including supply-air and room-air temperature.
    d. Occupied and unoccupied schedules.

J. Electrical Connection: Factory wire motors and controls for a single point electrical connection to power source. Provide factory mounted non-fused disconnect switch.

2.2 PROPELLER UNIT HEATERS

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

1. Electric heaters:

    a. Berko Electric Heating.
    b. Chromalox.
    c. Indeeco.
    d. Markel Products Company.
    e. Q-Mark.

B. Description: An assembly including casing, coil, fan, and motor in **[vertical] [and] [horizontal]** discharge configuration with adjustable discharge louvers. Minimum 18 gage steel casing.

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**] [**custom**] 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 ASHRAE 62.1.

H. Discharge Louver: Adjustable fin diffuser for horizontal discharge units and conical diffuser for vertical discharge units.

I. 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 (4 mm). Element ends shall be enclosed in terminal box. Fin surface temperature shall not exceed 550 deg F (288 deg C) at any point during normal operation.

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.

J. Fan: Propeller type with aluminum wheel directly mounted on motor shaft in the fan venturi. Static and dynamic balance. Include fan guard.

K. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Motor Type: Permanently lubricated, multispeed.
2. Automatic reset thermal overload protection.

L. Control Devices:

1. Unit-mounted, fan-speed switch.
2. Unit-mounted thermostat, two pole thermostat with an OFF position on the dial.
3. All internal wiring shall be by manufacturer; motor prewired to an electrical junction box.
4. Mount electrical components in galvanized enclosure with removable cover.

M. Provide single point electrical connection to power source with factory mounted non-fused disconnect switch.

2.3 WALL AND CEILING HEATERS

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

1. Berko Electric Heating; a division of Marley Engineered Products.
2. Chromalox, Inc.; a division of Emerson Electric Company.
3. Indeeco.
4. Markel Products; a division of TPI Corporation.
5. Marley Electric Heating; a division of Marley Engineered Products.
6. QMark Electric Heating; a division of Marley Engineered Products.

B. Description: An assembly including chassis, electric heating coil, fan, motor, and controls. Comply with UL 2021.

C. Cabinet:

1. Front Panel: Stamped-steel louver with removable panels fastened with tamperproof fasteners.
2. Finish: Baked enamel over baked-on primer with manufacturer's standard color selected by Architect, applied to factory-assembled and -tested wall and ceiling heaters before shipping.
3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Surface-Mounting Cabinet Enclosure: Steel with finish to match cabinet.

E. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from expansion noise and hum, embedded in magnesium oxide refractory and sealed in corrosion-resistant metallic sheath. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware, and limit controls for high temperature protection. Provide integral circuit breaker for overcurrent protection.

F. Fan: Aluminum propeller directly connected to motor.

1. Motor: Permanently lubricated, multispeed. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

G. Controls: Unit-mounted thermostat, two pole thermostat with an OFF position on the dial.

H. Electrical Connection: Factory wire motors and controls for a single field connection with disconnect switch.

2.4 COMBUSTION AIR HEATERS

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

1. Armstrong.
2. L.J. Wing.
3. Marlo.

B. Description:

1. A factory assembled unit to heat outside air for the boiler room. Unit shall be capable of maintaining discharge air temperature regardless of fluctuations in inlet air temperature. Each unit will consist of a heater section containing an integral face and bypass coil consisting of built-in multiple alternate finned heating elements and bypasses. Separate dampers shall control the airflow through these face and bypass sections. Each set of dampers shall be interlocked and controlled by a separate [**electric**] damper motor. Actuator provided by the [**unit manufacturer.**][**ECC.**] Finned heating elements shall be fabricated of seamless return bend type 3/8" o.d. copper tubes with rectangular 0.010" thick aluminum fins. Each tube shall be secured to the headers by a brazed joint. The opposite end of the tubes shall be secured by channel shaped retainers that permit expansion and contraction. Finned elements shall be factory tested with 200 psig steam and 500 psig hydrostatic pressure. Unit shall have a propeller type fan driven by a TEFC motor with characteristics as scheduled. Casing and discharge shall be constructed of galvanized sheet metal.

C. Controls:

1. Unit shall be controlled by the Building Automation System with a room thermostat and overriding low limit thermostat to prevent the unit’s discharge temperature from falling below the desired minimum.

D. Discharge – Horizontal Units:

1. Unit shall have a discharge consisting of horizontal and vertical vanes for adjustable airflow projection and spread. Discharge shall be attached to and supported by flanged brackets bolted to the outlet of the unit for easy vane positioning.

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 [**piping and**] 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 wall boxes in finished wall assembly; seal and weatherproof. Joint-sealant materials and applications are specified in Division 7 Section "Joint Sealants."

B. Install cabinet unit heaters to comply with NFPA 90A.

C. Install propeller unit heaters level and plumb.

D. Suspend cabinet unit heaters from structure with elastomeric hangers and seismic restraints. Vibration isolators and seismic restraints are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

E. Suspend propeller unit heaters from structure with all-thread hanger rods and spring hangers. Hanger rods and attachments to structure are specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment." Vibration hangers are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

F. Install wall-mounting thermostats and switch controls in electrical outlet boxes at heights to match lighting controls. Verify location of thermostats and other exposed control sensors with Drawings and room details before installation.

G. Install new filters in each fan-coil unit within two weeks of Substantial Completion.

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. Connect piping to cabinet unit heater's factory, hot-water piping package. Install the piping package if shipped loose.

D. Connect supply and return ducts to cabinet unit heaters with flexible duct connectors specified in Division 23 Section "Air Duct Accessories."

E. Comply with safety requirements in UL 1995.

F. Unless otherwise indicated, install union and gate or ball valve on supply-water connection and union and calibrated balancing valve on return-water connection of unit heater. Hydronic specialties are specified in Division 23 Section "Hydronic Piping."

G. Unless otherwise indicated, install union and gate or ball valve on steam-supply connection and union, strainer, steam trap, and gate or ball valve on condensate-return connection of unit heater. Steam specialties are specified in Division 23 Section "Steam and Condensate Heating Piping."

H. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

I. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

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. Refer to Division 1 Section "Demonstration and Training."

END OF SECTION