

2.9 ACCESSORIES

A. Pipe Alignment Guides:

1. Two piece welded steel with enamel paint, bolted, with spider to fit standard pipe, frame with four mounting holes.
2. Clearance for minimum one inch thick insulation.
3. Minimum three inches travel.

2.10 EXPANSION TANKS

A. General:

1. Performance as scheduled.
2. Full acceptance flexible heavy duty butyl removable bladder or flexible heavy duty butyl diaphragm sealed into tank, as scheduled.

B. Construction:

1. Designed, tested and stamped in accordance with ASME SEC 8-D standards; supplied with National Board Form U-1.
2. Welded steel shell and base.
3. Forged steel system connections.
4. Steel support stand.

C. Ratings:

1. Working pressure: 125 PSIG.
2. Working Temperature: 240 degrees F.
3. Precharge: As Scheduled.

D. Accessories:

1. Pressure gage.
2. Air charging fitting.
3. Tank drain isolation valve.
4. System connection isolation valve.

E. Model and size: As scheduled.

F. Manufacturers: Taco, Amtrol, Armstrong, Bell & Gossett, or equal.

2.11 AIR VENTS

A. Coin operated vent: Manual low profile vent for use in baseboard and other enclosures where automatic vent will not fit. 150 PSIG working pressure, 212 degrees F. operating temperature. Bell & Gossett No. 4V or approved equal.

B. Float Type:

1. Brass or semi-steel body, copper, polypropylene, or solid non-metallic float, stainless steel valve and valve seat; suitable for system operating temperature and pressure; with isolating valve.
2. Iron body and cover, float, bronze pilot valve mechanism suitable for system operating temperature and pressure; with isolating valve.
3. Operating pressure 150 PSIG, 250 deg F maximum temperature, intended for use in hot or cold lines. Provide ball type isolation valves for air vents that do not have integral shut off valves.
4. Manufacturers: Spirotherm Spirotop, Honeywell EA791004, or equal.

C. Disc Type:

1. Designed to be replaced without removal from line, with built-in check valve.
2. Limited to baseboard, unit ventilators, cabinet unit heaters, convectors, and elsewhere where air vent must be installed in a cabinet or enclosure, unless other type detailed on drawings.
3. Maximum working pressure: 50 PSIG.
4. Manufacturer: Hoffman No. 500, or equal.

2.12 AIR SEPARATORS

A. Construction:

1. Designed, tested and stamped in accordance with ASME standards.
2. Welded steel shell with flanged connections.
3. Entering velocity not to exceed 4 feet per second.
4. Internal copper wound coalescing eliminator.
5. Top venting chamber with integral full port float actuated brass venting mechanism.
6. Side tap with valve to flush dirt or liquids and quick air bleed.

B. Ratings:

1. Working pressure: 150 PSIG (minimum).
2. Working Temperature: 125 degrees F (minimum).
3. Capable of removing 100 percent of free air, 100 percent of entrained air, and 99.6 percent of dissolved air in the system fluid.
4. Dirt separation of at least 80 percent of all particles larger than 30 micron and larger within 100 passes.

C. Size: As scheduled.

D. Manufacturer: Spirotherm VDX (Basis of Design), B&G CRS, Wessels.

2.13 STRAINERS

A. Size two inch and under:

1. Screwed brass or iron body for 175 PSIG working pressure.
2. Y pattern with 1/32-inch stainless steel perforated screen.

- B. Size 2-1/2 inches to four inches:
 - 1. Flanged or grooved iron body for 175 PSIG working pressure.
 - 2. Y pattern with 3/64-inch stainless steel perforated screen.
- C. Size five inches and larger:
 - 1. Flanged or grooved iron body for 175 PSIG working pressure.
 - 2. Basket pattern with 1/8-inch stainless steel perforated screen.
- D. Manufacturers: Metraflex, Armstrong, Crane, Hayward, Watts Regulator, Hoffman, Sarco.

2.14 AUTOMATIC FLOW LIMITING AND ISOLATION VALVES

- A. Supply pipe side: Brass alloy body with stainless steel flow cartridge assembly, integral ball valve, 20 mesh strainer element, two pressure/temperature test valves and drain valve with hose bibb adapter and end cap. Body design allows removal of flow cartridge without disturbing piping connections. Threaded sweat adapter inlet. Union with sweat adapter outlet.
- B. Return pipe side: Forged brass body with integral ball valve, pressure/temperature test valve and manual air vent. Union with sweat adapter inlet. Threaded sweat adapter outlet.
- C. Calibration: Control flow within five percent of selected rating, over operating pressure range of at least 10 times minimum pressure required for control. Provide three operating pressure ranges with a minimum range requiring less than 3.5 PSID to actuate flow control cartridge.
- D. Flow Control Cartridge: Stainless steel one piece cartridge with segmented port design and full travel linear coil spring.
- E. Provide supply and return components packaged as a system and labeled in accordance with the equipment schedule tag to match terminal heating unit served.
- F. Manufacturer: Griswold Controls, Bell & Gossett, or approved equal.

2.15 BALANCING VALVES

- A. Provide calibrated plug or ball valve type balancing valves with self-sealing quick connect pressure taps, scale and locking device. Include schedule with submittal.
- B. Manufacturers: Bell & Gossett, Taco, or equal.

2.16 FLUSHING AGENT

- A. Synthetic organic dispersant manufacturer: CH2O, Product 6149 or approved equal.

2.17 WATER TREATMENT

- A. Hydronic loop treatment manufacturer: CH2O, Product 6439 or approved equal.

2.18 GLYCOL SYSTEMS

- A. Provide equipment and products specifically designed and approved for continuous operation with the glycol solution specified.
- B. Glycol Solution:
 - 1. Inhibited propylene glycol solution premixed to 50 percent by volume for use with hydronic heating systems.
 - 2. Fluid analysis test kit.
 - 3. Manufacturer: Dow Chemical Company Dowfrost. No substitutes.
- C. Automatic Glycol Make-up System:
 - 1. Provide packaged glycol make-up system as scheduled with single point electrical connection.
 - 2. Fill glycol make-up tank one half full with clean solution after testing and final system check out has been completed.

PART 3 - EXECUTION

3.1 INSTALLERS

- A. Installer: Perform work by experienced personnel previously engaged in hydronic system construction and under the supervision of a qualified installation supervisor.

3.2 PREPARATION

- A. Protection of In-Place Conditions: Cover equipment and plug piping connections to protect components from construction dirt and debris.
- B. Surface Preparation:
 - 1. Prior to installation of equipment, verify concrete housekeeping pads are complete and properly sized for equipment mounting.
 - 2. Prior to installation of piping and equipment, verify that shop drawings are approved, and locations and routing have been coordinated with the work of other trades.

3.3 INSTALLATION

- A. Special Techniques:

1. Install equipment in accordance with manufacturer's instructions and requirements of the codes specified herein.
2. Provide finished products with protective covers during balance of construction.
3. Provide accessible ball type isolation valves at major piping branches, and on main lines as shown, and at terminal devices. Provide drains and manual vents at main line and branch line valves to facilitate draining and filling piping sections. Provide caps on drain outlets.
4. Access Doors: Provide appropriate size and install such that hydronic system features are readily accessible and maintainable.
5. Install balancing valves and automatic flow limiting valves to be accessible and adjustable.
6. Install piping to maintain headroom, conserve space, and not interfere with use of space.
7. Use of bullhead tee with opposed flow, double inlet configuration not allowed.
8. Provide clearance in hangers and from structure and other equipment for installation of insulation and access to valves and fittings.
9. Where pipe support members are welded to structural building framing, scrape, brush clean, and apply one coat of zinc rich primer to welding.
10. Prepare exposed, unfinished pipe, fittings, supports, and accessories ready for finish painting. Refer to Division 9 - Finishes.
11. Thermal Expansion:
 - a. Install piping to allow for normal thermal expansion and contraction without stressing pipe, joints, or connected equipment.
 - b. Provide anchors where necessary and as shown.
 - c. Provide support and expansion loops, expansion compensators, and alignment guides to suit conditions and as shown on drawings.
 - d. Piping shall be guided and restrained as recommended by the manufacturer.
12. Provide test plugs on both inlet and outlet sides of heat transfer elements to allow measurement of both fluid pressure drop and differential temperature.
13. Install flexible pipe connectors on pipes connected to equipment supported by vibration isolation. Provide line size flexible connectors.
14. Install flexible connectors at right angles to displacement. Install one end immediately adjacent to isolated equipment and anchor the other end. Install in horizontal plane unless indicated otherwise.
15. Provide pipe anchors, offsets, loops and expansion compensators as required to control the expansion of pipelines.
16. Flushing:
 - a. Where hydronic piping installed under this project is connected to an existing hydronic system, provide branch isolation valves and provision for cleaning and flushing consisting of tees with valve, hose fittings and caps immediately adjacent to the branch isolation valves.
 - b. Clean internal surfaces of the completed heating system as follows:
 - 1). Flush hydronic piping to remove black magnetic iron oxide and mill scale from the system.
 - 2). Flush system piping with synthetic organic dispersant to remove grease. Circulate solution through system at 150 degrees F or greater for 12 to 24 hours.

- 3). Repeat process until the system is clean to the satisfaction of the Contracting Agency.
 - 4). Flush system with fresh water as necessary to remove residual cleaning agent.
 - 5). Exercise proper care during flushing and cleaning of systems to make sure no damage is done to equipment, valves, fittings, or Work of other trades. Restore damaged system components or Work of other trades to new or original condition at no additional cost to Owner.
- B. Interface with Other Work: Coordinate and sequence installation of hydronic products with trades responsible for portions of this and other related sections of the Project Manual.

3.4 REPAIR/RESTORATION

- A. Repair any product components broken during installation or startup with replacement parts supplied by the product manufacturer.
- B. Substitute replacement parts from other manufacturers are not acceptable.
- C. Touch-up finished surfaces with touch-up paint provided by the equipment manufacturer.

3.5 SITE QUALITY CONTROL

- A. Non-Conforming Work: Rework required as a result of failure to follow the manufacturer's written installation instructions or to properly coordinate with related Work shall be completed at no additional expense to the Owner.
- B. Manufacturer Services:
 1. Verify units are installed and operational in accordance with the manufacturer's written installation instructions.
 2. Both the Contractor and Manufacturer's Representative(s) shall sign start-up and operational checklist to confirm proper unit installation and operation.
 3. Provide samples of the inhibited propylene glycol solution to the manufacturer for testing using the fluid analysis test kit provided.
 4. The manufacturer of the inhibited propylene glycol solution shall provide free testing of the solution 24 hours after system startup and again 90 days later to verify proper fluid performance for both tests.
 5. Provide one copy of manufacturer's test reports to the Owner. Adjust fluid concentration and/or correct deficiencies as addressed in the report.
- C. Hydronic System Cleaning and Treatment Coordination Meeting:
 1. Conduct a meeting prior to flush cleaning and treatment of the hydronic heating system to discuss cleaning agents, treatment chemicals and procedures to be used. Discuss system fill procedures with inhibited propylene glycol solution.
 2. Participants shall include the Contractor and Subcontractor directly performing the work and the Owner's Maintenance Staff personnel.
 3. Provide one week notice prior to the meeting.

4. Cleaning, filling and treatment of any hydronic system is not permitted until this coordination meeting has been conducted and the Contracting Agency's concerns have been adequately addressed.

D. System fill:

1. After flush cleaning the hydronic heating system, fill the primary system with water and add treatment chemicals to the concentration recommended by the manufacturer. Fill the secondary loop system with inhibited propylene glycol solution as specified.
2. Thoroughly vent the systems to include piping high points and equipment vents (pump casings, air separators, etc.).

E. Site Tests:

1. Hydrostatic Pressure Test:

- a. Make sure hydronic heating system is filled with clean operating fluid. Hydrostatically test system to 100 PSIG. System must hold test pressure for a two hour period with no pressure drop to pass test.
- b. Inspect system during test and repair leaks.
- c. Provide written report indicating that the pressure test has been satisfactorily completed.

2. Operational Test:

- a. Inspect system for proper fluid circulation, sufficient clearance for expansion and contraction of piping and proper system pressure control.
- b. Note and correct discrepancies and deficiencies.
- c. Provide written report indicating that the operational test has been satisfactorily completed.

3. Test results shall be certified in writing as required by General Conditions. Include dates and sections tested, test pressure, test duration, printed names and signatures of person performing the test and Contracting Agency witnessing the test.

- F. Inspection: Arrange for inspections and provide written notice to the Contracting Agency when the entire work or logical portions thereof, is ready for inspection.

- G. Verify penetrations are installed to maintain assembly integrity.

3.6 SYSTEM STARTUP

- A. Start-up and operate hydronic heating systems and equipment in accordance with the manufacturer's written installation and operation manual checklist.

- A. Document start-up and operational checks using the checklist and submit in accordance with submittal requirements.

3.7 ADJUSTING

- A. Adjust functional components for proper operation in accordance with manufacturer's recommendations, or as otherwise directed.
- B. Coordinate and work directly with the Balancing and Testing Agency and the requirements of Section 230593 - Testing, Adjusting and Balancing, to provide systems in proper operating order.
- C. Make corrections and adjustments as required by the Testing, Adjusting and Balancing (TAB) Agency in a timely manner.

3.8 CLEANING

- A. Waste Management: After construction is completed, clean and wipe down exposed surfaces of pumps, piping and appurtenances.

3.9 CLOSEOUT ACTIVITIES

- A. Demonstration: Provide 2 hours of demonstration conducted by authorized factory start-up personnel to the Contracting Agencies authorized maintenance personnel.
- B. Training: Provide 4 hours of operational instruction conducted by authorized factory start-up personnel to the Contracting Agencies authorized maintenance personnel.

END OF SECTION 232113

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PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. In-line circulators.
2. Vertical in-line pumps.

B. Related Sections:

1. 019100 - Commissioning
2. 200000 - Mechanical General Requirements
3. 200529 - Mechanical Hangers and Supports
4. 200548 - Mechanical Vibration and Seismic Control
5. 200553 - Mechanical Identification
6. 204100 - Mechanical Demolition
7. 230593 - Testing, Adjusting and Balancing
8. 232113 - Hydronic Piping and Specialties
9. 235216 - Condensing Boilers and Accessories
10. 253000 - Building Automation System Field Devices
11. 254000 - Variable Speed Drives
12. 255000 - Building Automation System
13. 259000 - Sequence of Operations

1.2 REFERENCES

A. Codes and Standards:

1. See Section 200000 - Mechanical General Requirements.
2. UL 778 - Motor Operated Water Pumps.

1.3 SYSTEM DESCRIPTION

A. Design Requirements:

1. This section describes specific requirements, products and methods of execution for interrelated systems necessary for the pumping of heating fluid, which will be distributed to the locations shown.
2. The method of generation of, and distribution of, this heat is specified elsewhere.

B. Performance Requirements:

1. Select pumps to operate at specified system fluid temperatures without vapor binding and cavitation, are non-overloading in parallel or individual operation, and operate within 25 percent of midpoint of published maximum efficiency curve.

2. Provide performance and output shown or scheduled on drawings.

1.4 PRE-INSTALLATION MEETINGS

- A. See Section 200000 - Mechanical General Requirements.

1.5 SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements for general submittal requirements for the items listed below, supplemented with the additional requirements listed.

- B. Product Data:

1. Provide manufacturers' product literature, clearly annotated to indicate specified salient features and performance criteria.
2. Include the following:
 - a. Catalog data sheets for each pump scheduled. Indicate which model is being submitted.
 - b. Certified pump curves showing performance characteristics with pump and system operating point plotted. Include NPSH curve when applicable.
 - c. Dimensional data.
 - d. Features and appurtenances being provided.
 - e. Electrical characteristics and connection requirements.

- C. Shop Drawings:

1. Submit fully dimensioned shop drawings of boiler room showing major equipment and housekeeping pads, with clear callouts indicating deviations from layout shown.
2. Indicate mechanical and electrical service locations and requirements.

- D. Quality Assurance/Control Submittals:

1. Design Data and Test Reports: Provide design data and test reports for each pump.
2. Certificates, Manufacturer's Instructions, and Manufacturer's Field Reports:
 - a. Provide a complete manufacturer's written installation, operation and maintenance manual for each installed pump. Clearly annotate the manual to indicate applicable information for the specific equipment model(s) installed.
 - b. Test pump operation and sequencing in accordance with the manufacturer's written installation and testing instructions and Section 259000 - Sequence of Operations.
 - c. Submit a letter of certification indicating that the pump installation and start-up has been completed, that the pumps are properly adjusted and operating within the tolerances as specified by the manufacturer, and that the sequence of operation is fulfilled.
 - d. Included with the manual one copy of the completed start-up and operation checklist. The checklist shall include:
 - 1). Printed names and signatures of the installers.

- 2). Documentation from Manufacturer's representative and Contracting Agency that the pumps have been properly installed and each is fully operational, thus validating the equipment warranty.

1.6 CLOSEOUT SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements.
- B. Closeout Submittals:
- C. Project Record Documents: Record actual locations of pumps and associated valves, and areas required for maintenance access.
- D. Operation and Maintenance (IO&M) Manuals:
 1. Provide copies of approved submittal information for inclusion within the project IO&M Manual.
 2. Include manufacturer's descriptive literature, operating instructions, installation instructions, assembly views, lubrication instructions, maintenance and repair data, parts listings, and spare parts list.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements.

1.8 QUALITY ASSURANCE

- A. See Section 200000 - Mechanical General Requirements.
- B. Regulatory Requirements: Products Requiring Electrical Connection shall be listed and classified by Underwriters Laboratories Inc., as suitable for the purpose specified and indicated.

1.9 DELIVERY, STORAGE AND HANDLING

- A. See Section 200000 - Mechanical General Requirements.

1.10 WARRANTY

- A. Manufacturer Warranty: See Section 200000 - Mechanical General Requirements, for general mechanical warranty requirements.

PART 2 - PRODUCTS

2.1 IN-LINE CIRCULATORS

- A. Type: Horizontal shaft, single stage, direct connected, with resiliently mounted motor for in-line mounting.
- B. Materials:
 - 1. Pump Volute: Cast iron, with 125 pound ANSI flanged pump connections.
 - 2. Impeller: Stainless Steel.
 - 3. Shaft: Alloy steel copper sleeve.
 - 4. Mechanical Seal Assembly: Carbon brass trim, ceramic seat.
- C. Performance:
 - 1. As scheduled.
 - 2. Maximum working temperature: 230 degrees F.
 - 3. Maximum working pressure: 145 PSIG.
- D. Electrical Characteristics:
 - 1. As scheduled.
 - 2. Wiring Terminations: Provide terminal lugs to match branch circuit conductor quantities, sizes, and materials indicated. Enclose terminal lugs in terminal box sized to NFPA 70.
- E. Manufacturers: Taco (Basis of Design), Grundfos UPS Series, Armstrong, Bell and Gossett.

2.2 VERTICAL IN-LINE PUMPS

- A. Type: Single stage, single suction, split coupled, vertical in-line pump with inverter duty motor for VSD operation.
- B. Materials:
 - 1. Pump Body: Cast iron, with 125 PSIG ANSI flanged connections.
 - 2. Impeller: Stainless Steel.
 - 3. Bearings: Sleeve, Oil Lubricated.
 - 4. Shafts: Stainless steel.
 - 5. Mechanical Seal Assembly.
 - a. Stationary face: Carbon.
 - b. Rotating face: Tungsten Carbide.
- C. Performance:
 - 1. As scheduled.
 - 2. Maximum working temperature: 230 degrees F.
 - 3. Maximum working pressure: 145 PSIG.

- D. Electrical Characteristics:
 - 1. As scheduled.
 - 2. Wiring Terminations: Provide terminal lugs to match branch circuit conductor quantities, sizes, and materials indicated. Enclose terminal lugs in terminal box sized to NFPA 70.
- E. Manufacturers: Taco (Basis of Design), Grundfos, Armstrong, Bell and Gossett.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Protection: Cover pumps and plug piping connections to protect pumps from construction dirt and debris.
- B. Preparation: Prior to installation of pumps, verify that electrical power is available and of the same voltage and phase characteristics as the pump being installed.

3.2 INSTALLATION

- A. Install pumps, pump supports, suction guides, mechanical seal piping, pressure gauges and other pump appurtenances in accordance with the manufacturer's written installation instructions.
- B. Provide access space around pumps for service. Provide no less than the minimum as recommended by manufacturer.
- C. Decrease from line size with long radius reducing elbows or reducers. Support piping adjacent to pump such that no weight is carried on pump casings.
- D. Provide line sized shut-off valve on pump suction, and line sized soft seat check valve.
- E. Provide air cock and drain connection on horizontal pump casings.
- F. Provide gauges with connections to suction and discharge.
- G. Lubricate pumps before start-up.

3.3 CONSTRUCTION

- A. Interface with Other Work:
 - 1. Coordinate and sequence installation of pumps and appurtenances with trades responsible for portions of this and other related sections of the Project Manual.
 - 2. Rework required as a result of failure to follow the manufacturer's written installation instructions or to properly coordinate with related Work shall be completed at no additional expense to the Owner.

3.4 REPAIR/RESTORATION

- A. Repair any product components broken during installation or startup with replacement parts supplied by the product manufacturer.
- B. Substitute replacement parts from other manufacturers are not acceptable.

3.5 FIELD QUALITY CONTROL

- A. Manufacturer's Field Services:
 - 1. After completion of the installation, a qualified representative of the pump manufacturer shall conduct pump start-up and written certification.
 - 2. Start-up and adjust the system to within the tolerances as specified by the equipment manufacturer. Verify pump impellers rotate in the correct direction.
 - 3. Provide two hours operating instruction to authorized Owner's Representative.
 - 4. Test pump operation and sequencing in accordance with submittal requirements.
 - 5. Submit a letter of certification indicating that the pump installation and start-up has been completed.

3.6 ADJUSTING

- A. Coordinate and work directly with the Testing, Adjusting and Balancing Agency to provide systems in proper operating order. Make corrections and adjustments as required by the Balancing and Testing Agency in a timely manner.

3.7 CLEANING

- A. After construction is completed, clean and wipe down exposed surfaces of pumps, piping and appurtenances.
- B. Touch up marred or scratched factory finished surfaces using finish materials furnished by manufacturer.

3.8 DEMONSTRATION & START-UP

- A. Start-up and operate hydronic pumps in accordance with the manufacturer's written installation and operation manual checklist.
- B. Document start-up and operational checks using the checklist and submit in accordance with submittal requirements.

END OF SECTION 232123

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Metal Ductwork and Fittings.
2. Flexible Ductwork.
3. Acoustical Linings.
4. Volume Dampers.
5. Smoke and Combination Fire/Smoke Dampers.
6. Flexible Duct Connectors.
7. Access Panels and Doors.

B. Related Sections:

1. 019100 - Commissioning
2. 200000 - Mechanical General Requirements
3. 200529 - Mechanical Hangers and Supports
4. 200548 - Mechanical Vibration and Seismic Control
5. 200700 - Mechanical Insulation
6. 230593 - Testing, Adjusting and Balancing
7. 233400 - HVAC Fans
8. 233600 - Air Terminal Units
9. 233700 - Air Outlets and Inlets
10. Division 28 - Electrical

1.2 REFERENCES

A. Codes and Standards:

1. See Section 200000 - Mechanical General Requirements.
2. ASHRAE Standard 90.1-2010 Energy Standard for Buildings Except Low-Rise Residential Buildings.
3. SMACNA HVAC Duct Construction Standards - Metal and Flexible, Third Edition 2005.
4. SMACNA HVAC Air Duct Leakage Test Manual, Second Edition 2012.
5. SMACNA Fire, Smoke and Radiation Damper Installation Guide for HVAC Systems, Fifth Edition 2002.
6. NFPA 90A - Installation of Air-Conditioning and Ventilating Systems.
7. ACR the National Air Duct Cleaners Association (NADCA) Standard for Assessment, Cleaning and Restoration of HVAC Systems, 2013.

1.3 PRE-INSTALLATION MEETINGS

- A. See Section 200000 - Mechanical General Requirements.

1.4 SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements for general submittal requirements for the items listed below, supplemented with the additional requirements listed.
- B. Product Data: Include manufacturer's detailed fire, smoke, and combination fire/smoke damper installation instructions for each specific wall, ceiling, and floor construction type(s) for the project.
- C. Shop Drawings:
 - 1. Include the following information in the scaled ventilation system shop drawings:
 - a. Label duct sizes using the same labeling method as the Contract Documents.
 - b. Show terminal equipment ductwork connections.
 - c. Volume, control, backdraft, fire, smoke, and combination fire/smoke damper locations as applicable.
 - d. Flexible connection locations.
 - e. Access panels and doors with sizes and swing directions shown.
 - 2. Casings and plenums: Submit detailed shop drawings showing the proposed plenum and casing materials to be used and the construction method.
- D. Test and Evaluation Reports:
 - 1. Provide written certification to the Contracting Agency that smoke and combination fire/smoke dampers have been operationally tested and function in accordance with Section 283100 - Addressable Fire Alarm sequences of operation.
- E. Installation, Operation and Maintenance (IO&M) Manuals.

1.5 CLOSEOUT SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements.
- B. Record Documentation: Record actual locations of ductwork and areas required for maintenance access in accordance with Section 200000 - Mechanical General Requirements.

1.6 QUALITY ASSURANCE

- A. See Section 200000 - Mechanical General Requirements.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. See Section 200000 - Mechanical General Requirements.

1.8 WARRANTY

- A. Manufacturer Warranty: See Section 200000 - Mechanical General Requirements, for general mechanical warranty requirements.

PART 2 - PRODUCTS

2.1 METAL DUCTWORK AND FITTINGS

- A. General: Provide metal ductwork and fittings fabricated in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible, G90 zinc coated unless otherwise noted.
- B. Medium Pressure/Velocity Ductwork:
 - 1. Duct Pressure Class: 6 inches WC.
 - 2. Seal Class: A.
 - 3. Maximum Velocity: 2,200 FPM.
- C. Low Pressure/Velocity Ductwork:
 - 1. Duct Pressure Class: 2 inches WC.
 - 2. Seal Class: A.
 - 3. Maximum Velocity: 1,500 FPM.

2.2 FLEXIBLE DUCTWORK

- A. Manufacturers:
 - 1. Thermaflex, Model M-KE.
 - 2. Hart & Cooley.
 - 3. JPL.
 - 4. Any other manufacturer meeting the requirements of the Contract Documents. Substitution request not required.
- B. Description: UL listed, Class 1 flexible ductwork in compliance with NFPA 90A and 90B.
- C. Performance/Design Criteria:

1. Positive Pressure Rating:

Ten inches WC	(4"-12" ID).
Six inches WC	(14"-16" ID).
Four inches WC	(18"-20" ID).

2. Negative Pressure Rating:

One inch WC	(4"-12" ID).
One half inch WC	(14"-20" ID).

3. Maximum Velocity: 5000 FPM.
4. Operating Temperature Range:
 - a. 0 degrees F to 140 degrees F (continuous).
 - b. Minus 20 degrees F to 250 degrees F (intermittent).
5. Insulating Value: R-4.2.

D. Materials:

1. Acoustically rated black polyester core permanently bonded to coated spring steel wire helix.
2. Fiberglass insulation.
3. Tear resistant, reinforced metalized vapor barrier.

2.3 ACOUSTICAL LININGS

A. Manufacturers:

1. Knauf.
2. Johns Manville.
3. Owens-Corning.
4. Any other manufacturer meeting the requirements of the Contract Documents. Substitution request not required.

B. Description:

1. UL listed.
2. NFPA 90A and 90B compliant.
3. One inch thick, 1.5 PCF, flexible, edge-coated, mat-faced glass fiber insulation bonded with thermosetting resin.
4. Does not promote growth of fungi or bacteria.

C. Performance/Design Criteria:

1. Maximum Velocity: 6000 FPM.
2. Operating Temperature Range: Up to 250 degrees F.
3. Maximum Water Vapor Sorption: Three percent by weight.

2.4 VOLUME / BALANCING DAMPERS

A. Manufacturers:

1. Ruskin.
2. Greenheck.
3. Any other manufacturer meeting the requirements of the Contract Documents. Substitution request not required.

B. Materials:

1. Refer to SMACNA HVAC Duct Construction Standards - Metal and Flexible for fabricated volume damper construction requirements.
 2. Round ducts to 12 inches diameter and rectangular to 18 inches width:
 - a. Flat sheet, galvanized steel, single blade damper.
 - b. Damper blade two gauges thicker than the duct gauge at the location installed (24 gauge minimum for round, 22 gauge minimum for rectangular).
 - c. Manual hand quadrant.
 3. Round ducts over 12 inches diameter:
 - a. Flat sheet, galvanized steel, single blade damper.
 - b. Damper blade two gauges thicker than the duct gauge at the location installed (22 gauge minimum).
 - c. Manual hand quadrant with continuous steel rod.
 4. Rectangular ducts over 18 inches width:
 - a. Flat sheet, galvanized steel, single blade damper.
 - b. Damper blade 18 gauge minimum.
 - c. Manual hand quadrant with continuous steel rod.
 5. Accessible and lockable damper operators.
- C. Extractors: Not Permitted.
- D. Splitter Dampers: Not Permitted.

2.5 REMOTE VOLUME DAMPER OPERATORS

- A. Manufacturers:
1. Duro-dyne.
 2. Young Regulator.
 3. Any other manufacturer meeting the requirements of the Contract Documents. Substitution request not required.
- B. Provide flush mounted chrome plated remote operators with tamperproof cover, extension rod, and not more than one 90 degree angle gear drive.
- C. Regulator: Duro-dyne Series SRC-380 or Young Regulator 301.
- D. Angle Drive: Duro-dyne Model AD-38 or Young Regulator 927.

2.6 SMOKE AND COMBINATION FIRE / SMOKE DAMPERS

- A. Manufacturers:
1. Ruskin FSD60 (Basis of Design).

2. Greenheck.
3. Pottorff.
4. Any other manufacturer meeting the requirements of the Contract Documents. Substitution request not required.

B. Regulatory Requirements:

1. Smoke dampers UL listed and labeled in accordance with UL Standard 555S.
2. Combination fire/smoke dampers also listed in accordance with UL Standard 555.

C. Performance/Design Criteria:

1. Fire rating suitable for the applicable wall construction rating in accordance with IBC.
2. Rated for use in dynamic system with maximum velocity of 4,000 FPM and maximum 8 inches WC static pressure.
3. Elevated temperature rating: Minimum 250 degrees F.
4. Leakage classification: Class I.
5. Supply damper actuators as part of the listed damper assembly. If the damper actuators must be provided separately, actuators must be UL listed for a temperature rating greater than or equal to that of the damper.
6. Provide damper actuators powered by 120 VAC, energized in the normal open position and spring driven closed on loss of power. See Section 283100 - Addressable Fire Alarm for sequences of operation.
7. Provide thermal actuation of combination fire/smoke dampers by a UL listed electric temperature-sensing device (165 degrees F electric fuse) with manual remote reset capability from the fire alarm system.

2.7 FLEXIBLE DUCT CONNECTORS

A. Manufacturers:

1. Duro-dyne Corporation.
2. Vent Fabrics.
3. Ductmate.
4. Any other manufacturer meeting the requirements of the Contract Documents. Substitution request not required.

B. Performance/Design Criteria: Provide fan connectors with static pressure ratings suitable for each specific application. Minimum pressure ratings must be greater than, or equal to, the fan's shut-off static pressure, as indicated by the submitted fan curve, with a 50 percent safety factor.

C. Materials:

1. Metal edging: 24 gauge galvanized steel.
2. Fabric: UL Listed, polyester blend with vinyl coating. Double folded seams. Four inches width.

2.8 ACCESS PANELS AND DOORS FOR DUCTS AND PLENUMS

A. Manufacturers:

1. Air Balance Inc. model FSA-100 (Basis of Design).
2. Ruskin.
3. Ductmate.
4. Any other manufacturer meeting the requirements of the Contract Documents. Substitution request not required.

B. Material:

1. Frame and Door: Minimum 24 gauge galvanized steel.
2. Reinforced doors with cross-bracing and/or otherwise stiffened to prevent rattling and vibration.
3. Seals: Rubber gaskets, secured to door or frame.
4. Where ductwork is insulated or lined, provide double-walled access door panels with one inch of internal insulation to match duct or plenum insulating and/or sound attenuating characteristics.
5. Walk Through Doors:
 - a. Construct in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible.
 - b. Provide insulation and inner liner to match plenum or casing.

C. Hinges and Latches:

1. Low velocity system access panels:
 - a. Sizes 12 inches by 12 inches through 24 inches by 24 inches.
 - b. Continuous steel hinge mechanically fastened to frame and quarter turn cam latches.
2. Medium velocity system access panels:
 - a. Sizes 12 inches by 12 inches through 24 inches by 24 inches.
 - b. Continuous steel hinge mechanically fastened to frame.
 - c. Provide a minimum of two latches for rolled plate doors.
 - d. Cement sheet rubber gasket to door.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verify location, size and type (i.e. fire resistive construction) of wall, floor and ceiling/roof penetrations.

3.2 PREPARATION

- A. Protection on In-Place Conditions: During construction, install temporary closures of sheet metal, cardboard or polyethylene taped over ductwork openings to prevent construction dust and debris from entering duct systems.

3.3 INSTALLATION

A. Metal Ductwork and Fittings:

1. Install, seal and support ductwork and fittings in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible for the duct pressure class and seal class specified. The use of “duct tape” as a duct seal method is prohibited.
2. Provide medium pressure/velocity ductwork at the following locations: VAV ventilation systems from air handler cabinet discharge plenum connection to VAV terminal unit inlet neck connection.
3. Provide low pressure/velocity ductwork at the following locations:
 - a. VAV terminal unit discharge connections to air outlet connections.
 - b. Outside air intake ductwork.
 - c. Exhaust air ductwork.
 - d. Constant volume ventilating systems.
4. Proprietary or other joint systems may be substituted for SMACNA details when submitted and approved in writing before starting work.
5. Where ducts penetrate through walls exposed in occupied spaces, provide sheet metal escutcheons at each penetration to provide a clean, finished appearance.
6. Duct penetrations: See Section 200529 - Mechanical Hangers and Supports.
7. Provide standard 45-degree lateral wye takeoffs. When space does not allow 45-degree lateral wye takeoffs, use 90-degree conical tee or low-loss tee connections.
8. Increase duct sizes gradually, not exceeding 15 degrees divergence wherever possible; maximum 30 degrees divergence upstream of equipment and 45 degrees convergence downstream of equipment.
9. Provide orifice plates or balance dampers at branch connections as required for proper ventilation system balancing. Select balancing device and installation method to limit noise from mechanical vibration or air bypass.
10. Do not use turning vanes in medium velocity duct systems.
11. Support duct mounted equipment equal to or greater than 40 pounds, such as heating coils, independently from ductwork.
12. Support duct mounted equipment less than 40 pounds using standard duct supports and sway bracing located within 12 inches of equipment.
13. Where offsetting ductwork is not possible, ducts may be reduced a maximum of 20 percent to clear obstacles with Contracting Agency’s permission.
14. Where steel ductwork is visible through air outlets or inlets, paint visible interior ductwork flat black.

B. Flexible Ductwork:

1. Install, connect and support flexible ductwork in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible.
 2. Connection to air outlets in suspended grid ceiling systems: Provide a flexible duct length of 6 to 8 feet with one 90-degree bend or large radius 180-degree curve in addition to outlet connection. Support flexible duct at connections to air outlets to maintain minimum recommended bend radius.
 3. Seal flexible duct connections to rigid ductwork with draw bands to the pressure class of the rigid duct system.
 4. Flexible duct connections between medium pressure ductwork and air terminal units are prohibited.
 5. Flexible ductwork is prohibited in inaccessible locations, such as above "hard" ceilings.
 6. Flexible ductwork is prohibited at penetrations through walls.
- C. Acoustical Lined Ductwork:
1. Provide standard one inch thick acoustically lined ductwork as indicated using the acoustical liner material specified. Attach the lining material to the ductwork in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible. Provide thicker acoustical lining where specifically noted.
 2. Duct dimensions indicated are net free-area duct dimensions. Add twice the liner thickness to obtain outside duct dimensions.
 3. Sleeve acoustical duct penetrations through full height walls perpendicular to wall surface. Provide 1/2-inch minimum gap between sleeve and duct. Fill gap with mineral wool backer and seal each side of penetration with acoustical sealant.
- D. Volume Dampers:
1. Provide air volume dampers at each low-pressure duct main and branch take-off for proper air balancing.
 2. Locate dampers a minimum of 10 feet from diffusers except where shown otherwise.
 3. Volume dampers are not to be installed in medium pressure, variable air volume systems.
- E. Control Dampers:
1. Provide opposed blade type dampers for the following applications:
 - a. Exhaust fan discharge dampers.
 - b. Outside air intake dampers.
 - c. Isolation dampers.
 2. Provide parallel dampers for the following application: Air handling unit mixing box.
- F. Fire, Smoke and Combination Fire/Smoke Dampers:
1. Before starting work, verify the location and types of fire resistive construction as indicated by the Contract Drawings. Typical fire rated separations include:
 - a. Area separation walls, vertical only.
 - b. Occupancy separation walls, or partitions and floors. Vertical or horizontal.
 - c. Fire resistive egress corridors, halls and vestibules.

- d. Fire resistive enclosures of hazardous spaces within an occupancy, including rooms for fuel-fired or electric heating equipment.
 - e. Fire resistive floor/ceiling assemblies associated with any of the above.
2. Verify locations and types of dampers indicated on drawings. If dampers appear to be incorrectly located or missing, obtain clarification from Contracting Agency.
 3. Install dampers at locations indicated on the Drawings and in accordance with manufacturer's UL approved installation instructions.
 4. Install round dampers plumb and free from racking. Install rectangular dampers square and free from racking.
 5. Do not compress or stretch damper sleeve into duct or opening.
 6. Handle damper using frame/sleeve. Do not lift damper using blade, actuator, or jackshaft.
- G. Flexible Duct Connectors:
1. Install duct connectors in accordance with the manufacturers written installation instructions.
 2. Provide a flexible airtight joint between fans and other vibrating equipment and the air distribution ductwork systems.
 3. Externally isolated air handling units and fans: Provide flexible connections where ducts attach to unit inlet and outlet(s) of unit.
- A. Penetrations:
1. Coordinate mechanical penetrations with architectural and structural construction details prior to installation. Set sleeves in position in concrete formwork. Provide reinforcement around sleeves as required.
 2. Provide compatible materials, fasteners, adhesives, sealants, and other products required for proper installation.
 3. Penetrations through roof, exterior walls and floors to be weather and water tight.
 4. Penetrations through fire rated assemblies to be UL listed.
 5. Penetrations through smoke partitions and barriers to resist passage of smoke.
 6. Other penetrations to have acoustical seals.
- H. Access Panels and Doors:
1. Locate access doors to enable in-duct equipment to be easily inspected, cleaned, maintained and tested and/or reset.
 2. Provide access doors at the following locations:
 - a. Fire, smoke and combination fire/smoke dampers.
 - b. Motor operated dampers.
 - c. Each side of duct mounted coils.
 - d. As necessary for duct cleaning in accordance with NADCA Industry Standard for Mechanical Cleaning of Non-Porous Air Conveyance System Components.
 - e. As necessary for maintenance access to serviceable instrumentation and control equipment.
 3. Coordinate location and size of access doors in walls, partitions and ceilings to correspond with duct access doors, dampers and automatic control devices and instruments.

4. Coordinate with supplier of component air handlers, package units and similar equipment to ensure that access doors and panels will not be obstructed when the equipment is installed.

I. Interface with Other Work:

1. Assist electrical and controls trades in mounting instrumentation devices and safety controls in ductwork and air handling units.
2. Make penetrations through exterior building walls watertight. Detail ductwork connections to prevent condensation or leakage from entering into surrounding building construction. Provide sleeves, special connections and sealant as required to accomplish this performance requirement.

3.4 SITE QUALITY CONTROL

A. Site Tests and Inspections:

1. Smoke and Combination Fire/Smoke Dampers: Test automatic closure and reset of smoke and combination fire/smoke dampers in accordance with Section 283100 - Addressable Fire Alarm sequences of operation.

B. Verify accessibility to ventilation system components for maintenance, adjustment and cleaning.

3.5 ADJUSTING

A. Adjust and balance dampers in accordance with Section 230593 - Testing, Adjusting and Balancing.

3.6 CLEANING

A. Refer to section 230131 - Duct Cleaning.

END OF SECTION 233100

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PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:

1. In-line centrifugal fans.
2. Roof exhaust fans.

B. Related Sections:

1. 019100 - Commissioning
2. 200000 - Mechanical General Requirements
3. 200529 - Mechanical Hangers and Supports
4. 200548 - Mechanical Vibration and Seismic Control
5. 200553 - Mechanical Identification
6. 230593 - Testing, Adjusting and Balancing
7. 233100 - Ducts and Accessories
8. 233700 - Air Outlets and Inlets
9. 253000 - Building Automation System Field Devices
10. 254000 - Variable Speed Drives
11. 255000 - Building Automation System
12. 259000 - Sequence of Operations
13. Divisions 26, 27 and 28 - Electrical

1.2 REFERENCES

A. Codes and Standards:

1. See Section 200000 - Mechanical General Requirements.
2. Air Movement and Control Association (AMCA) 99 - Standards Handbook.
3. ANSI/AMCA 210 (ANSI/ASHRAE Standard 51) - Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating.
4. AMCA Publication 261 Directory of Products Licensed to Bear the AMCA Certified Rating Seal.
5. AMCA 300 - Reverberant Room Method for Sound Testing of Fans.
6. AMCA 301 - Methods for Calculating Fan Sound Ratings from Laboratory Test Data.

1.3 SYSTEM DESCRIPTION

- #### A. Performance Requirements: Provide product performance characteristics and output as specified or scheduled on drawings.

1.4 PRE-INSTALLATION MEETINGS

- A. See Section 200000 - Mechanical General Requirements.

1.5 SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements for general submittal requirements for the items listed below, supplemented with the additional requirements listed.
- B. Product Data:
 - 1. Provide fan curves with scheduled operating point clearly plotted.
 - 2. Provide sound power levels (in decibels) for each octave band for inlet, discharge, and radiated sound power for the assembled fan unit. Obtain sound level data by one of the following methods:
 - a. Actual measurements from tests performed in accordance with AMCA Standards in an AMCA registered test chamber.
 - b. Documented calculations that start with AMCA tested fan sound data and are modified in accordance with ASHRAE procedures identified in Chapter 48 of the 2011 ASHRAE HVAC Applications Handbook to accurately predict the sound power levels for the configuration shown.
 - 3. Provide electrical requirements for power supply wiring including wiring diagrams for interlock and control wiring, clearly indicating factory-installed and field-installed wiring.
- C. Shop Drawings. Include the following information in the scaled ventilation system shop drawings:
 - 1. Location, orientation, and size of fans.
 - 2. Maintenance access and clearance requirements.
 - 3. Fan support methods (i.e. housekeeping pads, roof curbs, etc.).
 - 4. Ductwork connections and sizes.
- D. Operation and Maintenance (IO&M) Manuals.

1.6 CLOSEOUT SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements.
- B. Record Documentation: Record actual locations of fans and components and areas required for maintenance access.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements.

1.8 QUALITY ASSURANCE

- A. See Section 200000 - Mechanical General Requirements.

1.9 DELIVERY, STORAGE AND HANDLING

- A. See Section 200000 - Mechanical General Requirements.

1.10 WARRANTY

- A. Manufacturer Warranty: See Section 200000 - Mechanical General Requirements, for general mechanical warranty requirements.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Manufacturers:
 - 1. Greenheck.
 - 2. Cook.
 - 3. Acme.
 - 4. Substitution request required.
- B. Regulatory Requirements:
 - 1. AMCA Certified Ratings seal for sound and air performance.
 - 2. Products Requiring Electrical Connection - Listed and classified by Underwriters Laboratories Inc., or by a testing firm acceptable to the Authority Having Jurisdiction as suitable for the purpose specified and indicated.
- C. Performance/Design Criteria: As scheduled.
- D. Manufacturer's Nameplate: Permanently affixed, embossed metal containing model number and individual serial number for future identification, located on a permanent part of the fan.

2.2 IN-LINE CENTRIFUGAL FANS

- A. Duct mounted, direct drive, in-line centrifugal type fans. Rectangular fan housing design constructed of heavy gauge galvanized steel with rectangular duct mounting collars.
- B. Removable panel in fan cabinet of sufficient size to permit access for service to internal components without dismantling the cabinet.
- C. Centrifugal backward inclined fan wheel, constructed of aluminum and matched wheel and inlet cones for precise running tolerances. Dynamically and statically balanced at the factory.

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- D. Heavy duty ball bearing type fan motors, carefully matched to the fan load, and furnished at the specified voltage, phase, and enclosure. Motors and drives readily accessible for maintenance.
- E. NEMA 1 disconnect switch provided as standard. Factory wiring provided from motor to the handy box.
- F. AMCA Certified Ratings. Seal for both sound and air performance.
- G. Electronically Commutated Motor (ECM) with manual speed adjustment for balancing.
- H. Basis of Design: Greenheck SQ with VariGreen ECM.

2.3 ROOF EXHAUST FAN

A. Description:

- 1. General: Provide roof curb mounted up-blast type roof exhauster.
- 2. Regulatory Requirements:
 - a. UL 762 listed.
 - b. IMC compliant.
 - c. AMCA certified ratings seal for sound and air performance.

B. Construction: Heavy gauge aluminum, leak-proof construction.

C. Standard Components:

- 1. Fan wheel: Backward inclined, non-overloading centrifugal fan wheel.
- 2. Motor and drive assembly:
 - a. Provide heavy duty ball bearing type motor with voltage and phase as scheduled.
 - b. Belt drive with adjustable pulleys for final system balancing. Drives sized for 150 percent of driven horsepower.
 - c. Heavy gauge galvanized steel drive frame assembly.
 - d. Precision ground and polished fan shafts mounted in permanently sealed or pillow block ball bearings. Bearings selected for a minimum (L10) life in excess of 100,000 hours (or (L50) life in excess of 500,000 hours) at maximum cataloged operating speed.
 - e. Motors and drives mounted on vibration isolators and located out of air stream and readily accessible for maintenance. Out of air stream motor cooling intake.
- 3. Wind band:
 - a. One piece, heavy duty aluminum construction, continuously welded to aluminum roof cap and drain trough. Aluminum motor cover.
 - b. Galvanized steel bird screen.
 - c. Aluminum drain trough.

D. Vibration Isolation:

- 1. Double studded or pedestal style true vibration isolators.

2. No metal to metal contact.
 3. Sized to match the weight of each fan.
- E. Electrical:
1. Wiring located out of air stream.
 2. Factory installed, NEMA -3R disconnect switch.
- F. Accessories:
1. Non-stick fan wheel coating.
 2. Hinged roof cap for access to fan wheel and ductwork with rubber curb seal.
 3. Breather tube shall be 10 square inches in size for fresh air motor cooling and designed to allow wiring to be run through it.
 4. Removable grease repellent compression rubber plug to allow access for cleaning wheel through wind band.
 5. Corrosion resistant, lockable curb cap closure device.
- G. Coordinate with existing roof curb. Modify curb as needed.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Surface Preparation:
1. Provide roof penetrations and level roof curbs for roof mounted fans.
 2. Coordinate penetration locations with structure.

3.2 INSTALLATION

- A. General:
1. Install fans in compliance with manufacturer's written installation instructions.
 2. Provide flexible connections at fan duct connections as shown or specified. See Section 233100 - Ducts and Accessories for flexible duct connectors.
 3. Support fans independently from ductwork. Provide fan support in accordance with 200529 - Mechanical Hangers and Supports.
 4. Provide vibration isolation and seismic restraint for fans in accordance with 200548 - Mechanical Vibration and Seismic Control.
 5. Ensure that fan access doors and panels are not obstructed when the equipment is installed.
 6. Extend lubrication points so each is easily reached for maintenance.
- B. Interface with Other Work:
1. Coordinate and sequence installation of fans with trades responsible for portions of this and other related sections of the Project Manual.

2. Rework required as a result of failure to follow the manufacturer's written installation instructions or to properly coordinate the installation with related work shall be completed at no additional expense to the Owner.

3.3 REPAIR/RESTORATION

- A. Refer to Section 200000 - Mechanical General Requirements for general repair/restoration requirements.

3.4 SITE QUALITY CONTROL

- A. Manufacturer Services: Verify fans are installed and operational in accordance with the manufacturer's written installation instructions.

3.5 SYSTEM STARTUP

- A. Start-up and operate fans in accordance with the manufacturer's written installation and operation manual check list.

3.6 ADJUSTING

- A. Adjust and balance fans in accordance with Section 230593 - Testing, Adjusting and Balancing.

3.7 CLEANING

- A. Upon completion of installation and prior to initial start-up, vacuum clean and wipe down external system components and internal shrouded areas.

3.8 CLOSEOUT ACTIVITIES

- A. Demonstration: Demonstrate proper system operation in accordance with Section 259000 – Sequence of Operations, utilizing the building automation system.

END OF SECTION 233400

PART 1 - GENERAL

1.1 SUMMARY

- A. Section Includes: Single duct variable air volume terminal units.
- B. Products Installed But Not Supplied Under This Section: Coordinate installation of damper control actuators and application specific controllers, furnished under Section 255000 - Building Automation System. Control enclosure shall be factory mounted by the air terminal unit manufacturer.
- C. Related Sections:
 - 1. 019100 - Commissioning
 - 2. 200000 - Mechanical General Requirements
 - 3. 200529 - Mechanical Hangers and Supports
 - 4. 200548 - Mechanical Vibration and Seismic Control
 - 5. 200553 - Mechanical Identification
 - 6. 200700 - Mechanical Insulation
 - 7. 230131 - Duct Cleaning
 - 8. 230593 - Testing, Adjusting and Balancing
 - 9. 232113 - Hydronic Piping and Specialties
 - 10. 233100 - Ducts and Accessories
 - 11. 233700 - Air Outlets and Inlets
 - 12. 255000 - Building Automation System
 - 13. 259000 - Sequence of Operations
 - 14. Divisions 26, 27 and 28 - Electrical

1.2 REFERENCES

- A. Codes and Standards:
 - 1. See Section 200000 - Mechanical General Requirements.
 - 2. SMACNA - HVAC Duct Construction Standards, Metal and Flexible, Third Edition 2005.
 - 3. NFPA 90A - Installation of Air Conditioning and Ventilating Systems.
 - 4. ANSI/AHRI 880-2011 - Performance Rating of Air Terminals.
- B. Abbreviations, Acronyms and Definitions:
 - 1. Refer to Division 01 for general abbreviations, acronyms, and definitions.
 - 2. Refer to Section 200000 - Mechanical General Requirements for general mechanical related definitions.
 - 3. Refer to Mechanical Drawings legend sheet for general mechanical related abbreviations.

1.3 SYSTEM DESCRIPTION

A. Design Requirements:

1. This section describes specific requirements, products and methods of execution for the single duct, variable air volume, direct digital control terminal units.
2. The method of distribution of air is specified elsewhere.

B. Performance Requirements:

1. Provide product performance characteristics as specified or scheduled on drawings.
2. Operate ventilation system in accordance with Section 259000 - Sequence of Operations.

1.4 PRE-INSTALLATION MEETINGS

- A. See Section 200000 - Mechanical General Requirements.

1.5 SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements for general submittal requirements for the items listed below, supplemented with the additional requirements listed.

B. Product Data.

C. Shop drawings:

1. This Section shop drawings to be submitted under Section 200000 - Mechanical General Requirements.
2. Include the following information on the scaled ventilation system shop drawings:
 - a. Air terminal unit locations and sizes, including discharge plenum.
 - b. Equipment tags.
 - c. Control enclosure orientation and access clearance requirements.
 - d. Ductwork connections and sizes.
 - e. Reheat coil and hydronic piping connections and valving as applicable.
 - f. Coil access door locations.

D. Installation, Operation and Maintenance (IO&M) Manuals.

1.6 CLOSEOUT SUBMITTALS:

- A. See Section 200000 - Mechanical General Requirements.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements.

1.8 QUALITY ASSURANCE:

- A. See Section 200000 - Mechanical General Requirements.
- B. Certifications: Air terminal units shall be certified under AHRI Standard 880 Certification Program and carry the AHRI seal.

1.9 DELIVERY, STORAGE AND HANDLING

- A. See Section 200000 - Mechanical General Requirements for general delivery, storage and handling requirements.

1.10 WARRANTY

- A. Manufacturer Warranty: See Section 200000 - Mechanical General Requirements, for general mechanical warranty requirements.

PART 2 - PRODUCTS

2.1 SINGLE DUCT VARIABLE AIR VOLUME TERMINAL UNITS

- A. Manufacturers:
 - 1. Titus, model DESV (basis of design).
 - 2. Price.
 - 3. Nailor Industries.
 - 4. Substitution request required.
- B. Performance/Design Criteria:
 - 1. Capacities: Provide terminal units of the sizes and performance capacities as scheduled.
 - 2. Sound Rating:
 - a. Sound data certified by AHRI.
 - b. Sound ratings for basic air terminal units with inlet diameters less than or equal to 16 inches shall not exceed NC-20 at maximum rated flow (CFM) with a differential static pressure drop of 1.0 inch water column.
 - c. Sound ratings for basic air terminal units with inlet diameters larger than 16 inches shall not exceed NC-30 at maximum rated flow (CFM) with a differential static pressure drop of 1.0 inch water column.
 - d. Radiated and discharge sound power levels at maximum air flow operating conditions shall be submitted with product information.
 - 3. Casing Leakage: Less than 2 percent of nominal CFM at 1.5 inches WC differential pressure.

- C. Control Actuator and Application Specific Controller: NEMA 1 control enclosures/digital control packages furnished by Section 255000 - Building Automation System to the air terminal unit manufacturer for factory mounting on side of casing.
- D. Materials:
1. Casing:
 - a. Minimum 22 gauge galvanized steel.
 - b. Mechanically sealed and gasketed, leak resistant construction.
 - c. Beaded inlet for low leakage construction, sized to fit standard round duct.
 - d. Rectangular discharge opening designed for slip and drive cleat connection to low pressure ductwork or reheat coil.
 - e. Multi-port, center averaging inlet velocity sensor with sensor tubing. Flow measurement taps provided for connection to application specific controller.
 - f. Internally line casing with sound liner specified below.
 2. Control Damper:
 - a. Heavy gauge galvanized steel, butterfly type damper.
 - b. One-piece, 1/2-inch diameter damper shaft with self-lubricating Delrin® or bronze oilite bearings or self-lubricating. Notched shaft end, to indicate damper position.
 - c. Synthetic damper seal to limit close-off leakage to less than 1% of terminal rated airflow at 3.0 inches water column differential pressure.
 - d. Mechanical stop to prevent damper over-stroking.
 3. Duct Transitions:
 - a. Provide rectangular reheat coil discharge plenum:
 - 1). Minimum width to match reheat coil width.
 - 2). Minimum height to match reheat coil height or maximum downstream branch duct spin-in connection diameter plus 4 inches, whichever is greater.
 - 3). Minimum length 36 inches or longer to accommodate branch ducts, or as indicated on drawings.
 - b. Sound line duct transitions and plenums to match terminal unit casing liner.
- E. Accessories:
1. Sound Liner:
 - a. UL Listed and in conformance with NFPA Standard 90A. Liners shall be fungi and bacterial resistant.
 - b. Liners shall be fiberglass with foil facing such that no fibers are exposed to airstream, as follows:
 - 1). 1" thick aluminum foil faced fiberglass insulation, 4 pound per cubic foot density, cut edges sealed from airstream using mechanically bonded metal barrier strips.

- 2). Cut liner edges and seal to prevent erosion with discharge edges secured with metal barrier strips for fiberglass or similar insulation.
2. Hydronic Reheat Coils:
 - a. Performance characteristics as scheduled.
 - b. Constructed from seamless copper tubing (minimum 0.016-inch wall thickness) with aluminum fins, enclosed in 20 gauge (minimum) galvanized steel casing with slip and drive connections. Provide extended copper sweat connections.
 3. Access Doors: Provide access doors upstream and downstream of reheat coils for coil cleaning. Refer to Section 233100 - Ducts and Accessories.

PART 3 - EXECUTION

3.1 INSTALLERS

- A. Installer: Perform work by experienced personnel previously engaged in ventilation system construction and under the supervision of a qualified installation supervisor.

3.2 PREPARATION

- A. Protection of In-Place Conditions: Cover air terminal unit inlet and discharge openings to protect components from construction dirt and debris.

3.3 INSTALLATION

- A. General:
 1. Install air terminal units in strict compliance with the manufacturer's written installation instructions.
 2. Do not locate any part of the terminal unit assembly, including reheat coil and associated low pressure sound lined plenums, such that it passes over a partition wall or through a full height wall penetration.
 3. Locate terminal units such that the bottom of the complete assembly is 6 to 18 inches above the top of the ceiling grid or hard lid ceiling framing as applicable.
 4. Locate terminal unit controller, coil hydronic piping/valves, and coil access doors on same side of unit. Locate on side that maximizes accessibility (i.e. above accessible ceiling tiles, away from full height walls and main duct runs).
 5. Support air terminal units independent of duct system. Provide sway bracing within 12 inches of support attachment.
 6. Connect air terminal unit inlets to ductwork using straight sections of unrestricted rigid duct of the same inlet diameter as terminal unit inlet. Provide a minimum straight duct length of 4 duct diameters at each terminal unit inlet. Medium pressure flexible duct connections to terminal units is not allowed except where specifically shown.

7. Close-coupling of a terminal inlet to the side of a main supply duct is not acceptable without written permission from the Contracting Agency. When this method is approved, provide an inlet flow straightening device.
8. Install low pressure ductwork branches vertically centered along the sides of the low pressure sounded lined plenum. A minimum of two (2) inches of sheet metal is required between the spin-in (or similar connection) and top and bottom external edge of the metal plenum.
9. Provide insulated access doors upstream and downstream of reheat coil for coil cleaning.
10. Secure control enclosure cover in place as intended by the manufacturer.
11. Verify mechanical connections, electrical and control wiring and sensor tubing are properly secured.

B. Interface with Other Work:

1. Coordinate and sequence the installation of air terminal units with trades responsible for portions of this and other related sections of the Project Manual.
2. Coordinate ceiling and/or wall access panel locations to provide convenient maintenance and cleaning access for each air terminal unit.
3. Coordinate air terminal unit locations with ceiling grids, lighting troffers, air outlets and return grilles to maximize accessibility and minimize interference.
4. Rework required as a result of failure to follow the manufacturer's written installation instructions, properly coordinate the installation with related work, or provide adequate access (as determined by the Contracting Agency) shall be completed at no additional cost to the Owner.

3.4 REPAIR/RESTORATION

- A. Refer to Section 200000 - Mechanical General Requirements for general repair/restoration requirements.

3.5 SYSTEM START-UP

- A. With the applicable central ventilation system air balancing completed and the ventilation system operating under automatic control utilizing the BAS, cycle each air terminal unit control damper between minimum and maximum scheduled air flow settings to demonstrate proper operation and capacity in accordance with 259000 - Sequence of Operations for verification by the Contracting Agency.
- B. Verify reheat coil and auxiliary heating unit (as applicable) hydronic control valves properly cycle with terminal unit control damper, in accordance with Section 259000 - Sequence of Operations.

3.6 ADJUSTING

- A. Adjust velocity sensor bias adjustment as necessary to provide accurate air flow measurement.
- B. For units with reheat coil supply temperature sensors, verify maximum supply temperature is limited to 20 degrees F above zone temperature setpoint.

3.7 CLEANING

- A. Upon completion of installation and prior to initial operation, vacuum clean and wipe down air terminal units and control enclosures.
- B. Remove any debris from control enclosure.
- C. Inspect and clean reheat coils. Re-straighten coil fins if necessary.

END OF SECTION 233600

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PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Air Diffusers and Registers.
2. Return/Exhaust Grilles.

B. Related Sections:

1. 200000 - Mechanical General Requirements
2. 200529 - Mechanical Hangers and Supports
3. 230593 - Testing, Adjusting and Balancing
4. 233100 - Ducts and Accessories

1.2 REFERENCES

A. Codes and Standards:

1. See Section 200000 - Mechanical General Requirements.
2. SMACNA HVAC Duct Construction Standards - Metal and Flexible Third Edition 2005.
3. NFPA 90A - Installation of Air Conditioning and Ventilation Systems.
4. ARI Standard 890-2001 - Air Diffusers and Air Diffuser Assemblies.
5. MOA Handout A.04 - Suspended Ceilings Industry Standard Construction, May 1, 2008.

1.3 SYSTEM DESCRIPTION

- #### A. Performance Requirements:
- Provide product performance characteristics as specified or scheduled on drawings.

1.4 PRE-INSTALLATION MEETINGS

- #### A.
- See Section 200000 - Mechanical General Requirements.

1.5 SUBMITTALS:

- #### A.
- See Section 200000 - Mechanical General Requirements for general submittal requirements for the items listed below, supplemented with the additional requirements listed.
- #### B. Product Data:
- Air outlets and inlets performance data at operating conditions.
- #### C. Shop Drawings:

1. This Section shop drawings to be submitted under Section 200000 - Mechanical General Requirements.
 2. Include the following information on scaled ventilation system shop drawings:
 - a. Air diffuser, register and grille locations, duct connection sizes and throw directions.
- D. Installation, Operation and Maintenance (IO&M) Manuals.
- 1.6 CLOSEOUT SUBMITTALS:
- A. See Section 200000 - Mechanical General Requirements.
- 1.7 MAINTENANCE MATERIAL SUBMITTALS
- A. See Section 200000 - Mechanical General Requirements.
- 1.8 QUALITY ASSURANCE:
- A. See Section 200000 - Mechanical General Requirements.
- 1.9 DELIVERY, STORAGE AND HANDLING
- A. See Section 200000 - Mechanical General Requirements.
- 1.10 WARRANTY
- A. Manufacturer Warranty: See Section 200000 - Mechanical General Requirements, for general mechanical warranty requirements.

PART 2 - PRODUCTS

- 2.1 AIR DIFFUSERS AND REGISTERS
- A. Manufacturers:
1. Titus (Basis of Design).
 2. Price.
 3. Nailor Industries Inc.
 4. Any other manufacturer meeting the requirements of the Contract Documents. Substitution request not required.
- B. Performance/Design Criteria: As scheduled.
- C. Finishes: Unless noted otherwise, standard white baked enamel or powder coated finish suitable for field application of custom finish color as required.

D. Accessories:

1. Equalizing grids.
2. Earthquake tabs.

E. Correlate diffuser style, dimension, and fit with ceiling. Provide diffusers with modules of the proper size to match the suspended ceiling layout or with appropriate factory provided frame for surface mounting.

2.2 RETURN/EXHAUST GRILLES

A. Manufacturers:

1. Titus (Basis of Design).
2. Price.
3. Nailor Industries Inc.
4. Any other manufacturer meeting the requirements of the Contract Documents. Substitution request not required.

B. Performance/Design Criteria: As scheduled.

C. Finishes: Unless noted otherwise, standard white baked enamel or powder coated finish suitable for field application of custom finish color as required.

D. Accessories: Earthquake tabs.

E. Correlate grille style, dimension, and fit with ceiling. Provide grilles with modules of the proper size to match the suspended ceiling layout or with appropriate factory provided frame for surface mounting.

PART 3 - EXECUTION

3.1 PREPARATION

A. Removal: Remove existing air diffusers, registers and grilles designated for relocation and reuse after repair and cleaning.

3.2 INSTALLATION

A. General:

1. Install products in compliance with the manufacturer's written installation instructions.
2. Connect air outlets, registers, grilles, and louvers to ventilation duct systems in accordance with SMACNA HVAC Duct Construction Standards - Metal and Flexible.

B. Air Diffusers, Registers and Grilles:

1. Install air diffusers, registers and return/exhaust grilles at the locations shown.

2. Orient and adjust diffusers to provide the throw directions indicated.
3. Provide appropriate borders for the ceiling, wall, or floor construction type.

3.3 REPAIR/RESTORATION

- A. Refer to Section 200000 - Mechanical General Requirements for general repair/restoration requirements.
- B. Where air outlets and inlets are indicated for reuse, clean and repair existing air outlets and inlets to function as originally intended prior to reinstallation. Air outlets and inlets which require major repair may be replaced at the Contractor's option.

3.4 CLEANING

- A. Clean exposed surfaces of air outlets and inlets, with water and mild soap or detergent not harmful to finish, in order to remove fingerprints and dirt.

END OF SECTION 233700

PART 1 - GENERAL

1.1 SUMMARY

- A. Section includes: Boiler venting system.
- B. Related sections:
 - 1. 200000 - Mechanical General Requirements
 - 2. 200529 - Mechanical Hangars and Supports
 - 3. 200548 - Mechanical Vibration and Seismic Control
 - 4. 235216 - Condensing Boilers and Accessories

1.2 REFERENCES

- A. Codes and Standards: See Section 200000 - Mechanical General Requirements.
- B. Abbreviations, Acronyms and Definitions:
 - 1. Refer to Division 01 for general abbreviations, acronyms, and definitions.
 - 2. Refer to Section 200000 - Mechanical General Requirements for general mechanical related definitions.
 - 3. Refer to Mechanical Drawings legend sheet for general mechanical related abbreviations.

1.3 SYSTEM DESCRIPTION

- A. Design Requirements: This section describes specific requirements, products, and methods of execution for boiler venting systems.
- B. Performance Requirements: Provide product performance characteristics as specified or scheduled on drawings.

1.4 PRE-INSTALLATION MEETINGS

- A. See Section 200000 - Mechanical General Requirements.

1.5 SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements for general submittal requirements for the items listed below, supplemented with the additional requirements listed.
- B. Product Data:
 - 1. Provide manufacturers' product literature.

2. Annotate to indicate specified salient features and performance criteria for each product specified.

C. Calculations:

1. Provide calculations from the stack manufacturer based on the submitted stack shop drawings and submitted and approved boiler draft requirements to demonstrate adequate draft available under the following operating conditions:
 - a. Boiler high and low firing rates for winter conditions of -19 degrees F.
 - b. Boiler high and low firing rates for summer conditions of 75 degrees F.
2. For multiple boilers with a common boiler stack, identify number of operating boilers and the boiler flue connection position in the manifold.

D. Shop Drawings:

1. Submit fully dimensioned shop drawings of boiler room(s) showing the following:
 - a. Major equipment and housekeeping pads, with clear callouts indicating deviations from layout shown:
 - 1). Submitted boiler shall be dimensionally equal to scheduled product within 6 inches in each dimension. Maintain clearances shown on drawings. Submit fully dimensioned shop drawings of boiler room(s) at drawing scale of 1/4-inch equals 1 foot 0 inches or larger, showing entire boiler room, equipment and deviations. Provide boiler room modifications required due to dimensional and technical deviation at no additional cost to the Owner. Submit shop drawings of proposed equipment layout and base or pad for each piece of equipment.
 - 2). If equipment to be provided exceeds the weight of the specified equipment by more than 20 percent, or if the location is to be altered, submit shop drawings and calculations of proposed revised structural design, noting location of pertinent loads, stamped by a registered professional engineer.
 - b. Service area boundaries as required by manufacturer's installation.
 - c. Boiler piping and vent stack locations with dimensions. Coordinate stack roof penetrations with roof structure.
 - d. Indicate mechanical and electrical service locations and requirements.

1.6 CLOSEOUT SUBMITTALS:

- A. See Section 200000 - Mechanical General Requirements.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements.

1.8 QUALITY ASSURANCE

- A. See Section 200000 - Mechanical General Requirements.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. See Section 200000 - Mechanical General Requirements.

1.10 WARRANTY

- A. Manufacturer Warranty: See Section 200000 - Mechanical General Requirements, for general mechanical warranty requirements.

PART 2 - PRODUCTS

2.1 BOILER VENTING SYSTEMS

- A. Manufacturers:

- 1. Schebler.
- 2. Heat-Fab.
- 3. Approved equal.

- B. Description:

- 1. Provide complete, engineered venting system for flue gas exhaust for each boiler to include straight duct, fittings, connections, adapters, thimbles, terminations and support brackets.
- 2. Provide supports and seismic restraints in accordance with the manufacturer's UL listing, Section 200529 - Mechanical Hangers and Supports, and Section 200548 - Mechanical Vibration and Seismic Control.

- C. Performance/Design Criteria: UL 1738 listed for use with Category IV appliances (operating temperatures up to 600 Degrees F, positive pressure, condensing flue gas service).

- D. Materials:

- 1. Inner wall shall be AL29-4C stainless steel.
- 2. Outer wall shall be type 304 stainless steel.

- E. Assembly/Fabrication:

- 1. Double walled venting system with 1 inch air space between walls.
- 2. Vent sections shall be sealed with banded flanges and silicone joint sealant for temperatures up to 600 degrees F with a UL tested pressure rating of 4.0 inches WC.
- 3. Inner liner seams shall be fully welded. Riveted, tack or spot welded seams are not permitted.

4. Supports and seismic restraints in accordance with the manufacturer's UL listing.

PART 3 - EXECUTION

3.1 INSTALLERS

- A. Installer: Perform work by experienced personnel under the supervision of a qualified installation supervisor.

3.2 PREPARATION

- A. Surface Preparation: Prior to installation of stacks, verify that shop drawings are approved and stack locations and routing have been coordinated with other trades.

3.3 INSTALLATION

- A. Special Techniques:
 1. Install equipment in accordance with manufacturer's instructions and requirements of the codes specified herein.
 2. Install with clearances from building elements in accordance with chimney listing and IMC.
 3. Install components that were furnished loose with equipment for field installation.
 4. Touch up marred or scratched factory finished surfaces using finish materials furnished by manufacturer.
- B. Interface with Other Work: Coordinate and sequence installation of boiler and water heater and stacks with trades responsible for portions of this and other related sections of the Project Manual.

3.4 REPAIR/RESTORATION

- A. Repair any product components broken during installation or startup with replacement parts supplied by the product manufacturer.
- B. Substitute replacement parts from other manufacturers are not acceptable.

3.5 SITE QUALITY CONTROL

- A. Non-Conforming Work: Rework required as a result of failure to follow the manufacturer's written installation instructions or to properly coordinate with related Work shall be completed at no additional expense to the Owner.

3.6 CLEANING

- A. Waste Management: After construction is completed, clean and wipe down exposed surfaces of boiler stacks.

END OF SECTION 235100

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PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:

1. Packaged condensing gas fired boilers and appurtenances.
2. Packaged boiler management system.

B. Related sections:

1. 019100 - Commissioning
2. 200000 - Mechanical General Requirements
3. 200529 - Mechanical Hangers and Supports
4. 200548 - Mechanical Vibration and Seismic Control
5. 200553 - Mechanical Identification
6. 230593 - Testing, Adjusting and Balancing
7. 231123 - Fuel Gas Piping and Specialties
8. 232113 - Hydronic Piping and Specialties
9. 232123 - Hydronic Pumps
10. 235100 - Breechings, Chimneys and Stacks
11. 255000 - Building Automation System
12. 259000 - Sequence of Operations
13. Divisions 26, 27 and 28 - Electrical

1.2 REFERENCES

A. Codes and Standards:

1. See Section 200000 - Mechanical General Requirements.
2. NFPA 54 - National Fuel Gas Code.
3. ASME Boilers and Pressure Vessel Code (1998), Sections IV & VI.
4. ASME CSD-1 - Controls and Safety Devices for Automatically Fired Boilers.

B. Abbreviations, Acronyms and Definitions:

1. Refer to Division 01 for general abbreviations, acronyms, and definitions.
2. Refer to Section 200000 - Mechanical General Requirements for general mechanical related definitions.
3. Refer to Mechanical Drawings legend sheet for general mechanical related abbreviations.

1.3 SYSTEM DESCRIPTION

A. Design Requirements:

1. This section describes specific requirements, products and methods of execution for the generation of heat, which will be distributed to the locations shown.
2. The method of distribution of this heat is specified elsewhere.

B. Performance Requirements:

1. Provide product performance characteristics as specified or scheduled on drawings.
2. Operate central heating system in accordance with Section 259000 - Sequence of Operations.

1.4 PRE-INSTALLATION MEETINGS

- A. See Section 200000 - Mechanical General Requirements.

1.5 SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements for general submittal requirements for the items listed below, supplemented with the additional requirements listed.

B. Product Data:

1. Provide manufacturers' product literature, clearly annotated to indicate specified salient features and performance criteria to include:
 - a. Product model and selected optional equipment, appurtenances and special features.
 - b. Boiler physical and performance characteristics as scheduled.
 - c. Total equipment weight (filled with water). Boilers weighing 20 percent more than the scheduled equipment will be disapproved unless it is determined by the Owner's Representative that the structure as designed is capable of bearing the additional load with an adequate safety margin.
 - d. Dimensional data.
 - e. Anchoring method.
2. Regulatory Requirements: Provide automatic boiler controls listed in the IMC and ASME CSD-1, latest edition, together with most current addenda and interpretations.

C. Shop Drawings:

1. Submit fully dimensioned shop drawings of boiler room(s) showing the following:
 - a. Major equipment and housekeeping pads, with clear callouts indicating deviations from layout shown:
 - 1). Submitted boiler shall be dimensionally equal to scheduled product within 6 inches in each dimension. Maintain clearances shown on drawings. Submit fully dimensioned shop drawings of boiler room(s) at drawing scale of 1/4-inch equals 1 foot 0 inches or larger, showing entire boiler room, equipment and deviations. Provide boiler room modifications required due to

dimensional and technical deviation at no additional cost to the Owner. Submit shop drawings of proposed equipment layout and base or pad for each piece of equipment.

- 2). If equipment to be provided exceeds the weight of the specified equipment by more than 20 percent, or if the location is to be altered, submit shop drawings and calculations of proposed revised structural design, noting location of pertinent loads, stamped by a registered professional engineer.

- b. Service area boundaries as required by manufacturer's installation.
- c. Boiler piping and vent stack locations with dimensions. Coordinate stack roof penetrations with roof structure.
- d. Indicate mechanical and electrical service locations and requirements.
- e. Boiler management system location.

D. Quality Control Submittals: Refer to Section 019100 - Commissioning for submittal requirements.

E. Manufacturer Reports:

1. Provide start-up and operational test reports for each boiler. Refer to Article on Site Quality Control.
2. Provide start-up report for boiler control system with selected presets annotated.
3. Submit a letter to document that the training was conducted. Include in the letter the date, start/stop times for the training, list of attendees and signature/title of the person(s) providing the training.

1.6 CLOSEOUT SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements.

1.8 QUALITY ASSURANCE

- A. See Section 200000 - Mechanical General Requirements.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. See Section 200000 - Mechanical General Requirements.

1.10 WARRANTY

- A. See Section 200000 - Mechanical General Requirements.

- B. Provide prorated 10-year warranty on pressure vessel/heat exchanger against failure due to condensate corrosion, thermal stress, mechanical defects or workmanship.
- C. Provide 2-year warranty on control circuit boards.

PART 2 - PRODUCTS

2.1 CONDENSING GAS FIRED BOILERS

A. Manufacturer:

- 1. Aerco Benchmark series.
- 2. Approved equal.

A. Description:

- 3. Gas fired, condensing fire tube design with modulating power burner and positive pressure discharge.
- 4. UL Listed, CSD-1 approved, ASME coded and stamped.
- 5. IRI gas train.

- B. Performance/Design Criteria: Manufacturer must publish known partial load efficiencies, and the thermal efficiency must increase as the firing rate decreases.

B. Assembly/Fabrication:

1. Size and clearances:

- a. Minimum 28 inches wide, 44.5 inches long and 79 inches high.
- b. Listed for 0 wall clearance.
- c. Max weight 1533 pounds dry.

2. Air/Fuel Supply/Burner:

- d. Turndown capacity: 20 to 1 without loss of combustion efficiency or staging of gas valves.
- e. Burner shall produce less than 16 PPM of NO_x corrected.
- f. Burner shall be metal fiber mesh covering a stainless steel body, with spark ignition and flame rectification.
- g. All material exposed to combustion shall be stainless steel.
- h. Modulating air/fuel valve with single linkage that does not require field adjustment. VFD pre-mix blower for optimum air/gas mixture.
- i. Gas train safety shut-off valve with proof of closure switch.
- j. Minimum 4.2 inch W.C. gas input at rated capacity.

3. Pressure Vessel/Heat Exchanger:

- k. Boiler capable of sustained operation with return water temperature down to 40 Degree F without failure due to thermal shock or fireside condensation.
 - l. ASME steel construction for working pressure: 160 PSIG.
 - m. Pressure vessel of SA53 carbon steel, 1/4 inch wall and upper head.
 - n. Heat exchanger of 316L stainless steel fire tube and 3/8 inch tube sheets, one-pass combusting gas flow.
 - o. 3-inch steel flange water connection.
 - p. Maximum water pressure drop through boiler: 4.9 PSIG at 130 GPM.
 - q. Working temperature: 200 degrees F.
 - r. ASME approved relief valve: 50 PSIG.
4. Exhaust Flue and Condensate Drain:
- s. Corrosion resistant stainless with 6-inch diameter steel flue connection.
 - t. Gravity condensate drain with collecting reservoir.
5. Packaged Boiler Controls:
- u. UL approved.
 - v. Control panel consisting of multiple circuit boards for separate control functions that area individually field replaceable. Boards provide display functions, low water cutoff, power supply, ignition control, a connector board, and a control function board.
 - w. The control panel hardware shall support both RS-232 and RS-485 remote communications.
 - x. The controls shall annunciate boiler & sensor status and include extensive self-diagnostic capabilities that incorporate a minimum of 8 separate status messages and 34 separate fault messages.
 - y. Integrated control panel with operating sequence, system fault and outlet temperature display, operating mode selector switch.
 - z. Self-governing features to take over controlled as set up by user in the event of over temperature, improper control signal, or loss of signal.
 - aa. Combustion safeguard/flame control and monitoring system with spark ignition and rectification type flame sensor.
 - bb. Electric low water cutoff with test and manual reset functions.
 - cc. Each boiler shall utilize an electric single seated combination safety shutoff valve/regulator with proof of closure switch in its gas train and incorporate dual over-temperature protection with manual reset in accordance with ASME Section IV and CSD-1.
 - dd. Self-diagnostic capabilities.
 - ee. Adjustable high and low setpoint limits.
 - ff. Temperature control modes:
 - 1). Internal setpoint.
 - 2). Indoor/outdoor Reset.
 - 3). 4mA to 20mA Temperature Setpoint.
 - 4). Network Temperature Setpoint.
 - 5). 4 mA to 20 mA Direct Drive.
 - 6). Network Direct Drive.

7). Boiler management system (ACS) with Combination Control System (CCP).

gg. Additional control system features to include:

- 1). Ambient temperature system start/stop.
- 2). Circulator pump delay timer.
- 3). Auxiliary start delay timer.
- 4). Auxiliary temperature sensor.
- 5). Analog output (mA) monitoring of temperature setpoint, supply temperature, or boiler fire rate.
- 6). Remote interlock circuit.
- 7). Delayed interlock circuit.
- 8). Remote alarm fault relay.

6. Electrical Power: 120 VAC/1 PH/60 Hz.

2.2 BOILER MANAGEMENT SYSTEM

A. Manufacturers:

1. Aerco Boiler Control System (ACS).
2. Approved equal.

B. Description: Boiler manufacturer's boiler management system control the integrated operation of the boilers on the project, and to provide a communication gateway to the building automation system. The boiler management system shall control operation and sequencing of multi-boiler central heating system.

C. Operation:

1. Control all operation and energy input of the multiple boiler heating plant.
2. Utilize MODBUS protocol to communicate with the boilers via a RS-485 port.
3. Controller shall have the following capabilities:
 - a. Vary the firing rate and energy input of each individual boiler throughout its full modulating range to maximize condensing capability and thermal efficiency.
 - b. Maintain boiler header temperature setpoint within 2 degrees F. Control will be PID.
 - c. Provide contact closure for auxiliary equipment such as pumps and combustion air inlets dampers.
 - d. Operational modes:
 - 1). Internal setpoint.
 - 2). Outdoor temperature reset control.
 - 3). 4 mA to 20 mA setpoint control.
 - 4). Network temperature setpoint control.

D. Assembly/Fabrication:

1. Other features shall include:

- a. UL approved.
 - b. Microprocessor based PID type control.
 - c. LCD display monitoring of sensors and interlocks.
 - d. Non-volatile backup of control setpoints.
 - e. Automatic rotation of lead boiler to balance operating time.
 - f. Provision for setback and remote alarm contacts.
 - g. Adjustable seasonal start/stop ambient temperature.
 - h. Contact closure control for auxiliary equipment (i.e. circulator pumps).
 - i. Supply header temperature control utilizing external inputs:
 - 1). Temperature Setpoint (4-20 mA): Boiler outlet temperature setpoint controlled linearly using a 4-20 mA input signal supplied from the building automation system.
 - 2). MODBUS Temperature Setpoint: Boiler outlet temperature setpoint controlled by external communication utilizing MODBUS protocol via a RS-232 port.
2. Open Protocol Interface: When the building automation system does not have MODBUS protocol capability and interoperability is required, provide MODBUS Gateway to act as interface/translator between the BAS and the boiler management system. Supported protocols to include BACNET, LON and N2. Provide protocol interface for the HVAC control system selected for the project.

2.3 EMERGENCY BOILER SHUTOFF

- A. Provide an emergency boiler shutoff switch. See Division 26.

PART 3 - EXECUTION

3.1 INSTALLERS

- A. Installer: Perform work by experienced personnel previously engaged in boiler plant construction and under the supervision of a qualified installation supervisor.

3.2 PREPARATION

- A. Protection of In-Place Conditions: Cover products and plug piping connections to protect equipment from construction dirt and debris.
- B. Surface Preparation:
1. Prior to installation of boilers, verify concrete housekeeping pads are complete and properly sized for boiler mounting.
 2. Prior to installation of stacks, verify that shop drawings are approved and stack locations and routing have been coordinated with required roof penetrations and the work of other trades.

3.3 INSTALLATION

A. Special Techniques:

1. Install equipment in accordance with manufacturer's instructions and requirements of the codes specified herein.
2. Install Boiler management system (BMS) in accordance with manufacture's installation instructions. Connect each of the boilers to the BMS. Program BMS to maintain boiler water temperature control as described in Sequence of Operation below.
3. Connect to the building automation system through the open protocol communication port in the BMS.
4. Setting of equipment:
 - a. Set equipment on concrete housekeeping pads compatible with the building structural system.
 - b. Level equipment to within recommended tolerances.
5. Anchoring:
 - a. Anchor boilers to housekeeping pads as recommended by the manufacturer and to allow for normal expansion and contraction.
 - b. Coordinate with Section 20 0548 - Vibration and Seismic Control.
6. Thermal Expansion:
 - a. Install hydronic piping to allow for normal thermal expansion and contraction.
 - b. Provide anchors where necessary and as indicated.
 - c. Provide expansion loops, anchors and alignment guides to suit conditions and as indicated.
7. In systems containing glycol, provide only products specifically designed and approved for continuous operation with the glycol solution specified.
8. Install components that were removed from equipment for shipping purposes.
9. Install components that were furnished loose with equipment for field installation.
10. Provide interconnecting electrical control and power wiring.
11. Provide fuel gas vent and service piping.
12. Provide piping for boiler pipe connections.
13. Program, adjust and operationally test boiler operation and sequencing in accordance with the manufacturer's written installation and testing instructions and Section 25 9000 - Sequence of Operations.
14. Touch up marred or scratched factory finished surfaces using finish materials furnished by manufacturer.
15. Install emergency boiler shutoff switch outside the boiler room at each exit at 48 inches above finished floor.

B. Interface with Other Work: Coordinate and sequence installation of boilers and stacks with trades responsible for portions of this and other related sections of the Project Manual.

C. Systems Integration: Coordinate location and operation of boiler emergency shutoff switch(es) with Divisions 26, 27 and 28.

3.4 REPAIR/RESTORATION

- A. Repair any product components broken during installation or startup with replacement parts supplied by the product manufacturer.
- B. Substitute replacement parts from other manufacturers are not acceptable.

3.5 SITE QUALITY CONTROL

- A. Non-Conforming Work: Rework required as a result of failure to follow the manufacturer's written installation instructions or to properly coordinate with related Work shall be completed at no additional expense to the Owner.
- B. Manufacturer Services:
 - 1. Provide manufacturer's representative start-up and instruction of each complete boiler system including all components assembled and furnished by the manufacturer whether or not of his own manufacture.
 - 2. Start-up shall be conducted by experienced and factory authorized technician in the regular employment of the authorized service organization.
 - 3. Start-up and adjust the system to within the tolerances as specified by the equipment manufacturer.
 - 4. Operationally test safety devices and record settings. Test and record oxygen, carbon dioxide, stack temperature, and calculate excess air and steady state efficiency. Make final lead/lag setpoint adjustments. List setpoints in report. Submit final data for review.
 - 5. Test boiler operation and sequencing in accordance with the manufacturer's written installation and testing instructions and Section 25 9000 - Sequence of Operations.
 - 6. Provide a start-up report that includes final control settings, and a performance chart of the control system furnished.
 - 7. Submit a letter of certification with copy of start-up report, indicating that the boiler start-up has been completed, that the boilers are properly adjusted and operating within the tolerances as specified by the manufacturer, and that the sequence of operation is fulfilled.

3.6 ADJUSTING

- A. Coordinate and work directly with the requirements of Section 230593 - Testing, Adjusting and Balancing, to provide systems in proper operating order.
- B. Make corrections and adjustments as required by the Balancing and Testing Agency in a timely manner.

3.7 CLEANING

- A. Waste Management: After construction is completed, clean and wipe down exposed surfaces of boilers and burners.

3.8 CLOSEOUT ACTIVITIES

- A. Demonstration: Provide 2 hours of demonstration conducted by authorized factory start-up personnel to the Contracting Agencies authorized maintenance personnel.
- B. Training: Provide 2 hours of operational instruction conducted by authorized factory start-up personnel to the Contracting Agencies authorized maintenance personnel.

END OF SECTION 235216

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:

1. Roof top air handling units.
2. Air filter media and support frames.

B. Related Sections:

1. 019100 - Commissioning
2. 200000 - Mechanical General Requirements
3. 200529 - Mechanical Hangers and Supports
4. 200548 - Mechanical Vibration and Seismic Control
5. 200553 - Mechanical Identification
6. 230131 - Duct Cleaning
7. 230593 - Testing, Adjusting and Balancing
8. 232113 - Hydronic Piping and Specialties
9. 233100 - Ducts and Accessories
10. 254000 - Variable Speed Drives
11. 255000 - Building Automation System
12. 259000 - Sequence of Operations
13. Divisions 26, 27 and 28 - Electrical

1.2 REFERENCES

A. Codes and Standards:

1. See Section 200000 - Mechanical General Requirements.
2. AMCA 99 (Air Movement and Control Association) - Standards Handbook.
3. ASHRAE Standard 90.1 - Energy Standard for Buildings Except Low-Rise Residential Buildings.
4. ASHRAE Standard 52.2-2012 - Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size.

B. Abbreviations, Acronyms and Definitions:

1. Refer to Division 01 for general abbreviations, acronyms, and definitions.
2. Refer to Section 200000 - Mechanical General Requirements for general mechanical related definitions.
3. Refer to Mechanical Drawings legend sheet for general mechanical related abbreviations.

1.3 SYSTEM DESCRIPTION

A. Design Requirements:

1. This section describes specific requirements, products and methods of execution for the packaged rooftop air handling equipment, which will be distributed to the locations shown.
2. The method of air distribution is specified elsewhere.

B. Performance Requirements:

1. Provide product performance characteristics as specified or scheduled on drawings.
2. Operate ventilation systems in accordance with Section 259000 - Sequence of Operations.

1.4 PRE-INSTALLATION MEETINGS

- A. See Section 200000 - Mechanical General Requirements.

1.5 SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements for general submittal requirements for the items listed below, supplemented with the additional requirements listed.

B. Product Data:

1. Provide clearly annotated manufacturer's product literature that demonstrates compliance with the specified performance, manufacturing methods, appurtenances and salient features.
2. Provide fully labeled fan curve(s) with system curve and operating point clearly plotted. For variable speed fans, provide fan curves for both minimum and maximum operating points.
3. Provide custom sound power level data (decibels) for each octave band for fan inlet, fan discharge and radiated sound power of the assembled air handling unit as shown. Determine sound level data using one of the following methods:
 - a. Actual measurements from tests performed in accordance with AMCA Standards in an AMCA registered test chamber.
 - b. Documented calculations that start with AMCA tested fan sound data and are modified in accordance with 2011 ASHRAE HVAC Applications, Chapter 48 - Noise and Vibration Control accurately predict the sound power levels for the configuration shown.
4. Provide electrical connection requirements.
5. Provide electrical power connection and control logic wiring diagrams. Diagrams must differentiate between factory installed and field-installed wiring.

- C. Substitutions: Cost of any design modifications as a result of proposed product substitutions shall be borne by the Contractor.

D. Shop Drawings:

1. Provide dimensional and orientation information (plan and elevation) for the approved rooftop air handling unit(s) incorporated into the ventilation system shop drawings.

2. Indicate actual cabinet location, sectional and overall cabinet dimensions, roof curb dimensional requirements, mixing box damper sizes and arrangement, access door locations, access clearances for filter, coil and fan replacement, duct connections, and electrical connection points.
3. Provide detail for filter holding frames, grids and filter housing arrangements as applicable. Indicate filter sizes and number of each filter size necessary to complete each filter bank, Using 24 inch x 24 inch filter dimensions whenever possible.
4. Coordinate roof curb requirements and roof penetration location with Architectural and Structural.
5. Label overall roof top unit(s) as scheduled. Label each cabinet section as specified.
6. Provide cabinet anchoring method approved by the seismic design engineer in accordance with Section 200548 – Mechanical Vibration and Seismic Control.

E. Operation and Maintenance (O&M) Manual:

1. Provide a complete copy of the manufacturer's written installation, operation and maintenance manual to include the following information:
 - a. Approved product data submittal information.
 - b. Installation instructions.
 - c. Operating instructions.
 - d. Troubleshooting guide.
 - e. Preventative maintenance requirements.
 - f. Complete parts list.
 - g. Recommended spare parts list.
2. Neatly annotate the O&M manual to clearly indicate information applicable to the equipment installed.

F. Manufacturer Reports:

1. Provide a certificate from the Manufacturer's Representative indicating that the roof top unit(s) is/are installed and operational in accordance with the manufacturer's written installation, operation and maintenance manual.
2. Provide start-up and operational checks using manufacturer checklists, signed by both the installing Contractor and Manufacturer's Representatives.

G. Quality Control Submittals: Refer to Section 019100 - Commissioning for submittal requirements.

1.6 CLOSEOUT SUBMITTALS

- A. See section 200000 - Mechanical General Requirements.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements.

- B. Extra Stock Materials: Spare Filters. Furnish one complete set of replacement filters for each roof top unit upon final completion of project. Filters are to remain sealed in their original boxes and labeled by equipment tag as scheduled. Locate filters in storage area designated by the Contracting Agency.

1.8 QUALITY ASSURANCE

- A. See Section 200000 - Mechanical General Requirements.
- B. Manufacturer qualifications: Company specializing in manufacturing the products specified in this section with a minimum of 10 years' documented experience.
- C. Certifications: Air filters certified and tested in accordance with ASHRAE Standard 52.2.
- D. Regulatory requirements: Products requiring electrical connection shall be listed and classified by Underwriters Laboratories Incorporated, or by a testing firm acceptable to the Authority Having Jurisdiction.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. See Section 200000 - Mechanical General Requirements.
- B. Storage and Handling Requirements: Maintain access doors shut, dampers and supply duct connections covered, and drain connections capped to protect components from construction dirt and debris.

1.10 WARRANTY

- A. Manufacturer Warranty: See Section 200000 - Mechanical General Requirements, for general mechanical warranty requirements.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Trane.
- B. Daikin-McQuay.
- C. Approved equal.

2.2 ROOFTOP AIR HANDLING UNITS (RTU-1)

- A. Dimensions:

1. Overall roof top unit dimensions scheduled are for the basis of design air handler manufacturer as indicated.
2. The dimensions for “as equal” manufacturers may differ.

B. Unit Casing Construction:

1. Heavy gauge steel cabinet, reinforced, and braced with steel angle framing for maximum rigidity. Designed for outdoor use and roof curb mounting. Unit base shall be watertight.
2. Exterior panels shall be zinc-coated, galvanized steel painted with gray air-dry finish.
3. Unit shall be double-wall construction in the air handling section with insulation. Interior insulation subject to the airstream shall be lined.
4. Acoustically lined cabinet interior with 2-inch thick UL listed acoustical liner materials.
5. Exterior casing, base frame and accessories coated with baked enamel finish.
6. Internal components and accessories coated with baked enamel finish or galvanized.
7. Connect parts with plated, galvanized steel fasteners.
8. Provide interior liner type and drain pan as indicated under each air handler section.
9. Provide steel stamped nameplate with air handler performance date clearly indicated.

C. Weather Hood: Galvanized steel construction with intake mounted bird screen painted to match cabinet.

D. Mixing Box Section:

1. Twenty gauge solid galvanized steel interior liner.
2. Hinged, insulated, double walled access door.
3. Interior lighting with wall switch for maintenance and general cleaning.
4. Sloped, galvanized steel drip pan with capped drain plug and drain hose adapter.
5. Outside Air Damper:
 - a. Manufacturer: Tamco, Series 9000 or pre-approved equal.
 - b. Low leakage, heavy gauge, internally insulated, extruded aluminum, air foil blades with extruded EDPM blade gaskets and frame seals.
 - c. Galvanized steel frame with parallel blade action.
 - d. Damper Sizing: Size outside air damper for maximum RTU air flow rate (CFM) scheduled using a flow velocity of 1,000 FPM not to exceed 0.1-inch static pressure drop with damper fully open.
6. Return Air Damper:
 - a. Manufacturer: Ruskin, Model CD50 or pre-approved equal.
 - b. Low leakage, heavy gauge, extruded aluminum, parallel arrangement, air foil blades with vinyl edge seals.
 - c. Galvanized steel frame with parallel blade action.
 - d. Damper Sizing: Size return air damper for maximum RTU air flow rate (CFM) scheduled using a flow velocity of 1,000 FPM not to exceed 0.1-inch static pressure drop with damper fully open.
7. Damper Arrangement:
 - a. Provide dampers, factory installed and sealed to the mixing box as indicated.
 - b. Provide outside air intake damper horizontally centered to front of mixing box

- c. Provide return air damper horizontally centered on base of mixing box.

E. Filter Section:

1. Twenty gauge solid galvanized steel interior liner.
2. Two sets of pre-filters for summer/winter arrangement with preheat coil.
3. Provide factory installed filter frames by the roof top unit by manufacturer with closed cell synthetic rubber and positive spring type clamps to hold filter elements securely against gaskets.
4. Provide access for changing filters from one or both sides of housing.
5. Filters:
 - a. Provide disposable, pleated dry media filters having a Minimum Efficiency Reporting Value of MERV 8 for prefilters, and MERV 14 for final filters when tested in accordance with ASHRAE 52.2.
 - b. 2-inch filter depth for prefilters, 12-inch filter depth for final filters.
 - c. Complete filter shall be UL listed as a Class 2 air filter.
 - d. Filter shall be constructed from pleated media supported and bonded to welded wire grid within a rigid beverage board frame. Media shall be non-woven, reinforced cotton and synthetic fabric. Media shall provide not less than 4.6 square feet of filter area for each square foot of face area. Media and frame shall be bonded to prevent air leakage.
 - e. Design of filter bank shall be based on an airflow rate of not more than 350 CFM per square foot of gross face area unless otherwise indicated. Initial static pressure loss shall not exceed 0.08 inches water column at 250 feet per minute face velocity. Filter shall be designed to operate at up to 0.9 inch water column, if required.
 - f. Preferred filter sizes are 24 by 24 by 2 inches with maximum of one 24 by 12 by 2 inches per row. Filter banks shall be designed to use the minimum number of readily available standard filter sizes.
 - g. Manufacturers: Farr 30/30 (Basis of Design), American Air Filter, or approved equal.
6. Filter Gauges:
 - a. Provide a dial type gauge with diaphragm magnetically coupled to pointer and with connections to upstream and downstream static pressure probes for each filter bank.
 - b. Provide monitoring contacts for connection to the BAS. Coordinate with 255000 - Building Automation System and Section 25 9000 - Sequence of Operations to connect filter monitoring pressure switches to same probes as the gauge.
 - c. Gauge scale range shall be 0 to 1 inch water column.
 - d. Manufacturers: Magna-helic (Basis of Design) or approved equal.

F. Refrigeration System:

1. Compressor:
 - a. Industrial grade, energy efficient direct drive speed scroll type.
 - b. Motor shall be suction gas cooled hermetic design.
 - c. Include centrifugal oil pump with dirt separator, oil sight glass, and oil charging valve.

2. Evaporator Coil:
 - a. Heavy duty aluminum fins mechanically bonded to copper tubes.
 - b. Provide thermostatic expansion valve for each refrigerant circuit.
 - c. Positive pitched galvanized drain pan.
3. Air Cooled Condenser Section:
 - a. Coil shall have aluminum microchannel coils.
 - b. Vertical discharge, direct drive fan.
 - c. Factory installed electronic low ambient option to allow for operation down to 0 degrees F.
 - d. Factory-installed louvered steel guards around perimeter of condensing section.

G. Preheat and Heating Coil Sections:

1. Cabinet:
 - a. Twenty gauge solid galvanized steel interior liner with sloped drip pan and capped drain plug with hose adapter.
 - b. Sloped, galvanized steel drip pan with capped drain plug and drain hose adapter.
 - c. Provide split casing panel to facilitate coil removal. Coordinate panel location with coil access and coil piping.
2. Preheat and Heating Coil:
 - a. Factory assembled and installed, non-freeze Type 5W AHRI Certified coil, with hot water modulating valve and actuator. Coil construction shall allow for complete drainage.
 - b. Provide heating coil section with adequate interior space for terminal hydronic heating piping and components as shown.
 - c. Provide coil with scheduled operational performance characteristics.
 - d. Coils designed for counter-flow heat transfer with equal pressure drop through each circuit.
 - e. Working Pressure: 250 PSIG.
 - f. Primary surface:
 - 1). Round, seamless, 0.020 inch thick copper tubing.
 - 2). Tubes mechanically expanded into fins over the entire finned length.
 - 3). Brazed joints.
 - g. Secondary surface:
 - 1). Solid aluminum fins (no punched openings to accumulate lint and dirt) with full drawn collars (Bare copper tube not visible between fins).
 - 2). Fin thickness: 0.0075 inches.
 - h. Coil Casing: Continuous 16 gauge galvanized steel with reinforced flange type side plates.
 - i. Coil Headers:
 - 1). Seamless, copper tubing.

2). Low point coil drain and high point coil vent.

H. Fan Section:

1. Cabinet:
 - a. Twenty gauge perforated, galvanized steel interior liner.
 - b. Hinged, insulated, double walled access door.
 - c. Interior lighting with wall switch for maintenance and general cleaning.
 - d. Sloped, galvanized steel drip pan with capped drain plug and drain hose adapter.
2. Fan Manufacturers:
 - a. Greenheck.
 - b. Cook.
 - c. Barry Blower.
 - d. Twin City.
3. General Fan Requirements:
 - a. Provide factory assembled, balanced and tested fan unit of the size, type and capacity scheduled. AMCA listed and labeled.
 - b. Provide factory applied enamel coating system to fan assembly components (except aluminum).
 - c. Provide fan arrangement with accessibility for complete cleaning, component replacement and preventative maintenance. Provide grease fitting(s) with extended grease lines (as necessary for direct access).
4. Vibration Isolation:
 - a. Isolate fan frame from unit casing using stable spring vibration isolators with a seismic snubbers.
 - b. Bearings: Greater than 200,000 hours average rated life at rated load and speed specified.
5. Fan Drives:
 - a. Provide v-belt drive for each fan selected for not less than 1.5 times the motor nameplate horsepower. Light duty belts (FHP) acceptable only with motors less than one (1)-horsepower. Sheaves shall be cast iron or steel.
 - b. Provide fixed speed drive sheave. Change fan and drive sheave in the field as necessary to attain required fan performance.
 - c. Provide OSHA belt guard with hinged tachometer cap.
6. Motors: See Section 200513 – Common Motor Requirements, for detailed fan motor specifications.
7. Sound data:
 - a. Factory test fan assemblies to determine suction, discharge and radiated sound levels (decibels) for each octave band in accordance with AMCA Standards. Include sound level data with fan submittals.

- b. When sound ratings are not specified, physical characteristics including type, wheel diameter and fan speed shall be the basis of comparison with specified requirements.
- c. Octave band sound power levels shall not exceed those scheduled.

I. Electrical:

- 1. Factory pre-wired for single point connection.
- 2. Auxiliary fan motor starter contact.
- 3. High voltage control panel shall have door handle disconnect switch.
- 4. Unit mounted 115 volt convenience outlet.

2.3 BUILDING AUTOMATION SYSTEM CONTROLS

- A. Provide roof top unit controls in accordance with Section 255000 - Building Automation System to include temperature and pressure sensors, damper actuators, controllers, and interface panels to control the roof top unit in accordance with Section 259000 -Sequence of Operations.

PART 3 - EXECUTION

3.1 INSTALLERS

- A. Installer: Perform work by experienced personnel previously engaged in ventilation system construction and air handling unit installation, and under the supervision of a qualified installation supervisor.

3.2 PREPARATION

A. Protection:

- 1. Maintain access doors shut, air handler box dampers and supply duct connections covered and drain connections capped to protect components from construction dirt and debris.
- 2. Provide a complete set of pre-filters for use during construction. Final filter bank media is to remain sealed in original boxes until final building housekeeping has been completed.
- 3. Protect return air inlet with 30 percent filters during construction.

3.3 EXAMINATION

- A. Verify that roof curb is installed, level and of the correct dimensions to accept and support the weight of the roof top unit.
- B. Verify that the roof curb's interior footprint has been pre-insulated with vapor barrier to match the adjacent roof R-value.
- C. Verify power supply is roughed in, located, and sized properly for the unit's single point power connection.

- D. Verify that hydronic piping penetrations have been installed, sleeved water-tight and are aligned with the heating coil section coil piping chase locations. Piping shall penetrate up through bottom of unit at pipe chase locations.

3.4 INSTALLATION

- A. Install rooftop air handling units and components in compliance with the manufacturer's written installation instructions and the following:
 - 1. Install BAS actuators, sensors, controls and control wiring in accordance with Section 25 5000 - Building Automation System.
 - 2. Install electrical power and wiring in accordance with Divisions 26, 27 and 28.

3.5 CONSTRUCTION

- A. Interface with other Work:
 - 1. Coordinate and sequence installation of each component with trades responsible for portions of this and other related sections of the Project Manual.
 - 2. Rework required, as a result of failure to follow the manufacturer's written installation instructions or to properly coordinate with related Work, shall be completed at no additional expense to the Owner.

3.6 REPAIR/RESTORATION

- A. Repair any product components broken during installation or startup with replacement parts supplied by the product manufacturer.
- B. Substitute replacement parts from other manufacturers are not acceptable.

3.7 FIELD QUALITY CONTROL

- A. Manufacturer's Field Services:
 - 1. Verify roof top unit(s) is/are installed and operational in accordance with the manufacturer's written installation instructions.
 - 2. Both the Contractor and Manufacturer's Representative(s) shall sign start-up and operational checklist to confirm proper system installation and operation.
- B. Site testing, conducted with ventilation system operating at maximum air volume flow rate with clean filter media installed:
 - 1. Verify each filter bank is properly sealed and filter bank leakage is within manufacturer's performance tolerances.
 - 2. Verify that filter bank differential pressure gauges are operating properly in accordance with manufacturer's written installation, operation and maintenance instructions.

3. Verify that clean filter differential pressures are as indicated in manufacturer's submittal data (within 5 percent) for actual filter bank flow velocity.

3.8 CLEANING

- A. Upon completion of installation and prior to initial start-up, vacuum clean internal and external surfaces.
- B. Upon completion of final housekeeping and with written approval of the Contracting Agency, replace construction filters with a complete set of new filters for use during testing and balancing.

3.9 SYSTEM START-UP

- A. Start-up and operate roof top units in accordance with the manufacturer's written installation, operation and maintenance (IO&M) manual.
- B. Verify proper operation of sequences in accordance with Section 259000 - Sequence of Operations.
- C. Document start-up and operational checks using manufacturer and PC/FC checklists and submit in accordance with submittal requirements.

3.10 ADJUSTING

- A. Test, adjust and balance roof top air handling equipment in accordance with Section 23 0593 - Testing, Adjusting and Balancing, the manufacturer's recommendations, and as otherwise directed by the Contracting Agency.

END OF SECTION 237416

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PART 1 - GENERAL

1.1 SUMMARY

- A. Section Includes: Packaged, direct expansion, air conditioning systems with microprocessor based controls for electrical room cooling.
- B. Related Sections:
 - 1. 019100 - Commissioning
 - 2. 200000 - Mechanical General Requirements
 - 3. 200548 - Mechanical Vibration and Seismic Control
 - 4. 221300 - Sanitary Waste and Vent Piping and Specialties
 - 5. 259000 - Sequence of Operations

1.2 REFERENCES

- A. Codes and Standards:
 - 1. See Section 200000 - Mechanical General Requirements.
 - 2. ARI 360 - Commercial and Industrial Unitary Air Conditioning Equipment testing and rating standard.
 - 3. ANSI/ASHRAE 15 - Safety Code for Mechanical Refrigeration.
 - 4. ANSI/ASHRAE 37 - Testing Unitary Air Conditioning and Heat Pump Equipment.
 - 5. ANSI/UL 465 - Central Cooling Air Conditioners Standard for Safety Requirements.

1.3 SYSTEM DESCRIPTION

- A. Design Requirements: This section describes specific requirements, products and methods of execution for the dedicated air conditioning units.
- B. Performance Requirements:
 - 1. Provide product performance characteristics as specified or scheduled on drawings.
 - 2. Operate system in accordance with Section 259000 - Sequence of Operations.

1.4 PRE-INSTALLATION MEETINGS

- A. See Section 200000 - Mechanical General Requirements.

1.5 SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements for general submittal requirements for the items listed below, supplemented with the additional requirements listed.
- B. Product Data: Submit copies of product data indicating rated capacities, weights, accessories, and electrical requirements.
- C. Shop Drawings: Submit drawings indicating components, dimensions, weights and loadings, required clearances, and location, routing and size of refrigerant lines and condenser discharge ductwork.
- D. Closeout Submittals: Submit copies of operation and maintenance manuals in accordance with Section 20 0000 - Mechanical General Requirements.
- E. Quality Control Submittals: Refer to Section 019100 - Commissioning for submittal requirements.

1.6 CLOSEOUT SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements.

1.8 QUALITY ASSURANCE

- A. See Section 200000 - Mechanical General Requirements.
- B. Regulatory Requirements: Units shall be UL listed.

1.9 DELIVERY, STORAGE AND HANDLING

- A. See Section 200000 - Mechanical General Requirements.

1.10 WARRANTY

- A. Manufacturer Warranty: See Section 200000 - Mechanical General Requirements, for general mechanical warranty requirements.

PART 2 - PRODUCTS

2.1 SELF-CONTAINED AIR CONDITIONING UNIT (AC-1/CU-1, AC-2/CU-2)

A. General:

1. Provide packaged, direct expansion, self-contained air conditioning systems as scheduled. System consists of ceiling wall mounted evaporator unit with a variable speed inverter driven compressor and fan motor and a separate, remote, mounted condenser unit. System refrigerant shall be R-410A. The system shall maintain zone setpoint temperatures using a packaged wall mounted controller.
2. Basis of Design: Mitsubishi P Series.

B. Indoor Unit:

1. The indoor unit shall be factory assembled and tested complete with factory wiring, piping, electronic proportional expansion valve, control circuit board, fan motor thermal protector, condensate drain pan, self-diagnostics, auto-restart function, 3-minute fused time delay, and test run switch.
2. Indoor unit and refrigerant pipes shall be charged with dehydrated air prior to shipment from the factory.
3. Cabinet:
 - a. The cabinet shall be fixed to factory supplied wall hanging brackets.
 - b. Multi-directional refrigerant and drain piping offering four (4) directions for refrigerant piping and two (2) directions for draining are required.
4. Fans and Motors:
 - a. The fan shall be direct-drive fan type with statically and dynamically balanced impeller with high and low fan speeds available.
 - b. The fan motor shall operate on voltage as scheduled on the drawings.
 - c. The fan motor shall be thermally protected.
5. Filter: Filter return air by means of an easily removable, washable filter.
6. Evaporator Coil:
 - a. Coils shall be of nonferrous construction with smooth plate fins on copper tubing. Tubing shall have inner grooves for high efficiency heat transfer. Tube joints shall be brazed with phos-copper or silver alloy.
 - b. The coil shall be pressure tested at the factory.
7. Electrical:
 - a. The fan motor shall operate on voltage as scheduled on the drawings.
 - b. 208-230 volts, 1 phase, 60 hertz. System shall be capable of satisfactory operation within voltage limits of 198 to 253 volts. Power to the unit shall be supplied from the outdoor unit, using the Mitsubishi Electric A-Control system. For A-Control, a

three (3) conductor AWG-14/16 wire with ground shall provide power feed and bi-directional control transmission between the outdoor and indoor units.

C. Remote Condensing Unit:

1. The outdoor unit shall be factory assembled and pre-wired with all necessary electronic and refrigerant controls. The refrigeration circuit of the condensing unit shall consist of a swing compressor, motors, fan, condenser coil, electronic expansion valves, solenoid valves, 4-way valve, distribution headers, capillaries, filters, shut off valves, service ports and suction accumulator.
2. The outdoor unit shall be equipped with front, rear, and side advanced wind baffles.
3. The system will automatically restart operation after a power failure and will not cause any settings to be lost, eliminating the need for re-programming.
4. The following safety devices shall be included on the condensing unit; high pressure switch, control circuit fuses, fusible plug, high pressure switch, overload relay, inverter overload protector, thermal protectors for compressor and fan motors, over current protection for the inverter and anti-recycling timers.
5. The condensing 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.
6. Fans and Motors:
 - a. The condensing unit fan shall consist of one propeller type, direct-drive fan motor that has multiple speed operation via a DC (digitally commutating) inverter.
 - b. The fan motor shall have inherent protection and permanently lubricated bearings and be mounted.
 - c. The fan motor shall be provided with a fan guard to prevent contact with moving parts.
7. Condenser Coil:
 - a. The condenser coil shall be manufactured from copper tubes expanded into aluminum fins to form a mechanical bond.
8. Compressor:
 - a. The compressor for models PUZ(Y)-A12/18/24/30/36/42NH/KA7 shall be a DC twin-rotor rotary compressor with Variable Speed Inverter Drive Technology.
 - b. The compressor shall be driven by inverter circuit to control compressor speed. The compressor speed shall dynamically vary to match the room load for significantly increasing the efficiency of the system which shall result in significant energy savings.
 - c. To prevent liquid from accumulating in the compressor during the off cycle, a minimal amount of current shall be automatically, intermittently applied to the compressor motor windings to maintain sufficient heat to vaporize any refrigerant. No crankcase heater is to be used.
 - d. The outdoor unit shall have an accumulator and high pressure safety switch. The compressor shall be mounted to avoid the transmission of vibration.

D. Quality Assurance:

1. The units shall be tested by a Nationally Recognized Testing Laboratory (NRTL), and bear the ETL label.
2. Wiring shall be in accordance with the National Electric Code (NEC).
3. System rated in accordance with Air Conditioning Refrigeration Institute's (ARI) Standard 210/240 and bear the ARI label.
4. Provide a holding charge of dry nitrogen in the evaporator.
5. System efficiency meets or exceeds 17.6 SEER.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General:

1. Install units in accordance with manufacturer's written installation instructions.
2. Install units plumb and level, firmly anchored in the locations indicated while maintaining manufacturer's recommended clearances.
3. Adjust evaporator unit location to align with ceiling grid.

B. Electrical Wiring: Furnish one copy of manufacturer's electrical connection diagrams to the electrical subcontractor.

C. Piping Connections: Furnish one copy of manufacturer's condensate pump connection diagram to the plumbing subcontractor.

3.2 FIELD QUALITY CONTROL

A. Startup air conditioning unit in accordance with the manufacturer's written start up instructions.

B. Test control features and demonstrate compliance with operational requirements.

END OF SECTION 238123

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PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Unit heaters.
2. Radiant ceiling panels.

B. Related Sections:

1. 019100 - Commissioning
2. 200000 - Mechanical General Requirements
3. 200529 - Mechanical Hangers and Supports
4. 200548 - Mechanical Vibration and Seismic Control
5. 200553 - Mechanical Identification
6. 200700 - Mechanical Insulation
7. 204100 - Mechanical Demolition
8. 230593 - Testing, Adjusting and Balancing
9. 232113 - Hydronic Piping and Specialties
10. 233100 - Ducts and Accessories
11. 233600 - Air Terminal Units
12. 233700 - Air Outlets and Inlets
13. 253000 - Building Automation System Field Devices
14. 255000 - Building Automation System
15. 259000 - Sequence of Operations

1.2 REFERENCES

A. Codes and Standards: See Section 200000 - Mechanical General Requirements.

B. Abbreviations, Acronyms and Definitions:

1. Refer to Division 01 for general abbreviations, acronyms, and definitions.
2. Refer to Section 200000 - Mechanical General Requirements for general mechanical related definitions.
3. Refer to Mechanical Drawings legend sheet for general mechanical related abbreviations.

1.3 SYSTEM DESCRIPTION

A. Design Requirements: Provide terminal heating and cooling units, piping, appurtenances, and controls to automatically maintain interior temperature setpoint for each area of the building.

B. Performance Requirements: Provide performance and output shown or scheduled on drawings.

1.4 PRE-INSTALLATION MEETINGS

- A. See Section 200000 - Mechanical General Requirements.

1.5 SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements for general submittal requirements for the items listed below, supplemented with the additional requirements listed.

- B. Product Data:

- 1. Submit product literature for items specified in Part 2 and those products required by the performance standards of this section. Literature clearly annotated to indicate specified salient features and performance criteria.
- 2. Include the following:
 - a. Performance characteristics as scheduled.
 - b. Enclosure style, material and grille arrangement.
 - c. Dimensional data.

- C. Shop Drawings:

- 1. For custom architectural fintube heating enclosures, provide shop drawings which include:
 - a. Custom enclosure dimensions and method of construction.
 - b. Fintube location and support method to include expansion/contraction compensation.
 - c. Inlet and outlet grille model and fastening method.
- 2. Submit schedules of equipment and enclosures typically indicating length and number of pieces of element and enclosure, corner pieces, end caps, cap strips, access doors, pilaster covers, and comparison of specified heat required to actual heat output provided.
- 3. Indicate mechanical and electrical service locations and requirements.

- D. Samples:

- 1. Provide color samples of fintube and cabinet unit heater enclosures.
- 2. Colors to be selected by the Contracting Agency.

- E. Provide certificates, manufacturer's instructions, and manufacturer's field reports for Quality Assurance/Control Submittals:

- 1. Provide a complete manufacturer's written installation, operation and maintenance manual for each type of installed equipment.
- 2. Clearly annotate the manual to indicate applicable information for the specific equipment model(s) installed.
- 3. Included with the manual one copy of the completed start-up and operation checklist. The checklist shall include:

- a. Printed names and signatures of the installers.
- b. Documentation from Manufacturer's representative and Contracting Agency that the equipment has been properly installed and is fully operational, thus validating the equipment warranty.

F. Closeout Submittals:

1. Project Record Documents: Record actual locations of components and locations of access doors in terminal unit cabinets required for access or valves.
2. Operation and Maintenance (IO&M) Manuals:
 - a. Refer to Section 200000 - Mechanical General Requirements, for IO&M Manual formatting requirements and number of copies required.
 - b. Provide copies of approved submittal information for inclusion within the project IO&M Manual. Include manufacturer's descriptive literature, operating instructions, installation instructions, maintenance and repair data, parts listings, and spare parts list.

- G. Quality Control Submittals: Refer to Section 019100 - Commissioning for submittal requirements.

1.6 CLOSEOUT SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements.
- B. Extra Stock Materials: Provide one set replacement filters for cabinet unit heaters and fan coil units.

1.8 QUALITY ASSURANCE

- A. See Section 200000 - Mechanical General Requirements.
- B. Regulatory requirements: Products requiring electrical connection shall be listed and classified by Underwriters Laboratories Incorporated, or by a testing firm acceptable to the Authority Having Jurisdiction.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. See Section 200000 - Mechanical General Requirements.

1.10 WARRANTY

- A. Manufacturer Warranty: See Section 200000 - Mechanical General Requirements, for general mechanical warranty requirements.
- B. Provide 5-year manufacturer's warranty for unit heaters and cabinet unit heaters.

PART 2 - PRODUCTS

2.1 UNIT HEATERS

- A. Coils: Seamless copper tubing, silver brazed to steel headers, and with evenly spaced aluminum fins mechanically bonded to tubing.
- B. Casing: 0.0478-inch steel with threaded pipe connections for hanger rods.
- C. Finish: Factory applied baked enamel finish.
- D. Fan: Direct drive propeller type, statically and dynamically balanced, with fan guard; horizontal models with permanently lubricated sleeve bearings; vertical models with grease lubricated ball bearings.
- E. Air Outlet: Adjustable pattern diffuser on projection models and two way louvers on horizontal throw models.
- F. Motor: Permanently lubricated sleeve bearings on horizontal models, grease lubricated ball bearings on vertical models. Refer to Section 200513 - Common Motor Requirements.
- G. Control: Local disconnect switch.
- H. Capacity: As scheduled.
- I. Electrical Characteristics:
 - 1. Horsepower, voltage, and phase as scheduled on the Drawings, 60 Hz.
 - 2. Refer to Divisions 26, 27 and 28.
- J. Manufacturers: Sterling, Modine, Rittling, Trane, Vulcan, JAGA.

2.2 HYDRONIC RADIANT CEILING PANELS

- A. Panel shall consist of extruded aluminum with copper tubing of 0.50 inch ID mechanically attached to the aluminum faceplate. Hold copper tubing in place with an integral aluminum saddle or similar metal fastener which positively secures the tube to the panel. Use of adhesives or clips is not acceptable.

- B. Not all panel hardware, mounting and attachment components and features are detailed on the Mechanical and Architectural Drawings. Provide backing, supports, moldings, hangers, cross tees, seismic restraints, hardware, and other appurtenances required for a complete and properly operating finished system. Mechanical fasteners shall not be exposed in the finish work.
- C. In addition to the Mechanical Drawings, refer to Architectural reflected ceiling plans and room finish schedule to determine other panel requirements.
- D. Provide finish and color selected by the Contracting Agency.
- E. Cross brace entire assembly with structural members and insulate with 1-inch thick fiberglass insulation. Configure panels within T-bar ceiling module and run wall to wall.
- F. Heating Capacity: Panel total output rating shall be not less than 250 Btuh/SF at 190 degrees F when tested against an average unheated surface temperature (AUST) of 70 degrees F. Data shall be certified by qualified independent test lab.
- G. Manufacturers: Airtex, Sterling, or Aero Tech AX.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Protection: Cover equipment and plug piping connections to protect components from construction dirt and debris.
- B. Preparation: Prior to installation of terminal units, make sure wall construction is complete enough to correctly locate and mount units.

3.2 INSTALLATION

- A. Install terminal equipment in accordance with manufacturer's instructions.
- B. Install equipment exposed to finished areas after walls and ceilings are finished and painted.
- C. Unit Heaters: Hang from building structure, with pipe hangers anchored to building, not from piping. Mount as high as possible to maintain greatest headroom unless otherwise indicated.
- D. Hydronic Units:
 - 1. Provide accessible ball type isolation valves on supply and return lines to each terminal unit to allow for unit drain down and repair.
 - 2. Provide low-point drain valve that allows for complete gravity draining of terminal unit.
 - 3. Provide balancing valve as specified elsewhere.
 - 4. Provide high-point automatic air vent as specified elsewhere.
- E. Radiant Panels:

1. Provide each panel circuit with shutoff valve on supply and balancing valve on return piping.
 2. Install in accordance with the manufacturer's shop drawings.
 3. Coordinate with ceiling system and other related work.
 4. Mechanical fastenings shall not be exposed in the finished work.
 5. Install suspension system in accordance with ASTM C636.
 6. Completely cover panel with minimum of 2 inches of fibrous glass, unfaced blanket insulation.
 7. Do not connect to supply and return system until system has been flushed and cleaned.
- F. Access Doors: Install such that a drain hose may be easily connected to each drain line hose bibb, allowing the applicable portion of the system to be completely drained.
- G. Install balancing valves and serviceable products for heating terminal units to be operable and adjustable without removal of the finish cover.
- H. Provide pressure and temperature test plugs on both sides of heat transfer elements to measure the drop across runs of heat transfer elements.
- I. In systems containing glycol, provide only products specifically designed and approved for continuous operation with the glycol solution specified.

3.3 CONSTRUCTION

- A. Interface with Other Work:
1. Coordinate and sequence installation of terminal heating and cooling units with trades responsible for portions of this and other related sections of the Project Manual.
 2. Rework required as a result of failure to follow the manufacturer's written installation instructions or to properly coordinate with related Work shall be completed at no additional expense to the Owner.

3.4 REPAIR/RESTORATION

- A. Repair any product components broken during installation or startup with replacement parts supplied by the product manufacturer.
- B. Substitute replacement parts from other manufacturers are not acceptable.

3.5 FIELD QUALITY CONTROL

- A. Manufacturer's Field Services:
1. Verify units are installed and operational in accordance with the manufacturer's written installation instructions.
 2. Both the Contractor and Manufacturer's Representatives shall sign start-up and operational checklist to confirm proper unit installation and operation.

3.6 ADJUSTING

- A. Adjust functional components for proper operation in accordance with manufacturer's recommendations, or as otherwise directed.
- B. Coordinate and work directly with the Testing, Adjusting and Balancing Agency to provide systems in proper operating order. Make corrections and adjustments as required by the Balancing and Testing Agency in a timely manner.

3.7 CLEANING

- A. After construction is completed (including painting), and prior to initial start-up, clean and wipe down exposed surfaces of units. Vacuum clean coils and inside of cabinets and enclosures.
- B. Touch up marred or scratched surfaces of factory finished cabinets and enclosures, using finish materials furnished by manufacturer.
- C. Clean permanent filters or install new disposable filters.

3.8 DEMONSTRATION AND START-UP

- A. Start-up and operate terminal heating and cooling units in accordance with the manufacturer's written installation and operation manual check list.
- B. Demonstrate proper system operation using the building automation system.
- C. Document start-up and operational checks using the checklist and submit in accordance with submittal requirements.

END OF SECTION 238200

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PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Requirements, products, procedures, performance requirements, and methods of execution relating to the Building Automation System (BAS) terminal devices and field hardware.
2. Refer to related sections for other technical requirements, products, and methods of execution relating to the controls system for monitoring and control of mechanical systems.

B. Related Sections: Refer to Section 255000 - Building Automation System

1.2 REFERENCES

A. Refer to Section 255000 - Building Automation System.

1.3 SYSTEM DESCRIPTION

A. Refer to Section 255000 - Building Automation System.

1.4 PREINSTALLATION MEETINGS

A. Refer to Section 255000 - Building Automation System.

1.5 SUBMITTALS

A. Submit in accordance with Section 255000 - Building Automation System and in accordance with Division 1.

1.6 CLOSEOUT SUBMITTALS

A. Submit in accordance with Section 255000 - Building Automation System and in accordance with Division 1.

1.7 MAINTENANCE MATERIAL SUBMITTALS

A. See Section 200000 - Mechanical General Requirements.

1.8 QUALITY ASSURANCE

- A. Refer to Section 255000 - Building Automation System.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Refer to Section 255000 - Building Automation System.

1.10 WARRANTY

- A. Refer to Section 255000 - Building Automation System.

PART 2 - PRODUCTS

2.1 TEMPERATURE SENSOR

- A. Digital room sensors:

1. Temperature monitoring range: 55/95 degrees F.
2. Network jack.
3. Output signal: Changing resistance.
4. Accuracy at Calibration point: Plus or minus 0.5 degrees F.
5. Wall Mounted unit with finished cover:

- a. Private offices and rooms:

- 1). LCD display, day/night override button, and setpoint slide adjustment override options. The setpoint slide adjustment can be software limited by the automation system to limit the amount of room adjustment.
- 2). Set Point and Display Range: 55 degrees to 95 degrees F.

- b. Public Spaces: Blank Cover.

- B. Duct (single point) temperature:

1. Temperature monitoring range: 20/120 degrees F.
2. Output signal: Changing resistance.
3. Accuracy at Calibration point: Plus or minus 0.5 degrees F.
4. Sensing element shall be located a minimum of 25 percent across duct width.

- C. Duct Average temperature:

1. Temperature monitoring range: 20/120 degrees F.
2. Output signal: 4-20 mA DC.
3. Accuracy at Calibration point: Plus or minus 0.5 degrees F.
4. Sensor Probe Length: 25 feet.

2.2 WALL MOUNTED SENSOR GUARD

- A. Heavy-duty wire cage type with mounting plate.
- B. Cast Aluminum Guard and mounting bracket.
- C. Clear or opaque butyrate plastic guard, key lock, mounting plate.

2.3 MEDICAL GAS ROOM HYDRONIC UNIT HEATER THERMOSTAT AND ROOM TEMPERATURE MONITORING

- A. Unit Heater Thermostat: Amperage capacity sufficient to cycle fan without need for contactor.
- B. Provide a blank face BAS temperature sensor for monitoring of medical gas room temperatures.

2.4 BOILER ROOM HYDRONIC UNIT HEATER THERMOSTAT

- A. Unit Heater Thermostat: Amperage capacity sufficient to cycle fan without need for contactor.

2.5 DIGITAL STATUS POINTS

- A. Digital status shall be monitored by sensing normally closed contacts (contact closed in alarm conditions). The addition of the monitoring relay shall not affect the operation of the systems involved.

2.6 DIGITAL COMMAND POINTS

- A. Command relays shall be momentary, automatic, maintained, or magnetic latch fail/safe as required. Maintained contacts located in occupied spaces or plenum spaces shall be mechanically latched. Relays shall be plug in and field replaceable. Contact ratings shall be in accordance with service.

2.7 CURRENT SENSOR

- A. Provide current sensors that convert AC current to a proportional (4-20 mA) DC current.
- B. Provide reverse voltage and high over current capacity.
- C. Provide red LED light to indicated relay status and power.
- D. Temperature operating range: 5 to 140 degrees F.
- E. Provide UL Listed device.

2.8 CURRENT SENSING RELAY

- A. Provide solid-state, self-calibrating, current operated relay suitable for equipment status monitoring. Provide a relay that changes switch contact state in response to an adjustable set point value of current in the monitored A/C circuit.
- B. Provide red LED light to indicated relay activation.
- C. Temperature operating range: minus 30 to 140 degrees F.
- D. Provide UL Listed device that is rated for plenum installation.

2.9 RELAYS

- A. Applications: Relays external to the controls shall include (but not be limited to) the following:
 - 1. Control relays for start/stop or open/close control of equipment.
 - 2. Monitoring relays for electrical circuit on/off or open/closed status detection.
 - 3. Interposing relays to provide interface between solid state circuitry and ac-driven control relays.
- B. Requirements: Relays shall be housed in dust-tight cases conveniently located for wiring and inspection:
 - 1. Control Relay: Control relays shall be suitable for continuous operation of 120 VAC and be able to interrupt the control circuits of various HVAC equipment. The number of contacts required for the relay shall be determined from the number of independent equipment to be controlled. The number of control relays required for the motor start/stop circuit shall be determined from examination of the equipment to be controlled.
 - 2. Monitoring Relay: Monitoring relays shall be suitable for continuous operation at the voltages of the circuits to be monitored. The monitoring relays shall be connected in such a way that the operation of the relay contact shall represent the change of status of the monitored circuit (i.e. ON/OFF, etc.) or duplicate the operation of the existing alarm circuit (i.e. high/low, etc.). The addition of the monitoring relay shall not affect the operation of the systems involved.
 - 3. Interposing Relay: Interposing relays shall be DC driven and be utilized to provide interface between solid state circuitry and ac-driven control relays as required.

2.10 CONTROL VALVE

- A. Control Valve: Factory fabricated, of type, body material, and pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated.
- B. Globe Valve 2 inch and Smaller: Bronze body, bronze trim, rising stem, renewable composition disc, and sweat ends.
- C. Globe Valve 2-1/2 inch and Larger: Iron body, bronze trim, rising stem, plug-type disc, flanged ends, and renewable seat and disc.

D. Hydronic system globe valve shall have the following characteristics:

1. Rating: ANSI Class 125 for service at 125 PSIG and 32/250 degrees F operating conditions.
2. Internal Construction:
 - a. Replaceable plugs and seats of stainless steel or brass.
 - b. Single-Seated Valves: Cage trim provides seating and guiding surfaces for plug on top and bottom of guided plugs.
 - c. Double-Seated Valves: Balanced plug; cage trim provides seating and guiding surfaces for plugs on top and bottom of guided plugs.
3. Sizing: 3 PSIG maximum pressure drop at design flow rate.
4. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics. Operators shall close valves against pump shutoff head.
5. Select heating valves shall fail to a Normally Open to heat position, unless otherwise indicated. Select cooling valves to normally closed to cooling position.
6. Three-way valves: Mixing type, unless otherwise indicated.

2.11 CONTROL DAMPER

A. Rectangular:

1. Frame: Five inches by one inch by minimum 0.125 inch 6063-T5 extruded aluminum hat-shaped channel, mounting flanges on both sides of frame, reinforced at corners.
2. Blades: Provide airfoil-shaped, single-piece blades made of heavy-duty 6063-T5 extruded aluminum. Maximum six inch blade width.
3. Bearings: Molded synthetic sleeve, turning in hole in frame.
4. Seals:
 - a. Blade: Extruded vinyl type for ultra-low leakage from minus 50 degrees F. to 350 degrees F. Mechanically attached to blade edge.
 - b. Jamb: Flexible metal compression type.
5. Linkage: Concealed in frame.
6. Axles: Minimum 1/2-inch diameter plated steel, hex-shaped, mechanically attached to blade.
7. Finish: Mill aluminum.
8. Performance Data:
 - a. Temperature Rating: Withstand minus 50 degrees F. to 350 degrees F.
 - b. Capacity: Demonstrate capacity of damper to withstand HVAC system operating conditions:
 - 1). Closed Position: Maximum pressure of 13 inches W.C. at a 12-inch blade length.
 - 2). Open Position: Maximum air velocity of 6,000 feet per minute.

- c. Leakage: Maximum 2.0 cubic feet per minute per square foot at 1.0 W.C. for sizes 24 inches wide and above.
 - d. Pressure Drop: Maximum 0.03 inch W.C. at 1,500 feet per minute across 24 inch by 24 inch damper.
 9. Manufacturer: Ruskin CD50, Louvers and Dampers, Air Balance, Pottorff, or equal.
- B. Round:
 1. Frame:
 - a. Under 6 inches Diameter: 2 inches by 1/2 inch minimum 12 gage galvanized steel tube.
 - b. 6 thru 12 inches Diameter: 2 inches by 1/2 inch by minimum 14 gage galvanized steel channel.
 - c. Above 12 thru 24 inches Diameter: 2 inches by 1/2 inch by minimum 1/8 inch galvanized steel channel.
 - d. Above 24 inches Diameter: 2 inches by 1 inch by minimum 3/16 inch galvanized steel channel.
 2. Blade: Provide single-piece construction made of the following material:
 - a. 18 inches diameter and smaller: Minimum 12 gage galvanized steel.
 - b. Over 18 inches diameter: Minimum 10 gage galvanized steel, stiffeners as required.
 3. Blade Seals: Closed cell polyethylene foam rubber fully encompassing and mechanically attached to blade edge.
 4. Bearings: Self-lubricating stainless steel sleeve.
 5. Axles:
 - a. 22 inches Diameter and smaller: Minimum 1/2 inch diameter, full length, plated steel, mechanically attached to blade.
 - b. Over 22 inches Diameter: Minimum 3/4 inch diameter, full length, plated steel, mechanically attached to blade.
 6. Finish: Mill.
 7. Performance Data.
 - a. Temperature Rating: Withstand maximum 250 degrees F.
 - b. Capacity: Demonstrate capacity of damper to withstand HVAC system operating conditions.
 - 1). Closed Position: Maximum pressure of 10 inches W.C.
 - 2). Open Position: Maximum air velocity of 4,000 feet per minute /min.
 - c. Leakage: Maximum 10 cubic feet per minute total at 1 inch W.C.
 - d. Pressure Drop: Maximum 0.05 inch W.C. at air volume of 7,000 cubic feet per minute through 24 inch diameter damper.
 8. Manufacturer: Ruskin CDR25, Louvers and Dampers, Air Balance, Pottorff, or equal.

2.12 VALVE AND DAMPER ACTUATORS

A. General:

1. Provide electronic direct-coupled actuation for control valves and dampers.
2. Proportional actuators shall accept a 0-10 VDC or 0-20 mA control input and provide a 2-10 VDC or 4-20 mA operating range. Damper actuators and control valve actuators serving valves larger than 3/4" shall provide a 2-10 VDC position feedback signal. The feedback signal shall be independent of the input signal.
3. Actuators indicated by Normally Closed or Normally Open designation on drawings or in sequence of operation shall be spring return type.
4. The actuator shall have electronic overload circuitry to prevent damage to the actuator.
5. Provide actuators listed by Underwriters Laboratories Standard 873 Standard for Safety Temperature-Indicating and -Regulating Equipment.

B. Damper Actuator:

1. Provide damper actuator shall be direct-coupled over the shaft, enabling it to be mounted directly to the damper shaft without the need for connecting linkage.
2. Spring return actuators shall be capable of both clockwise and counterclockwise spring return operation by simply changing the mounting orientation.
3. Non-spring return actuators shall have an external manual gear release to allow manual positioning of the damper when the actuator is not powered. Spring return actuators with more than 60 in-lb torque capacity shall have a manual crank for this purpose.
4. Provide actuators in sufficient size, quantity and type to match application. Provide a minimum of one damper actuator for each 24 square feet of damper area. Damper areas shall not exceed manufacturer's ratings.
5. Outside air and return air dampers on mixing boxes shall be linked such that one opens while the other closes. It shall not be possible to close both dampers simultaneously.
6. Dampers: Size for minimum running torque calculated as follows:
 - a. Parallel-Blade Damper with Edge Seals: 7 inch-pounds/sq. ft. of damper.
 - b. Opposed-Blade Damper with Edge Seals: 5 inch-pounds/sq. ft. of damper.
 - c. Parallel-Blade Damper without Edge Seals: 4 inch-pounds/sq. ft. of damper.
 - d. Opposed-Blade Damper without Edge Seals: 3 inch-pounds/sq. ft. of damper.
 - e. Dampers with 2 to 3 Inches WC of Pressure Drop or Face Velocities of 1000 to 2500 FPM: Multiply the minimum full-stroke cycles above by 1.5.
 - f. Dampers with 3 to 4 Inches WC of Pressure Drop or Face Velocities of 2500 to 3000 FPM: Multiply the minimum full-stroke cycles above by 2.0.
 - g. Values noted above do not include normally open or normally closed open spring return dampers. Provide additional torque as required.
7. Size operators with ample power to overcome friction of damper linkage and air pressure acting on the damper blades.

C. Valve Actuator:

1. Provide actuators with enough torque and force required for proper valve close-off against the system pressure.

- 2. The valve actuator shall be sized based on valve manufacturer’s recommendations for flow and pressure differential.
- D. Actuators shall be of the following types, unless noted otherwise on the drawings or in the sequences of operation:

Service	Type (1)
Exhaust Air Damper	NC
Air handler/MUA units with outside air:	
Heating Coil valves	NO
Cooling Coil Valves	NC
Air Terminal Units Heating Coil Valves	Floating
Reheat Coil Valves	Floating
Glycol Loop Control valve	NO
Heating Zone Temperature Control Valve	NO
Fan Coil Units	NO

(1) NC = Normally closed. NO = Normally open

2.13 INSTRUMENT ENCLOSURE

- A. Steel construction with hinged and lockable doors.
- B. NEMA 12 construction only in areas where panels are subject to moisture damage.
- C. Wiring connections including I/O and power shall be extended to a numbered, color-coded, and labeled terminal strip for ease of maintenance and expansion.
- D. Provide labeling and color coding for wiring. Wiring shall follow a common format typical for the entire facility. Terminal strip color coding and numbering shall follow a common format. Wiring shall be neatly installed in plastic trays or tie-wrapped.
- E. Line voltage wiring shall be segregated from I/O wiring and shall be UL listed, 300-volt service and provide adequate clearance for field wiring.
- F. Provide a convenience 120 VAC duplex receptacle shall be provided in each enclosure, fused on/off power switch, and required transformers. Provide convenience receptacle for enclosures containing equipment that can be configured or adjusted with a portable computer.

2.14 POWER SUPPLY

- A. DC power supplies shall be sized for the connected device load. Total rated load shall not exceed 75 percent of the rated capacity of the power supply.

- B. Input: 120 VAC plus 10 percent, 60Hz.
- C. Output: 24 VDC.
- D. Line Regulation: Plus 0.05 percent for 10 percent line change.
- E. Load Regulation: Plus 0.05 percent for 50 percent load change.
- F. Provide an appropriately sized fuse and fuse block shall be provided and located next to the power supply.
- G. Provide a power disconnect switch shall be provided next to the power supply.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Special Techniques:

1. Wiring:

- a. The HVAC Control Contractor shall provide conduit, wiring, accessories, and wiring connections required for the installation of the control system, as herein specified, unless specifically shown in Divisions 26, 27 and 28.
- b. Conduit and wiring shall comply with the requirements of applicable portions of Divisions 26, 27 and 28 and local and national electric codes, unless specified otherwise in this section.
- c. System input wiring shall be twisted shielded pair, minimum 20 gauge wire. System analog output wiring shall be twisted shielded pair/3-wire as required, minimum 20 gauge wire. Preconfigured cables between Terminal Unit Controllers and Thermostats are acceptable, minimum 24 gauge.
- d. Internal panel device wiring for binary outputs and pilot relay shall be minimum 16 gauge wire.
- e. Provide separate conduit for control system power wiring including but not limited to 120 VAC and greater. I/O sensor wiring and data communication cabling shall be segregated from 120 VAC control system power wiring.
- f. Wiring in mechanical rooms shall be in conduit. Minimum control wiring conduit size 3/4 inch. One half inch conduit may be used for thermostats and valve stub-ups where conduit contains only a single pair.

2. Temperature Sensors:

- a. Temperature sensor assemblies shall be readily accessible and adaptable to each type of application in such manner as to allow for quick, easy replacement and servicing without special tools or skills.
- b. Outdoor installations shall be of weatherproof construction or in appropriate NEMA enclosures. These installations shall be protected from solar radiation and wind effects. Protective shield shall be stainless steel.

- c. Wall Mounted Sensor and Thermostats:
 - 1). Install wall mounted room sensors at a height of 44 inches above finish floor level.
 - 2). Locate sensors as shown on the Drawings.
 - 3). Provide insulated base for sensors mounted on sheet metal, steel columns or exterior walls. Wire penetrations shall be caulked airtight to prevent thermal convection.
 - 4). Provide heavy-duty guards for sensors and thermostats in public areas and as shown on the Drawings.
 - d. Duct Temperature Sensor: The sensor shall measure the representative temperature of the entire cross-section of the duct or plenum. Sensors in ducts shall be mounted in locations to sense the correct temperature of the air only and shall not be located in dead air spaces. Ductwork shall be securely sealed where elements or connections penetrate ducts to avoid measuring false conditions.
 - e. Fluid Temperature Sensors: Provide sensors with thermal wells fabricated and installed for the intended service. Wells shall be non-corrosive to the medium being measured and shall have sufficient physical strength to withstand all pressures, (including test pressures) and velocities to which they are subjected. Well shall not restrict flow area to less than 70 percent of line-size-pipe normal flow area. Where piping is smaller than the length of the well or exceeds the area requirements, the well shall be installed at an elbow and installed to effect uniform flow across the well. Sensors installed in wells shall be installed in horizontal piping below the pipe centerline.
 - f. Low Temperature Detection Thermostats: Mount sensor element similar to Mixed Air Temperature Sensors.
3. Current Sensors:
 - a. Provide flow proof for constant volume fans and pumps with a current sensor connected to the motor wiring at the starter. Set upper alarm limit to the maximum rated current of the motor, or as advised by the TAB Agency. Set lower alarm limit at 1/2 the motor running amps.
 - b. Provide flow proof for variable speed control system through utilization of the variable speed drive serial communication option. Drive will communicate directly with BAS system.
 4. Digital Status, Digital Command Points, Lighting Controls:
 - a. Provide relays in a separate instrument enclosure or control panel adjacent to the monitored or controlled equipment. The relays shall mounted and connected in a manner that does not violate controlled equipment listing or code requirements.
 - b. Provide relays that operate in conjunction with the motor control system. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.
 - c. Coordinate motor control requirements with Divisions 26, 27 and 28.
 - d. Coordinate lighting control requirements with Divisions 26, 27 and 28.

5. Identification:

- a. Panel and Instrument Enclosure Identification: Panels and instrument enclosures shall be identified by a plastic engraved nameplate securely fastened to the outside of the controller enclosure.
- b. Field Devices: Field devices shall be identified by a typed (not handwritten) securely attached tag label.
- c. Panel or Instrument Enclosure Devices: Devices shall be identified by a typed label securely fastened to the backplane of the local control panel or instrument enclosure.
- d. Wall Mounted Temperature Sensors: Device covers shall be identified by a typed label securely fastened to the front cover. The label shall indicate the terminal unit zone identification tag.
- e. Raceway Identification: The covers to junction and pull boxes of the control system raceways shall be painted blue or have identification labels stating "Control System" affixed to the covers. This requirement includes control system tubing. Labels shall be typed, not hand written.
- f. Wire Identification: Low and line voltage control wiring shall be identified by a number, as referenced to the associated control diagram, at each end of the conductor or cable. Identification number shall be permanently secured to the conductor or cable and shall be typed.

3.2 SYSTEM STARTUP

- A. Commissioning: Perform tests and verification procedures required for the commissioning process as requested by the Owner and directed by the Owner's Commissioning Authority.

3.3 MAINTENANCE

- A. Arrange work so that wherever possible serviceable or operable products are located within mechanical or electrical spaces and are accessible.

END OF SECTION 253000

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PART 1 - GENERAL

1.1 SUMMARY

- A. Section Includes: Requirements for solid-state, pulse-width modulated (PWM) Adjustable Frequency Drives, herein referred to as AC Drives, for use with NEMA design AC motors. The term “VSD” (Variable Speed Drive) is also used in this specification.
- B. Related Sections:
1. 019100 - Commissioning
 2. 200000 - Mechanical General Requirements
 3. 200529 - Mechanical Hangers and Supports
 4. 200548 - Mechanical Vibration and Seismic Control
 5. 200553 - Mechanical Identification
 6. 230593 - Testing, Adjusting and Balancing
 7. 232123 - Hydronic Pumps
 8. 233400 - HVAC Fans
 9. 237413 - Packaged Rooftop Units
 10. 253000 - Building Automation System Field Devices
 11. 255000 - Building Automation System
 12. 259000 - Sequence of Operations

1.2 REFERENCES

- A. Codes and Standards:
1. See Section 200000 - Mechanical General Requirements.
 2. Institute of Electrical and Electronic Engineers (IEEE): IEEE 519-2014.
 3. Underwriters Laboratories (as appropriate): UL 508, 508A, 508C, UL 61800, 61800-5-1, 61800-5-2, UL 1995.
 4. The Association of Electrical Equipment and Medical Imaging Manufacturers (NEMA): NEMA ICS 7-2014, Adjustable Speed Drives.
 5. National Electric Code (NEC): NEC 430.120, Adjustable-Speed Drive Systems.
 6. CSA Group: CSA C22.2 No. 274.
 7. International Building Code (IBC): IBC 2018 Seismic – referencing ASCE 7-16 and ICC AC-156.
- B. Abbreviations, Acronyms and Definitions:
1. Refer to Division 01 for general abbreviations, acronyms, and definitions.
 2. Refer to Section 200000 - Mechanical General Requirements for general mechanical related definitions.
 3. Refer to Mechanical Drawings legend sheet for general mechanical related abbreviations.

1.3 SYSTEM DESCRIPTION

- A. This specification is for a complete Variable Frequency Drive (VFD) consisting of a pulse width modulated (PWM) inverter designed for use with both asynchronous and permanent magnet motors.
- B. The drive manufacturer shall supply the drive and all necessary options as specified. drives installed on this project shall be from the same manufacturer and have a common user interface (control panel). Drives that are manufactured by a third party and “brand labeled” shall not be acceptable.
- C. This specification is intended to supplement a drive schedule. The drive schedule identifies the optimized BOM for the project and includes quantity, size, voltage, enclosure rating, options, and harmonic mitigation requirements of the drives. IEEE 519-2014 is an electrical system standard for harmonic mitigation. Drives are a major source of harmonics, therefore the VFD manufacturer shall conduct a harmonic analysis for this particular jobsite to verify compliance with IEEE 519-2014.

1.4 PRE-INSTALLATION MEETINGS

- A. See Section 200000 - Mechanical General Requirements.

1.5 SUBMITTALS

- A. See Section 200000 - Mechanical General Requirements for general submittal requirements for the items listed below, supplemented with the additional requirements listed.
- B. Submittals shall include the following information:
 - 1. Outline dimensions, conduit entry locations and weights. Customer connection and power wiring diagrams.
 - 2. Complete technical product description with complete list of options provided. Any portions of this specification not met shall be clearly indicated or the Contractor shall be liable to provide all additional components required to meet this specification.
 - 3. Submit shop drawings showing specific VSD mounting arrangements. Include verification that mounting of VSD complies with IBC chapter 16 requirements.
 - 4. Clearly note any exceptions/deviations to this specification with the submittal.
 - 5. Submit information from harmonic analysis demonstrating that the drives have proper internal harmonic mitigation and will not take the system out of compliance with IEEE Standard 519. Notify the Contracting Agency if additional mitigation measures are indicated.
 - 6. Submit the following information:
 - a. Combined harmonic content of all drives and combined harmonic content of all drives to be operated on generator.
 - b. Amount of regenerated power put back into the distribution system from each drive (include drives operated on generator and drives only operated on normal power).
- C. Closeout

1. Furnish two complete sets of Installation, Operation and Maintenance Manuals and other information necessary for the operation and maintenance of the system unless otherwise noted.
 2. Submit Startup Service test results as specified under Start-up Service below.
- D. Quality Control Submittals: Refer to Section 019100 - Commissioning for submittal requirements.

1.6 QUALITY ASSURANCES

- A. See Section 200000 - Mechanical General Requirements.
- B. Drives shall be UL labeled as a complete assembly. The base VFD shall be UL listed for 100 kA SCCR when installed in accordance with the manufacturer's guidelines.
- C. The base drive shall be CE and meet EN 61800-3 for the First Environment restricted distribution (Category C2).
- D. The base drive shall be seismically certified per 2018 International Building Code (IBC) with a seismic importance factor of 1.5, and minimum 2.5 SDS rating.
- E. The base drive shall be SEMI-F47 certified. The drive must tolerate voltage sags to 50 percent for up to 0.2 seconds, sags to 70 percent for up to 0.5 seconds, and sags to 80 percent for up to one second.

1.7 DELIVERY, STORAGE AND HANDLING

- A. See Section 200000 - Mechanical General Requirements.

1.8 WARRANTY

- A. Manufacturer Warranty: See Section 200000 - Mechanical General Requirements, for general mechanical warranty requirements.
- B. Warranty shall be 24 months from the date of certified startup. The warranty shall include all parts, labor, travel time and expenses. There shall be 24/365 support available via a toll free phone number.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Acceptable Manufacturers are limited to the following:
 1. ABB ACH 580 Series (basis of design).
 2. Yaskawa.

3. Siemens SED2.

2.2 VARIABLE FREQUENCY DRIVES

- A. The drive package as specified herein and defined on the drive schedule shall be enclosed in a NEMA Type 12 enclosure.
- B. The drive shall provide full rated output from a line of +10 percent to -15 percent of nominal voltage across an ambient temperature range of -15 to 40 degrees C (5 to 104 degrees F).
- C. Drives shall utilize the same Advanced Control Panel (keypad) user interface.
 1. Plain English text:
 - a. The display shall be in complete English words for programming and fault diagnostics.
 - b. Safety interlock and run permissive status shall be displayed using predetermined application specific nomenclature, such as: Damper end switch or vibration trip. Customized terms, such as: AHU-1 End Switch or CT-2 Vibration shall also be available.
 2. The control panel shall include at minimum the followings controls:
 - a. Four navigation keys (Up, Down, Left, Right) and two soft keys.
 - b. Hand-Off-Auto selection, Fault Reset, and manual speed control.
 - c. A Help key shall include assistance for programming and troubleshooting.
 3. There shall be a built-in time clock in the control panel with 10-year battery backup.
 4. I/O Summary display with a single screen shall indicate and provide:
 - a. The status/values of all analog inputs, analog outputs, digital inputs, and relay outputs.
 - b. The function of all analog inputs, analog outputs, digital inputs, and relay outputs.
 - c. The ability to force all inputs and outputs to either a high, low, or specific value.
 5. The drive shall automatically backup parameters to the control panel. The drive shall allow two additional unique manual backup parameter sets to be stored.
 6. The control panel shall be removable, capable of remote mounting.
 7. The drive shall be able to support a Bluetooth Advanced Control Panel. The Bluetooth control panel shall be FCC and QDL (Qualified Design Listing) certified.
 - a. A free app (iOS and Android) shall replicate the control panel on a mobile device or tablet. The control panel's programming and control functionality shall function on the device. Customizing text, such as AHU-1 End Switch, shall be supported by the device's keyboard.
 - b. Bluetooth connectivity shall allow uploading, downloading, and emailing of parameters.
 - c. Bluetooth connectivity shall include two pairing modes: Always discoverable with a fixed passcode, and manual discovery with a unique generated passcode every pairing.

D. Drives shall have the following hardware features/characteristics as standard:

1. Two (2) programmable analog inputs, two (2) programmable analog outputs, six (6) programmable digital inputs, and three (3) programmable Form-C relay outputs.
2. The drive shall include an isolated USB port for interface between the drive and a laptop.
3. An auxiliary power supply rated at 24 VDC, 250 mA shall be included.
4. At a minimum, the drives shall have internal impedance equivalent to 5 percent to reduce the harmonics to the power line. 5 percent impedance may be from dual (positive and negative DC link) chokes, or AC line reactor. Drives with only one DC link choke shall add an AC line choke integral to the drive enclosure. Reference the required harmonic analysis to determine if additional harmonic mitigation is required for the system to comply with IEEE 519-2014.
5. The combined harmonic content of all the drives on the project shall be small enough to not interfere with an emergency generator's voltage regulator. The impact of drives capable of regeneration on applications with a generator shall be verified. On projects where drives will be operated on generator include detailed information in submittals for both of these items to allow verification of impacts on generator operation.
6. The drive shall have variable speed primary cooling fans.
7. The overload rating of the drive shall be 110 percent of its normal duty current rating for 1 minute every 10 minutes, 130 percent overload for 2 seconds every minute.
8. The input current rating of the drive shall not be greater than the output current rating.
9. Circuit boards shall be coated per IEC 60721-3-3; Chemical gasses Class 3C2 and Solid particles Class 3S2.
10. Coordinated AC transient surge protection system consisting of 4 MOVs (phase-to-phase and phase-to-ground), a capacitor clamp, and internal chokes. The MOVs shall comply with UL 1449 4th Edition.
11. The drive shall include a robust DC bus to provide short term power-loss ride through. An inertia-based ride through function should help maintain the DC bus voltage during power loss events. Drives with control power ride through only, are not acceptable.

E. Drives shall have the following software features as standard:

1. A Fault Logger that stores the last 16 faults in non-volatile memory. The most recent 5 faults save at least 9 data points, including but not limited to: Time/date, frequency, DC bus voltage, motor current, DI status, temperature, and status words.
2. An Event Logger that stores the last 16 warnings or events that occurred, in non-volatile memory. Events shall include, but not limited to: Warning messages, checksum mismatch, run permissive open, start interlock open, and automatic reset of a fault.
3. Programmable start methods: Flying-start, Normal-start, and Brake-on-start.
4. Programmable loss-of-load (broken belt / coupling) indication. This function to include a programmable time delay to eliminate false loss-of-load indications.
5. Motor heating function to prevent condensation build up in the motor. Motor heating adjustment, via parameter, shall be in "Watts."
6. There shall be a run permissive circuit for damper or valve control.
7. Four separate start interlock (safety) inputs shall be provided. The control panel will display the specific safety(s) that are open.
8. The drive shall include a switching frequency control circuit that reduces the switching frequency based on actual drive temperature. It shall be possible to set a minimum and a target switching frequency.
9. The ability to automatically restart after non-critical faults.

10. PID functionality shall be included in the drive.
11. Drive shall be compatible with an accessory that allows the control board to be powered from an external 24 VDC/VAC source.
12. A computer-based software tool shall be available to allow a laptop to program the drive. The drive shall be able to support programming without the need for line voltage. All necessary power shall be sourced via the laptop USB port.
13. The drive shall include a fireman's override mode.

F. Security Features:

1. The drive manufacture shall clearly define cybersecurity capabilities for their products.
2. The drive shall include password protection against parameter changes. There shall be multiple levels of password protection including: End User, Service, Advanced, and Override.
3. A checksum feature shall be used to notify the owner of unauthorized parameter changes made to the drive.
4. The "Hand" and "Off" control panel buttons shall have the option to be individually disabled (via parameter) for drives mounted in public areas.

G. Network Communications:

1. The drive shall have an EIA-485 port with removable terminal blocks. The onboard protocols shall be BACnet MS/TP, Modbus, and Johnson Controls N2. Optional communication cards for BACnet/IP and LonWorks shall be available.
2. The drive shall have the ability to communicate via two protocols at the same time, one onboard protocol and one option card-based protocol.
3. The drive shall not require a power cycle after communication parameters have been updated.
4. The embedded BACnet connection shall be a MS/TP interface. The drive shall be BTL Listed to Revision 14 or later.

H. Disconnect:

1. A circuit breaker type disconnect shall be provided.
2. The disconnect shall be door interlocked and padlockable.
3. Drive input fusing shall be included on all packaged units that include a disconnecting means.
4. Disconnect configurations shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508 label.

I. A manual bypass system is not desired or required.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verify that jobsite conditions for installation meet factory-recommended and code-required conditions for VSD installation prior to start-up. These shall include as a minimum:

1. Clearance spacing.
2. Temperature, contamination, dust, and moisture of the environment.
3. Conduit installation of the motor wiring and power wiring separation.

3.2 INSTALLATION

- A. VSDs shall be furnished under Division 25 and installed under Division 26. The contractor shall install the drive in accordance with the recommendations of the VSD manufacturer as outlined in the installation manual.
- B. Power wiring shall be provided under Division 26. The contractor shall complete wiring in accordance with the recommendations of the VSD manufacturer as outlined in the installation manual.
- C. Verify that the location is ready to receive work and the dimensions are as indicated.
- D. Do not install VSD until the building environment can be maintained within the service conditions required by the manufacturer. Before and during the installation, the VSD equipment shall be protected from site contaminants. The VSD shall be covered and protected from construction dust and contamination until the environment is cleaned and ready for operation. The VSD shall not be operated while the unit is covered.
- E. Details of the installation shall comply with the manufacturer's applicable instructions.
- F. Minimize the length of conductors between the drive and the motor to avoid motor damage from reflected wave phenomenon.
- G. Mounting of VSD shall be suitable for seismic anchorage and/or restraints as required by International Building Code.

3.3 WIRING

- A. Conductors feeding Variable Frequency Drives (VFDs) and between VFDs and equipment supplied by the VFDs shall be Type XHHW-2.

3.4 CONTROL WIRING

- A. Control wiring and control devices shall be provided under the specification section in which the controlled equipment is specified. Coordinate related work.
- B. Control wiring shall be routed completely separately from power wiring.

3.5 PRODUCT SUPPORT

- A. Factory trained application engineering and service personnel that are thoroughly familiar with the VSD products offered shall be locally available at both the specifying and installation locations. A 24/365 technical support line shall be available on a toll-free line.

- B. A computer based training CD shall be provided to the owner at the time of project closeout. The training shall include installation, programming and operation of the VSD and serial communication.

3.6 FIELD QUALITY CONTROL

- A. Start up: Certified factory startup shall be provided for each drive by a factory authorized service center. A certified startup form shall be filled out for each drive with copies submitted and included in the O&M Manuals, and a copy kept on file by the manufacturer.
- B. Training: Onsite training shall be provided as part of the startup service. The training shall include installation, programming, and operation of the VSD and serial communication.
- C. Document each installation and operational step utilizing the approved PC/FC checklists in accordance with Section 01 9100 - Commissioning.

3.7 ADJUSTING

- A. Coordinate hydronic and ventilation system static pressure control set points with Section 23 0593 - Testing, Adjusting and Balancing. Make necessary corrections and adjustments as required by the Balancing and Testing Agency in a timely manner.

3.8 CLEANING

- A. Upon completion of installation and prior to initial operation, vacuum clean and wipe down VSD enclosures. Remove debris for interior of enclosures.

END OF SECTION 254000