PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes control sequences for HVAC systems, subsystems, and equipment.

B. See "Instrumentation and Control for HVAC" for control equipment and devices and for submittal requirements.

1.2 DEDICATED VENTILATION-AIR WATER SOURCE HEAT PUMP WITH ENERGY RECOVERY VENTILATOR CONTROL SEQUENCES

A. Unit Control:

1. System ventilation and exhaust fans shall start and run continuously during occupied periods. System shall not operate during unoccupied periods, regardless of override.

2. System shall stop and close the ventilation and exhaust-air dampers if any alarms are indicated.

3. The unit’s outside and exhaust-air dampers shall open 100% on a call for the system to operate and shall close when system is not operational. Dampers shall not open when unit is not operational.

4. A discharge, duct-mounted temperature sensor shall control the unloading compressor(s), reversing valve(s), and energy recovery ventilator operation. The sensor shall operate the unloading compressor(s), reversing valve(s) and/or energy recovery ventilator to maintain cooling or heating ventilation air set-point.

5. A discharge, duct-mounted humidity sensor shall control the dehumidification operation. The modulating hot gas reheat system shall be controlled to maintain the target discharge relative humidity by overriding the reversing valve in cooling mode.

6. An outdoor humidity comparative enthalpy control shall operate an air-side economizer operation. This may only operate if the discharge temperature and humidity set-points are satisfied. During economizer operation the unit’s compressors shall not be allowed to operate.

7. Except for the modulating hot gas reheat operation, the cooling and heating operations shall be configured to not operate simultaneously.

8. During override periods of any system, fans shall remain off and ventilation and exhaust-air dampers remain closed.

9. During morning warm-up and cool down, fans shall be off and ventilation and exhaust-air dampers closed.

10. Pressure-independence control valves shall be motorized such that the assembly will shut-off flow of water to the unit when the unit is not operating. Valve shall open when equipment is running. Valve assembly shall be quick opening and slow closing. Valve shall fail closed if signal/power is lost.

B. Operator Interface: Display the following on operator workstation display terminal:
1. System graphic.
2. System on-off indication.
3. System occupied/unoccupied mode indication operates from 7:00 a.m. to 3:00 p.m.,
   (adjustable).
4. System ventilation supply fan on-off command and status indication.
5. System exhaust fan on-off command and status indication.
6. System compressor(s) on-off command and status indication.
7. System reversing valve(s) heat-cool command and status indication.
8. System capacity control on-off command and status indication.
9. System energy recovery ventilator on-off command and status indication.
10. System heat or cool command and status indication.
11. System reheat (dehumidifying) command and status indication.
13. Supply fan-discharge humidity set-point, 50% RH(summer)/35% RH(winter),
    (adjustable).
14. Supply fan-discharge air-temperature set-point, 70°F(cooling)/75°F(heating),
    (adjustable).
15. Freeze-stat status.
16. Alarm and stop system if fan-discharge humidity exceeds a range of 25% RH to 70% RH,
    (adjustable).
17. Alarm and stop system if fan-discharge air-temperature exceeds a baseline range of 65°F
    to 80°F, (adjustable).
18. Alarm and stop system if fan-discharge air-temperature exceeds a reset range of 50°F to
    100°F, (adjustable).
19. Alarm output and stop system for other unit failures.
20. Alarm control valve failure.
21. Control valve position (open/closed)

1.3 WATER SOURCE HEAT PUMP CONTROL SEQUENCES

A. When any heat pump is required to operate, a loop run request shall be transmitted to the loop
   control panel. The heat pump compressor will not be allowed to operate until receiving a loop
   status normal indication from the loop controller. The loop status normal point will require the
   loop temperature within normal limits, a primary loop pump commanded on and proving status.

   1. Unoccupied Operation – In the unoccupied mode, the unit shall be shut off. If the space
      temperature as sensed by the zone sensor falls below or rises above the unoccupied
      setpoint, the control valve shall be opened, the compressor, fan and reversing valve shall
      be energized based on the need for either heating or cooling until the unoccupied setpoint
      is reached.

   2. Transition from Unoccupied to Occupied – When the water source heat pump transitions
      from the unoccupied mode to the occupied mode, morning warm-up or morning cool-
      down and random start programs shall be activated.

      a. Morning Warm-Up – When there is a call for heating and the zone temperature is
         -2°F off setpoint, a morning warm-up shall be initiated. The water control valve
         shall be opened, compressor and the fan shall be turned on and the reversing valve
         shall be energized. When the zone temperature reaches the heating setpoint, the
         unit shall operate in the occupied mode.
b. **Morning Cool-Down** – When there is a call for cooling and the zone temperature is +2°F off setpoint, a morning cool-down shall be initiated. The water control valve shall open, the compressor and fan shall be turned on and the reversing valve shall be energized. When the zone temperature reaches the cooling setpoint, the unit shall operate in the occupied mode.

c. **Random Start** – Random start of the unit is intended to prevent all units in a building from energizing major loads at the same time. Control valve operation, fan and compressor start shall be delayed from 3 to 32 seconds when power has been either restored after a loss or outage, or after the unit is enabled. A random number generator in software shall be used to generate the delay.

3. **Occupied Operation** – In the occupied mode, the unit fan shall run continuously. If the space temperature, as sensed by the zone sensor, falls below or rises above the occupied setpoint, the water control valve shall open, the compressor and reversing valve shall be energized based on the need for either heating or cooling until the occupied setpoint is reached.

4. **Override Operation** – When override is depressed in a room, the water source heat pump shall operate as if in occupied mode. This operation shall be timed and will cause loop pumps to operate.

5. Pressure-independence control valves shall be motorized such that the assembly will shut-off flow of water to the unit when the unit is not operating. Valve shall open when equipment is running. Valve assembly shall be quick opening and slow closing. Valve shall fail closed if signal/power is lost.

B. 

1. **Operator Interface**: Indicate the following on operator workstation display terminal:

   a. System graphic.
   b. System on-off indication.
   c. System occupied/unoccupied mode indication, operate from 7:00 a.m. to 3:00 p.m. (adjustable).
   d. System fan on-off command and status indication.
   e. System compressor on-off command and status indication.
   f. System reversing valve heat-cool command and status indication.
   g. Outside air temperature indication.
   h. Room temperature indication.
   i. Room temperature setpoint indication (adjustable).
   j. Unoccupied heating setpoint indication (adjustable).
   k. Unoccupied cooling setpoint indication (adjustable).
   l. Occupancy override status indication.
   m. Occupancy override time duration indication, set for 2 hours, (adjustable).
   n. Room temperature setpoint high and low limit indication, set ± 2°F bias, (adjustable).
   o. Discharge air temperature indication.
   q. Alarm control valve failure.
   r. Control valve position (open/closed)
1.4 WATER SOURCE HEAT PUMP CONTROL SEQUENCES (HPH)

A. When a heat pump serving Lecture Hall 137 is required to operate, a loop run request shall be transmitted to the loop control panel. The heat pump compressor will not be allowed to operate until receiving a loop status normal indication from the loop controller. The loop status normal point will require the loop temperature within normal limits, a primary loop pump commanded on and proving status.

2. Unoccupied Operation – In the unoccupied mode, the unit shall be shut off. If the space temperature as sensed by the zone sensor falls below or rises above the unoccupied setpoint, the water control valve shall open, the compressor, fan and reversing valve shall be energized based on the need for either heating or cooling until the unoccupied setpoint is reached. The heat pumps shall be staged to operate one at a time, until the space load is greater than one unit’s capabilities. Unit shall operate lead/lag based on timed operation.

3. Transition from Unoccupied to Occupied – When the water source heat pump transitions from the unoccupied mode to the occupied mode, morning warm-up or morning cool-down and random start programs shall be activated.

   d. Morning Warm-Up – When there is a call for heating and the zone temperature is -2°F off setpoint, a morning warm-up shall be initiated. The water control valve shall open, the compressor and the fan shall be turned on and the reversing valve shall be energized. When the zone temperature reaches the heating setpoint, the unit shall operate in the occupied mode. The heat pumps shall be staged to operate one at a time, until the space load is greater than one unit’s capabilities. Unit shall operate lead/lag based on timed operation.

   e. Morning Cool-Down – When there is a call for cooling and the zone temperature is +2°F off setpoint, a morning cool-down shall be initiated. The water control valve shall open, the compressor and fan shall be turned on and the reversing valve shall be energized. When the zone temperature reaches the cooling setpoint, the unit shall operate in the occupied mode. The heat pumps shall be staged to operate one at a time, until the space load is greater than one unit’s capabilities. Unit shall operate lead/lag based on timed operation.

   f. Random Start – Random start of the unit is intended to prevent all units in a building from energizing major loads at the same time. The water control valve shall open, the fan and compressor start shall be delayed from 3 to 32 seconds when power has been either restored after a loss or outage, or after the unit is enabled. A random number generator in software shall be used to generate the delay.

4. Occupied Operation – In the occupied mode, the unit fan shall run continuously. If the space temperature, as sensed by the zone sensor, falls below or rises above the occupied setpoint, the water control valve shall open, the compressor and reversing valve shall be energized based on the need for either heating or cooling until the occupied setpoint is reached. The heat pumps shall be staged to operate one at a time, until the space load is greater than one unit’s capabilities. Unit shall operate lead/lag based on timed operation.

5. Override Operation – When override is depressed in a room, the water source heat pump shall operate as if in occupied mode. This operation shall be timed and will cause loop pumps to operate.

6. Pressure-independence control valves shall be motorized such that the assembly will shut-off flow of water to the unit when the unit is not operating. Valve shall open when
equipment is running. Valve assembly shall be quick opening and slow closing. Valve shall fail closed if signal/power is lost.

7. **Operator Interface:** Indicate the following on operator workstation display terminal:

   a. System graphic.
   b. System on-off indication.
   c. System occupied/unoccupied mode indication, operate from 7:00 a.m. to 3:00 p.m. (adjustable).
   d. System fan on-off command and status indication.
   e. System compressor on-off command and status indication.
   f. System reversing valve heat-cool command and status indication.
   g. Outside air temperature indication.
   h. Room temperature indication.
   i. Room temperature setpoint indication (adjustable).
   j. Unoccupied heating setpoint indication (adjustable).
   k. Unoccupied cooling setpoint indication (adjustable).
   l. Occupancy override status indication.
   m. Occupancy override time duration indication, set for 2 hours, (adjustable).
   n. Room temperature setpoint high and low limit indication, set ± 2°F bias, (adjustable).
   o. Discharge air temperature indication.
   q. Alarm control valve failure.
   r. Control valve position (open/closed)

1.5 **HYDRONIC PUMP AND VARIABLE SPEED PUMPING CONTROL SEQUENCES**

A. Pumps shall be started, through their on-off-auto selector switches, by the BAS. In auto position, the BAS shall modulate the pump’s variable frequency drive (VFD) to maintain the two (2) adjustable differential pressure sensor’s settings.

1. Two (2) differential pressure sensors shall be located on the supply and return lines as indicated:

   a. First Floor
   b. Second Floor

2. The BAS system shall continuously monitor all sensors and control pump speed to maintain the most demanding call for pressure. Note, each sensor shall have individual set points that can be adjusted for “tuning” of the building’s system.

B. **Occupied Operation** – Pumps shall operate continuously on a call for heating or cooling and shall modulate fluid flow based on differential pressure readings from various system monitoring points. Pumps shall be controlled such that the equipment worked together to best meet the required load. The lead pump shall operate first, modulating to meet the required demand. If the lead pump operates for 5 minutes (adjustable) and the demand is not meet, the lead and lag pumps shall operated together to meet the system demand. When the lag pump is started, the lead pump shall modulate to accommodate the additional flow/pressure.
C. **Unoccupied Operation** – Pumps shall not operate unless called for by another system’s manual override.

D. **Operator Interface:** Display the following data:

1. Operating command of pump(s) (lead/lag).
2. Each differential pressure setpoint indication (adjustable)
3. Status of pump(s). Current transmitter(s) are required. Include:
   a. Flow rate (GPM) calculated not measured.
   b. Pump Speed (RPM).
   c. VFD output frequency (Hz.)
4. Alarm for pump failure and/or differential pressure transmitter failure.
5. Provide Lead/lag control and automatic duty switching for pump run times.

1.5 **COMPUTER-ROOM AIR CONDITIONER CONTROL SEQUENCES**

A. Space temperature and humidity shall be communicated to the BAS via a dedicated zone sensor in the space served by the computer-room air conditioner.

B. The space temperature and humidity shall be out of range for at least five (5) minutes, adjustable, prior to initiation of alarm.

C. **Operator Interface:** Display the following data:

1. System graphic.
2. Space temperature (°F).
3. Space humidity (% RH).
4. Alarm if space temperature exceeds a range of 60° F to 80° F, (Adjustable).
5. Alarm if space humidity exceeds a range of 40% to 60% RH, (Adjustable).

1.6 **STORAGE WATER HEATER EMS CONTROL SEQUENCES**

A. All storage hot water heaters shall have a scheduled occupied/unoccupied mode from 7:00 a.m. to 3:00 p.m., (adjustable). Anticipator control will be required for morning warm-up.

1. Occupied Mode: Water heater EMS controls are allowed to heat water and maintain set-point.
2. Unoccupied Mode: Water heater EMS controls shall stop via field-installed relay. Coordinate installation with plumbing contractor and electrical contractor.
3. **Operator Interface:** Indicate the following data:
   a. Graphic Screen.
   b. Occupied/Unoccupied Mode (adjustable).
   c. Water Heater Status (on/off).
1.7 GEOTHERMAL LOOP WATER SUPPLY CONTROL SEQUENCES

A. Operator Interface: Display the following data:
   1. Loop water supply temperature indication.
   2. Loop water return temperature indication.
   3. Out of range temperature alarm.

B. Any time the system is activated, the primary loop pump(s) shall run and modulate flow rate based on system demand and the heat pumps allowed to operate under control of their temperature sensor.

C. The loop temperature will operate in a range between 35° F. and 110° F. (adjustable). A sensor in the loop supply water shall deenergize pumps, all heat pumps and outdoor air units and provide alarm if temperature exceeds this range.

1.8 CEILING MOUNTED RADIANT PANEL HEATERS CONTROL SEQUENCES

A. Unit control:
   1. The heater shall operate per the wall mounted tamperproof zone sensor and BMS outdoor-air temperature sensor.

B. Unit schedule:
   1. Unit shall operate when the temperature sensed by the BMS outdoor-air temperature sensor and the unit’s wall mounted sensor are less than set-point.

C. Operator Interface: Display the following data:
   1. System graphic.
   2. Space temperature indication.
   3. Outdoor-air temperature indication.
   4. Space temperature set-point, 70°F, adjustable.
   5. Outdoor-air temperature set-point, 60°F, adjustable.
   7. System command and status indication
   8. Alarm for temperature out of range.

1.9 LOUVERS CONTROL SEQUENCES

A. Unit control:
   1. The louvers shall be interlocked with dedicated ventilation air unit.

B. Unit schedule:
   1. Unit shall open upon operation of the dedicated ventilation air unit.
2. Louvers shall open prior to ventilation and exhaust air fan start-ups. If ventilation air alarms, shutdown, or otherwise is not in operation, the louvers shall close.

3. Louvers shall fail closed.

C. Operator Interface: Display the following data:

1. System graphic.
2. Ventilation air unit status (on/off)
3. Louver command and status indication

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION (Not Applicable)

END OF SECTION 230993
SECTION 231123 - FACILITY NATURAL-GAS PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Pipes, tubes, and fittings.
   2. Piping specialties.
   3. Piping and tubing joining materials.
   4. Valves.
   5. Pressure regulators.

1.2 PERFORMANCE REQUIREMENTS

A. Minimum Operating-Pressure Ratings:
   1. Piping and Valves: 100 psig minimum unless otherwise indicated.
   2. Service Regulators: 65 psig minimum unless otherwise indicated.

1.3 SUBMITTALS

A. Welding certificates.

B. Operation and maintenance data.

1.4 QUALITY ASSURANCE

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

B. Pipe Welding Qualifications: Qualify procedures and operators according to ASME.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

PART 2 - PRODUCTS

2.1 PIPES, TUBES, AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.

B. PE Pipe: ASTM D 2513, SDR 11.
   1. PE Fittings: ASTM D 2683, socket-fusion type or ASTM D 3261, butt-fusion type with dimensions matching PE pipe.
   2. PE Transition Fittings: Factory-fabricated fittings with PE pipe complying with ASTM D 2513, SDR 11; and steel pipe complying with ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
      a. Underground Portion: PE pipe complying with ASTM D 2513, SDR 11 inlet connected to steel pipe complying with ASTM A 53/A 53M, Schedule 40, Type E or S, Grade B, with corrosion-protective coating for aboveground outlet.
      b. Outlet shall be threaded or suitable for welded connection.
      c. Bridging sleeve over mechanical coupling.
      d. Factory-connected anode.
      e. Tracer wire connection.
      f. Ultraviolet shield.
      g. Stake supports with factory finish to match steel pipe casing or carrier pipe.

2.2 PIPING SPECIALTIES

A. Y-Pattern Strainers:
   1. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
   2. End Connections: Threaded ends for NPS 2 and smaller.
   3. Strainer Screen: 40-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.

B. Weatherproof Vent Cap: Cast- or malleable-iron increaser fitting with corrosion-resistant wire screen, with free area at least equal to cross-sectional area of connecting pipe and threaded-end connection.

2.3 JOINING MATERIALS

A. Joint Compound and Tape: Suitable for natural gas.

2.4 MANUAL GAS SHUTOFF VALVES

A. See "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles for where each valve type is applied in various services.

B. General Requirements for Metallic Valves, NPS 2 and Smaller: Comply with ASME B16.33.
   1. CWP Rating: 125 psig.
   3. Dryseal Threads on Flare Ends: Comply with ASME B1.20.3.

C. Bronze Plug Valves: MSS SP-78.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Lee Brass Company.
      c. Approved equal.
   5. Operator: Square head or lug type with tamperproof feature where indicated.
   6. Pressure Class: 125 psig.
   7. Service: Suitable for natural-gas service with "WOG" indicated on valve body.

D. Valve Boxes:
   1. Cast-iron, two-section box.
   2. Top section with cover with "GAS" lettering.
   3. Bottom section with base to fit over valve and barrel a minimum of 5 inches in diameter.
   4. Adjustable cast-iron extensions of length required for depth of bury.
   5. Include tee-handle, steel operating wrench with socket end fitting valve nut or flat head, and with stem of length required to operate valve.

2.5 PRESSURE REGULATORS

A. General Requirements:
   1. Single stage and suitable for natural gas.
   2. Steel jacket and corrosion-resistant components.
   3. Elevation compensator.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. American Meter Company.
   b. Fisher Control Valves and Regulators; Division of Emerson Process Management.
   c. Maxitrol Company.
   d. Richards Industries; Jordan Valve Div.
   e. Approved equal.

2. Body and Diaphragm Case: Cast iron or die-cast aluminum.
5. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
6. Orifice: Aluminum; interchangeable.
8. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet, and no pressure sensing piping external to the regulator.
9. Pressure regulator shall maintain discharge pressure setting downstream, and not exceed 150 percent of design discharge pressure at shutoff.
11. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.
12. Maximum Inlet Pressure: as specified on drawings.

2.6 DIELECTRIC UNIONS

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

4. Watts Regulator Co.; Division of Watts Water Technologies, Inc.
5. Wilkins; Zurn Plumbing Products Group.
6. Approved equal.

B. Minimum Operating-Pressure Rating: 150 psig.

C. Combination fitting of copper alloy and ferrous materials.

D. Insulating materials suitable for natural gas.

E. Combination fitting of copper alloy and ferrous materials with threaded, brazed-joint, plain, or welded end connections that match piping system materials.
2.7 LABELING AND IDENTIFYING

A. Warning Tape: Acid- and alkali-resistant, PE film warning tape manufactured for marking and identifying underground utilities, a minimum of 6 inches wide and 4 mils thick, continuously inscribed with a description of utility, colored yellow.

PART 3 - EXECUTION

3.1 OUTDOOR PIPING INSTALLATION

A. Comply with the National Fuel Gas Code for installation and purging of natural-gas piping.
B. Install underground, natural-gas piping buried at least 36 inches below finished grade.
C. Install underground, PE, natural-gas piping according to ASTM D 2774.
D. Install fittings for changes in direction and branch connections.
E. Aboveground Exterior-Wall Pipe Penetrations: Seal penetrations using steel pipe sleeves and caulk. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve.

3.2 INDOOR PIPING INSTALLATION

A. Comply with the National Fuel Gas Code for installation and purging of natural-gas piping.
B. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements are used to size pipe and calculate friction loss, expansion, and other design considerations.
C. Arrange for pipe spaces, chases, slots, sleeves, and openings in building structure during progress of construction, to allow for mechanical installations.
D. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
E. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
F. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
G. Locate valves for easy access.
H. Install natural-gas piping at uniform grade of 2 percent down toward drip and sediment traps.
I. Install piping free of sags and bends.
J. Install fittings for changes in direction and branch connections.
K. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials.

L. Verify final equipment locations for roughing-in.

M. Comply with requirements in Sections specifying gas-fired appliances and equipment for roughing-in requirements.

N. Drips and Sediment Traps: Install drips at points where condensate may collect, including service-meter outlets. Locate where accessible to permit cleaning and emptying. Do not install where condensate is subject to freezing.
   1. Construct drips and sediment traps using tee fitting with bottom outlet plugged or capped. Use nipple a minimum length of 3 pipe diameters, but not less than 3 inches long and same size as connected pipe. Install with space below bottom of drip to remove plug or cap.

O. Extend relief vent connections for service regulators, line regulators, and overpressure protection devices to outdoors and terminate with weatherproof vent cap.

P. Conceal pipe installations in walls, pipe spaces, utility spaces, above ceilings, below grade or floors, and in floor channels unless indicated to be exposed to view.

Q. Use eccentric reducer fittings to make reductions in pipe sizes. Install fittings with level side down.

R. Connect branch piping from top or side of horizontal piping.

S. Install unions in pipes NPS 2 and smaller, adjacent to each valve, at final connection to each piece of equipment.

T. Do not use natural-gas piping as grounding electrode.

U. Install strainer on inlet of each line-pressure regulator.

3.3 VALVE INSTALLATION

A. Install manual gas shutoff valve for each gas appliance.

B. Install underground valves with valve boxes.

C. Install regulators and overpressure protection devices with maintenance access space adequate for servicing and testing.

D. Install anode for metallic valves in underground PE piping.

3.4 PIPING JOINT CONSTRUCTION

A. Ream ends of pipes and tubes and remove burrs.
B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

C. Threaded Joints:
   1. Thread pipe with tapered pipe threads complying with ASME B1.20.1.
   2. Cut threads full and clean using sharp dies.
   3. Ream threaded pipe ends to remove burrs and restore full inside diameter of pipe.
   4. Apply appropriate tape or thread compound to external pipe threads unless dryseal threading is specified.
   5. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

D. Welded Joints:
   2. Bevel plain ends of steel pipe.
   3. Patch factory-applied protective coating as recommended by manufacturer at field welds and where damage to coating occurs during construction.

E. PE Piping Heat-Fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657.
   1. Plain-End Pipe and Fittings: Use butt fusion.

3.5 HANGER AND SUPPORT INSTALLATION

A. Install hangers for horizontal steel piping with the following maximum spacing and minimum rod sizes:
   1. NPS 1 and Smaller: Maximum span, 96 inches; minimum rod size, 3/8 inch.
   2. NPS 1-1/4: Maximum span, 108 inches; minimum rod size, 3/8 inch.
   3. NPS 1-1/2 and NPS 2: Maximum span, 108 inches; minimum rod size, 1/2 inch.
   4. NPS 3 and NPS 4: Maximum span, 120 inches; minimum rod size 5/8 inches.

3.6 CONNECTIONS

A. Connect to utility's gas main according to utility's procedures and requirements.

B. Install natural-gas piping electrically continuous, and bonded to gas appliance equipment grounding conductor of the circuit powering the appliance according to NFPA 70.

C. Install piping adjacent to appliances to allow service and maintenance of appliances.

D. Connect piping to appliances using manual gas shutoff valves and unions. Install valve within 48 inches of each gas-fired appliance and equipment. Install union between valve and appliances or equipment.
E. Sediment Traps: Install tee fitting with capped nipple in bottom to form drip, as close as practical to inlet of each appliance.

3.7 LABELING AND IDENTIFYING

A. Install warning tape directly above gas piping, 12 inches below finished grade, except 6 inches below subgrade under pavements and slabs.

B. Install continuous tracer wire with all buried piping.

3.8 FIELD QUALITY CONTROL

A. Test, inspect, and purge natural gas according to the National Fuel Gas Code and authorities having jurisdiction.

B. Natural-gas piping will be considered defective if it does not pass tests and inspections.

C. Prepare test and inspection reports.

3.9 OUTDOOR PIPING SCHEDULE

A. Underground natural-gas piping shall be the following:

1. PE pipe and fittings joined by heat fusion; service-line risers with tracer wire terminated in an accessible location.

B. Aboveground natural-gas piping shall be the following:

1. Steel pipe with malleable-iron fittings and threaded joints.

3.10 INDOOR PIPING SCHEDULE

A. Aboveground, branch, and distribution piping shall be the following:

1. NPS 2½ and Larger: Steel pipe with wrought-steel fittings and welded joints.
2. NPS 2 and Smaller: Steel pipe with malleable-iron fittings and threaded joints.

3.11 UNDERGROUND MANUAL GAS SHUTOFF VALVE SCHEDULE

A. Connections to Existing Gas Piping: Use valve and fitting assemblies made for tapping utility's gas mains and listed by an NRTL.

B. Underground: Bronze plug valves.
3.12 ABOVEGROUND MANUAL GAS SHUTOFF VALVE SCHEDULE

A. Valves for pipe sizes NPS 4 and smaller at service meter shall be the following:
   1. Bronze plug valve.

B. Distribution piping valves for pipe sizes NPS 3 and smaller shall be one of the following:
   1. Bronze plug valve.

C. Valves in branch piping for single appliance shall be one of the following:
   1. Bronze plug valve.

END OF SECTION 231123
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SECTION 232113.33 - GROUND-LOOP HEAT-PUMP PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes piping for vertical, direct-buried, ground-loop, heat-pump systems that operate between 23 and 104 deg F.

B. Scope of work shall include the furnishing and complete installation of the geothermal system(s), ready for University’s use. Contractor shall bid this project as unclassified. The entire geothermal field(s) shall be installed regardless of material encountered.

1.2 PERFORMANCE REQUIREMENTS

A. Components and installation shall be capable of withstanding the following minimum working pressure, unless otherwise indicated:


1.3 SUBMITTALS

A. Product Data: For the following:

   1. Geothermal In-Ground Vault.
   2. Pipe and fittings.
   3. Joining method and equipment.
   4. Propylene glycol solution.
   5. Installer’s Qualifications.
   6. Record drawings of as-built loop system.

B. Field quality-control test reports.

1.4 QUALITY ASSURANCE

A. Installer Pre-Qualification:

   1. Due to the scale of this project, the Geothermal Contractor/Bidder must receive prequalification prior to bid. Requests for prequalification approval must be received by the Engineer a minimum of nine (9) days prior to bid date. Applicants that are approved will be listed in Addendum approximately seven (7) days prior to bid. Geothermal Contractors that are not listed in said Addendum will not be acceptable subcontractors for this project.
   2. Prequalification applications must be complete to be considered and must include the following:
a. Contractor’s qualifications as noted below.
b. List of current installation contracts and their status.
c. Contractor’s proposed manpower and equipment resources.
d. List of proposed subcontractors, alliances, joint-venture companies, etc. to be utilized in facilitating the project
e. Current IGSHPA certifications.
f. List of five (5) completed projects (similar in size, complexity and cost). Include project description, the time started & completed, Owner’s contact information, and Engineer’s contact information.
g. Written description of proposed drilling method and installation approach considering the relevant geological conditions on site and drilling conditions encountered during Geothermal Test Bore Drilling as per the “Geothermal Drill Logs” specification included within the contract documents. Written description of proposed installation schedule (time line) for this project.
h. Written description of proposed method for purging the geothermal fields for this project.
i. List of any involvement in any past or current litigation.

3. The Geothermal Contractor/Bidder shall obtain a Performance Bond for the required installation of this project and in conformance with the Contract Document’s requirements for Bonding.

4. The Geothermal Contractor/Bidder is not restricted to subcontract ‘through’ the Mechanical Contractor for this project. If the General Contractor chooses to construct the project with such a separate contract, the Contractor is cautioned to determine receipt of separate proposals from the Geothermal Contractor and Mechanical Contractor to include all requirements of the Contract Documents for a complete and operational system.

B. Installer’s Qualifications: Installer must have completed a certified training program offered by the International Ground Source Heat Pump Association and shall have a minimum of ten (10) years successful installation experience, similar in size, complexity and cost to the required for this project.

C. Pipe fabricators qualifications: Fabricator must have successfully completed training for polyethylene heat fusion in accordance with International Ground Source Heat Pump Association Standards.

D. Comply with local and state standards and regulations.

E. **A ground-loop pre-installation conference shall be held prior to the installation of the ground loop.** Present should be the University’s Representative, Engineer, General Contractor, Mechanical Contractor and Geothermal Contractor. At this meeting, the Contractor shall advise the project team of all the installation materials and specified installation requirements to meet project design intent.

F. The Owner/Engineer will conduct random testing up to 5% of boreholes for Geothermal Field.

1. This testing will be completed by a third party employed by the Owner. The formation thermal conductivity test will be for verification of total borehole heat input and compared with the original Data Analysis following this section.
2. The purpose of the tests will be to determine proper unicoil installation and 100% backfill.

3. If a borehole random test deviates greater than 10% of original Data Analysis, the Contractor must correct borehole and pay for an additional 5% of random testing. This process will repeat until one set of random testing conforms with original Data Analysis.

G. Engineer shall conduct random testing of 10% of all installed unicoils to assure installation of proper depth and agreement with drill logs to be provided to Engineer prior to testing. If unicoils are found to be installed shallower than specified, the Contractor will be required to install additional unicoils to the specified depth at no additional cost to the Owner.

1. The Contractor shall furnish materials required to test well depth.

2. The Engineer shall be present to witness tests.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Furnish and install all materials indicated and/or required to provide a complete operating system.

2.2 PIPES AND FITTINGS

A. Underground Pipe and Fittings:

1. NPS 2 or smaller: ASTM D-2239, SDR-11 HDPE with PE compound number required to achieve required system working pressure.

2. NPS 3 or larger: ASTM D-2239, SDR-15.5 HDPE with PE compound number required to achieve required system working pressure.

3. Molded PE Fittings: ASTM D 2683 or ASTM D 3261, PE resin, socket- or butt-fusion type, made to match PE pipe dimensions and class.

B. Unicoil Assembly: Factory fabricated with embossed depth stamp every 36 inches from U-bend.

2.3 BOREHOLE BACKFILL

A. Surface Seal: Ten (10) foot depth of Bentonite with thermal conductivity greater than 1.2 Btu/h x sq. ft. x deg F. Top of seal shall be equal to top of consolidated (bed) rock.

B. Backfill below and above Surface Seal:

1. Boreholes shall be backfilled with #9M classified limestone.
2.4 ANTIFREEZE SOLUTION

A. Propylene Glycol: Propylene glycol with corrosion inhibitors and environmental stabilizer additives to be mixed with water to protect the piping circuit and connected equipment from physical damage from freezing or corrosion.

B. Quantity: Sufficient solution for initial system startup and for preventive maintenance for twelve (12) months from date of Substantial Completion. System shall be charged to 10% solution by volume as specified.

C. Dilution Water: Chloride content shall be less than 25 ppm, sulfate less than 25 ppm, and hardness less than 100 ppm.

PART 3 - EXECUTION

3.1 EARTHWORK

A. Excavating, trenching, warning tape, and backfilling are specified in other Specification Sections.

B. Contractor shall not start installation until completion of rough grading.

3.2 HORIZONTAL PIPING INSTALLATION

A. General Locations and Arrangements: Drawing plans and details indicate general location and arrangement. Install piping as indicated, to extent practical.

B. Install piping per manufacturer’s standards. Pipe ends shall be taped until joining so as to maintain cleanliness.

C. Piping shall be installed with minimum field fusion welds as practical.

D. Placement of piping shall be relatively straight with no restrictions to water flow. Changes in directions shall be accomplished with sweeps or pipe fittings if necessary.

E. Line branches, reductions, and changes in direction, shall be made with manufacturer’s approved fittings.

F. Install valves as indicated on plans.

G. Valves shall be accessible.

H. Valves shall be installed with mechanical connections for service or replacement.

I. Remove rocks in trenches that could contact pipe.
J. Backfill to 6” above pipe with crushed limestone. Backfill from bedding level to grade with suitable material as specified, compacting as specified for pipe burial in applicable Specification Sections.

K. Install PE piping in trenches according to ASTM D 2774 or ASTM F 645.
   1. Clean PE pipe and fittings and make heat-fusion joints according to ASTM D 2657. Minimize number of joints.

L. Purge, flush, and pressure test piping before backfilling trenches. After backfill of boreholes and prior to trench backfill, the complete system shall be hydrostatically tested and shall maintain pressure. Before backfilling, the ground loop system shall be flushed and purged of air.

M. Install continuous tracer wire adjacent to piping. Partially backfill and install warning tape for underground piping. Locate tape a minimum of 12” inches below finished grade, directly over piping. Common piping installation requirements are specified in other Specification Sections.

3.3 VERTICAL PIPING INSTALLATION

A. The vertical boreholes shall be installed to depth indicated on plans and of sufficient diameter to accept the installation of the unicoil.

B. Bore holes shall not be cased unless drilling/soil conditions require temporary/removable casing.

C. Bore Backfill: Contractor shall carefully backfill to avoid crushing, cutting, and/or damaging loop piping. Contractor shall measure amount of backfill to reassure bridging has not occurred.

D. Install PE piping in boreholes according to ASTM D 2774 or ASTM F 645.
   1. Clean PE pipe and fittings and make heat-fusion joints according to ASTM D 2657. Minimize number of joints.

E. Purge, flush, and pressure test piping before backfilling boreholes. If necessary, a purging unit shall be utilized to remove air and verify that flow requirements are met.

F. After installation of loop pipe in borehole, fill piping loop with water/antifreeze solution, and backfill borehole.

G. Fill borehole with specified backfill material.

H. Extend piping and connect to condenser-loop piping systems within building in locations and pipe sizes indicated.
   1. Terminate ground-loop piping at building wall until building condenser loop systems are installed. Terminate piping with caps. Make connections to building condenser loop systems when those systems are installed.
3.4 ANTIFREEZE SOLUTION FILL
   A. Fill system with required quantity of propylene glycol to 10% solution.
   B. Test the dilute solution using gas chromatography to verify concentration of propylene glycol, and forward report to Engineer.
   C. Add 10% solution for outdoor geothermal solution. The Mechanical Contractor is responsible for achieving 10% solution for interior building system.

3.5 CONNECTIONS
   A. Drawings indicate general arrangement of piping, fittings, and specialties.
   B. The contractor shall operate the system for twenty-four (24) hours and balance each loop piping circuit flow to obtain equal temperature differences.

3.6 FIELD QUALITY CONTROL
   A. Piping Tests: Fill piping 24 hours before testing and apply test pressure to stabilize piping. Use potable water only.
   B. Hydrostatic Tests: Test at not less than 1-1/2 times the pipe working-pressure rating or 100 PSIG, whichever is more.
      1. Increase pressure in 50-psig increments and inspect each joint between increments. Hold at test pressure for 30 minutes. Slowly increase to next test pressure increment and hold for 30 minutes. After testing at maximum test pressure, reduce pressure to 30 psig. Hold for 90 minutes, and measure pressure at 30-minute intervals. Repair leaks and retest until no leaks exist.
   C. Prepare reports of testing activity.

END OF SECTION 232113.33
SECTION 232113.33A – FORMATION THERMAL CONDUCTIVITY TEST

GRTI

Formation Thermal Conductivity Test & Data Analysis

Test Location
Murray State University
Paducah Campus
Paducah, KY

Test Date
June 4-6, 2012

Analysis For
Mid-South Geothermal, LLC
8275 Tournament Drive, Suite 185
Memphis, TN 38125
Phone: (901) 748-9095
Fax: (901) 748-9097

Test Performed By
Mid-South Geothermal, LLC
Executive Summary

A formation thermal conductivity test was performed at the Murray State University site in Paducah, Kentucky. The vertical bore was completed on May 31, 2012 by Mid-South Geothermal, LLC. Geothermal Resource Technologies’ (GRTI) test unit was attached to the vertical bore on the afternoon of June 4, 2012.

This report provides an overview of the test procedures and analysis process, along with plots of the loop temperature and input heat rate data. The collected data was analyzed using the “line source” method and the following average formation thermal conductivity was determined.

Formation Thermal Conductivity = 1.04 Btu/hr·ft·°F

Due to the necessity of a thermal diffusivity value in the design calculation process, an estimate of the average thermal diffusivity was made for the encountered formation.

Formation Thermal Diffusivity = 0.66 ft²/day

The undisturbed formation temperature for the tested bore was unable to be determined from the initial loop temperature data collected at startup. However, a temperature range has been estimated from previous tests in the area. It is recommended that the undisturbed formation temperature be verified prior to final system design by inserting a thermocouple probe down the u-bend and taking measurements down the length of the bore.

Estimated Undisturbed Formation Temperature = 58.5-60.5°F

The formation thermal properties determined by this test do not directly translate into a loop length requirement (i.e. feet of bore per ton). These parameters, along with many others, are inputs to commercially available loop-field design software to determine the required loop length. Additional questions concerning the use of these results are discussed in the frequently asked question (FAQ) section at www.grti.com.
**Test Procedures**

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) has published recommended procedures for performing formation thermal conductivity tests for geothermal applications (ASHRAE 2011 HVAC Applications handbook, pages 32.12-32.13). The International Ground Source Heat Pump Association (IGSHPA) also lists test procedures in their 2010 Design and Installation Standards. GRTI’s test procedures meet or exceed those recommended by ASHRAE and IGSHPA, with the specific procedures described below:

**Grouting Procedure for Test Loops** – To ensure against bridging and voids, it is recommended that the bore annulus is uniformly grouted from the bottom to the top via tremie pipe.

**Time Between Loop Installation and Testing** – A minimum delay of five days between loop installation and test startup is recommended for bores that are air drilled, and a minimum waiting period of two days for mud rotary drilling.

**Undisturbed Formation Temperature Measurement** – The undisturbed formation temperature should be determined by recording the loop temperature as the water returns from the u-bend at test startup.

**Required Test Duration** – A minimum test duration of 36 hours is recommended, with a preference toward 48 hours.

**Data Acquisition Frequency** - Test data is recorded at five minute intervals.

**Equipment Calibration/Accuracy** – Transducers and datalogger are calibrated per manufacturer recommendations. Manufacturer stated accuracy of power transducers is less than ±2%. Temperature sensor accuracy is periodically checked via ice water bath.

**Power Quality** – The standard deviation of the power should be less than or equal to 1.5% of the average power, with maximum power variation of less than or equal to 10% of the average power.

**Input Heat Rate** – The heat flux rate should be 51 Btu/hr (15 W) to 85 Btu/hr (25 W) per foot of installed bore depth to best simulate the expected peak loads on the u-bend.

**Insulation** – GRTI’s equipment has 1 inch of foam insulation on the FTC unit and 1/2 inch of insulation on the hose kit connection. An additional 2 inches of insulation is provided for both the FTC unit and loop connections by insulating blankets.

**Retesting in the Event of Failure** – In the event that a test fails prematurely, a retest may not be performed until the bore temperature is within 0.5°F of the original undisturbed formation temperature or until a period of 14 days has elapsed.
Data Analysis

Geothermal Resource Technologies, Inc. (GRTI) uses the "line source" method of data analysis to determine the thermal conductivity of the formation. The line source method assumes an infinitely thin line source of heat in a continuous medium. A plot of the late-time temperature rise of the line source temperature versus the natural log of elapsed time will follow a linear trend. The linear slope is inversely proportional to the thermal conductivity of the medium. If a u-bend grouted in a borehole is used to inject heat into the ground at a constant rate in order to determine the average formation thermal conductivity, the test must be run long enough to allow the finite dimensions of the u-bend pipes and the grout to become insignificant. Experience has shown that approximately ten hours is required to allow the error of early test times and the effects of finite borehole dimensions to become insignificant.

In order to analyze real data from a formation thermal conductivity test, the average temperature of the water entering and exiting the u-bend heat exchanger is plotted versus the natural log of elapsed testing time. Using the Method of Least Squares, linear equation coefficients to produce a line that fits the data are calculated. This procedure is normally repeated for various time intervals to ensure that variations in the power or other effects are not producing inaccurate results.

The calculated results are based on test bore information submitted by the driller/testing agency. GRTI is not responsible for inaccuracies in the results due to erroneous bore information. All data analysis is performed by personnel that have an engineering degree from an accredited university with a background in heat transfer and experience with line source theory. The test results apply specifically to the tested bore. Additional bores at the site may have significantly different results depending upon variations in geology and hydrology.

Through the analysis process, the collected raw data is converted to spreadsheet format (Microsoft Excel®) for final analysis. If desired, please contact GRTI and a copy of the data will be made available in either a hard copy or electronic format.

Contact: Chad Martin
Regional Managing Engineer
Asheville, NC

(828) 225-9166
cmartin@grti.com
### Test Bore Details
(As Provided by Mid-South Geothermal, LLC)

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Murray State University Paducah Campus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Paducah, KY</td>
</tr>
<tr>
<td>Driller</td>
<td>Mid-South Geothermal, LLC</td>
</tr>
<tr>
<td>Installed Date</td>
<td>May 31, 2012</td>
</tr>
<tr>
<td>Borehole Diameter</td>
<td>4 3/4 inches</td>
</tr>
<tr>
<td>U-Bend Size</td>
<td>1 inch HDPE</td>
</tr>
<tr>
<td>U-Bend Depth Below Grade</td>
<td>350 ft</td>
</tr>
<tr>
<td>Backfill Type</td>
<td>#9 limestone</td>
</tr>
<tr>
<td>Backfilled Portion</td>
<td>10-350 ft</td>
</tr>
<tr>
<td>Note: Bore was grouted with bentonite from 0-10 ft.</td>
<td></td>
</tr>
</tbody>
</table>

### Drill Log

<table>
<thead>
<tr>
<th>Formation Description</th>
<th>Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red clay</td>
<td>0'-8'</td>
</tr>
<tr>
<td>Gravel</td>
<td>8'-15'</td>
</tr>
<tr>
<td>Tan clay</td>
<td>15'-25'</td>
</tr>
<tr>
<td>Grey clay</td>
<td>25'-30'</td>
</tr>
<tr>
<td>Tan clay</td>
<td>30'-35'</td>
</tr>
<tr>
<td>Dark grey clay</td>
<td>35'-280'</td>
</tr>
<tr>
<td>Chert</td>
<td>280'-281'</td>
</tr>
<tr>
<td>Dark grey clay</td>
<td>281'-350'</td>
</tr>
</tbody>
</table>

JUNE 13, 2012
Figure 1 above shows the loop temperature and heat input rate data versus the elapsed time of the test. The temperature of the fluid in the u-bend is plotted on the left axis, while the amount of heat supplied to the fluid is plotted on the right axis on a per foot of bore basis. In the test statistics below, calculations on the power data were performed over the analysis time period listed in the Line Source Data Analysis section.

**Summary Test Statistics**

Test Date: June 4-6, 2012  
Undisturbed Formation Temperature: N/A  
Duration: 41.7 hr  
Average Voltage: 244.2 V  
Average Heat Input Rate: 21,327 Btu/hr (6,249 W)  
Avg Heat Input Rate per Foot of Bore: 60.9 Btu/hr-ft (17.9 W/ft)  
Calculated Circulator Flow Rate: N/A  
Standard Deviation of Power: 0.07%  
Maximum Variation in Power: 0.15%
The loop temperature and input heat rate data versus the natural log of elapsed time are shown above in Figure 2. The temperature versus time data was analyzed using the line source method (see page 3) in conformity with ASHRAE and IGSHPA guidelines. A linear curve fit was applied to the loop temperature data between 10 and 41.7 hr. The slope of the curve fit was found to be 4.67. The resulting thermal conductivity was found to be $1.04 \text{ Btu/hr-ft}^\circ\text{F}$. 

**FIG. 2: TEMPERATURE & HEAT RATE VS NATURAL LOG OF TIME**
THERMAL DIFFUSIVITY

The reported drilling log for this test borehole indicated that the formation consisted of gravel, chert, and clay. A weighted average of heat capacity values based on the indicated formation was used to determine an average heat capacity of 37.8 Btu/ft²·°F for the formation. A diffusivity value was then found using the calculated formation thermal conductivity and the estimated heat capacity. The thermal diffusivity for this formation was estimated to be 0.66 ft²/day.
SECTION 232113 - HYDRONIC PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes pipe and fitting materials, joining methods, special-duty valves, and specialties for the following:

1. Condenser-water piping.
2. Makeup-water piping.
3. Condensate-drain piping.
5. Glycol.

B. Refer to Section “HVAC Water Treatment” for Additional Information.

1.2 PERFORMANCE REQUIREMENTS

A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature:

1. Condenser-Water Piping: 150 psig at 150 deg F.
2. Makeup-Water Piping: 80 psig at 150 deg F.
3. Condensate-Drain Piping: 150 deg F.
4. Air-Vent Piping: 200 deg F.

1.3 SUBMITTALS

A. Product Data: For each type of the following:

1. Pipe and fittings.
2. Valves. Include flow and pressure drop curves based on manufacturer's testing for control valves.
3. Air control devices.
5. Hydronic specialties.

B. Operation and maintenance data.

1.4 QUALITY ASSURANCE

A. ASME Compliance: Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation. Safety valves and pressure vessels shall bear the appropriate ASME
label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

PART 2 - PRODUCTS

2.1 COPPER TUBE AND FITTINGS

A. Drawn-Temper Copper Tubing: ASTM B 88, Type L.

B. Wrought-Copper Fittings: ASME B16.22.

C. Wrought-Copper Unions: ASME B16.22.

2.2 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53, black steel with plain ends; type, grade, and wall thickness as indicated in Part 3 "Piping Applications" Article.

B. Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

2. End Connections: Butt welding.
3. Facings: Raised face.

C. Grooved Mechanical-Joint Fittings and Couplings:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Anvil International, Inc.
   b. Tyco Fire & Building Products.
   c. Victaulic Company of America.
   d. Approved equal.

2. Joint Fittings: ASTM A 536, Grade 65-45-12 ductile iron; ASTM A 47, Grade 32510 malleable iron; ASTM A 53, Type F, E, or S, Grade B fabricated steel; or ASTM A 106, Grade B steel fittings with grooves or shoulders constructed to accept grooved-end couplings; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

3. Couplings: Ductile- or malleable-iron housing and synthetic rubber gasket of central cavity pressure-responsive design; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

D. Branch Line Fittings:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   b. Tyco Fire & Building Products.
   c. Victaulic Company of America.
   d. Approved equal.

2. Pressure Rating: 175 psig minimum.
3. Body Material: Steel
4. Type: Weld-o-lets or thread-o-lets.
5. Configurations: Fully welded to main, with welded or threaded connection. Refer to “Piping Applications” for connection method.
6. Size: Of dimension to fit onto hydronic main and with outlet connections as required to match connected branch piping.
7. Branch Outlets: Grooved or threaded.

2.3 JOINING MATERIALS

A. Joining materials as specified in Section “Common Work Results for Mechanical”.

2.4 DIELECTRIC FITTINGS

A. Dielectric Fittings are specified in Section “Common Work Results for Mechanical”.

2.5 VALVES

A. General duty valves are specified in Section “General-Duty Valves for Mechanical Piping”.

B. Automatic flow control valves are specified in Section “Instrumentation and Control for HVAC”.

C. Diaphragm-Operated, Pressure-Reducing Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Armstrong Pumps, Inc.
   b. Bell & Gossett.
   c. Patterson Pump Company.
   d. Approved equal.

2. Body: Bronze or brass.
3. Disc: Glass and carbon-filled PTFE.
5. Stem Seals: EPDM O-rings.
6. Diaphragm: EPT.
7. Low inlet-pressure check valve.
8. Inlet Strainer: Stainless steel, removable without system shutdown.
10. Valve Size, Capacity, and Operating Pressure: Selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

2.6 AIR CONTROL DEVICES

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

1. Amtrol, Inc.
2. Armstrong Pumps, Inc.
3. Bell & Gossett.
4. Patterson Pump Company.
5. Approved equal.

B. Manual Air Vents:

2. Internal Parts: Nonferrous.
3. Operator: Screwdriver or thumbscrew.
4. Inlet Connection: NPS 1/2.
7. Maximum Operating Temperature: 225 deg F.

C. Expansion Tanks:

1. Tank: Welded steel, rated for 125-psig working pressure and 375 deg F maximum operating temperature, with taps in bottom of tank for tank fitting and taps in end of tank for gage glass.
2. Air-Control Tank Fitting: Cast-iron body, copper-plated tube, brass vent tube plug, and stainless-steel ball check, sized for expansion-tank diameter. Provide tank fittings for 125-psig working pressure and 250 deg F maximum operating temperature.
3. Tank Drain Fitting: Brass body, nonferrous internal parts; 125-psig working pressure and 240 deg F maximum operating temperature; constructed to admit air into expansion tank, drain water, and close off system.

D. In-Line Air/Dirt Separators:

1. Tank: One-piece cast iron with an integral weir constructed to decelerate system flow to maximize air separation and sediment trap to capture and contain distilled foreign matter in hydronic system.
3. Maximum Operating Temperature: Up to 300 deg F.
2.7 CHEMICAL TREATMENT

A. Bypass Chemical Feeder: Welded steel construction; 125-psig working pressure; 5-gal. capacity; with fill funnel and inlet, outlet, and drain valves. Reference Section “HVAC Water Treatment” for coordination.

   1. Chemicals: Specially formulated, based on analysis of makeup water, to prevent accumulation of scale and corrosion in piping and connected equipment.

B. Propylene Glycol: Industrial grade with corrosion inhibitors and environmental-stabilizer additives for mixing with water in systems indicated to contain antifreeze or glycol solutions.

2.8 HYDRONIC PIPING SPECIALTIES

A. Stainless-Steel Bellow, Flexible Connectors:

   2. End Connections: Threaded or flanged to match equipment connected.
   4. CWP Rating: 150 psig.
   5. Maximum Operating Temperature: 250 deg F.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Condenser-water piping, aboveground, NPS 2 and smaller, shall be the following:

   1. Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered joints.

B. Condenser-water piping, aboveground, NPS 2-1/2 and larger, shall be the following:

   1. Schedule 40 steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.

C. Makeup-water piping installed aboveground shall be the following:

   1. Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered joints.

D. Condensate-Drain Piping:

   1. Schedule 40 PVC with solvent welded joints and fittings.

E. Air-Vent Piping:

   1. Inlet: Same as service where installed.
   2. Outlet: Type K, annealed-temper copper tubing with soldered joints.
3.2 VALVE APPLICATIONS

A. Install shutoff-duty valves at each branch connection to supply mains, and at supply connection to each piece of equipment as specified.

B. Install automatic flow control valves in the return pipe of each heating or cooling terminal as specified.

C. Install check valves at each pump discharge and elsewhere as required to control flow direction as specified.

D. Install pressure-reducing valves at makeup-water connection to regulate system fill pressure as specified.

3.3 PIPING INSTALLATIONS

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

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

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

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

E. Install piping to permit valve servicing.

F. Install piping at indicated slopes.

G. Install piping free of sags and bends.

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

I. Install piping to allow application of insulation.

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

K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

L. Install drains, consisting of a tee fitting, NPS 3/4 ball valve, and short NPS 3/4 threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.

M. Install piping at a uniform grade of 0.2 percent upward in direction of flow.
N. Reduce pipe sizes using eccentric reducer fitting installed with level side up.

O. Install branch connections to mains using manufactured fittings in main pipe, with the branch connected to the main pipe.

P. Install unions in piping, NPS 2 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

Q. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated.

R. Identify piping as to contents and flow direction as specified in Section “Identification for Mechanical Piping and Equipment”.

3.4 HANGERS AND SUPPORTS

A. Install the following pipe attachments:

1. Adjustable steel clevis hangers for individual horizontal piping.
2. Provide copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.

B. Install hangers for steel piping with the following maximum spacing and minimum rod sizes:

1. NPS 2-1/2: Maximum span, 11 feet; minimum rod size, 1/2 inch.
2. NPS 3: Maximum span, 12 feet; minimum rod size, 1/2 inch.
3. NPS 4: Maximum span, 8 feet; minimum rod size, 5/8 inch.
4. NPS 6: Maximum span, 8 feet; minimum rod size, 3/4 inch.
5. NPS 8: Maximum span, 19 feet, minimum rod size, 7/8 inch.
6. NPS 10: Maximum span, 20 feet, minimum rod size, 7/8 inch.
7. NPS 12: Maximum span, 23 feet, minimum rod size, 7/8 inch.

C. Install hangers for drawn-temper copper piping with the following maximum spacing and minimum rod sizes:

1. NPS 3/4: Maximum span, 5 feet; minimum rod size, 3/8 inch.
2. NPS 1: Maximum span, 6 feet; minimum rod size, 3/8 inch.
3. NPS 1-1/2: Maximum span, 8 feet; minimum rod size, 3/8 inch.
4. NPS 2: Maximum span, 8 feet; minimum rod size, 3/8 inch.

D. Support vertical runs at each floor, and at 10-foot intervals between floors.

3.5 PIPE JOINT CONSTRUCTION

A. Pipe joint construction is specified in Section “Common Work Results for Mechanical”.


3.6 HYDRONIC SPECIALTIES INSTALLATION

A. Install manual air vents at all high points in piping, at heat-transfer coils, and elsewhere as required for system air venting.

B. Install piping from air separator or air purger to expansion tank with a 2 percent upward slope toward tank.

C. Install in-line air separators in pump suction. Install drain valve on air separators NPS 2 and larger.

D. Install bypass chemical feeder in hydronic system where indicated, in upright position with top of funnel not more than 48 inches above the floor. Install feeder in minimum NPS 3/4 bypass line, from main with full-size, full-port, ball valve in the main between bypass connections. Install NPS 3/4 pipe from chemical feeder drain, to nearest equipment drain and include a full-size, full-port, ball valve.

E. Install expansion tanks above the air separator. Install tank fitting in tank bottom and charge tank. Use manual vent for initial fill to establish proper water level in tank.

   1. Install tank fittings that are shipped loose.
   2. Support tank from structure above with sufficient strength to carry weight of tank, piping connections, fittings, plus tank full of water. Do not overload building components and structural members.

3.7 TERMINAL EQUIPMENT CONNECTIONS

A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.

B. Install control valves in accessible locations close to connected equipment.

C. Install ports for pressure gages and thermometers at coil inlet and outlet connections.

3.8 CHEMICAL TREATMENT

A. Fill system with fresh water and add liquid alkaline compound with emulsifying agents and detergents to remove grease and petroleum products from piping. Circulate solution for a minimum of 24 hours, drain, clean strainer screens, and refill with fresh water.

B. Add initial chemical treatment and maintain water quality in ranges noted above for the first twelve (12) months of operation. Reference Section “HVAC Water Treatment”.

C. Fill system with glycol solution with the following concentrations:

   1. Condenser-Water Piping: Minimum ten (10) percent propylene glycol.
3.9 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Leave joints un-insulated and exposed for examination during test.
2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.
5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Perform the following tests on hydronic piping:

1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
3. Isolate expansion tanks and determine that hydronic system is full of water.
4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's working pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components and repeat hydrostatic test until there are no leaks.
6. Prepare written report of testing.

C. Perform the following before operating the system:

1. Open manual valves fully.
2. Inspect pumps for proper rotation.
3. Set makeup pressure-reducing valves for required system pressure.
4. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type), or bleed air completely (manual type).
5. Set temperature controls so all coils are calling for full flow.
6. Verify lubrication of motors and bearings.
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SECTION 232123 - HYDRONIC PUMPS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following:

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

1.2 SUBMITTALS

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

B. Shop Drawings: Show pump layout and connections. Include setting drawings with templates for installing foundation and anchor bolts and other anchorages.

C. Operation and maintenance data.

1.3 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. UL Compliance: Comply with UL 778 for motor-operated water pumps.

PART 2 - PRODUCTS

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

A. Available Manufacturers:

1. Armstrong Pumps Inc.
2. Bell & Gossett.
3. Patterson Pump Company.
4. Approved equal.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, end-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for base mounting, with pump
and motor shafts horizontal. Rate pump for 175-psig minimum working pressure and a continuous water temperature of 225 deg F.

C. Pump Construction:

1. Casing: Radially split, cast iron, with threaded gage tappings at inlet and outlet, drain plug at bottom and air vent at top of volute.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket.
5. Pump Bearings: Grease-lubricated ball bearings contained in cast-iron housing with grease fittings.

D. Shaft Coupling: Molded rubber insert and interlocking spider capable of absorbing vibration. EPDM coupling sleeve for variable-speed applications.

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

F. Mounting Frame: Welded-steel frame and cross members, factory fabricated from ASTM A 36 channels and angles. Fabricate to mount pump casing, coupling guard, and motor.

G. Motor: Premium-efficiency, with grease-lubricated ball bearings; secured to mounting frame, with adjustable alignment. Select motor to be non-overloading over full range of pump performance curve.

H. Capacities and Characteristics: as specified on drawings.

2.2 PUMP SPECIALTY FITTINGS

A. Suction Diffuser: Angle pattern, 175-psig pressure rating, cast-iron body and end cap, pump-inlet fitting; with bronze startup and bronze or stainless-steel permanent strainers; bronze or stainless-steel straightening vanes; drain plug; and factory-fabricated support.

PART 3 - EXECUTION

3.1 PUMP INSTALLATION

A. Comply with HI 1.4.

B. Install pumps with access for periodic maintenance including removal of motors, impellers, couplings, and accessories.

C. Independently support pumps and piping so weight of piping is not supported by pumps.
D. Set base-mounted pumps on concrete foundation. Disconnect coupling before setting. Do not reconnect couplings until alignment procedure is complete.

1. Support pump baseplate on rectangular metal blocks and shims, or on metal wedges with small taper, at points near foundation bolts to provide a gap of 3/4 to 1-1/2 inches between pump base and foundation for grouting.

2. Adjust metal supports or wedges until pump and driver shafts are level. Check coupling faces and suction and discharge flanges of pump to verify that they are level and plumb.

E. Install pumps on vibration isolators as specified in Section “Vibration and Seismic Controls for HVAC Piping and Equipment”.

3.2 ALIGNMENT

A. Align pump and motor shafts and piping connections after setting on foundation, grout has been set and foundation bolts have been tightened, and piping connections have been made.

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

C. Adjust pump and motor shafts for angular and offset alignment by methods specified in HI 1.1-1.5, "Centrifugal Pumps for Nomenclature, Definitions, Application and Operation."

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

3.3 CONNECTIONS

A. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to machine to allow service and maintenance.

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

D. Install suction and discharge pipe sizes as detailed on drawings.

E. Install suction diffuser and shutoff valve on suction side of pumps.

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

G. Install pressure gages on pump suction and discharge.

END OF SECTION 232123
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SECTION 232125 – VARIABLE SPEED PUMPING SYSTEM

PART 1 - GENERAL

1.1 SECTION INCLUDES:

A. Variable Speed Pumping Package
   1. Pump Control Panel.
   2. Variable Frequency Drive.
   4. Sequence of Operation.

1.2 REFERENCES

A. Hydraulic Institute
B. ANSI - American National Standards Institute
C. NEMA - National Electrical Manufacturers Association
D. UL - Underwriters Laboratories. Inc.
E. ETL - Electrical Testing Laboratories
G. NEC - National Electrical Code
H. ISO - International Standards Organization
I. IEC - International Electrotechnical Commission

1.3 SUBMITTALS

A. Submittals shall include the following:
   2. Sequence of operation.
   3. Shop drawing indicating dimensions, required clearances and location and size of each field connection.
   4. Power and control wiring diagrams.
   5. System profile analysis including variable speed pump curves and system curve. The analysis shall also include pump, motor and VFD efficiencies, job specific load profile, staging points, horsepower and kilowatt/hour consumption.
   6. Pump data sheets.

B. Submittals must be specific to this project. Generic submittals will not be accepted.
1.4 QUALITY ASSURANCE

A. The pumping package shall be assembled by the pump manufacturer. An assembler of pumping systems not actively engaged in the design and construction of centrifugal pumps shall not be considered a pump manufacturer. The manufacturer shall assume “Unit Responsibility” for the complete pumping package. Unit responsibility shall be defined as responsibility for interface and successful operation of all system components supplied by the pumping system manufacturer.

B. The manufacturer shall have a minimum of Twenty (20) years experience in the design and construction of variable speed pumping systems.

C. All functions of the variable speed pump control system shall be tested at the factory prior to shipment. This test shall be conducted with motors connected to VFD output and it shall test all inputs, outputs and program execution specific to this application.

F. Manufacturer shall be listed by Underwriter's Laboratories as a manufacturer of packaged pumping systems.

G. Bidders shall comply with all sections of this specification relating to packaged pumping systems. The supplier or contractor shall be bound by these specifications.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with these specifications, the following manufacturers shall be acceptable:

1. Armstrong Pumps Inc.
2. Bell & Gossett.
3. Patterson Pump Company.
4. Approved equal.

2.2 MANUFACTURED UNITS

A. Furnish and install as shown on the plans a Variable Speed Pumping System.

B. The control system shall include as a minimum, the programmable logic pump controller, variable frequency drives and remote sensor/transmitters as indicated on the drawings. Provide additional items as specified or as required to properly execute the sequence of operation.

C. The variable speed pump logic controller, adjustable frequency drives and VFD bypass circuitry shall be mounted within a UL-Listed, Nema 1 enclosure. Unit shall be pre-wired at the factory to permit a single point incoming power connection.

D. The control panel shall have provisions to be installed remotely against an equipment room wall. All control panel components shall be completely interwired at the factory. Only
connections for input power, output power and remote sensor/transmitters shall be made in the field.

2.3 COMPONENTS

A. Pump Logic Controller

1. The pump logic controller assembly shall be listed by and bear the label of Underwriter's Laboratory, Inc. (UL). The controller shall meet Part 15 of FCC regulations pertaining to class A computing devices. The controller shall be specifically designed for variable speed pumping applications.

2. The variable speed pump controller shall function to a proven program that safeguards against damaging hydraulic conditions including:

   c. Hunting.
   d. End of Curve Protection: The pump logic controller through a factory pre-programmed algorithm, shall be capable of protecting the pumps from hydraulic damage due to operation beyond their published end-of-curve. This feature requires a flow meter.

3. The pump logic controller shall be capable of staging and destaging pumps based on an Efficiency Optimization Program to provide the lowest kW draw. This optimization program requires a flow meter, kW meter, and system differential pressure sensors for activation.

4. The pump logic controller shall be capable of accepting all discrete analog inputs from zone sensors/transmitters as indicated on the plans. Analog input resolution shall be 12-bit minimum, and the controller shall scan each analog input a minimum of once every 100 milliseconds. Use of a multiplexer for multiple sensor inputs is not acceptable. All sensor/transmitter inputs shall be individually wired to the pump logic controller for continuous scan and comparison function. All analog inputs shall be provided with current limit circuitry to provide short circuit protection and safeguard against incorrect wiring of sensors.

5. The pump logic controller will select the analog input signal that deviates the greatest amount from its setpoint. This selected signal will be used as the command feedback input for a closed loop hydraulic stabilization function to minimize hunting. The hydraulic stabilization program shall utilize a proportional-integral-derivative control function. The proportional, integral and derivative values shall be user-adjustable over an infinite range. The scan and compare rate that selects the command setpoint and process variable signal shall be continuous and automatically set for optimum performance. Each sensor shall be scanned at least once every 100 milliseconds.

6. The pump controller shall be capable of controlling two (2) pumps in parallel as described in the sequence of operation section.

7. The pump logic controller shall be self-prompting. All messages shall be displayed in plain English. The following features shall be provided: Multi-fault memory and recall, On-screen help functions, LED pilot lights and switches and Soft-touch membrane keypad switches.
8. The variable speed pumping system shall be provided with a user friendly operator interface complete with membrane switches and numeric keypad. Display shall be no less than four lines with each line capable of displaying up to twenty characters. The operator interface panel shall display the following values:

a. Pump On/Off Status.
b. Pump % Speed.
c. Individual Alarm Conditions.
d. Troubleshooting Diagnostics.
e. User-adjustable parameters such as alternation, PID, setpoints, etc.

9. A data-logging feature shall be provided as a function of the pump logic controller. The Alarm log shall include the last 20 alarms with date/time stamp. The Pump data log shall display individual pump run timers and pump cycle counters. A Signal log shall be provided to display the maximum and minimum values with date/time stamps for each process variable and flow. The Signal log shall also be capable of displaying the cumulative value of kilowatt-hours for each pump and of system minimum and maximum flow along with individual counter reset capability.

10. The Logic controller shall incorporate a Flash Memory for saving and reloading customized settings. These field determined values shall be permanently retained in Flash memory for automatic reloading of the site specific setup values in the event of data corruption due to external disturbances. The Controller shall also employ a sensor setup copy feature.

11. The pump controller shall be capable of communicating peer-to-peer with the Building Automation System (BAS) by both hard-wired and serial communications.

a. The following communication features shall be provided to the BAS in “hardwired” form via 4-20ma analog signals and digital outputs:

1. Remote system start/stop.
2. Failure of any system component.
4. VFD speed.
5. Individual Pump on/off status.

b. The following communication features shall be provided peer-to-peer to the Building Automation System utilizing BACnet protocol:

1. All sensor process variables.
2. Individual zone setpoints.
3. Individual pump failure.
4. Individual pump on/off status.
5. Individual VFD on/off status.
6. VFD speed.
7. Individual VFD Failure.
8. VFD bypass status.

12. The pump logic controller shall be a Bell & Gossett Technologic 5500 or approved equal. Enclosure shall be NEMA 1.
B. Variable Frequency Drive

1. The variable frequency drives shall be pulse width modulation (PWM) type, microprocessor controlled design. Unit shall be the HVX 9000 Series manufactured by Eaton Corporation or approved equal.
2. The VFD, including all factory installed options, shall be tested to UL Standard 508. The VFD shall also be built to ISO 9001 standards.
3. The VFD shall employ an advanced sine wave approximation and voltage vector control to allow operation at rated motor shaft output speed with no derating. This voltage vector control shall minimize harmonics to the motor to increase motor efficiency and life. Power factor shall be near unity regardless of speed or load.
4. The VFD shall have balanced DC link reactors to minimize power line harmonics. VFDs without a DC link reactor shall provide a 3% impedance line reactor.
5. AH Automatic motor adaptation (AMA) algorithm shall be utilized. This feature shall allow for automatically optimized drive performance and efficiency leading to additional energy savings.
6. Input and output power circuit switching can be done without interlocks or damage to the VFD.
7. The following customer modifiable adjustments shall be provided:
   a. Accel time.
   b. Decel time.
   c. Minimum frequency.
   d. Maximum frequency.
8. An automatic energy optimization selection feature shall be provided. This feature shall reduce voltages when lightly loaded and provide 3% to 10% additional energy savings.
9. Maximum operating ambient temperature shall not be less than 104 degrees F. VFD shall be suitable for operation in environments up to 95% non-condensing humidity.
10. The VFD shall be capable of displaying the following information in plain English via a 40 character alphanumeric display:
    a. Frequency.
    b. Voltage.
    c. Current.
    d. Kilowatts per hour.
    e. Fault identification.
    f. Percent torque.
    g. Percent power.
    h. RPM.
11. All VFDs shall be warranted for a period of twelve (12) months after date of Substantial Completion. This warranty shall cover parts and labor.

C. Sensor / Transmitters

1. Provide all field-mounted differential pressure sensor transmitters as indicated on the drawings. Unit shall transmit an isolated 4-20mA dc signal indicative of process variable to the pump logic controller via standard two wire 24 DC system. Unit shall have stainless steel wetted parts with two 0.25” male NPT process connections. It shall be
protected against radio frequency interference and shall have a watertight, NEMA 4 electrical enclosure capable of withstanding 2000 PSI static pressure with a 0.5" NPT conduit connection. Accuracy shall be within 0.25% of full span.

D. Sequence of Operation

1. The system shall consist of a pump logic controller, multiple pump/VFD sets with manual and automatic alternation and pump staging.
2. The pumping system shall start upon the closure of customer's contact when the pump logic controller Mode of Operation selector switch is in the REMOTE position.
3. When the pump logic controller selector switch is in the LOCAL position, the pumping system shall operate automatically.
4. Sensors/transmitters shall be provided as indicated on the plans.
5. Each sensor/transmitter shall send a 4-20mA signal to the pump logic controller, indicative of process variable condition.
6. The pump logic controller shall compare each signal to the independent, user-determined set points.
7. When all set points are satisfied by the process variable, the pump speed shall remain constant flow at the optimum energy consumption level.
8. The pump logic controller shall continuously scan and compare each process variable to its individual set point and control to the least satisfied zone.
9. If the set point cannot be satisfied by the designated lead pump, the pump logic controller shall initiate a timed sequence of operation to stage a lag pump.
10. The lag pump shall accelerate resulting in the lead pump decelerating until they equalize in speed.
11. Further change in process variables shall cause the pumps to change speed together.
12. When the set point criteria can be safely satisfied with one pump, the pump logic controller shall initiate a timed destage sequence and continue variable speed operation.
13. As the worst case zone deviates from set point, the pump logic controller shall send the appropriate analog signal to the VFD to speed-up or slow-down the pump/motor.
14. In the event of a system differential pressure failure due to a pump or VFD fault, the pump logic controller shall automatically start the other variable speed pump/VFD set in sequence and continue variable speed operation, and initiate an alarm condition through the BAS.
15. In the event of the failure of a zone sensor/transmitter, its process variable signal shall be removed from the scan/compare program. Alternative zone sensors/transmitters, if available, shall remain in the scan/compare program for control.
16. The zone number corresponding to the failed sensors/transmitters shall be displayed on the operator interface of the pump logic controller, and initiate an alarm condition through the BAS.
17. In the event of failure to receive all zone process variable signals, all VFDs shall maintain 100% speed, reset shall be automatic upon correction of the zone failure. Status indication shall be communicated through the BAS.
18. PUMP or VFD fault shall be continuously scrolled through the display on the operator interface of pump logic controller until the fault has been corrected and the controller has been manually reset.
19. Control shall function as follows:
a. The controller shall monitor the zone differential pressure sensors and compare actual process values with the required set points. The pump speed is modulated to maintain set point. Pump staging will occur if required to meet set point.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install equipment in accordance with manufacturer's instructions.

B. The contractor shall align the pump and motor shafts to within the manufacturer's recommended tolerances prior to system start-up.

C. Power wiring, as required, shall be the responsibility of the electrical contractor. All wiring shall be performed per manufacturer’s instructions and applicable state, federal and local codes.

D. Control wiring for remote mounted switches and sensor / transmitters shall be the responsibility of the controls contractor. All wiring shall be performed per manufacturer’s instructions and applicable state, federal and local codes.

3.2 DEMONSTRATION

A. The system manufacturer or factory trained representative shall provide start-up of the packaged pumping system. This start-up shall include verification of proper installation, system initiation, adjustment and fine tuning. Start-up shall not be considered complete until the sequence of operation, including all alarms, has been sufficiently demonstrated to the owner or owner's designated representative. This jobsite visit shall occur only after all hook-ups, tie-ins, and terminations have been completed and signed-off on the manufacturer's start-up request form.

B. The system manufacturer or factory trained representative shall provide on-site training for owner's personnel. This training shall fully cover maintenance and operation of all system components as specified.

END OF SECTION 232125
SECTION 232500 - HVAC WATER TREATMENT

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following HVAC water-treatment systems:
   1. Bypass chemical-feed equipment and controls.
   2. pH control.
   3. HVAC water-treatment chemicals.

B. Refer to Section “Hydronic Piping” for additional information.

1.2 PERFORMANCE REQUIREMENTS

A. Water quality for HVAC systems shall minimize corrosion and scale buildup for optimum efficiency of HVAC equipment without creating a hazard to operating personnel or the environment.

B. Base HVAC water treatment on quality of water available at Project site, HVAC system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.

C. Closed hydronic systems shall have the following water qualities:
   1. pH: Maintain a value within 9.0 to 10.5.
   2. "P" Alkalinity: Maintain a value within 100 to 500 ppm.
   3. Boron: Maintain a value within 100 to 200 ppm.
   4. Chemical Oxygen Demand: Maintain a maximum value of 100 ppm.
   5. Soluble Copper: Maintain a maximum value of 0.20 ppm.
   6. TDS: Maintain a maximum value of 10 ppm.

1.3 SUBMITTALS

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

B. Shop Drawings: Pretreatment and chemical treatment equipment showing tanks, maintenance space required, and piping connections to HVAC systems. Include plans, elevations, sections, details, and attachments to other work.

C. Field quality-control test reports.

D. Other Informational Submittals:
1. **Water-Treatment Program:** Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in the "Performance Requirements" Article above.

2. **Water Analysis:** Illustrate water quality available at Project site.

### 1.4 QUALITY ASSURANCE

A. **HVAC Water-Treatment Service Provider Qualifications:** An experienced HVAC water-treatment service provider capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.

### PART 2 - PRODUCTS

#### 2.1 MANUFACTURERS

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

1. Aqua-Treat
2. Bluegrass Kesco, Inc.
3. Atom Chemical, Inc.
4. Approved equal.

#### 2.2 MANUAL CHEMICAL-FEED EQUIPMENT

A. **Bypass Feeder:** Steel, with corrosion-resistant exterior coating, minimum 3-1/2-inch fill opening in the top, and NPS 3/4 bottom inlet and top side outlet. Quarter turn or threaded fill cap with gasket seal and diaphragm to lock the top on the feeder when exposed to system pressure in the vessel.

1. **Capacity:** 5 gal.
2. **Minimum Working Pressure:** 175 psig.

#### 2.3 CHEMICAL TREATMENT TEST EQUIPMENT

A. **Test Kit:** Manufacturer-recommended equipment and chemicals in a wall-mounting cabinet for testing pH, TDS, inhibitor, chloride, alkalinity, and hardness.

#### 2.4 CHEMICALS

A. **Chemicals:** Shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment, and that can attain water quality specified in Part 1 "Performance Requirements" Article.
PART 3 - EXECUTION

3.1 WATER ANALYSIS
A. Perform an analysis of supply water to determine quality of water available at Project site.

3.2 INSTALLATION
A. Mechanical Contractor shall install all equipment and piping. Water Treatment Contractor shall coordinate with Mechanical Contractor all installations and necessary rough-ins.
B. Install chemical application equipment level and plumb. Maintain manufacturer's recommended clearances. Arrange units so devices that require servicing are accessible. Anchor floor-mounting accessories to substrate.
C. Install water testing equipment on wall near water chemical application equipment.
D. Bypass Feeders: Install in closed hydronic system with the following:
   1. Install bypass feeder in a bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
   2. Install water meter in makeup water supply.
   3. Install test-coupon assembly in bypass circuit around circulating pumps.
   4. Install full-port ball isolation valves on inlet, outlet, and drain below feeder inlet.

3.3 CONNECTIONS
A. Drawings indicate general arrangement of piping, fittings, and specialties.
B. Install piping adjacent to equipment to allow service and maintenance.
C. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings.
D. Install shutoff valves on HVAC water-treatment equipment inlet and outlet.

3.4 FIELD QUALITY CONTROL
A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.
B. Tests and Inspections:
   1. Inspect field-assembled components and equipment installation including piping.
2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.

3. Place HVAC water-treatment system into operation and calibrate controls during the preliminary phase of HVAC systems' startup procedures.

4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.

5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.

6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.

7. Cap and subject piping to static water pressure of 50 psig above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.

8. Repair leaks and defects with new materials and retest piping until no leaks exist.

C. Remove and replace malfunctioning units and retest as specified above.

D. Comply with ASTM D 3370 and with the following standards:


3.5 DEMONSTRATION

A. Engage a factory-authorized service representative to train maintenance personnel designated by University to adjust, operate, and maintain HVAC water-treatment systems and equipment.

END OF SECTION 232500
SECTION 233113 - METAL DUCTS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Rectangular ducts and fittings.
   2. Round ducts and fittings.
   4. Sealants and gaskets.
   5. Hangers and supports.

1.2 PERFORMANCE REQUIREMENTS

A. Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible".

B. Structural Performance: Duct hangers and supports shall withstand the effects of gravity loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible".

1.3 AIR LEAKAGE TESTING OF THE DUCTWORK SYSTEMS:

A. It is the intent of this section to insure the ductwork installed has minimal air leakage.

B. Air leakage testing shall be accomplished by an AABC certified company. Refer to the Test & Balance specifications.

C. A duct pre-installation conference shall be held prior to the installation of the ductwork. Present should be the University, Engineer, Test & Balance Contractor, General Contractor, Mechanical Contractor, Sheet Metal Contractor, and Insulation Contractor. At this meeting, the contractor shall advise all of the duct materials and sealant materials to be used to meet the air leakage allowances.

D. The duct systems which will require testing are as follows:
   1. Supply air duct systems.
   2. Return air duct systems.
   3. Ventilation air duct systems.
   4. Relief air and exhaust air duct systems.

E. Testing shall be based on a 10% blind sampling method. The 10% duct sampling shall be selected by the Engineer. If the first 10% sampling does not meet the requirements set forth in
this Section and Section “Testing, Adjusting, and Balancing for HVAC,” the first sampling shall be corrected and an additional 10% shall be sampled until the system(s) maintain an acceptable leakage rate. All remediation and additional testing shall be paid by the Contractor.

F. Do not insulate the air systems prior to testing.

G. The maximum allowable supply, return, exhaust, and outside air leakage rate is 2.5% of the systems design CFM when the ductwork is pressurized to 2.0” WG. (Therefore, if a supply air system is tested, and the supply air fan rated capacity is 10,000 CFM, the allowable leakage is 250 CFM.)

H. All sheet metal ductwork associated with the system(s) shall be tested. Flexible ductwork shall not be tested. Cap the main duct prior to the central equipment fan connection. Also cap the branch ducts which serve the diffusers at the location in which flexible duct will be installed. Cap ends with sheet metal caps. Seal caps well to avoid air loss at this location. This air loss, from the caps, is included in the noted leakage rate.

I. The noted allowable leakage rate is the total allowable. It shall include leakage associated with the following:

1. All ductwork as described in above paragraphs.
2. Access doors.
3. Volume dampers.
4. Fire dampers.
5. End caps used to seal ducts.

J. If any duct system fails a test, the contractor shall reseal the system. It shall then be retested until the duct system meets the leakage allowance at no additional cost to the Owner.

1.4 SUBMITTALS

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

B. Shop Drawings:

1. Fittings.
2. Hangers and supports, including methods for duct and building attachment and vibration isolation.

C. Welding certificates.

1.5 QUALITY ASSURANCE

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

PART 2 - PRODUCTS

2.1 RECTANGULAR DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

B. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-4, "Transverse (Girth) Joints,” for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-5, "Longitudinal Seams - Rectangular Ducts," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 2, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.2 ROUND DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.

1. Subject to compliance with requirements, provide products by one of the following:
   a. Lindab Inc.
   b. McGill AirFlow LLC.
   c. SEMCO Incorporated.
   d. Sheet Metal Connectors, Inc.
   e. Spiral Manufacturing Co., Inc.
   f. Approved equal.

B. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Transverse Joints - Round Duct," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Seams - Round Duct and Fittings," for static-pressure class, applicable sealing requirements, materials involved, duct-support...
intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Tees and Laterals: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "90 Degree Tees and Laterals," and Figure 3-5, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.3 SHEET METAL MATERIALS

A. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
   2. Finishes for Surfaces Exposed to View: Mill phosphatized.

C. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

D. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.4 SEALANT AND GASKETS

A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.

B. Water-Based Joint and Seam Sealant:
   1. Application Method: Brush on.
   2. Solids Content: Minimum 65 percent.
   5. Mold and mildew resistant.
   6. VOC: Maximum 75 g/L (less water).
   7. Maximum Static-Pressure Class: 10-inch wg, positive and negative.
   8. Service: Indoor or outdoor.
   9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

C. Flanged Joint Sealant: Comply with ASTM C 920.
2. Type: S.
3. Grade: NS.
5. Use: O.

D. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

E. Round Duct Joint O-Ring Seals:
   1. Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg and shall be rated for 10-inch wg static-pressure class, positive or negative.
   2. EPDM O-ring to seal in concave bead in coupling or fitting spigot.
   3. Double-lipped, EPDM O-ring seal, mechanically fastened to factory-fabricated couplings and fitting spigots.

2.5 HANGERS AND SUPPORTS

A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.

B. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 4-1, "Rectangular Duct Hangers Minimum Size," and Table 4-2, "Minimum Hanger Sizes for Round Duct."

C. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A 603.

D. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.

E. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

F. Trapeze and Riser Supports:

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.

B. Install ducts according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.
C. Install round ducts in maximum practical lengths.

D. Install ducts with fewest possible joints.

E. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.

F. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.

G. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

H. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.

I. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.

J. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches.

K. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers with access doors.

L. Protect duct interiors from moisture, construction debris and dust, and other foreign materials. Comply with SMACNA's "Duct Cleanliness for New Construction Guidelines."

3.2 SEAM AND JOINT SEALING

A. Seal duct seams and joints for duct static-pressure and leakage classes specified in "Performance Requirements" Article, according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 1-2, "Standard Duct Sealing Requirements," unless otherwise indicated.

B. Seal Classes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 1-2, "Standard Duct Sealing Requirements."

3.3 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 4, "Hangers and Supports."

B. Building Attachments: Powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

C. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 4-1, "Rectangular Duct Hangers Minimum Size," and Table 4-2, "Minimum
Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.

D. Hangers Exposed to View: Threaded rod and angle or channel supports.

E. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at a maximum intervals of 16 feet.

F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.4 CONNECTIONS

A. Make connections to equipment with flexible connectors.

B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.5 DUCT SCHEDULE

A. Fabricate ducts with galvanized sheet steel.

B. Intermediate Reinforcement:


C. Elbow Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Elbows."
   a. Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-3, "Vanes and Vane Runners," and Figure 2-4, "Vane Support in Elbows."

2. Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-3, "Round Duct Elbows."
   a. Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 3-1, "Mitered Elbows." Elbows with less than 90-degree change of direction have proportionately fewer segments.
      1) Velocity 1000 fpm or Lower: 0.5 radius-to-diameter ratio and three segments for 90-degree elbow.
   b. Round Elbows, 12 Inches and Smaller in Diameter: Stamped or pleated.
   c. Round Elbows, 14 Inches and Larger in Diameter: Welded.
D. Branch Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-6, "Branch Connections."
   
   a. Rectangular Main to Rectangular Branch: 45-degree entry.
   b. Rectangular Main to Round Branch: 45-degree entry.

2. Round: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "90 Degree Tees and Laterals," and Figure 3-5, "Conical Tees." Saddle taps are permitted in existing duct.
   
   a. Round main to Round Branch: 45-degree lateral.

END OF SECTION 233113
SECTION 233300 - AIR DUCT ACCESSORIES

PART 1 - GENERAL

1.1 SUMMARY
A. Section Includes:
   2. Fire dampers.
   3. Turning vanes.
   4. Duct-mounted access doors.
   5. Flexible connectors.
   6. Flexible ducts.
   7. Duct accessory hardware.

1.2 SUBMITTALS
A. Product Data: For each type of product indicated.
B. Operation and maintenance data.

1.3 QUALITY ASSURANCE
B. Comply with AMCA 500-D testing for damper rating.

PART 2 - PRODUCTS

2.1 MATERIALS
A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.
B. Galvanized Sheet Steel: Comply with ASTM A 653.
   2. Exposed-Surface Finish: Mill phosphatized.
C. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts.

D. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.2 MANUAL VOLUME DAMPERS

A. Standard, Steel, Manual Volume Dampers:

1. Subject to compliance with requirements, provide products by one of the following:
   a. Arrow United Air.
   b. Greenheck Fan Corporation.
   c. Nailor Industries.
   d. Ruskin Company.
   e. United Enertech.
   f. Approved equal.

2. Standard leakage rating, with linkage outside airstream.
3. Suitable for horizontal or vertical applications.
4. Frames:
   a. Hat-shaped, galvanized-steel channels, 0.064-inch minimum thickness.
   b. Mitered and welded corners.
   c. Flanges for attaching to walls and flangeless frames for installing in ducts.

5. Blades:
   a. Multiple or single blade.
   b. Opposed-blade design.
   c. Stiffen damper blades for stability.
   d. Galvanized-steel, 0.064 inch thick.

7. Bearings:
   a. Molded synthetic.
   b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

8. Tie Bars and Brackets: Galvanized steel.

2.3 FIRE DAMPERS

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

1. Arrow United Air.
2. Greenheck Fan Corporation.
4. Ruskin Company.
5. United Enertech.
6. Approved equal.

B. Type: “B” dynamic; rated and labeled according to UL 555 by an NRTL.

C. Closing rating in ducts up to 4-inch wg static pressure class and minimum 4000-fpm velocity.

D. Fire Rating: 1-1/2 hours.

E. Frame: Curtain type “B” with blades outside airstream; fabricated with roll-formed, 0.034-inch-thick galvanized steel; with mitered and interlocking corners.

F. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel.
   1. Minimum Thickness: 0.052 or 0.138 inch thick, as indicated, and of length to suit application.
   2. Exception: Omit sleeve where damper-frame width permits direct attachment of perimeter mounting angles on each side of wall or floor; thickness of damper frame must comply with sleeve requirements.

G. Mounting Orientation: Vertical or horizontal as indicated.

H. Blades: Roll-formed, interlocking, 0.034-inch-thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch-thick, galvanized-steel blade connectors.

I. Horizontal Dampers: Include blade lock and stainless-steel closure spring.


2.4 TURNING VANES

A. Turning Vanes for Metal Ducts: Curved blades of galvanized sheet steel; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.

B. General Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 2-3, "Vanes and Vane Runners," and 2-4, "Vane Support in Elbows."

C. Vane Construction: Double wall.

2.5 DUCT-MOUNTED ACCESS DOORS

A. Subject to compliance with requirements, provide products by one of the following:
   1. Arrow United Air.
   2. Greenheck Fan Corporation.
   4. Ruskin Company.
5. United Enertech.
6. Approved equal.


1. Door:
   a. Double wall, rectangular.
   b. Galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class.
   d. Fabricate doors airtight and suitable for duct pressure class.

2. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.
3. Number of Hinges and Locks:
   a. Access Doors Less Than 12 Inches Square: No hinges and two sash locks.
   b. Access Doors up to 18 Inches Square: Piano hinge and two sash locks.

2.6 FLEXIBLE CONNECTORS

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

1. Ductmate Industries, Inc.
2. Ventfabrics, Inc.
3. Approved equal.

B. Materials: Flame-retardant or noncombustible fabrics.

C. Coatings and Adhesives: Comply with UL 181, Class 1.

D. Metal-Edged Connectors: Factory fabricated with a fabric strip 3-1/2 inches wide attached to 2 strips of 2-3/4-inch- wide, 0.028-inch- thick, galvanized sheet steel or 0.032-inch- thick aluminum sheets. Provide metal compatible with connected ducts.


   1. Minimum Weight: 26 oz./sq. yd.
   2. Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
   3. Service Temperature: Minus 40 to plus 200 deg F.

2.7 FLEXIBLE DUCTS

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

1. Atco.
2. Hart and Cooley.
3.  ThermaFlex.
4.  Approved equal.

B. Insulated, Flexible Duct: UL 181, Class 1, 2-ply vinyl film supported by helically wound, spring-steel wire; fibrous-glass insulation; polyethylene vapor-barrier film.
   1.  Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
   3.  Temperature Range: Minus 10 to plus 160 deg F.
   4.  Insulation Value: R-6.0 minimum.

C. Flexible Duct Connectors:
   1.  Clamps: Nylon strap in sizes 3 through 8 inches, to suit duct size.

2.8 DUCT ACCESSORY HARDWARE

A. Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts.

B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel ducts.

C. Install volume dampers at points on supply, return, and relief/exhaust systems where branches extend from larger ducts.
   1.  Install steel volume dampers in steel ducts.

D. Set dampers to fully open position before testing, adjusting, and balancing.

E. Install fire dampers according to UL listing.

F. Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:
   1.  Adjacent to and close enough to fire dampers, to reset or reinstall fusible links.
   2.  On both sides of duct silencers.
   3.  Elsewhere as indicated.

G. Install access doors with swing against duct static pressure.
H. Access Door Sizes:

1. One-Hand or Inspection Access: 8 by 5 inches.
2. Two-Hand Access: 12 by 6 inches.

I. Label access doors.

J. Install flexible connectors to connect ducts to equipment.

K. Connect diffusers to low-pressure ducts with maximum 60-inch lengths of flexible duct clamped or strapped in place.

L. Connect flexible ducts to metal ducts with draw bands.

3.2 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Operate dampers to verify full range of movement.
2. Inspect locations of access doors and verify that purpose of access door can be performed.
3. Operate fire dampers to verify full range of movement and verify that proper heat-response device is installed.
4. Inspect turning vanes for proper and secure installation.

END OF SECTION 233300
SECTION 233423 - HVAC POWER VENTILATORS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following:

1. Ceiling-mounting ventilators.
2. Inline centrifugal fans.

1.2 SUBMITTALS

A. Product Data: Include rated capacities, furnished specialties, and accessories for each type of product indicated and include the following:

B. Operation and maintenance data.

1.3 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. NEMA Compliance: Motors and electrical accessories shall comply with NEMA standards.

C. UL Standard: Power ventilators shall comply with UL 705.

PART 2 - PRODUCTS

2.1 CEILING-MOUNTING VENTILATORS

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

1. Greenheck.
2. Loren Cook Company.
3. Penn Berry.
4. Approved equal.

B. Description: Centrifugal fans designed for installing in ceiling or for concealed in-line applications.

C. Housing: Steel, lined with acoustical insulation.
D. Fan Wheel: Centrifugal wheels directly mounted on motor shaft. Fan shrouds, motor, and fan wheel shall be removable for service.

E. Grille: Aluminum with white enamel finish.

F. Electrical Requirements: Junction box for electrical connection on housing and receptacle for motor plug-in.

G. Accessories:
   1. As specified on drawings.

2.2 IN-LINE CENTRIFUGAL FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Greenheck.
   2. Loren Cook Company.
   3. Penn Barry.
   4. Approved equal.

B. Description: In-line, direct-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, mounting brackets, and accessories.

C. Housing: Split, spun aluminum with aluminum straightening vanes, inlet and outlet flanges, and support bracket adaptable to floor, side wall, or ceiling mounting.

D. Direct-Driven Units: Motor mounted out of airstream, factory wired to disconnect switch located on outside of fan housing.

E. Fan Wheels: Aluminum, airfoil blades welded to aluminum hub.

F. Accessories:
   1. Companion Flanges: For inlet and outlet duct connections.
   3. As specified on drawings.

2.3 MOTORS

A. Enclosure Type: As specified on drawings.
PART 3 - EXECUTION

3.1 INSTALLATION

A. Install power ventilators level and plumb.
B. Support units using vibration isolation mounts.
C. Support suspended units from structure using threaded steel rods and vibration isolation mounts.
D. Install units with clearances for service and maintenance.
E. Label units according to Section “Identification for Mechanical Piping and Equipment”.
F. Duct installation and connection requirements are specified in Section “Metal Ducts”. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors.
G. Install ducts adjacent to power ventilators to allow service and maintenance.

3.2 FIELD QUALITY CONTROL

A. Perform the following field tests and inspections:
   1. Verify that shipping, blocking, and bracing are removed.
   2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
   3. Verify that cleaning and adjusting are complete.
   4. Verify lubrication for bearings and other moving parts.
   5. Verify that manual and automatic volume control and fire dampers in connected ductwork systems are in fully open position.
   6. Disable automatic temperature-control operators, energize motor and adjust fan to indicated rpm, and measure and record motor voltage and amperage.
   7. Shut unit down and reconnect automatic temperature-control operators.
   8. Remove and replace malfunctioning units and retest as specified above.

B. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

END OF SECTION 233423
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SECTION 233713 - DIFFUSERS AND GRILLES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Diffusers and grilles.

1.2 SUBMITTALS

A. Product Data: For each type of product indicated, include the following:
   1. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
   2. Diffuser and Grille Schedule: Indicate drawing designation, quantity, model number, size, and accessories furnished.

B. Samples: For each color specified.

PART 2 - PRODUCTS

2.1 DIFFUSERS AND GRILLES

A. Diffusers and Grilles, as specified on drawings:
   1. Subject to compliance with requirements, provide products by one of the following:
      a. Krueger.
      b. Nailor Industries.
      c. Price Industries.
      d. Titus.
      e. Approved equal.

2.2 SOURCE QUALITY CONTROL

A. Verification of Performance: Rate diffusers and grilles according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."
PART 3 - EXECUTION

3.1 INSTALLATION

A. Install diffusers and grilles level and plumb.

B. Ceiling- and Wall-Mounted Outlets and Inlets: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where Architectural features or other items conflict with installation, notify Engineer for a determination of final location.

C. Install diffusers and grilles with airtight connections to ducts and to allow service and maintenance of volume and fire dampers.

3.2 ADJUSTING

A. After installation, adjust diffusers and grilles to air patterns indicated, or as directed, before starting air balancing.

END OF SECTION 233713
SECTION 233716 - LOUVERS AND VENTS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Combination louver/damper, extruded-aluminum louvers.
   2. Cast aluminum wall vents (brick vents).

1.2 PERFORMANCE REQUIREMENTS

A. Structural Performance: Louvers shall withstand the effects of gravity loads and the following loads and stresses within limits and under conditions indicated without permanent deformation of louver components, noise or metal fatigue caused by louver blade rattle or flutter, or permanent damage to fasteners and anchors.

   1. Wind Loads: Determine loads based on a uniform pressure of 30 lbf/sq. ft., acting inward or outward.

B. Louver Performance Ratings: Provide louvers complying with requirements specified, as demonstrated by testing manufacturer's stock units identical to those provided, except for length and width according to AMCA 500-L.

1.3 SUBMITTALS

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

   1. Include printed catalog pages showing specified models with appropriate AMCA Certified Ratings Seals.

B. Shop Drawings: For louvers and accessories. Include plans, elevations, sections and details. Show frame profiles and blade profiles, angles, and spacing.

C. Samples: For each type of metal finish required.

D. Product Test Reports: Based on tests performed according to AMCA 500-L.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Aluminum Extrusions: ASTM B 221, Alloy 6063-T5, T-52, or T6.
B. Fasteners: Use types and sizes to suit unit installation conditions.
   1. For color-finished louvers, use fasteners with heads that match color of louvers.

2.2 FABRICATION, GENERAL

A. Fabricate frames, including integral sills, to fit in openings of sizes indicated, with allowances made for fabrication and installation tolerances, adjoining material tolerances, and perimeter sealant joints.

B. Join frame members to each other and to fixed louver blades with fillet welds, threaded fasteners, or both, as standard with louver manufacturer unless otherwise indicated or size of louver assembly makes bolted connections between frame members necessary.

2.3 COMBINATION LOUVER/DAMPER, EXTRUDED-ALUMINUM LOUVERS

A. Louver:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Greenheck Fan Corporation.
      b. Nailor
      c. NCA
      d. Ruskin Company.
      e. United Enertec.
      f. Approved equal.
   2. Louver Depth: As specified on drawings.
   3. Frame and Blade Nominal Thickness: Not less than 0.060 inch for blades and 0.080 inch for frames.
   4. Louver Performance Ratings: As specified on drawings.
   5. AMCA Seal: Mark units with AMCA Certified Ratings Seal.
   6. Actuator: As specified on drawings.
   7. Linkage: Linkage shall be concealed in the frame of the unit.

2.4 LOUVER SCREENS

A. General: Provide screen at each exterior louver.

B. Louver Screen Frames: Same kind and form of metal as indicated for louver to which screens are attached.

C. Louver Screening:
   1. Bird Screening: Aluminum, 1/2-inch- square mesh, 0.063-inch wire.
2.5 WALL VENTS (BRICK VENTS)

A. Cast-Aluminum Wall Vents:

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

   a. Arrow United Air.
   b. Greenheck Fan Corporation.
   c. Nailor Industries.
   d. Ruskin Company.
   e. United Enertec.
   f. Approved equal.

2. One-piece, cast-aluminum louvers and frames; with 18-by-14- mesh, aluminum insect screening on inside face; incorporating integral waterstop on inside edge of sill; of load-bearing design and construction.

2.6 ALUMINUM FINISHES

A. High-Performance Organic Finish: Factory applied, 3-coat fluoropolymer finish complying with AAMA 2604 and containing not less than 70 percent PVDF resin by weight in color coat. Prepare, pretreat, and apply coating to exposed metal surfaces to comply with coating and resin manufacturers' written instructions.

   1. Color and Gloss: As selected by Architect from manufacturer's full range.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Locate and place louvers and vents level, plumb, and at indicated alignment with adjacent work.

B. Use concealed anchorages where possible. Provide brass or lead washers fitted to screws where required to protect metal surfaces and to make a weathertight connection.

C. Provide perimeter reveals and openings of uniform width for sealants and joint fillers, as indicated.

D. Repair damaged finishes so no evidence remains of corrective work. Return items that cannot be refinished in the field to the factory and refinish entire unit or provide new units.

E. Protect galvanized and nonferrous-metal surfaces that will be in contact with concrete, masonry, or dissimilar metals from corrosion and galvanic action by applying a heavy coating of bituminous paint.

END OF SECTION 233716
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SECTION 237438 – DEDICATED VENTILATION-AIR WATER SOURCE HEAT PUMP WITH ENERGY RECOVERY VENTILATORS

PART 1 - GENERAL

1.1 SUMMARY
A. This Section includes dedicated ventilation-air water source heat pumps with energy recovery ventilators.

1.2 SUBMITTALS
A. Product Data: Include rated capacities at operating conditions listed on drawings, furnished specialties, and accessories.
B. Shop Drawings: From manufacturer, detailing equipment assemblies and indicating dimensions, weights, loadings, required clearances, method of field assembly, components, and location and size of each field connection.
C. Product certificates.
D. Operation and maintenance data.
E. Warranty.

1.3 QUALITY ASSURANCE
A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
B. Comply with ASHRAE Standard 84.
C. Comply with ARI 1060.
D. Fans shall be manufactured and certified per AMCA.

1.4 EXTRA MATERIALS
A. One (1) extra set of filters.
1.5 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to replace components listed below that fail in materials or workmanship within specified warranty period.

1. Warranty Period for Compressors: Manufacturer's standard, but not less than five (5) years from date of Substantial Completion.
2. Warranty Period for Parts: Manufacturer's standard, but not less than one (1) year from date of Substantial Completion.
3. Warranty Period for Limited Labor: Manufacturer’s Standard, but not less than one (1) year from date of Substantial Completion.
4. Warranty Period for Energy Recovery Ventilators: Manufacturer's standard form in which manufacturer agrees to repair or replace energy recovery ventilators that fails in materials and workmanship within one (1) year from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Desert-Aire Corp.
2. Innovent.
3. Venmar.
4. Approved equal.

2.2 CABINET

A. Construction: Double wall.

B. Exterior Casing: Galvanized steel with baked-enamel paint finish with lifting lugs and knockouts for electrical and piping connections.

C. Interior Casing: Galvanized steel.

D. Service Doors: Hinged access doors with neoprene gaskets.

E. Internal Insulation: Fibrous-glass duct lining complying with ASTM C 1071, Type II.

1. Thickness: 2 inches.
2. Insulation Adhesive: Comply with ASTM C 916, Type I.
3. Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to casing without damaging liner and without causing air leakage when applied as recommended by manufacturer.

F. Condensate Drain Pans: Formed sections of stainless-steel sheet designed for self-drainage. Fabricate pans with slopes to preclude buildup of microbial slime.
2.3 SUPPLY AND EXHAUST-AIR FAN

A. Fans: Premium-efficiency backward-curved centrifugal air-foil; statically and dynamically balanced, galvanized steel, mounted on solid-steel shaft with self-aligning, permanently lubricated ball bearings.

B. Motors: VFD-controlled motors as specified.

C. Drives: V-belt drives with matching fan pulley and adjustable motor sheaves and belt assembly with minimum 1.4 service factor.

D. Mounting: Fan wheels, motors, and drives shall be mounted in fan casing with spring isolators.

2.4 ENERGY RECOVERY VENTILATOR

A. Unit: Shall have the following features:

   1. Total energy recovery wheel shall be mounted in a slide-out track for ease of inspection, removal and cleaning.
   2. Wheel shall be of the enthalpy type for both sensible and latent heat recovery, and be designed to insure laminar flow. Desiccant shall be suitable for scheduled performance. Wheel shall be constructed of lightweight polymer or aluminum media to minimize shaft and bearing loads. Polymer or Aluminum media shall be mounted in a stainless steel rotor for corrosion resistance.
   3. Wheel design shall consist of removable segments for ease of service and/or cleaning. Segments shall be removable without the use of tools. Desiccant shall be at maximum 4 angstrom size, and shall be permanently bonded to wheel media to retain latent heat recovery after cleaning. Wheels with sprayed on desiccant coatings are not acceptable. Wheels with desiccant applied after the wheel formation is not acceptable. Energy recovery device shall transfer moisture entirely in the vapor phase.

2.5 REFRIGERATION SYSTEM

A. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Code for Mechanical Refrigeration."

B. Compressors: Hermetic scroll compressors with integral vibration isolators, internal overcurrent and over-temperature protection, and internal pressure relief.

C. EER and COP: Meet or exceed that specified on drawings.

D. Refrigerant: R-410A.

E. Refrigeration System Specialties:

   1. Expansion valve with replaceable thermostatic element.
   2. Refrigerant reversing valve.
   3. Refrigerant dryer.
4. High-pressure switch.
5. Low-pressure switch.
6. Thermostat for coil freeze-up protection during low ambient temperature operation or loss of air.
7. Brass service valves installed in discharge and liquid lines.
8. Operating charge of refrigerant.

F. Capacity Control: Hot-gas by pass refrigerant control for capacity control with continuous dehumidification on all system compressors.

G. Humidity Control: Zero (0) to one hundred (100) percent modulating humidity control using coil and hot-gas reheat valve on the lead refrigerant circuit.

H. Refrigerant Coils: Evaporator, condenser, and reheat condenser coils shall be designed, tested, fabricated, and rated according to ARI 410 and ASHRAE 33. Coils shall be leak tested under water with air at 315 psig.

I. Safety Controls:
   1. Compressor motor and outside-coil fan motor low ambient lockout.
   2. Overcurrent protection for compressor motor and outside-coil fan motors.

2.6 OUTDOOR- AND EXHAUST-AIR INTAKE/EXHAUST AND DAMPERS

A. Dampers: Leakage rate, according to AMCA 500, shall not exceed 2 percent of air quantity at face velocity of 2000 fpm through damper and pressure differential of 4-inch wg.

B. Damper Operators: Electric.

2.7 FILTERS

A. Comply with NFPA 90A.

B. Disposable Panel Filters: 2-inch-thick, factory-fabricated, flat-panel-type, disposable air filters with holding frames, with a minimum efficiency reporting value of 11 according to ASHRAE 52.2 and 60 percent average arrestance according to ASHRAE 52.1.
   1. Media: Interlaced glass fibers sprayed with nonflammable adhesive.
   2. Frame: Galvanized steel.

2.8 CONTROLS

A. Factory-wire connection for controls' power supply.

B. Control devices, including sensors, transmitters, relays, switches, thermostats, humidistats, detectors, operators, actuators, and valves, shall be manufacturer's standard items to accomplish indicated control functions.
C. Unit Controls: Solid-state control board and components with field-adjustable control parameters.

1. System Control: Units shall be monitored, controlled, and displayed by the Building Automation System (BAS). System shall run continuously during occupied periods, and remain off during unoccupied periods.

D. Unit-Mounted Status Panel:

1. Cooling/Off/Heating Controls: Control operational mode.
2. Damper Position: Indicates position of outdoor-air dampers in terms of percentage of outdoor air.
3. Status Lights:
   a. Filter dirty.
   b. Fan operating.
   c. Cooling operating.
   d. Heating operating.

E. Refrigeration and ERV System Controls:

1. Unit-mounted enthalpy controller shall lock out refrigerant system and/or ERV Wheel when outdoor-air enthalpy is less than 28 Btu/lb, (adjustable) of dry air and/or outdoor-air temperature is less than 55 deg F.
2. Relative-humidity sensor energizes dehumidifier operation when relative humidity of leaving air is more than 60 percent.

F. Heating and Cooling Controls:

1. Sensor in supply-fan outlet with sensor adjustment located in control panel modulates heat pump operation to maintain neutral discharge-air temperature in heating or cooling mode.

G. Integral Smoke Alarm: Smoke detector installed in exhaust air duct.

H. DDC Temperature Control: Stand-alone control module for link between unit controls and DDC temperature-control system. Control module shall communicate peer-to-peer with native BAC net protocol with temperature-control system specified in other Specification Sections. Links shall include the following:

1. Start/stop interface relay, and relay to notify DDC temperature-control system alarm condition.
2. Hardware interface or additional sensors for the following:
   a. Ambient outside air temperature.
   b. Discharge air temperature and set point.
   c. Relative humidity level and set point.
   d. Heating/Cooling mode indicator and status.
   e. Monitor cooling load.
   f. Monitor heating load.
g. Monitor economizer cycles (Refrigerant and ERV).

h. Monitor ventilation and exhaust air volume.
i. Monitor variable frequency drive operation.
j. Monitor air distribution static pressure.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install duct-mounted sensors, thermostats, and humidistats furnished by manufacturer for field installation. Install control wiring and make final connections to control devices and unit control panel.

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

C. Install hydronic piping adjacent to machine to allow service and maintenance.

D. Duct Connections: Duct installation requirements are specified in Section “Metal Ducts”. Drawings indicate the general arrangement of ducts. Connect supply and exhaust ducts to unit with flexible duct connectors. Flexible duct connectors are specified in Section “Air Duct Accessories”.

3.2 STARTUP SERVICE

A. Complete installation and startup checks according to manufacturer's written instructions and perform the following:

1. Inspect for visible damage to compressor, coils, and fans.
2. Inspect casing insulation for integrity, moisture content, and adhesion.
3. Verify that controls are connected and operable.
4. Verify bearing lubrication.
5. Inspect fan-wheel rotation for movement in correct direction without vibration and binding.
6. Adjust fan belts to proper alignment and tension.
7. Start unit.
8. Start refrigeration system when outdoor-air temperature is within normal operating limits.
9. Inspect and record performance of interlocks and protective devices including response to smoke detectors by fan controls and fire alarm.
10. Operate unit for run-in period.
11. Inspect outdoor-air dampers for proper stroke and interlock with exhaust-air dampers.
12. Calibrate thermostats.
13. Start refrigeration system and measure and record the following:

   a. Coil leaving-air, dry- and wet-bulb temperatures.
   b. Coil entering-air, dry- and wet-bulb temperatures.
   c. Outdoor-air, dry- and wet-bulb temperature.
14. Verify operational sequence of controls.
15. Verify operation of control panel including operation and failure modes. Inspect the following:
   a. Alarms.
   b. Status indications.

B. After startup and performance testing, change filters, verify bearing lubrication, and adjust belt tension.

C. Remove and replace components that do not pass tests and inspections and retest as specified above.

D. Prepare written report of the results of startup services.

3.3 ADJUSTING

A. Adjust initial temperature and humidity set points.

B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

3.4 DEMONSTRATION

A. Engage a factory-authorized service representative to train maintenance personnel designated by University to adjust, operate, and maintain dedicated ventilation-air water source heat pumps with energy recovery ventilators as specified.

END OF SECTION 237438
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SECTION 238123 - COMPUTER-ROOM AIR-CONDITIONERS

PART 1 - GENERAL

1.1 SUMMARY
   
   A. Section Includes:
      
      1. Console-type computer-room air conditioners.

1.2 SUBMITTALS
   
   A. Product Data: For each type of product indicated.
   
   B. Shop Drawings: For computer-room air conditioners. Include plans, elevations, sections, details, and attachments to other work.
      
      1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
      
      2. Wiring Diagrams: For power, signal, and control wiring.
   
   C. Operation and maintenance data.

1.3 QUALITY ASSURANCE
   
   A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
   
   B. ASHRAE Compliance:
      
      1. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Standard for Refrigeration Systems."
   
   C. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1

1.4 WARRANTY
   
   A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of computer-room air conditioners that fails in materials or workmanship within specified warranty period.
      
      1. Warranty Period for Compressors: Manufacturer's standard, but not less than five (5) years from date of Substantial Completion.
2. Warranty Period for Parts and Labor: Manufacturer's standard, but not less than one (1) year from date of Substantial Completion.
3. Warranty Period for Control Boards: Manufacturer's standard, but not less than three (3) years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 CONSOLE-TYPE UNITS

A. Subject to compliance with requirements, provide products by one of the following:
   1. Compu-Aire, Inc.
   2. Data Aire Inc.
   3. Liebert Corporation.
   4. Stulz.
   5. Approved equal.

B. Description: Self-contained, factory assembled, prewired, and pre-piped; consisting of cabinet, fan, filters, and controls; for floor mounting.

C. Cabinet: Galvanized steel with baked-enamel finish, insulated with 1/2-inch-thick duct liner.
   1. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Supply-Air Fan: Forward curved, centrifugal, and directly driven by two-speed motor.

E. Refrigeration System:
   1. Compressor: Hermetic, with oil strainer, internal motor overload protection, resilient suspension system, and crankcase heater.
   2. Refrigeration Circuit: Low-pressure switch, manual-reset high-pressure switch, thermal-expansion valve with external equalizer, sight glass with moisture indicator, service shutoff valves, charging valves, and charge of refrigerant.
   3. Refrigerant: R-410A.
   4. Refrigerant Evaporator Coil: Direct-expansion coil of seamless copper tubes expanded into aluminum fins.
      a. Mount coil assembly over stainless-steel drain pan complying with ASHRAE 62.1.
   6. Split system shall have suction- and liquid-line compatible fittings and refrigerant piping for field interconnection.

F. Filter: 2-inch-thick, disposable, glass-fiber media.
   1. Arrestance (ASHRAE 52.1): 90 percent.

G. Control System: Unit-mounted panel with main fan contactor, compressor contactor, and compressor start capacitor, control transformer with circuit breaker, solid-state temperature-control modules, and time-delay relay. Provide solid-state, wall-mounted control panel with start-stop switch and adjustable temperature set point.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install computer-room air conditioners level and plumb, maintaining manufacturer's recommended clearances. Install according to ARI Guideline B.

B. Air-Cooled Refrigerant Condenser Mounting: Install using elastomeric mounts.

3.2 CONNECTIONS

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

B. Install piping adjacent to machine to allow service and maintenance.

C. Drainage Connections: Comply with applicable requirements in other Sections. Provide adequate connections condensate drain.

D. Refrigerant Piping: Provide shutoff valves and piping.

3.3 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Inspect for and remove shipping bolts, blocks, and tie-down straps.
2. After installing computer-room air conditioners and after electrical circuitry has been energized, test for compliance with requirements.
3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

B. Computer-room air conditioners will be considered defective if they do not pass tests and inspections.

C. Prepare test and inspection reports.

D. After startup service and performance test, change filters.
3.4 ADJUSTING

A. Adjust initial temperature set points.

B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

C. Occupancy Adjustments: When requested within twelve (12) months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two (2) visits to Project during other-than-normal occupancy hours for this purpose.

END OF SECTION 238123
SECTION 238146 – WATER-SOURCE HEAT PUMPS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes water-source heat pumps.

1.2 SUBMITTALS

A. Product Data: Include rated capacities, furnished specialties, and accessories for each model.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

C. Operation and maintenance data.

D. Special warranties.

1.3 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. Comply with ASHRAE 15.

C. Meet or exceed minimum COP/efficiency levels as specified on drawings.

D. Comply with NFPA 70.

E. Comply with safety requirements in UL 484 for assembly of free-delivery water-source heat pumps.

F. Comply with safety requirements in UL 1995 for duct-system connections.

1.4 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace refrigeration components of water-source heat pumps that fail in materials or workmanship within one (1) year from date of Substantial Completion.
B. Extended Warranty: The compressor shall have a five (5) year warranty from date of Substantial Completion

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:

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

2.2 CONCEALED WATER-SOURCE HEAT PUMPS

A. Manufacturers:

1. ClimateMaster, Inc.
2. McQuay.
3. Trane.
5. Approved equal.

B. Description: Packaged water-source heat pump with temperature controls; factory assembled, tested, and rated according to ARI-ISO-13256-1.

C. Cabinet and Chassis: Galvanized-steel casing with the following features:

1. Access panel for access and maintenance of internal components.
2. Knockouts for electrical and piping connections.
3. Flanged duct connections.
4. Cabinet Insulation: Aluminum-faced glass-fiber liner, minimum 1/2 inch thick, complying with UL 181.
5. Condensate Drainage: Stainless-steel drain pan pitched as required in ASHRAE 62 with condensate drain piping projecting through unit cabinet.
6. Sound Attenuation Package:
   a. Minimum 0.598-inch- thick compressor enclosure and front panel. Minimum 0.0937-inch- thick foam gasket around the compressor and perimeter of end panel.
   b. Sound attenuating blanket over compressor.
   c. Hot-gas muffler.

D. Fan: Direct driven, centrifugal, with multispeed motor resiliently mounted in fan inlet.

1. Motor: Multispeed, permanently lubricated, PSC or ECM motor as specified on drawings.

E. Water Circuit:
1. Refrigerant-to-Water Heat Exchangers: Coaxial heat exchangers with cupronickel water tube with enhanced heat-transfer surfaces inside a steel shell; both shell and tube leak tested to 450 psig on refrigerant side and 400 psig on water side. Factory mount heat exchanger in unit on resilient rubber vibration isolators. Factory installed insulation to prevent condensation from below ambient condenser water temperatures.

F. Refrigerant-to-Air Coils: Copper tubes with aluminum fins, leak tested to 450 psig.

G. Refrigerant Circuit Components:

1. Sealed Refrigerant Circuit: Charge with refrigerant.
2. Charging Connections: Service fittings on suction and liquid for charging and testing.
3. Reversing Valve: Pilot-operated sliding-type valve designed to be fail-safe in heating position with replaceable magnetic coil.
4. Compressor: Hermetic scroll compressor installed on vibration isolators and housed in an acoustically treated enclosure with factory-installed safeties as follows:
   a. Anti-re short cycle timer.
   b. High-pressure cutout.
   c. Low-pressure cutout or loss of charge switch.
   d. Internal thermal-overload protection.
   e. Freezestat to stop compressor if water-loop temperature in refrigerant-to-water heat exchanger falls below 35 deg F.
   f. Condensate overflow switch to stop compressor with high condensate level in condensate drain pan.

6. Pipe Insulation: Refrigerant minimum 3/8-inch thick, flexible elastomeric insulation on piping exposed to airflow through the unit. Maximum 25/50 flame-spread/smoke-development indexes according to ASTM E 84.
7. Refrigerant Metering Device: Thermal expansion valve to allow specified operation with entering-water temperatures from 25 to 125 deg F.

H. Filters: Disposable, pleated type, 2 inches thick, with adhesive, shall have minimum 60 percent arrestance according to ASHRAE 52.1 and a minimum efficiency reporting value (MERV) of 8 according to ASHRAE 52.2.

I. Controls:

1. Unit Controls – Provided by Temperature Controls Contractor – shall provide the following:
   a. Low- and high-voltage protection.
   b. Overcurrent protection for compressor and fan motor.
   c. Random time delay, three to ten seconds, start on power up.
   d. Time delay override for servicing.
   e. Control voltage transformer.
   f. Control as specified in section “Sequence of Operation for HVAC Controls.”
J. Electrical Connection: Single electrical connection with non-fused disconnect.

2.3 HOSE KITS

A. General: Hose kits shall be designed for minimum 400 psig working pressure, and operating temperatures from 33 to 211 deg F. Tag hose kits to equipment designations.

B. Hose: Length 24 inches. Diameter as necessary to meet required flow rate, as specified.

C. Isolation Valves: Two-piece bronze-body ball valves with stainless-steel ball and stem and galvanized-steel lever handle. Provide valve for supply and return. If balancing device is combination shutoff type with memory stop, the isolation valve may be omitted on the return.

D. Strainer: Y-type with blow-down valve in supply connection.

E. Control Valve: Mount in return connection. Include meter ports to allow flow measurement with differential pressure gage.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Mount water-source heat pumps on indicated bases with vibration isolators.

1. Units with Internally Isolated Fans and Compressors: Support on bases using neoprene pads with minimum 0.125-inch static deflection. Secure units to bases.

B. Drawings indicate general arrangement of piping, fittings, and specialties. Specific connection requirements are as follows:

1. Connect supply and return hydronic piping to heat pump with hose kits.
2. Connect heat-pump condensate drain pan to indirect waste connection with condensate trap of adequate depth to seal against the pressure of fan. Install cleanouts in piping at changes of direction.

C. Duct installation requirements are specified in Section “Metal Ducts.” Drawings indicate general arrangement of ducts. Specific connection requirements are as follows:

1. Connect supply and return ducts to water-source heat pumps with flexible duct connectors.

D. Install electrical devices furnished by manufacturer but not specified to be factory mounted.

E. Install piping adjacent to machine to allow service and maintenance.
3.2 FIELD QUALITY CONTROL

A. Perform the following field tests and inspections and prepare test reports:

   1. After installing water-source heat pumps and after electrical circuitry has been energized, test units for compliance with requirements.
   2. Inspect for and remove shipping bolts, blocks, and tie-down straps.
   3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

B. Remove and replace malfunctioning units and retest as specified above.

END OF SECTION 238146
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SECTION 238323 - RADIANT-HEATING ELECTRIC PANELS

PART 1 - GENERAL

1.1 SUMMARY
   A. This Section includes prefabricated radiant-heating electric panels.

1.2 SUBMITTALS
   A. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories for each type of product indicated.
   B. Shop Drawings: For electric heating panels. Include plans, sections, details, and attachments to other work.
   C. Field quality-control test reports.
   D. Operation and maintenance data.
   E. Warranty: Special warranty specified in this Section.

1.3 QUALITY ASSURANCE
   A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

PART 2 - PRODUCTS

2.1 PREFABRICATED RADIANT-HEATING ELECTRIC PANELS
   A. Subject to compliance with requirements, provide products by one of the following:
      2. Markel Products.
      3. QMark Electric Heating.
      4. TPI.
      5. Approved equal.
   B. Description: Sheet-metal-enclosed panel with heating element suitable for lay-in installation flush with T-bar ceiling grid or recessed mounting. Comply with UL 2021.
1. Panel: Minimum 0.0276-inch thick, galvanized-steel sheet back panel riveted to minimum 0.0396-inch thick, galvanized-steel sheet front panel with fused-on crystalline surface.
2. Heating Element: Powdered graphite sandwiched between sheets of electric insulation.
4. Electrical Connections: Non-heating, high-temperature, insulated-copper leads, factory connected to heating element.

C. Control: Unit control to be provided by the Temperature Controls Contractor. Refer to Section “Sequence of Operation for HVAC Controls.”

D. Capacities and Characteristics:
   1. Nominal Panel Size: 24 by 48 inches.
   2. Heating Capacity: 750 kW.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install radiant-heating panels level and plumb.

B. Support for Radiant-Heating Panels in or on Grid-Type Suspended Ceilings: Use grid as a support element.
   1. Install a minimum of four ceiling support system rods or wires for each panel. Locate not more than 6 inches from panel corners.
   2. Support Clips: Fasten to panel and to ceiling grid members at or near each panel corner with clips designed for the application.
   3. Install at least one independent support rod or wire from structure to a tab on panel. Wire or rod shall have breaking strength of the weight of panel at a safety factor of 3.

C. Verify locations of thermostats with Drawings and room details before installation. Install devices 48 inches above finished floor.

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

E. Connect wiring according to other sections and NEC requirements.

3.2 FIELD QUALITY CONTROL

A. Testing: Perform the following field tests and inspections and prepare test reports:
1. Operate electric heating elements through each stage to verify proper operation and electrical connections.
2. Test and adjust controls and safeties.

B. Remove and replace malfunctioning units and retest as specified above.