

SECTION 23 81 49
GROUND-SOURCE HEAT PUMPS

SPEC WRITER NOTES:

1. Delete between // -- -- // if not applicable to project. Also delete any other item or paragraph not applicable in the Section and renumber the paragraphs.
2. Provide the year of latest edition to each publication listed in Article 1.7 APPLICABLE PUBLICATIONS.
3. This Section is intended for use with Closed-Loop Ground Loop Heat Exchangers, not Open-Loop systems with water wells used to abstract and/or inject groundwater from a local aquifer.

PART 1 - GENERAL

1.1 DESCRIPTION

- A. The requirements of this Section apply to all sections of Division 23 related to ground-source heat pump systems.
- B. A complete listing of common acronyms and abbreviations are included in Section 23 05 11, COMMON WORK RESULTS FOR HVAC.

1.2 RELATED WORK

- A. //Section 01 00 00, GENERAL REQUIREMENTS//
- B. Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES
- C. Section 01 91 00, GENERAL COMMISSIONING REQUIREMENTS
- D. //Section 23 05 11, COMMON WORK RESULTS FOR HVAC//
- E. Section 23 05 93 TESTING, ADJUSTING AND BALANCING FOR HVAC
- F. Section 23 07 11, HVAC AND BOILER PLANT INSULATION
- G. Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS
- H. Section 23 09 23, DIRECT DIGITAL CONTROL SYSTEM FOR HVAC
- I. Section 23 21 13, HYDRONIC PIPING
- J. //Section 23 21 23, HYDRONIC PUMPS//
- K. Section 23 81 46, WATER-SOURCE UNITARY HEAT PUMPS

1.3 DEFINITIONS

- A. Unless otherwise specified or indicated, ground source heat pump terms used in these contract documents shall be defined in AHRI 330.

1.4 QUALITY ASSURANCE

- A. The wellbore driller and/or installer of downhole piping shall be accredited by the International Ground Source Heat Pump Association (IGSHPA), or an equivalent accreditation or certification from a

nationally-recognized association. Furthermore, the driller/installer of the vertical boreholes and piping shall be Licensed by the State Government's well drilling regulatory body where the project is occurring, as a Water Well Driller, a Well Driller, a Vertical Borehole Driller, etc. (as applicable) in that jurisdiction, for the installation of closed-loop vertical geothermal or ground source heat pump systems. This state licensed driller shall conform to all state and local laws and regulations including, but not limited to the grouting materials and methods, drilling techniques and disposition of drilling spoils and fluids, acceptable piping materials, acceptable anti-freeze fluids (as applicable), minimal burial depth and more as codified in the relevant state laws, rules, regulations and ordinances. Local and state laws and ordinances, as they pertain to buried pipe systems, shall be strictly followed or a variance obtained and approved by the Contracting Officer.

- B. Installer(s) shall demonstrate that they have successfully installed at least four projects that, in aggregate, equal or exceed the size of the proposed project. References shall be provided for each of these installed projects.
- C. Water-to-Water Heat Pump Heat Recovery Modular Chiller Type Installer Qualifications: This project involves the installation of (multiple) 6-pipe, heat recovery, modular chiller(s) suitable for geothermal heat pump duty. Accordingly, the chiller installer shall be engaged in the installation of large (equivalent to the total tonnage shown on the Contract Documents) chillers for the immediate five years prior to the submittal of the chiller installer's Statement of Qualifications. The chiller installer's Statement of Qualifications shall include a copy of the installer's mechanical contractor's state license and data identifying the location, chiller type, and capacity of at least three chiller systems, of at least the total tonnage of this project. The Contractor shall furnish documentation to the Contracting Officer of these three WWHP systems verifying that each system has performed in the manner intended for the 6 months prior to submission of the Statement of Qualifications.
- D. Soil thermal values shall be used by the Engineer-of Record (EOR) in calculating loop length and shall be presented in the Contract Documents. For horizontal ground heat exchanger applications, determination of the soil's thermal properties shall have been

determined with an in-situ conductivity test (handheld meter) at the anticipated depth of the installation, or via an estimated value determined based on the known composition of geology. In either event, this value and the geologies composition shall be shown on the Contract Documents. For larger projects in which the heat exchanger shall be installed vertically, the thermal properties of the soil/rock formation shall only be determined by performing an in-situ thermal conductivity test per ASTM D5334 and the ASHRAE HVAC Applications Handbook and an abbreviated version of this report shall be present in the Contract Documents. If the installing Contractor observes geological conditions significantly deviate from that shown in the Contract Documents, this deviation shall be reported to the COR for guidance on how to proceed with the installation of the ground loop heat exchanger.

SPEC WRITER NOTE: Caution should be exercised when specifying horizontal ground heat exchangers as drought conditions can sometime drastically reduce the anticipated thermal conductivity of sand and/or cause clay formations to shrink away from heated piping systems. If these possibilities exist, consider vertically oriented ground heat exchangers or (potentially problematic) "soaker lines" to keep the soil in the vicinity of the heat exchanger moist/thermally conductive.

E. Warranties: Ground-source heat pump systems shall be subject to the terms of FAR Clause 52.246-21, except that the warranty period shall be as noted for the items below:

1. Polyethylene piping: 25-year manufacturer's warranty against defects in materials and workmanship.

SPEC WRITER NOTE: Local Authorities Having Jurisdiction are likely to have requirements in place to protect resources such as groundwater. Research local requirements and consult with VA to determine applicability to project. Insert applicable authorities and regulations below.

1.5 PERMITS AND FEES

A. The wellbore driller/installer of downhole piping shall, without additional expense to the Government, be responsible for obtaining and paying for any and all necessary licenses and permits in connection with the performance of its services; installer shall maintain said

licenses and permits current until the work has been accepted by the Government, and alone shall bear financial responsibility for any and all violations of said licenses and permits

1.6 SUBMITTALS

- A. Submit six copies in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES, and with requirements in the individual specification sections, to the COR.
- B. Contractor shall make all necessary field measurements and investigations to assure that the equipment and assemblies shall meet contract requirements.
- C. If equipment submitted differs in arrangement from that shown on the submittals, provide drawings that show the rearrangement of all associated systems. Approval shall be given only if all features of the equipment and associated systems, including accessibility, are equivalent to that required by the contract and acceptable to the COR.
- D. Prior to submitting shop drawings for approval, contractor shall certify in writing that manufacturers of all major items of equipment have each reviewed the contract documents from the applicable other manufacturers and have jointly coordinated and properly integrated their equipment and controls to provide a complete and efficient installation.
- E. Submittals and shop drawings for independent items, containing applicable descriptive information, shall be furnished together and complete in a group. Coordinate and properly integrate materials and equipment in each group to provide a completely compatible and efficient installation. Final review and approvals shall be made only on complete groups.
- F. Shop Drawings: Include heat pump equipment structural supports, //control sequences, // monitoring instruments and controls, interconnections and all other components, parts and pieces required to complete the functioning assembly. Where applicable, include shop drawings for foundations or other support structures.
- G. Product Data: Include detailed information for components of the ground-source heat pump system.
 - 1. Geothermal Source Well and Grouts
 - 2. Ground Heat Exchanger
 - 3. Ground-Source Heat Pump Unit
 - 4. Circulation System

5. Wiring
 6. Wiring Specialties
 7. Valves
 8. Piping and Piping Specialties
 9. Header Assemblies
 10. Heat Transfer Fluid
 11. Heat Exchanger
 12. Insulation
 13. Instrumentation consisting of monitoring systems and control systems compatible with the facility's existing data and control systems.
- H. Certificates: Submit technical representative's certification that the installation has been implemented as intended by the system designer and where applicable, recommended by the manufacturer. Provide IGSHPA Certification for the ground loop heat exchanger installer and driller.
- I. Manufacturer's Instructions.
- J. Operation and Maintenance Ground-Source Heat Pump System Data Package:
1. Safety precautions
 2. Operator restart
 3. Startup, shutdown, and post-shutdown procedures
 4. Normal operations
 5. Emergency operations
 6. Operator service requirements
 7. Environmental conditions
 8. Lubrication data
 9. Preventive maintenance plan and schedule
 10. Cleaning recommendations
 11. Troubleshooting guides and diagnostic techniques
 12. Wiring and control diagrams
 13. Maintenance and repair procedures
 14. Removal and replacement instructions
 15. Spare parts and supply list
 16. Corrective maintenance man-hours
 17. Product submittal data
 18. O&M submittal data
 19. Parts identification
 20. Warranty information
 21. Personnel training requirements

- 22. Testing equipment and special tool information
- 23. Testing and performance data
- 24. Contractor information

K. Closeout Submittals:

- 1. Posted operating instructions for ground-source heat pump system that provide for wiring identification codes and diagrams, operating instructions, control matrix, and troubleshooting instructions.
- 2. As-built drawings of geo-heat exchanger field wells, piping locations, and distribution system shall be provided in the Autodesk digital file format (*.dwg or *.rvt) that is directed by the COR.

SPEC WRITER NOTE: Insert the year of approved latest edition of the publications between the brackets // // and delete the brackets if applicable to this project.

1.7 APPLICABLE PUBLICATIONS

- A. Publications listed below (including amendments, addenda, revisions, supplements and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by the basic designation only. Where conflicts occur these specifications and the VHA standards will govern.
- B. Air Conditioning, Heating & Refrigeration Institute (AHRI)
550/590-//2020//.....Performance Rating of Water-chilling and Heat Pump Water-heating Packages Using the Vapor Compression Cycle
- C. American National Standards Institute (ANSI):
60-//2020//.....Drinking Water Treatment Chemicals - Health Effects
- D. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE):
15-//2019//.....Safety Standard for Refrigeration Systems and Designation and Classification of Refrigerants.
90.1-//2019//.....Energy Standard for Buildings Except Low-Rise Residential Buildings
Handbook-//2019//.....Heating, Ventilating and Air-Conditioning APPLICATIONS, I-P Edition
- E. American Society of Mechanical Engineers (ASME)
B31.1-//2020//.....Power Piping
B40.100-//2013//.....Pressure Gauges and Gauge Attachments

ASME Boiler and Pressure Vessel Code (BPVC):
 BPVC Section VIII-//2021// Rules for Construction of Pressure Vessels

F. American Society for Testing and Materials (ASTM):

D92-//2018//.....Standard Test Method for Flash and Fire Points
 by Cleveland Open Cup Tester

D1177-//2017//.....Standard Test Method for Freezing Point of
 Aqueous Engine Coolants

D2513-//2020//.....Standard Specification for Polyethylene (PE)
 Gas Pressure Pipe, Tubing, and Fittings

D2683-//2020//.....Standard Specification for Socket-Type
 Polyethylene Fittings for Outside Diameter-
 Controlled Polyethylene Pipe and Tubing

D2765-//2016//.....Standard Test Methods for Determination of Gel
 Content and Swell Ratio of Crosslinked Ethylene
 Plastics

D2837-//2021//.....Standard Test Method for Obtaining Hydrostatic
 Design Basis for Thermoplastic Pipe Materials
 or Pressure Design Basis for Thermoplastic Pipe
 Products

D3035-//2021//.....Standard Specification for Polyethylene (PE)
 Plastic Pipe (DR-PR) Based on Controlled
 Outside Diameter

D3261-//2016//.....Standard Specification for Butt Heat Fusion
 Polyethylene (PE) Plastic Fittings for
 Polyethylene (PE) Plastic Pipe and Tubing

D3350-//2021//.....Standard Specification for Polyethylene
 Plastics Pipe and Fittings Materials

D5084-//2016//.....Standard Test Methods for Measurement of
 Hydraulic Conductivity of Saturated Porous
 Materials Using a Flexible Wall Permeator

D5334-//2014//.....Standard Test Method for Determination of
 Thermal Conductivity of Soil and Soft Rock by
 Thermal Needle Probe Procedure

E1-//2018//.....Standard Specification for ASTM Liquid-in-Glass
 Thermometers

F714-//2021//.....Standard Specification for Polyethylene (PE)
 Plastic Pipe (DR-PR) Based on Outside Diameter

- F876-//2020//.....Standard Specification for Crosslinked Polyethylene (PEX) Tubing
- F877-//2020//.....Standard Specification for Crosslinked Polyethylene (PEX) Hot- and Cold-Water Distribution Systems
- F894-//2019//.....Standard Specification for Polyethylene (PE) Large Diameter Profile Wall Sewer and Drain Pipe.
- F1055-//2016//.....Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing
- F1105-09//(2020)//.....Standard Practice for Preparing Aircraft Cleaning Compounds, Liquid-Type, Temperature-Sensitive, or Solvent-Based, for Storage Stability Testing
- F2080-//2019//.....Standard Specification for Cold-Expansion Fittings with Metal Compression-Sleeves for Cross-Linked Polyethylene (PEX) Pipe
- G. International Code Council (ICC)
- IBC-//2021//.....International Building Code
- IECC-//2021//.....International Energy Conservation Code
- IMC-//2021//.....International Mechanical Code
- H. International Ground Source Heat Pump Association (IGSHPA)
- #21020-//1988//.....Closed Loop/Ground Source Heat Pump Systems: Installation Guide
- #21035-//2017//.....Closed Loop/Geothermal Heat Pump Systems: Design and Installation Standards
- I. International Organization for Standardization (ISO)
- 9001-//2015//.....Quality Management Systems - Requirements
- 13256-2//2021//.....Water-source heat pumps -- Testing and rating for performance -- Part 2: Water-to-water and brine-to-water heat pumps
- 14531-//2010//.....Plastics pipes and fittings -- Crosslinked polyethylene (PE-X) pipe systems for the conveyance of gaseous fuels -- Metric series - Specifications - Part 2: Fittings for heat-fusion jointing

SPEC WRITER NOTE: Research if bore wells have the potential to impact local resources, including ground water. Include applicable NSF certifications on all equipment. NSF 60 is specifically mentioned in Part 3.1.C.d regarding boreholes.

J. National Fire Protection Association (NFPA):

70-//2020//.....National Electrical Codes

704-//2022//.....Standard System for the Identification of the Hazards of Materials for Emergency Response

K. //National Sanitation Foundation/American National Standards Institute NSF/ANSI:

14-//2019//.....Plastics Piping System Components and Related Materials

60-//2018//.....Drinking Water Treatment Chemicals - Health Effects

61-//2016//.....Drinking Water System Components - Health Effects

//358-1-//2021//.....Polyethylene Pipe and Fittings for Water-Based Ground-Source "Geothermal" Heat Pump Systems//

372-//2020//.....Drinking Water System Components - Lead Content//

L. Underwriters Laboratories Inc. (UL)

486A-486B-//2018//.....Wire Connectors

1995-//2015//.....Heating and Cooling Equipment

PART 2 - PRODUCTS

SPEC WRITER NOTE: Ground-source heat exchange systems and hybrid systems are typically suited for applications requiring temperature sources of 4 degrees C to 32 degrees C [40 degrees F to 90 degrees F].

2.1 GENERAL

A. Provide materials to fabricate ground-source heat pump systems in accordance with this section. At the Contractor's option, provide factory-prefabricated ground-source heat pump equipment packages which meet the requirements of this section.

2.2 DOWNHOLE HEAT EXCHANGER PIPING AND SPECIALTIES

SPEC WRITER NOTE: Copper piping for direct exchange geothermal vertical closed loops shall not be used unless the

grout/piping combination has been shown by a third party testing laboratory to not result in pipe corrosion and testing reports have been submitted to the COR. PEXa piping shall not be specified unless mechanical fittings are acceptable to the specification writer as PEXa cannot generally be heat fusion welded in the field resulting in metal components (that are subject to corrosion) being located in the underground domain.

- A. The acceptable pipe and fitting materials for the underground portion of the ground heat exchanger shall be polyethylene and cross-linked polyethylene.
- B. Polyethylene heat exchanger shall meet the following requirements:
 - 1. Pipe and heat fused materials shall be manufactured from virgin polyethylene extrusion compound material per ASTM D2513, Section 4.1 and 4.2. Pipe shall be manufactured to outside diameters, wall thickness, and respective tolerances as specified in ASTM, D3035 or F714. Fittings shall be manufactured to diameters, wall thickness, and respective tolerances as specified in ASTM D3261 for butt-fusion fittings, ASTM D2683 for socket fusion fittings and ASTM F1055 for electro-fusion fittings.
 - 2. The material shall have a Hydrostatic Design Basis of 11 MPa [1600 psi] at 23 degrees C [73 degrees F] per ASTM D2837. The material shall be listed in PPI TR4 as PE 4710 piping formulation. The material shall be a high-density polyethylene compound having a minimum cell classification of PE345464C per ASTM D3350.
 - 3. The total system pressure shall remain below the working pressure of the pipe. The piping systems Standard Dimension Ratio (SDR) shall be 11 unless indicated otherwise on the Contract Documents.
 - 4. Sufficient information shall be permanently marked on the length of the pipe as defined by the appropriate ASTM pipe standard.
 - 5. Manufacturer shall supply a notarized document confirming compliance with the above standards.
- C. Cross-linked polyethylene heat exchanger (PEXa) shall be:
 - 1. Of tubing manufactured by the high-pressure peroxide method (known as PEXa), and shall conform to ASTM F876, and F877 or D2513. Polymer electro-fusion fittings for PEXa pipes of each dimensional specification shall conform to ASTM F1055 or ISO 14531-2; metal cold compression-sleeve fittings shall conform to ASTM F2080.

2. Of PEXa tubing material of high-density cross-linked polyethylene manufactured using the high-pressure peroxide method of cross-linking with a minimum degree of cross-linking of 75 percent when tested in accordance with ASTM D2765, Method B. The tubing material designation code as defined in ASTM F876 shall be PEX 1006 or PEX 1008.
3. Of polymer electron-fusion fittings manufactured using a material in accordance to IGSHPA 2014, Section 1C.2.2.
4. Of PEXa tubing manufactured in accordance to the dimensional specifications of ASTM F876, and F877 with a minimum working pressure rating of 1.1 MPa [160 psi] at 23 degrees C [73.4 degrees F].
5. Of fittings used with PEXa tubing intended for geothermal applications shall be polymer electro-fusion fittings or cold expansion compression-sleeve metal fittings. Polymer electro-fusion fittings shall conform to ASTM F1055 or ISO 14531-2 whereas cold-expansion compression-sleeve fittings shall conform to ASTM F2080, and shall have a minimum inside diameter of 82 percent of inside pipe diameter.
6. Required product standard information shall be marked on PEXa tubing and fittings as defined by the appropriate product standard specifications.

2.3 GROUND-SOURCE WATER-TO-AIR HEAT PUMP UNIT

- A. Comply with Section 23 81 46, WATER-SOURCE UNITARY HEAT PUMPS.

2.4 FOUR-PIPE, NON-HEAT RECOVERY, GROUND-SOURCE WATER-TO-WATER HEAT PUMP UNITS

- A. Water source heat pumps used in conjunction with ground heat exchangers shall be appropriately ISO 13256-2 GLHP or GWHP certified.
- B. Hydronic systems with a total pump power exceeding 5 hp shall be variable flow and each water source heat pump shall have a two position isolating valve that closes when the compressor is not operating as per ASHRAE 90.1.
- C. The maximum and minimum ground heat exchanger system entering temperature shall not exceed the manufacturer's recommendations.
- D. The heat pump load flow (air or fluid) shall be within the manufacturer's allowed tolerances.

E. Shall meet or exceed ENERGY STAR guidelines as necessary to achieve a 30 percent better energy efficiency than required by ASHRAE 90.1, and display label.

F. Shall have integral power disconnects.

SPEC WRITER NOTE: Select the appropriate controls infrastructure to suit the project.

G. //Shall have digital control units which communicate directly with the facility's existing building automation system.//

H. //Comply with requirements in Section 23 09 23, DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC for control equipment and sequence of operation.//

I. Shall have galvanized steel cabinets with a minimum 0.5 inch thick, 1.75 pounds/cubic foot fiberglass insulation adhering to NFPA flame and smoke indices requirements.

J. Water-to-Water Heat Exchanger:

1. Heat exchanger shall be coaxial tube-in-tube type with steel outer tube and copper inner tube.
2. Compressor shall be internally isolated scroll type with high and low pressure safety switches.

2.5 WATER-SOURCE WATER-TO-WATER HEAT PUMPS (HEAT RECOVERY MODULAR CHILLERS)

A. Unit Description: The specific type of chiller utilized for this project can be further described as a simultaneous heating & cooling heat recovery modular scroll chiller of the six header design (two each dedicated factory installed, source, chilled and hot water headers) suitable for geothermal heat pump duty. This chiller shall have factory installed modulating valves on each water "type" to isolate which water stream is routed to the condenser or evaporator heat exchanger and also serves as head pressure and source-limiting control. The hydronic circuiting and valving shall be arranged to allow for the equalization of run time on any chiller in the bank, independent of mode (heating, cooling or heat recovery).

B. Additional Submittal Requirements: The chiller manufacturer shall submit the following criteria:

1. Manufacturer's warranty details as specified herein.
2. Product Data: Include refrigerant, rated cooling and heating capacities, operating characteristics, furnished specialties, and accessories.

3. Shop Drawings: Complete set of manufacturer's certified prints of water chiller assemblies, control panels, sections and elevations, and unit isolation. Include the following:
 - a. Assembled unit dimensions.
 - b. Evaporator and condenser heat exchanger construction
 - c. Compressor data
 - d. Required clearances for maintenance and operation.
 - e. Size and location of piping and wiring connections.
 - f. Wiring Diagrams: Power, signal, and control wiring.
 - g. Control panel product data and BAS interface information
 4. Warranty Certificate
 5. Certificates: For certification required in "Quality Assurance" Article herein.
 6. Startup service reports
 7. Operation and Maintenance Data: For each equipment item to include in emergency, operation, and maintenance manuals.
- C. Quality Assurance:
1. Products shall be Designed, Tested, Rated and Certified in accordance with, and installed in compliance with applicable sections of the following Standards and Codes:
 - a. ANSI/ASHRAE Standard 15 - Safety Code for Mechanical Refrigeration
 - b. ASHRAE 90.1- Energy Efficiency compliance.
 - c. ANSI/NFPA Standard 70 - National Electrical Code (N.E.C.)
 - d. ASME Boiler & Pressure Vessel Code, Section VIII, Division 1
 - e. ASHRAE 34 - Number Designation and Safety Classification of Refrigerants
 - f. ARI Standard 550/590 - Positive Displacement Compressors and Water Cooled Rotary Screw Water-Chilling Packages
 - g. Conform to UL code 1995 for construction of chillers and provide UL/cUL listing label for electrical panel construction.
 - h. OSHA - Occupational Safety and Health Act
 2. Factory Test: Chiller shall be pressure-tested, evacuated, fully charged and run tested with a copy of run test reports furnished.
- D. Warranty: Provide Manufacturer's 1-year, "Parts-Only" Warranty on the entire unit. Also, provide 4-year additional extended parts-only warranty for the compressors only (5 years total). Provide labor for all warranty work during the first year of operation.

- E. Basis of Design: The equipment utilized by the AE as the "basis of design" of this equipment is Model # UCH-085 (SCH-HR) as manufactured by ClimaCool Corporation, a Division of LSB Industries. The basis of design data is provided for informational purposes only and not intended to restrict competition. The Contractor shall furnish equipment from any manufacturer that complies with the performance requirements found in the Contract Documents and inherent in the basis of design equipment.
- F. Manufactured Unit: Chiller shall be a factory-assembled and wired, water cooled water chiller capable of cooling, heating and heat recovery duty. Each module of the chiller consists of two or greater compressors, an evaporator, a water cooled condenser, safety controls, and operational controls. All modules' electrical panels shall be constructed in accordance with UL and bear the UL Listing mark. Additionally, the heat exchangers shall bear the UL 508A Stamp. All modules shall be shipped completely wired and fully charged with refrigerant R-410a and oil, ready for installation. All modules shall be factory run tested at simulated full load design conditions prior to shipment. The assembled chiller shall be completely capable of being serviced and repaired in place without the need for removal of a module. ALL major components shall be accessible from front, back or top. Designs requiring removal from the bank for servicing are prohibited. The modular chiller's design shall allow for all maintenance to be performed without removal of a module from the bank or disassembly of the bank. (e.g. heat exchanger back flushing shall be done by the use of fill and flush ports extended to the back of the unit, strainer cleaning shall not require the module to be disturbed, etc.). Valve modules shall be provided on both ends as needed to allow all modules to operate in the all-cooling or all-heating mode. All modules shall be capable of operating in the same mode at once - i.e. all cooling, all heating or all heat recovery. An inter-module valve systems shall be acceptable in lieu of 6 header design specified herein, provided valves are factory installed and wired in valve modules and the chiller shall fit in the available space and provide all the functions specified herein. Ship loose valves are prohibited. Each of the five modules provide for this project shall contain two hermetically sealed scroll compressors and be resiliently mounted to the module with rubber-in-shear isolation. Suction gas cooled

compressor motor shall have a utilization range of ± 10 percent from nameplate voltage and shall be equipped with internal thermostats for direct protection against overheating and external over current and single phasing protection. Each system also shall include high discharge pressure and low suction pressure cutouts. Refrigerant shall be R-410a. Provide full operating charge of refrigerant and oil. No other refrigerants are acceptable.

G. Simultaneous Heating & Cooling Heat Recovery Modular Chillers:

1. System Description: Chiller shall incorporate scroll compressors and consist of multiple refrigerant circuits. Each refrigerant circuit shall consist of an individual compressor, condenser, evaporator, thermal expansion valve, filter drier, sight glass and control system. The multi-circuit chiller shall be able to produce chilled water and/or hot water in the event of a failure of one or more refrigerant circuits. All operating components for each module, including compressors, heat exchangers, piping, and controls shall be securely fastened to a unitized heavy gauge galvanized steel frame having an electro-statically applied powder, oven baked enamel finish. Individual compressor motor contactors, fuses/breakers per circuit and control transformers with primary and secondary fuses are located in the control panel. Each chiller module has three (3) steps of control (100 percent, 50 percent, off) accomplished by cycling off the compressors.

2. Basic Construction:

- a. The frame design shall consist of heavy gauge galvanized steel with 3 mil powder coat paint finish baked at 350 degrees F for resilience in transport and installation. The module shall have a low center of gravity, detachable schedule 40 carbon steel pipe water headers for two (2) for chilled water loop and two (2) for hot water loop and two (2) for source water loop, each insulated with 3/4 inch closed cell insulation, designed to connect to adjacent modules through the use of 300 psi rated grooved couplings, base with cutouts for forklift or pallet jack and the frame shall be designed to fit through a standard 36 inch doorway.
- b. Six Header Modular Design: Six header module design shall be provided to enable the modular chiller bank to supply required chilled water and/or hot water and/or utilize the source water as

a heat sink or heat source. Internal Proportional Motorized Valves with an end switch shall be provided for Cooling, Heating and Source and allow for variable pumping as well as provide internal head pressure control (during cooling) source limiting control (during heating) and module isolation (flow blockage) during inactivity. Three distinct module modes of operation are provided - Heat recovery (simultaneous heating and cooling without source water), cooling and heating. The modular chiller bank master controller shall enable operation of any module in any position in the bank to provide hot water and/or chilled water and automatically equalize run time compressor hours for all modules and compressors contained in the bank. If the chilled water (evaporator) or hot water (condenser) is not required for the building load, then it shall be diverted within the module and sent to the source or sink (ATES well system). Chiller modules shall include all necessary safety and operating controls for high temperature operating range to 135 degrees F leaving hot water temperature.

- c. Evaporators and Condensers: Each evaporator and condenser shall be dual circuited, brazed plate heat exchangers constructed of 316 stainless steel; designed, tested, and UL stamped in accordance with ASME Section VIII pressure vessel code for 650 psig working refrigerant pressure on the evaporator and 650 psig working pressure on the condenser and bear a UL label. Both evaporator and condenser brazed plate heat exchangers shall have a waterside flush connection with ball valve on each module to allow back flushing or cleaning of heat exchangers without removing chiller headers or other in place components
- d. Compressor: Each chiller module (3 minimum) shall contain multiple hermetic scroll compressors independently circuited and with internal isolation mounted with rubber-in-shear isolators. Each compressor system also includes high discharge pressure and low suction pressure manual reset safety cut-outs. The compressors shall be direct-drive, hermetic, 3600 rpm (@ 60 Hz) fixed compression, scroll compressors. Each compressor shall have an integral centrifugal oil pump, oil level sight-glass, oil charging service port, and an internal check valve on the scroll

discharge port. Motor shall be suction gas-cooled, hermetically sealed, two-pole, squirrel cage induction type.

- e. Factory Insulated Surfaces: Factory insulate all internal water piping and refrigeration piping (except discharge line) with 1/2-inch closed-cell insulation. Factory insulate cooling, heating and source headers with 3/4-inch closed-cell insulation. Factory insulate load and source heat exchangers with 3/4 inch closed-cell insulation.

- f. Master Controller System

- 1) Master Controller System: The Master Control System shall be fully compatible with the existing Building Automation System via native BACnet communication. Control system shall provide advanced algorithms for maintaining precise leaving chilled and hot water temperatures. Scheduling of the various compressors shall be performed by the master microprocessor based controller. A module/compressor run time equalization sequence shall be provided to ensure even distribution of module/compressor run time. A load limit control shall be available to limit the number of compressors that can be energized at one time. All controls shall comply with Federal/DOD Risk Management Framework (RMF) requirements.

- 2) Multiple Module Chillers:

- a) Each chiller shall be equipped with a dedicated standalone direct digital control (DDC) system including a master controller and display which shall perform the numerous functions discussed in this section. All chiller operations and computer features shall be accessed through the LCD display. BAS interface shall be provided for BACnet communication.
- b) An RS232 or USB port shall be provided for use of an optional remote Windows based monitoring and control software via hardwire.
- c) Each module control panel shall communicate with the master controller via a daisy chained two conductor shielded low voltage cable. The module control panel shall monitor and control each refrigeration system in response to commands by the master controller. The master controller shall have a terminal strip to accept field wired low voltage system

interlock such as flow switches, remote start/stop, common alarm output, etc. The master controller shall be provided by the unit manufacturer and field mounted in the equipment room by the controls sub-contractor.

3) Safeguarding Operation of Refrigeration System

- a) Each module is equipped to control all alarm and fault conditions protecting the compressor and feedback input conditions and output conditions to the master controller for it to monitor individual chiller module status. The master controller shall continually monitor all of the following areas for each individual module's refrigeration circuit including:
- (1) High discharge pressure cutout.
 - (2) Low suction pressure cutout.
 - (3) Suction pressure via pressure transducers.
 - (4) Discharge pressure via pressure transducers.
 - (5) Solid state compressor motor protection.
 - (6) Leaving chilled water temperature (for module freeze protection).
 - (7) Leaving hot water temperature (for module protection).
- b) The master controller shall additionally monitor the following master level inputs:
- (1) Leaving chilled water temperature (for capacity control).
 - (2) Entering chilled water temperature.
 - (3) Leaving hot water temperature (for capacity control).
 - (4) Entering hot water temperature.
 - (5) Entering source temperature.
 - (6) Leaving source temperature.
 - (7) Phase loss (each phase), phase imbalance, phase reversal and over/under voltage protection.
 - (8) Chilled water flow status.
 - (9) Heating water flow status.
 - (10) Source water flow status.
- c) A potentially unsafe (out of tolerance) condition from any of these controls or sensors shall cause a "fault" shutdown of that compressor with an automatic transfer of load requirements to another available compressor. A running

history of the complete fault occurrence conditions shall be automatically maintained (up to the last 100 occurrences) should it ever be required for troubleshooting.

- d) Continuous individual monitoring of leaving chilled water temperature from each module's refrigeration system shall provide protection against freeze-up in the event of unusual, unexpected operating conditions.
- 4) Master Controller Operation: The master controller shall lead/lag the dual scroll compressors, balance the run time, prevent short cycling of compressors, and register the last 100 failure occurrences. Fault conditions shall be alarmed so the compressor can be taken off line. Both alarm and failed conditions shall be displayed on digital display on front of the master control panel. An alarm relay for remote indication of faults and failed conditions with a normally open and normally closed dry contact shall be supplied. The "Master Controller" shall be able to be controlled by and monitored by the central BAS via BACnet. The AE shall advise which points shall be communicated to/from the building BAS system via BACnet. The operating control of chilled and hot water temperature shall be able to be reset remotely via BACnet communications. Staging of the all scroll compressors, lead/lag of the compressors, equalize runtime of compressors and preventing compressor short cycling shall be done by the master controller. Compressor staging is accomplished through PID control logic, adjustable in response times and settings, for both chilled water and hot water control. The system shall provide for variable time between compressor sequencing and temperature sensing. Inputs/Outputs to the Master controller shall include as a minimum:
- a) Remote Start/Stop.
- b) Chiller Failure Output (Note: Chiller is comprised of one or more modules - Each module shall indicate its own individual failure at the chiller. The "Chiller Failure" indication shall be a remote signal sent remotely to indicate that the chiller has had sufficient modules fail that operation of the chiller shall not be beneficial. This

failure signal shall be capable of adjusting to provide a failure signal according to the percentage of capacity that has failed.

- c) Chilled Water Flow Status (via differential pressure transducer, provided by chiller manufacturer and field installed by others).
 - d) Hot Water Flow Status (via differential pressure transducer, provided by chiller manufacturer and field installed by others).
 - e) Source Water Flow Status (via differential pressure transducer, provided by chiller manufacturer and field installed by others)
 - f) Six temperature sensors & thermal wells shall be provided with the chiller for field installation and wiring into the chiller control panel by the controls sub-contractor. These sensors are for monitoring entering and leaving water temperatures of the chilled, hot and source water connected to the chiller bank.
 - g) BAS Interface - BACnet interface shall be provided for communication to Building Automation System (BAS). AE shall advise which points are to be communicated to/from the BAS.
 - h) Phase Loss Protection: The chiller is fed by five independent power circuits that are located in a separate electrical panel (as indicated on drawings). The chiller manufacturer shall provide, and the contractor shall install a loss-of-phase-monitor at the feeder circuit connection and interconnect it with the chillers internal safety controls safety as directed by the chiller manufacturer.
- 5) Power Connections: Each module shall have its own electrical power panel mounted to the unit frame. Each module shall be independently powered by a field installed fused disconnect switch (or equivalent module circuit breaker) supplied by others, so that any one module can be shut down for repair without interrupting the remaining chiller modules' operation. Continuous electrical buss bars or other conductors that run the entire length of the chiller, and do not allow each module

to be electrically isolated are not permissible. The power panel for each module shall contain:

- a) Main input terminal block
 - b) Compressor motor contractors
 - c) Motor overload protection per compressor
 - d) Individual compressor motor fusing or circuit breakers
 - e) Local manual "ON" / "OFF" compressor switch to allow service or repair to individual modules and compressors without interrupting service of the entire chiller.
 - f) Single point power connection to entire chiller bank is prohibited due to need for power redundancy. The use of buss bars to power chillers is prohibited.
- 6) Cooling, Heating & Source Water Strainers
- a) Strainers shall be provided by the chiller manufacturer and shall be installed in the field by the Contractor on the cooling, heating and source water inlets of the chiller bank. Strainers shall be basket type with minimum 60-mesh rating.
 - b) Strainers shall be field installed external to chiller for ease of service.
 - c) Strainers located inside of headers, requiring disassembly for cleaning are prohibited.
- 7) Chilled Water, Hot Water and Source Water Bypass: The chiller manufacturer shall provide motorized bypass kits for chilled, hot and source water loops to prevent deadheading of the pumps when all of the internal unit valves go closed as well as allow temperature and differential pressure sensors to sense active flow. The chiller manufacturer's kits shall include all necessary stainless steel hoses, motorized valves, end caps, couplings, connections and hardware.
- 8) Sound Attenuation Panels:
- a) Provide factory-installed, 18-gauge galvanized steel sound attenuation panels with 1 inch fiberglass insulation and 3 mill powder-coat paint finish for front, back and top.
 - b) Provide chiller bank end panels with same construction as above for field installation.
- 9) Water Testing: Manufacturer shall provide water bottles and certified sample testing for chilled, hot and source water,

prior to commencement of equipment warranty. All water loops that come into contact with the brazed plate HX's shall be treated until they adhere to chart below as tested and reported by the chiller manufacturer:

WATER CONTAINING	CONCENTRATION
Ammonia	Less than 2.0 mg/l
CaCO ₃ Alkalinity	30 - 500 mg/l
CaCO ₃ Hardness	30 - 500 mg/l
Chlorides	Less than 200 mg/l
Dissolved Solids	Less than 1000 mg/l
Iron	Less than 5.0 mg/l
Manganese	Less than 0.4 mg/l
Nitrate	Less than 100 mg/l
pH	7.0 - 9.0
Sulphate	Less than 200 mg/l

- 10) Safeties, Controls And Operation: Chiller safety controls system shall be provided with the unit (minimum) as follows:
- a) Low evaporator refrigerant pressure.
 - b) Loss of chilled water flow.
 - c) Loss of hot water flow.
 - d) Loss of source water flow.
 - e) High condenser refrigerant pressure
 - f) High compressor motor temperature
 - g) Low leaving chilled water temperature
 - h) High leaving hot water temperature
 - i) Failure of chiller to start or chiller shutdown due to any of the above safety cutouts shall be enunciated by display of the appropriate diagnostic description at the unit control panel. This annunciation shall be in plain English- Alphanumeric codes shall be prohibited.

H. Examination: Examine areas to receive chillers for compliance with installation tolerances and other conditions effecting performance and maintenance of chillers. Examine proposed route of moving chillers into place and verify that it is free of interferences. Verify piping roughing-in locations. Verify branch circuit wiring suitability and

proper supply voltage. Do not proceed with installation until unsatisfactory conditions have been corrected.

- I. Installation: Install chillers according to manufacturer's written instructions. Install chillers plumb and level, and anchor housekeeping pads to building floor. Anchor chiller and vibration isolators to housekeeping pad as recommended by the chiller manufacturer. Install vibration isolators as recommended by the chiller manufacturer according to isolator manufacturer's written instructions. Maintain manufacturer's recommended clearances for service and maintenance. Install piping connections maintaining clearances for service and maintenance of chillers. Install differential pressure transducers across chilled-water, hot-water and source-water connections. Install grooved couplings at chiller modules. Install chiller bank end caps, furnished by chiller manufacturer, where required. Install flexible pipe connections for chillers if chiller manufacturer recommends the chiller be mounted on vibration isolators. Install MAIN shutoff valves at chiller inlet and outlet of both chilled-water and condenser-water connections. Thoroughly clean and flush chilled, hot and source water systems prior to allowing flow to chiller bank. Install entering and leaving temperature sensors for chilled, hot and source water master level control. Install phase monitor at main power supply to chiller bank. Install master panel and wire to separate 115 volt power supply. Install communication wire (daisy chain) between master panel and bank. Install water strainers as required for chilled, hot and source water loops. Install chiller bank end panels. Install water bypass kits for chilled, hot and source water loops.
- J. Electrical Connections: Install all necessary electrical wiring devices and services such as fused disconnect switches or circuit breakers to power each module, phase loss monitors. Install all wires and cables routing between each module and the master controller. Install electrical service to the master control panel. All wiring is done in the field and shall be according to local and national electrical codes where applicable. Ground equipment. Tighten electrical connectors and terminals, including grounding connections, according to manufacturers published torque-tightening values. Where manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

- K. Field Quality Control: Test and adjust controls and safeties. Replace if damaged or malfunctioning.
- L. Commissioning: Energize chiller and operate controls and safeties. Verify that motor amperage conforms to manufacturer's data. Start simultaneous heating and cooling system and verify performance. Demonstrate operation to Owner. The factory authorized chiller start-up technician shall assist the AE, Contractor, CxA and other parties with a ATES and dry-cooler "load test." The chiller shall then be temporarily controlled to provide the specified leaving hot water "source" water temperature directed by the AE to "load" the dry-cooler or the ATES with the load intensity specified, for the duration the AE specifies (not to exceed 8 hours).
- M. Demonstration: Factory-Authorized Startup Services: Engage a factory-authorized service representative to perform startup services, and to demonstrate and train Owner's maintenance personnel as specified. Train the Owner's maintenance personnel on procedures and schedules related to startup, shutdown, troubleshooting, servicing, preventative maintenance and other area as specified herein. See the commissioning specification for additional information.

2.6 ADIABATIC DRY-COOLER (HYBRID DRY COOLER)

- A. Furnish and install adiabatic dry cooler arranged for vertical flow (induced draft), conforming in all aspects to the specifications, schedules and as shown in the contract documents. Overall dimensions shall not exceed the (scaled) dimensions shown in the contract documents. The heat rejection (cold storage) equipment for this project shall be a double-stacked double-sided bank dry-cooler design which also has evaporative cooling pads located upstream of the dry-coil to allow for adiabatic (evaporative) cooling of the incoming air during peak ambient conditions if needed. It shall also feature "EC" (electronically commutated) fan motors and a microprocessor based fan speed control system. The unit shall be manufactured according to quality standard ISO 9001 and designed for horizontal inlet air and vertical upflow discharge.
- B. Heat Exchanger Coil (Double Vertical Bank Coil, Double-Stacked on Each Side): The dry cooler shall be equipped with a floating coil design which prevents any contact of the water-carrying tubes with the supporting frame and shall be fully epoxy coated and suitable for coastal environment application where the ocean is within 1000 feet of

installation. Leakage through thermal expansion shall be prevented, insuring maximum operational safety and service life is achieved. The tube pattern shall be 50.0 x 25.0 mm staggered in the direction of air flow. The water tubes shall be made of copper with a 0.47 inch diameter and the fins shall be made of aluminum with a fin spacing of 10.6 FPI. The aluminum utilized for the fins shall be epoxy coated before it is formed into the fin shape with collars and area not covered by the coated fin collars shall be painted with polyester paint. Smaller fin spacing and split fins are prohibited due to increased risk of clogging. The entire end and center plates shall be made of galvanized steel. The tube system shall be cleaned, dried and filled with dehumidified air (approx. 1 bar overpressure). For testing purposes, all circuits shall be fitted with 'Schrader' valves and all outlet and inlet headers shall be made of copper and all brazed connections shall be made of copper. Provide vent and drain connections on all headers to allow for venting of air during startup or draining of the coil during servicing. The coil shall be ETL listed and bear the ETL label.

- C. Unit Casing: The casing shall be of a robust, self-supporting construction design and shall be made of galvanized steel and painted with a RAL 7035 light grey polyester paint. Galvanized interior baffles shall be provided between each fan section to prevent short circuiting of air during partial fan operation. Provide OSHA-approved access ladder and perimeter railing system atop the unit.
- D. Fan Motors: Fan motors shall be furnished for operation on a 460 VAC, 3 phase, 60 hertz power supply. Motors shall be sealed with a labyrinth seal impeding the ingress of splash water and include drain holes for condensation water drainage. Thermal contacts shall be integrated into the motor windings. Motors shall have protection class IP 55 and windings with thermal class F according to DIN EN 60 034-1. Fan motors shall operate off of 0 - 10 VDC signal from DDC control panel. Motors shall be UL listed and bear the UL label.
- E. Axial Fans: The drive motor, fan blades and the fan guard construction shall form an optimal unit according to airflow and heat rejection requirements on the drawing at the horsepower specified (which is the maximum that shall be allowed). Provide low-noise, maintenance-free EC motors capable of operation down to 10 percent of their peak/design RPM. All fans shall be subject to balance quality Q 6.3 according to

VDI 2060. Drive motors shall be provided with protection class IP 55. All windings shall be provided with thermal class F according to DIN EN 60 034-1. All three phase motor(s) shall be 460 V, 60 Hz designed for temperature operating ranges from -40 degrees F to 140 degrees F. Fan protection guards shall be constructed according to EN294. Provide easy-to-maintain mounting of all axial fans. The thermal protection shall be integrated into the motor windings.

F. Dry Cooler Fan and Adiabatic Evaporative Controls: Provide a microprocessor-based adiabatic dry cooler fan speed and adiabatic evaporative water controls system (FSAEWCS) with a Modbus communication link to the existing Building Automation System (BAS). Control panel shall be UL listed and bear the UL label.

1. General: The FSAEWCS shall provide the following benefits: Reduced commissioning through the simple setting of the controller. The parameter setting of the EC fans shall be executed automatically by the FSAEWCS, even after fan exchange. Fault and operating messages shall be shown in the display of the controller. All settings shall be made in the plain text display (in German, English, French, Spanish). Comprehensive operating information shall be available (e.g. operating hours, energy data, speed, etc.). This data shall be available for analysis and thus improve the operation of the entire system. High operational reliability shall be achieved by means of a bypass function that is integrated in the system. Energy reduction through EC motors, high-efficiency fans and in combination with an optimally adapted control shall be achieved. A Modbus interface shall be provided. System shall be capable of receiving a speed signal input and an on-off enable/disable signal input and communicating all fault conditions to the BAS.

2. Operation Reliability Controls:

a. In the case of an electronic fault, the system operation shall be guaranteed by the integrated bypass function. In this mode, the fans shall run at a predefined speed and the controller shall display a fault message. The emergency mode shall be defined by the FSAEWCS as follows.

- 1) Bypass IN/OUT
- 2) Bypass speed in percent

b. The operating conditions such as motor temperatures, power supply (phase control), operating time meter, etc., shall be shown on

the controller display and shall additionally be communicated to the BAS via the Modbus interface.

3. Energy Data For Energy Management: The FSAEWCS shall record all energy data. After evaluation and preparation of the data, this data shall be available for energy management purposes and shall be communicated to the BAS by means of the Modbus link. The data can be shown on the control display or via the Modbus system.
- G. Low Capacity Motor Management: EC fans shall have a minimum speed that is between 8 percent and 12 percent of full load operation. For a control in the lower capacity range of the heat exchanger (e.g. 5 percent) the FSAEWCS shall be equipped with a function where the control signal is newly calculated according to the number of fans and their minimum speed (10 percent) to achieve an equivalent capacity between 2.5 and 10 percent by operation of only a select number of fans. This control signal shall be communicated to individual fans. With this function, it shall be possible to easily achieve an energy-efficient control also in lower capacity ranges, down to 2.5 percent of the nominal capacity of the dry-cooler.
- H. Data Transfer (Communication): A Modbus interface shall be provided for future integration into main BAS with traditional analog and digital inputs/outputs used for integration with BAS under this contract. See also Section 23 09 23. This integration shall provide the following features.
1. Detailed fault messages relating to a fan or to the entire heat exchanger unit shall be communicated to the BAS.
 2. The system shall have a higher operational reliability due to the option of activating a backup control and the bypass function.
 3. Detailed information relating to the operating state shall be communicated, e.g. fan speed / air volume - heat exchanger capacity, etc.
 4. Due to 100 percent integration of the heat exchanger into the BAS, a more precise control shall be possible for setting an optimal operating point for the entire system.
 5. Remote maintenance and remote setting of parameters shall be possible be executed via online data transfer to the BAS system. The heat exchanger shall be addressed directly and fault messages shall be communicated online.

6. The transfer of energy data (kWh, kW, etc.) to the BAS shall be provided.
7. A 0 - 10 VDC speed signal to the ECM motors shall be used in lieu of Modbus.
- I. Electrical: Provide a single point non-fused disconnect switch in a NEMA 4X enclosure as well as fused branch circuit protection for each fan, control transformer, Modbus compatible controller and all other electrical components in a factory installed NEMA 4 enclosure.
- J. Adiabatic Evaporative Cooling System: Provide a factory piped and installed internal, once through adiabatic evaporative system complete with minimum 2 inch diameter, schedule 80, PVC or PP-RT or HDPE distribution header piping, type 304 stainless steel drainage system/gutter and hydrophilic treated cellulose evaporative cooling pads. Pads shall have a tap distribution pad to evenly distribute water over the entire pad. Pad shall have dual flute angles to maximize efficiency, fully wet all surfaces and minimize carryover and shall be treated to minimize rotting and scaling. Basis of design for the pads is CELdek as manufactured by Munters. The basis of design data is provided for informational purposes only and not intended to restrict competition. The Contractor shall furnish equipment from any manufacturer that complies with the performance requirements found in the Contract Documents and inherent in the basis of design equipment. External piping connections shall be made by Contractor as indicated on drawings. Distribution header orifice size shall be as recommended by the evaporative cooling pad manufacturer. Total pressure drop thru distribution piping header shall not exceed 5.0 psig.
- K. Spare Parts: Provide a complete set of extra evaporative cooling pads for both Adiabatic Dry Coolers.
- L. Basis of Design: The equipment utilized by the AE as the "basis of design" of the adiabatic dry-cooler is as shown in the contract documents as manufactured by Guntner U.S., LLC, 847-781-0900, sales@guntnerus.com or j.heyneck@guntnerus.com. The basis of design data is provided for informational purposes only and not intended to restrict competition. The Contractor shall furnish equipment from any manufacturer that complies with the performance requirements found in the Contract Documents and inherent in the basis of design equipment.

2.7 CIRCULATOR SIZING AND SYSTEM AND COMPONENTS

- A. Comply with Section 23 21 23, HYDRONIC PUMPS as well as the additional requirements below.
- B. The circulator wattage for closed loop systems shall not exceed 150 watts/ton.
- C. Proper sizing of the circulating pump shall be within the heat pump manufacturer's required flow rate range for the specified unit. Pumps shall be selected to operate within 5 percent of maximum efficiency. Circulating system shall also include lead and lag pumps.
- D. Particulate contaminants shall be removed from piping system prior to initial start-up.
- E. Start-up pressurization of the circuit to a minimum of 1.38 - 2.07 bar [20 to 30 psi] when installed in the summer with circulating water temperature of 20 - 30 degrees C [70 - 90 degrees F] and 2.76 - 3.45 bar [40 to 50 psi] when installed in the winter with circulating water temperature of 5 - 10 degrees C [40 - 50 degrees F] is required. Standing column designs of circulating systems that ensure a flooded volute and meet the manufacturer's requirements are excluded from these pressure requirements.
- F. The circulation system shall incorporate provisions for flow and temperature-sensing capability for testing the performance of the water side of the heat pump system. Pressure and temperature-sensing ports shall be within 600 mm [24 inches] of the heat pump.

2.8 HEAT TRANSFER FLUID

- A. Shall meet local and state requirements and be acceptable by component manufacturers.
- B. Shall meet requirements of ICC IMC Section 1207.
- C. The ground-source heat pump system shall have a permanent label at the loop charging valve identifying the antifreeze type and concentration, service date, and the name and phone number of the service company.
- D. Heat transfer fluids used shall be one of the following:
 - 1. Food-grade propylene glycol-water solution at a concentration specified by the product manufacturer.
 - 2. Nontoxic compounds meeting IGSHA #21035, Sections 3B and 3C, and which are compatible with heat pump manufacturers' specifications.
- E. The fluid shall conform to the following requirements, and tests shall be performed in accordance with specified test methods on the fluid:

1. Flash point shall not be lower than 90 degrees C [194 degrees F], determined in accordance with ASTM D92.
 2. Five days biological oxygen demand (BOD) at 10 degrees C [50 degrees F] shall not exceed 0.2 gram oxygen per gram not be less than 0.1 gram oxygen per gram.
 3. Freezing point shall not exceed -8 degrees C [+18 degrees F], determined in accordance with ASTM D1177.
 4. Toxicity shall not be less than LD 50 (oral-rats) of 5 grams per kilogram. The NFPA 704 hazardous material rating for health shall not be greater than 1 (slight).
 5. The fluid, tested in accordance with ASTM F1105, shall show neither separation from exposure to heat or cold, nor show an increase in turbidity.
- F. The fluid, as received by the purchaser, shall be homogeneous, uniform in color, and free from skins, lumps, and foreign materials detrimental to usage of the fluid.
- G. Water used to dilute the antifreeze heat transfer fluids shall be of potable quality. Final heat transfer fluid solutions shall not be flammable.
- H. Vertical Closed Loops for direct exchange geothermal system shall use only a non-ozone depleting refrigerant such as R-410A, R-407C, R-134, or an equally safe refrigerant as specified by the heat pump manufacturer, as a heat transfer fluid.
- I. Isolation Valves:
1. Each incoming loop leg shall be isolatable by manual shut off valves. The main loop supply and return lines shall contain manual or powered isolation valves. There shall be access ports in the main loop supply and return lines to allow for loop flushing.
- J. Packaging and Identification:
1. Fluid shall be packaged in containers of a type and size agreed upon by purchaser and vendor, or shall be delivered in bulk, as ordered.
 2. Containers of fluid shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the fluid to ensure carrier acceptance and safe delivery.
 3. An up-to-date Material Safety Data Sheet (MSDS) shall be supplied to each purchaser on request and concurrent with each delivery.

2.9 INSULATION

- A. Comply with Section 23 07 11, HVAC AND BOILER PLANT INSULATION.

2.10 INSTRUMENTATION

SPEC WRITER NOTE: Either reference the applicable specification section (A) or specify products herein (A-C).

- A. //Comply with Section 23 21 13, HYDRONIC PIPING, for pressure gauge and thermometer requirements.// Use corrosion resistant materials for wetted parts of instruments.
- B. Pressure Gauges: ASME B40.100, brass body, and minimum 90 mm [3.5 inches] diameter dial face.
- C. Thermometers: ASTM E1, //liquid-in-glass type// //dial type, liquid-filled tube and bulb//.//

SPEC WRITER NOTE: For small systems, do not use monitoring system, due to high initial cost and the labor to maintain it. For projects where a direct-digital control system exists or is otherwise being installed, consider integrating the geothermal system into it.

- D. //Monitoring System:
1. Kilojoule Btu Meter: Sensing and Monitoring device to measure and display the heat energy produced by the ground-source heat pump system, with minimum sensitivity of 0.5 percent over the entire scale. Provide electromechanical kJ Btu counter plus digital-panel meter indicating sensor temperatures, differential temperature, flow rate, and watt Btu per minute or hour.
 2. //Water// //and// //Heat Transfer Fluid// Leak Detection: UL-listed system consisting of a sensor probe, control panel, and LED indicators for //water; yellow, // //and// //heat transfer fluid; red, // with audible alarm at minimum 75 dB sound level; reference 10 exponential minus 12 watts. //
- E. //System Controls and Monitoring
1. Comply with Section 23 09 23, DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC. //

2.11 GEOTHERMAL HDPE PRE-FABRICATED MANIFOLD CHAMBER OR VAULT

- A. Basic Construction:
1. The geothermal manifold chamber shall meet the minimum requirements of this specification.

2. The internal HDPE pipe and fitting material shall meet the minimum requirements of this or other sections of the specifications.
 3. The inlets and outlets shall be extrusion welded on the outside of the structure using trained welders with documented training records.
 4. All external field connections to structure shall be butt fusion welded or electrofusion welded, when 3 inch or greater. Socket fusion is allowed for 2 inch connections and smaller.
 5. The piping system shall be hydrostatically tested to 160 psi with water for no less than 30 minutes, with no leaks. The contracting officer (CO) or their representative shall request to observe the test. Contractor shall provide four weeks' notice to the co of when this test shall be conducted.
- B. Materials: the raw materials for the HDPE pre-cast vault shall be made from materials meeting the following requirements:
1. HDPE material specifications
 - a. HDPE Extruded Solid Wall Pipe Material - Solid wall pipe under this specification shall be a minimum grade of PE 4710 with a minimum cell classification value of 345464C as defined in ASTM D3350. Dimensions of all pipe shall meet ASTM F714 requirements unless otherwise approved.
 - b. HDPE Profile Wall Pipe Material - Profile wall pipe supplied under this specification shall be manufactured to the dimensions and material requirements of ASTM F894 with a minimum cell classification value of 334433E for gray colored cylinder or 334433C for black colored cylinder, including those with a yellow interior, as defined in ASTM D3350.
 - c. HDPE sheet and fittings material- Sheet, plate and other HDPE materials under this specification shall be minimum grade of PE 4710 with a minimum cell classification value of 345464C as defined in ASTM D3350.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install the ground-source heat pump system in accordance with this section and the printed instructions of the manufacturer.
- B. Prior to any excavation, trenching, or drilling, all existing buried utilities, drainage, and irrigation systems shall be located and flagged by the appropriate utility and Contractor representative.

C. //Vertical Closed Loop Source Well

1. Borehole Construction

- a. Loop installation shall be in accordance with IGSHPA Configuration C, and modeling to determine loop lengths shall be in accordance with IGSHPA Configuration B.
- b. Surface water shall not be used as a source of water during the drilling of a Vertical Closed Loop borehole unless it is obtained from a municipal water supply system. Water used for drilling purposes shall be potable water that contains a free chlorine residual of no less than 10 milligrams per liter. Chlorine residual level shall be checked with chlorine test strips.
- c. Boreholes shall have a minimum diameter such that it is large enough to accommodate the specified u-bend assembly and tremie pipe (grout pipe). The tremie pipe shall have a minimum nominal inside diameter of 31.8 mm [1.25 inches].
- d. When penetrating greater than one aquifer, all vertical boreholes shall be grouted bottom to top within 24 hours with a material that is certified by the National Sanitation Foundation International to ANSI/NSF 60 and has the minimal thermal conductivity (k value) specified herein and the sealing characteristic (hydraulic conductivity) specified herein. The grouting material shall be classified as either a pliable (such as bentonite-based) or rigid (such as cement based) material based on the characteristics of the geology as specified herein.

2. Grouting - The following provisions are required for grouting (sealing) of the void space between the piping and borehole of a Vertical Closed Loop:

- a. Grouting is to be completed in a manner that prevents the introduction of surface or near surface contaminants into an aquifer, the interchange of water from different aquifers, or the loss of natural artesian pressure from an aquifer.
- b. The void space between the piping and the borehole shall be grouted in a continuous operation from bottom to top using grout placement procedures set forth in the IGSHPA Grouting for Vertical Heat Pump Systems, Engineering Design and Field Manual, 2000, but as a minimum shall be done via tremie pipe and in sufficient volume to fully fill the annulus

- c. A tremie pipe (grout pipe) not less than 31.8 mm [1.25 inch] nominal diameter shall be placed to the bottom of the borehole before grouting. The tremie pipe shall be used to assist with the insertion of the closed-loop piping into the borehole but the utilization of a hydraulically driven U-bend/pipe reel is preferred. The tremie tube shall be retracted at an appropriate rate to match the grouting rate (filling rate) as the grouting process proceeds. If the formation is highly porous (e.g. karst limestone), and with the permission of the COR, pea gravel shall be delivered as needed from the surface at the same rate as the grouting is filling the hole to act as a matrix to prevent excessive grout losses to the formation. In highly porous formations, graphite in lieu of high silica sand shall be used to reduce the density of the grout mixture and reduce the losses to the formation. The tremie pipe shall be removed from the borehole upon completion of grouting.
- d. Grout shall be pumped through the tremie pipe until the density of the grout flowing from the borehole at the ground surface equals the density of the grout being pumped in. Each borehole shall be grouted upon completion. The contractor shall monitor each borehole for settling for a period of not less than 48 hours. Additional grout shall be added and the monitoring period shall be extended until the settling of grout stops.
- e. A borehole drilled using horizontal directional drilling techniques shall be grouted by pumping grout as the tremie pipe is retracted through the borehole.
- f. Grout manufacturer's product specifications shall be followed when mixing and pumping grout and the quantity and pH of the potable water mixed with the grout shall strictly conform to the grout manufacturer's requirements. NSF/ANSI 60 certified, rounded grain, high silica sand of the proper grain diameter or graphite, approved in writing by the grout manufacturer, shall be mixed with the bentonite grout to achieve the thermal conductivity rating (k value) shown on the Contract Documents. //The Contractor// //An independent third Party//shall test the thermal conductivity of the grout a minimum of // // times during the placement of grout over the project duration to confirm it meets the minimum k value specified.

- g. To minimize potential leaching of chemical constituents into an aquifer, grouts, drilling fluids, and additives to grouts and drilling fluids, including sand added to grout as thermal-enhancer for Vertical Closed Loop applications, shall meet NSF/ANSI 60.
 - h. The maximum allowable permeability value of the set grout shall be 1×10^{-7} cm per second, as determined in accordance with ASTM D5084.
 - i. Cementitious Grout: The groundwater at the site shall be tested by the Contractor to determine if the salinity and pH of the water is suitable for proposed grout. If it is not (or if local or state Codes require the use of cementitious grout, the Contractor shall use Type II Portland Cement or other approved additives, as specified by the grout manufacturer to ensure the grout is suitable for the salinity of the water and/or confirms to local and State Code requirements.
- D. //Horizontal Closed Loop Source Piping
- 1. All buried Ground-Source Heat Pump pipes in systems containing antifreeze and passing parallel within 1.5 meter [5 feet] of any wall, structure, or water pipe shall be insulated with R2 minimum closed cell insulation.//
 - 2. Prevent any sharp-edged rocks from coming into contact with the pipe by removal of the rocks before backfilling. Use the IGSHPA Slinky backfilling procedures found in IGSHPA's Slinky Installation Guide to assure elimination of air pocket around the pipes. Return bends in narrow trenches shall be partially backfilled by hand to properly support the pipes and prevent kinking.//
- E. //Pond and Lake Loop Well Systems: Heat pump system manufacturer's procedures shall be followed. Provisions shall be provided for heat exchanger removal for cleaning.//
- F. Tracer wire shall be installed along entire length of header piping, perimeter piping and as specified herein.
- G. Piping installation shall be compliant with ICC IMC Section 1206.
- H. Pipe Joining Methods:
- 1. The only acceptable methods for joining buried polyethylene pipe systems are: 1) a heat fusion process or 2) stab-type fittings quality controlled to provide a leak-free union between pipe ends that is stronger than the pipe itself.

2. Polyethylene pipe shall be heat fused by butt, socket, sidewall or electro-fusion in accordance with the piping manufacturer's procedures.
 - a. Heat-Fusion Joints: Joint surfaces shall be clean and free of moisture. Joint surfaces shall be heated to melt temperatures and joined. The joint shall be undisturbed until cool. Fittings shall be manufactured in accordance with ASTM D2683.
 - b. Electro-fusion Joints: Joint surfaces shall be clean and free of moisture, and scoured to expose virgin resin. Joint surfaces shall be heated to melt temperatures for the period of time specified by the manufacturer. The joint shall be undisturbed until cool. Fittings shall be manufactured in accordance with ASTM F1055.
 - c. Stab-type Insert Fittings: These type fittings are prohibited.
 3. Polyethylene fusion transition fittings with threads shall be used to adapt to copper. Polyethylene fusion transition fittings with threads or barbs shall be used to adapt to high strength hose. Barbed fittings utilizing mechanical clamps are prohibited to be connected directly to polyethylene pipe, with the exception of stab-type fittings as described above. All mechanical connections shall be accessible.
 4. PEXa tubing shall not be butt-fused or socket-fused to fittings. Polymer electro-fusion fittings shall be used with PEXa tubing when installed in accordance with manufacturer's published procedures. Cold-expansion compression-sleeve fittings shall be used for all PEXa connections when installed according to the manufacturer's published procedures and are permitted to be direct buried with manufacturer approved corrosion covering.
- I. Circulator System:
1. Loop charging valve handles shall be removed and/or the ports sufficiently plugged to prevent accidental discharge of system fluid and pressure.
 2. Boiler-type service valves shall not be used.
 3. Transition fittings between dissimilar materials shall be inside or accessible.
 4. All indoor piping shall be insulated where condensate shall cause damage.

5. All above ground piping subject to condensation or freezing shall be insulated.
6. All pipes passing through walls shall be sleeved and sealed with non-hardening caulking material.

SPEC WRITER NOTE: Some antifreeze solutions require more fitting torque than others to prevent leaks and corrosion of external surfaces when the antifreeze is exposed to oxygen.

7. Threaded fittings shall be visually inspected for quality and a thread sealant specified for use with the antifreeze selected shall be used.
- J. Any penetrations of walls or horizontal assemblies shall be compliant with ICC IBC Section 714.
- K. Instrumentation: Install instruments as recommended by the control manufacturers.
- L. //Meters shall tie into the building direct digital control system per the requirements of Section 23 09 23, DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC.//
- M. Heat Pump System
 1. Maintenance access to each piece of equipment shall not be compromised by any type of piping, electrical conduit, or any other utility. Further, install equipment in accordance with NFPA 70 and with the manufacturer's written installation instructions, including the following:
 - a. Water-source water-to-water heat pumps - installation instructions
 - b. Adiabatic Dry-Coolers - installation instructions
 - c. Injection Valves and Controllers
 - d. As-Built Drawings of the installed systems. As-built drawings shall also show and document the as-constructed locations of the well field with dimensions, including all wells and loop fields.
 2. Connections to Existing Systems: Notify the Contracting Officer in writing at least 15 calendar days prior to the date the connections are required. Obtain approval before interrupting service. Furnish materials required to make connections into existing systems and perform excavating, backfilling, compacting, and other incidental labor as required. Furnish labor and tools for making actual connections to existing systems. Flush existing systems in

accordance with paragraph entitled "Flushing the Ground Heat Exchanger" prior to making connections.

- N. Aboveground Piping: Provide above ground piping as specified in section 23 64 27 CHILLED, HOT AND OTHER WATER PIPING SYSTEMS and as specified herein.
1. Cleaning of Piping: Keep interior and ends of new piping and existing piping, affected by Contractor's operations, cleaned of water and foreign matter during installation by using plugs or other approved methods. When work is not in progress, securely close open ends of pipe and fittings to prevent entry of water and foreign matter. Inspect piping before placing into position.
 2. Flushing and Purging of Piping: Before connection of the header to the polyethylene ground heat exchanger loops, flush and purge the entire aboveground piping system thoroughly in accordance with IGSHPA 21020 recommendations except that a minimum flush velocity of four (4) feet/second is required and leave filled with clean water. If the header is not immediately joined to the ground heat exchanger loop, the open ends shall be taped or capped. Purge and vent the above ground system piping of all air.
 3. Above ground ATES piping shall be HDPE as specified herein.
- O. Earthwork
1. Earthwork shall be performed in accordance with applicable provisions of Section 31 00 00 EARTHWORK.
 2. Excavating, trenching, warning tape, and backfilling shall be as specified herein and in the contract documents. All earthwork performed under this section of the specifications shall also conform to all requirements in the Division 31 specifications.
 3. Sharp bending of pipe around trench corners shall be prevented by using a shovel to round corners, or by installing an appropriate elbow fitting. Manufacturer's procedures shall be followed.
 4. Backfilling procedures shall include prevention of any sharp-edged rocks from coming into contact with the pipe by removal of the rocks before backfilling.
- P. Underground Piping: Examine areas and conditions under which underground piping systems shall be installed. Prior to excavation, trenching, or drilling, locate and mark buried utilities. Do not proceed with work until approved by the Contracting Officer. Sharp bends and mitered joints shall not be used in piping. Provide fittings

for changes in direction when minimum bend radius, as recommended by the pipe manufacturer, is exceeded. All pipe bends shall be radius type elbows. Make changes in piping sizes through tapered concentric fittings. Leaks shall be "cut-out" and repaired in accordance with the pipe manufacturer's recommendations. Direct buried threaded or flanged connections are prohibited. Inspect all piping for damage prior to installation. Installation shall follow IGSHPA guidelines as well as local, state, and Federal guidelines and regulations. Upon delivery of piping, inspect the pipe for damage and verify that the pipe meets the project specifications. Prior to installation of pipe, carefully inspect pipe for damage. Do not use the pipe if it has a cut or a gouge that is greater than 10 percent of the minimum wall thickness of the pipe. Provide reels and pipe coil. Reels shall be used to securely hold the pipe coil while being pressure tested.

1. Underground Piping: Horizontal trenches for underground piping shall be dug with a backhoe. The piping shall be buried a minimum of 48 inches deep or as indicated. Make joints while pipe is lying beside the trench. If the soil contains rocks, dig the trench 6 inches deeper than required and install a base of 6 inches of fines or sand before placing the pipe. After the piping is installed, tested, and flushed, purged, (minimum 4 feet per second) inspected, and approved while still under pressure, backfill 6 inches above with fines or sand. Complete backfill in accordance with IGSHPA 21020 recommended procedures. When laying pipe in trench, ensure the bottom of the trench is smooth, free from rocks and debris. When laying pipe, use a fine to medium backfill to fill trench. If there are multiple pipes in the trench, ensure each pipe is completely surrounded and supported with backfill before the next pipe is installed.
 - a. Piping at Building Entries: Install a rigid non-metallic conduit (PVC) as a pipe casing at building entries and floor penetration. The casing allows ease of installation of the ground heat exchanger piping into the building. The conduit should extend 24 inches from the building foundation. The conduit should end 6 inches above the floor. The ends of the conduit where the pipe is located, fill the annular space with insulation and a silicone seal.

2. High Density Polyethylene (HDPE) Piping: Install piping in accordance with manufacturer's written instructions. Polybutylene piping shall not be used. Piping components shall be joined by a heat fusion method that conforms the piping manufacturer's recommendation for this application. During installation, keep trash, soil, and foreign objects out of the pipe. Tape or cap ends of the pipe until the pipe is joined to the circuit. The vertical loop take-off tee fittings shall be made using tee fittings or the saddle fusion process on header piping 1.25 inches diameter and above. Completely remove the cutout on the saddle tees. Use bell reductions at pipe reductions. Use reducing socket tees when fabricating socket type reducing headers. Avoid sharp bends and mitered elbows and bends in piping. Consult pipe manufacturer for minimum bend radius. Install elbow fittings at changes in pipe direction that are tighter than the minimum recommended bend radius. Use only continuous pipe in vertical U-bend loops.
3. Heat Fusion Process: Joining shall be by butt fusion in accordance with the manufacturer's Heat Fusion Qualification Guide. Socket fusion joints are allowed only for pipe 3/4 inches diameter and less. Use butt fusion joints for pipe greater than 3/4 inches diameter. Different plastics or grades of plastic shall not be fused together. When fusing pipe, perform heat fusion tests to verify the quality of the joints. Notify the Contracting Officer, the results of the heat fusion tests.
4. Pressurizing: After assembly of the entire underground piping system, fill the system with water and pressure test to 100 psi for a minimum of four (4) hours in accordance with ASTM F164-02. Visually inspect welds prior to backfill of the trenches.
5. Pipe Identification: Install metalized (detectable) warning and identification tape above each horizontal pipe run. Install tape a minimum of 6 inches below finish grade.
6. Tracer Wire: Install a continuous length of tracer wire for the full length of each run of nonmetallic pipe as previously described. Attach wire to top of pipe in such manner that it will not be displaced during construction operations.
7. Threaded Fittings: Threaded joints shall be sealed with a sealant compatible with the circulating fluid; use of lubricating tape for sealing is prohibited. Do not thread metal pipe into plastic pipe

or vice versa. Direct buried threaded joints are prohibited.

Threaded joints shall be used only above grade, within mechanical spaces, or within valve pits.

- Q. Flushing and Purging Ground Heat Exchanger: Before connection of the plastic ground heat exchanger loops to the header, flush and purge each loop thoroughly in accordance with IGSHPA 21020 recommendations except that minimum purge velocity shall be four (4) feet per second or higher as required to remove all air and debris and leave filled with clean water after purging is complete. If the loop is not immediately joined to the header, it shall be taped or capped. Purge and vent the ground heat exchanger system piping of all air.
- R. Adjustments: Adjust controls and equipment so as to give satisfactory operation. Adjust entire water temperature control system and place in operation so that water quantities circulated are as indicated. Adjust and balance air duct systems so that air quantities at outlets are as indicated and so that distribution from supply outlets is free from drafts and has uniform velocity over the face of each outlet.
- S. Instructing Operating Personnel: Upon completion of work and at time designated by Contracting Officer, provide services of water source heat pump manufacturer's technical representative for period of not less than one 8-hour working day for instruction of Government operating personnel in proper operation and maintenance of equipment.
- T. Field Quality Control: Upon completion and before final acceptance of work, test each system in service to demonstrate compliance with the contract requirements. Adjust controls and balance systems prior to final acceptance of completed systems. Test controls through every cycle of operation. Test safety controls to demonstrate performance of required function. Correct defects in work provided by Contractor and repeat tests. Furnish fuel, water, electricity, instruments, connecting devices, and personnel for tests. Flush and clean piping before placing in operation. Clean equipment, piping, strainers, ducts, and filters.
1. Piping Systems Except for Ground Heat Exchanger and Refrigerant:
For above ground piping systems, and steel or copper piping systems: Before insulating, hydrostatically test each new piping system at not less than 1.5 times the system working pressure. Maintain pressure for 2 hours with no leakage or reduction in gauge pressure. Obtain approval before applying insulation.

2. Flow Test of Underground Piping: Before backfilling the trenches, flush, purge, and vent systems of air and flow test to ensure all portions of the heat exchanger are properly flowing using the procedures recommended by IGSHPA 21020 and as specified herein. Utilize a portable temporary purging unit consisting of the following:
 - a. High volume, high head purge pump
 - b. Open reservoir
 - c. Filter assembly with bypass
 - d. Flow meter
 - e. Pressure gauge
 - f. Connecting piping
 - g. Connecting hoses
3. Using a purge pump and the procedures recommended by IGSHPA 21020, flush and purge each ground heat exchanger system until free of air, dirt, and debris. A velocity of four (4) feet per second or higher is required in pipe sections to remove the air. Purge and vent all air from the piping.
4. Perform the flushing and purging operation with the water source heat pumps isolated by shutoff valves from the ground heat exchanger system. Allow purge pump to run 15 minutes after the last air bubbles have been removed. After the ground heat exchanger is completely flushed of air and debris, open the isolation valves and permit circulation through the heat pumps until the entire system is flushed and purged.
5. Utilizing the purging unit and the procedures recommended by IGSHPA 21020, conduct a pressure and flow test on the ground heat exchanger to ensure the system is free of blockage. If the flow test indicates blockage, locate the blockage using the manufacturer's recommendation, remove the blockage, then repeat the purge procedure and conduct the pressure and flow test again until all portions of the system are free flowing. The flow test shall be observed and approved by the Contracting Officer.
6. Form 1, "Underground Piping Inspection and Test Report" located below, shall be completed for each system by the Contractor after completion of the flow and before the systems can be backfilled.

FORM 1

UNDERGROUND PIPING INSPECTION AND TEST REPORT

Building(s) : _____ Inspection Date: _____

Description: _____

Do the ATES Wells have a Well Construction Permit? _____

Permit No.? _____

List the Chiller No.'s served by these ATES Wells:

Design Water Flow - _____ gpm

Calculated purging flow and press to achieve 4 feet/sec

Purging: Flow _____ gpm Head _____ psi, Duration of test _____ min.

Hydrostatic test pressure _____ psi; Duration _____ min.

Did the system pass the pressure test? _____

Depth of horizontal piping is _____ feet. (Design is _____ feet.)

Are the trenches clear of sharp bends, rocks, or other sharp objects that could restrict flow? _____

Are all joints butt welded heat fused? _____

Do the joints have the proper amount of roll-out? _____

Cement Grout Manufacturer Mixture Formula? _____

Was the system backfilled properly with good clean backfill material? _____

Comments: _____

Inspected and approved this _____ date by _____

Title: _____

7. Pressure Test of Underground Piping: Prior to any cover or backfill of bore holes or trenches and after flow testing, flushing, and purging, the ground heat exchanger piping and headers shall be pressure tested by hydrostatic test. The system shall be isolated from all connections to piping. Ensure that the piping system has been flushed of all dirt and debris. The piping shall then be plugged or capped as necessary in preparation for the hydrostatic test(s).
- a. Hydrostatic Test: The piping shall be hydrostatically pressurized to the pressure designated by the AE and then monitoring of the pressure shall begin. If there is any pressure loss or visible leakage during the testing, the leak shall be identified and repaired in accordance with the piping components manufacturer's recommendations. Test shall be repeated until there is no loss in pressure during the test period. Provide results of test in test report. During testing, do not exceed the pipe/pipe fitting manufacturer test pressure rating or 150 percent of the pipe pressure rating. Do not pneumatic test the pipe. Prior to testing, remove all air from the system. Provide test in accordance to IGSHPA standards.
8. Equipment Tests
- a. Field Testing: Test each item of equipment in operation, for continuous period of not greater than 24 hours under every condition of operation in accordance with each equipment manufacturer's recommendation and as directed by the AE. Verify that each item of equipment operating parameters are within limits recommended by the manufacturer.
- b. Field Test Plans: Furnish ATES wells and adiabatic dry-cooler field test plans developed by each equipment manufacturer detailing recommended field test procedures for each item of equipment. Field test plans developed by the installing Contractor, or the equipment sales agency furnishing the equipment shall not be acceptable. The Contracting Officer shall review and approve the field test plan for each item of equipment listed below prior to commencement of field testing of the equipment.
- 1) Equipment Items to Test:

- a) Water-source water-to-water heat pumps - field acceptance test plan.
 - b) Adiabatic Dry-Cooler - field acceptance test plan.
- 2) Coordinated Testing: Indicated in each field test plan when work required by this section requires coordination with test work required by other specification sections. Furnish test procedures for the simultaneous or integrated testing of equipment controls which interlock and interface with controls factory prewired or external controls for the equipment provided under the Controls Section.
 - 3) Prerequisite Testing: Equipment for which performance testing is dependent upon the completion of the work covered by 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC shall have that work completed as a prerequisite to testing work under this section. Indicate in each field test plan when such prerequisite work is required.
 - 4) Test Procedure: Indicate in each field test plan each equipment manufacturer's published installation, start-up, and field acceptance test procedures. Include in each test plan a detailed step-by-step procedure for testing automatic controls provided by the manufacturer. Each test plan shall include the required test reporting forms to be completed by the Contractor's testing representatives. Structure procedures to test the controls through all modes of control to confirm that the controls are performing with the intended sequence of control. Controllers shall be verified to be properly calibrated and have the proper set point to provide stable control of their respective equipment.
 - 5) Performance Variables: Each test plan shall list performance variables that are required to be measured or tested as part of the field test. Include in the listed variables performance requirements indicated on the equipment schedules on the design drawings. Furnish with each test procedure a description of acceptable results that have been verified. Identify the acceptable limits or tolerances within which each tested performance variable shall acceptably operate.
 - 6) Job Specific: Each test plan shall be job specific and shall address the particular item of equipment and particular

conditions which exist with this contract. Generic or general preprinted test procedures are prohibited.

- 7) Specialized Components: Each test plan shall include procedures for field testing and field adjusting specialized components, such as hot gas bypass control valves, or pressure valves.

c. Field Test Reports

- 1) Equipment Items to Test:
 - a) Water-source water-to-water heat pumps - field acceptance test report.
 - b) Adiabatic Dry-Coolers - field acceptance test report.
- 2) Manufacturer's Recommended Test: Conduct the manufacturer's recommended field testing in compliance with the approved test plan specified above. Furnish a factory trained field representative authorized by and to represent the equipment manufacturer at the complete execution of the field testing.
- 3) Operational Test: Conduct a standard continuous 24 hour operational test for each item of equipment. Equipment shutdown before the test period is completed shall result in the test period being started again and run for the required duration. For the duration of the test period, compile an operational log of each item of equipment. Log required entries every 2 hours. Use the test report forms for logging the operational variables.
- 4) Notice of Tests: Conduct the manufacturer's recommended tests and the operational tests; record the required data using the approved reporting forms. Notify the Contracting Officer in writing at least 15 calendar days prior to the testing. Within 30 calendar days after acceptable completion of testing, submit each test report for review and approval.
- 5) Report Forms: Type data entries and writing on the test report forms. Completed test report forms for each item of equipment shall be reviewed, approved, and signed by the Contractor's test director and the QC Manager. The manufacturer's field test representative shall review, approve, and sign the report of the manufacturer's recommended test. Signatures shall be accompanied by the person's name typed.

- 6) Deficiency Resolution: The test requirements acceptably met; deficiencies identified during the tests shall be corrected in compliance with the manufacturer's recommendations and corrections retested to verify compliance.
- U. Additional Field Testing: Requirements for testing, adjusting, and balancing (TAB) of ducts, piping, and equipment are specified in Section 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC.
- V. On-Site Training: The Chiller manufacturer shall conduct a training course for operating and maintenance personnel as designated by the Contracting Officer. Training shall be provided for a period of 16 hours of normal working time and shall start after the system is functionally complete but prior to the performance tests. The on-site training shall cover all of the items contained in the approved Operation and Maintenance Data packages.

3.2 FIELD QUALITY CONTROL

- A. Field Inspection: Prior to initial operation, inspect the piping system for conformance to drawings, specifications and ASME B31.1. Inspect the following information on each unit:
1. Manufacturer's name or trademark.
 2. Model name or number.
 3. Certifying agency label and rating.
- B. Tests: Provide equipment and apparatus required for performing tests. Correct defects disclosed by the tests and repeat tests. Conduct testing in the presence of the //COR//.
1. Polyethylene piping, tubing, fusion joints and loops shall be pretested before installation per IGSHPA 2014 Section 1E.
 2. Piping Test: //Pneumatically test new piping for leakage using air at a pressure of 200percent of design pressure.// //Test new water piping for leakage using water at a pressure of at least 690 kPa (gauge) [100 psig] per ICC IMC Section 1208 but no less than 150 percent of design operating pressure.// Install a calibrated test pressure gauge in the system to indicate loss in pressure occurring during the test. Apply and maintain the test pressure for one hour, during which time there shall be no evidence of leakage, as detected by a reduction in test pressure. Should a reduction occur, locate leaks, repair, and repeat the test.

SPEC WRITER NOTE: Use pneumatic test if non-aqueous heat transfer fluid is used,

to avoid contamination of fluids with water and to eliminate seepage problems.

3. Operation Tests: Perform tests on mechanical systems, including pumps, controls, controlled valves, and other components in accordance with manufacturer's written recommendations.
4. Test entire system in accordance with Section 23 05 93, TESTING, ADJUSTING AND BALANCING FOR HVAC.

3.3 FOLLOW-UP VERIFICATION

- A. Upon completion of acceptance checks, settings, and tests, the Contractor shall show by demonstration in service that the ground-source heat exchange system and associated heat pump system are in good operating condition and properly performing the intended function.
- B. Testing the thermal-transfer capacity of the well field shall be completed prior to demobilizing the well drilling equipment.
- C. Shall pressure test the well field piping to verify no leaks in the system and shall occur prior to backfill or burring and element of the well field. No element of the well field horizontal distribution shall be buried until after successful acceptance testing via pressure test.

3.4 INSTRUCTION

- A. A complete set of operating instructions for the ground-source heat pump system shall be laminated or mounted under acrylic glass and installed in a frame near the equipment.
- B. Furnish the services of a factory-trained technician for one, 8-hour training period for instructing personnel in the maintenance and operation of the ground-source heat pump system, on the dates requested by the COR.

3.5 COMMISSIONING

- A. Provide commissioning documentation in accordance with the requirements of Section 01 91 00, GENERAL COMMISSIONING REQUIREMENTS and Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS for all inspection, start up, and Contractor testing required above and required by the System Readiness Checklist provided by the CxA.
- B. Components provided under this section of the specification shall be tested as part of a larger system. Refer to Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS and related sections for Contractor responsibilities for system commissioning.

---END---