Final Scientific / Technical Report

1. **DOE Award Number:** DE-EE0002971

   Recipient Organization: Geothermal Heat Pump Consortium

   Project Title: National Certification Standard for the Geothermal Heat Pump Industry

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   Teaming Members: UT-Battelle, LLC dba Oak Ridge National Laboratory
   Oklahoma State University
   dba International Ground Source Heat Pump Association
   Kelly Group LLC
   Colorado Geo Energy & Heat Pump Association
   National Ground Water Association
   Meline Engineering Corporation

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3. Executive Summary

   The *National Certification Standard for the Geothermal Heat Pump Industry* adds to the understanding of the barriers to rapid growth of the geothermal heat pump (GHP) industry by bringing together for the first time an analysis of the roles and responsibilities of each of the individual job tasks involved in the design and installation of GHP systems. The standard addresses applicable qualifications for all primary personnel involved in the design, installation, commissioning, operation and maintenance of GHP systems, including their knowledge, skills and abilities. The resulting standard serves as a foundation for subsequent development of curriculum, training and certification programs, which are not included in the scope of this project, but are briefly addressed in the standard to describe ways in which the standard developed in this project may form a foundation to support further progress in accomplishing those other efforts. Follow-on efforts may use the standard developed in this project to improve the technical effectiveness and economic feasibility of curriculum development and training programs for GHP industry personnel, by providing a more complete and objective assessment of the individual job tasks necessary for successful implementation of GHP systems. When incorporated into future certification programs for GHP personnel, the standard will facilitate increased consumer confidence in GHP technology, reduce the potential for improperly installed GHP systems, and assure GHP system quality and performance, all of which benefit the public through improved energy efficiency and mitigated environmental impacts of the heating and cooling of homes and businesses.

4. Comparison of Actual Accomplishments with the Goals and Objectives of the Project

The accompanying document meets the goal of this project to create a national certification standard for all primary personnel involved in the design, installation, commissioning, operation and maintenance of ground source heat pump (GHP) systems. In order for a national GHP certification standard to be effective, it must reflect the real-world circumstances that result in reliable and high-performance geothermal heating and cooling systems. Consumers need to be able to trust that personnel who meet the standard are highly qualified industry professionals who can be relied upon to provide them with promised results. GHP industry participants must agree that the standard adequately represents qualifications relevant to their respective GHP responsibilities. Federal and State regulators need to have confidence that the standard supports their ability to protect the public and the environment. All project objectives were accomplished through a collaborative methodology to accomplish these needs.

- A conceptual foundation for the standard was developed from research that identified the characteristics of standards that increase customer confidence and result in predictable performance of designated professionals.
- Underlying causes of GHP system successes and failures were identified by researching and investigating existing GHP systems to identify the roles played by each trade and categorizing knowledge elements and working relationships that contribute to success. Qualification requirements were developed for each trade involved in GHP projects, to provide a basis for design of qualifications incorporated into the standard.
- Collaborative consensus was created around criteria for standards for each trade involved in GHP system design, installation, commissioning, operation and maintenance, by soliciting information and input from a wide variety of stakeholders, including GHP customers, government regulators, designers, installers, heat pump and auxiliary equipment manufacturers, utilities and professional and trade organizations.
- An initial prototype standard was developed based on industry best practices, additional feedback was solicited from industry stakeholders, and the initial prototype was refined to arrive at the structure and content of the final standard.

5. Summary of Project Activities

The development of this standard relied heavily on the 2008 Oak Ridge National Laboratory report by Patrick Hughes *Geothermal (Ground-source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers*, which identified the following barriers to rapid growth of the GHP industry:

- Lack of consumer knowledge and /or confidence in GHP system benefits
- Lack of policymaker and regulator knowledge of and/or confidence in GHP system benefits

The original hypothesis of this project was that these barriers could both be addressed by development of a GHP certification standard designed to increase customer confidence in the technology, reduce the potential for improperly installed systems, and assure product quality and performance. The standard was developed by a consensus process that solicited information and input from a variety of industry stakeholders, and is based on a nationally-recognized competency regimen developed in conjunction with professional and trade organizations, product manufacturers, and government regulatory authorities.

The only significant problem encountered in the accomplishment of the project was the extended time needed to thoroughly address each objective, along with unanticipated delays in the contractual and administrative responsibilities required. In addition, while there was no departure from the separate elements of the planned project methodology, the order of accomplishment of some of the project tasks was modified during the course of the project as a result of things we learned during our efforts, as well as extended subcontracting activities.

The only impact on project results was completion of the project later than originally planned.

6. Products Developed and Technology Transfer Activities

   a. Aside from the accompanying standard document, the project resulted in no technical publications, conference papers or other public releases of results.
   b. In addition to the attached standard document, project results are available at the following Internet website: http://www.geoexchange.org.
   c. Networks and collaborations were fostered with the Teaming Members listed above.
   d. No new technologies or techniques were developed in the course of this project. Instead, the standard represents best practices resulting from extensive input from industry stakeholders regarding the roles played by each trade involved in the design and installation of GHP systems.
   e. No inventions, patent applications, or licensing agreements resulted from this project.
   f. As part of the research accomplished in support of project objectives, a summary of State regulations governing the design and installation of geothermal heat pump systems was created and is available at the following Internet website: http://www.geoexchange.org.

7. No computer modeling was accomplished in the conduct of this project.

8. The project deliverable is the accompanying *National Certification Standard for Ground Source Heat Pump Personnel*.

NATIONAL CERTIFICATION STANDARD

FOR

GROUND SOURCE HEAT PUMP

PERSONNEL

7/31/2013

Geothermal Heat Pump Consortium
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ACKNOWLEDGEMENTS

This national certification standard for the ground source heat pump (GHP) industry was developed as an industry consensus standard under U.S. Department of Energy Assistance Agreement DE-EE0002971 with funding provided by the American Recovery and Reinvestment Act of 2009 (Public Law 111-5). The project was managed by the Geothermal Heat Pump Consortium, in partnership with the International Ground Source Heat Pump Association at Oklahoma State University, and the Oak Ridge National Laboratory Building Technologies Research and Integration Center. Outstanding assistance was also provided by the National Ground Water Association, the Association of Heating, Refrigerating and Air-Conditioning Engineers, Colorado Geo Energy & Heat Pump Association, and Meline Engineering Corporation, as well as countless other ground source heat pump industry professionals who contributed their time and expertise to the content of the standard.

The standard was developed by a consensus process that solicited information and input from a variety of industry stakeholders, and is based on a nationally-recognized competency regimen developed in conjunction with professional and trade organizations, product manufacturers, and government regulatory authorities. It is based on industry best practices for system design and installation, to provide the highest level of system performance, quality and safety.

The development of this standard relied heavily on the 2008 Oak Ridge National Laboratory report by Patrick Hughes *Geothermal (Ground-source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers*, which identified the following barriers to rapid growth of the GHP industry:

- Lack of consumer knowledge and /or confidence in GHP system benefits
- Lack of policymaker and regulator knowledge of and/or confidence in GHP system benefits

These barriers can both be addressed by this GHP certification standard, which is designed to increase customer confidence in the technology, reduce the potential for improperly installed systems, and assure product quality and performance.

CONTENTS

1.0 Forward

The goal of this project is to create a national certification standard for all primary personnel involved in the design, installation, commissioning, operation and maintenance of ground source heat pump (GHP) systems (also known as geothermal heat pump systems), including drillers, plumbers, electricians, heating and air conditioning specialists, engineers and architects. The standard will be designed to increase customer confidence in the technology, reduce the potential for improperly installed systems, and assure product quality and performance.

In order for a national GHP certification standard to be effective, it must be overwhelmingly accepted by industry stakeholders to consistently reflect the real-world circumstances that result in reliable and high-performance geothermal heating and cooling systems. Consumers can trust that personnel who meet the standard are highly qualified industry professionals who can be relied upon to provide them with promised results. GHP industry participants must agree that the standard adequately represents qualifications relevant to their respective GHP responsibilities. Federal and State regulators can have confidence that the standard supports their ability to protect the public and the environment. The following objectives provide a collaborative methodology to accomplish these needs.

- Develop a conceptual foundation for the standard from market research that identifies the characteristics of standards that increase customer confidence and result in predictable performance of designated professionals.
- Identify underlying causes of GHP system successes and failures by researching and investigating existing GHP systems. Identify the roles played by each trade and categorize knowledge elements and working relationships that contribute to success. Define best practices and criteria in the design and installation of GHP systems, as well as qualification requirements for each trade involved in GHP projects, to provide a basis for design of qualifications incorporated into the standard.
- Create collaborative consensus around criteria for standards for each trade involved in GHP system design, installation, commissioning, operation and maintenance, by soliciting information and input from a wide variety of stakeholders, including GHP customers, government regulators, designers, installers, heat pump and auxiliary equipment manufacturers, utilities and professional and trade organizations.

2.0 Scope

This standard addresses applicable qualifications for all primary personnel involved in the design, installation, commissioning, operation and maintenance of GHP systems, including their knowledge, skills and abilities. Curriculum development, training and certification are not included in the scope of this project, but are briefly addressed below to describe ways in which the standard developed in this project may form a foundation to support further progress in accomplishing those other efforts. Follow-on efforts may use the standard developed in this project as a basis for developing curriculum and training programs to further accomplish the objectives of this project. Further, the standard does not separately address the technical specifications associated with the actual design and operation of GHP systems, but *Appendix B – Related Resources* provides some relevant references.

2.1 **Curriculum Development and Training**

Development of curriculum and training materials for GHP certification programs should meet or exceed established industry minimum requirements and address knowledge requirements relevant to the associated GHP discipline(s), including training components such as training session length, material to be covered in class or outside of class, allocation of training coverage devoted to specific topics, utilization of hands-on exercises, and minimum acceptable testing and assessment methods, in addition to qualification of instructors.

2.2 **Certification Programs**

GHP certification programs may be delivered by organizations relevant to the scope of the associated certification program, and may group individual professional disciplines together to form classifications that are relevant to real-world circumstances for the design, installation, commissioning, operation and maintenance of different size GHP systems. For example, a "Residential GHP Professional" certification might be associated with a training program designed to address the personnel qualifications appropriate for the "Looper" and "Mechanical System Installer" disciplines.

Certification programs should clearly define the scope of any certification, including any specification of the level of the certification and progression between related certification levels. Applicant work experience and prerequisite certifications and licenses should be documented, and associated testing should demonstrate the knowledge, skills and abilities required for all of the applicable individual disciplines. Maintenance of certification should include minimum reassessment methods and continuing education/training requirements, as well as well-defined processes for revocation of certification.

2.3 **How to Use the National Certification Standard for Ground Source Heat Pump Personnel**

The following sequence illustrates how this standard might be employed as the foundation for training and certification programs.

An industry organization or government agency:

2.3.1 Determines that the development of a certification program serves the best interests of a defined population that they serve
2.3.2 Determines which facet(s) of GHP systems are appropriate for their defined audience
2.3.3 Selects the applicable set of individual disciplines from the standard
2.3.4 Identifies the personnel qualifications for the relevant disciplines
2.3.5 Develops a curriculum to provide the requisite knowledge, skills and abilities
2.3.6 Develops a training program to deliver the curriculum
2.3.7 Develops appropriate testing to assess trainee understanding
2.3.8 Develops a certification program in accordance with the ISO 17024 standard or another industry-recognized protocol
2.3.9 Implements the training and certification programs

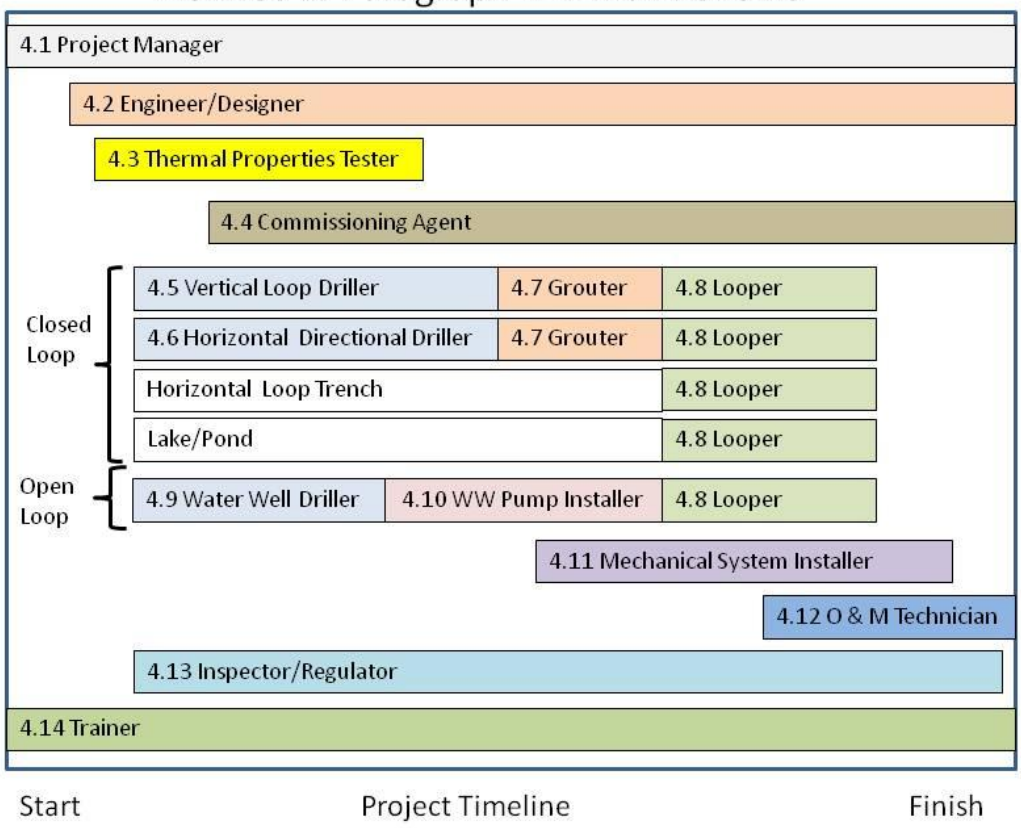
3.0 Introduction

Personnel qualifications apply to each separately identifiable task undertaken in the design, installation, commissioning, operation and maintenance of a GHP system, and are associated with a professional discipline performed by the person(s) who accomplish each task. Depending on the specific circumstances of each GHP project, various tasks may be accomplished by the same person. In order to make the standard useful in actual GHP project settings, training and certification processes that use the standard as a foundation may combine tasks into broader certification classifications.

In order to accomplish assigned tasks for a GHP system, various GHP disciplines may require underlying prerequisite certifications and/or licenses for conventional facility, mechanical system and/or drilling/excavation assignments. Then, additional GHP-unique qualifications may be applicable. This standard is structured to identify the underlying qualifications as well as the additional GHP-related qualifications.

Figure 3.1 below portrays a simplified example of typical relationships between the various individual disciplines generally utilized during the course of GHP projects in the following order: site analysis, design, licensing and permits, construction, system start-up and commissioning, system performance evaluation, maintenance and operation.

Figure 3.1 GHP Personnel Qualifications Defined in Paragraph 4 Which Follows



3.1 **Personnel Responsibilities and Attributes**

In addition to the section 4.0 qualifications for each professional discipline involved in the design, installation, commissioning, operation and maintenance of GHP systems, all positions share responsibilities and attributes generally accepted as essential to the successful performance of their assigned tasks.

3.1.1 **Safety**

3.1.1.1 Working knowledge of Occupational Safety and Health Administration (OSHA) requirements and guidelines relative to the workplace
3.1.1.2 Knowledge of relevant equipment, policies, procedures, and strategies to promote effective local, state, or national security operations for the protection of people, property, and institutions
3.1.1.3 Knowledge of applicable personal safety equipment, for example hard hats, ear protection, eye protection and other supplemental safety equipment appropriate to the work environment
3.1.1.4 Knowledge of ground water quality protection and preservation requirements for the installation of ground heat exchangers.

3.1.2 **Code of Ethics**

3.1.2.1 Comply with a recognized code of ethics in conjunction with the related certification process

3.1.3 **Code of Standard Business Practices**

3.1.3.1 Ability to effectively and professionally communicate with all involved stakeholders
3.1.3.2 Knowledge of business and management principles involved in planning, resource allocation, human resources, leadership techniques, production methods, and coordination of people and resources applicable to assigned duties
3.1.3.3 Well versed in the requirements and enforcement processes of local, state and federal building codes and regulations governing ground water and its protection, design, installation, commissioning, operation and maintenance of ground source heat pump systems applicable to assigned duties
3.1.3.4 Maintenance of insurance policies appropriate to assigned duties

4.0 Personnel Qualifications

Personnel qualifications are detailed for individual disciplines applicable to the design, installation, commissioning, operation and maintenance of ground source heat pump systems. Depending on the size, scope and type of system, some personnel may perform one or more of the identified disciplines, and/or not all disciplines may be applicable to any given project. Qualifications include the following components:

- Description – describes the nature of the job, specifies the scope of the position, and identifies other jobs that directly interface with it
- Certifications and Licenses – official recognition by an applicable regulatory agency or organization of well-defined aptitudes defined by a published set of criteria relating to underlying capabilities that are necessary but not sufficient for the design, installation, commissioning. operation and maintenance of ground source heat pump systems
- Knowledge – includes understanding of principles and practices, as evidenced by the following:
  - Education and Training – formal classroom and/or on-the-job learning taught by recognized experts in a given field of study
  - Experience – application of skills and abilities in actual situations relevant to assigned duties
- Skills and Abilities - A proficient worker possesses key skills and abilities that influence job success:
  - Skills are developed through experience and training and may apply to a wide range of tasks; proper skills enable workers to perform their tasks with precision and quality
  - Abilities are more fundamental than knowledge and skills; they represent underlying, enduring traits, both cognitive and physical, that support the successful performance of a wide range of job tasks

The following paragraphs detail personnel qualifications for individual disciplines relevant to the design, installation, commissioning, operation and maintenance of ground source heat pump systems, as depicted in Figure 3.1:

4.1 Ground Source Heat Pump System Project Manager
4.2 Ground Source Heat Pump System Engineer/Designer
4.3 Geological Formation Thermal Properties Tester
4.4 Ground Source Heat Pump System Commissioning Agent
4.5 Vertical Loop Driller
4.6 Horizontal Directional Driller
4.7 Ground Heat Exchanger Grouter
4.8 Ground Heat Exchanger Looper
4.9 Ground Source Heat Pump System Water Well Driller
4.10 Ground Source Heat Pump System Water Well Pump Installer
4.11 Ground Source Heat Pump Mechanical System Installer
4.12 Ground Source Heat Pump System Operations/Maintenance Technician
4.13 Ground Source Heat Pump System Inspector/Regulator
4.14 Ground Source Heat Pump System Trainer

4.1 GROUND SOURCE HEAT PUMP SYSTEM PROJECT MANAGER (See Figure 3.1 - PROJECT MANAGER)

4.1.1 **Description** - The Ground Source Heat Pump System Project Manager is responsible for overall management of all aspects of the ground source heat pump (GHP) system project, consisting of, but not be limited to, all aspects of the design, installation, commissioning, operation and maintenance, regulation, and industry best practices relative to the entire system including the ground heat exchange system and the Heating, Ventilation and Air Conditioning (HVAC) system.

Associated tasks are performed by all relevant positions for applicable projects.

4.1.2 **Prerequisite Certifications and Licenses**

4.1.2.1 Professional Engineer's license, architects license, contractor's license, or other seasoned professionals from the GHP industry

4.1.2.2 Other third party nationally recognized certification program, e.g., the International Ground Source Heat Pump Association (IGSHPA) Accredited Installer or Certified GeoExchange Designer (CGD)

4.1.3 **Knowledge**

4.1.3.1 Fundamental knowledge of and ability to assess site geology as it relates to the GHP system design

4.1.3.2 Working knowledge of soil removal, remediation, and/or replacement requirements

4.1.3.3 Fundamental knowledge and ability to review annual load calculations.

4.1.3.4 Basic knowledge of mechanical systems, including their designs, uses, maintenance and regulation

4.1.3.5 Familiarity with ground heat exchanger materials and joining processes (e.g., high density polyethylene (HDPE) fusion joining), IGSHPA *Closed-Loop/Geothermal Heat Pump Systems Design and Installation Standards*, and National Ground Water Association (NGWA) *Guidelines for the Construction of Loop Wells for Vertical Closed Loop Ground Source Heat Pump Systems*

4.1.3.6 Basic understanding of building energy management and control systems

4.1.3.7 Knowledge of engineering mathematics, algebra and trigonometry

4.1.3.8 Thorough knowledge of the content of current building codes and standards, as well as appropriate texts, guidelines, standards, and best suggested practices of organizations such as the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), the International Ground Source Heat Pump Association, the National Ground Water Association, the United States Environmental Protection Agency, and the Occupational Safety and Health Administration

4.1.3.9 Site Assessment Phase

4.1.3.9.1 Understand the Phase I Environmental Site Assessment (ESA) process and reporting requirements and Phase II (if required) for contaminated sites

4.1.3.9.2 Understand the federal, state and local codes as they relate to the design and installation of ground heat exchangers

4.1.3.9.3 Understand the federal, state and local codes for the installation of groundwater production and injection wells

4.1.3.10 **Education and Training**

4.1.3.10.1 Four-year college degree in a related technical field or meet one of the following qualifications:

4.1.3.10.1.1 Four-year, non-technical degree with five years combined experience in commercial GHP system design and/or heating, ventilation and air conditioning; or

4.1.3.10.1.2 Two-year technical degree with eight years of combined experience in commercial GHP system design and/or heating, ventilating and air conditioning; or

4.1.3.10.1.3 Ten years or more of combined experience in commercial GHP design and/or heating, ventilating and air conditioning

4.1.3.10.2 Four years of additional education or field experience in project or construction management. Additional courses in Phase I and II Site Assessment and System Commissioning

4.1.3.10.3 Supplemental education in geology, design of ground heat exchangers, mechanical systems, groundwater production and return well specification and codes and standards applicable to ground heat exchanger design

4.1.3.10.4 Job Training

4.1.3.10.4.1 Extensive training in ground heat exchanger design, vertical loop drilling techniques, system commissioning and other related subjects to provide cradle-to-grave oversight of a project

4.1.3.10.4.2 GHP Project Managers learn the basis of the technology and its many design elements through experience and networking with peers

4.1.3.11 **Experience** – See applicable requirements in paragraph 4.1.3.10 above

4.1.4 **Skills and Abilities**

4.1.4.1 Ability to effectively and professionally facilitate communication between all positions relevant to each project

4.1.4.2 Computer and/or calculator skills appropriate to assigned duties

4.1.4.3 Site Assessment Phase

4.1.4.3.1 Evaluate site for all open and closed loop configurations and provide site-specific options

4.1.4.3.2 Provide guidance and oversight of site feasibility assessment, feasibility studies and preliminary building energy calculations

4.1.4.4 Design Phase

4.1.4.4.1.1 Oversee GHP system design by GHP Engineer / Designer to ensure compliance with industry best practices codes, standards and owner expectations

4.1.4.4.1.2 Ensure ground heat exchanger design does not conflict with site assessment findings and complies with all requirements

4.1.4.4.1.3 Provide peer review of applicable GHP construction drawings, calculations, and specifications

4.1.4.4.1.4 Coordinate GHP construction drawings with civil and architectural drawings and resolve conflicts

4.1.4.4.1.5 Review engineering cost estimates for system installation

4.1.4.5 Construction Phase

4.1.4.5.1 Provide review of submittals, substitutions, construction change orders, requests for information (RFIs) as needed to assist GHP Engineer / Designer

4.1.4.5.2 Coordinate work with other site trades, building trades, and the general contractor

4.1.4.5.3 Provide site visits (observations) as required during ground heat exchanger installation, mechanical equipment installation and/or mechanical system start-up, controls installation, test and balance, and system commissioning

4.1.4.5.4 Generate construction punch list

4.1.4.5.5 Ensure building owner receives record drawings, operation and maintenance manuals, test results and other relevant documentation to close-out project

4.1.4.5.6 Assure that owners operating personnel fully understand the design intent and operation of the system

4.2 GROUND SOURCE HEAT PUMP SYSTEM ENGINEER / DESIGNER (See Figure 3.1 – ENGINEER / DESIGNER)

4.2.1 **Description –** The Ground Source Heat Pump System Engineer / Designer is responsible for the design and specification of the ground source heat pump (GHP) system including site evaluation, the ground heat exchanger or open loop well(s) and related open loop supply, return and/or standing column well(s), including physical location(s), and the balance of the GHP system

Associated tasks are performed by all positions relevant to the specific project.

4.2.2 **Prerequisite Certifications and Licenses**

4.2.2.1 Engineer: professional engineering licensure in the state having jurisdiction

4.2.2.2 Designer: as required by the applicable jurisdiction

4.2.3 **Knowledge**

4.2.3.1 Well-versed in traditional mechanical system design and installation in addition to GHP systems as a subset of a larger mechanical systems expertise

4.2.3.2 Knowledge of building energy usage, ground heat exchanger design and installation system hydraulics, and basic geology in addition to the traditional subset of mechanical systems design

4.2.3.3 Knowledge of refrigeration, machines, motors and tools, including their designs, uses, repair and maintenance

4.2.3.4 Understanding of thermostatic controls for residential and commercial applications and a more detailed understanding of building energy management systems and control logic for non-residential applications

4.2.3.5 Knowledge of drilling and preservation of ground water quality

4.2.3.6 Knowledge of soil removal, remediation, and/or replacement requirements

4.2.3.7 Understand federal, state and local codes as they relate to the design and installation of ground heat exchangers

4.2.3.8 Understand federal, state and local codes for the installation of water production and injection wells

4.2.3.9 Understanding of ANSI/AHRI/ASHRAE ISO Standards 13256-1 and 13256-2 and methodologies for analyzing GHP system performance

4.2.3.10 Well-versed in the profession's standard of care defined by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), International Ground Heat Pump Association (IGSHPA), and/or other applicable governing bodies

4.2.3.11 Knowledge of engineering mathematics, algebra and trigonometry

4.2.3.12 **Education and Training**

4.2.3.12.1 Supplemental education in drilling techniques, geology, design of ground heat exchangers, water well specification, injection well specification and local codes and standards governing various ground heat exchanger designs

4.2.3.12.2 Engineer: Possess the necessary credentials for professional engineering licensure in the applicable jurisdiction. Supplemental education in building commissioning and validation, drilling techniques, geology, design of ground heat exchangers, water well

specification, water return well specification and local codes and standards governing ground heat exchanger design. Additional training in life cycle cost analysis.

4.2.3.12.3 Designer: Four-year college degree in a related occupational field or meet one of the following qualifications:

4.2.3.12.3.1 Four-year, non-technical degree with five years combined experience in commercial GHP system design and/or heating, ventilation and air- conditioning

4.2.3.12.3.2 Two-year technical degree with eight years of combined experience in commercial GHP system design and/or heating, ventilation and air- conditioning

4.2.3.12.3.3 Ten years or more of combined experience in commercial GHP system design and/or heating, ventilation, and air conditioning

4.2.3.12.3.4 Additional training in life cycle cost analysis.

4.2.3.13 **Experience** – see applicable requirements in paragraph 4.2.3.12 above

4.2.4 **Skills and Abilities**

4.2.4.1 Provide a site feasibility assessment to include environmental considerations, site geology, alternative ground-coupling techniques, and drilling and ground-coupling installation techniques

4.2.4.2 Prepare specifications for test wells or boreholes and oversee installation for same

4.2.4.3 Oversee and review the results of performance testing, for example draw down testing for water production, testing for water return wells, and thermal conductivity and thermal resistance testing of ground heat exchangers

4.2.4.4 Prepare heating and cooling load calculations and energy simulation models which appropriately simulate the energy usage of a ground source heating and cooling system

4.2.4.5 Exhibit proficiency in the Air Conditioning Contractors of America (ACCA) Manual J and Manual N and bin analysis for residential and commercial buildings and peak load calculations and hourly analysis using industry-recognized software packages

4.2.4.6 Provide detailed design and construction documents and/or scopes of work to install a complete ground source heating and cooling system, including sizing of the ground heat exchanger

4.2.4.7 Specify the mechanical system for the delivery of heating and cooling energy within the building including, but not limited to: duct design and hydraulic design of pumps and piping systems

4.2.4.8 Provide system control specifications, system and equipment sequence of operation, and control algorithms

4.2.4.9 Oversee the installation of ground heat exchanger, mechanical equipment and start-up per manufacturer's guidelines

4.2.4.10 Purge and flush the complete ground heat exchanger system

4.2.4.11 Specify the installation of GHP-related water lines, air ducts and vents, circulation pumps, and other components such as cooling towers, expansion tanks and other piping specialties

4.2.4.12 Integrate ground heat exchanger and heat pump equipment with the appropriate distribution system, for example: ductwork, fan coils, radiant heating and cooling systems, domestic hot water heating system, process piping, etc.

4.2.4.13 Integrate GHP system with other renewable energy system such as solar thermal and energy recovery equipment
4.2.4.14 Provide review of submittals, substitutions, construction change orders, requests for information (RFI) as needed.
4.2.4.15 Specify and review the initial testing and balancing of the system (air side and water side) to make sure the system is functioning properly
4.2.4.16 Review final system commissioning and validation report
4.2.4.17 Provide post-construction validation services to assure conformity to the design intent
4.2.4.18 Provide and/or specify system training for the owner or owner's representative
4.2.4.19 Generate detailed design and construction documents in accordance with Section 5 of the most current edition of IGSHPA *Closed-Loop/Geothermal Heat Pump Systems Design and Installation Standards* or other applicable standards
4.2.4.20 Design pumping systems, including
4.2.4.20.1 Calculation of field and building head losses
4.2.4.20.2 Accurately size required circulating pumps
4.2.4.20.3 Properly schedule applicable variable frequency drive (VFD) controls so as not to expend unnecessary pumping energy during off-peak conditions
4.2.4.21 Computer and/or calculator skills appropriate to assigned duties

4.3 GEOLOGICAL FORMATION THERMAL PROPERTIES TESTER (See Figure 3.1 – THERMAL PROPERTIES TESTER)

4.3.1 **Description** - The Geological Formation Thermal Properties Tester is responsible for testing and/or analyzing the physical properties of geological formations surrounding a horizontal or vertical closed loop 'test' ground heat exchanger in accordance with industry accepted thermal testing standards. Within this job, there are two related job functions: 1) setting up and performing the test; and 2) analyzing the results of the test for the Engineer / Designer's use.

Associated tasks are performed by the Looper and/or Engineer / Designer to design a closed-loop or standing column well ground heat exchanger.

4.3.2 **Prerequisite Certifications and Licenses**

4.3.2.1 Certification from test equipment supplier

4.3.3 **Knowledge**

4.3.3.1 Knowledge of machines, motors and tools, including their designs, uses, repair, and maintenance

4.3.3.2 For the testing stage, full understanding of the mechanical operation, the testing apparatus and the software supporting the data logging, acquisition, device, and the requirements of applicable testing procedures and standards

4.3.3.3 For the data analysis phase, knowledge of computer system operations, data logging software and data reduction of collected information

4.3.3.4 Knowledge of arithmetic and algebra

4.3.3.5 **Education and Training**

4.3.3.5.1 High school diploma or equivalent

4.3.3.5.2 Training in the operation, repair, calibration, installation and monitoring of the testing apparatus

4.3.3.5.3 For data analysis, an engineering degree from an accredited university with a background in heat transfer and line source theory, or comparable training on applicable software and design manuals.

4.3.3.6 **Experience**

4.3.3.6.1 One year of training by on-the-job work with experienced GHP employees

4.3.3.6.2 For data analysis, experience using line source theory or comparable experience with applicable software and design manuals.

4.3.4 **Skills and Abilities**

4.3.4.1 Determine thermal properties of formations from short term (~48 hour) field test of previously installed vertical ground heat exchangers using the following tasks/and or skills:

4.3.4.2 Computer and/or calculator skills appropriate to assigned duties

4.3.4.3 Testing Phase

4.3.4.3.1 Maintain calibration of equipment used in performing geological formation thermal properties test such as temperature sensors, circulating pumps, heating elements, flow and power meters

4.3.4.3.2 Ensure operation of mechanical equipment in accordance with manufacturer's specifications, such as pumps, valves, water heaters and generators, and electronic equipment related to collection and storage of monitored field data

4.3.4.3.3 Collect and report relevant data regarding the drilling operation, including but not limited to, drilling logs, methodology and equipment

4.3.4.3.4 Communicate with ground heat exchanger installer to document ground heat exchanger depth, nominal loop assembly size (e.g., ¾" SDR-11) and material (e.g., high density polyethylene, etc.), and characteristics of grout (type and mixing and placing requirements)

4.3.4.3.5 Operate test apparatus in accordance with methods specified in the current American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), Heating, Ventilation, and Air Conditioning (HVAC) *Applications Handbook on Geothermal Energy Utilization*

4.3.4.4 Analysis Phase

4.3.4.4.1 Analyze test data in accordance with methods specified in the current ASHRAE HVAC *Applications Handbook on Geothermal Energy Utilization* to determine, at a minimum, deep earth temperature and geological formation thermal conductivity. Other parameters such as thermal diffusivity and ground heat exchanger thermal resistance may be determined as well

4.3.4.4.2 Prepare a report including items identified in the most current edition of the International Ground Source Heat Pump Association (IGSHPA) *Closed-Loop/Geothermal Heat Pump Systems Design and Installation Standards*

4.4 GROUND SOURCE HEAT PUMP SYSTEM COMMISSIONING AGENT (See Figure 3.1 – COMMISSIONING AGENT)

4.4.1 **Description** – The Ground Source Heat Pump System Commissioning Agent is responsible for verifying that the ground source heat pump (GHP) system is designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent and owner's project requirements. The activities of the Commissioning Agent include the technical review of the design, construction, and acceptance of the GHP system.

Associated tasks are performed by the Project Manager, Engineer / Designer, Mechanical System Installer and Inspector / Regulator positions.

4.4.2 **Prerequisite Certifications and Licenses**

4.4.2.1 Certifications and licenses required by applicable regulatory agencies, in addition to one or more of the following:

4.4.2.1.1 A Professional Engineering license

4.4.2.1.2 Commissioning certification through ASHRAE, Associated Air Balance Council Commissioning Group (ACG), Building Commissioning Association (BCA), national Conference on Building Commissioning (NCBC), National Environmental Balancing Bureau (NEBB) or other qualified organization with a recognized certification program

4.4.2.1.3 IGSHPA Accredited Installer or Association of Energy Engineers (AEE) Certified GeoExchange Designer (CGD) certification or other third party nationally recognized certification program

4.4.2.1.4 For open loop ground heat exchanger systems, NGWA or other third-party nationally recognized water well construction and/or water well pumping system certification

4.4.3 **Knowledge**

4.4.3.1 Knowledge of building O&M training and Test, Adjust and Balance (TAB) of both air and water system, and knowledge of the design, installation, control, and operation of GHP systems

4.4.3.2 Knowledge of tools and testing equipment typically utilized in commissioning processes

4.4.3.3 Well-versed in mechanical codes and standards relevant to building construction, the GHP industry and their local jurisdiction

4.4.3.4 Strong background in college level mathematics including algebra, geometry and calculus

4.4.3.5 Good knowledge of the current building codes and standards, ASHRAE, IGSHPA, NGWA and Occupational Health and Safety Administration (OSHA) guidelines relative to the job site

4.4.3.6 **Education and Training -** Other training, past commissioning experience and field experience may be substituted in lieu of the education requirement.

4.4.3.6.1 Bachelor's degree in engineering or other applicable discipline

4.4.3.6.2 GHP-specific training or certification provided through the International Ground Source Heat Pump Association (IGSHPA), the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), the National Ground Water Association (NGWA), or other recognized third-party certification program

4.4.3.6.3 Training in mechanical codes and standards provided through the Sheet Metal and Air Conditioning Contractors Association (SMACNA), Air Conditioning Contractors of America (ACCA), the American Society of Mechanical Engineers (ASME), and American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), or other recognized organization

4.4.3.7 **Experience**

4.4.3.7.1 Design or construction experience with GHP systems

4.4.3.7.2 A strong background in building energy management and control systems

4.4.3.7.3 Basic data collection experience is also beneficial to this position

4.4.3.7.4 Breadth of system experience such that they can easily understand and manipulate operational parameters of a GHP system to assure highly efficient and low maintenance operation.

4.4.3.7.5 Experience operating and troubleshooting heating, ventilating and air conditioning (HVAC) systems, building energy management and control systems, and other systems related to the GHP system

4.4.3.7.6 Experience with tools and testing equipment typically utilized in commissioning process

4.4.4 **Skills and Abilities**

4.4.4.1 Ability to work in both indoor and outdoor environments, exposed to the environment of construction fields such as inclement weather including heat and cold, wind, rain, fog, and sun, as well as some exposure to hazardous conditions related to operation of mechanical and electrical equipment and/or movement of heavy objects, contact with drilling, grouting, and related chemicals

4.4.4.2 Strong organizational skills and the ability to focus on the finer details of an installation

4.4.4.3 Computer and/or calculator skills appropriate to assigned duties

4.4.4.4 Design & Programming Phase

4.4.4.4.1 Ability to develop the Commissioning Plan, from design review through final acceptance, including activities required to support the process and schedule

4.4.4.4.2 Ability to develop the Commissioning Specification, which is the document that stipulates what testing will be done and by whom, when, and with what supervision.

4.4.4.4.3 Ability to develop tracking documentation forms that are specific to the project

4.4.4.4.4 Verify that the design review process accommodates commissioning, including verifying that the design will achieve the design intent, that the schedule allows commissioning, and that the documents include the commissioning process

4.4.4.4.5 Assist the GHP Engineer in developing a Basis of Design and Owner's Performance Requirements (OPR) Documents, and verify that the delivered design complies with these documents

4.4.4.4.6 Review the design documents as they are developed, including progress reviews for design, development and construction documents in order to ensure commissionability and to ensure that the documents meet the OPR and contain adequate information and detail for proper construction

4.4.4.4.7 Report any noted design document deficiencies to the design team for correction or modification

4.4.4.5 Construction Phase

4.4.4.5.1 Develop and utilize a construction phase commissioning plan

4.4.4.5.2 Form a commissioning team (per commissioning plan) and hold a commissioning kickoff meeting to review the commissioning plan and roles and responsibilities of the team. Hold subsequent commissioning meetings on an as-needed basis

4.4.4.5.3 Keep the commissioning plan synchronized with the design changes that occur during the construction process

4.4.4.5.4 Review submittals of commissioned systems for commissionability, and conformance with the basis of design. The GHP Engineer or engineer of record has primary submittal approval authority

4.4.4.5.5 Observe construction and installation of GHP systems. Key inspections would typically include the following. If physical inspections are not possible, ensure that the contractor has properly documented the procedures with installation/test procedures and photographs observed by the GHP Project Manager or construction manager.

4.4.4.5.5.1 For vertical loop installations, observe installation of vertical loop and grouting procedures to ensure proper methods and procedures are followed

4.4.4.5.5.2 Observe installation of horizontal loop (as applicable) and loop installation (headering) prior to backfill to ensure installation meets specifications and industry standards.

4.4.4.5.5.3 Observe installation of any above ceiling, or behind wall installations prior to the ceiling tile or wall enclosure

4.4.4.5.5.4 Observe flushing and purging of loop

4.4.4.5.5.5 Observe in-progress and final ground heat exchanger pressure testing.

4.4.4.5.6 Develop or review contractor's installation, pre-start-up and start-up documentation forms (pre-functional test forms). Approval all forms prior to contractor execution.

4.4.4.5.7 Observe startup of key GHP system components

4.4.4.5.8 Approve Test, Adjust and Balance (TAB) plan and procedure, and observe and verify proper TAB procedures per specification requirements

4.4.4.5.9 Coordinate Operations and Maintenance (O&M) training plan for the Owner's staff by the installation team

4.4.4.5.10 Review the tests that have been done (TAB, automatic control system tests, etc.) and carefully evaluate that everything, including the controls, works under all foreseeable operating conditions

4.4.4.5.11 Collect and review all commissioned systems pre-functional test procedure forms for accuracy and completeness prior to functional performance verification. Verify that completion of the pre-functional performance tests were in a logical, systematic fashion

4.4.4.5.12 Create and maintain a systems deficiency log to be provided to the members of the commissioning team for issues resolution

4.4.4.6 Acceptance Phase

4.4.4.6.1 Conduct functional performance verification testing to ensure that each subsystem is performing according to the design intent. Functional testing should be done for all modes of operation, including simulated full load as practical, part load, power failure, etc. Reverse season test may be required to verify full load testing procedures

4.4.4.6.2 Review the tests that have been done (TAB, automatic control system tests, etc.) and carefully evaluate that everything, including the controls, works under foreseeable operating conditions

4.4.4.6.3 Anticipate, identify and evaluate probable out-of range feedback conditions and evaluate impacts and corrective actions
4.4.4.6.4 Update issues resolution log
4.4.4.6.5 Complete final commissioning report, which includes:
4.4.4.6.5.1 The final Commissioning Plan
4.4.4.6.5.2 A complete record of all pre-functional tests, equipment startups, and functional performance verification tests
4.4.4.6.5.3 Recommendations for acceptance, or otherwise, the conditions that must be met before acceptance can be recommended
4.4.4.6.6 Complete the systems manual and record documentation and provide documentation to the Owner and Design Team
4.4.4.6.7 Oversee and/or train operation and maintenance staff prior to occupancy of the building

4.5 VERTICAL LOOP DRILLER (See Figure 3.1 - VERTICAL LOOP DRILLER)

4.5.1 **Description** - The Vertical Loop Driller is responsible for construction of loop wells for vertical ground heat exchangers, providing a closed-loop system for heat exchange with the earth while protecting surrounding groundwater resources from contamination. The Vertical Loop Driller is involved in the planning, execution and management of all phases of any vertical loop installation. The Vertical Loop Driller also provides technical support to clients and other crew members at the well-site. The Vertical Loop Driller must also be aware of applicable regulations governing the drilling process, as well as interference with buried utilities and other underground structures. Many of the training and skills required of the Vertical Loop Driller are transferrable from related drilling operations required for water wells, environmental monitoring wells, geotechnical bores, seismic, shallow oil and gas drilling, and other comparable operations. The functions should not be confused with those of a Water Well Driller.

Associated tasks are performed by the Engineer / Designer, Grouter and Looper positions.

4.5.2 **Prerequisite Certifications and Licenses**

4.5.2.1 Certifications and/or licenses required by state and local regulatory agencies

4.5.3 **Knowledge**

4.5.3.1 Knowledge of applicable codes and regulations that pertain to vertical ground heat exchanger design and construction

4.5.3.2 Knowledge of GHP system installation

4.5.3.3 Knowledge of geology and hydrology

4.5.3.4 Knowledge of drilling fluids and fluid additives and their resulting effects on fluid dynamics, viscosity and weights as necessary for maintaining and stabilizing a clean borehole

4.5.3.5 Knowledge of machines and tools, including their designs, uses, repair, and maintenance

4.5.3.6 Working knowledge of applicable National Ground Water Association standards, guidelines, and suggested best practices; and International Ground Source Heat Pump Association standards

4.5.3.7 Knowledge of business and management principles involved in planning, resource allocation, human resources, leadership techniques, production methods, and coordination of people and resources

4.5.3.8 Knowledge of arithmetic, algebra and geometry

4.5.3.9 **Education and Training**

4.5.3.9.1 High school diploma or equivalent, or applicable on-the-job training

4.5.3.9.2 Applicable regulatory agency education and training

4.5.3.10 **Experience**

4.5.3.10.1 Minimum of two years of relevant experience working with an experienced vertical ground heat exchanger driller, for example as a driller's helper, or successful completion of an applicable recognized apprenticeship program or its formal equivalent

4.5.4 **Skills and Abilities**

4.5.4.1 Read and understand design drawings and specifications

4.5.4.2 Review client requirements and proposed locations for drilling operations to determine feasibility, and to determine cost estimates

4.5.4.3 Review proper setback requirements between onsite utilities and the ground loop heat exchange system above and below ground

4.5.4.4 Select the appropriate drilling methodology for the geologic conditions, using knowledge of rock or soil characteristics, depths and formations

4.5.4.5 Per applicable regulatory requirements and client and contract specifications, develop and maintain a log to record observations of cuttings for geological data, drilling techniques, materials used, drilling progress and required fluids, taking particular note of any special drilling conditions such as lost returns, tool drops, and unexpected down hole conditions

4.5.4.6 Regulate and supervise the drilling process based on the drill type and geologic conditions

4.5.4.7 Drive or guide motorized vehicle-mounted and trailer-mounted equipment into position, level and stabilize drilling machine, and extend derricks of drilling machine

4.5.4.8 Operate drill rig in accordance with job requirements and industry practice, including regulating air pressure, pump pressure, rotary speed, and downward drill bit pressure, according to the type of material being drilled

4.5.4.9 Verify depths and alignments of drilled boreholes so as to avoid interference with other boreholes

4.5.4.10 Monitor drilling operations, checking gauges and listening to operating equipment to assess drilling conditions and to determine the need to adjust or alter drilling equipment and parameters, including air or pump pressure, rotary speed and downward pressure or change the properties of the drilling fluid being used

4.5.4.11 Circulate approved fluids into boreholes as needed to cool drill bits, remove cuttings, stabilize borehole and maintain design borehole diameter using industry acceptable tools and procedures

4.5.4.12 Operate controls to stabilize machines and to position and align drills

4.5.4.13 Select, prepare and attach drill bits and drill rods, adding more rods as borehole depths increase, and changing drill bits as needed

4.5.4.14 Operate machines to maintain borehole diameter and flush earth cuttings or to remove debris from boreholes

4.5.4.15 Start, stop, and control drilling speed of machines

4.5.4.16 Assemble and install temporary or permanent well casing as required by borehole conditions and regulatory requirements

4.5.4.17 Withdraw drill rods from boreholes and extract core samples

4.5.4.18 Retrieve lost equipment from boreholes, using retrieval tools

4.5.4.19 Pressure test loop assembly prior to insertion into borehole

4.5.4.20 Install loop assembly into borehole with tremie pipe secured near the u-bend for grouting of borehole where required

4.5.4.21 Assist with or operate machines to mix and emplace grout

4.5.4.22 Understand different grout emplacement ratios and their resulting thermal conductivities

4.5.4.23 Oversee and coordinate with others to complete and grout loop assembly

4.5.4.24 Undertake drilling disinfection procedures

4.5.4.25 Maintain, assemble and position drilling machines, drilling tools, casing, and other equipment, using hand and power tools

4.5.4.26 Conduct preventive maintenance and equipment repairs as appropriate

4.5.4.27 Manage and dispose of drill cuttings and drilling fluids as required by applicable regulations
4.5.4.28 Troubleshoot drilling problems encountered during drilling operations
4.5.4.29 Ensure timely and accurate fulfillment of all regulatory reporting requirements
4.5.4.30 Good mechanical aptitude and ability to work confidently with small tools and power tools
4.5.4.31 Communicate effectively with all involved stakeholders
4.5.4.32 Computer and/or calculator skills appropriate to assigned duties

4.6 HORIZONTAL DIRECTIONAL DRILLER (See Figure 3.1 – HORIZONTAL DIRECTIONAL DRILLER)

4.6.1 **Description** - The Horizontal Directional Driller is responsible for construction of horizontally bored ground loop heat exchangers, providing a closed-loop system for heat exchange with the earth while protecting surrounding groundwater resources from contamination. The Horizontal Directional Driller is involved in the planning, execution and management of all phases of horizontally bored ground loop heat exchanger installation. The Horizontal Directional Driller also provides technical support to clients and other crew members at the jobsite. The Horizontal Directional Driller must also be aware of applicable regulations governing the drilling process, as well as interference with buried utilities and other underground structures.

Associated tasks are performed by the Engineer / Designer, Grouter and Looper positions.

4.6.2 **Prerequisite Certifications and Licenses**

4.6.2.1 Certifications and/or licenses required by state and local regulatory agencies

4.6.2.2 Any applicable nationally recognized directional drilling third party certification program requiring continuing education

4.6.3 **Knowledge**

4.6.3.1 Knowledge of applicable codes and regulations that pertain to directional drilling ground loop heat exchanger design and construction

4.6.3.2 Knowledge of GHP system installation

4.6.3.3 Knowledge of geology and hydrology

4.6.3.4 Knowledge of state-of-the-art directional drilling techniques and all relevant surveying methods

4.6.3.5 Basic understanding of bore planning and the potential for intersection with other underground structures

4.6.3.6 Knowledge of machines and tools, including their designs, uses, repair, and maintenance

4.6.3.7 Working knowledge of applicable National Ground Water Association standards, guidelines, and suggested best practices; and International Ground Source Heat Pump Association standards

4.6.3.8 Knowledge of business and management principles involved in planning, resource allocation, human resources, leadership techniques, production methods, and coordination of people and resources

4.6.3.9 Knowledge of arithmetic, algebra and geometry

4.6.3.10 Education and Training

4.6.3.10.1 High school diploma or equivalent, or applicable on-the-job training

4.6.3.10.2 Applicable regulatory agency education and training

4.6.3.11 **Experience**

4.6.3.11.1 Minimum of two years of relevant experience working with an experienced horizontal directional ground loop heat exchanger driller, or successful completion of an applicable recognized apprenticeship program or its formal equivalent

4.6.4 **Skills and Abilities**

4.6.4.1 Read and understand design drawings and specifications
4.6.4.2 Review client requirements and proposed locations for drilling operations to determine feasibility and possible buried structure interference, and to determine cost estimates
4.6.4.3 Review proper setback requirements between onsite utilities and the ground loop heat exchange system above and below ground
4.6.4.4 Select the appropriate drilling equipment and tools for the geologic conditions, using knowledge of rock or soil characteristics, depths and formations
4.6.4.5 Per applicable regulatory requirements and client and contract specifications, develop and maintain a log to record observations of geological data, drilling techniques, materials used, drilling progress and required fluids, taking particular note of any special drilling conditions and unexpected borehole conditions
4.6.4.6 Regulate and supervise the drilling process based on the equipment type and geologic conditions
4.6.4.7 Drive or guide motorized vehicle-mounted and trailer-mounted equipment into position, level and stabilize drilling machine
4.6.4.8 Use location equipment to measure drilling progress and position of the drill in accordance with planned routing
4.6.4.9 Adjust the operation of the drilling machine to control the direction and penetration of the drill head
4.6.4.10 Adjust the drilling fluid to maintain proper chip removal, bit penetration and maintain the integrity of the borehole
4.6.4.11 Record drilling progress and collect, analyze and log geological data as required by project specifications and applicable regulations
4.6.4.12 Verify depths and alignments of boring positions
4.6.4.13 Monitor drilling operations, checking gauges and listening to operating equipment to assess drilling conditions and to determine the need to adjust or alter drilling equipment and parameters
4.6.4.14 Operate controls to stabilize machines and to position and align drills
4.6.4.15 Select, prepare and attach drill bits and drill rods, adding more rods as boring lengths increase, and changing drill bits as needed
4.6.4.16 Start, stop, and control drilling speed of machines as required
4.6.4.17 Withdraw drill rods from boreholes
4.6.4.18 Retrieve lost equipment from boreholes, using retrieval tools and equipment
4.6.4.19 Pressure test loop assembly
4.6.4.20 Install loop assembly into borehole with tremie pipe secured for grouting of borehole where required
4.6.4.21 Assist with and operate machines to mix and emplace grout when required
4.6.4.22 Oversee and coordinate with others to complete and grout loop assembly when required
4.6.4.23 Maintain, assemble and position machines, augers, casings, and other equipment, using hand and power tools
4.6.4.24 Maintain a complete listing of all directional tools and survey equipment on location and days on location
4.6.4.25 Conduct preventive maintenance and equipment repairs as appropriate
4.6.4.26 Manage and dispose of drill cuttings and drilling fluids as required by applicable regulations
4.6.4.27 Troubleshoot drilling problems encountered during drilling operations
4.6.4.28 Ensure timely and accurate fulfillment of all regulatory reporting requirements

4.6.4.29 Good mechanical aptitude and ability to work confidently with small tools and power tools
4.6.4.30 Communicate effectively with all involved stakeholders
4.6.4.31 Computer and/or calculator skills appropriate to assigned duties

4.7 GROUND HEAT EXCHANGER GROUTER (See Figure 3.1 - GROUTER)

4.7.1 **Description** - The Ground Heat Exchanger Grouter is responsible for the mixing and placement of grout through a tremie pipe to surround the loop assembly in a borehole, which comprises a ground heat exchanger. The Grouter mixes grout, in accordance with the manufacturer's instructions, in an appropriate mechanical mixer in accordance with the grout manufacturer's instructions, and ensures the proper placement of the grout from the bottom to the top of the borehole. The Grouter is also responsible for checking the grouted boreholes for subsidence of the grout and adding additional grout to the loop well if the grout level is not within specified limits of the top of the hole. This position is essential to protect the public safety of drinking water supplies and to ensure the proper performance of the ground heat exchanger.

Associated tasks are performed by the Vertical Loop Driller position.

4.7.2 **Prerequisite Certifications and Licenses** – none

4.7.3 **Knowledge**

4.7.3.1 Knowledge of engine-powered machines and tools, including their designs, uses, repair, and maintenance
4.7.3.2 Knowledge to calculate mix quantities and document the volume of grout placed in each application
4.7.3.3 Knowledge of arithmetic, algebra and geometry

4.7.3.4 **Education and Training**

4.7.3.4.1 High school diploma or equivalent, or applicable on-the-job training
4.7.3.4.2 Additional requirements of applicable jurisdictions

4.7.3.5 **Experience**

4.7.3.5.1 Minimum of one year of on-the-job working with an experienced closed loop driller or water well driller, which may be part of a recognized apprenticeship program for a Vertical Loop Driller or Water Well Driller

4.7.4 **Skills and Abilities**

4.7.4.1 Organize and inventory grouting materials in order to prepare for use
4.7.4.2 Operate purpose-designed machines to mix and/or emplace grout
4.7.4.3 Repair and maintain grouting equipment, using hand tools
4.7.4.4 Assist with insertion of loop assembly and tremie into borehole
4.7.4.5 Document the depth of borehole, loop assembly and tremie
4.7.4.6 Document the volume of grout placed in the loop well
4.7.4.7 Document the mix of the grout, recognizing the need for adding additional grout if settlement is greater than five feet during the time appropriate to the grout, or the locally specified or regulated level
4.7.4.8 Perform any tests on the grout as required in the job specifications, for example thermal conductivity tests and weighing grout
4.7.4.9 Collect and secure grout samples for lab testing as required in the job specifications

4.7.4.10 Clean-up work areas and remove debris after placement of grout during and after completion of loop well construction
4.7.4.11 Dismantle, clean, reassemble and maintain grouting equipment, using hand tools
4.7.4.12 Unload materials, devices and machine parts using appropriate tools
4.7.4.13 Ability to effectively and professionally communicate with the Vertical Loop Driller
4.7.4.14 Computer and/or calculator skills appropriate to assigned duties

4.8 GROUND HEAT EXCHANGER LOOPER (See Figure 3.1 - LOOPER)

4.8.1 **Description** - The Ground Heat Exchanger Looper is responsible for ensuring that the connection between the ground heat exchanger and mechanical equipment will function to manufacturer specifications throughout the manufacturer's projected product lifespan. This may include the installation of a surface water heat exchanger, horizontal trenched ground loop heat exchanger or the connecting (looping or headering) of a vertically drilled or horizontally bored ground loop heat exchanger. The primary focus of this position is the process of joining of approved loop assembly materials (for example, heat fusion of high density polyethylene pipe (HDPE)) and performing required tests to ensure the integrity of the final product.

Associated tasks are performed by the Mechanical System Installer position.

4.8.2 **Prerequisite Certifications and Licenses** – Certifications and licenses required by applicable jurisdictions, in addition to joining certification for the applicable materials used in the installation of the GHP system, for example:

4.8.2.1 High density polyethylene (HDPE) fusion certification through recognized union or industry organization or fusion equipment manufacturer or distributor

4.8.2.2 Direct exchange (DX) ground heat exchanger copper brazing and soldering certification as part of an accredited program such as the Northern American Technician Excellence (NATE)

4.8.2.3 Mechanical joining certification from the manufacturer of such joining systems

4.8.3 **Knowledge**

4.8.3.1 Understanding of plumbing and construction equipment and tools including their use, repair and maintenance

4.8.3.2 Understanding of the expansion and contraction characteristics of approved ground heat exchanger materials (e.g., HDPE, PEX, etc.) and methods to ensure appropriate material placement to mitigate the effects of thermal expansion and contraction within the ground heat exchanger

4.8.3.3 Understanding of headering and manifolding techniques that allow for loop well isolation and leak management

4.8.3.4 Basic knowledge of arithmetic and algebra

4.8.3.5 **Education and Training**

4.8.3.5.1 High school diploma or equivalent, or applicable on-the-job training

4.8.3.5.2 Job training – apprenticeship programs in career and technical schools, community colleges or manufacturer-related training programs

4.8.3.5.3 On-the-job training under experienced fusion technicians, formal instruction through career and technical institutions, training workshops through industry associations, manufacturers and/or product distributors. International Ground Source Heat Pump (IGSHPA) training, trade unions, or other third-party nationally recognized training program

4.8.3.6 **Experience**

4.8.3.6.1 Two years of relevant experience working with experienced GHP employees

4.8.4 **Skills and Abilities**

4.8.4.1 Use, repair and maintenance of plumbing and construction equipment and tools

4.8.4.2 Maintenance of proper working order of joining equipment, including fusion machines, tools, heating tools and adaptors

4.8.4.3 Read and follow blueprints, project schematics or other specifications or scopes of work to install the ground heat exchanger

4.8.4.4 Adhere to OSHA and other applicable safety requirements prior to, during and following the installation of the ground heat exchanger

4.8.4.5 Communicate with other jobsite personnel to determine necessary job parameters, for example job start/completion dates and times, desired pipe/tubing sizes, ground heat exchanger site plan or design layout schematic

4.8.4.6 Prepare jobsite and all necessary tools and equipment as desired to begin work.

4.8.4.7 Clean and prepare pipe/tubing and ends and associated fittings for the joining process

4.8.4.8 For fusion joining, verify and maintain heater surface temperature at desired and recommended temperature

4.8.4.9 Take proper temperature and pressure measurements

4.8.4.10 Perform HDPE heat fusion or other applicable joining methods of all desired ground heat exchanger and/or indoor piping connections

4.8.4.11 Prepare and place surface water heat exchanger

4.8.4.12 Construct entry and passage points through walls, ceiling and/or floors as required to route piping. Install piping supports as needed to properly maintain integrity of indoor piping system

4.8.4.13 Provide initial inspection and testing of all joints, including HDPE heat fused joints

4.8.4.14 Provide inspection or regulation personnel with required information and material as required to properly approve HDPE heat fused joints

4.8.4.15 Perform jobsite and tool/equipment cleanup as required to successfully complete required Work

4.8.4.16 Ensure maintenance of location marking and protection of piping during backfilling

4.8.4.17 Perform any necessary repairs to piping system due to faulty installation or accidental breach of piping system during installation

4.8.4.18 Purge and flush the complete ground heat exchanger system

4.8.4.19 Ensure trenches for loops and loop manifolds are properly backfilled, compacted and marked in accordance with specifications

4.8.4.20 Provide as-built drawings of ground heat exchanger installation

4.8.4.21 Computer and/or calculator skills appropriate to assigned duties

4. 9 GROUND SOURCE HEAT PUMP SYSTEM WATER WELL DRILLER (See Figure 3.1 – WATER WELL DRILLER)

4.9.1 **Description** – The Ground Source Heat Pump System Water Well Driller is responsible for construction of water well(s) for open loop ground source heat pump (GHP) systems while protecting surrounding groundwater resources from contamination, including selection of the drilling methods and needed equipment to drill boreholes and/or install well casing and screen, evaluation of the drill site for safety hazards, and determination of water production capabilities of the local geology.

Associated tasks are performed by the Engineer / Designer and Pump Installer positions.

4.9.2 **Prerequisite Certifications and Licenses**

4.9.2.1 Certifications and/or licenses required by state and local regulatory agencies

4.9.2.2 National Ground Water Association Certified Water Well Driller (CWD) certification or other nationally recognized third party certification program requiring continuing education

4.9.3 **Knowledge**

4.9.3.1 Knowledge of applicable codes and regulations that pertain to water well and groundwater return well construction, permitting requirements, and the use of produced water

4.9.3.2 Knowledge of geology and hydrology

4.9.3.3 Knowledge of water chemistry

4.9.3.4 Knowledge of drilling fluids and fluid additives and their resulting effects on fluid dynamics, viscosity and weights as necessary for maintaining a clean borehole

4.9.3.5 Understanding of chemical treatments to break down additives

4.9.3.6 Knowledge of machines and tools, including their designs, controls, uses, repair, and maintenance

4.9.3.7 Working knowledge of applicable National Ground Water Association standards, guidelines, and suggested best practices; and International Ground Source Heat Pump Association standards

4.9.3.8 Knowledge of business and management principles involved in planning, resource allocation, human resources, leadership techniques, production methods, and coordination of people and resources

4.9.3.9 Knowledge of arithmetic, algebra and geometry

4.9.3.10 **Education and Training**

4.9.3.10.1 High school diploma or equivalent, or applicable on-the-job training

4.9.3.10.2 Applicable regulatory agency education and training

4.9.3.11 **Experience**

4.9.3.11.1 Minimum of two years of relevant experience working with an experienced water well driller, or successful completion of an applicable recognized apprenticeship program or its formal equivalent

4.9.4 **Skills and Abilities**

4.9.4.1 Read and understand design drawings and specifications

4.9.4.2 Review client requirements and proposed locations for drilling operations to determine feasibility, and to determine cost estimates
4.9.4.3 Review proper setback requirements between the well and other onsite utilities
4.9.4.4 Design well to deliver specified water flow
4.9.4.5 Select the appropriate drilling methodology for the geologic conditions, using knowledge of rock or soil characteristics, depths and formations
4.9.4.6 Per applicable regulatory requirements and client and contract specifications, develop and maintain a log to record observations of cuttings for geological data, drilling techniques, materials used, drilling progress and required fluids, taking particular note of any special drilling conditions such as lost returns, tool drops, and unexpected down hole conditions
4.9.4.7 Regulate and supervise the drilling process based on the drill type and geologic conditions
4.9.4.8 Drive or guide vehicle-mounted or trailer-mounted drilling machine and related tools
4.9.4.9 Operate drill rig in accordance with job requirements and industry practice, including regulating air pressure, pump pressure, rotary speed, and downward drill bit pressure, according to the type of material being drilled
4.9.4.10 Verify depths and alignments of drilling positions
4.9.4.11 Monitor drilling operations, checking gauges and listening to operating equipment to assess drilling conditions and to determine the need to adjust or alter drilling equipment and parameters, including air or pump pressure, rotary speed and downward pressure or change the properties of the drilling fluid being used
4.9.4.12 Circulate approved fluids into boreholes as needed to cool drill bits, remove cuttings and stabilize borehole and maintain design borehole diameter using industry acceptable tools and procedures
4.9.4.13 Operate controls to stabilize machines and to position and align drills
4.9.4.14 Select, prepare and attach drill bits and drill rods, adding more rods as borehole depths increase, and changing drill bits as needed
4.9.4.15 Operate machines to maintain borehole diameter and flush earth cuttings or to remove debris from boreholes
4.9.4.16 Start, stop, and control drilling speed of machines
4.9.4.17 Assemble and install temporary or permanent well casing as required by borehole conditions and regulatory requirements
4.9.4.18 Withdraw drill rods from boreholes and extract core samples
4.9.4.19 Retrieve lost equipment from boreholes, using retrieval tools
4.9.4.20 Assist with and operate machines to mix and emplace grout
4.9.4.21 Manage high production water wells
4.9.4.22 Adjust well design to accommodate artesian or water table wells used for connection to GHP systems
4.9.4.23 Inspect core samples to determine nature of strata, or take samples to laboratories for analysis
4.9.4.24 Collect and deliver production water samples for laboratory testing and designer review
4.9.4.25 Select and install appropriate well screen
4.9.4.26 Understand and facilitate the proper grouting of water production and return wells
4.9.4.27 Develop the water production of the well in keeping with the well type and design
4.9.4.28 Perform pumping tests to assess well performance as per design specifications
4.9.4.29 Disinfect, reconstruct, and redevelop fouled wells and water pumping systems, and clean and disinfect new wells in preparation for use

4.9.4.30 Prepare and deliver end-of-well reports and client's final product delivery to well designer and system installer
4.9.4.31 Maintain, assemble and position drilling machines, drilling tools, well casing, and other equipment, using hand and power tools
4.9.4.32 Conduct preventive maintenance and equipment repairs as appropriate
4.9.4.33 Manage and dispose of drill cuttings and drilling fluids as required by applicable regulations
4.9.4.34 Ensure timely and accurate fulfillment of all regulatory reporting requirements
4.9.4.35 Troubleshoot drilling problems encountered during drilling operations
4.9.4.36 Good mechanical aptitude and ability to work confidently with small tools and power tools
4.9.4.37 Communicate effectively with all involved stakeholders
4.9.4.38 Computer and/or calculator skills appropriate to assigned duties

4.10 GROUND SOURCE HEAT PUMP SYSTEM WATER WELL PUMP INSTALLER (See Figure 3.1 – WATER WELL PUMP INSTALLER)

4.10.1 **Description** - The Ground Source Heat Pump System Water Well Pump Installer is responsible for the installation, service, and repair of water well pumping systems and related equipment connected to open loop ground source heat pump (GHP) systems. The Water Well Pump Installer must have detailed knowledge of the different types of water well pumping equipment.

Associated tasks are performed by the Water Well Driller and Mechanical System Installer positions.

4.10.2 **Prerequisite Certifications and Licenses**

4.10.2.1 Certifications and licenses required by State and regulatory agencies

4.10.2.2 National Ground Water Association Certified Pump Installer certification or other nationally recognized third party certification program

4.10.3 **Knowledge**

4.10.3.1 Understand how the water well pump, water well and open loop GHP system functions as part of a complete GHP heating and cooling system

4.10.3.2 Understand ground water delivery to the borehole and how it affects well system design

4.10.3.3 Understand ground water permitting requirements for the installation of water pumps

4.10.3.4 Understand the functionality of pump controls as they relate to water well, return well and standing column well systems

4.10.3.5 Thorough understanding of basic and direct digital controls for integration of water well pump with GHP system sequence of operation

4.10.3.6 Thorough knowledge of electrical wiring and plumbing necessary to install or repair water well pumps and related equipment

4.10.3.7 Working knowledge of applicable International Ground Source Heat Pump Association Standards

4.10.3.8 Knowledge of parameters used in ANSI/AHRI/ASHRAE ISO Standards 13256-1 and 13256-2

4.10.3.9 Knowledge of arithmetic

4.10.3.10 **Education and Training**

4.10.3.10.1 High school diploma or equivalent, or applicable on-the-job training

4.10.3.10.2 On-the-job training. Industry-specific courses offered through organizations such as the National Ground Water Association

4.10.3.11 **Experience**

4.10.3.11.1 Minimum of two years of working with an experienced water well pump installer or successful completion of a recognized apprenticeship program

4.10.4 **Skills and Abilities**

4.10.4.1 Ability to perform lifting and physical labor

4.10.4.2 Good mechanical aptitude

4.10.4.3 Install, service and repair water well pumps for GHP applications

4.10.4.4 Install, repair or service related equipment such as intermediate heat exchangers, valves, tanks, and water treatment systems
4.10.4.5 Troubleshoot water system components
4.10.4.6 Design well pumping systems
4.10.4.7 Develop the water production of the well in keeping with the well type and design
4.10.4.8 Perform pumping tests to assess well performance
4.10.4.9 Install electrical wiring and plumbing in order to install or repair pumps and related equipment.
4.10.4.10 Install pump controls appropriate to the water well, reinjection well or standing column well system
4.10.4.11 Ability to program and service variable frequency and variable speed well pump drives
4.10.4.12 Install basic and direct digital controls for integration of water well pump with GHP system sequence of operation
4.10.4.13 Ensure timely and accurate fulfillment of all regulatory reporting requirements
4.10.4.14 Prepare and deliver water well pump draw down test report(s) to client
4.10.4.15 Maintain good communication with the client's well site representative, rig crew, and field support staff.
4.10.4.16 Computer and/or calculator skills appropriate to assigned duties

4.11 GROUND SOURCE HEAT PUMP MECHANICAL SYSTEM INSTALLER (See Figure 3.1 – MECHANICAL SYSTEM INSTALLER)

4.11.1 **Description**- The Ground Source Heat Pump Mechanical System Installer is responsible for the installation and service of ground source heat pump (GHP) heating, ventilating, and air conditioning (HVAC) systems inside the building, and may coordinate overall installation of residential GHP systems with other contractors for installation of the ground heat exchanger or open-loop components of the GHP system.

Associated tasks are performed by all positions relevant to the specific project.

4.11.2 **Prerequisite Certifications and Licenses**

4.11.2.1 Applicable Refrigeration and/or HVAC Contractor's license

4.11.2.2 Pipe/tubing joining certification and licenses required by applicable jurisdictions for the materials used in the installation of the GHP system, for example:

4.11.2.2.1 High density polyethylene (HDPE) fusion certification through recognized union or industry organization or fusion equipment manufacturer or distributor

4.11.2.2.2 Direct exchange (DX) ground heat exchanger copper brazing and soldering certification as part of an accredited program such as the Northern American Technician Excellence (NATE)

4.11.2.2.3 Mechanical joining certification from the manufacturer of such joining systems

4.11.3 **Knowledge**

4.11.3.1 Understanding of the GHP system as a whole including the ground heat exchanger, hydronics, air distribution, mechanical equipment, and their respective and integrated control systems, in addition to traditional mechanical system installations

4.11.3.2 Knowledge of refrigeration, machines, motors and tools, including their designs, uses, repair, and maintenance

4.11.3.3 Knowledge of current refrigerants and handling dynamics

4.11.3.4 Understanding of thermostatic controls for residential applications and a more detailed understanding of building energy management systems and controls logic for non-residential applications.

4.11.3.5 Knowledge of local codes and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) 90.1 Standard or individual State's energy efficiency codes

4.11.3.6 Working knowledge of International Ground Source Heat Pump Association standards and National Ground water Association guidelines

4.11.3.7 Knowledge of state-of-the-art practices of the Radiant Panel Association (RPA), Sheet Metal and Air Conditioning Contractors Association (SMACNA), Refrigeration Service Engineers Society (RSES), or Air Conditioning Contractors of America (ACCA)

4.11.3.8 Knowledge of basic mathematics, algebra and cash accounting

4.11.3.9 **Education and Training**

4.11.3.9.1 High school diploma or equivalent

4.11.3.9.2 One of the following:

4.11.3.9.2.1 On-the-job training or formal apprenticeship program

4.11.3.9.2.2 Associates degree and/or advanced industry or technical school training

4.11.3.9.2.3 Specialized programs sponsored by manufacturing organizations of GHP products

4.11.3.10 **Experience** – Two years of experience with installation and servicing of applicable mechanical equipment, for example heat pumps and chillers

4.11.4 **Skills and Abilities**

4.11.4.1 Read and follow blueprints or other specifications or scopes of work for GHP heating and cooling systems
4.11.4.2 Create shop drawings for installed systems
4.11.4.3 Provide Manual D and/or Manual J calculations for residential building load calculations
4.11.4.4 Coordinate the work of others providing the ground heat exchanger or open- loop component of the complete GHP system
4.11.4.5 Flush and purge the ground heat exchanger
4.11.4.6 Measure, cut, bend, shape and fasten pieces of sheet metal to make ductwork
4.11.4.7 Prepare the required calculations and use tapes, rulers and other measuring devices for layout work
4.11.4.8 Cut or stamp the parts with machine tools
4.11.4.9 Install water lines, air ducts and vents, circulation pumps, and other components such as cooling towers, expansion tanks and other piping specialties
4.11.4.10 Integrate GHP equipment with the appropriate distribution system, for example: ductwork, fan coils, radiant heating and cooling systems, domestic hot water heating system, process piping, etc.
4.11.4.11 Integrate GHP system with other renewable energy system such as solar thermal and energy recovery equipment
4.11.4.12 Cut holes in walls, ceiling and floors as required to route piping and/or ductwork
4.11.4.13 Hang steel supports from ceiling joists or properly fasten steel supports to walls, floors and roofs for piping and/or ductwork
4.11.4.14 Set mechanical equipment and start-up per manufacturer's guidelines
4.11.4.15 Connect low voltage electrical wiring and controls and check the mechanical equipment for proper function
4.11.4.16 Provide initial testing and balancing of the system (air side and water side) to make sure the system is functioning properly or service existing air conditioning and ventilation systems to ensure they are functioning properly and to improve their energy efficiency
4.11.4.17 Verify proper system operation by checking the thermostat, equipment and system components to diagnose and correct problems
4.11.4.18 Ability to program applicable controls, e.g. feed-back and other digital controls
4.11.4.19 Perform routine maintenance and repair work to keep the system operating efficiently after installation
4.11.4.20 Service equipment by following all protocols to conserve, recover and recycle the refrigerants used in GHP equipment
4.11.4.21 Perform any necessary repairs to HDPE piping system due to faulty installation or breach of piping system
4.11.4.22 Provide as-built drawings of final HVAC system installation
4.11.4.23 Computer and/or calculator skills appropriate to assigned duties

4.12 GROUND SOURCE HEAT PUMP SYSTEM OPERATION & MAINTENANCE TECHNICIAN (See Figure 3.1 – O&M TECHNICIAN)

4.12.1 **Description** – The Ground Source Heat Pump System Operation & Maintenance Technician is responsible for operation and maintenance of installed ground source heat pump (GHP) systems.

Associated tasks are performed by the Engineer / Designer and Mechanical System Installer positions.

4.12.2 **Prerequisite Certifications and Licenses**

4.12.2.1 Applicable Refrigeration and/or HVAC Contractor's license

4.12.2.2 Pipe/tubing joining certification and licenses required by applicable jurisdictions for the materials used in the installation of the GHP system, for example:

4.12.2.2.1 High density polyethylene (HDPE) fusion certification through approved trade organization or manufacturer

4.12.2.2.2 Direct exchange (DX) ground heat exchanger copper brazing and soldering certification as part of an accredited program such as the Northern American Technician Excellence (NATE)

4.12.2.2.3 Mechanical joining certification from the manufacturer of such joining systems

4.12.3 **Knowledge**

4.12.3.1 Understanding of basic GHP system operation and associated energy systems such as solar thermal and energy recovery equipment

4.12.3.2 Understanding basic thermostatic controls and building energy management system operation

4.12.3.3 Understanding of applicable reporting and control systems

4.12.3.4 Working knowledge of International Ground Source Heat Pump Association standards and National Ground water Association guidelines

4.12.3.5 Knowledge of state-of-the-art practices of the Radiant Panel Association (RPA), Sheet Metal and Air Conditioning Contractors Association (SMACNA), Refrigeration Service Engineers Society (RSES), and Air Conditioning Contractors of America (ACCA)

4.12.3.6 Knowledge of basic mathematics, algebra and cash accounting

4.12.3.7 **Education and Training**

4.12.3.7.1 High school and/or trade school courses in refrigeration, controls, piping systems, Heating, Ventilation and Air Conditioning (HVAC) repair and maintenance, mechanical drawing, electricity, woodworking, science, mathematics and computers

4.12.3.7.2 Job Training - Formal and informal on-the-job training, including:

4.12.3.7.2.1 Operation of computers that manage building energy management systems

4.12.3.7.2.2 Equipment manufacturers training for specific equipment or systems

4.12.3.7.2.3 GHP-specific training provided through third-party nationally recognized certification programs, including the International Ground Source Heat Pump Association (IGSHPA), The American Society of Heating (ASHRAE), Refrigerating and Air Conditioning Engineers, and the Refrigeration Service Engineers Society (RSES).

4.12.3.8 **Experience** – Two years of experience with installation and servicing of applicable mechanical equipment, for example heat pumps and chillers

4.12.4 **Skills and Abilities**

4.12.4.1 Ability to stand for long periods as well as walk, push, pull, bend, stoop, kneel or lie down as conditions require in order to access ductwork and mechanical system equipment and materials

4.12.4.2 Technical and mechanical aptitude, manual dexterity, and the ability to apply shop mathematics

4.12.4.3 Read and follow blueprints, repair manuals and equipment O&M manuals or other specifications to troubleshoot a GHP heating and cooling system

4.12.4.4 Review mechanical equipment performance against manufacturer's data, including taking electrical, pressure, and temperature data at heat pumps to verify system flow rate, heat of extraction and heat of rejection

4.12.4.5 Follow all protocols relevant to applicable working conditions in order to conserve, recover, recharge and recycle refrigerants used in GHP equipment during maintenance and repair projects

4.12.4.6 Monitor chemical treatment system and periodically check fluid concentrations of all hydronic systems

4.12.4.7 Provide ground heat exchanger system pressure testing, flushing and purging as required per International Ground Source Heat Pump Association Standards and local codes after any repairs or changes that require removing fluid from the system

4.12.4.8 Monitor hydronic air removal system for proper operation

4.12.4.9 Repair or replace water lines, air ducts and vents, circulation pumps, and other GHP components such as compressors and thermal expansion valves, expansion tanks and other piping specialties as needed

4.12.4.10 Join piping materials as needed for repairs and replacement

4.12.4.11 Troubleshoot electrical wiring and controls

4.12.4.12 Check mechanical equipment for proper function

4.12.4.13 Provide routine maintenance and repair work to keep the system operating efficiently

4.12.4.14 Provide testing and balancing of the system (air side and water side) as required to service existing air conditioning and ventilation systems to ensure they are functioning properly and to improve their energy efficiency

4.12.4.15 Check thermostats and other controls, equipment and system components to diagnose and correct problems in order to ensure proper system operation

4.12.4.16 Develop and provide preventative maintenance plans to the building owner

4.12.4.17 Computer and/or calculator skills appropriate to assigned duties

4.13 GROUND SOURCE HEAT PUMP SYSTEM INSPECTOR / REGULATOR (See Figure 3.1 – INSPECTOR / REGULATOR)

4.13.1 **Description** – The Ground Source Heat Pump System Inspector / Regulator is responsible for verifying that ground source heat pump (GHP) systems are installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent and local codes and regulations. The Inspector / Regulator may be privately employed to provide inspection services for an owner, general contractor, architect/engineering (A/E) firm or government agency, or represent the legal authority having jurisdiction, which may be the groundwater regulating agency, the building department or other related organizations within the local, state and federal government(s). More than one type of Inspector / Regulator may be required for a GHP project.

Associated tasks are performed by the Project Manager and Engineer / Designer positions. Inspection activities occur during the design, construction, and acceptance phases, respectively.

4.13.2 **Prerequisite Certifications and Licenses**

4.13.2.1 Accreditation as a code review authority

4.13.2.2 Additional or supplementary certifications and licenses required by state and regulatory agencies

4.13.2.3 Other third party nationally recognized certification program

4.13.3 **Knowledge**

4.13.3.1 Basic knowledge of mechanical systems, GHPs, ground heat exchanger design and installation, ductwork fabrication drilling operations, pumps, and the operation of HVAC systems, building energy management control systems, and other systems related to GHP systems

4.13.3.2 Knowledge of all applicable codes, regulations and policies that apply to ground source heat pump systems

4.13.3.3 Knowledge of system water chemistry and best practices for the protection of ground water

4.13.3.4 Knowledge of mathematics, algebra and geometry

4.13.3.5 **Education and Training -** Five years of field experience may be substituted in lieu of education requirements

4.13.3.5.1 Post high school education or technical school

4.13.3.5.2 GHP-specific training provided through a third party nationally recognized certification program, for example the International Ground Source Heat Pump Association (IGSHPA), The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), or the National Ground Water Association (NGWA)

4.13.3.5.3 IGSHPA and NGWA instruction on ground water protection and the proper procedures for the installation of GHP systems

4.13.3.6 **Experience**

4.13.3.6.1 One year of experience with Heating, Ventilation and Air Conditioning (HVAC) systems
4.13.3.6.2 One year of experience with ground heat exchanger installations
4.13.3.6.3 One year of experience with GHP operation

4.13.4 **Skills and Abilities**

4.13.4.1 Ability to read and understand engineering drawings and project specifications
4.13.4.2 Verify that the design is in compliance with local codes and regulations
4.13.4.3 Verify that the proper permits have been applied for and issued prior to the construction process
4.13.4.4 Verify proper conduct of any drilling procedure, grouting procedure, and materials utilization
4.13.4.5 For vertical loop well installations, inspect and verify the depth of u-bend emplacements
4.13.4.6 Collect grout samples or perform field tests on the grout and verify that grouting procedure conforms to industry standards and state and local codes
4.13.4.7 Witness ground heat exchanger pressure test
4.13.4.8 Witness applicable GHP water well draw down test and sterilization
4.13.4.9 Verify that materials being used for the GHP system is in accordance with the design, and free of defects that could cause system failures
4.13.4.10 Verify the duct being used for the system is as per design, and that it is fabricated and insulated according to applicable codes
4.13.4.11 Observe startup, operation, and test, adjust, and balance (TAB)
4.13.4.12 Review the tests that have been done (TAB, automatic control system tests, etc.) and evaluate that everything, including the controls, works under foreseeable operating conditions
4.13.4.13 Provide progress inspections and reports to the Owner, General Contractor, and A/E Firm (as applicable) regarding conformity to project drawings and specifications
4.13.4.14 Observe or review all items listed on the permit and sign off that they have been completed
4.13.4.15 Computer and/or calculator skills appropriate to assigned duties

4.14 GROUND SOURCE HEAT PUMP SYSTEM TRAINER (See Figure 3.1 – TRAINER)

4.14.1 **Description** – The Ground Source Heat Pump System Trainer is responsible for training others about specific aspects of the design, installation, commissioning, operation and maintenance of ground source heat pump (GHP) systems, in a classroom and/or job site setting.

Associated tasks are performed by all relevant positions for applicable training.

4.14.2 **Prerequisite Certifications and Licenses -** the same or higher level of certification being taught

4.14.3 **Knowledge**

4.14.3.1 Broad knowledge of the GHP industry covering the education of engineers and designers, installers, drillers and other related occupations

4.14.3.2 Be a subject matter expert for the coursework taught, for example heating energy utilization and cooling loads for facilities and the ground heat exchanger

4.14.3.3 Strong knowledge of the construction process

4.14.3.4 Knowledge of engineering mathematics, algebra and trigonometry

4.14.3.5 Well versed in the profession's standard of care defined by ASHRAE

4.14.3.6 Strong knowledge of International Ground Source Heat Pump Association (IGSHPA) standards and National Ground Water Association (NGWA) guidelines

4.14.3.7 Knowledge of state-of-the-art practices of related industry organizations, including Sheet Metal and Air Conditioning Contractors Association (SMACNA), Refrigeration Service Engineers Society (RSES), or Air Conditioning Contractors of America (ACCA)

4.14.3.8 Familiarity with industry related design guides, depending upon training specialty. Design guidance is typically provided through tests and papers presented by the National Ground Water Association (NGWA), International Ground Source Heat Pump Association (IGSHPA) and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)

4.14.3.9 Knowledge of ANSI/AHRI/ASHRAE ISO Standards 13256-1 and 13256-2

4.14.3.10 Understanding of the different ways people learn

4.14.3.11 **Education and Training -** GHP Trainers learn the basis of the technology and its many design elements through coursework, field experience, involvement with professional and trade organizations and networking with peers

4.14.3.11.1 High school diploma or equivalent for teaching ground heat exchanger driller or installer coursework

4.14.3.11.2 Training in teaching techniques and methodologies

4.14.3.11.3 Same or greater level of education required by the trainees

4.14.3.11.4 For teaching the engineering and design coursework, a minimum of a four-year college degree in a related occupational field or one of the following:

4.14.3.11.4.1 Four-year, non-technical degree with five years combined experience in commercial GHP system design and/or heating, ventilation and air conditioning

4.14.3.11.4.2 Two-year technical degree with eight years of combined experience in commercial GHP system design and/or heating, ventilating and air conditioning.

4.14.3.11.4.3 Ten year or more of combined experience in commercial GHP system design and/or heating, ventilating and air conditioning
4.14.3.11.5 Supplemental education in drilling techniques, geology, design of ground heat exchangers, water well and injection well specification and local codes and standards governing ground heat exchanger design
4.14.3.11.6 Courses in Phase I and II Site Assessment and System Commissioning
4.14.3.11.7 Apprenticeships or additional education from career and technical institutions
4.14.3.11.8 Initial classroom education in the form of technical training

4.14.3.12 **Experience**
4.14.3.12.1 Five years of experience in the field
4.14.3.12.2 Experience operating and troubleshooting Heating, Ventilation and Air Conditioning (HVAC) systems, building energy management and control systems, and other systems related to the GHP system

4.14.4 **Skills and Abilities**
4.14.4.1 Effectively communicate and demonstrate to the student a reasonably thorough understanding of the training
4.14.4.2 Strong presentation skills
4.14.4.3 Utilize well-organized approaches and methodologies that facilitate student learning
4.14.4.4 Computer and/or calculator skills appropriate to assigned duties

APPENDICES

A. Abbreviations and Glossary

B. Related Resources

APPENDIX A

ABBREVIATIONS AND GLOSSARY

List of Common Acronyms & Abbreviations:

ACCA: Air Conditioning Contractors of America
AEE: The Association of Energy Engineers
AGL: Annual Ground Load
α (Alpha): Soil Thermal Diffusivity
ARI: Air-Conditioning and Refrigeration Institute
A_s: Annual Soil Temperature Swing Above and Below the Mean (In the top 10 feet of earth)
ASHP: Air Source Heat Pump
ASHRAE: American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASTM: American Society for Testing and Materials
BM: Bore Length Multiplier
C-C: Center to Center Spacing
CF: Correction Factor
CFM: Cubic Feet per Minute
d_{avg}: Average Pipe Burial Depth
DMD: Electrical Demand
DOE: U.S. Department of Energy
d_{bp}: Depth to the Bottom of the Pipe
DR: Dimension Ratio
DSIRE: Database of State Incentives for Renewables & Efficiency
EAT: Entering Air Temperature
ECM: Electrically Commutated Motor
EER: Energy Efficiency Ratio
EPA: Environmental Protection Agency
ELT: Entering Load Temperature
EPRI: Electric Power Research Institute
ESP: External Static Pressure
EST: Entering Source Temperature
EWT: Entering Water Temperature
F_C: Run-Fraction during the cooling design month
FFR: Flushing Flow Rate
F_H: Run-Fraction during the heating design month
FLRH: Full-Load Run Hours
FPS: Feet per Second
GHEX: Ground Heat Exchanger
GHPC: Geothermal Heat Pump Consortium

GPM: Gallons per Minute
GSHP: Ground Source Heat Hump
HC: Heating Capacity
HE: Heat of Extraction
HL: Head Loss
HR: Heat of Rejection
HSPF: Heating Seasonal Performance Factor
HVAC: Heating, Ventilating, and Air Conditioning
HWG: Hot Water Generation
IGSHPA: International Ground Source Heat Pump Association
IN. WG: Inches of Water Gauge
ISO: International Organization for Standardization
k_G: Formation Thermal Conductivity
k_{Grout}: Grout Thermal Conductivity
LAT: Leaving Air Temperature
LLT: Leaving Load Temperature
LST: Leaving Source Temperature
LWT: Leaving Water Temperature
NNAGL: Net Normalized Annual Ground Load
OAT: Outdoor Air Temperature
P/T Port: Pressure/Temperature Measurement Port
PM: Pipe Multiplier
PSC: Permanent Split Capacitor
PSI: Pounds per Square Inch
Re: Reynolds Number
ROI: Return on Investment
R_p: Pipe Thermal Resistance
R_S: Soil Resistance
SC: Sensible Cooling Capacity
SCC: Center to Center Trench Spacing
SDSURR: Step-Down, Step-Up Reverse-Return Header
SEER: Seasonal Energy Efficiency Ratio
SHF: Sensible Heat Factor
S_M: Spacing Multiplier
TAB: Test, Adjust and Balance
TC: Total Cooling Capacity
T_M: Mean Earth Temperature (In the top 10 feet)
T_O: Number of Days After January 1 to Reach the Minimum Earth Surface Temperature
VFD: Variable Frequency Drive
WPD: Water Pressure Drop
WSHP: Water Source Heat Pump

Glossary

Absolute Pressure: A pressure reading relative to absolute zero pressure, expressed as the sum of atmospheric pressure and gauge pressure (psia).
Active Borehole Length: The length of the U-bend in the borehole below the header trench (usually 4 to 6feet less than the total borehole length from the surface).
Air Source Heat Pump (ASHP): A heat pump that uses an air-to-refrigerant heat exchanger to extract and reject heat to the outside air.
Ambient Air: The surrounding air (usually outdoor air or the air in a specific location).
Annual Fuel Utilization Efficiency (AFUE): The average efficiency for fuel-burning equipment for an entire heating season, expressed as seasonal heating energy delivered (Btu) divided by the seasonal fuel energy consumed (Btu).
Annual Ground Load: Defined to be the difference between the annual amount of heat rejected to the GHEX in the cooling mode and the annual amount of heat extracted from the GHEX in the heating mode.
As-Built Drawing: A detailed drawing that shows everything included on the site plan in addition to the exact location, dimensions, and other pertinent details for a given GHEX installation after the installation is complete.
Balance Point Temperature: The outdoor air temperatures where internal heat gains from people, appliances, etc. offset the envelope heat loss to the atmosphere. It is at the balance point temperatures where no indoor heating or cooling will be required to maintain the temperature of the home at the thermostat set point.
Bend: A fitting either molded separately or formed from pipe for the purpose of accommodating a directional change.
Bin: In the bin method, a temperature increment, usually 5 F, into which the range of temperatures for an area are divided. Bins are used to produce a frequency distribution of hourly, monthly, or annual outdoor temperature occurrences for a specified location.
Block Load: Defined to be the sum of the zone loads. A block load calculation is necessary for a building with multiple zones served by a centralized heating/cooling system.
Blowers: Fans used to force air across the heat exchanger. With a ground source heat pump, the only blower used is to force air through the central heating system.
British Thermal Unit (Btu): The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at a specified temperature.
Cavitation: The formation of bubbles due to partial vacuums in a flowing liquid as a result of separation of fluid particles.
Centralized Pumping System: Flow centers located centrally in a ground source system that produce flow to all heat pump units in that system.
Circulating Pump(s): The pump(s) that circulates the fluid in the closed-loop system during normal operation.
Closed-Loop System: The heat exchange loop in a GSHP system that is comprised of the ground heat exchanger, the circulating pump, and the water-source or direct exchange heat pump in which the heat transfer fluid is not exposed to the atmosphere.
Coefficient of Performance (COP): A measure of heating efficiency for heat pump equipment, expressed as the heating energy provided to the space (Btu) divided by the electric energy consumed to provide that heating (Btu).

Coil: A heat exchanger used to transfer energy from one source to another. In ground source heat pumps, water-to-refrigerant and refrigerant-to-air coils are used.
Combination GSHP Unit: A GSHP that has the ability to heat or cool air at full capacity or to heat or cool water at full capacity, but not both at the same time.
Compressor: The central component of a heat pump system. The compressor increases the pressure of a
refrigerant fluid, and simultaneously reduces its volume, while causing the fluid to move through the system.
Compressor, Reciprocating: A positive displacement compressor in which the change in internal volume of the compression chamber(s) is accomplished by the reciprocating motion of one or more pistons.
Compressor, Rotary: A positive displacement compressor in which the change in internal volume of the compression chamber(s) is accomplished by the rotation of a rolling piston or rotating sliding vanes.
Concentric Fitting: A fitting used to connect the GSHP desuperheater piping to the domestic hot water tank. The concentric fitting is one for which the suction and discharge lines coming into and out of the hot water tank are through the same opening.
Condenser: A heat exchanger in which hot, pressurized (gaseous) refrigerant is condensed by transferring heat to cooler surrounding air, water, or earth.
Cycling Efficiency: Ratio of actual efficiency to steady-state efficiency. The actual efficiency of a heating or cooling system is somewhat lower due to start-up and shut-down losses.
Damper: A device used to vary the air flow rate through an air outlet, inlet, or duct.
Defrost Cycle: The control-activated process of removing accumulated frost and ice from the outdoor heat exchanger of air source heat pumps.
Degradation Coefficient: A dimensionless number used to help quantify the amount of efficiency loss due to startup, shutdown, and other part-load operation. For practical purposes in the case of a ground source heat pump system, a value within the range of 0.10 - 0.15 is a reasonable approximation for this coefficient.
Degree Day: A measure of the severity and duration of an outdoor temperature deviation above or below a fixed temperature (65 F), used in estimating the heating or cooling requirement and fuel consumption of a building for either summer or winter conditions.
Demand (DMD): The electrical input required to operate a GSHP unit for space conditioning.
Design Loads: The peak heating or cooling load used to select the equipment for a system (such as a heat pump) and to design the air distribution system (supply air diffusers, return air grilles, and the duct system). Design loads are based on standard or accepted conditions for a given locality (a design day).
Design Temperature, Summer: A specific temperature used in calculating the cooling load of a building. The summer design temperature is typically the outdoor air temperature that is exceeded 0.4% or 1.0% of the time.
Design Temperature, Winter: A specific temperature used in calculating the heating load of a building. The winter design temperature is typically the outdoor temperature that is exceeded 99.0% or 99.6% of the time.
Desuperheater: A device for recovering superheat from the compressor discharge gas of a heat pump or central air conditioner for use in heating or preheating water. Also known as a heat recovery water heater.
Diffuser (Air): A supply air outlet composed of deflecting elements discharging air in various directions and patterns to accomplish mixing of supply and room air.

Dimension Ratio (DR): A specific ratio of the average specified outside diameter to the minimum specified wall thickness (OD/t) for outside-diameter controlled plastic pipe.
Direct Expansion (DX) Earth-Coupled Heat Pump: A heat pump system in which the refrigerant is circulated in pipes buried underground.
Distributed Pumping System: A system made up of smaller, individual pumping stations (one flow center for each heat pump) each controlled individually by the operation of the specific heat pump unit that they serve.
Dual Circuit GSHP Unit: A GSHP which utilizes two compressors (generally of different capacities) connected to two refrigeration circuits to allow multiple modes of operation. This unit may use one compressor in heating or cooling of ducted air only, one compressor to heat water only, one compressor heating or cooling air while the other is heating water, or both compressors either heating or cooling air.
Dynamic System Check: A GSHP system startup check procedure performed after the system has been started and consists of measuring various system performance parameters to ensure that the system is performing as promised.
Effective Length: The design parameter for calculating the friction loss for a run. Effective length, expressed in feet, is the sum of the actual length and the equivalent fitting lengths.
Efficiency: A measure of the useful output of a system divided by the input required to drive the system.
Energy Efficiency Ratio (EER): A measure of cooling efficiency for heat pump equipment, expressed as the cooling energy removed from the space (Btu) divided by the electric energy consumed to provide that cooling (W).
Energy Loads: Used in predicting the energy necessary to operate the system for some prescribed time such as a month, year, or season. The calculation methodology may be the same as for the design load; however, the actual operating and weather data are used instead of design conditions.
Equipment Loads: Loads served by the heating/cooling system that are not included in peak heating/cooling block load calculations. These loads include duct and hydronic piping losses/gains as well as ventilation loads.
Equivalent Length: Used in duct system calculation procedures to express the same pressure loss for pipes of various diameters.
Envelope Load: The total heating or cooling load through any building component surrounding a conditioned space, including fenestration and infiltration loads.
Environmental Stress Cracking: The development of cracks in a material that is subjected to stress or strain in the presence of specific chemicals.
Evaporator: A heat exchanger in which cold, low-pressure (liquid) refrigerant is vaporized to absorb heat from the warmer surrounding air, earth, or water.
EWT_{max}: The maximum temperature that the circulating fluid will reach in a closed-loop ground heat exchanger during the entire cooling season over the life of the equipment. This parameter is specified by the designer during the closed-loop GHEX design process.
EWT_{min}: The minimum temperature that the circulating fluid will reach in a closed-loop ground heat exchanger during the entire heating season over the life of the equipment. This parameter is specified by
the designer during the closed-loop GHEX design process.
Expansion Valve: A device that reduces the pressure of liquid refrigerant entering the evaporator and meters and regulates the flow of refrigerant so that it can properly absorb heat.

Fitting: A piping component used to join or terminate sections of pipe or to provide changes of direction or branching in a pipe system.
Flow Center: A packaged set of circulating pumps mounted in a cabinet, which often includes valves and ports for flushing/purging, antifreeze charging (if used), and loop pressurization (if a pressurized flow center is used).
Flow Regime: A term used in fluid mechanics to define the nature of fluid flow in any situation. Flow regime can either be regarded as laminar, transitional, or turbulent.
Flush Cart: A system which integrates the purge pump with the valving, hose connections, electrical connections, filtration, and reservoir tank on a hand cart for maximum portability and ease of use during operation. Flush carts fabricated for residential or light commercial use will typically utilize high-head, high-volume purge pumps from 1-1/2 hp to 3 hp in size.
Fuse: To make a plastic pipe joint by heat and pressure.
Gauge Pressure: Pressure reading directly taken from a pressure sensor or gauge (psi).
Grille: A louvered or perforated covering of an inlet or outlet opening through which air flows.
Ground Heat Exchanger: One or more loop wells made up of pipe or tubing buried in the earth.
Ground Loads: Associated with ground source systems and related to the design of the GHEX. In principle, these calculations are similar to the energy loads except the ground load is heat rejected to the ground (cooling mode) or removed from it (heating mode).
Ground Source Heat Pump (GSHP) (sometimes referred to as "geothermal heat pump")**:** A heat pump that uses the earth itself as a heat source and heat sink. It is coupled to the ground by means of a closed-loop heat exchanger (ground coil) installed horizontally or vertically underground.
Grout: A material used during the grouting process specifically designed to form a hydraulic barrier in the loop well and to promote transfer between the GHEX piping and the earth. Most grouting products are bentonite-based with fewer being cement-based.
Grouting: The practice of making a conscious effort to form a hydraulic barrier in a loop well to protect the integrity of the deep earth environment. Proper grouting implies that an approved grouting material is used and that it is placed in the hole starting through a tremie line, filling it from bottom to top.
Head Loss: The pressure drop due to the flow of a specific fluid at a given temperature and flow rate through a specific type and size of pipe.
Headering: The process of connecting individual GHEX loops to the supply-return piping to be taken into a mechanical room or vault.
Heat Exchanger: A device, often a coil, specifically designed to transfer heat between two physically separated fluids of different temperatures.
Heat Fusion: Making a joint by heating the mating surfaces of the pipe components to be joined and pressing them together so that they fuse and become essentially one piece.
Heat of Extraction: The portion of a GSHP's heating capacity that is extracted from the earth in the heating mode. Heat of extraction is always smaller than the heating capacity of the heat pump because the electrical power consumption of the compressor, fan, and pumps add to the heating capacity of the GSHP.
Heat of Rejection: The amount of heat that must be rejected to the earth in the cooling mode to provide cooling to the space. The heat of rejection is always larger than the cooling capacity of the heat pump because the electrical power consumption of the compressor, fan, and pumps must also be rejected to the heat sink (ground connection).
Heat Pump: A mechanical device used for heating and cooling which operates by pumping heat from a cooler to a warmer location. Heat pumps can draw heat from a number of sources, e.g., air, water, or earth, and are most often either air source or water source.

Heat Sink: The medium—air, water, earth, etc.—which receives heat from a heat pump.
Heat Source: The medium—air, water, earth, etc.—from which heat is extracted by a heat pump.
Heating Seasonal Performance Factor (HSPF): A measure of heating efficiency for air source heat pump equipment on an annual basis, expressed as the heating energy provided to the space (Btu) divided by the electric energy consumed (Watt-hour) over the entire heating season.
Heat Transfer Resistance: A system's resistance to heat flow resulting from the specific thermal properties and dimensions of the system.
Hoop Stress: The tensile stress in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure.
Hose Kit: A packaged set of hose, clamps, and fittings used to connect the GHEX piping to the GSHP unit as well as the flow center.
Hydronic: A heating or cooling distribution system using liquid piped throughout the house to radiators or convectors.
Inhibitor: A fluid additive specifically designed to decrease the rate of oxidation in metal (rust) and promotion of microbial life (bacteria) in the closed-loop circulating fluid.
Isolation Hangers: Insulated, tubular holders for refrigerant piping used to prevent transmission of vibration from pipes to the structure.
Joint: The location at which two pieces of pipe or a pipe and a fitting are connected.
Joint, Butt-Fused: A joint in which the prepared ends of the joint components are heated and then placed in contact to form the joint.
Joint, Clamped Insert-Fitting: A mechanical joint using external metal clamps or other mechanical
devices to form a pressure seal between an insert fitting and the outside surface of the pipe.
Joint, Heat-Fused: A joint made using heat and pressure only. There are three basic types of heat-fused joints: butt-fused, socket- or insert-fused, and saddle-fused.
Joint, Saddle-Fused: A joint in which the curved base of the saddle fitting and a corresponding area of the pipe surface are heated and then placed together to form the joint.
Joint, Socket-Fused: A joint in which the two pieces to be heat fused are connected using a third fitting or coupling with a female end.
Laminar Flow Regime: A term used to describe the flow condition where fluid flow is streamlined and smooth.
Latent Cooling Load: The amount of moisture that must be removed to maintain the space at the desired humidity level.
Life-Cycle Cost: A method of analyzing the cost of HVAC systems that considers all the significant costs of ownership, including the time value of money, initial capital investment, energy costs, and maintenance costs over the service life of each system under consideration.
Loop well: The subsystem of a geothermal heat pump system that consists of the drilled vertical borehole into the earth that is equipped with a heat exchange media conveyance tube (loop tube), and is grouted from the bottom of the vertical borehole to the earth's surface at the drilling site. Construction of a loop well includes, in continuous order, drilling of the vertical borehole, placement of the loop tube to the bottom of the vertical borehole with the grout tremie, and grouting of the vertical borehole from the bottom of the vertical borehole to the earth's surface at the drill site. When these three steps are completed, the vertical borehole may now be considered a loop well. Loop tube emplacement and grouting should be performed in a timely manner to guarantee successful loop tube placement, grout installation, and environmental protection.
Loop Well Driller: Any person engaged in constructing, altering, testing, developing, or repairing a loop well.

Non-Pressurized Flow Center: A flow center that maintains positive suction pressure on the pumps via a standing column of water. These systems do not require that the loop field piping be pressurized to ensure proper operation.
Open-Loop System: In a ground-coupled heat pump, a heat exchanger system in which the transfer fluid is exposed to the atmosphere.
P/T Ports: Pressure/temperature ports used to monitor the performance of a heat pump system. A small diameter opening that allows a probe to be inserted during system operation.
Packaged Heat Pump: A self-contained heat pump unit available as either a free-delivery, ductless system for single rooms or as a larger, central ducted unit that can heat or cool an entire home.
Packaged Terminal Heat Pump: A window or through-the-wall-mounted, air-to-air heat pump unit designed to heat or cool a single room or zone.
Parallel System: A flow condition where two or more fluid paths are possible in the closed-loop circuit.
Performance Factor: The ratio of useful output capacity of a system to the input required to obtain it. Units of capacity and input need not be consistent.
Positive Displacement Pump: A pump that moves a set volume of fluid through the system for each revolution of the driving shaft. Positive displacement pumps are commonly used in conjunction with high solids grouting materials.
Power Flushing: A higher than normal water flow and pressure in a ground heat exchanger used to flush air and debris from the closed-loop piping system.
Pressure: When expressed with reference to pipe, the force per unit area exerted by the medium in the pipe.
Pressure Drop: The decrease in pressure down the length of a pipe resulting from fluid flow.
Pressure Rating: The estimated maximum pressure that the medium in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur.
Pressurized Flow Center: A flow center that typically consists of circulating pumps mounted in a cabinet. Positive pressure must be maintained on the system at all times (via pressurization of the lines) to ensure positive suction-side pressure on the pumps in order to produce flow.
Pump Curve: A curve used to display the amount of back pressure (head loss, feet) that a given circulating pump would be able to overcome at a given flow rate, typically provided by the pump manufacturer.
Purge Pump: A high-pressure and high-flow-rate pump used to flush air and debris from the closed-loop circuit of a closed-loop/ground-source (cl/gs) heat pump system.
Refrigerant: A fluid of extremely low boiling point used to transfer heat between the heat source and heat sink. It absorbs heat at low temperature and low pressure and rejects heat at a higher temperature and higher pressure, usually involving changes of state in the fluid (i.e., from liquid to vapor and back).
Register: A combination grille and damper device covering an air inlet or outlet opening.
Return (Air): Air returned to the space conditioning unit from the conditioned space.
Reynolds Number: A dimensionless parameter calculated to describe internal pipe flow condition. Defined to be the ratio of inertia forces to viscous forces. A Reynolds Number less than 2,500 indicates that the internal pipe flow condition is laminar. A Reynolds Number greater than 2,500 indicates that the flow condition is turbulent.

Riprap: The heavy cobbles used at the waterfront of oceans/lakes/rivers, storm water discharge outflows, drainage ditches, etc. to prevent erosion. Particle size can range from 4-6-inch gravel to natural or manmade boulders several feet in diameter, depending on the requirement.
Run Fraction: The fraction of time that a GSHP system operates to condition a space for a given period of time, expressed as a decimal.
Run Time: The number of hours that a GSHP system operates to condition a space for a given period of time.
Saturated Liquid: The temperature and pressure where refrigerant is all liquid, but will immediately begin to evaporate with addition of heat.
Saturated Vapor: The temperature and pressure where refrigerant is all vapor, but will immediately begin to condense with removal of heat.
Saturation Temperature: The temperature at which refrigerant will either immediately condense with the removal of heat (if in the vapor phase) or evaporate with the addition of heat (if in the liquid phase) at a given pressure.
Scaling: The build up of water impurities on the inside surface of the water-to-refrigerant heat exchanger in a GSHP, primarily caused by hardness and alkalinity of the water. This problem occurs primarily in open-loop systems and can cause fouling in the heat exchanger, diminishing the overall effectiveness
and efficiency of the system.
Schedule: A pipe size and wall thickness classification system (outside diameters and wall thicknesses) originated by the iron pipe industry.
Seasonal Energy Efficiency Ratio (SEER): A measure of cooling efficiency for air source heat pump equipment on an annual basis, expressed as the cooling energy removed from the space divided by the electric energy consumed over the entire cooling season.
Sensible Cooling Load: The amount of sensible heat that must be removed to maintain the space at the thermostat set point temperature.
Sensible Heat Factor (SHF): The percentage of the total cooling load that can be attributed to the sensible load. Defined to be sensible cooling load divided by the total load, expressed as a decimal.
Series System: A system in which the circulating fluid from the heat pump(s) has a single flow path through the ground heat exchanger.
Simple Payback Method: A method for analyzing the cost of HVAC systems which considers only the time it takes for annual energy and maintenance cost savings to offset an initial difference in cost between two systems.
Site Plan: A detailed drawing that shows where buildings, buried utilities, landscaping, permanent fencing, etc. are located on a property and also where a potential GHEX could be installed.
Slinky: A horizontally-trenched or pond-loop configuration where loop piping is coiled into a slinky shape to reduce the amount of surface area necessary for a given GHEX installation.
Soil/Field Resistance: The resistance to heat flow resulting from soil thermal properties and underground pipe placement.
Standing Column Flow Center: See Non-Pressurized Flow Center.
Static System Check: A GSHP system startup check procedure performed before the system is turned on to identify obvious problems that must be resolved before proper operation can be expected.
Suction Line: The tube of pipe that carries the refrigerant vapor from the evaporator to the compressor inlet.

Supplemental Heating: A heating system component used when a heat pump cannot satisfy the space heating requirements by itself, during the defrost cycle (for air source equipment only), or as an emergency backup when the main system is inoperable. Usually electric resistance heat, but natural gas, LPG, or oil heating systems are also used.
Therm: A quantity of heat equivalent to 100,000 Btu.
Thermostat: An instrument that responds to changes in temperature and is used to directly or indirectly control indoor temperature by operating a space conditioning system.
Throw: The distance an airstream travels after leaving a supply outlet before the velocity is reduced to a specific terminal velocity (usually 50 ft/min).
Ton of Refrigeration: A measure of the amount of heat absorption required to melt 1 ton of ice in 24 hours. A ton of refrigeration is a measure of the amount of cooling delivered by a heat pump (or other air conditioning system). One ton of refrigeration is equivalent to a cooling rate of 12,000 Btu per hour.
Total Cooling Load: The total amount of heat energy that must be removed from a space to keep it at the thermostat set point temperature as well as at the desired humidity level, defined to be the sum of the sensible cooling load and the latent cooling load.
Tremie Line: The pipe used to pump an appropriate grouting material into a borehole from the bottom of the hole to the top. A tremie line will commonly be made of 1-inch or 1-¼-inch diameter HDPE pipe.
Turbulent Flow Regime: A term used to describe the flow condition where fluid flow becomes chaotic and disordered. The mixing effect caused by turbulent flow maximizes heat transfer between the fluid and pipe walls in the closed-loop GHEX while also increasing the system pumping pressure.
U-Bend: A prefabricated closed-return pipe assembly used in vertical heat exchangers to connect the two pipes at the bottom of the bore hole.
Unitary Heat Pump: A complete factory-assembled heat pump.
Valve, Expansion: A device for regulating the flow of liquid refrigerant to the evaporator. Two types of valves are commonly used: an electronic valve that responds to variation in electric resistance reflecting changes in refrigerant temperature, and a thermostatic valve that uses a refrigerant-filled bulb to sense changes in refrigerant temperature.
Valve, Reversing: An electrically operated valve that allows the heat pump to switch from heating to cooling, or vice versa, by changing the refrigerant's direction of flow.
Water Source Heat Pump: A heat pump that uses a water-to-refrigerant heat exchanger to extract heat from the heat source.
Water Source Heat Pump, Closed Loop (sometimes referred to as "geothermal heat pump")**:** Closed-loop systems circulate a heat transfer fluid (such as water or a water-antifreeze mixture) continuously to extract or reject heat from a ground or water heat source or sink.
Water Source Heat Pump, Open Loop (sometimes referred to as "geothermal heat pump")**:** Open-loop systems pump groundwater or surface water from a well, river, or lake through a water-to-refrigerant heat exchanger and return the water to its source, a drainage basin, pond, or storm sewer.
Zone Load: The amount of heating or cooling that the delivery system must provide to satisfy the peak loads for a specific zone, and a single thermostat is used to control the delivery system for that zone.
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APPENDIX B

RELATED RESOURCES

- Air Conditioning Contractors of America - http://www.acca.org/
  - ACCA Standard 5 - *HVAC Quality Installation Specification*

- American Society of Heating, Refrigerating and Air-Conditioning Engineers - www.ashrae.org/
  - *Ground-Source Heat Pumps – Design of Geothermal Systems for Commercial and Institutional Buildings*
  - *Geology and the Ground Heat Exchanger: An Introduction for Design Engineers*
  - *Operating Experiences with Commercial Ground-Source Heat Pump Systems*
  - *2007 ASHRAE handbook – HVAC Applications, Chapter A32 Commercial/Institutional Ground-Source Heat Pump Engineering Manual*
  - *2008 ASHRAE Handbook – Systems and Equipment, Chapter S8*

- Association of Energy Engineers - www.aeecenter.org/
  - The Certified GeoExchange Designer (CGD®) Program

- American Society for Testing and Materials – www.astm.org/
  - ASTM F2620-12 – *Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings*

- International Ground Source Heat Pump Association - http://www.igshpa.okstate.edu/
  - *Closed Loop Geothermal Heat Pump Systems Design and Installation Standards*
  - *Residential and Light Commercial Design and Installation Manual*
  - *Slinky Installation Guide*
  - *Soil and Rock Classification Field Manual*
  - *Grouting for Vertical Geothermal Heat Pump Systems*
  - *Closed Loop Ground-Source Heat Pump Systems Installation Guide*

- International Organization for Standardization – www.iso.org/
  - *ISO 12176-1:2012 – Plastics pipes and fittings – Equipment for jointing polyethylene systems – Part 1: Butt fusion*
  - ISO 21307:2011 – *Plastics pipes and fittings – Butt fusion jointing procedures for polyethylene (PE) pipes and fittings used in the construction of gas and water distribution systems*
  - ISO/IEC 17024:*2012 – Conformity assessment – General requirements for bodies operating certification of persons*

- National Ground Water Association - http://www.ngwa.org/
  - *Guidelines for Construction of Loop Wells for Vertical Closed Loop Ground Source Heat Pump Systems*, third edition
  - *Hydrogeologic Guidelines for Large-scale Ground-source Heat Pump Installations* (in development, 2013)
  - *Compilation of State Regulatory Oversight of Ground-source Heat Pump Installations: 2012*

- New York City
  - *Geothermal Heat Pump Manual* - http://www.nyc.gov/html/ddc/downloads/pdf/GeothermalHeatPumpManual.pdf

- Oak Ridge National Laboratory – www.ornl.gov/
  - *Summary and Analysis of Responses to Surveys on Experience with GHP Installations in Federal Facilities and Minimum Qualifications of GHP-related Professionals*, ORNL/TM-2012/452 - http://info.ornl.gov/sites/publications/files/Pub39375.pdf
  - *ORNL/TM-2000/132 Generic Guide Specifications for Geothermal Heat Pump System Installation* - http://www.ornl.gov/~webworks/cpr/v823/rpt/107119.pdf

- Plastic Pipe Institute
  - *Handbook of PE Pipe* – http://www.plasticpipe.org/publications/pe_handbook.html
  - *PEX Design Guide* – http://www.plasticpipe.org/publications/pex_handbook.html

- U.S. Department of Energy –
  - http://www1.eere.energy.gov/buildings/technologies/heating_cooling_research.html

- U.S. Environmental Protection Agency Energy Star Program
  - http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=HP