Pikes Peak ASHRAE Luncheon
January 20, 2011

General Fundamental and Commercial Design Questions

Q. How does a ground source heat pump function to heat and cool?

A. GSHP equipment functions just as a refrigerator, water source heat pump or conventional air conditioner function. They move heat from one medium to another.

Q. What might be the required parameters for a Division 23 specification for a commercial GSHP system?

A. There are general narratives available for a GSHP specification but some of the key parts reference that the equipment must be *extended range capable*, not just ARI-ISO/ASHRAE 13256-1 and 13256-2 components. Other items to be covered are the HDPE pipe schedule in the loopfield, pressure testing and validation requirements, as-built documentation of the loopfield, etc. Other fabrication/installation items that should be included are the minimum thermal conductivity requirements of the grout (for vertical ground loops), detailed headering schedules to minimize purging requirements, etc.

Several items we have noted that are often left to the installation contractor include items such as purging of the loopfield "to achieve 2' of fluid movement per second". This minimum flow and pressure drop should be provided by the designer, not left to the contractor (most contractors do not understand how to determine this). We even include the purging procedure since even experienced loop installers do not have often understand how to purge multiple header pair systems typical of larger commercial installations.

Other items include identifying points of responsibility for purging, how this interacts with the above-ground part of the mechanical system, etc.

Many of the specifications, such as the grout performance, circuit spacing, etc., must be personalized for each application.

Q. What tests need to be addressed for designing a ground heat exchanger?

A. Typically a thermal conductivity (TC) test is necessary prior to completing a commercial closed loop design. Most residential applications cannot justify the cost of a TC test.

A thermal conductivity (TC) test should not be confirmed and run until **AFTER** the system has been pre-designed to determine optimum parameters. The system cannot be pre-designed until the annual energy loads and heat pump equipment schedule are known.

Many projects start with a TC test before a mechanical design is even accounted for, forcing the design to follow the test parameters. For example, one project started with a TC test using a vertical borehole of 300' without benefit of a pre-design; due to site constraints the project required a 500' deep hole – the test values for one depth cannot be guaranteed to be the same for another. Remember, the ground loop is a major part of the mechanical system. The TC test parameters should only be selected and approved by those responsible for the design, operation and performance of the mechanical system. Leaving such tests to contractors with no perspective or understanding of the entire mechanical system and site limitations is a recipe for disaster, or at the very least costly change-orders.

TC tests may be used for both vertical and horizontal ground loop options, but the testing methodology for each is different.

Q. What certification(s) are required for TC testing?

A. Currently there are no state or federal requirements for TC testing. However, experienced designers will post a specific testing specification for either a vertical or horizontal TC test, require specific power requirements for vertical TC testing efforts and equipment, rely on ASHRAE minimum standards for vertical testing, ASTM testing standards for horizontal probe tests, etc.

Q. What other tests might be required for a ground loop?

A. It is common practice to routinely test random batches of thermally enhanced grout to validate thermal conductivity performance of this installation component as required by the design specifications during the installation of a vertical ground loop.

Q. What certification(s) are required for designing a closed loop ground heat exchanger?

A. Most states do not have a certification requirement for the person designing the ground loop specifically. However, as a GSHP system is a component of the mechanical system, it might be considered the responsibility of the mechanical engineer. As closed loop heat exchanger design is a detailed process that is not commonly taught or covered in most mechanical engineering curriculums, this is often farmed out to specialists that may or may not possess a PE certification and the client mechanical engineer often stamps these designs.

There is a certification called the Certified GeoExchange Designer (CGD), with certification status conveyed by the Association of Energy Engineers (AEE). Many clients, architects and others require that the ground loop specifications be the responsibility of an individual possessing a CGD. Many military projects for example specifically require that a CGD be involved in the design of any closed ground loop.

A qualified, experienced CGD can often justify his or her design fees resulting from a streamlined, efficient ground loop specification.

Q. What certification(s) are required for installing a closed loop ground heat exchanger?

A. Some states have no minimum standards for the personnel installing a ground loop, while others such as Oklahoma require anyone installing any closed ground loop be IGSHPA/NATE certified as installation contractors.

Many states are requiring either specialized permits of licenses for the installation of closed loop ground heat exchangers. For example Colorado's Division of Water Resources requires that individuals installing any type of closed loop system be licensed by DWR and submit as-build construction reports.

Most commercial GSHP installation specifications will require that the installation contractor's key on-site personnel possess current IGSHPA/NATE certifications as installers. Further requirements include current HDPE fusion accreditation cards from a recognized polyethylene pipe vendor for competent construction and pipe fusion, as well as verifiable experience.

Q. Can anything be built over a closed loop ground heat exchanger?

A. Yes, in most cases for vertical ground loops just about anything including parking lots and in some cases even buildings may be sited on top of the loopfield. There is often a coordination issue but in most situations this is not significant. In some cases construction over a horizontal field may be done, but not generally a building.

Q. What kind of material is used in constructing a ground loop?

A. The only acceptable material is high-density polyethylene (HDPE) pipe and fittings in most cases for vertical and horizontal ground loops ("dry" loops). Most industry-spec HDPE is warranted for 50 years. HDPE is often mandated in most states by law for any type of closed loop ground heat exchanger. For surface water loops ("wet" loops), stainless steel heat exchangers are often cost competitive and economic to install. Colorado DWR recognizes HDPE for both dry and wet loop installations.

Q. How are loopfield parameters determined, including pipe size, depth, spacing, headering schedule, etc.?

A. Loopfields must meet the demands of the loads and load durations, equipment flow rates and account for how much heat transfer is accounted for in the host geology. The designer must understand the site and available area to work with and even consider local installation assets and their capabilities. While the variables to consider are numerous, the design procedures are standardized (ASHRAE, IGSHPA).

The key variables to commence a system design are loads and load durations, equipment schedule, and a site plan. The configuration of the field must also consider flow and pressure drop for least pump sizing, turbulence for heat transfer within the ground heat exchanger (particularly for heating dominated loads), fluid type and antifreeze type if required and other impacts.

Once the key variables are identified, there are several industry-recognized software programs used for loop design. However, unless the user understands the fundamentals of GSHP design, evaluation, and the desired outcome, more often than not such software will not help with a competent design. Detailed peer review by experienced design assets is recommended for any novice design efforts.

The worst enemy of GSHP installations is the use of rule-of-thumb assumptions. As the size and scope of a project increases, the more this is true. For example, a 100 ton peak cooling load for a church and office building, located next to one another and using the same exact mechanical equipment with the same geology and climate, could have vastly different loop sizes. The church could for example end up with a ground loop with 50' of borehole per peak equipment ton, and the office building could require 300'+ of borehole per peak ton. For this reason, assuming so much "borehole per ton" could result in a catastrophic failure of the system if it is "short-looped" or may not even get past the design phase if excessively oversized. It boils down to determining how long does the peak ton exist. The bottom line is that rule-of-thumb assumptions have no place for finalizing system designs, in particular closed loop ground heat exchanger parameters.

Q. What are the maintenance considerations of a GSHP system?

A. For the above-ground portion of a system, the maintenance issues are the same as for a conventional mechanical system. For example, from a maintenance perspective a boiler-cooling tower WSHP is no different than a GSHP. Air filters, maintaining the pH balance of mechanical fluid, etc., are equivalent.

A ground loop has no moving parts, therefore the conventional items that are replaced – traditional boiler, cooling tower and related infrastructure – completely eliminates the maintenance issues of these associated components as they no longer exist. As the HDPE materials of a ground loop do not react with water or water/antifreeze brine, pH balance issues are reduced; further, the water temperature bandwidth is much narrower decreasing maintenance issues from large fluid temperature swings normally associated increased corrosion or aggressive water/brine degradation.

One item that is often not accounted for in life cycle costing estimates with closed loop GSHP maintenance is the reduction in controls architecture for the elimination of conventional components by the ground loop. Reduced controls architecture simplifies controls design, operation, and post installation maintenance adjustments.

Q. Are there other operational issues to be concerned with for GSHP systems?

A. As a rule, no. However all concerned, from the design team to the contractor to the end-user, must realize that a GSHP installation is a ***system***. That is, every item involved with the mechanical installation, from the ground loop to the thermostats, impacts the operation, performance, reliability and operating cost of the installation. Every part and specification interacts and affects the adjoining components. In other words, taking a short-cut on one portion of the system could adversely impact the operation of the entire installation. This is no different than a conventional mechanical system.

One good example of this is an ice rink and combined recreation center in Canada serviced by a GSHP system; this facility included large indoor community pools, retail stores, restaurant facilities, etc. The design team had a specific protocol for setpoints for the ice sheet, fluid servicing fan coils and hydronic floor heat portions of the building, etc. After about a year of operation, the client noted an extremely high operating cost, approximately $30,000 over the projected mechanical system operating cost (the control system included power consumption tracking). The design team functional performance tested the system and found that the supply water temperature setpoints were off by as much as 2° F. After adjustment, the next year's savings exceeded $50,000 (*example courtesy of Ed Lohrenz, GeoXergy Systems*).

Q. What is the life expectancy of a GSHP system?

A. The key components of GSHP equipment, that is the most expensive items such as compressors, are expected to last in excess of twenty years (ASHRAE). Much of this long-term performance is a direct result of moderate EWT ranges fed to GSHP equipment. Industry history supports this product life expectancy. Repair or replacement of key heat pump components, or the entire unit, is no different than for conventional WSHP products.

Closed loop ground heat exchangers should exceed the life of the building in most cases. The industry standard warranty for most HDPE pipe is 50 years.

Q. What is the installation cost of commercial GSHP installations?

A. Historically the cost range of commercial GSHP systems is $15 to $25 per ft² of conditioned space, inclusive of the ground loop. This is often in the same range as competing conventional boiler/chiller options. Industry has noted that the larger the building the more likely that a GSHP system can compete on a first-cost basis, in some cases being less costly than competing conventional systems.

Items that impact first costs are design strategy, experience of the design team, experience of the mechanical contractor, controls architecture, etc.

Note: We have observed in some cases that ground loop costs to the end-user were doubled, or more, from what the looping contractor quoted to the general contractor. Reasonable markup should be permitted for any general contractor running subcontractor costs through them, but it is our view that these markups and actual costs should be revealed to the end-user to maintain fairness and perspective.

Q. What temperature ranges can be expected from a ground loop?

A. Supply temperatures from a ground loop are driven by the building loads. For example, most commercial ground loops that are internally driven (cooling dominant) will operate in the 50°F to 90°F range, regardless if in Colorado or even an extreme cold climate such as Alaska. For heating dominant loads the loop may be designed to operate at no less than 30°F. If the loads are reasonably balanced, the range could be 30°F to 90°F if the loop is sized as small as possible, or have a much narrower band width if the loop size is increased.

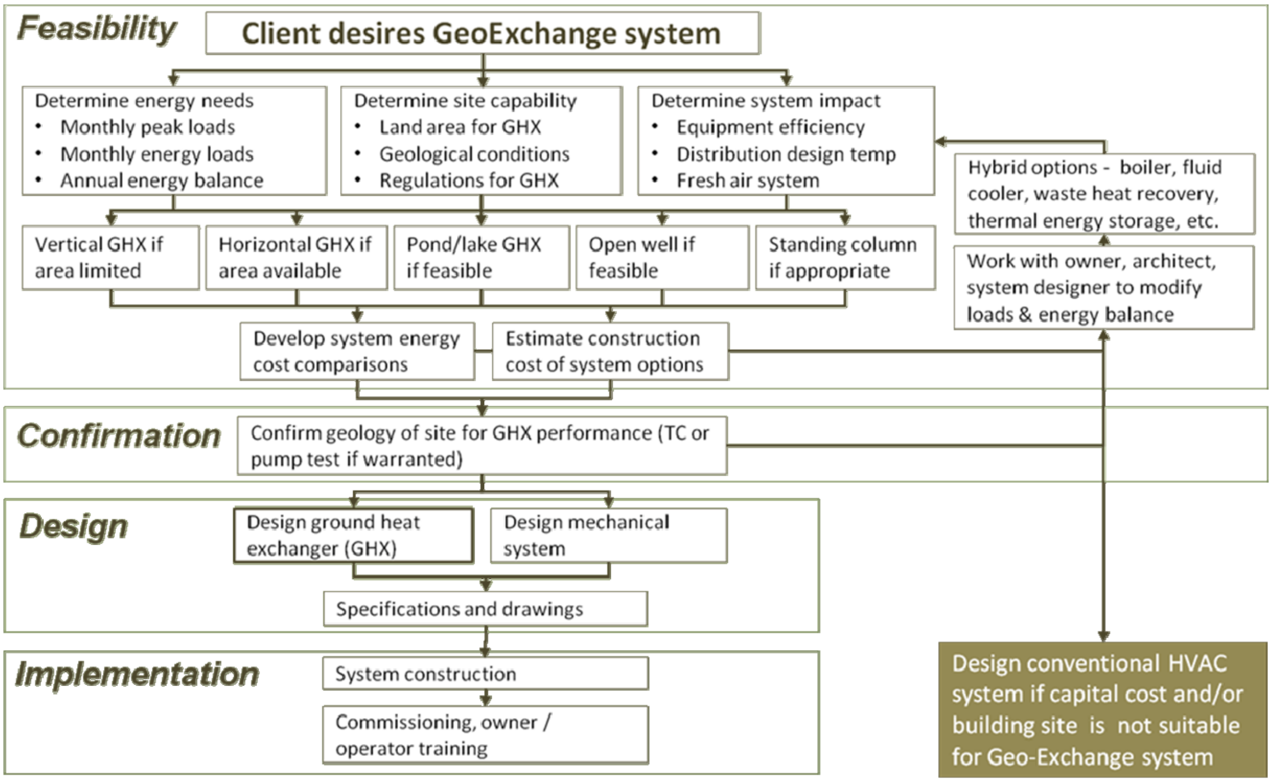
Most current GSHP product will operate within a temperature range as low as 20°F to as high as 120°F. The loop design will take advantage of this extended range and design the loop to provide an optimum temperature range to maintain best performance of the heat pump system.

Q. What types of applications or buildings can use GSHP systems?

A. Schools, office buildings, emergency services, various types of military facilities, churches and others have all used GSHP systems. The short answer is that any building that can be conditioned by a conventional system may use a GSHP installation to provide space conditioning.

Design Process

The design process for a closed loop ground heat exchanger is a methodical procedure that merely accounts for the needs of the building, site considerations, mechanical system variables and host conditions for the ground loop. Please note that a TC test should not be commissioned until after the building requirements are determined in sufficient detail and site variables have been accounted for by an experienced designer (see *Confirmation* section of flow chart below).



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