TRANE

engineers newsletter

providing insights for today's hvac system designer

efficiency, environment, economics…

The Three E's of Geothermal Heat Pump Systems

from the editor…
Rising energy prices, rolling blackouts, and interest in environmental issues remain headline news, prompting building owners and facility managers to redouble their efforts to find the "grail" of comfort systems: an HVAC system that reduces energy costs, benefits the environment … and *is economically justifiable.*

That quest should lead many consulting engineers to consider the ***geothermal heat pump (GHP) system****. In this EN, we explain how the GHP system minimizes the environmental impact of providing efficient, economical comfort.*

The Geothermal Advantage

A simple way to understand the geothermal system is to compare it with a conventional water-source heat pump (WSHP) system. The principal components of a WSHP system are the heat pumps, piping loop, water pump, cooling tower, and boiler. As long as the loop water remains between preset limits—60°F [16°C] and 90°F [32°C], for example—the heat pumps can provide either cooling or heating.

When all zones require cooling, each heat pump transfers heat from the space it serves to the piping loop. Excess heat is rejected from the loop by the cooling tower. Conversely, when all zones require heating, the heat pumps extract heat from the water loop to warm each zone. The boiler operates as needed to maintain the desired loop-water temperature.

For much of the year, some heat pumps provide cooling at the same time that others provide heating. In effect, the WSHP system recovers heat from one area of the building and transfers it to another, making it unnecessary to operate either the boiler or the cooling tower. As discussed later in this *EN*, a *geothermal* heat pump system further conserves energy by replacing the cooling tower and boiler with a heat exchanger (Figure 1) that taps a renewable source of energy: the Earth.

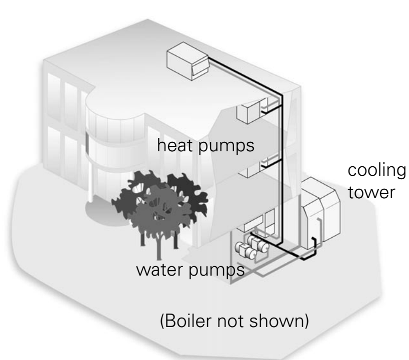
"E" is for…

Efficiency. Rather than discard excess heat like a conventional WSHP system, a geothermal heat pump system stores this excess energy beneath the Earth's surface for later recovery. The process relies on the fact that subterranean temperatures remain relatively constant throughout the year: warmer during the winter, and cooler during the summer, than ambient air. Without a cooling tower and boiler, the GHP comfort system consumes significantly less energy than other types of HVAC applications. Only the heat pumps (which are already noted for their efficient performance) and the water pump use purchased energy.

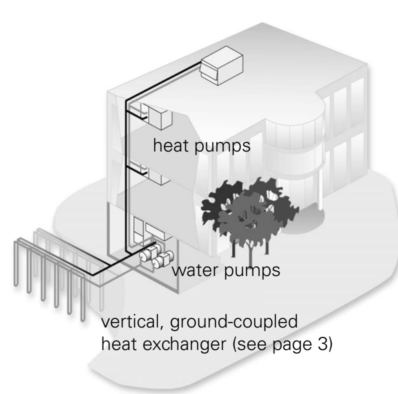
Environment. The benefits of recovering stored energy from the ground extend beyond the building. Purchasing less energy eases the burden of demand at the power plant. In turn, the power plant consumes less fossil fuel and emits fewer greenhouse gases into the atmosphere.

GHP systems also encourage optimized site designs that lessen the visual impact of the building on its

Figure 1. Comparison of Conventional and Geothermal Heat Pump Systems



Conventional Water-Source Heat Pump System



Geothermal Heat Pump System

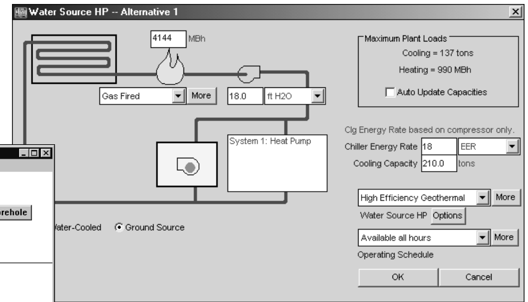
surroundings. All of the heat collected by a GHP system is removed from the building without any visible sign of the transfer process.

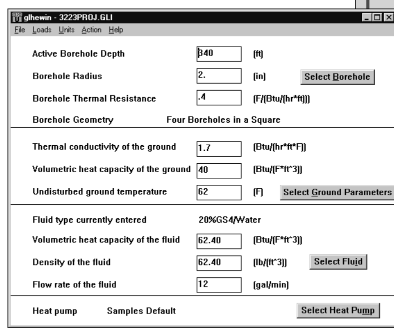
Economics. Profitability underlies most decisions in a commercial enterprise. Efficient systems for lighting, plumbing, and comfort can significantly reduce the operating expense of doing business but usually cost more to obtain. To remain profitable, a business must balance future cost savings with present capital expenditures.

It is no coincidence that consideration of a geothermal heat pump system becomes a matter of economics. With no cooling tower or boiler to operate and maintain, the life-cycle cost is attractively low. This benefit must be balanced with a comparatively high cost of installation, however. Ground-coupled heat exchangers require excavation, trenching, or boring as well as the services of a qualified contractor… services that may be difficult to obtain depending on the location.

Figure 2. Prequalify the GHP Concept with the Help of Specialized Tools

"Scoping" tools (System Analyzer, for example) help estimate HVAC system costs based on monthly building loads.





GLHEPRO calculates the vertical bore-hole depth for ground-loop heat exchangers based on monthly loads, soil conditions, and well-field size.

To "pay off," the operation-and-maintenance cost savings afforded by the GHP system must produce a satisfactory return on the added investment.

Note: The ENERGY STAR® labeling program identifies and promotes energy-efficient products. To earn this label, geothermal heat pumps installed in a closed-loop system must achieve an energy efficiency ratio (EER) of 14.1 during cooling operation and a coefficient of performance (COP) of 3.3 while heating. Higher efficiencies are required for heat pumps applied in open-loop systems.

The Shape of Geothermal Recovery

Ground-coupled geothermal systems rely on closed piping loops that are buried in the ground at a depth that takes advantage of the Earth's natural capacity for thermal storage. The loops are usually arranged vertically, but can also be configured in horizontal or spiral patterns.

Surface-water geothermal systems submerge a series of closed piping loops in a pond or lake. Although the loop temperature varies more widely than in ground-coupled applications, the surface-water design can be more cost effective …particularly where local building codes require water-retention ponds for short-term storage of surface runoff.

Ground-water geothermal systems use an open system of piping loops, drawing water from a well and returning it there or to a drain field or sewer. Quality and adequacy of the water supply become important design considerations, as does providing an acceptable, code-compliant means of discharging the return water. ■

Justifying the Benefits

A study by the U.S. Environmental Protection Agency (EPA) indicates that, of the space conditioning options available today, geothermal heat pump systems provide the lowest life-cycle cost and the least environmental impact. However, the cost effectiveness of a GHP system for a particular application depends on local factors such as climate, soil conditions, land availability, and utility costs as well as interest rates and the relative installation costs for other types of comfort systems.

Consequently, a *conceptual* design of the geothermal heat exchanger is critical to determine (within 10 percent of the actual installation cost) whether the additional expense is warranted. The magnitude of the building's cooling and heating loads will significantly affect the size and cost of the geothermal loop, so it is important to know how much heat will be rejected to and extracted from the ground.

Scoping tools such as System Analyzer™ (Figure 2) or Ener-Win software—can help estimate the monthly cooling and heating loads. As Figure 3 demonstrates, the load profiles for a building that is occupied for only 10 hours of each day differ dramatically from the loads of a building with continuous occupancy.

Specialized software also exists to assist with heat-exchanger design. GLHEPRO, for example, simplifies "the design of vertical bore-hole-type, ground-loop heat exchangers." The program calculates the required depth for the heat-exchanger bore holes based on monthly cooling and heating loads, soil type, heat pump performance, and the approximate size of the well field.

Armed with a cost estimate for the piping loop, economic analysis software can be used to predict the life-cycle cost and payback period of the GHP system.

Note: Incentives may be available to pay part of the installation costs for the well field, despite recent changes in electric utility regulations and the present deregulation environment.

Delivering Performance

Having established the economic feasibility of geothermal heat pumps to the owner's satisfaction, the next step is to develop a comprehensive design for the entire comfort system. Tools such as DOE–2 or TRACE™ energy-and-economic-analysis software make it easier to refine the final design by simulating the effects of various

Figure 4. Heat-Exchanger Site Preparation

equipment combinations and control strategies.

Ground-coupled geothermal systems require an additional design step: **drilling a test bore hole** to determine the actual thermal properties and soil conditions at the site. Engineers and contractors who are new to geothermal systems often seek a rule of thumb to circumvent this step. Once acquainted with ground-coupled heat exchangers and their construction, however, they understand why such a shortcut simply doesn't exist…*and* why the cost of installing the heat exchanger is so important to the economic performance of the GHP system.

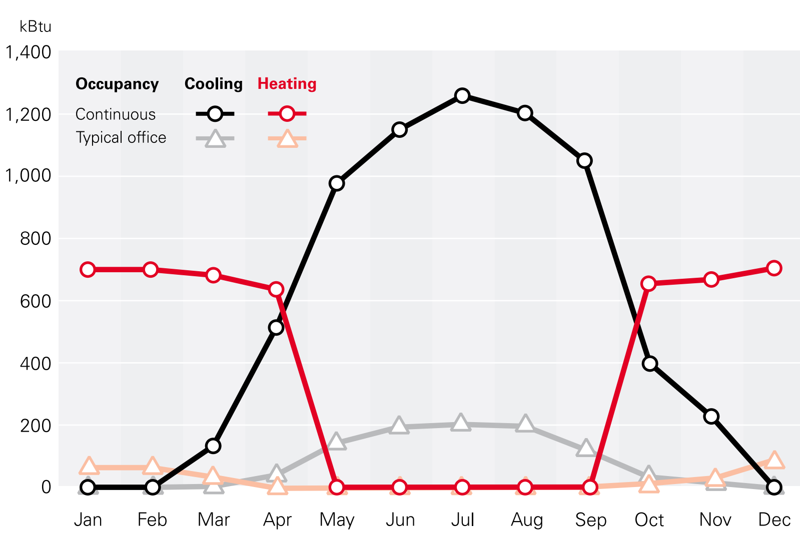
In commercial applications, geothermal heat exchangers are often configured as a series of closed, vertical loops to minimize the size of the well field, particularly when available land is limited. As shown in Figure 4, the well field is created by drilling bore holes—usually 6 inches [150 mm] in diameter—at intervals of 15 to 20 ft [4 to 6 m] and at depths ranging from 100 to 500 ft [30 to 150 m]. Site conditions and building loads determine how many holes must be drilled. Each ton of building load can require a well-field area that occupies anywhere from 225 to 400 ft² [20 to 30 m²].

Pipes (typically fabricated of high-density polyethylene, HDPE) are formed into closed loops, which are then inserted into the bore holes. After inserting the loops, each bore hole is grouted with a material that enhances heat transfer between the pipe and the soil. The grout also serves as a seal to protect the groundwater from contamination.

Minimizing pump power. Potential operating cost savings associated with geothermal comfort systems need not be limited to elimination of the cooling tower and boiler. As in other types of applied chilled water systems, the pumping power required to circulate water through the piping loop can also be reduced. For example:

- Bypass the geothermal heat exchanger whenever the loop water temperature falls within the required range.
- Maintain the loop flow rate between 2.5 and 3.0 gpm/ton [0.045 and 0.054 lps/kW] to minimize the pressure drop.
- Add a two-position valve at each pump. To lessen the hydraulic head

Figure 3. Comparison of Building Loads Based on Monthly Occupancy



of the system, close the valve whenever the heat pump is off. (ASHRAE/IESNA 90.1–1999 requires such valves for hydronic systems larger than 10 hp [7.5 kW].)

Significant savings in pumping energy can be achieved in either situation by letting the system pump "ride its curve" or by modulating pump speed with a variable-frequency drive.

Consider hybrid opportunities. Removing the cooling tower avoids the expense of operating and maintaining it; however, providing a small amount of mechanical heat rejection can be advantageous for some ground-coupled applications. Doing so reduces the size of the geothermal heat exchanger, which may make it easier to achieve an acceptable return on investment.

Hybrid geothermal systems that combine water-source heat pumps with other types of water-cooled HVAC equipment may best address the specific requirements of an application. For example, if interior zones always require cooling but the loads vary, self-contained air conditioners equipped with variable-volume supply fans can provide part-load energy savings. The heat rejected by these units into the common water loop can be recovered by water-source heat pumps to warm perimeter spaces.

An application that requires lots of ventilation offers another hybrid opportunity: adding a dedicated, chilled-water air handler and water-cooled chiller to treat the outdoor air. Heat rejected into the common water loop by the chiller can be used by water-source heat pumps to satisfy space heating demands.

Remember, too, that geothermal comfort systems need not always include heat pumps. With proper piping and valves, incorporating a geothermal heat exchanger in a central cooling/heating plant can deliver efficiency, environmental, and economic benefits that are similar to those provided by traditional GHP systems.

Stated Simply…

GHP systems may indeed be the "grail" sought by building owners and facility managers. Geothermal comfort is:

- **Efficient.** It uses the Earth as a natural heat sink *and* heat source rather than mechanical cooling towers and boilers.
- **Environmentally sensitive.** It consumes less purchased energy than other types of HVAC systems and ultimately reduces power-plant emissions of greenhouse gases.
- **Economical.** It greatly reduces the operation and maintenance costs of thermal comfort. ■

By Mick Schwedler, PE, applications engineer, and Brenda Bradley, information designer, The Trane Company.

You can find this and other issues of the Engineers Newsletter *in the commercial section of www.trane.com. To comment, send a note to The Trane Company, Engineers Newsletter Editor, 3600 Pammel Creek Road, La Crosse, WI 54601-7599, or e-mail us at comfort@trane.com.*

Become a Geothermal Savant

Achieving the inherent benefits of a geothermal heat pump system requires proper application…and expertise.

The Geothermal Heat Pump Consortium, (GHPC) and the International Ground Source Heat Pump Association (IGSHPA) can be invaluable resources for building owners or design professionals who are unfamiliar with geothermal technology.

IGSHPA (www.igshpa.okstate.edu) is a nonprofit organization that promotes the use of ground-coupled heat pump systems. The organization also develops detailed training materials covering various aspects of system design and installation.

Besides sponsoring regional training, GHPC (www.geoexchange.org) offers assistance with feasibility studies and system design. Reserved for Consortium members, the mentorship program familiarizes engineers and architects with "optimum or innovative designs" that apply geothermal heat pump technology.

Another useful source of information is *Ground Source Heat Pumps: Design of Geothermal Systems for Commercial and Institutional Buildings,* an engineering manual published by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). It can be purchased from the ASHRAE Online Bookstore at www.ashrae.org. ■

TRANE®

The Trane Company
An American Standard Company
www.trane.com

For more information, contact your local district office or e-mail us at comfort@trane.com