Outside the Loop

A Newsletter for Geothermal Heat Pump Designers and Installers

Fall 1998 - Volume 1, Number 4 - Published Quarterly

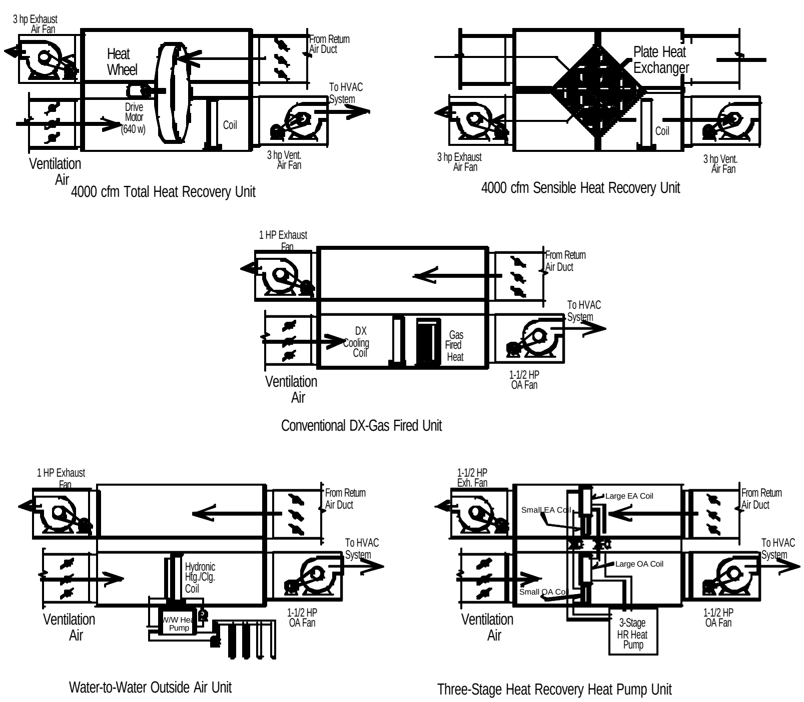
Outdoor Air and GSHPs

Engineers often avoid ground-source heat pumps because of the perception that there are no acceptable methods for conditioning the ventilation air. However, effective solutions for GSHPs are no more complicated than those for other HVAC systems. This is especially true compared to the options available for (ASHRAE 62 compliant) VAV systems.

A study is underway to evaluate the energy use and cost of outdoor air methods for GSHPs. Three building types in three different climates are being compared. The figure below details five of the equipment options that are being evaluated.

Preliminary conclusions regarding this comparison are:

- Fan energy is a significant portion of annual energy use.
- In some climates heat recovery units can consume more energy than conventional ventilation air systems.
- For heat recovery or conventional systems to be efficient, fan losses must be minimized and control strategies optimized.
- The economizer mode provides significant energy savings.
- Evaluation of ventilation air systems should include energy use of all fans, pumps, motors, compressors, and furnaces.
- Climate, building type, and occupancy patterns dictate optimum technologies. **(See page 4 for an example.)**



Outdoor Air Equipment Options in Comparison

GSHP Bore Hole Water Migration

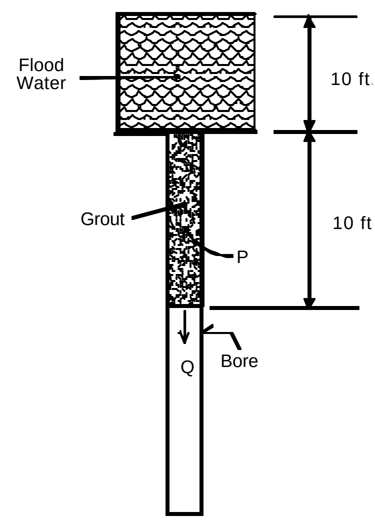
An ideal GSHP bore grout would protect groundwater, promote heat transfer, be easy to install, and have a reasonable cost. Conventional grouts that are used to seal the annular region around U-tubes may protect groundwater at the expense of effective heat transfer. This imbalance could result in a less efficient system that would reduce the environmental benefits associated with high efficiency (reduced power plant emissions and greenhouse gases).

The potential of contamination from surface water pollutants can be demonstrated by calculation of the flow through a 6 inch grouted bore (only the top 10 ft. grouted) when a loop field is flooded with 10 feet of water, a fairly extreme assuption.

$$\text{Flow} = \text{Permeability} \times \text{Bore Area} \times \text{Water height} \div \text{Thickness}$$

Permeability $= 1.97 \times 10^{-7}$ *ft/min* $(1 \times 10^{-7}$ *cm/s*$)$,
Bore Area $= \pi/4\ (6''/12)^2 = 0.196\ ft^2$
Flow $= 1.97 \times 10^{-7}$ *ft/min* $\times\ 0.196\ ft^2 \times 10$ *ft.* $\div\ 10$ *ft.*

Flow $= \mathbf{0.0000000386\ ft^3/min = 0.000000289\ gpm}$
OR $\Rightarrow$ 3,460,000 BORES REQUIRED TO FLOW 1 GPM



Surface Water Flow in Grouted Bore

Note: ASHRAE is currently initiating a research project to study the environmental issues related to GSHP loop fields. See their website: www.ashrae.org.

Design Issues and Tools

Injection Well Issues

"The injection well failed!" These words are misleading because injection wells don't often fail. The failure is more commonly that of the production well, the design of the injection well, or the drilling and completion methods used. Attention to sand control, screen design, piping and sealing can reduce or eliminate many problems.

A common problem with injection wells is plugging. While this is normally considered an injection problem the fault often lies in the production well. High amounts of sand from the production well, unless removed, will end up in the injection well. A well producing just 5 ppm of sand and operating at 200 gpm for 2000 hrs per year will produce 1000 lbs. of sand. Half a ton! That's enough to flatten the springs on my pick-up and more than enough to give any injection well a bad case of indigestion. The answer is to carefully specify the acceptable suspended solids (sand) content for the production well. For injection well systems, the production well should be required to produce "sand free" (<1ppm) water. Surface separators (centrifugal or strainer) should be considered a secondary strategy for sand control. Any sand removed at the surface has to pass through the well pump first. Pumps don't like sand any more than injection wells do. The primary method for controlling sand is careful screen design, gravel pack selection (if used), and development practices.

If one is used, the design of the screen in the injection well is also an important factor. The rule of thumb is the screen face velocity in an injection well should be one half of that in a production well. The additional screen area reduces the problem of clogging due to suspended solids. Commonly used values are 0.1 ft/sec for production wells and 0.05 ft/sec in injection wells. The face velocity is a function of aperture (slot) size, percent open area, diameter and length. For the same type, slot size and diameter screen as the production well, the injection screen would have to be twice as long to achieve the recommended velocity. The use of a different type of screen and slot size may be worth considering in the injection well. Wire wound or continuous slot-type screens often employ a wire with a triangular cross section. Wound around the circumference of the screen, this wire forms an opening that increases in size toward the ID of the screen. This imparts a "non-clogging" characteristic to the screen when used in production wells. In an injection well with the water flow direction reversed, this same type of screen may be more prone to clogging than other designs. This could be compounded by the fact that the screen would be more difficult to clean using swabbing and surging techniques. A bridge slot or louvered- type screen may be less prone to problems in an injection application. For injection wells which do not serve as a backup production wells, the screen (and gravel pack if used) do not need to provide a filtering function as they do in a production well. The use of a coarse, formation stabilizer type gravel along with a larger slot size (in comparison to the production well) would provide for a less restrictive flow path for the injected fluid. The pack gradation and the slot size are site specific determinations but simply replicating the design for the production well is unlikely to be a wise strategy in most cases.

Injection well piping should be designed to minimize the entrainment of air bubbles in the fluid. Bubbles can enter the area surrounding the well and plug aquifer passages just as effectively as sand or other solid particulates. To reduce this problem, injection wells should be equipped with an injection tube, which extends from the well head to below the static water level. The water is injected through this tube and it's function is to eliminate the "cascading" of water into the well, a practice that results in turbulence and bubbles. For systems in which water flow is intermittent (most heat pump systems), an air vent valve should be placed on the line entering the well. This valve serves to vent the air from the injection piping as flow is initiated.

Sealing of an injection well is more important than for a production well particularly if the injection well is expected to operate at a positive pressure at the well head. If the seal between the casing and the formation is inadequate, the potential exists for water to migrate up along the outside of the casing to the surface. Most regulatory jurisdictions require some minimum surface seal, usually a 1½or 2" thickness of cement, to a depth of 15 to 20 ft for all wells. For injection wells, the minimum requirement should be for the seal to extend to an impermeable (clay or uncreviced rock) stratum and preferably that the well be continuously cemented from the top of the aquifer to the ground surface.

Drilling method can impact the performance of a well. Generally, methods that do not involve drilling "mud" are more desirable for injection wells. These would include air rotary, air hammer and cable tool methods. Reverse circulation drilling also fits this category but is typically only used to drill much larger wells than GSHP applications.

Injection of water into a well is something like disposing of household garbage - the less to get rid of, the easier the job is. Design intelligently - use only as much groundwater as the system needs to optimize performance. Open loop systems can operate efficiently on less than 1.0 gpm/ton of ground water and rarely require more than 2.0 gpm/ton.

In summary:
Pump less water
Specify "sand free" production wells
Carefully design screens and gravel packs
Keep the air out - use an injection tube and an air vent
Consider alternate drilling methods
Have fun - this isn't brain surgery it's only ground water!

The Geo-Heat Center has assembled a set of specifications for water wells. These include both open hole and screen/gravel pack completions for production wells and modifications necessary for injection wells. Specifications for production well pumps are also included in the package. See the publications section of the newsletter for more information.

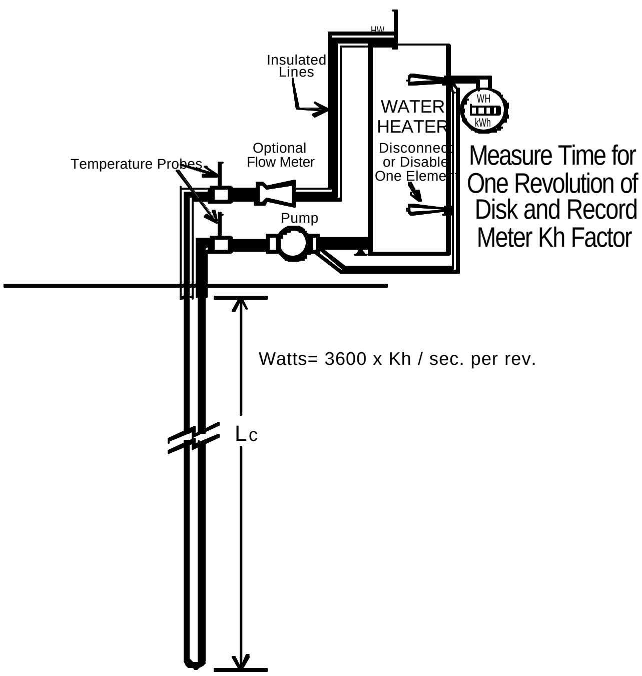
Fundamentals: Mother Nature Can Be a Wonderful Partner

(But she can also be a real hard to live with if you ignore her.)

Determining Thermal Properties of Soils and Rocks for Ground Loop Design

Identifying soil and rock thermal properties is not an activity most design engineers do on a regular basis. Geologists have generated a wealth of soil, rock, and ground water information that is available from most state geological surveys. This information must be translated into thermal conductivity (k) and diffusivity (α) in order to design GSHP ground loops

A promising method of identifying properties is the use of short-term (2-3 day) field tests as shown below. A ground loop is installed, a heat load is imposed, and the conductivity is calculated based on the loop temperature rise. However, this method is not always available (or affordable) and a debate continues regarding recommended test methods to provide the best accuracy. A project to investigate and enhance these procedures is being proposed by ASHRAE, TC 6.8 ("Investigation of Methods for Determining Soil and Rock Formation Thermal Properties from Short-Term Field Tests").



Several ground loop design procedures require the thermal diffusivity of the ground in addition to conductivity. Most soils and rocks have a specific heat near 0.2 Btu/lb-°F, thus the other unknown would be density. The tables in the next column list average values for typical soils and rocks. If a field test gave a conductivity of 1.6 Btu/hr-ft-°F for limestone, the diffusivity would be (average density = 150 + 175/2),

$$\alpha = k/c_p\rho = 1.6 \text{ Btu/hr-ft-°F}/(0.22 \text{ Btu/lb-°F} \times 162.5 \text{ lb/ft}^3) =$$
$$= 0.045 \text{ ft}^2/\text{hr} = 1.07 \text{ ft}^2/\text{day}$$

If the field test is not available, standard procedures can identify the soil and rock types. This can be combined with the information in the Table below to estimate thermal properties. The geotechnical survey for the building structural design will provide the soil type (ASTM-422) and moisture content (ASTM-2216). However, samples are not typically taken beyond 10 to 20 ft below grade. A field identification of formations (ASTM-2488) can be specified for greater depths.

The presence of moisture complicates the calculation of diffusivity, since water has a higher specific heat (1.0 Btu/lb-°F) and lower density (62.4 lb/ft^3). A weighted-average for the density and specific heat of the moist soil must be determined before the diffusivity is computed. As an example, find the thermal diffusivity of clay with a dry density of 100 lb/ft^3, a dry specific heat of 0.22 Btu/lb-°F, a moisture content of 10%, and a thermal conductivity of 0.7 Btu/hr-ft-°F.

$$c_p = [10\% \times 1.0 + (100\text{-}10\%) \times 0.22]/100\% = 0.298 \text{ Btu/lb-°F}$$
$$\rho = [10\% \times 62.4 + (100\text{–}10\%) \times 100 \text{ lb/ft}^3] /100\% = 96.2 \text{ lb/ft}^3$$

$$\alpha = k/c_p\rho = 0.7 /(0.298 \times 96.2) = 0.0244 \text{ ft}^2/\text{hr} = 0.59 \text{ ft}^2/\text{day}$$

Thermal Conductivity of Soils and Rocks

Soil Type	Dry	Percent Moist.			
(Grain size)	Density	5%	10%	15%	20%
Sand	120 lb/ft^3	1.2-1.9	1.4-2.0	1.6-2.2	-
(.075-5 mm)	100 lb/ft^3	0.8-1.4	1.2-1.5	1.3-1.6	1.4-1.7
Clay	120 lb/ft^3	0.6-0.8	0.6-0.8	0.8-1.1	-
(< 0.075mm)	100 lb/ft^3	0.5-0.6	0.5-0.6	0.6-0.7	0.6-0.8

Rock Type	k Ther. Con. Btu/h-ft-F	c_p Spec. Heat Btu/lb-F	r Density lb/ft^3
Igneous Rocks			
Granite (10% Quartz)	1.3-1.9	0.21	165
Basalt	1.2-1.4	0.17-0.21	180
Gabbro (Cen. Plains)	0.9-1.6	0.18	185
Diorites	1.2-1.7	0.22	180
Sedimentary Rocks			
Dolomite	1.6-3.6	0.21	170-175
Limestone	1.4-2.2	0.22	150-175
Sandstone	1.2-2.0	0.24	160-170
Wet Shale (25% Qrtz.)	1.0-1.8		
Wet Shale (No Qrtz.)	0.6-0.9	0.21	130-165
Dry Shale (25% Qrtz.)	0.8-1.4		
Dry Shale (No Qrtz.)	0.5-0.8		
Metamorphic Rocks			
Gneiss	1.3-2.0	0.22	160-175
Marble	1.2-1.9	0.22	170
Quarzite	3.0-4.0	0.20	160
Slate	0.9-1.5	0.22	170-175

Reference: *Ground Source Heat Pumps*, ASHRAE 1997

Products, Services, and Installation Innovations

Commercial Building GCHP Loop Contractors

(Talk to these people before you design something that's hard to install.)

A&E Drilling Services, Greenville, SC 864-288-1986
Ball Drilling, Austin TX, 512-345-5870
Bergerson-Caswell, Maple Plain, MN 612-479-3121
Bertram Drilling, MT and PA, 406-259-2532
Can-America Drilling, Simla, CO 80835, 719-541-2967
Craig Test Boring, Mays Landing, NJ, 609-625-4862
Donamarc Geothermal, Union Town, OH, 330-896-4949
Earth Energy Engineering, Big Stone Gap, VA 540-523-2283
Ewbank & Associates, Enid, OK, 405-272-0798
Falk Brothers, Hankinson, ND 701-242-7252
Georgia Geothermal, Columbus, GA, 800-213-9508
Geothermal Services, KY 502-499-1500
Ground Source Systems, Buffalo, MO, 417-345-6751
Hammett & Hammett, Andalusia, AL, 334-222-3562
Johnson Drilling Co., Dallas, TX 972-924-2560
K & M Shillingford, Tulsa, OK, 918-834-7000
Loop Tech International, Huntsville, TX, 800-356-6703
Mid-America Drilling, Oakland, IA 712-482-6911
Morrison Inc., Duncannon, PA 717-834-5667
Neese Jones Heating-Cooling, Alpharetta, GA, 770-751-1850
Larry Pinkston, Virginia Beach, VA, 804-426-2018
Reith Brothers Well-Drilling, Emmaus, PA 610-965-5692
Thermal Loop, Joppa, MD 410-538-7722
Venture Drilling, Inc. Tahlequah, OK 918-456-8119
Virginia Service Co., Virginia Beach, VA, 757-468-1038
Winslow Pump & Well, Hollywood, MD, 301-373-3700
Yates & Yates, Columbia, KY 502-384-3656

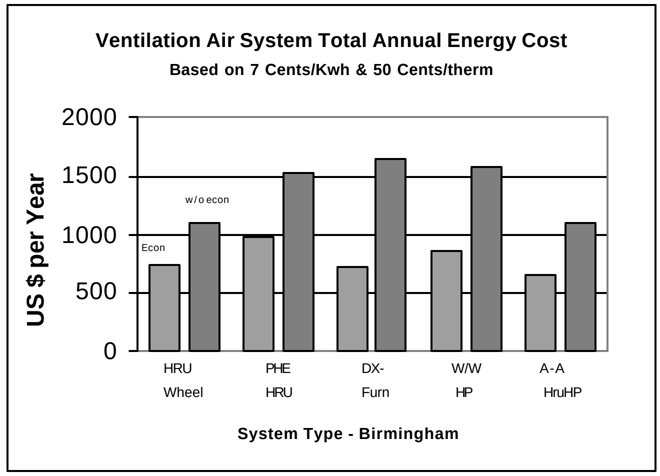
Please inform of us of other contractors who specialize in large buildings.

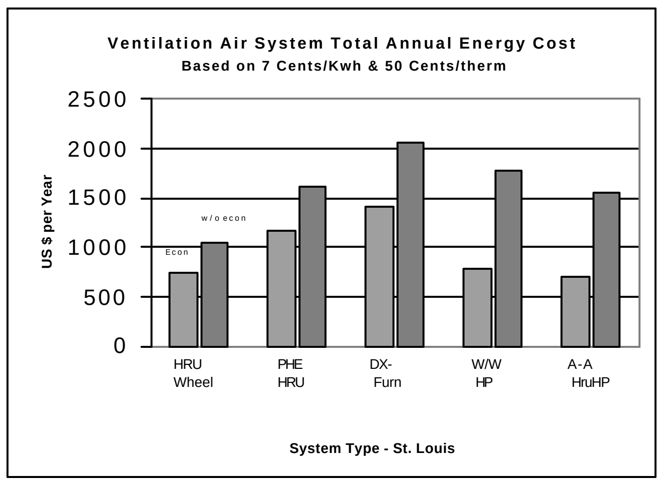
Virginia Service Company (757-468-1037)

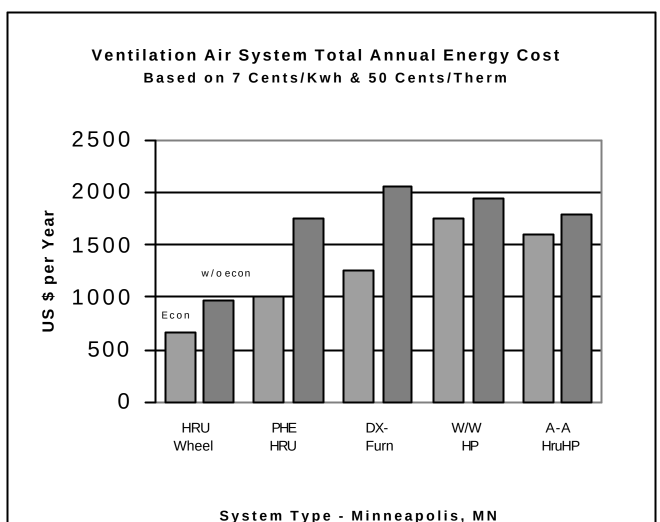
Ed Battelle founded this company in 1984 with an emphasis on solar systems and water source-ground source heat pumps. His son, Thomas, was his only employee. Virginia Service subcontracted out all water and ground loop work, until January 1994. The Batelles started a second company, Virginia Well Service, to specialize in ground loop systems. These guys now do everything to complete a ground source heat pump system. Fourteen years in this business is a testimonial to quality installations. A second indicator of the commitment of Virginia Service is the fact that they assume sole responsibility for they entire ground source system. (Ever been associated with a poorly functioning GSHP where the HVAC guy blames the loop contractor and the engineer; the loop contractor blames the HVAC people and the engineer; and the engineer blames them both; and everybody talks bad about the architect and the lawyers?)

Outdoor Air Equipment Energy Use for Three Locations, With and Without Economizer

Based on 32,000 ft^2 Office, 4000 cfm Ventilation Air
Five Days/Week, Eight Hours/Day Occupancy







Cost and Performance of Ground Source Heat Pump Buildings

Environmental Benefits of GSHPs

A major factor influencing the U.S. Environmental Protection Agency's support of GSHPs is the reduced emissions possible when the technology is properly applied (Space Conditioning: The Next Frontier, EPA 430-R-93-004). However, the technology has occasionally been on the defensive with regard to the environmental impact upon groundwater quality and temperature. On more than one recent occasion, I have heard electric utility representatives bemoan the amount of time appeasing the "greens" when attempting to promote electro-technologies.

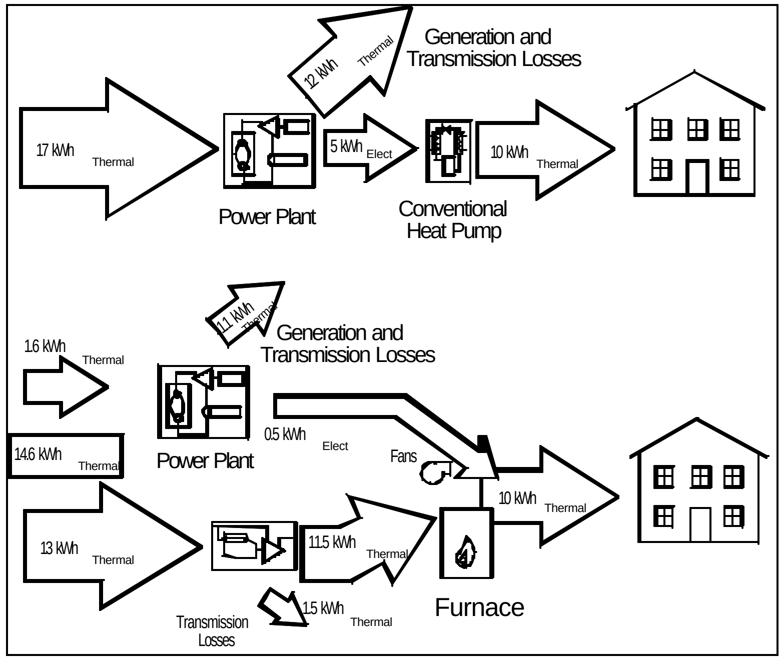
The energy flow diagrams in the next column demonstrate graphically the impact of GSHP compared to conventional heating systems. The results show why the EPA numbers favor this technology. It takes far less source energy to provide heat to a building, especially if the electrical energy could be generated with a natural gas-fired combined-cycle power plant.

The required input energy to deliver 10 kWh of heat (34,120 Btus) to a home using an air-source heat pump would be 17 kWh. About 70% of the input energy is lost during the generation and transmission process of a typical fossil-fuel power plant. The air-based heat pump will deliver a COP of 2 (2+ in warmer climates but < 2 in colder areas) when defrost and auxiliary heat penalties are properly applied. The natural gas system losses about 10% in the transmission process and another 10 to 20% at the furnace. However, electricity is also needed for the furnace fan(s). The total required to deliver 10 kWh to the building is 14.6 kWh from the source.

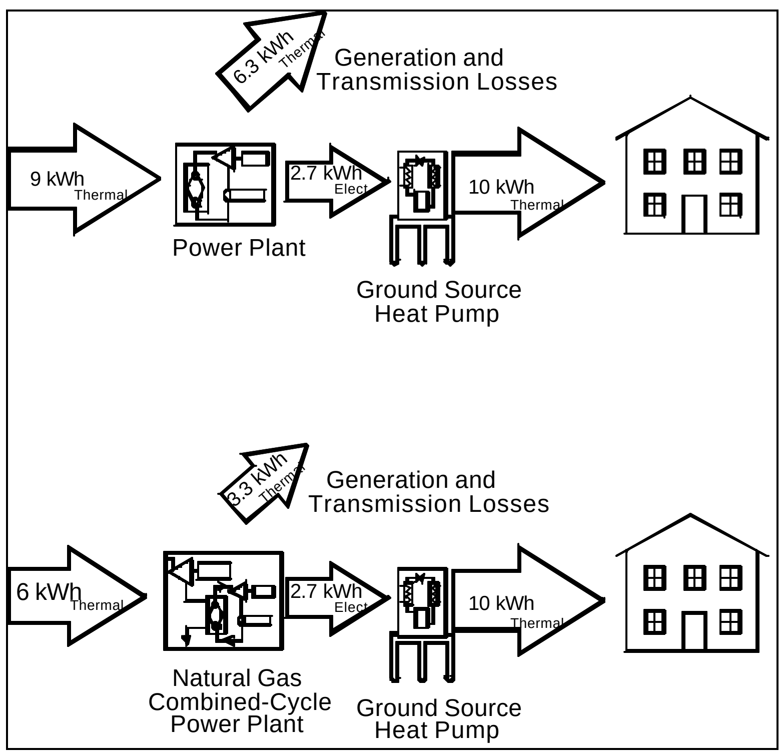
However, GSHP require only 9 kWh from the source to provide 10 kWh to the building since they can provide a COP of 3.7. **This situation could be even better if we all were to take a cue from the folks in Missouri.**

Associated Electric Cooperative, Inc. (in cooperation with Duke Energy) is building a second combined-cycle power plant. The technology uses waste heat from a gas turbine generator to power a steam turbine generator. Generation efficiency approaches 55% compared to 35% for a steam cycle alone (Power News, AECI, Springfield, MO, Vol.16, #1).

AECI and its member co-ops have been using GSHPs successfully for years. The two concepts allow them to provide 10 kWh with only 6 kWh of source energy (Based on 45% G&T efficiency). Plus, they're not even trying to run the gas people out of business. They're just trying to use a good thing (natural gas) in a wise and environmentally responsible manner.



Required Energy Input for Conventional HVAC Systems



Required Energy Input for Ground Source Heat Pumps

Letters, Comments, Questions, & Suggestions

Plastic Casing for Water Wells

We are installing an open loop system in a school in northern Nevada. To save money the suggestion has arisen to use plastic casing in the well instead of steel. Can you comment on the relative advantages and disadvantages of this strategy?

Pinching Pennies in Paradise Valley

Dear Pinching Pennies:

Plastic casing has been used in wells for many years and properly applied can provide adequate service. Low cost and lack of susceptibility to corrosion are the two greatest advantages of these materials. Lower strength is the greatest disadvantage. It is the lower strength that governs the conditions under which plastic casing can be used successfully. As with steel casing, collapse forces due to hydrostatic pressure, formations penetrated and completion (grouting) determine the wall thickness required. As an example of the difference in strength between steel and plastic casing, the hydrostatic collapse pressure for schedule 40 8" steel is 1920 psi and the same value for PVC is 59 psi.

Guidelines in standard references recommend caution in applying plastic casing at depths greater than 150 - 300 ft in unconsolidated formations due to the potential external collapsing forces exerted. In consolidated formations plastic has been used successfully to depths of 800 ft. The design of the well can also influence the forces exerted on the casing. Cementing and/or gravel packing can cause excessive external forces. For example in a well several hundred feet deep which will be fully cemented, the pressure exerted by the wet cement at the bottom of the casing could easily exceed the collapse strength of plastic material. Due to the lower strength, plastic casing cannot be driven as is often done in cable tool drilling.

In most cases, "plastic" refers to PVC but ABS, SR and even fibreglass have been used. Materials are governed by ASTM F-480 "Thermoplastic Water Well Casing Made in Standard Dimension Ratios". Common cell classifications are PVC - 12454C, ABS - 434 and 533, SR - 4434.

Where plastic casing is used, common SDR designations are 13.5, 17 and 21. Schedule 40 and schedule 80 are also used. Most states approve PVC casing, but fewer approve ABS and/or SR materials. Some states also require NSF stamping for potable water wells. Generally, plastic casing is used in smaller wells (< 10") that typically serve residences.

In summary, for a well serving a GSHP system in a school, it would be wiser to forgo the carpeting in the principal's office and use steel casing in the well.

KR

Two U-Tubes Better than One

In some areas of our market we are experiencing high drilling costs. It seems that putting as many tubes in the bore as possible can reduce the required length of high dollar bore holes. Can this be a cost-effective solution?

A Guy Who Can Get a Good Price on Pipe

Dear Mr. Goodprice,

Multiple U-tubes can be used to reduce required length. The economic value depends on the cost of drilling vs. cost of pipe (as you imply), the thermal properties of the soil (or rock) and bore grout/fill material, and the amount of heat removed from (or added to) the ground on a long-term basis.

Double U-tubes are standard practice in Switzerland where drilling costs are high. Research conducted in 1983-4 demonstrated a 12 to 15% reduction in loop length when a double ¾in. U-tube was used in a 4½in. bore compared to a single ¾in. U-tube. However, this test was conducted for only one year. The benefit may depreciate in applications where the heat may build-up (i.e. high cooling requirements) because of the reduced ground volume that accompanies shorter bores.

Consider a basic equation for required bore length.

$$\mathbf{L = q \times (R_{ground} + R_{pipe} + R_{grout}) \div (t_{ground} - t_{water}).}$$

Typically, R_{ground} is the most significant of the terms (40 to 70% of the total), R_{grout} can become as large if low conductivity grouts are used, and R_{pipe} is normally 10 to 20% of the total. Two U-tubes cuts R_{pipe} in half and will result in a reduction in R_{grout} since the tubes will be in closer contact with the outer bore wall. Although R_{ground} may increase (due to heat imbalances), greater bore separation can offset this penalty.

We have not done an exhaustive study of the multiple U-tube concept. An estimate based on resistance calculations would be a reduction of up to 20% (heating dominated application, low conductivity grouts, U-tubes near the outer bore wall) to as little as 5% (cooling dominated application, high conductivity fill, U-tubes bundled near the center of the bore).

Consider a reduction of 12% with a 180 ft/ton loop, \$6/ft. drilling/grout cost, and a pipe material/insertion cost of 25¢/ft.

\$/ton (1 U-tube) = (\$6 + 2 × 25¢) × 180 = \$1170 per ton
\$/ton (2 U-tubes) = (\$6 + 4 × 25¢) × 158 = \$1106 per ton

While there will be some incremental changes in grout and U-tube installation costs, multiple U-tubes appears to be a good idea. However, more accurate length requirements will require a better understanding of the resistance of the grout/backfill when more than one U-tube is used.

Meetings, Publications, and Information Sources

Meetings & Seminars - 1998

Nov. 11-12 – Western GeoExchange Heat Pump Conference, Sacramento, CA, Geothermal Energy Assoc., 530-750-0135

Nov. 12-13, General GHP Seminar + One-Day Seminar for Engineers, Knoxville, TN - TVA, 615-882-2802

Nov. 20, One-Day Seminar for Engineers, Jonesboro, AR, City Water & Light, 870-935-5581

Dec. 13-16, National Ground Water Association Convention & Expo, Las Vegas, NV, 614-337-1949

1999

Jan. 23-27 -- ASHRAE Winter Annual Meeting, Chicago, Palmer House Hilton
  1/24 Thermal Properties Symposium (4 Papers)
  1/24 Ground Water HP Seminar (5 Presentations)
  1/25 GSHP Design Short Course (4 hrs.-4PDHs)

Publications

ASHRAE (404-636-8400) web site: www.ashrae.org

Ground-Source Heat Pumps: Design of Geothermal Heat Pump Systems for Commercial/Institutional Buildings, 1997

Commercial/Institutional Ground-Source Heat Pump Engineering Manual, 1995

Design, Operation, and Maintenance of GSHP Systems (Symposium Papers from 1998 Annual Meeting)
 Operating Experiences with Commercial GSHP, Part 2
 Ground Water Source Application for a Water Park
 A Design Method for Hybrid GSHPs
 Maintenance & Service Cost of Commercial GSHP Systems

Operating Experiences with Commercial Ground-Source Heat Pumps, 863RP (Research Project Report), 1995

Operating Experiences with Commercial Ground-Source Heat Pump Systems. Special Publication (Detail case studies), 1998

Air-Conditioning & Refrigertion Institute (Fax 703-524-9011)

"Directory of Certified Applied Air-Conditioning Products" – Directory of ratings for GSHP, GWHP, and WSHP products.

ARI Standard 320: Water Source Heat Pumps
ARI Standard 325: Ground-Water Source Heat Pumps
ARI Standard 320: Ground Source Closed-Loop Heat Pumps

Electric Power Research Institute (510-934-4212)

EPRI has recently released 17 new GSHP publications covering introductory topics, equipment directories, bore hole grout properties and installation guides, soil classification, anti-freeze solutions, and loop installation guides.

Geothermal Heat Pump Consortium (888-255-4436)
www.ghpc.org

GeoExchange Site List – A list of commercial and institutional GHP buildings in North America (RP-011)

GeoExchange Material and Publications – A list of materials and publication available through the GHPC (RP-015)

"Development of Head Loss Data and Design Tools for GHP Piping", 1996 (RP-017) – Includes Piping Design Software

"Maintenance and Service Costs in Commercial Building Geothermal Systems", 1997 (RP-024)

Analysis of Existing GeoExchange Installation Data (RP-026)

Icemakers, Coolers & Freezers, and GX – A survey of water requirements for refrigeration equipment. (RP-030)

Counting Geoexchange Systems: Issues & Estimates (RP-031)

A Survey of Methods to Provide Ventilation for Acceptable Indoor Air Quality (RP-032)

Geo-Heat Center (541-885-1750) www.oit.edu/~geoheat

"Outline Specifications for Water Wells and Pumps", 1998.

"A Capital Cost Comparison of Commercial Ground-Source Heat Pump Systems", 1994.

"An Information Survival Kit for the Prospective Geothermal Heat Pump Owner", 1997 - RESIDENTIAL

IGSHPA (800-626-GSHP) www.igshpa.okstate.edu

Closed-Loop/GSHP Systems: Installation Guide, 1988.

GHP Systems: Design and Installation Standards, 1994.

Grouting for Vertical GHP Systems: Engineering and Field Procedures Manual, 1997 (a.k.a. EPRI Report # TR-109169)

National Ground Water Assoc. (800-551-7379)

"Guidelines for the Construction of Vertical Bore Holes for Closed-Loop Heat Pump Systems", 1997

Fall 1998 – Volume 1, Number 4 - Published Quarterly

"Outside the Loop" is supported by a grant from the Geothermal Heat Pump Consortium through the Strategic Outreach Program

Please let us know if:

- **There is a type of information you need.**
- **You would like to add to our information.**
- **We need to add someone to our mailing list.**
- **You would like to write an article.**
- **You have an announcement to share.**
- **You know a loop contractor we need to add to our list (see page 4).**
- **You have verifiable cost data you want to share.**

Send information and requests to:

Outside the Loop
The University of Alabama, ME Dept.
Box 870276
Tuscaloosa, AL 35487-0276
Fax: 205-348-6419
e-mail: skavanaugh@coe.eng.ua.edu

A "Freebie" from Driscopipe & GHPC

A recently completed research project sponsored by Phillips Driscopipe and the Geothermal Heat Pump Consortium included the delivery of a Windows-based software program to design GSHP piping loops and calculates head losses. The report (RP-017) and diskettes are available from the GHPC. The program was developed by Joe Hoggle, a former graduate student at the University of Alabama and a current employee of the Trane Co. in Birmingham. It incorporates a large amount of measured head loss data for high-density polyethylene pipe and fittings. Joe devoted so much time to this project that he didn't quite finish his thesis. But he did a good job, which will be evident to you if you try the program.

Back Issues of *Outside the Loop* **can soon be accessed at the ME Department website of the University of Alabama. MS Word 7 users can view the documents in their original format, others can view an html file.**

[http://www.me.ua.edu (/faculty/outsidetheloop/outsidetheloop.html)]

Outside the Loop

A Newsletter for Geothermal Heat Pump Designers and Installers

The University of Alabama
Box 870276
Tuscaloosa, AL 35487-0276

- **GSHPs and Outside Air**
- **GSHP Bore Hole Water Migration**
- **Injection Wells for GWHPs**
- **Thermal Properties of Soils and Rocks**
- **Environmental Benefits of GSHPs**
- **Outdoor Air Equipment Energy Use**
- **Letters – PVC Well Casing, Multiple U-Tubes**
- **GSHP Loop Contractors**
- **Publications and Meetings**

GEOEXCHANGE