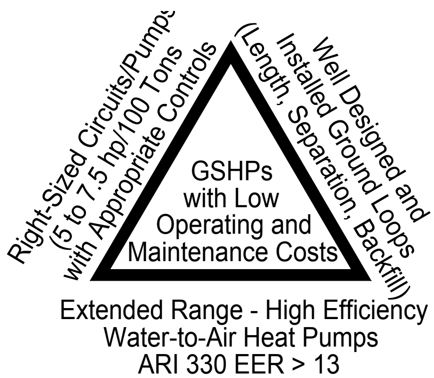
Outside the Loop

A Newsletter for Geothermal Heat Pump Designers and Installers

April 1998 - Volume 1, Number 2 - Published Quarterly

Think System to Get the Most from GSHPs

For best results the three major components of a ground source heat pump (GSHP) should be designed as a system. The experienced GSHP design team will be able to adjust heat pump specifications, the piping/pump network, and the ground loop to optimize the system. For example, it would be prudent to improve the heat pump EER from 11 to 14 at a cost of $150 per ton rather than to increase the loop length by 50 ft. per ton at $7 per ft. to achieve the same level of performance. The figure below illustrates the primary characteristics of an efficient and low maintenance system.



Heat Pumps – An EER of 13 (ARI 330) should be a minimum. This type of equipment should not be expensive since this level of efficiency can be easily achieved with the same compressors, fans, and motors used in a 10 SEER air-source heat pump. Higher EER (14 to 18) single speed units can often be justified. However, multi-speed (or multi-stage) units are usually unnecessary in commercial applications.

Ground Loops – Tools are available for loop design, which is performed in conjunction with heat pump selection. Closed loops must be of sufficient length, depth and bore separation to provide design capacity and efficiency during extreme conditions. Bore grouts must have good thermal properties and protect groundwater. Open loop wells must properly designed and isolation (plate) heat exchangers are required.

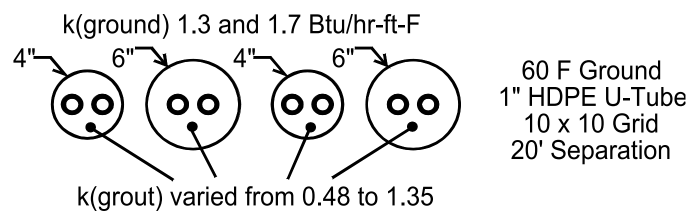
Piping and Pumps – Required pump motor size should fall in the range of 5 to 7½ hp per 100 tons. If pumps are larger, head loss or flow rates are probably excessive. Variable speed pump control is recommended, but there are a variety of other options that can minimize pump energy to below 10% of total energy use. Continuously operating fixed-speed pumps are discouraged, even in primary-secondary loops.

Impact of Grout on Required GSHP Bore Length

The last issue of "Outside the Loop" provided results of a U-tube thermal test that compared conventional bentonite grout, enhanced grout, and wet sand. A reader requested that this information be "translated" into the impact on bore length required. The thermal resistance of the grout around the U-tube is one of four resistances to heat flow. The overall impact depends on the magnitude of the other resistances. If the U-tube is placed in a soil with very poor thermal conductivity, the impact is smaller. If the U-tube is in a high conductivity formation, the impact is much greater.

The tables below were generated using an example heat pump system connected to a 32,000 ft² office building with a maximum block 100 ton cooling load and 1000 full load cooling hours annually. Heat loss was 950 MBtu/h with 500 equivalent full load heating hours. The heat pumps had an EER of 13.8 Btu/w-hr at ARI 330 conditions.

The ground loop bores for all test runs were arranged in a 10 by 10 grid with 20 ft. separation. One inch, SDR 11, HDPE U-tubes were used with a ground temperature of 60°F. The thermal conductivity of the grout was varied from 0.48 to 1.35 Btu/hr-ft-°F for two bore sizes (4 and 6 inch) and two ground conductivities (1.3 and 1.7 Btu/hr-ft-°F).



Variation of Required GSHP Bore Length (Feet per Ton) With Grout Conductivity, Bore Diameter, and Ground Conductivity

k_{GROUT} Btu/hr-ft-F	D_{bore} = 4" k_{Grnd} = 1.3	D_{bore} = 6" k_{Grnd} = 1.3	D_{bore} = 4" k_{Grnd} = 1.7	D_{bore} = 6" k_{Grnd} = 1.7
0.48	225 (17%)	244 (27%)	213(+25%)	231(+36%)
0.85	199 (+4%)	210 (+9%)	179 (+5%)	191(+12%)
1.00	192 BASE	197 (+3%)	170 BASE	179 (+5%)
1.25	186 (-3%)	186 (-3%)	162 (-5%)	166 (-2%)
1.35	182 (-5%)	182 (-5%)	160 (-6%)	162 (-5%)

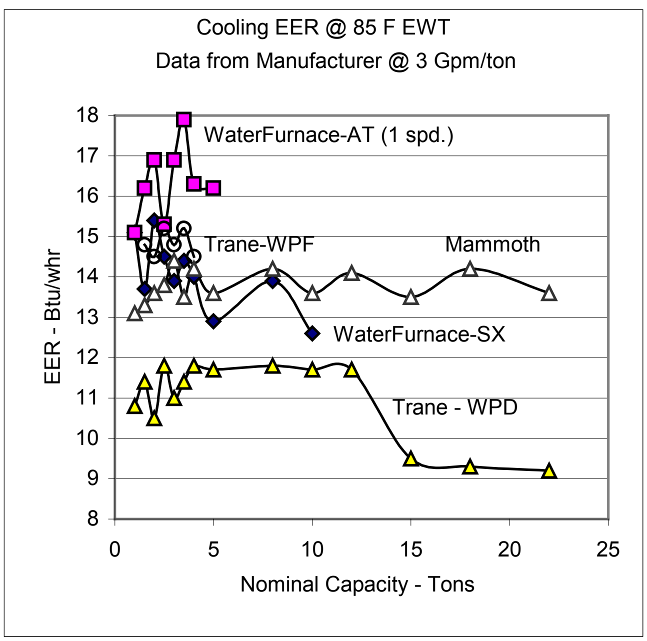
Send Comments to:
Steve Kavanaugh, University of Alabama, 205-348-6419 fax, skavanaugh@coe.eng.ua.edu or
Kevin Rafferty, Geo-Heat Center, 541-885-1754 fax, raffertk@oit.edu

Design Issues and Tools

Water/Air Heat Pumps: Bigger Not Always Better

The demand for high efficiency water-to-air heat pumps has been strong in the residential sector for several years. Only recently has this need been felt in the larger heat pumps sizes that may be required in commercial buildings. Therefore, a notable drop in EER may occur for sizes above 5 tons. Another drop may occur above 10 tons (or manufactures may not even offer a rated product above this capacity).

The table below displays this situation graphically. One manufacturer (WaterFurnace) offers a product line (AT-single speed) with extremely high EERs below 6 tons and a second product line (SX) with good values up to 5 tons and acceptable EERs to 10 tons. Trane offers a high efficiency product line to 5 tons. Their equipment line between 6 and 12 tons is somewhat lower and a further decline in EERs is noted in the 15 to 22 ton range. Mammoth, however, offers a line with fairly consistent EERs between one and 22 tons.



Designers are encouraged to avoid the mistake of basing decisions solely on <u>rated</u> EER. There are 2-speed and dual capacity products in the ARI Directory with EERs above 20. However, these products may not have acceptable latent cooling capacities for many applications when operated in the high EER mode. This equipment also typically has lower EER than high efficiency, single-speed units under actual operating conditions.

The ARI Directory of Certified Applied Air-Conditioning Products is published bi-annually. It contains the ratings of GSHP heat pumps, which are tested at entering liquid temperatures of 77°F in cooling and 32°F in heating. The rating includes compressor, pump, and fan input power.

Suggested Heat Pump Specifications

The following components are suggested to be included in specifications for GSHP systems. These recommendations are based on the assumption that the designer is attempting to deliver a high efficiency <u>system</u> for a reasonable first cost.

(1) All heat pumps shall be rated under ARI Standard 330-93 and have a minimum energy efficiency ratio (EER) of 13.0 Btu/w-hr at ARI 330 conditions. Multiple or variable speed heat pumps shall achieve this rating at high speed.

(2) All heat pumps shall have a head loss of not more than 15 feet of water (6.5 psi) at the flow rate used to obtain the ARI 330 rating.

(3) All heat pumps shall have extended range capability to operate in the cooling mode with entering liquid temperatures up to 100°F in cooling and down to 32°F in heating.

(4) Heat pump units with proprietary controls should also include connections for the use of conventional thermostats.

Pipe Used in GSHP Industry Has Different Head Loss Characteristics and Inside Diameters

The high-density polyethylene (HDPE) pipe used in the GSHP industry conforms to a standard dimension ratio in order to maintain a constant pressure for all sizes. Outer diameters are the same as conventional pipe (Schedule 40, 80, etc.). The inside diameter is adjusted to give a constant Dimension Ratio (DR = O.D./wall thickness) and pressure rating. For example, DR 11, HDPE 3408, has a pressure rating of 160 psig for all sizes. Schedule 40 pipe has a higher pressure rating for ¾ and 1 inch pipe but a lower rating for 1¼ inch and larger. The table below compares the diameters for DR 11 and DR 17 HDPE with Schedules 40 and 80. The table also includes the maximum allowable water flow that produces a head loss of 4 feet per100 linear feet of pipe as called for by ASHRAE Standard 90.1.

	Inside Diameter (Inches)				***Max. Flow @ 4 ft./100' Head Loss (GPM)***			
Dia.	DR 11	DR 17	Sch 40	Sch 80	DR 11	DR 17	Sch 40	Sch 80
3/4	0.86	0.93	0.824	0.742	4.5	-	4	3
1	1.08	1.16	1.049	0.957	8	-	7	6
1¼	1.36	1.46	1.38	1.278	15	-	15	13
1½	1.55	1.68	1.61	1.50	22	-	23	21
2	1.94	2.10	2.067	1.939	40	-	45	40
3	2.86	3.09	3.068	2.90	110	140	150	125
4	3.68	3.97	4.026	3.826	220	300	260	250
6	5.42	5.84	6.065	5.761	600	750	800	750
8	7.06	7.61	7.98	7.625	1200	1500	1600	1500
10	8.80	9.49	10.02	9.562	2200	2600	3000	-
12	10.43	11.25	11.94	11.37	3500	4200	4600	-

Fundamentals: Mother Nature Can Be a Wonderful Partner

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

The ABC's of Scaling (and some corrosion info)

Scaling is a common occurrence in any system that contains water but it can pose a particular problem with untreated ground water or in water heating applications (heat recovery units/desuperheaters). Of the many chemical sources that can produce scaling, the most common is calcium carbonate ($CaCO_3$). As a general rule, any water with a pH of greater than 8.5 and a hardness of greater than 75 ppm (or 4 grains) should be carefully evaluated.

Fortunately, the potential for the occurrence of carbonate scale can be predicted if the necessary chemical analysis is performed on the water. The required data includes: total (or "M") alkalinity (as ppm $CaCO_3$), Calcium hardness (as ppm $CaCO_3$), total solids (or TDS as ppm), pH and temperature. Using these parameters, the two most often used indicators of carbonate scaling the Ryznar Stability Index (RSI) and the Langlier Saturation Index (LSI) can be calculated. Both indices are dimensionless, determined from the same basic data and differ only in the mathematical manipulation of the numbers. The RSI produces a value between 4.0 (heavy scale) and 9.0+ (heavy corrosion) while the LSI produces a value between 2.0 (heavy scale) and -2.0 (heavy corrosion). A nomograph for making the calculations can be found in the 1995 ASHRAE Handbook of Applications (chapter 44) and many water treatment texts. An alternative is to simply have the water analysis lab perform the calculation and include the result in their report. Table 1 provides interpretation of RSI values.

Table 1 - Interpretation of Ryznar Stability Index Values

4.0 - 5.0	*heavy scale*
5.0 - 6.0	*light scale*
6.0 - 7.0	*little scale or corrosion*
7.0 - 7.5	*corrosion significant*
7.5 - 9.0	*heavy corrosion*
9.0 and higher	*corrosion intolerable*

It is important to understand that the RSI and the LSI are reliable indicators of scaling but are less reliable in terms of corrosion. The assumption in both cases is that in the absence of scale formation, corrosion will occur and grow more serious with decreasing pH. This is true. It is also true that corrosion can result from other sources not considered by these indices such as hydrogen sulphide, ammonia or dissolved oxygen in the water. As a result these values are of greater use in scaling prediction than corrosion prediction.

At a given water chemistry, the designer does have some degree of control over the extent to which scaling occurs in the system. Two system design strategies that limit scaling are the use of an isolation heat exchanger and the elimination of open tanks in the system.

The use of a plate heat exchanger reduces scaling in two ways. The first and most obvious is by limiting the portion of the system to which the ground water is exposed. With a heat exchanger in place, the ground water is only in contact with the piping to and from the wells and the heat exchanger itself. Since the heat exchanger is easily disassembled for cleaning, the impact of scale on system performance can be virtually eliminated. A second impact of the exchanger is in the reduction of the temperature of the surfaces to which the ground water is exposed. Carbonate scale is partially a temperature driven phenomenon. In a system where the water is supplied directly to the heat pumps, surface temperatures in the refrigerant-to-water heat exchangers may be as high as 180ºF. In an indirect design (with a plate heat exchanger) the maximum temperature seen by the ground water will be in the range of 90ºF. As a result, for the same water chemistry, the propensity for scaling to occur is reduced using an isolation heat exchanger. Due to this temperature affect, the calculations for LSI or RSI should always be based upon the highest temperature the water will see in the system not the undisturbed aquifer temperature.

A second design strategy to reduce the potential for scale is to maintain the ground water side of the system under pressure and avoid the use of open or vented tanks. In many waters prone to carbonate scale problems, the solubility of bicarbonate is heavily influenced by the amount of dissolved CO_2 in the water. This is illustrated in table 2. At a pH of 7.0, a bicarbonate alkalinity of 400 ppm (as $CaCO_3$) can be maintained at a CO_2 content of 82 ppm. If the CO_2 content is reduced to 42 ppm (as it might be if the water was stored in an open tank allowing the CO_2 to evolve into the air) only half the bicarbonate (200 ppm as $CaCO_3$) can be maintained. The difference would precipitate out as calcium carbonate scale. Due to the relationship between pH and CO_2 tests for these parameters should always be done in the field.

Table 2 - Bicarbonate and Carbon Dioxide Equilibrium

Bicarbonate Alkalinity	*Free Carbon Dioxide (ppm)*		
as ppm $CaCO_3$	*pH 7.0*	*pH 7.5*	*pH 8.0*
100	*22*	*6*	*2*
200	*43*	*12*	*4*
300	*63*	*17*	*6*
400	*82*	*22*	*7*

(From: Groundwater and Wells, Johnson Division, 1986)

Maintenance of a positive pressure on the ground water side of the system and the avoidance of the use of open tanks helps to maintain the CO_2 in solution and reduce scaling problems. This also reduces the opportunity for oxygen to enter the system. Oxygen, when present, increases the general corrosion rate. If ferrous iron is present in the water along with oxygen, it is converted to a ferric form that due to its low solubility tends to come out of solution and deposit a rust colored sediment. Although not really a scale, this material does foul heat transfer surfaces.

In summary, know your water, isolate it from the building loop, and avoid the use of open tanks.

Products, Services, and Installation Innovations

Portrait of a Geo-Junkie – Allan Skouby

Allan Skouby was born and raised in Perry, OK where Ditch Witches are built. So he was probably predisposed to being a geo-junkie. In 1981 he began working for A/C Service, the HVAC company that had linked up with Jim Bose, Gerald Parker and others at Oklahoma State to reawaken the geothermal heat pump concept. From 1983 to 1988, he worked for GeoSystems, another collaborator in the early work around Stillwater. I first met Allan when he was putting together pump modules in their warehouse and I was a grad student bumming parts off owner, Jim Partin.

Allan served as Vanguard Plastic's Sales and Marketing Manager for GHP applications from 1988 to 1994. In this position he was able to respond to the needs of the growing GHP industry by pushing for the development of a package of fittings specifically designed for convenient ground loop fabrication and quick connections to the heat pumps. While at Vanguard, he was instrumental in the development of the IGSHPA standards for GHP pipe and fittings.

In 1994 he moved to Phillips Driscopipe, where he continued to oversee the development of components to serve the GHP industry. As the National Geothermal Marketing Manager he developed a plan to introduce Driscopipe directly to the GHP industry. The Unicoil , a pre-manufactured U-bend assembly, was introduced during his tenure. For the past two years Allan has been working for a friend at a hose company in San Marcos, TX, where he has probably made a lot more money than he ever did with GHPs.

Much to his wife's dismay, his addiction to geothermal has proven too strong. This was unfortunately coupled with the fact that he failed to sever his relationship with another geo-junkie, Chuck Remund of South Dakota State. (This is called co-dependency when referring to other forms of addiction.)

In January of this year, Allan, Chuck and three other geo-junkies (with a collective 50 years of GHP experience) formed Geothermal Resource Technologies, Inc. In Allan's many years of experience, he has observed a variety of reasons that larger GHP projects have failed to materialize or be completed successfully. The new company was created to assist in doing whatever it takes to insure GHP projects succeed. GRTI offers a unique combination of design, design assistance, training (IGSHPA certified), testing (in-situ ground conductivity), marketing, job site supervision, and trouble-shooting of problematic GHP installations.

Allan Skouby brings a wealth of integrity, experience, knowledge, and creativity to the GHP industry. Don't take our word for it, ask anyone who has been involved with the GHP industry. We encourage you to contact Geothermal Resource Technology, Inc. when you need geo-help at:

972-390-1537 (Voice), 972-390-1851 (Fax) or e-mail, allanps@aol.com

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
Craig Test Boring, Mays Landing, NJ, 609-625-4862
Ewbank & Associates, Enid, OK, 405-272-0798
Falk Brothers, Hankinson, ND 701-242-7252
Georgia Geothermal, 800-213-9508
Geothermal Services, KY 502-499-1500
Ground Source Systems, Buffalo, MO, 417-345-6751
K & M Shillingford, Tulsa, OK, 918-834-7000
Loop Tech International, Huntsville, TX, 800-356-6703
Larry Pinkston, Virginia Beach, VA, 804-426-2018
Thermal Loop, Joppa, MD 410-538-7722
Yates & Yates, Columbia, KY 502-384-3656
Winslow Pump & Well, Hollywood, MD, 301-373-3700

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

A Sample of GSHP Firms & Organizations

IGSHPA *(800-626-4747) The International Ground Source Heat Pump Association is headquartered on the campus of Oklahoma State University in Stillwater. OSU has been the center of activity since the reawakening of the GSHP concept in the mid-1970s. IGSHPA, created in 1987, provides a broad combination of publications, training, research, marketing tools, conferences, seminars, standards, and other resources. A publication catalog is available, a newsletter, "The Source", is published quarterly, a technical conference is conducted in May, and an industry conference is held in the fall. Web site: www.igshpa.okstate.edu.*

Phoenix Geothermal Services *315-685-2141 (NY) John Manning, PE and President, has 16 years of experience in the geothermal industry and his company operates in the US, Canada, and Australia. Phoenix provides GSHP system design, project implementation, training, and evaluation of GSHP project opportunities. They also provide a non-pressurized liquid flow center for residential and commercial closed-loop applications. In the last 2 years, these "GT Flow Centers" have provided benefits to over 1500 GSHP systems.*

Geo-Enterprises, Inc. *918-259-8154 (OK) If you have been involved with GSHPs and you have not met Phil or Fred Schoen, you really need to get out more! These boys were raised doing refrigeration work and have been involved with GSHP work for twenty years. Geo-Enterprises provides design assistance, specifications, CAD, equipment and supply sales, trouble-shooting, and project management.*

Cost and Performance of Ground Source Heat Pump Buildings

Monticello, Iowa High School – First Cost

A detailed breakdown of a recently completed 95,300 ft^2 high school in Monticello, Iowa was provided by Bob Diez of the DLR Group (Minneapolis). The GHP consists of 180 bores @ 160 feet each, 54 high efficiency heat pumps, and a variable frequency drive on the loop pump. A 10,000 ft^2 gym was heated but not cooled and make-up air was treated with a 3,936 MBtu/h indirect gas-fired furnace.

Well field cost with enhanced grout	\$ 2.38/ft^2
HVAC piping (Interior for heat pumps)	\$ 2.54/ft^2
HVAC equipment (Heat pumps, furnace)	\$ 2.45/ft^2
DDC control system	\$ 0.67/ft^2
Balancing	\$ 0.09/ft^2
Sheet metal	\$ 4.18/ft^2
Pipe and duct insulation	\$ 0.68/ft^2
	\$ 12.99/ft^2

Loop cost translated into \$7.88 per foot of bore hole. The total HVAC system cost was \$1,238,800. The local utility provided \$195,000 rebate to subsidize the project.

Pondering GSHP Costs for Commercial Buildings

GSHPs have a reputation in the residential sector of being expensive. This reputation owes itself to the relatively low cost of conventional systems compared to GSHPs. A study sited in the last issue of "Outside the Loop" found the national average of GSHPs to be almost \$3000 per ton compared to \$1500 per ton for electric cooling with gas heat.

However, \$3000 per ton for GSHPs is an AVERAGE cost for a commercial system. These numbers can be used to calculate the cost per square foot for a typical office.

$\$/ft^2 = \$3000/ton \div 325\ ft^2/ton = \$\ 9.23/ft^2$.

The table below gives the comparative cost of conventional HVAC systems for office buildings. Although the \$9.23/ft^2 is for residential GSHP buildings, there are practices that can generate the same costs for commercial buildings. For example, although interior costs for a commercial building will be higher, savings can be achieved due to lower set-up costs (travel) per bore for the loop contractor.

HVAC Square Foot Cost for Office Buildings

	Building Size	
HVAC System Type	5,000 ft^2	50,000 ft^2
Single Zone Rooftop Units	\$7.05/ ft^2	-
Multi-zone Rooftop	\$17.00/ ft^2	\$10.76/ ft^2
2-Pipe Air Cooled Chiller, Gas HW	\$12.70/ ft^2	\$9.57/ ft^2
2-Pipe Wtr Cooled Chiller, Gas HW	\$13.76/ ft^2	\$11.82/ ft^2

Reference: R. S. Means, Square Foot Cost Data, Kingston, MA, 1997 (617-585-7880)

GWHP Well Costs – Missouri and New Jersey

Groundwater heat pump systems can be a great bargain. Well costs, like those given by Kirk Mescher (CM Engineering, Columbia, MO) and J.B. Singh (J&P Engineers, Kendall Park, NJ), are the reason.

The completed cost of an 800 ft. well (6 in. casing with pump, tank, and electrical) in limestone is \$16,000 to \$20,000 in central Missouri.

A 91-ton GWHP system with three-4 inch supply and three-6 inch injection wells (75 ft. deep) developed 159 gpm. Total cost was \$25,000 or \$275 per ton in New Jersey.

Lincoln, Nebraska Schools – First Cost

The last issue of "Outside the Loop" reported the total energy costs for the four GHPs in new elementary schools were 40¢/ft^2-year, 75¢/ft^2-year for water-cooled chilled water systems (CWS), and 90¢/ft^2-year two air-cooled CWSs.

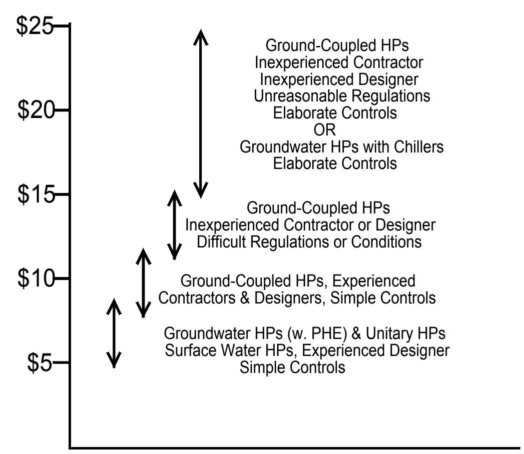
First costs for the four GHPs were:

Well field contractor	\$ 683,640	\$2.45/ft^2
HVAC contractor	\$ 1,868,142	\$6.70/ft^2
Other fees	\$ 80,978	\$0.29/ft^2
	\$ 2,632,760	\$9.44/ft^2

Each GHP school occupies 69,670 ft^2, and the total bore requirement was 28,800 feet per school (\$5.93/ft. of bore).

GSHP Cost Chart

The method used to develop the chart below are discussed in Ground Source Heat Pumps: Design of Geothermal Systems for Commercial and Institutional Buildings, (ASHRAE).



FIRST COST OF GSHPs - \$ / SQ.FT

Based on 275 to 325 Sq.Ft. / Ton

Letters, Comments, Questions, & Suggestions

Puddle Loop

I would appreciate it if you could direct me to a source of information about some problems I am having with my system. Unfortunately, I no longer trust the contractors involved.

I have a system with a loop that resides in my lake. There is only 2 feet of water over the loops when the lake is full and the lake level is lowered at times during the year. When the lake is full, the heat pump is very efficient even though the temperature in the loop is probably pretty low (winter). Currently about 10 inches of the loop are above the water level and I don't know what the consequences will be. Is there any possibility of using a different kind of pipe (like copper or aluminum) to make the system perform better?

I am wondering if a well system using water from the water table would be as efficient. It certainly would be less trouble. These are the kind of questions that I need answered. I live in Southern Indiana.

EH

Dear EH

It sounds like the nature of the installation will cause the heat pump to operate at temperatures higher than normal in the cooling mode and lower than normal in the heating mode. This is due to the shallow depth of the loop pipe and the closeness of the water temperature to the air temperature.

The option of going to an open loop may be worth considering but I would exhaust the possibilities for correction of the existing system first. Is there any possibility of moving the loop piping out farther into the lake to get it into deeper water?

For residential systems some useful rules of thumb are as follows: in locations where the pond surface does freeze, a minimum depth of 8 ft. is recommended, for locations where freezing does not normally occur a 10 ft. depth is recommended. Loading should not exceed 10 tons per acre. For commercial applications a minimum depth of 12 ft. is necessary. It is possible to install systems successfully under less favorable conditions but these applications require careful analysis by a trained professional.

Although the thermal conductivity of copper is approximately 1000 times that of PE, only a 3:1 loop length ratio will result because of the other thermal resistances involved (fouling, pipe internal and external film coefficients). When other factors, such as cost, durability, and ease of installation are considered, polyethylene remains the clear choice in most applications.

KR (OLG)

High Cost GCHPs

Our firm designed a closed loop geothermal heat pump system for an office building. Although the client was sold on the concept, we did not recommend the GHP because the bid was higher. We did not feel our client would be able to recoup the added cost in a reasonable amount of time. What can be done to lower the cost of geothermal systems?

There are a variety of reasons that GHPs can be more costly to install than conventional HVAC systems. However, there are also a number of practices that experienced designers, working with experienced contractors, have incorporated to reduce the cost of commercial GHP systems.

Too often designers focus on reducing loop cost, when they may only be 15 to 25% of the total. Other components, which may be required for traditional HVAC systems, can be often be eliminated or minimized. Loops are expensive, but they can also lead to savings on the inside of the building.

The most important step is to break down the costs by components. A recommended division is: exterior ground loop, interior piping (including insulation, pumps, and valves), heat pump units, controls, and ductwork.

Loop costs typically fall in the \$2 to \$4/ft^2 range. Compare your design, specifications and costs to completed and similar projects if bids are higher. The number of bores, bore depth, and header arrangements can often be adjusted to lower costs.

If duct costs are high, specifying smaller heat pumps and locating them in the middle of the zone they serve can yield ***big*** *savings. High efficiency, extended range heat pumps have much lower sound levels than their water loop cousins.*

Interior piping can also be a big-ticket item and can be reduced by avoiding one big central loop. Several smaller loops can lower interior piping costs without greatly reducing diversity factors (that lower required ground loop length). Short interior runs can be done with polyethylene pipe so the costly transition to metal (and inhibitors) can be avoided.

There is a healthy competition among manufacturers of high efficiency, single-speed heat pumps in the commercial market. The more expensive multi-capacity units are unnecessary in most commercial applications. While their rated efficiency may be high, actual performance in commercial applications is not nearly as impressive.

Control costs can also get out of hand. Clients can be "wowed" by the graphics with DDC control. If they insist on this type of option, they should be informed of their costs and possible alternatives. GHPs are inherently efficient and provide high levels of comfort with modest controls.

SK (GGS)

Publications, Information Sources, and Meetings

Publications

ASHRAE (404-636-8400)

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 Winter Annual Meeting)
- ***Performance of a Hybrid GSHP***
- ***GHP Design and Operation: Experience within Asia***
- ***GCHP Loop Design Using Thermal Conductivity Testing***
- ***Well Pumping Issues in Commercial GWHP Systems***
- ***Development of Design Tools for GSHP Piping***
- ***Antifreeze Acceptability for GSHP Loops in the US***
- ***Using Calibrated Models to Predict Large GSHP Energy***

Commercial Ground-Source Heat Pump Systems, (Collection of Papers), 1996

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

Assessment of Anti-Freeze Solution for Ground-Source Heat Pump Systems, 908RP (Research Project Report), 1996

1995 ASHRAE Handbook – HVAC Applications (Chapter 29 – Geothermal Energy)

Geothermal Heat Pump Consortium (888-255-4436)

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

Analysis of Existing GeoExchange Installation Data Sets, 1997 (RP-026)

"Analysis and Development of a Design Method for Hybrid GHPs", 1997

"Geothermal Heat Pump Systems in Two Pennsylvania Office Buildings", 1997 (RP-027)

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

Measuring Thermal Properties of Soil and Rock: Bibliography and Abstracts (RP-021)

National Ground Water Assoc. (614-337-1949)

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

Geo-Heat Center (541-885-1750)

"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

"Cost Containment for Ground-Source Heat Pumps", (TVA-Univ. of Alabama), 1995 - RESIDENTIAL

IGSHPA (800-636-GSHP)

Closed-Loop/Ground Source Heat Pump Systems: Installation Guide, 1988.

Geothermal Heat Pump Systems: Design and Installation Standards, 1994.

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

Meetings - 1998

Apr. 1-3 – IGSHPA Architect & Engineer Workshop, Stillwater, OK (Oklahoma State) 800-636-GSHP

Apr. 22-24 – IGSHPA Architect & Engineer Workshop, Stillwater, OK (Oklahoma State) 800-636-GSHP

Apr. 29 -- One-Day GSHP Design Seminar for Engineers, Spartanburg, SC - Duke Power/AEC, 919-857-9024

Apr. 30 -- One-Day GSHP Design Seminar for Engineers, Charlotte, NC - Duke Power/AEC, 919-857-9024

May 10-11 (Tentative) - Two-Day GSHP Design Seminar for Engineers, Ogden, Utah – Sound Geothermal, 435-722-5877

May 17-20 – IGSHPA Technical Conference & Expo, Stillwater, OK (Oklahoma State) 800-636-GSHP

June 18-19 -- Heat Pumping Solutions for Single Room Applications, Niagara Falls (Canada), International Energy Agency Heat Pump Centre. Registration 416-979-1300

June 20-24 -- ASHRAE Annual Meeting, Toronto, 404-636-8400

July 10-11 (Tentative) - Two-Day GSHP Design Seminar for Engineers, Portland, OR – Sound Geothermal, 435-722-5877

Nov. 1-4 –1998 Geothermal Heat Pump Industry Conference (IGSHPA), Pheasant Run Resort, St. Charles, IL 800-636-GSHP

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