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GHC

GEO-HEAT CENTER *Quarterly Bulletin*

OREGON INSTITUTE OF TECHNOLOGY -KLAMATH FALLS, OREGON 97601-8801
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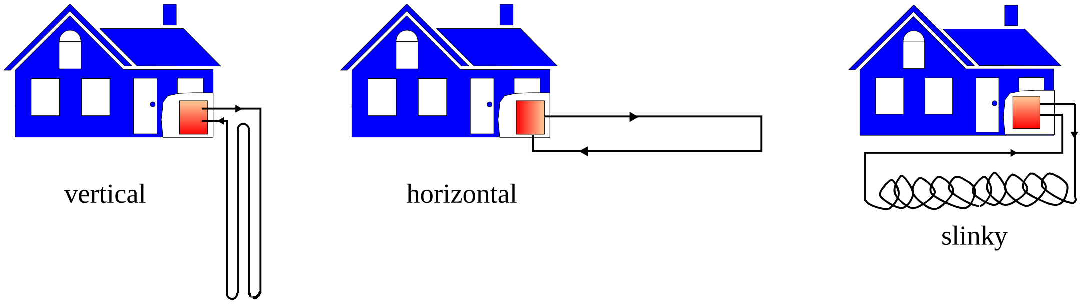
GEOTHERMAL HEAT PUMPS (GHP)

a.k.a. Ground Source Heat Pumps (GSHP)

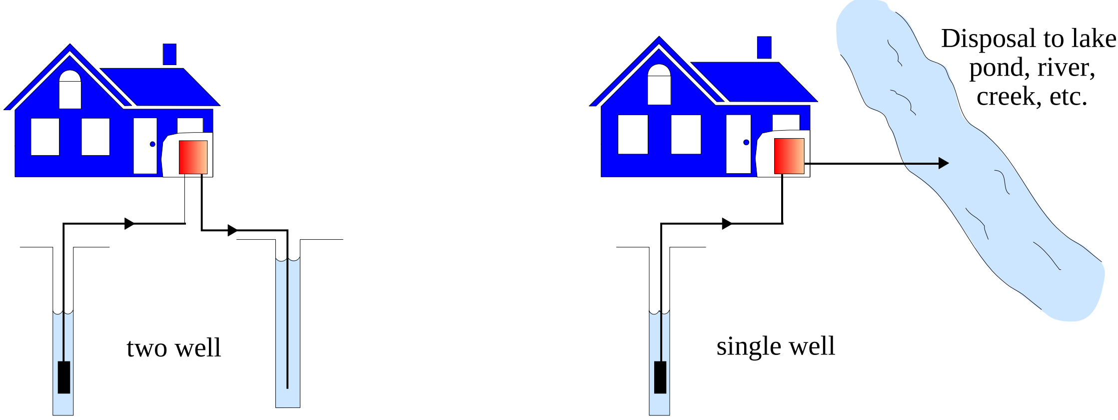
Ground Coupled Heat Pumps (GCHP)

a.k.a. closed loop heat pumps



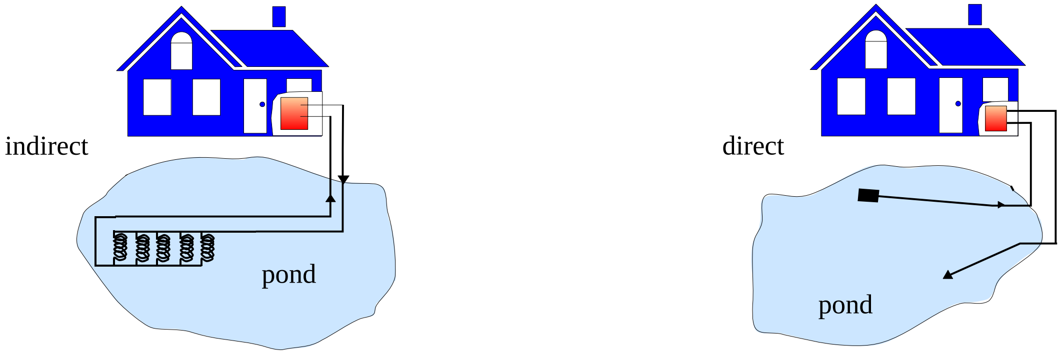
Groundwater Heat Pumps (GWHP)

a.k.a. open loop heat pumps



Surface Water Heat Pumps (SWHP)

a.k.a. lake or pond loop heat pumps



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A Quarterly Progress and Development Report
on the Direct Utilization of Geothermal Resources

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Cover: Geothermal heat pump technology.

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AN INFORMATION SURVIVAL KIT FOR THE PROSPECTIVE RESIDENTIAL GEOTHERMAL HEAT PUMP OWNER

Kevin Rafferty
Geo-Heat Center

INTRODUCTION

The fact that you are considering a geothermal (or ground-source) heat pump system, places you among the best informed and most innovative homeowners in the country. Geothermal heat pumps (GHPs), although not a new technology, remain a small (but growing) player in the residential heating/cooling sector. Although some what higher in first cost, this technology can, in the right application, quickly repay this cost premium through savings in energy costs.

Despite all the positive publicity on GHPs, they are not for everyone. Like any other heating and cooling system, GHPs tend to fit well in certain circumstances and poorly in others. Familiarizing yourself with the factors that effect the feasibility of GHPs will assist you in making an informed decision as to their suitability for your home.

It is the intention of this package to provide that information and to address some of the commonly asked questions regarding the technology. Please feel free to contact us if you have questions not covered in this package.

TERMINOLOGY

One of the major hurdles for this technology is reaching a consensus as to what it will be called. A great many names have been used in the past with confusion resulting for the public and the industry. The following figures outline the major residential system types and the various names used for each.

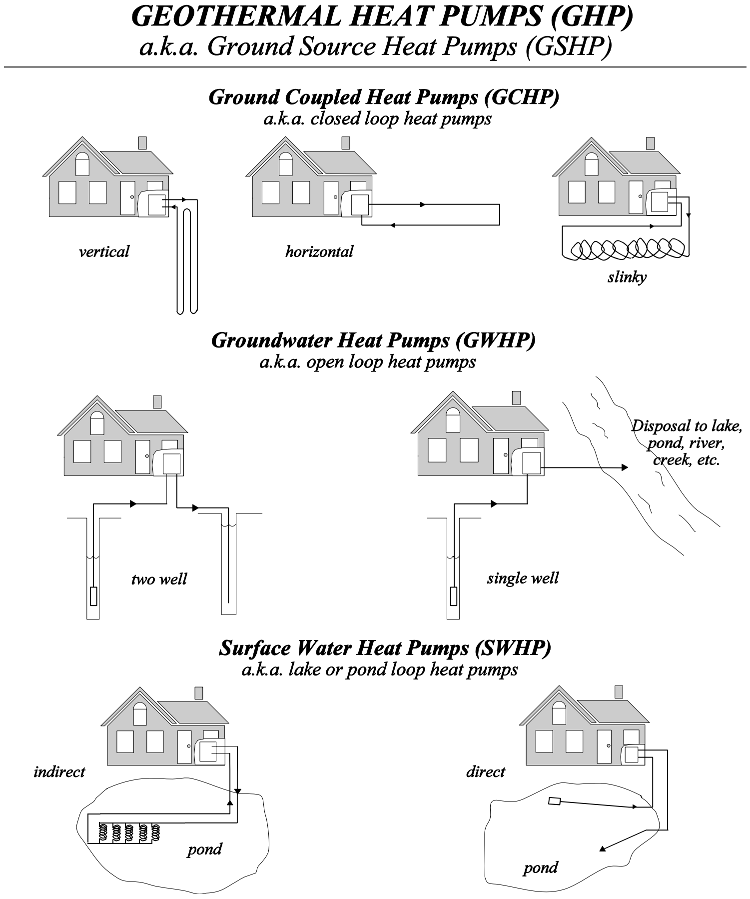

Figure 1.

Two terms are in use to describe the technology in general: geothermal heat pump (GHP) and ground-source heat pump (GSHP). The former is typically used by individuals in marketing and government, and latter by engineering and technical types. The terms appearing in bold (Figure 1) will be the ones used throughout this text.

Ground-coupled systems have been widely used since the mid-1980s. Currently, horizontal systems constitute about half of the installations, vertical 35%, and pond and "other" approximately 15% (Kavanaugh, 1995)..

Groundwater systems have been used for a somewhat longer time than ground-coupled systems, and have been popular since the early 1970s.

HEAT PUMPS - FUNDAMENTALS

Heat naturally flows "downhill", from higher to lower temperatures. A heat pump is a machine which causes the heat to flow in a direction opposite to its natural tendency or "uphill" in terms of temperature. Because work must be done (energy consumed) to accomplish this, the name heat "pump" is used to describe the device.

In reality, a heat pump is nothing more than an refrigeration unit. Any refrigeration device (window air conditioner, refrigerator, freezer, etc.) moves heat from a space (to keep it cool) and discharges that heat at higher temperatures. The only difference between a heat pump and a refrigeration unit is the desired effect--cooling for the refrigeration unit and heating for the heat pump. A second distinguishing factor of many heat pumps is that they are reversible and can provide either heating or cooling to the space.

One of the most important characteristics of heat pumps, particularly in the context of home heating/cooling, is that the efficiency of the unit and the energy required to operate it are directly related to the temperatures between which it operates. In heat pump terminology, the difference between the temperature where the heat is absorbed (the "source") and the temperature where the heat is delivered (the "sink") is called the "lift." The larger the lift, the greater the power input required by the heat pump. This is important because it forms the basis for the efficiency advantage of the geothermal heat pumps over air-source heat pumps. An air-source heat pump, must remove heat from cold outside air in the winter and deliver heat to hot outside air in the summer. In contrast, the GHP retrieves heat from relatively warm soil (or groundwater) in the winter and delivers heat to the same relatively cool soil (or groundwater) in the summer.

As a result, the geothermal heat pump, regardless of the season is almost always pumping the heat over a shorter temperature distance than the air-source heat pump. This leads to higher efficiency and lower energy use.

EQUIPMENT

The foundation of any GHP system is the heat pump unit itself. The most commonly used unit in these systems is the single package water-to-air heat pump. All of the components are contained in a single enclosure, about the size of a small gas furnace.

The unit includes a refrigerant-to-water heat exchanger, refrigerant piping and control value, compressor, air coil (heats in winter; cools and dehumidifies in summer), fan and controls (Figure 2).

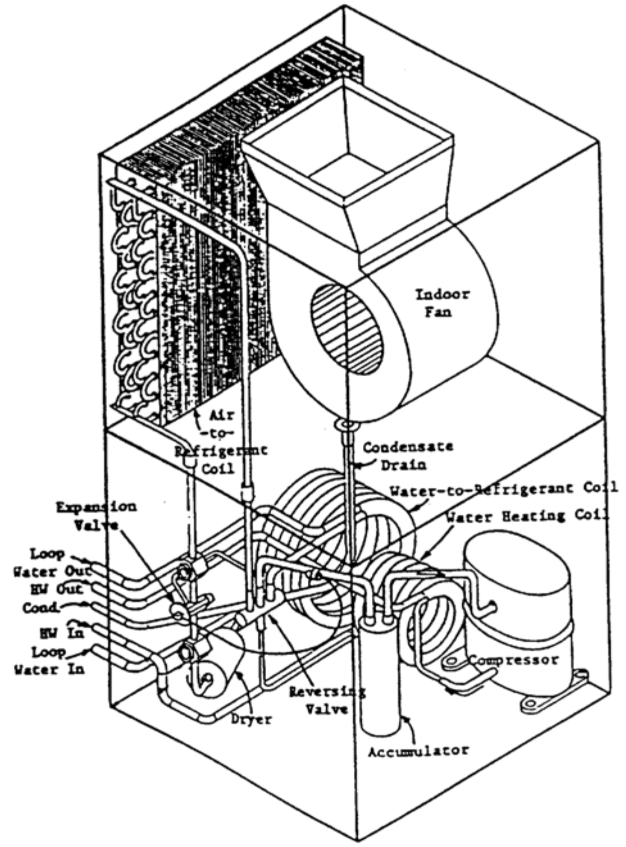

Figure 2. Horizontal water-to-air heat pump (Kavanaugh, 1991)

The single package design is a major advantage over the so-called "split" system used for air-source heat pumps (ASHP). The lack of an outside unit reduces the amount of refrigerant required and the potential for leaks--a major enhancement to reliability.

Virtually all GHP units use refrigerant R-22, an HCFC. R-22 is considered a transition refrigerant and has a ODP (ozone depletion value) of 0.05--only 5% of the most damaging refrigerants R-11 and R-12. This refrigerant is not scheduled for phase out until 2030.

Domestic hot water heating capability can be added to most GHP units. The components are installed in the cabinet by some manufacturers and supplied as a small add-on cabinet by others. The domestic hot water heating components consist of a refrigerant-to-water heat exchanger and a small circulating pump. Field installed piping connects this unit to your domestic hot water heater.

High efficiency equipment generally contains a high efficiency compressor, larger air coil, higher efficiency fan motor, and sometimes, a larger refrigerant-to-water heat exchanger.

Manufacturers also offer split systems, water-to-water heat pumps, multi-speed compressors, dual compressor, and rooftop versions of this equipment to suit various applications.

PERFORMANCE RATINGS

One of the most confusing aspects of geothermal heat pump technology is equipment ratings. These heating and cooling performance values are useful for comparing units of the same type (i.e., ASHP to ASHP or GHP to GHP). Unfortunately, the ratings used for different types of equipment (furnaces, ASHP, GHP) are not generally comparable making comparisons difficult. As a result, it is useful to know what the rating values include and what they don't.

Most heat pumps are rated by the American Refrigerant Institute (ARI). Results are published every six months in the *Directory of Certified Applied Air Conditioning Products (for GHPs)* and the *Directory of Certified Unitary Products (for ASHPs)*.

For water-source heat pumps (the type of heat pump used in all GHP systems), cooling performance is defined by an index called EER (Energy Efficiency Ratio). This is the cooling affect produced by the unit (in Btu/hr) divided by the electrical input (in watts) resulting in units of Btu/watthr. Electrical input includes compressor, fans and "pumping" allowance (for the groundwater or ground loop).

Heating performance is defined by the index called COP (Coefficient Of Performance). This is the heating affect produced by the unit (in Btu/hr) divided by the energy equivalent of the electrical input (in Btu/hr) resulting in a dimensionless (no units) value. Again, the COP includes an allowance for pumping.

Both the COP and EER values for groundwater heat pumps are single point (valid only at the specific test conditions used in the rating) values only. This in contrast to the seasonal values (HSPF and SEER) published for air-source equipment. COP and EER are not the same as, or valid for use in comparison to, SEER and HSPF.

GHP Ratings

Ratings for GHPs are published under two different headings: ARI 325 (open loop or groundwater heat pumps) and ARI 330 (closed loop or ground-coupled heat pumps). These ratings are intended for specific applications and cannot be used interchangeably.

ARI 325 is intended for groundwater heat pump systems. Performance (EER and COP) is published at two water temperatures: 70^{o} and 50^{o}F. The pumping penalty used in ARI 325 is higher than the pumping allowance for ARI 330.

ARI 330 is intended for closed loop or ground-coupled GHPs and is based upon entering water temperature of 77^{o}F in the cooling mode and 32^{o} in the heating mode. One of the limitations of this rating is that the temperatures used are reflective of a northern climate. Southern installations would see higher temperatures entering the heat pump and thus, have better winter and poorer summer performance than indicated.

ASHP Ratings

The major difference between ratings for ASHPs and GHPs is that the air source values are seasonal. They are intended to reflect the total heating or cooling output for the season divided by the total electrical input for the season. These ratings (HSPF - heating, SEER - cooling) cannot be directly compared to the GHP EER and COP numbers.

ASHPs are rated under ARI 210/240. In order to simplify the process, a number of assumptions are made regarding operation of the heat pump. The rating is based on a moderate climate (Washington, DC) and as a result, is not reflective of either very cold or very warm areas of the country.

Furnaces

Furnaces are rated by an index known as AFUE or annual fuel utilization efficiency. This is intended to reflect the annual heat energy supplied divided by the energy content of the fuel consumed to supply that heat. The major drawback is that the electricity required to operate the fan in the furnace (and the combustion air fan if so equipped) is not included in the rating.

FREQUENTLY ASKED QUESTIONS

1. What does it cost to install?

The best way to begin this answer is to say that it will cost more than a conventional system. How much more depends on where you live and which GHP system you use.

For ground-coupled systems (both horizontal and vertical), cost varies with the number of available contractors. Where the technology is not well established, the lack of competition results in higher prices. Open loop and pond loop systems, because they do not require specialized contractors, are less affected by this problem.

Much of the following information is taken from a recent study of GHP costs entitled "*Cost Containment for Ground-Source Heat Pumps*" (Kavanaugh, 1995). This report is available as a separate publication from the Geo-Heat Center. This report addressed only ground-coupled systems. Groundwater (GW) system values were added by the author of this publication. Costs shown are based on a national survey and costs in your area may vary.

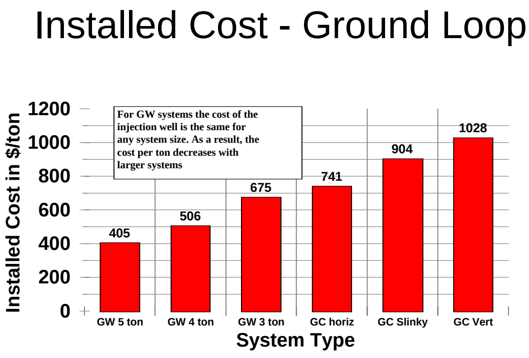

Figure 3.

Figure 3 shows the cost of the ground loop portion of the system. For groundwater systems, the costs shown include the cost of a larger well pump, tank, piping to and from the house, and a 50 ft disposal well. For ground-coupled systems, the costs include the trenching or boring, pipe installation and headers up to the home. This could be considered the "outside" the home costs for the system.

Figure 4 shows the "inside" the home costs which includes: the heat pump unit, circulating pump, distribution piping, ductwork and incidental mechanical and electrical items.

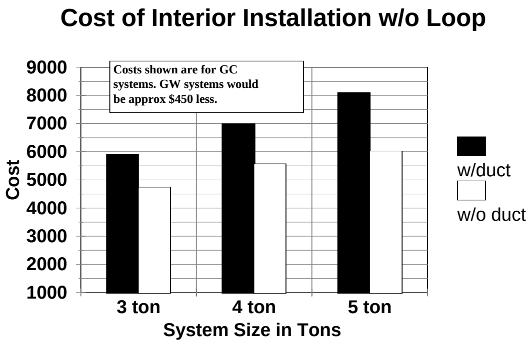

Figure 4.

Figure 5 indicates the cost for the heat pump unit only for the range of sizes normally found in residences.

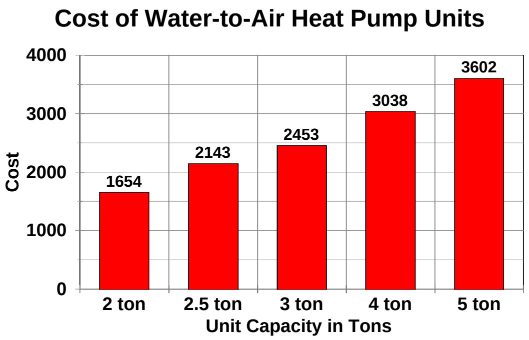

Figure 5.

Figure 6 compares the total costs associated with six different systems for 3-ton capacity. Costs shown include: units, ductwork, all associated components and the ground loop.

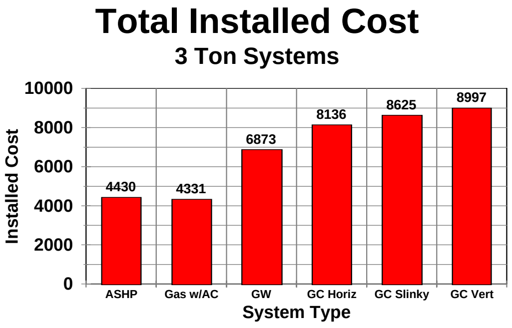

Figure 6.

2. How does the cost of heating with a GHP compare to other heating methods?

This has a great deal to do with your local rates for electricity and other fuels. The comparison involves the efficiency of the device, the type of fuel used and the cost of that fuel.

Commonly used heating fuels have the following approximate heating content:

Fuel oil - 138,000 Btu/gal
Propane - 90,000 Btu/gal
Natural gas -100,000 Btu/therm (1,000 Btu/ft^3)
Electricity - 3,413 Btu/kWh

A common index of the cost of heat is "dollars per 1,000,000 Btu of useful heat." In order to calculate useful heat (heat actually delivered to the house), it's necessary to adjust for the efficiency of the heating device and the cost of the fuel. The following equations can be used for this purpose:

Fuel oil $$\frac{7.25 x \$/gallon}{efficiency}$$

Propane $$\frac{11.1 x \$/gallon}{efficiency}$$

Natural gas $$\frac{10.0 x \$/therm}{efficiency}$$

Electric resistance $$293 \text{ x } \$/kWh$$

ASHP $$\frac{293 x \$/kWh}{COP}$$

GHP $$\frac{293 x \$/kWh}{COP}$$

As an example, let's look at a location in a moderately cold climate when the fuel costs are as follows:

Electricity, $0.07/kWh; fuel oil, $1.05/gal; propane, $1.20/gal; and natural gas, $0.60/therm. This would result in the following useful heat costs:

	$ per Million Btu
Electric resistance	20.51
Propane	15.86
ASHP	9.54 (2.15 COP)
Fuel oil	9.06
Natural gas	7.14
GHP	5.86 (3.5 COP)

Obviously, it is necessary to know the total amount of heat required for the year to calculate annual savings. The above values, however, provide an indication of the percentage savings to be expected from a GHP system compared to other options for heating.

Savings are also generated during domestic hot water heating and cooling. These will be small compared to the heating savings in all but southern climates. See the next question for some examples.

3. How much will it save?

As mentioned in the above question, this depends upon the particulars of your case and for an exact answer requires a sophisticated computer simulation. To provide a guide, the following data was developed (Kavanaugh, 1992a; Kavanaugh, 1992b) for three U.S. locations with widely differing climates. The values shown are annual kWh consumption for the different system types.

These figures are based on newly constructed homes conforming to local energy efficiency standards (which are much more stringent in the northwest portion of the country). GHPs are assumed to be equipped with desuperheaters for hot water heating. The balance of the water heating is by electric water heaters.

Additional savings information is available from the sources listed on page 22. The U.S. EPA report, "Space Conditioning: The Next Frontier" by L'Ecuyer and others (EPA 430-R93-004) also contains savings information

. 4. How much of the job can I do myself?

Very little. The performance of a ground-coupled heat pump system is determined by the quality of the installation. Assuring that proper backfilling is done around the pipe, fusing of the polyethylene piping, flushing the system and purging air from it, all require skills, tools and equipment only available to properly trained contractors. Ground loops are not do-it-yourself projects.

5. What about domestic hot water heating?

Most GHP units can be equipped (optionally) with a device called a desuperheater to partially heat domestic hot water (DHW). In the summer, this device uses some of the "waste" heat from the air conditioning to heat hot water. As a result, during the cooling season, this heat is free; although there is a small cost to operate a circulating pump to capture it. In the winter, some of the capacity of the heat pump is diverted from space heating to heat domestic hot water. It is important to understand, however, that the heat pump only produces domestic hot water when it is running for either space heating or cooling purposes. As a result, only a portion of the annual domestic hot water heating needs are met by the desuperheater.

The percentage of annual DHW heating needs met depends upon the run time of the heat pump and DHW use patterns in the home. The largest savings occur in applications where the heat pump runs a large number of

Atlanta, GA

	kWh Cooling	kWh Heating	kWh DHW	Total	kWh
ASHP	3,409	7,396	4,120	14,925	
ASHP (variable speed)	2,499	5,540	4,120	12,159	
GHP (std. eff.)	2,599	4,236	2,620	9,455	
GHP (high eff.)	2,079	3,510	2,509	8,098	

Spokane, WA

	kWh Cooling	kWh Heating	kWh DHW	Total	kWh
ASHP	773	11,475	4,120	16,458	
ASHP (variable speed)	435	9,295	4,120	13,850	
GHP (std. eff.)	451	5,562	3,150	9,163	

Portland, OR

	kWh Cooling	kWh Heating	kWh DHW	Total	kWh
ASHP	513	6,666	4,120	11,299	
ASHP (variable speed)	285	4,706	3,150	9,111	
GHP (std. eff.)	337	3,549	3,468	7,354	

hours (particularly in the cooling mode) and where alternative water heating is by electric resistance.

For an average family size (3.5 persons), with a 3-ton heat pump, the annual savings on domestic hot water would be in the range of 25% (colder climates) to 50% (warmer climates), or about $100 - $200 per year at $0.08/ kWh (Phetteplace, 1997). Since desuperheater capacity is directly related to heat pump capacity, the savings from a 4- or 5-ton system would be greater than the 3-ton savings cited above.

6. Should I use vertical, horizontal or open loop?

This is a tough question to answer. Let's look first at whether to go open loop or closed loop.

Open loop systems are best applied in situations where the house is, or will be, served by its own water well. A slightly larger well pump is installed to provide for the water required by the heat pump. A major consideration is the disposal of the water. Existing systems have used ponds, lakes, rivers, irrigation ditches, and return (or injection) wells. Surface disposal is obviously the least expensive option; but, even if a disposal well is required, the capital cost is likely to be much less than the cost of a closed loop ground coupling. Water quality is also an important issue. Since the water is used directly in the heat pump, the issue of corrosion and/or scaling can be a problem. If the water is hard (>100 ppm) high in iron or contains hydrogen sulphide (rotten egg smell), a closed loop system would be a better choice. If the water is of good quality and the house is to be served by a well for domestic water, serious consideration should be given to the open loop approach. See the costs section of this report for capital costs for the open loop system.

If the system is to be a closed loop design, the choice between vertical and horizontal system is sometimes a difficult one to grapple with. The major advantage of the vertical design is that it requires much less ground area at the surface and it places the loop in a much more thermally stable zone. Soil at 100 ft sees essentially no temperature fluctuations; whereas, soil at a 4 or 5 ft depth may fluctuate significantly in temperature. As a result, the vertical design offers the potential of supplying the heat pump warmer water in winter and cooler water in summer.

Subsurface conditions and contractor availability will be the dominant factor in determining which type of ground coupling is used for many projects. In most areas of the country, the availability of contractors is still very limited. As a result, if the local contractors only install horizontal systems, that will likely be your most economical installation.

The thermal advantages of the vertical over the horizontal are less of a factor in moderate climates. The more extreme the climate, either in heating or cooling, the greater the advantage of the vertical system.

See the cost section for a discussion of system costs.

7. Who makes the best equipment?

This is a lot like asking who makes the best car. All major manufacturers produce quality products and what is "under the hood" on most products is surprisingly similar.

One way to compare equipment is by the rated performance. This information is published periodically in the ARI (American Refrigeration Institute) Directory. The following tables list the heating (COP) and cooling (EER) performance data from the most recent directory (ARI, 1996).

			COP		
HEATING	**Tons: 2**	**3**	**3.5**	**4**	**5**
Addison "G"	3.1	3.1	3	3.1	2.9
Bard	3	3	2.8	2.7	2.5
Carrier	3	3	2.8	3	2.6
Carrier GT	3	3	2.8	3	2.6
Carrier GTX		3.5	3.8	3.7	3.4
Climate Master Classic (P)	3.4	3.2	3.2	3.2	3.2
Climate Master Geo-Thermal (E)	3	3	2.8	3	2.6
Climate Master Ultra TR		3.5	3.8	3.7	3.4
Command Aire	2.9	3.1	2.9	3.1	2.9
ECONAR	3.4	3.2	3	3	3.1
FHP Geo-Miser Single	3.3	3.4	3.4	3.4	
FHP Geo-Thermal	3.1	3.1	3.3	3	3.1
FHP GT 3000		2.4		2.4	
Heat Controller	3.1	3.1	3	3.1	2.9
Hydro Delta Hydro Heat	3.1	3.3	3.2	3.1	3.2
Mammoth	3.1	3.1	3	3.1	2.9
Millbrook Hydron Module	3.2	3.4	3.3	3.3	3.4
TETCO	3.3	3.2	3.1	3.1	3
Trane	2.9	3.1	3	3.1	2.9
WaterFurnace Premier AT	3.4	3.3	3.4	3.3	3.2
WaterFurnace Spectra (SX)	3.3	3.2	3.3	3.1	3.1
WaterFurnace Northern Ldr.	2.7	2.7			

	EER				
Cooling	**Tons: 2**	**3**	**3.5**	**4**	**5**
Addison "G"	14.1	14.6	14.2	14.2	13
Bard	13	12.5	11.5	11.5	11.5
Carrier	11.5	11.2	11.3	10.9	10.6
Carrier GT	11.5	11.2	11.3	10.9	10.6
Carrier GTX		16.2	17.5	16.6	14.3
Climate Master Classic (P)		13.8	13.2	13.5	13
Climate Master Geo-Thermal (E)	11.5	11.2	11.3	10.9	10.6
Climate Master Ultra TR		16.2	17.5	16.6	14.3
Command Aire	15.6	16.1	15	16	13.9
ECONAR	14.5	13.8	13.4	12.4	11.9
FHP Geo-Miser Single	16.6	15.4	15.7		
FHP Geo-Thermal	13.4	14.3	13.5	13	13
FHP GT 3000		12.5		12.1	11
Heat Controller	14.1	14.6	14.4	14.2	13
Hydro Delta Hydro Heat	13	13.2	13.1	13.1	13
Mammoth	13.8	14	13.4	13.4	13.1
Millbrook Hydron Module	13.5	13.6	13	13.1	13
TETCO	13.8	13.6	13.6	13.3	13
Trane	15.6	16.1	15	16	13.9
WaterFurnace Premier AT	16.8	16	17	16.1	15
WaterFurnace Spectra (SX)	15.5	13.6	13.9	13.9	13.4
WaterFurnace Northern Ldr.	14.1	14			

Reference: ARI, 1996

This information addresses only the standard packaged single speed (or single compressor) units of the manufacturers. Many produce other types of equipment of both higher and lower performance. The units listed here are the most widely used models.

8. How do I find a contractor?

Selection of a contractor for a geothermal heat pump system is very important, particularly for ground-coupled systems. There are several places to look for information.

Local utilities often have promotional and/or certification programs for both ASHP and GHP contractors. The utility may maintain a list of approved contractors to which they can refer you.

Manufacturers (see list below) of heat pump equipment can direct you to a dealer/contractor in your area. The International Ground Source Heat Pump Association (IGSHPA) maintains a list of contractors on their web site on the internet (http://www.okstate.igshpa.edu). The list is organized by state.

The search for a groundwater system contractor is somewhat simpler. In this case, most general heating and air conditioning contractors can handle the installation without any special training. It is necessary for him to coordinate with the well pump contractor to assure that an adequately sized well pump and tank are installed.

9. Who makes the heat pump units?

Addison/Weatherking
Corp
7050 Overland Road
Orlando, FL 32810
Ph: (407) 292-4400
Fax: (407) 290-1329

Aqua Cal
2737 24th Street North
St. Petersburg, FL 33713
Ph: (813) 823-5642
Fax: (813) 821-7471

Bard Manufacturing
PO Box 607
Bryan, OH 43506
Ph: (419) 636-1194

Carrier
Carrier Parkway
PO Box 4804
Syracuse, NY 13221
Ph: (315) 432-7383

Climate Master
7300 S.W. 44th Street
Oklahoma City, OK 73125
Ph: (405) 745-6000
Fax: (405) 745-3629

Econar Energy Systems
19230 Evans Street
Elk River, MN 55330
Ph: (612) 241-3110
Ph: 1-800-4-ECONAR
Fax: (612) 241-3111

FHP Manufacturing
Div. Leigh Products, Inc.
601 N.W. 65th Court
Ft. Lauderdale, FL 33309
Ph: (305) 776-5471
Fax: (305) 776-5529

Heat Exchanger, Inc.
PO Box 790
Skokie, IL 60076
Ph: (312) 679-0300

HydroDelta Corp
10205 Gravois
St. Louis, MO 63123
Ph: (314) 849-5550
Fax: (314) 849-8410

Hydro Temp
Hwy 67 South
PO Box 566
Pocahantas, AR 72455
Ph: (501) 892-8343
Ph: 1-800-382-3113
Fax: (501) 892-8323

Mammoth
101 West 82nd Street
Chaska, MN 55318
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Fax: (612) 361-2700

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Mitchell, SD 57301
Ph: (605) 995-0241
Fax: (605) 996-9186

Snyder General
PO Box 1551
Minneapolis, MN 55440
Ph: (612) 553-5330

Thermal Energy Transfer
Corp.
1290 U.S. 42 North
Delaware, OH 43015
Ph: 1-800-363-5002
Fax: (614) 363-0450

Trane/Command-Aire
Corp.
PO Box 7916
Waco, TX 76714
Ph: (817) 840-5329
Fax: (817) 840-2221

WaterFurnace Int'l
9000 Conservation Way
Ft. Wayne, IN 46809
Ph: (219) 478-5667
Ph: 1-800 222-5667
Fax: (219) 747-2828

Walen
Department 1
PO Box 1390
Easton, MD 21601
Ph: (301) 822-9200

10. What do I look for in a contractor?

CERTIFICATION and EXPERIENCE! The contractor should be certified by the International Ground Source Heat Pump Association (IGSHPA) and should have demonstrated experience in installing GHP systems. Don't be afraid to ask to see proof of certification and to ask the location of previous installations.

11. Can GHP systems be used in conjunction with hot water space heating?

Yes and no. Heat pumps are available from several manufacturers that produce hot and chilled water rather than hot and cold air. These units can be connected to some types of hot water heating equipment. The limitation in the heating mode is temperature. Conventional hot water radiators and base-board type elements are designed to operate at temperatures of 160°F and above (older systems as high as 200°F). Unitary heat pumps are limited to producing supply water temperatures of less than 120°F. As a result, on a retrofit basis (a home with existing hot water radiator or baseboard), the prospects are not favorable.

The best hot water system to connect to a GHP are radiant floor (or hydronic radiant slab) systems. This design, in which special plastic tubing is installed in the floor slab as it is poured, operate at water temperatures typically much lower than radiator type systems. In order to minimize the required water temperature, the home should be well insulated and use minimal floor coverings. This type of system is more complex, in terms of equipment and controls than a standard water-to-air system and requires careful design.

In general, complete space cooling cannot be accomplished with a floor system since condensation would occur on the floor surface. As a result, this system generally must be coupled with some sort of fan coil unit to provide cooling and dehumidification, if needed.

12. Can snow melting be done?

Snow melting can be accomplished with GHPs; but, there are serious cost impacts in residential applications.

Due to the nature of snow melting, a separate system must be installed to serve the load. This is due to its requirement for the circulation of an antifreeze fluid through the system, instead of the warm air supplied by water-to-air heat pumps. Beyond this, since the requirement for snow melting coincides with the need for space heating, additional ground loop or well capacity must be installed to serve the snow melting system.

Although GHPs produce heat less expensively than most other systems, because of the substantial quantities of heat required by snow melting systems, the annual cost remains high. The high energy cost is a result of the way snow melt systems are operated. Most systems are allowed to "idle" at a low heat output during the winter season. This allows the paved surface to quickly come up to temperature when snow fall occurs. The energy consumed by this idling operation, because of the number of hours over an entire season, is substantial. Because of the thermal mass of the paved surface, simply turning the system on when snow fall occurs results in a long time lag (several hours to one day) between start up and snow melting. This results in incomplete snow removal and a "corduroy" effect on the surface.

The high energy cost is compounded by the need for high water temperatures to produce the necessary output required for adequate snow melting. These temperatures, in areas where heavy snow occurs, are far in excess of what would be produced by available unitary heat pump equipment.

The following evaluation of a snow melt system for a residence in Michigan points out some of the limitations.

> "In your area, a snow melting system would be designed for an output of about 165 Btu/hr per square foot, under melting conditions. For a 12 ft wide 100 ft long driveway, this would amount to 198,000 Btu/hr or the equivalent of about a 20-ton heat pump. This is about six times the size heat pump required for the average house.

> For snow melting conditions below 30°F and wind speeds above 5 mph, required water temperatures in the snow melt loop are in excess of 130°F. This is higher than the average heat pump can produce.
>
> Because the snow melting system requires the circulation of hot water, a water-to-water heat pump is required. Most homes with a geothermal heat pump use a water-to-air heat pump.
>
> Snow melting requires a substantial amount of energy on an annual basis. In your area, a residential system would consume about 133,000 Btu/yr per square foot of driveway. Supplying this from a geothermal heat pump, at a COP of 3.5, would require an electrical input of 11 kWh/sq ft of driveway. For a driveway of 1200 sq ft (100 ft x 12 ft), this would be about 13,200 kWh/yr or $924 per year at $0.07/kWh."

Snow melting has been successfully incorporated into some commercial GHP systems serving gas stations/ convenience store operations. The advantage here is that the store contains a great deal of refrigeration equipment which continually produces waste heat that is used for the snow melting system.

The moral of the story is that snow melting can be done with GHPs if money is no object. For most folks though, it's much more economical to hire the neighborhood kid to shovel the driveway.

13. Can I heat my pool?

Pools can be heated with a GHP and in very warm climates, this makes a good match with a space conditioning GCHP. In cooling dominated climates, the space conditioning heat pump rejects much more heat to the ground than it absorbs from the ground. As a result, there is the potential for a gradual increase in ground temperature to occur over a period of years, where a marginally-sized ground-coupled system is used. Removing this excess heat and delivering it to a swimming pool reduces (or eliminates) the problem and may allow a reduction in the ground loop length.

Pool heating will require a separate heat pump for the pool. Beyond this, the heating capacity of the heat pump will likely be less than that of a typical gas-fired heater in the same application. This is a result of the fact that heat pumps cost about five times what gas-fired pool heaters do per unit of heating capacity. The smaller heat pump would not affect the ability to maintain pool temperature, but would result in a longer time required to bring the pool temperature from cold up to usable temperatures at the beginning of the season.

The pool heating unit would be of the water-to-water type rather than the water-to-air design used for home heating and air conditioning. The impact of the pool heating upon required loop length would depend upon the size of the pool and the amount of the year it is in operation.

14. I currently have a propane (or oil or gas) furnace and I am thinking about changing to a GHP. What should I be aware of?

First of all, there will be a major difference in the air temperature from the supply registers. Heat pumps, regardless of the type, produce lower temperature air than fossil fuel furnaces. Air-source heat pumps produce the coolest air 90°F to 95°F. GHPs produce air of 95°F to 103°F, a small but very noticeable improvement.

Another issue is the ductwork. If the house was not originally equipped for air conditioning, the ductwork may be undersized for the heat pump. Both central air conditioning and heat pumps require more air flow than fossil fuel furnaces. Be sure to have your contractor evaluate this issue. Under-sized ductwork results in noise and lower system efficiency.

15. Are there any substantial improvements in efficiency on the horizon?

There are always improvements to be made in mechanical devices like heat pumps. This is not a reason to put off the installation of a GHP system, however. Most of the substantial efficiency gains have been made over the past 10 years. Remaining improvements will likely be small in comparison to what has been achieved. As an example, the average performance of five manufacturer's equipment found in the 1987 and current ARI Directories has shown an average of 41% improvement in EER and 27% improvement in COP.

16. I am planning a large home. Should I use one large unit or two smaller ones?

There are several reasons why it may be advisable to use two smaller units than one large one. The use of two or more small units is referred to in the HVAC trade as "zoning." Generally a separate zone is established if one or more of the following criteria apply: the area has a specific use distinct from the rest of the home (mother-in-law's apartment), the area is maintained at a distinct temperature (basement), a separate level of the home (2nd floor bedrooms).

An additional reason for using two systems is that the equipment of many manufacturers falls off in performance above four tons. As a result, the use of two 3-ton units is likely to yield a higher performance than a single 6- or 7-ton unit. This performance difference, however, is not sufficient to justify the additional cost of the 2-system design; but, enhanced temperature control will result in greater comfort.

17. Is the system's antifreeze a potential environmental problem?

In residential applications, the commonly used antifreeze solutions pose little to no environmental hazard. Each state regulates the types of antifreeze materials used in GHP systems. The most commonly used ones are propylene glycol, and methanol. Propylene glycol is a non-toxic fluid which poses no hazards to the environment, humans or animals, and in fact, is used in food processing refrigeration.

Methanol (or alcohol) is potentially flammable, but not in the concentrations used in GHP systems. It is similar to the antifreeze solution used in windshield washer systems.

18. I have heard of a system where air is circulated through large diameter pipes buried in the soil and then supplied to the building for heating purposes. Is this possible?

Anything is possible. It's just that some things work better than others. Due to limitations in heat transfer and equipment, this is one of those ideas that doesn't work too well. The following is an excerpt from a response we recently sent to a farmer in Minnesota. He had 42°F soil and wanted to heat some new barns.

> "In order to transfer heat from a source (like the soil) to a fluid (like air), two things are necessary: a temperature difference and some surface area across which the heat will be transferred (the pipe). Because a temperature difference is required to drive the heat out of the soil, across the pipe and into the air, the temperature of the air leaving the buried pipe will always be less than the temperature of the soil. The closer you try to get the leaving air temperature to the soil temperature, the more pipe (surface area) it takes. For argument, let's figure that a 10°F difference is required (close to what ground-source heat pumps are designed for). This means that the air exiting the pipe will be 32°F in the coldest part of the year. In order for this air to deliver heat to the building to be heated, a temperature difference between the air exiting the pipe and the air in the space is required. The smaller this temperature difference is, the more air that must be circulated to meet the heating load. The problem is that these two temperature differences, combined with the temperature of the soil result in the ability to maintain only very low temperatures in the "heated" buildings. If we used another 10°F temperature difference between the space and the pipe exit air, this would result in the ability to maintain only 22°F maximum in the space. The above assumes that the soil would remain at the undisturbed temperature of 42°F minimum. This would not be the case since the removal of heat would cause the decline in the soil temperature, thus reducing the temperatures used above.
>
> This type of system has some real possibilities in the cooling season; but, as you can see, it's pretty limited in the heating season."

The soil is an excellent heat source; but, it requires a heat pump in the system to "amplify" the heat to usable levels for normal space heating.

19. Where can I go for more information?

Geo-Heat Center
3201 Campus Drive
Klamath Falls, OR 97601
http://www.oit.edu/~geoheat

International Ground Source Heat Pump Association (IGSHPA)
470 Cordell South
Stillwater, OK 74078-8018
Ph: 1-800 626-GSHP
http://www.igshpa.okstate.edu

Geothermal Heat Pump Consortium Inc.
701 Pennsylvania Avenue NW
Washington, DC 20004-2696
Ph: 202-508-5500
Fax: 202-508-5222
http://www.ghpc.org

National Rural Electric Corporative
Research Division
1800 Massachusetts Avenue NW
Washington, DC 20032
Ph: 202-857-9775
http://www.webplus.net/nreca/homepage.htm1

Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
Ph: 415-855-2810
http://www.epri.com/information/aboutEPRI.htm1

Your local electric utility

Your state energy office

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WELL PUMPING ISSUES IN COMMERCIAL GROUNDWATER HEAT PUMP SYSTEMS

Kevin Rafferty
Geo-Heat Center

INTRODUCTION

Groundwater heat pump (GWHP) systems have historically been considered by many to be characterized by excessive pumping energy. When poorly designed or controlled, this can be true; however, much of the perception is a carryover from experiences in residential systems. In large commercial GWHP systems, overall pump efficiency is much higher, flow requirements (per ton) are generally lower and in many applications, pump head is reduced relative to residential systems. These factors combine to result in much lower unit pumping energy requirements than is commonly believed. In fact, under some conditions, groundwater systems can offer system performance superior to ground-coupled systems.

Key to efficient well pumping design is the consideration of the three major power consuming components of the system: well pump, heat pumps and building loop pump. Careful consideration of the interaction between these components and their impact upon system performance is necessary in order to minimize operating costs for the building owner.

The strategies discussed in this article are intended to address large (>50 tons) commercial GWHP systems. The basic system configuration is illustrated in Figure 1. The heat exchanger, separating the building loop from the groundwater distinguishes large systems from smaller installations in which the groundwater is commonly supplied directly to the heat pumps.

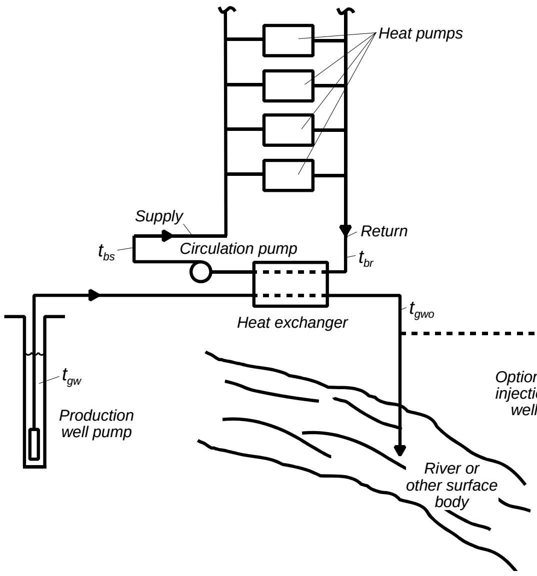

Figure 1. Groundwater heat pump system.

Discussion of system performance focuses on the cooling mode since this is usually the dominant load in large buildings regardless of the climate.

WELL PUMP HEAD

Well pump head in a GWHP application consists of three major components: lift, surface requirements and injection head. A small friction loss occurs in the pump column; however, this is minor in comparison to the other losses and is frequently neglected in head calculations.

In most water wells, the removal of water on a continuous basis results in a drop in water level from the static (non-pumping) level to the dynamic (pumping) level. This drop in water level is a manifestation of the drop in pressure necessary to cause water to flow from and through the aquifer into the well. The pumping level is a function of the pumping rate with higher flow resulting in lower (deeper) pumping levels. The vertical distance between the pumping level and the ground surface constitutes the "lift" portion of the well pump head. The lift varies with flow, but at far less than the second power relationship of frictional resistance. The total depth of the well and the distance the pump is submerged below the water surface have no bearing upon pump head.

For a system producing 300 gpm with an original static water level of 100 ft and a drawdown of 40 ft, the lift (and the pumping level) would be 140 ft.

Surface head loss includes the losses in the piping to and from the building, the isolation heat exchanger and associated fittings and accessories. Table 1 presents a summary of losses from a 300 gpm system with 300 ft of piping from the production well and 400 ft of piping to the surface disposal point.

Table 1.

		Loss @ 300 gpm (ft)
Well head	3 - 6" elbows	0.24
	1 - 6" butterfly valve	0.05
	1 - 6" check valve	0.3
Piping to building	300 ft, 6-in. PVC Class 160	2.4
Mechanical room	12 - 6" elbows	1.0
	Heat exchanger @ 7 psi	11.5
	2 - 6" butterfly valves	0.1
Piping to disposal point		
	400 ft, 6-in. PVC Class 160	3.2
	4 - 6" elbows	0.3
	1 - Pressure sustaining valve @ 3 psi	6.9
	Total Surface Loss	25.99 ft

The largest single loss, in most cases, is the heat exchanger and depending upon the design, the value will vary from about 12 to 28 ft. The example case includes a pressure sustaining valve (a device sometimes used in the absence of injection) to maintain a slight positive pressure on the disposal line.

The use of injection for disposal does not necessarily involve additional pump head. Most regulatory agencies require that the water be injected into the same aquifer from which it was withdrawn. As a result, the production well's performance is a good indication of potential injection well performance. In theory, the rise in water level required to force the water back into the aquifer mirrors the drop in water level required to produce it. As a result, if a production well had a 100 ft static water level and a 140 ft pumping level @ 300 gpm, the injection well (assuming the same 100 ft static level) would have injection water level of 100 - 40 ft or 60 ft below ground surface. Actual injection water level requirements frequently are higher than this theoretical relationship. With proper drilling practices, well design and moderate water quality, it is reasonable to expect that injection head (relative to the static level) will be approximately 20% greater than the production drawdown. For poor conditions, this value may be as much as 60%.

Using the 300 gpm production well as a guide, the injection pressure can be calculated assuming average injection conditions (injection head 40% greater than production drawdown).

Production drawdown = 40 ft
Injection well water level rise = 40 ft x 1.4 = 56 ft
Injection well static level = 100 ft
Injection level = 100 ft - 56 ft = 44 ft (below ground surface)

Since the water level in the injection well remains below ground level, there is no additional well pump head associated with injection in this case.

Summarizing the total pump head for the 300 gpm example:

Production well lift = 140 ft
Surface requirements = 26 ft
Injection head = 0 ft
Total pump head 166 ft

WELL PUMP POWER REQUIREMENTS

Well pump power requirement is a function of flow, head and efficiency. Properly selected vertical turbine well pumps in the 100 to 1000 gpm range have peak efficiencies of 77 to 80% (Peerless, undated; Layne and Bowler, 1991). Submersible pump motor efficiency varies with size from approximately 75% (5 hp) to 85% (75 hp) (Franklin Electric, 1996). Combining average values from these ranges results in an overall efficiency of 63% for the well pump and motor. Using this average value, a plot can be made of well pump power requirements for a variety of water flows and pump heads appropriate to GWHP systems. This data appears in Figure 2.

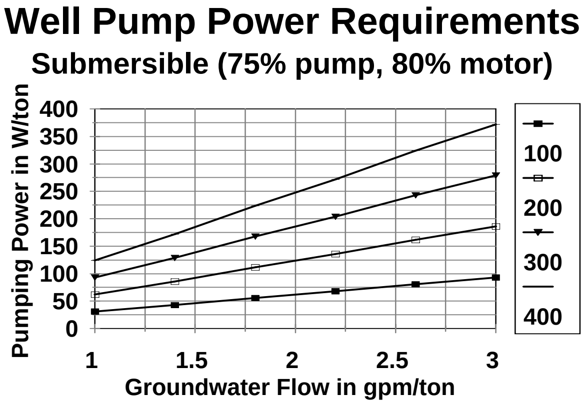

Figure 2. Well pump power requirements.

As indicated, in situations of high flow rate and high pump head, the well pump power consumption is substantial. This is particularly true when one considers that a water-source heat pump operating at a 15 EER requires 800 watts per ton. In a system with a water flow of 2.5 gpm/ton and a pump head of 400 ft, the well pump could consume 325 watts per ton or 40% or the heat pump power.

Avoidance of this excessive level of well pump power lies in a design procedure which rests upon total system performance rather than simply heat pump unit performance.

OPTIMUM WATER FLOW REQUIREMENTS

Optimum system performance is obtained when the power consumption of the well pump, loop pump and heat pumps is minimized through careful design. At a given loop flow rate, heat pump performance is largely a function of loop water temperature. Loop temperature, in turn, is governed by groundwater flow and temperature along with heat exchanger design. In most GWHP applications, the groundwater flow will be less than building loop flow, for optimum designs. Under these conditions, the heat exchangers can be designed economically for a 3^{o}F approach between the entering loop water (return from the heat pumps) and the leaving groundwater temperature.

Given a constant groundwater temperature and heat exchanger approach, increasing groundwater flow results in lower loop temperature and higher heat pump performance (in the cooling mode). For example, using heat pumps with an ARI 330 EER rating of 14.1, a 3^{o}F heat exchanger approach and 60^{o}F groundwater, a heat pump unit EER of 15 would require a flow rate of 0.79 gpm/ton; 16 EER a flow of 0.91 gpm/ton; 17 EER a flow of 1.05 gpm/ton and so on. At some point, the increasing heat pump performance will be compromised by rising well pump power consumption. As a result, for a given set of site conditions, there is an optimum groundwater flow with respect to system peak power consumption.

Power consumption of the building loop circulating pump must also be considered in the calculation of optimum flow.

Loop pump energy consumption is a function of the loop flow rate and system head loss. A recently developed design guide for ground-source heat pump systems (Kavanaugh, 1996) provides a range of values for acceptable design. According to this document, high efficiency systems are characterized by loop pumping energy loads of 75 watts/ton or less, average systems 75 to 100 watts/ton and poorly designed systems >100 watts/ton. These guidelines were developed for closed loop (ground-coupled) commercial systems. The values can also be used for groundwater systems. The major difference between the two designs is the presence of a plate-and-frame heat exchanger in place of the ground loop. On small systems (<75 tons), the ground loop friction losses are generally less than the plate heat exchanger. For larger systems, these losses are comparable. Since these losses constitute approximately 40% of the total system head loss, the resulting difference in loop pumping energy would amount to plus or minus 10% between groundwater and ground-coupled systems. This would translate into a difference of plus or minus 1% at a system EER of 13 and a loop pump rate of 75 watts/ton.

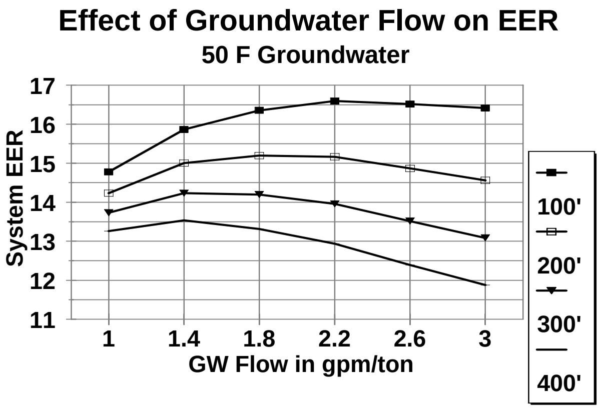

Figure 3. Effect of groundwater (50ºF) flow on EER.

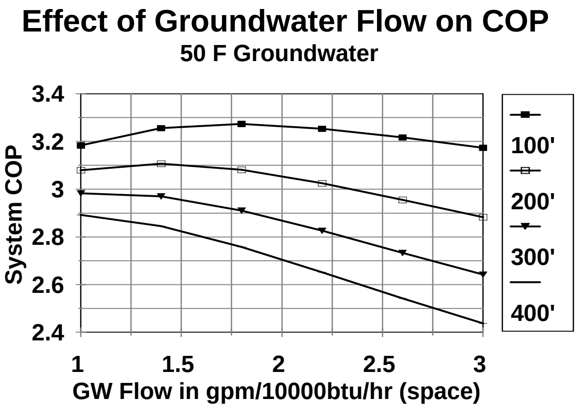

Figure 4. Effect of groundwater (50ºF) flow on COP.

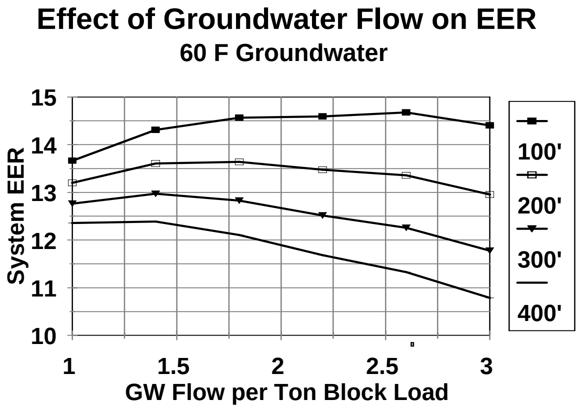

Figure 5. Effect of groundwater (60ºF) flow on EER

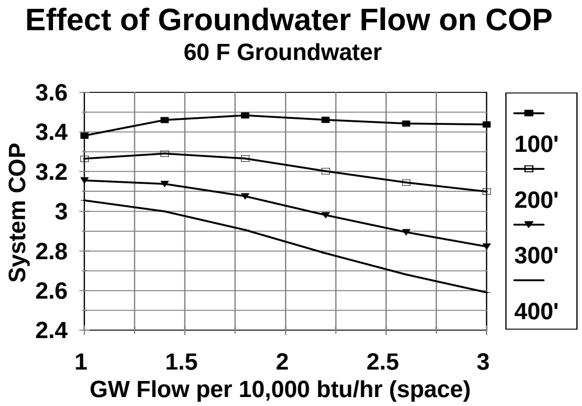

Figure 6. Effect of groundwater (60ºF) flow on COP.

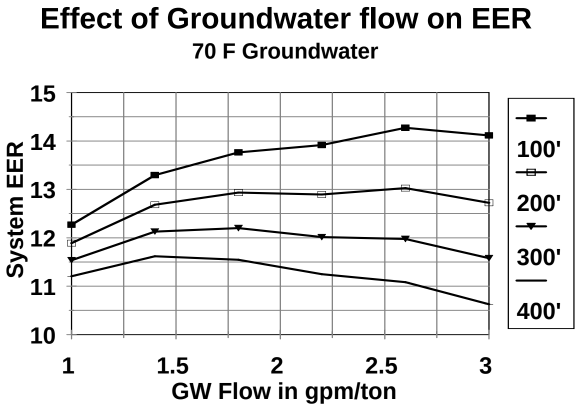

Figure 7. Effect of groundwater (70ºF) flow on EER.

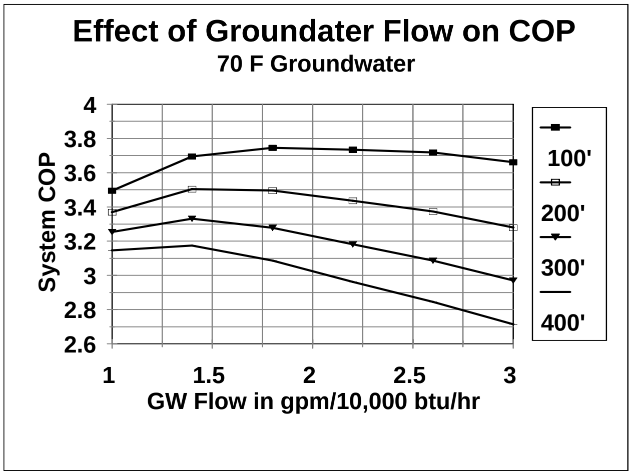

Figure 8. Effect of groundwater (70°F) flow on COP.

Using a loop pump power consumption of 75 watts/ton, an overall (pump and motor) well pump efficiency of 63% and performance data for moderate efficiency heat pumps (ARI 330 EER 14.1), Figures 3 through 8 provide information on total system performance at various well pump heads and flows.

For low pump head, these curves are very flat, particularly in heating. Although there is a clear optimum point on each curve, in some cases, it may be advisable to operate at flows much less than optimum. For example, consider a 300-ton (peak block) system with 60°F water in which cooling is the dominant load. Assuming a well pump head of 200 ft, the optimum flow would be about 1.8 gpm/ton or 540 gpm total, resulting in a system EER of 13.7. Reducing this flow 30% (to 1.25 gpm/ton or 375 gpm) would result in a system EER of approximately 13.5. Although this would increase system operating costs ($273/yr @ 1000 hr/yr and $0.07/kWh) slightly, the reduced flow would result in much lower well pump capital costs. Lower groundwater flows also ease disposal, particularly in the case of injection. These considerations often are very site specific; but, the nature of the curves does allow the designer some latitude in flow selection.

COMPARISON TO GROUND-COUPLED SYSTEM PERFORMANCE

It is useful to compare the performance of the groundwater system to that of a ground-coupled (closed loop) system in a similar location. The performance of the closed loop system is influenced by the length of the ground loop installed. Current guidelines recommend an entering water temperature to the heat pumps of 25°F (plus or minus 5°F) above the local undisturbed soil temperature. Using the 25°F value, and assuming that the undisturbed soil temperature is equal to the local groundwater temperature, appropriate values for heat pump entering water temperatures for ground-coupled system would be 75°F in the 50 °F case, 85 °F in the 60 °F case and 95°F in the 70 °F case. Based on the use of a ARI 330 rated 14.1 EER equipment, heat pump performance (EER) at these temperatures would be 75°F - 16.8, 85 °F - 14.9, and 95 °F - 13.2. System performance for the closed loop system is determined by only the heat pump and loop pump power consumption as there is no well pump. As a result, assuming again the use of a well designed system operating at 75 watts/ton loop pumping power, Table 2 summarizes the results for the ground-coupled system.

Based on these cooling EER values and the results for groundwater systems shown in Figures 3, 5 and 7 conclusions can be drawn with respect to the relative performance of ground-coupled and groundwater systems.

For water temperatures of 50°F and 60 °F, groundwater systems can offer higher system EER than ground-coupled systems when total well pump head is less than approximately 200 ft. At 70°F, groundwater systems can offer better performance at well pump TDH (total dynamic head) up to 300 ft.

The differences between the two system types is small however. At 60°F groundwater for example, the performance of the GWHP system at 100 ft head is 8% better than the ground-coupled system, and at 400 ft head only 8% worse than the ground-coupled system. In addition, these figures are based on average design parameters in both cases. As a result, it seems apparent that the skill of the designer has at least as much impact on system performance as does the system type.

Table 2. Ground-Coupled System Power Requirements - Summary

Soil Temperature	H/P EWT (°F)	H/P EER	H/P Watts	Loop Pump Watts	System Watts	System EER
50	75	16.8	714	75	789	15.2
60	85	14.9	805	75	880	13.6
70	95	13.2	909	75	984	12.2

CONCLUSIONS

Properly designed groundwater heat pump systems are characterized by peak load performance comparable to, or in some cases superior to, ground-coupled systems. To achieve this performance, it is necessary to select the groundwater flow with total system performance in mind. In addition, the flow should be based upon peak block load and not installed capacity.

The optimum groundwater flow requirement is a function of temperature, heat exchanger design and total pump head; but, in most applications, will be in the range of 1.0 to 2.5 gpm per ton--far less than the typical building loop flow of 2.5 to 3.0 gpm/ton.

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RENO INDUSTRIAL PARK
GEOTHERMAL DISTRICT HEATING SYSTEM

Paul J. Lienau
Geo-Heat Center

INTRODUCTION

Ten miles south of Reno, on U.S. 395 near the junction of the road to historic Virginia City, is Steamboat Hot Springs, a popular stop for travelers since the mid-1800s. Legend has it that Mark Twain named the geothermal area because it looked and sounded like a chugging Mississippi River paddle-wheeler. It is said when he first saw the steam rising from the ground he exclaimed, "Behold! A Steamboat in the desert." Over the years, the area has been used for its relaxing and curative qualities by Indians, settlers, and geothermal experts (Lund, 1978). Since the mid-1980s five geothermal power plants have been built at Steamboat Springs and in December 1996 it was announced that the proposed largest geothermal district heating system in the U.S. would supply an industrial park in the area.

The active geothermal area is located within the north-south trending graben like trough between the Carson and Virginia Ranges at the southern end of Truckee Meadows (Figure 1). Hot springs and other geothermal features occur over an area of about one square mile. The mid-basin location is controlled by faulting more or less parallel to the major mountain-front faults. It is believed that the heat source for the system is a cooling magmatic body at depth (Bateman, 1975).

The Steamboat geothermal area consists of a deep, high-temperature (215°C to 240 °C) geothermal system, a shallower, moderate-temperature (160°C to 18 °C) system, and a number of shallow low-temperature (30°C to 80 °C) subsystems (Garside, 1994). The higher temperature systems are used for electric-power generation. It is proposed that the exit fluids from the electric power plants be used for the geothermal district heating system. Geothermal electric power plants developed at Steamboat are summarized in Table 1

Table 1. Steamboat Geothermal Electric Power Plants, Source: GPM, 1996.

Plant Name (Year Online)	Type	Owner	Rated Capacity (MW)
Steamboat Geo I(1986)	B	Far West	6.8
Yankee/Caithness (1988)	SF	Caithness/ Sequa	12
Steamboat Geo IA (1989)	B	Far West	1.2
Steamboat 2 (1992)	B	Steamboat Dev.	12
Steamboat 3 (1993)	B	Steamboat Dev.	12

GEOTHERMAL DISTRICT HEATING SYSTEM

"Reno Energy is proposing a massive geothermal district heating system that could supply up to 30 million square feet (equivalent of 15,000 homes) of commercial and residential space. The energy cost would be about half of what potential customers would pay for natural gas." This news item appeared in the Reno Gazette Journal, December 13, 1996 (Johnson, 1996). Reno is a big city with a large geothermal potential. It is only one of 271 cities in western states with low-to moderate-temperature geothermal resources in their backyard (Lienau, 1996).

Reno Energy and Stone & Webster Engineering Corp. have worked together to develop the project and have signed agreements for the engineering and construction of the heating district. The estimated value of the project is currently $32 million (Burch, 1996). The University of Nevada, Mechanical Engineering Department has prepared an economic engineering analysis (Kanoglu, 1996) of the project which determined that the geothermal district heating system can deliver heat energy at 35 to 55 percent cheaper than natural gas or heating oil. Other independent research has confirmed that the clean, renewable resource from the Steamboat Hills Geothermal Field is plentiful and dependable enough to heat more than 30 million square feet of space. The project will be funded entirely by private funds; however, indirectly DOE has already assisted with the project through the GHC technical assistance program and the Geothermal Direct Use Engineering and Design Guidebook (Lienau, 1991). The Nevada Public Service Commission has contacted the GHC about regulatory considerations for the project. Developers hope to serve the first customers by the spring of 1998.

Wells within the Steamboat Hills geothermal field extract fluids from the fault zones 185 to 610 m below the surface. This water averages about 157°C and is used to run the turbines at the Steamboat Power Plants. The brine left over from the electrical generation process is currently injected back into the geothermal zone it originated from. The exit fluid temperature from the power plants averages 99°C in the summer and 85°C in the winter at a flow rate of 1,135 L/s. In addition, it is planned that four new wells will supply about 500 L/s of 160°C fluid to a high temperature heat exchanger, necessary for absorption cooling. The estimated capacity from the geothermal source is 352 MWt and the peak heat demand for the industrial park is 264 MWt; therefore, there is a 33% reserve (Kanoglu, 1996). The geothermal brine is returned to the production zone as required by state law. The freshwater will be heated to 116°C and circulated through a "closed loop" underground pipeline, supplying clean, economic and renewable heat energy to customers.

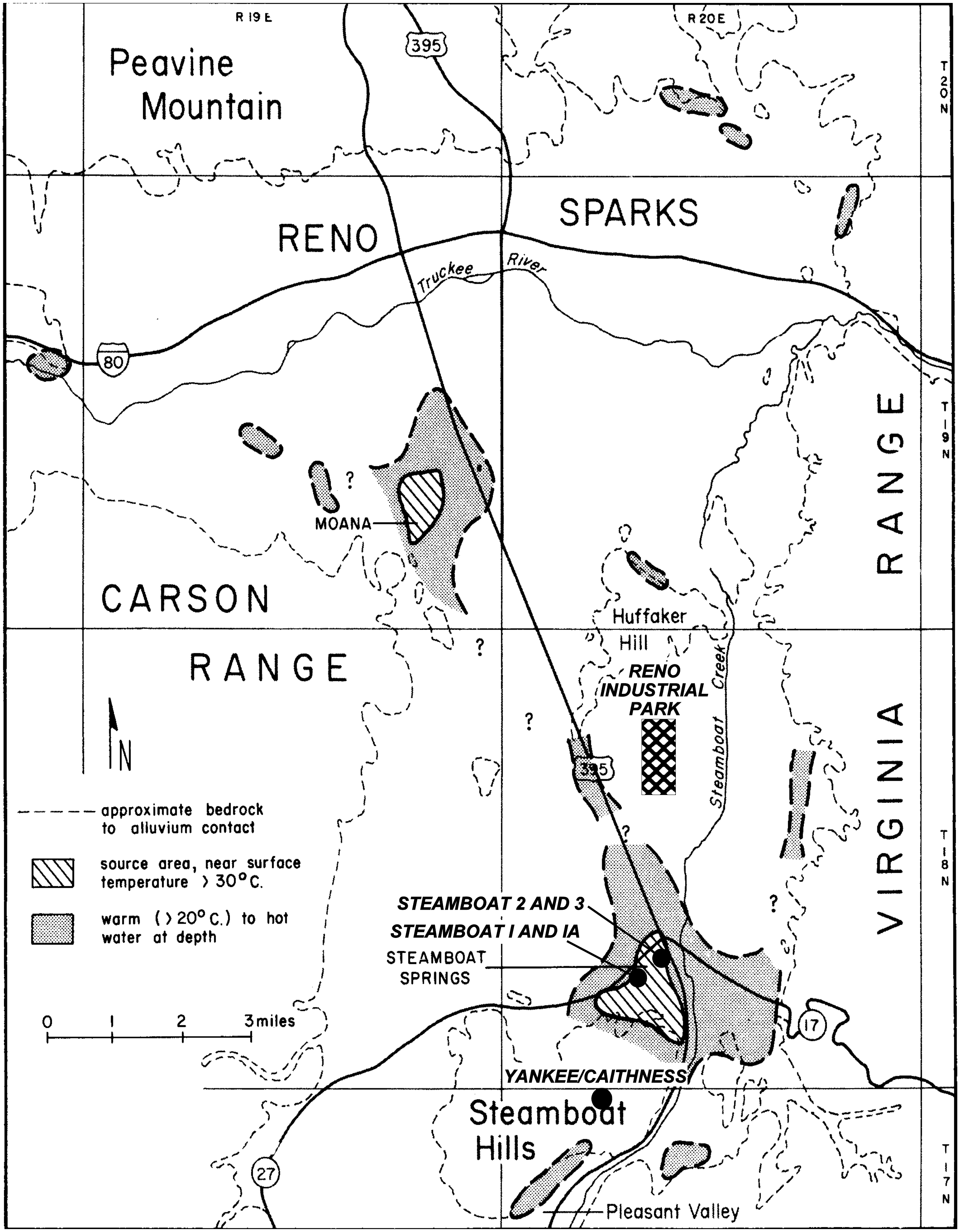

Figure 1. Areas of known thermal groundwater occurrence in the Truckee Meadows.

A large industrial park is being developed on a 1200 acre area in close proximity to the geothermal plants (Figure 1). The 300 acre 1st phase of the park is already sold out, and the entire park is expected to be developed within the next 7 years. The Park will house mostly commercial buildings with some industrial facilities, a 200-bed hospital and a 525-room hotel. It is expected that buildings with 30,000,000 square feet (264 MW_t) of floor space will be connected to the geothermal grid for heating (100%) and air-conditioning (45%). Also, Galena High School located nearby and the UNR Redfield Campus which will be built in the area as well as a planned Casino across the street are likely to be major consumers of geothermal heat (Kanoglu, 1996).

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Lienau, P., H. P. Ross and P.M. Wright, 1996. "Low-Temperature Resource Assessment". Geothermal Resources Council Transactions, Vol. 19, 63-68.

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GEOTHERMAL PIPELINE

Progress and Development Update
From the Geothermal Progress Monitor

ASHRAE GEOTHERMAL HEAT PUMP ACTIVITIES

Among the many organizations working to develop information on geothermal heat pump systems is ASHRAE, or American Society of Heating, Refrigeration and Air Conditioning Engineers, a professional organization whose members consist largely of engineers involved in Heating, Ventilation and Air Conditioning (HVAC) design, manufacturing, research and education. The Society is the primary source of design and application information for engineers involved in the HVAC industry. Through a variety of publications, ASHRAE makes this information available to its 60,000 members and the public.

Within the organization, approximately 100 Technical Committees (TCs) oversee the development of design information, research and standards in their respective areas of expertise. The primary committee for geothermal heat pumps (called ground-source heat pumps within ASHRAE) is TC 6.8 Geothermal Energy. For many years, this committee has been actively developing information for designers of commercial geothermal heat pump systems. Among the more important products of these efforts are:

Chapter 29 - Geothermal energy, ASHRAE Handbook of Applications

The ASHRAE Handbooks (a 4-volume set) are the most widely used source of design information for practicing engineers. These volumes are updated on a 4-year schedule. The current Geothermal Chapter is contained in the 1995 volume, and updating and improvements are underway in preparation for the 1999 issue.

Contained in the chapter is information on the design of direct use geothermal (100 - 300^{o}F), open loop (groundwater) and closed loop (ground-coupled) heat pump systems for commercial applications. This information focuses on the ground loop portion of the systems. Information on the building loop and heat pump equipment is contained in other chapters of the ASHRAE Handbook series.

Commercial/Institutional Ground-Source Heat Pump Engineering Manual

This manual was prepared by CANETA Research and published by ASHRAE in 1995. It contains information on design and installation for ground-coupled (closed loop), groundwater (open loop) and surface-water GHP systems. The vertical ground-coupled design methodology presented in this manual is the one developed by CANETA Research. This manual focuses on ground-coupled systems and provides somewhat less coverage of groundwater and surface water systems.

TC 6.8 is currently reviewing a second design manual for future publication by ASHRAE. This manual contains the design method developed by Dr. Steve Kavanaugh (University of Alabama) for vertical ground-coupled systems, and an expanded coverage of groundwater systems.

Commercial Ground-Source Heat Pump Systems

This document (referred to within ASHRAE as a Technical Data Bulletin) is a collection of papers previously published in the *ASHRAE Transactions* on the topic of commercial systems. It contains 15 papers on such issues as cost, design, modeling, energy use, standards and field testing of systems. The papers contained in the Bulletin were published between 1992 and 1995.

ASHRAE Transactions

The *ASHRAE Transactions* contains all of the papers presented at ASHRAE winter (January) and summer (June) meetings each year. TC 6.8 has been very active over the past several years holding sessions on GHPs at most meetings. Between 5 and 15 papers per year have been published as a result of these programs. All are included in the *ASHRAE Transactions*.

The research projects which have been conducted with oversight from TC 6.8 have recently resulted in two important publications.

Operating Experiences with Commercial Ground-Source Heat Pumps

This report by CANETA Research was published in October 1995 and resulted from ASHRAE Research Project RP-863. The report contains detailed case study information on 23 commercial ground-source heat pump systems. A wide variety of system types, designs and geographical locations included. Information on system cost, design, layout, operation and maintenance is included.

Assessment of Antifreeze Solutions for Ground-Source Heat Pump Systems

This report by the Center for Global Environmental Technologies (University of New Mexico) was completed as part of ASHRAE Research Project RP-908 and published in 1996. It contains a comprehensive review of the environmental, physical and thermodynamic properties of four current and two potential antifreeze fluids for GHP systems. Specific areas covered for each include: cost, corrosion, leakage, health hazard, fire risk and environmental risk.

In addition to these publications, TC 6.8 members are currently developing a 3-hour short course for presentation at the ASHRAE's January meeting in Boston. The course would include design information for large building GHP systems. Development of the 3-hour course is considered a stepping stone to preparation of an ASHRAE course on GHP to be included in the Professional Development Series (PDS).

This series presents 1-day seminars around the country each year on topics of current interest to ASHRAE members.

The publications described in this article can be ordered directly from ASHRAE by calling 1-800-527-4723 or www.ashrae.org. A Geo-Heat Center staff member is actively involved in the TC 6.8 and can provide additional information on any of the above publications.

GHP TRAINING CENTERS AND WEBSITES

Regional training centers for the installation of geothermal heat pumps have been established in seven areas of the U.S. The support for these centers has come through the Geothermal Heat Pump Consortium with funding from USDOE, USEPA and electric utilities. The purpose is to provide training and certification for HVAC firms involved with the installation of geothermal heat pump systems.

Alabama Heat Pump Training Center
Verbena, AL
800-634-0154

Alternative Energy Corp.
Raleigh, NC
919-857-9000

Geothermal Energy Association
Davis, CA
916-750-0135

Ferris State University
Big Rapids, MI
616-592-2351

Keystone Geothermal Heat Pump Training Center
Johnstown, PA
814-269-3874

Northern Geothermal Support Center
Brookings, SD
605-688-4288

International Ground Source Heat Pump Assoc.
Stillwater, OK
800-626-4747

The following websites have information on geothermal heat pumps.

- Geothermal Heat Pump Consortium
- http://www.ghpc.org

- Geo-Heat Center
- http://www/oit.edu/~geoheat

- IGSHPA
- http://www.igshpa.okstate.edu

- ERRI
- http://www.eprihp.com

- New Jersey Heat Pump Council
- http://www.njhpc.org

- DOE
- http://doegeothermal.inel.gov

- Geothermal heat pump manufacturers' websites:

- Addison Products Company
- http://www.addison-hvac.com

- ClimateMaster Inc.
- http://www.climatemaster.com

- Econar Energy Systems Corporation
- http://www.econar.com

- FHP Manufacturing
- http://www.fhp-mfg.com

- Mammoth Inc.
- http://www.mammoth-inc.com

- The Trane Company
- http://www.trane.com

- WaterFurnace International
- http://www/waterfurnace.com

CALIFORNIA

Geothermal Plant Shutting Down

One of 24 geothermal energy plants hooked into The Geysers outside Santa Rosa, the world's largest producer of natural steam energy, is slated for dismantling because that energy source has been tapped out by overuse.

A consortium of public utilities that serves Sacramento, Modesto and Santa Clara opened the $200 million Coldwater Creek Geothermal Power Plant in 1988. But from the beginning, it operated at only half capacity because there wasn't enough steam.

According to the U.S. Energy Commission, power production at Sonoma County's geysers, 60 miles north of San Francisco, peaked in 1988 but has declined steadily since then. The reason: too many plant operators tapped into its natural underground heat source (Source: *Herald & News*, March 31, 1997).

PENNSYLVANIA

New WEBFAXX Option Delivers ASTM Standards Any Day, Any Time, Any Where

American Society for Testing and Materials (ASTM) standards can now be delivered within 10 minutes to any fax machine, any time, any where.

Thanks to WEBFAXX, a new option on ASTM's website, users can receive copies of ASTM documents via fax for just $.75 per page in the United States, Canada and Mexico, and $1.50 per page in other countries (plus the cost of the standard). WEBFAXX can be accessed at: <http://www.astm.org>, in the "Search for Standards" area.

ASTM, the world's leading developer and publisher of voluntary consensus standards, is the first and only standards development organization to provide this service, which requires no customer service assistance.

ASTM updates the database weekly to ensure the most up-to-date standards are available. The quality of most standards is good, text, line drawings, and tables are perfectly legible and useable. Photographs, however, do not fax clearly because fax machines are incapable of the resolution necessary. If photographic clarity is essential to you, mail delivery is suggested.

Organized in 1898, ASTM is one of the largest standards development system in the world.