Outside the Loop

A Newsletter for Geothermal Heat Pump Designers and Installers

Winter 1999 - Volume 2, Number 1 - Published Quarterly

Geo-Geeks Find a Home in ASHRAE TC 6.8

ASHRAE Technical Committee for Geothermal Energy (TC 6.8) has become a hub of activity involving ground source heat pump (GSHP) research, development, and technical education. Although recent efforts have concentrated on GSHP technology, the committee's scope also includes the direct use of geothermal energy with hot water above 90°F. The committee has also co-sponsored symposia and seminars with TC 9.4, "Applied Heat Pump/Heat Recovery Systems".

There are approximately 85 technical committees in ASHRAE that cover all topics of interest in the HVAC&R industry. Committee tasks include: developing and overseeing research projects; updating ASHRAE handbooks and other special publications; organizing symposia (technical papers with oral presentations), seminars (oral presentations), and forums; and review of technical papers, books, and other educational materials, such as short courses and professional development seminars. Work is performed on a voluntary basis.

Current TC 6.8 officers include Patrick Hughes (chair) of Oak Ridge National Lab, Kevin Rafferty (Vice-chair) of the Geo-Heat Center, and George Penn (Secretary) of Global Energy Options. Several subcommittees share the bulk of the work load. Full committee meetings are held every six months at 3:30 pm Tuesday afternoon at the Winter and Annual ASHRAE meetings. Subcommittee meetings are held the preceding Monday evenings.

Research

Sub-committee chair John Shonder of Oak Ridge Lab has been instrumental in organizing several research projects. Two projects were awarded at the Winter Annual Meeting in January. The University of Arkansas will begin work on "An Investigation of Borehole Completion Methods to Optimize the Environmental Benefits of GCHPs". CDH Energy was awarded a contract for "Development of Equivalent Full Load Heating and Cooling Hours for Various Building Types". Two other projects, "Investigation of Methods for Determining Soil Formation Thermal Properties from Short-Term Field Tests" and "Standing Column Well Model Validation and Design Guide", are in the development stage. Another project, "Assessment of Anti-Freeze Solutions for GSHP Systems was completed by the University of New Mexico and the report (908RP) is available from ASHRAE.

Continued on Page 5

Well Pump Control

One of the most common methods of well pump control on open loop systems is that of the dual set point strategy. In this approach, well pump operation is initiated above a set point in the cooling mode and below a set point in the heating mode. Between these two temperatures, the well pump does not operate and the loop temperature is permitted to "float".

For systems served by a single, constant speed pump, a frequent concern is the size of the required temperature range around the set point to avoid short cycling of the well pump. Determination of the size of the range involves consideration of the system thermal mass and the well pump motor size.

Part of the design of an open loop system is the calculation of an optimum groundwater flow for the system. The procedure for establishing this flow is briefly described in Vol. 1 No. 1 issue of this newsletter and a more detailed treatment is available in Kavanaugh and Rafferty, 1998. The example used in the earlier issue involved a 150 ton system designed for a flow of 225 gpm of 60°F ground water with a heat pump EWT of 72.3°F and a heat pump LWT of 82.5°F. Assuming the return temperature was used for pump control purposes, this would constitute the setpoint in the cooling mode. Establishing the range between the cut-in and cut-out temperatures around the setpoint involves primarily consideration of well pump cycle time.

Submersible well pump motors, like all motors, are limited in terms of the frequency of starts. Excessive cycling results in shortened life. The following table presents recommended motor cycling data from Franklin Electric.

Allowable Starts per Day - Submersible Motors

Motor hp	1 Phase	3 Phase
< 5	100	300
7½ to 30	50	100
> 30	-	100

Based on this information, it appears that most commercial open loop systems will be served by motors with a 100 start per day limitation. Stating the same limitation in units more appropriate to HVAC, this would amount to 4 starts per hour or minimum time between starts of 15 min.

System thermal mass in terms of gallons of water per ton (peak block load NOT installed capacity) is a key parameter. This figure varies considerably with building configuration

Continued on Page 6

Design Issues and Tools

Pressure Rating and Properties of HDPE Pipe

The perception engineers and contractors have of the high-density polyethylene pipe (HDPE) recommended for GSHPs suffers somewhat because of the reputation of its lower-cost relatives. Black PE pipe can be purchased in just about any building supply store or home improvement center. There are some very important characteristics of common PE pipe that make it inappropriate for GSHP applications.

This first difference is the dimensions. Common PE pipe connections are made by pushing the pipe over barb-type fittings, which are secured with hose clamps. Therefore, the inside pipe diameter must be controlled. A common practice is to provide tubing that has the same inner diameter (ID) as schedule 40 pipe. If a higher pressure rating is needed, the outer diameter (OD) is increased. A standard dimension rating (SDR) is used for this type of pipe. In some cases an “I” is added to distinguish it from OD controlled pipe.

SIDR = Inner $\text{Dia.}_{\text{Sch40}}$ ÷ Wall Thickness (Not recommended)

Although banding machines offer some joint reliability improvement over hose clamps, **the GSHP industry abandoned the use of barb-band clamp PE fittings several years ago and their use is strongly discouraged.**

Thermally fused HDPE fittings are possibly the most important advancement toward GSHP system reliability since the reemergence of the technology in the mid-1970s. For both socket and butt fusion methods, the outside diameter of the fittings and pipe is controlled to standard iron pipe size (IPS). The inner diameter is reduced in order to attain a higher pressure rating.

DR (aka SDR or SODR) = Outer Dia._{IPS} ÷ Wall Thickness

Unlike the traditional pipe schedule classification, DR designation results in a consistent pressure rating for all pipe diameters. For example, 3/4 in., DR 11 pipe has the same pressure rating as 6 in., DR 11 pipe made of the same material.

A second difference is the physical properties of the pipe material. PE3408 is the general designation for acceptable piping (which may include common PE pipe). However, ASTM D3350 is the standard that rates the properties of the polyethylene resins, which must be virgin (not recycled). The minimum grade specified by the standards of the International Ground Source Heat Pump Association is 345434C. This designation corresponds to the following values:

- (3) ≡ Density of 0.955 gm/cm^3
- (4) ≡ Melt Flow of 0.11 g /10 min (@ 2.16Kg)
- (5) ≡ Flexural Modulus of 135,000 psi
- (4) ≡ Tensile Strength of 3200 psi
- (3) ≡ Envir. Stress Cracking Resistance, F_0>5000 hrs.
- (4) ≡ Hydrostatic Design Basis of 1600 psi @ 73.4°F
- (C) ≡ Color and UV Stabilizer, >2% carbon black

The table below reflects the resulting recommended design pressures for HDPE DRs used in GSHP systems. DR 11 is the most common size. Note the nominal rating temperature is 73.4°F (23°C) and that the recommended pressures decline with increasing temperature.

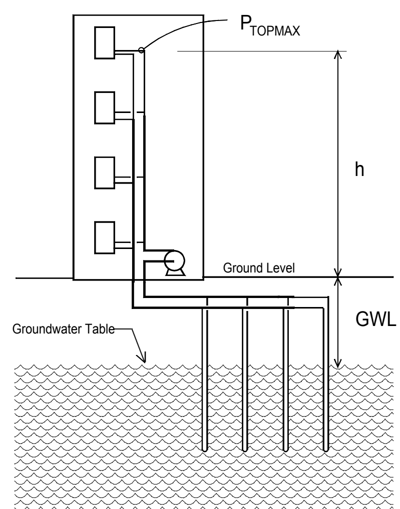
Pressure Rating (PSIG) of PE3408/ASTM-345434C Pipe

DR=OD/t	@60ºF	@73.4ºF (23ºC)	@90ºF	@120ºF
9	**217**	**200**	**173**	**130**
11	**170**	**160**	**140**	**100**
13.5	**138**	**128**	**11**	**80**
15.5	**119**	**110**	**96**	**69**
17	**108**	**100**	**87**	**63**

Safety Factor = 2.0 for Pressure Ratings

In order to establish the necessary pressure rating for a high rise building, the following equation is recommended.

$$P_{MAX}\text{ (psig)}= P_{MAXTOP} + 0.433 \times [(h + GWL)(\text{ft.})]$$



HDPE has several beneficial characteristics for use as interior piping. However, required support spacing is much less than the required spacing for metal piping. The table below is included for these applications.

Recommended Support Spacing (Feet)
For Water Filled PE 3408 Pipe @ 100°F

	Nominal Pipe Diameter						
DR=OD/t	2″	3″	4″	6″	8″	10″	12″
9	**3′-5″**	**4′-3″**	**4′-8″**	**5′-8″**	**6′-9″**	**7′-4″**	**8′-2″**
11	**3′-5″**	**4′-3″**	**4′-8″**	**5′-8″**	**6′-5″**	**7′-0″**	**7′-11″**
17	**-**	**3′-11″**	**4′-3″**	**5′-2″**	**6′-0″**	**6′-8″**	**7′-1″**

Separation can be increased by 6% for 70°F water.

Reference: *PE Piping System Manual,* 1998 and *Climate Guard System,* 1997, Phillips Driscopipe, Richardson, TX.

Fundamentals: Mother Nature Can Be a Wonderful Partner

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

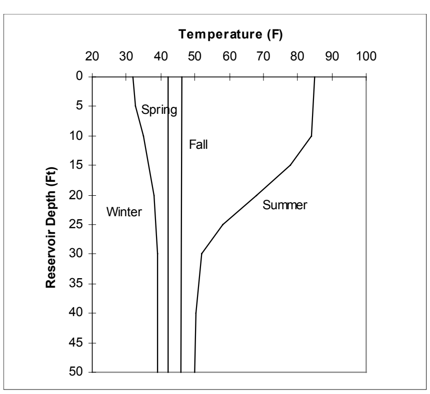
Pond Loops, Lake Loops, or Surface Water Heat Pumps

Heat pump systems that are linked to open bodies of water may suffer an identity crisis. There seems to be no consensus for their proper name. The 1995 ASHRAE Application Handbook refers to them as surface water heat pumps (SWHPs) but groups them as a subset of **ground** source heat pumps. However, these systems can work quite well and can be installed at a reasonable first cost. Performance can be outstanding when the water source is adequate in size (depth, surface area) and temperature. However, there has also been an occasional report of a problematic system when designers or installers have exceeded the limits of recommended practice. This article is a brief overview of the SWHP concept and a discussion of some basic recommended practices.

Lake Temperatures

The geological surveys of many states include lake and stream temperature reports, which are the best sources of information. A typical thermal pattern in the winter has the coldest water (or ice) near the surface while the water near the bottom is around 39°F, the temperature at which the maximum density of water occurs. In warm climates in which lakes do not freeze, the winter temperatures tend to be in the 40 to 50°F range, unless they are spring-feed.

In the summer the temperature of rivers, streams, and shallow lakes approaches the local average air temperature. Spring-feed lakes are the exception and are near the groundwater temperature. Deeper lakes (30+ ft.) are often stratified with cold water (40 to 60°F) remaining on the bottom of the lake throughout the summer if the reservoir does not have a high inflow/outflow. Sunlight can not penetrate to the lower depths to warm the water, which will not migrate up since its density is higher than the warm water near the surface. The sharp change in temperature from the warm to cold water is referred to as the thermocline. The depth to the thermocline varies with water clarity. The change may occur at a 10 ft. depth in turbid lakes and 50+ ft. in very clear lakes.



Systems Types and General Recommendations

Closed-loop systems are the more common system type for heat pump applications. The recommended piping is the same thermally-fused high density polyethylene (HDPE) tubing used in ground-coupled loops. The specifications for this tubing are given in the IGSHPA Standards (See reference, p. 7). Tubing sizes range from ¾ inch for use in protected lakes to 1, 1-¼, or 1-½ inch for use in lakes where a thick pipe wall may be required because of potential damage. UV stabilizers in the pipe are required.

The HDPE is unbundled from the tight shipping coils, fused to headers, pressure tested, floated into position, and sunk to the bottom of the reservoir. Placing the coils on 20-ft. centers insures an adequate separation to prevent thermal interference between adjacent coils in stagnant lakes. Required coil lengths vary from 250 to 500 ft. per ton depending on the desired lake-to-loop water approach temperature. The 1997 ASHRAE GSHP Manual (See p. 7) contains nomographs for sizing both bundled and spread (slinky type) coils. ASHRAE also provides a report of an antifreeze study (908RP). Propylene glycol received high marks in most categories except the pumping energy requirement. This fault can be mitigated somewhat by minimizing the solution to 15% to 20%, which provides sufficient protection in most applications unless the piping is exposed.

Open-loop systems are restricted to warm climates or applications that have net cooling only loads (buildings in cold climates with high internal loads or supplemental heating). When water temperatures fall below 45°F, heat pump (or isolation heat exchanger) outlet temperatures will approach the 34 to 40°F range. To remove heat the heat exchanger surface must be several degrees below the water temperature. Thus, ice accumulation will occur, the equipment capacity will decline, and the system will eventually shut down or fail.

However, open systems can both heat and cool in warm climates. The potential for huge energy savings with direct cooling is possible even in the south in deeper lakes. A project in Toronto to develop a district cooling system with Lake Ontario is progressing. Open systems tend not to disturb the natural stratification of a deep lake because the extracted heat can be returned above the thermocline unlike a closed system that must reject heat through a coil below the thermocline.

Pumps can be submersible (pump and motor below water), vertical shaft (pump below surface, motor above) or above surface. Filtration and fouling precautions used by the power generation and process industries (which have used rivers and lakes extensively) can be followed.

Pond Loops (continued)

Recommended Reservoir Depth and Capacity

A minimum depth of 10 ft. is recommended. This depth should be measured at the lowest seasonal level. Loops have been placed in ponds less than 10-ft. deep, but results have been mixed. Therefore, detailed analysis should be conducted to insure performance meets client expectations for efficiency.

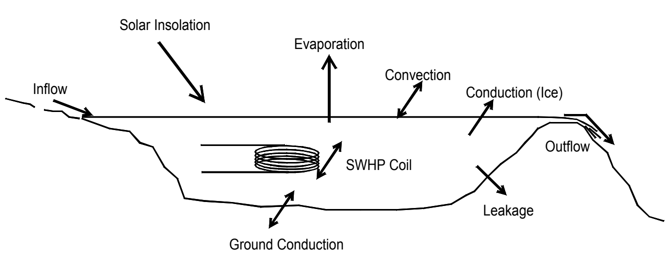
The maximum recommended capacity is 20 tons per acre in a **cooling dominated climate** and 10 tons per acre in a **heating dominated climate**. It is possible to exceed these recommendations if detailed analysis is performed. For example, deeper lakes or rivers with continuous flow can support greater loads. However, evaporation is the primary mode of lake cooling. **If a large load is imposed on a small, relatively shallow body of water, the increased evaporation rate may result in an undesirable decline in water level and an elevated temperature.**

Heat Balance for Reservoirs with Large Cooling Loads

Some successful applications with more than 20 tons per acre have been in operation. Systems with greater capacities per acre are acceptable when a good supply of make-up water is available, operating hours are moderate, the water body is spring feed, or the lake is very deep. Additionally, some customers may be willing to accept systems that operate with lower efficiencies that result with warmer loop temperatures.

However, designers should be aware of the limitations of large capacity systems linked to relatively small and shallow ponds. Customers should be informed that efficiencies and operating cost benefits will be compromised when water loop temperatures rise. So how much is too much?

Predicting reservoir temperatures is fairly complex since it involves weather and geology (rainfall, temperature, relative humidity, wind speed, cloud cover during the day and night, water clarity, solar radiation, surface water inflow and outflow, groundwater inflow and outflow, thermal conductivity of the lake bed, etc.). The heat load imposed on the reservoir by the heat pumps poses another complication.



The process of estimating water temperature can be simplified somewhat by only considering the primary heating/cooling modes in a shallow (non-stratified) pond with no inflow or outflow. The dominant cooling modes are therefore evaporation and back (night) radiation. Heating modes are solar gain and heat rejection by the heat pump coil. The modes can be reduced to three by combining the solar gain [insolation × (1 – average reflectance)] and night radiation.

An application in which a hospital with a 1600-ton peak load is connected to a 12 acre/12 ft. deep pond in the mid-west will serve as an example. St. Louis weather data will be used for the month of August and the daily part load factor (PLF) for the hospital is 40%. The large mass of the lake permits the heat balance analysis to be conducted over an entire day.

The lake temperature responds to the amount of solar radiation and heat pump rejection rate. The warmer water creates an increase in the vapor pressure difference between the lake and the air, which results in an increase in the evaporation rate. Since approximately 1050 Btus are rejected for every pound of water evaporated, the rate of water loss can be connected to heat pump condenser capacity by an equation of the form,

$$GPD_{hp} = 41.4\ (\text{gal/day-ton}) \times Tons_{Cooling} \times PLF$$
$$GPD_{hp} = 41.4 \times 1600 \times 0.40 = 26{,}500\ \text{gal/day}$$

The August solar radiation in St. Louis is 1817 Btu/ft^2-day (approximately 25% is reflected at the water surface) and the weighted-average dew point temperature is 65°F. Back radiation is effected by the sky temperature and emittance (which are a strong function of dew point) and surface temperature. For a 65°F dew point and 80°F water, the back radiation would be 300 Btu/ft^2 for an 8-hour night and 400 Btu/ft^2 for a 90°F lake. The evaporation rate can be related to net radiation by (assuming a 90°F lake),

$$GPD_{solar} = 5.0\ (\text{gal-ft}^2/\text{Btu-acre}) \times q_{Net\ solar}\ (\text{Btu/ft}^2\text{-day}) \times \text{acres}$$
$$GPD_{solar} = 5.0 \times [1817\ (1\text{-}0.25) - 400] \times 12 = 57{,}800\ \text{gal/day}$$

The temperature of the water can be found by finding the vapor pressure required to evaporate (GPD_{hp} + GPD_{solar}). An equation to describe this is:

$$p_W\ (psia) = \frac{GPD}{9600 \times Acres \times [0.417 + 0.004 V_w\ (mph)]} + p_{air}$$

$$p_W = \frac{26{,}500 + 57{,}800\ gal/day}{9600 \times 12 \times [0.417 + 0.096 \times 10\ mph]} + 0.31 = 0.84\ psia$$

This is the vapor pressure for water at 96°F. However, a temperature of 90°F was assumed when determining the night radiation. Iteration results in 95°F being the correct water temperature. Since the water in the loop returning to the building will be warmer than the lake, the expected heat pump entering water temperature should be above 100°F on a hot day in August when the system is operating near full load.

General comments

Surface water systems offer the potential for high efficiency with reasonable first costs. Large, deep lakes can be used in direct cooling applications or with extremely high heat pump efficiency. However, small, shallow pond loops can not match the efficiencies of ground-coupled or groundwater heat pumps (unless the ponds are spring-feed). Loop temperatures are normally higher in the summer and colder in the winter.

References: *Ground Source Heat Pumps,* ASHRAE, 1997
Heat Transfer, 7th Ed., Holman, McGraw-Hill, 1990
Bin Weather Data, RP-385, ASHRAE, 1994

Products, Services, and Installation Innovations

Commercial Building GCHP Loop Contractors

A&E Drilling Services, Greenville, SC 864-288-1986
Ash Drilling, Lebanon, TN, 615-444-0276
Ball Drilling, Austin TX, 512-345-5870
Bergerson-Caswell, Maple Plain, MN 612-479-3121
Bertram Drilling, Billings, MT (and PA), 406-259-2532
Harvey Cain Drilling, Atlanta, TX 903-796-6339
Can-America Drilling, Simla, CO 80835, 719-541-2967
Closed Loop Systems, Tallahassee, FL, 850-942-7668
Craig Test Boring, Mays Landing, NJ, 609-625-4862
Donamarc Geothermal, Union Town, OH, 330-896-4949
Earth Energy Engineering, Big Stone Gap, VA 540-523-2283
Enviro-Tec, Cresco, IA, 800-728-6187
Ewbank & Associates, Enid, OK, 405-272-0798
Falk Brothers, Hankinson, ND 701-242-7252
Geo-Energy, Vermillion, SD, 605-624-6745
Geo-Therm Heating-Cooling, Alexandria, KY, 606-635-7442
Geo-Systems Inc., Wallingford, KY, 606-876-4621
GeoMasters, Newton, TX 409-379-8537
Georgia Geothermal, Columbus, GA, 800-213-9508
Geothermal Drilling, Huntsville, TX, 409-293-8787
Geothermal Drilling, Louisville, KY 502-499-1500
Ground Source Systems, Buffalo, MO, 417-345-6751
Frame Drilling, Elkins, WV, 304-636-6025
Hammett & Hammett, Andalusia, AL, 334-222-3562
Henry Drilling, Franklin, TN, 615-794-1784
Jedi Drilling, Cibilo, TX, 210-658-7063
Johnson Drilling Co., Dallas, TX 972-924-2560
K & M Shillingford, Tulsa, OK, 918-834-7000
Layne-Atlantic, Suffolk, VA 757-934-8971
Loop Master, Indianapolis, IN, 317-872-3766
Loop Tech International, Huntsville, TX, 800-356-6703
Mid-America Drilling, Oakland, IA 712-482-6911
Mid-State Drilling, Livingston, TN, 931-823-7345
Middleton Geothermal, Akron, OH 330-620-0639
Mineral Services Plus, LLC, Cologne, MN 612-446-5503
Morrison Inc., Duncannon, PA 717-834-5667
Moses Drilling Co., Gray, KY, 606-523-1215
Murray Drilling Corp., Princeton, KY, 502-365-3522
Neese Jones Heating-Cooling, Alpharetta, GA, 770-751-1850
Larry Pinkston, Virginia Beach, VA, 804-426-2018
Reith Brothers Well-Drilling, Emmaus, PA 610-965-5692
Richard Simmons Drilling, Buchanan, VA 540-254-2289
Rock Drillers, Inc., Bardstown, KY, 502-348-6436
Saathoff Enterprises, Bruce, SD, 605-627-5440
Somerset Well Drilling, Westover, MD, 410-651-3721
Thermal Loop, Joppa, MD 410-538-7722
Venture Drilling, Inc. Tahlequah, OK 918-456-8119
Van and Company, Duncan, OK, 580-252-2205
Virginia Energy Services, Richmond, VA, 804-358-2000
Virginia Service Co., Virginia Beach, VA, 757-468-1038
Winslow Pump & Well, Hollywood, MD, 301-373-3700
Yates & Yates, Columbia, KY 502-384-3656

Please send names of other commercial GHP contractors.

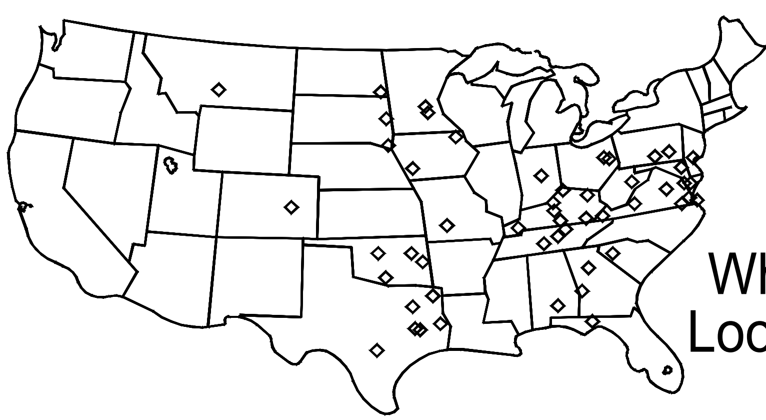
Geo-Geeks Find a Home (Continued from Page 1)

Handbook and Special Publications

Subcommittee chair Kevin Rafferty coordinated an effort to add a sizable amount of GSHP material to the "Geothermal Energy" chapter (29) of ASHRAE 1995 Applications Handbook. This material has been expanded and updated for the 1999 Handbook. A set of GSHP system case studies has been completed by Caneta Research. Two GSHP design manuals have been reviewed by TC 6.8 and published by ASHRAE within the last four years. (See Publications/ASHRAE, p. 7.)

Programs

ASHRAE TC 6.8 members have produced a barrage of symposium papers and seminar presentations that have heightened awareness of GSHPs technology. A symposium, two seminars, and a short-course were well attended at the January 1999 Winter Annual Meeting in Chicago. A symposium, two seminars, and a forum were conducted at the June 1998 Annual Meeting in Toronto. Two symposia, a seminar, and a short-course were presented at the January 1998 Winter Annual Meeting in San Francisco.



Where the Loopers Are

Letters, Comments, Questions, & Suggestions

Well Tests

We will be starting on the design of an open loop system in the near future for an office in Nebraska. We have identified a qualified driller and the well should be completed this May. What should we require for the "well test" as far as length, flow, instrumentation etc. Who provides these services?

Confused in Corinth

Dear Confused:

There are basically two kinds of tests: single well and multiple well (or aquifer) tests. The single well test provides information on the well itself such as yield (flow), pumping level, drawdown, and specific capacity. A multi-well or aquifer test, in which at least one nearby well is monitored, supplies similar data but also provides infomation on the aquifer that the well is producing from. Data from an aquifer test permits the calculation of long term effects of pumping such as impact on neighboring wells and the potential for aquifer decline over a period of years.

Single well tests, the type most often used, are typically run for a period of 4 hours to 24 hours. The actual time for a test is determined by the data that is collected. The object is to operate the test pump until the water level in the well has stabilized at each flow. In most cases the test is started at a low flow (1/3 of design rate) and the pump operated until water level stabilizes. The rate is the raised to a flow approximating 2/3 of design and again held until water level stabilizes. Finally the flow is raised to the design rate and operated until pumping water level stabilizes. The results provide information for establishing the pump setting depth and verification of well yield.

Sophisticated instrumentation is not required. Water flow is typically measured with an orfice plate installed on the end of a straight length of pipe such that discharge is to the atmosphere. Pressure in the line ahead of the orifice plate is measured with a length of clear tubing arranged to form a manometer. Well water level is most easily monitored with an electric wireline. The wire is calibrated in feet and a tape measure is used to refine the measurements.

One of the key considerations is to maintain stable flows at each "step" in the test. The test pump should be able to operate continuously for 24 hours. Disposal of the water from the test is a major issue and instructions to the contractor should be very specific as to where the flow must be directed. Tests are often conducted and instrumentation provided by well pump contractors. It is advisable for the engineer to witness the test.

Specification details of well pump tests are available from the Geo-Heat Center in "Outline Specifications for Water Wells". See the publications section of this newsletter.

Well Pump Control (Continued from page 1)

and height. The most compact systems may contain as little as 4 gal/ton while other systems may exceed 20 gal/ton. The smaller the volume of the system, the larger the temperature range on the controller must be to prevent pump short cycling. Although there is a common perception that short cycling is a very low load issue, the minimum time between pump starts actually occurs at 50% load. This results from the fact that at loads greater or less than 50%, either the pump on cycle is long (high load) or the pump off cycle (low load) is long.

Three strategies are available for avoiding short pump cycle time:

- Increasing controller temperature range
- Increasing system thermal mass
- Decreasing pump capacity

Of these, the least expensive is the adjustment of the controller temperature range. To a point, this is an effective strategy. Excessively large range causes the system to operate inefficiently however. Increasing system thermal mass is an approach that will result in increased cost for the storage tank and also the requirement for increased mechanical system floor space. Short of going to variable speed control of the well pump, throttling is the only option for control of pump capacity. This is an inefficient strategy and should not be considered.

The following table offers guidelines for minimum controller temperature range for systems of various volume and motor type based on the manufacturer recommended start interval limitations cited above. These values are for 3 phase motors. For single phase motors less than 5 hp, the values shown for 7 ½ hp and greater should be used. The table values are conservative in that thermal mass contributed by the piping system is neglected. For systems using steel piping, total thermal mass is increased by approximately 20 to 25%, plastic piping 15 to 20 % and copper 10 to 15%.

Minimum Controller Temperature Range (°F)

	System Volume in Gallons/ton						
	6	8	10	12	14	16	18
< 5 hp	**6**	**5**	**4**	**3**	**2**		
7½+ hp	**18**	**13**	**11**	**9**	**8**	**7**	**6**

Using the earlier example with the 82.5°F return temperature, it is likely that the 225 gpm flow would require a motor larger than 5 hp. Assuming the system had a volume of 10 gal/ton, the cut-in temperature for the well pump would be 82.5 + (11/2) = 88°F. The cut-out temperature would be 82.5 - (11/2) = 77°F in the cooling mode.

For systems characterized by volumes of less than 8 gal/ton and served by greater than 7 ½ hp well pumps, it may be worth considering the addition of some volume to the system or the use a variable speed drive to avoid pump shot cycling.

Meetings, Publications, and Information Sources

Meetings & Seminars - 1999

Apr. 9, One-Day Seminar for Engineers, Sayerville, NJ, GPU Energy, 973-455-8277

May 7, 10, 12, 14, a series of One-Day Seminar for Engineers, Dallas-Forth Worth, Austin, San Antonio, & Houston area. For details, Fax info requests to 903-454-8962.

May 16-19, GeoExchange Technical Conference & Expo, Stillwater, OK, IGSHPA, 800-626-4747

May 30-June 2 Heat Pumps - A Benefit for the Environment, 6th International Energy Agency (IEA) Heat Pump Centre Conference, Berlin, *sl@vwew.f.eunet.de* or +49-69-6304460

June 19-23 -ASHRAE Annual Meeting, Seattle, 404-636-8400

Sept. 26-29, 1999 Annual GeoExchange Conference & Expo, Sacramento, CA, IGSHPA, 800-626-4747

Oct. 20-22, Geothermal Heat Pump Consortium Annual 1999 Meeting (with the AEE World Energy Engineering Congress), Atlanta, GA 888-255-4436 or 202-508-5500

Publications

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

Operating Experiences with Commercial Ground-Source Heat Pumps, (Case Studies), 1998

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

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

"Thermal Properties & Estimation Techniques for GCHP Bore Grouts and Fills" (Papers from 1999 Winter Annual Meeting)
Borehole Thermal Resistance: Laboratory & Field Studies
Testing of Thermally Enhanced Cement GCHP Grouts
Borehole Grouting: Field Studies & Thermal Performance
Determining Soil Formation Properties from Field Data

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

Electric Power Research Institute (800-313-3774) www.epri.com

HVAC News Exchange – Quarterly Newsletter

"Grouting for Vertical GHP Systems: Engineering Design Guide and Field Procedures Manual", Report # TR-109169

"1998 Directory of GSHP Manufacturers & Equipment"

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

"Outside the Loop" Vol. 1, Nos. 1 to 4 (Back Issue of this Newsletter)

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

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

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

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

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

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

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

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

Analysis of Existing GeoExchange Installation Data (RP-026)

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

International Energy Agency Heat Pump Centre http://www.heatpumpcentre.org

The IEA Heat Pump Program (HPP) and its focal activity the IEA Heat Pump Centre (HPC) has been in operation for 20 years. The HPC publishes an international newsletters and provides a wide selection of Conference Proceedings, Workshop Reports, and Technical Reports.

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

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

GHP Systems: Design and Installation Standards, 1994.

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

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

"Guidelines for the Construction of Vertical Bore Holes for Closed-Loop Heat Pump Systems", 1997 (Also available from EPRI)

Winter 1999 – Volume 4, Number 1 - Published Quarterly

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

Please let us know if:

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

Send information and requests to:

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

Outside the Loop

A Newsletter for Geothermal Heat Pump Designers and Installers

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

GEOEXCHANGE

Second Try - Back Issues of *Outside the Loop*

We apologize to those who attempted to access the web site to view back issues of *"Outside the Loop"*. We have now included the newsletter on the web site of the Geo-Heat Center in Klamath Falls, Oregon. So please try again. New address is:

http://www.oit.edu/~geoheat/otl/index.htm