Outside the Loop

A Newsletter for Geothermal Heat Pump Designers and Installers

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Ground Coil Testing – (How Do I Know My Loop Contractor Installed What I Specified ?)

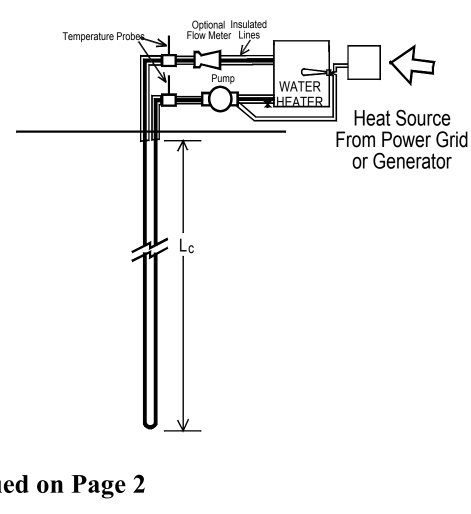
One answer to this question has been around for a long time. Dr. Jim Partin, formerly of Oklahoma State and GeoSystems, wrote a paper on the subject for the 7th Heat Pump Technology Conference in 1984. The figures in the paper are similar to the thermal conductivity (TC) rigs being used by several firms today. By measuring the rise in temperature in a ground loop for a given length, time and constant heat rate, a "U-value" can be calculated. This value can then be compared with the value computed during the design phase. If the measured value is lower than predicted; the loop may be too short, improperly grouted or filled, or the predicted thermal properties of the formation were incorrect.

Several developments since 1984 have made performing this type of tests much more feasible. They include:

- Wider availability of TC test rigs that can also be used to test loops after installation
- Improved correlations for "R-values" (inverse of U-value) for the ground, U-tube, and annular region between the two.
- An increase in the number of GHP systems in larger buildings than can justify random testing of one or more loops

Information gathered from the TC test rig includes the ground temperature at the start of the test (t_g), water temperatures in and out of loop (t_{wi} , t_{wo}), power input to the element and pump (watts), and loop length. These can also be used to calculate an overall R-value (R_o) for a given length of bore (L_c),

$$R_o = L_c \left(\frac{t_{wi} + t_{wo}}{2} - t_g \right) \div 3.412\, watts$$



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Impact of Conductivity Error on Design Results

In the last issue of *Outside the Loop,* we promised to show the impact of the uncertainty of ground property value on ground heat exchanger design and resulting GSHP performance. One design program can be used to demonstrate the change in required loop length when ground thermal properties errors are possible. It can also be used to predict performance of the system if the loop was designed using erroneous thermal properties. A ground loop was sized for an office building located in an area with a ground thermal conductivity of 1.2 Btu/hr-ft-°F, a diffusivity of 0.85 ft^2/day, and a temperature 58°F. The peak block-cooling load is 93 tons but the equipment will deliver 109 tons of cooling. The system was designed to maintain a 90°F temperature leaving the ground loop on a design day after 10 years of operation. The result is a loop field of 80 bores (8 x 10 rectangular grid) at 243 ft. with 20 ft. spacing. When the heating performance is predicted for the installed length, the loop temperature on the heating design day is 47°F, the capacity is 1410 MBtu/h with a COP of 4.1.

Figure 1 demonstrates the sensitivity of required bore length to a 10% error in thermal property determination. The design procedure was repeated for a 10% lower conductivity of 1.08 Btu/hr-ft-°F and a diffusivity of 0.77 ft^2/day. A third procedure was performed for a 10% higher conductivity of 1.32 Btu/hr-ft-°F and a diffusivity of 0.93 ft^2/day. **The required loop length increased to 257 ft. (5.8%) with 10% under-predicted thermal properties and decreased to 232 ft. (4.5%) with 10% over-predicted thermal properties.**

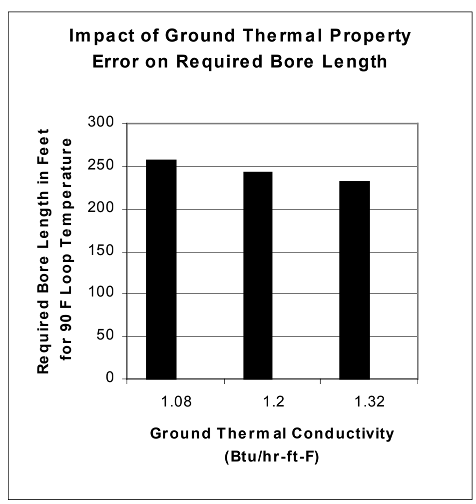

Figure 1. Required Lengths with ±10% Conductivity Error

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Design Issues and Tools

Ground Coil Testing (Continued)

This "measured overall resistance" (R_o) can be compared with the value that is used during the design phase. Unfortunately, the design value is often buried in a computer program, chart, or table. It can be calculated using a variety of methods, some of which are in public domain literature. Design methods consider the sum of the resistances of the pipe/fluid (R_p), annular fill (R_f), and ground (R_g).

The methods developed by Remund and Paul (see p. 7 under EPRI listing #109169) are recommended for determining R_p and R_f. An abbreviated discussion can also be found in Appendix D of Kavanaugh and Rafferty (see p. 7, ASHRAE listing). The equations require knowledge of the U-tube dimensions (D_o, D_i), pipe conductivity (k_p), film heat transfer coefficient (h_i), fill conductivity (k_f), and bore diameter (D_B).

$$R_p = \left(\frac{\ln\left(D_o / D_i \right)}{2\pi k_p} + \frac{1}{\pi D_i h_i} \right) \div 2, \quad R_f = 1 \Big/ k_f \, \beta_o \left(\frac{D_B}{D_o} \right)^{\beta_1}$$

The value of R_f also varies with the location of the tubes in the bore. This is adjusted by constants in the above equation. If the tubes are touching, β_o= 20.1 and β_1= -0.9447; if they are evenly spaced in the bore, β_o= 17.44 and β_1= -0.6052, and if they are touching the outer wall, β_o= 21.91 and β_1= -0.3796.

R_g can be determined from methods described in Kavanaugh and Rafferty (p. 29), which are also presented in the 1999 ASHRAE Applications Handbook, p. 31.18. This procedure requires that the dimensionless Fourier Number (Fo) for the bore dimensions be computed for the soil (Fo = Diffusivity × Test Time / Bore Radius^2). A "G-Function" is found from graph that appears in either of the above references. The ground resistance is R_g = G-Function ÷ Thermal Conductivity.

A computer program to perform the above calculations would be relatively brief. In fact, one already exists. If there is sufficient interest, a "free" public domain version could be updated and made available. So if it would be useful to you, please e-mail your request to skavanaugh@coe.eng.ua.edu.

From up in the Ivory Tower of Academia, loop testing seems like a good idea in some situations. Jim Partin thought so or he wouldn't have bothered to share his ideas with us back in '84. Maybe we just weren't ready for it yet.

Correction: The recipe for thermally enhanced cement grout on page 4 in the Spring 1999 edition of *Outside the Loop* had an error. The amount of cement should be 94 lbs. (standard cement bag) rather than 54 lbs. Marita Allen, Tom Amerman, and Allan Skouby noticed the goof. They will receive a one-year free subscription to *Outside the Loop*

Impact of Conductivity Errors (Continued)

In normal applications the design length will be installed according to the predicted thermal properties, and system performance will be altered if the estimates are incorrect. The program can also be manipulated to predict the resulting performance if the loop is installed at the recommended length with the same ±10% errors in properties.

Results are shown in Figure 2 for the cooling mode. The loop will operate at 92.1°F rather than 90°F with 10% lower thermal properties. However, the capacity will only decrease to 108 tons, which is less than 1%. EER will be lowered to 12.8, a 2% decrease. If the thermal properties are 10% higher than predicted, loop temperature will fall to 88.1°F, capacity will improve 1%, and EER will increase 2%.

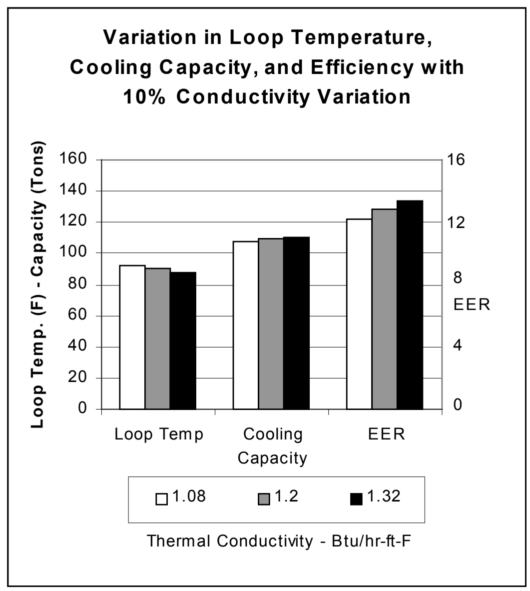


Figure 2. Loop Temperature, Cooling Capacity and EER Variations with ±10% Error in Ground Thermal Conductivity

The results are even less dramatic for the heating mode. The loop will operate at 46.5°F (down 0.5°F) with 10% lower thermal properties. However, the capacity will only decrease to 1400 MBtu/h, (0.7%) and COP will remain constant at 4.1. If the thermal properties are 10% higher than predicted, loop temperature will rise to 47.7°F (up 0.7°F), capacity will improve 0.9% with no change in COP. The primary reason for these small changes in the heating mode is that the system was sized for the larger cooling load.

Note: This discussion is a summary of a paper that will be presented as part of a Ground Source Heat Pump symposium at the ASHRAE 2000 Winter Annual Meeting in Dallas, TX (Feb. 5-9, 2000). See page 7.

Ground Source Heat Pump Fundamentals

Ground Water Site Characterization

Evaluating the ground water resource of a site is a multi-step process. The first is to determine if the area is underlain by an aquifer or aquifers capable of producing sufficient flow for the intended design and the general nature of the geology of the aquifer (consolidated, unconsolidated, confined, unconfined, depth, chemistry, etc). The second step is to determine the likely construction and performance of a well at the site (depth, type-open hole or gravel pack, specific capacity, static level, yield). If the results of these steps are positive, the third step is drilling, completion and testing.

A valuable information source is the United States Geological Survey (USGS) series of publications known as GROUND WATER ATLAS OF THE UNITED STATES. This publication is available in 13 volumes, each covering several individual states. It provides excellent information on a regional basis. Although a wide area is covered in each volume, the large size (18" x 24") permits a level of detail of +/- a mile in most maps. Basically each volume divides the region into principal aquifers and provides detailed information on local geology (with cross sections), aquifer transmissivity, and thickness (with which it is possible to estimate production and drawdown), water chemistry, existing withdrawals and regional ground water flow.

Beyond the volume of information contained, the most amazing aspect of these publications is the price - $4.00 per volume. For ordering information and a summary of contents see http://wwwcapp.er.usgs.gov/publicdocs/gwa or USGS Information Services, Box 25286, Denver CO 80225. The following information was developed on a site in Northern IL using the USGS publication:

"*The so-called surficial aquifer may be one target at the site. Relative to other areas in Northern IL, the sand and gravel in this area is very thin - certainly less than 100 ft and may thin to only a few feet in some locations. Evidently, the sand and gravel aquifers in this region receive their recharge by percolation through overlying clay and silt formations. Although the ability of the sand and gravel to transmit water is excellent, the long term production of large flows may be impeded by the slow recharge through the clay and silt. Depending on the size distribution of the aquifer materials, a gravel pack completion my be required in this aquifer.*

There is also a 2nd aquifer in the dolomite/limestone underlying the sand and gravel. It appears to have excellent production capability with specific capacities in the 5 to 30 gpm per ft of drawdown range and the ability to produce in excess of 500 gpm in most of the county (somewhat less in the extreme NE and SW portions of the county). This aquifer is generically referred to as the Silurian/Devonian but may be known by other names locally. Due to local geology, the water is very hard and may contain elevated levels of iron. No consideration should be given to using this water directly in the heat pumps. Use an isolation heat exchanger. Open hole completion may be a possibility for a well in this aquifer. Current withdrawals are 66% municipal, 12% domestic, 13% agriculture and 9% industrial."

The most useful source of information in the second step of the site characterization is information from nearby wells completed in the same aquifer. Most states require some form of report to be filed upon completion of a well. The level of information varies considerably from state to state but as public information this valuable data should always be consulted in the early stages of a project.

Well completion reports may contain information on such issues as drilling method, well use, hole construction (diameter, seal, placement method), casing (depth, diameter and wall thickness) screen (type, diameter, location, material), static water level, temperature, geologic formations penetrated and pump test results. This level of information provides a very clear picture of the type of construction and performance of wells in the target aquifer. The static level and flow test results from surrounding wells are especially useful in the heat pump system design stage. This information allows the prediction of well pump head at various flow rates, key data necessary to optimize groundwater flow for a particular system (see Vol. 1, No. 1 of OTL for additional discussion).

The well construction details from the completion reports of nearby wells along with the aquifer geology description from the USGS atlas provide important information for the preparation of the well specifications. Generic well specifications are available from many sources but in order to make the most of them it is necessary to know something of the local geology, specifically whether the aquifer materials are consolidated or unconsolidated, and depth to a competent formation in which to seat the surface casing. This information is included in the completion report.

The description of the formations penetrated is of use in determining the drilling difficulty at the site. It can also be of use in closed loop projects as a n indicator of the thermal conductivity and diffusivity that may be expected.

Well logs are normally available from the state water regulatory agency. In some states this is a separate agency and in others is a department of the Natural Resources or Environmental agency. In many cases county or regional offices of these agencies have the reports on file. Some states have placed these reports on the internet for easier access. Oregon and Idaho for example offer internet access to any well completion report on file. For Oregon the URL is http://deschutes.wrd.state.or.us/apps/gw/well_log and in Idaho www.idwr.state.id.us/info/water/drilling/wl_srch.htm

These are two of the more useful information sources for site characterization but there are many others. One of the best is drilling contractors. Many engineers are reluctant to seek their advice, but if you do a little homework and learn to speak their language, you will find in most cases, they won't bite.

Ground Source Heat Pump Costs

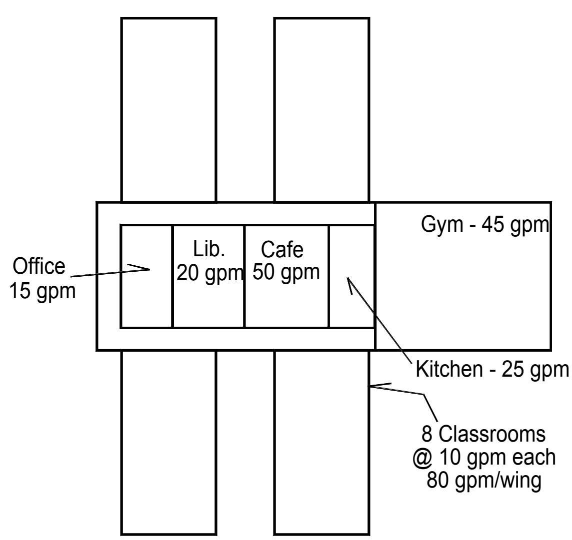
Look to Non-Central Piping Loops for Lower GSHP Costs in Large Footprint Buildings

Central piping loops make a lot of sense for chilled water systems. However, this doesn't always carry over to ground source heat pump systems, especially closed loops (ground–coupled) in buildings with non-compact floor plans. While ground loops are expensive and central systems reduce required lengths because of load diversity, the cost of interior large diameter piping is significant. A case in point is the cost summary for the school provided in the building described in *Outside the Loop*, Vol. 1, No. 2. The interior piping cost ($2.54/ft^2) exceeded the ground loop cost ($2.38/ft^2).

The cooling loads for a 32-classroom school are shown in the table below along with a floor plan showing approximate water flows. Three piping options are considered. The required bore length will be adjusted for the non-central loop(s) to account for the loss of diversity. The options are:
A central loop; six sub-central loops (one for each of the four classroom wings, office-library, and cafe-kitchen-gym); and a single loop for each of the 44 heat pumps. Ground loop costs are based on block loads (180 ft./ton @ $7/ft.) and interior piping on 1999 R.S. Means Mechanical Cost. Pipe sizes are based on friction losses not to exceed 4 ft. of head per 100 ft.

Cooling Loads and Floor Plan of Example School

	Zone Cooling Loads by Period – MBtu/h			
Zone	8 - Noon	Noon - 4	4 - 8	Night
West Class. (16)	32 (x16)	42 (x16)	0	0
East Class. (16)	42 (x16)	36 (x16)	0	0
Office	64	72	0	0
Library	66	90	0	0
Cafeteria	120	220	0	0
Kitchen	120	78	0	0
Gym	60	140	200	0
TOTAL	1614 (135 Tons)	1848 (154 Tons)	200 (17 Tons)	



Vertical Ground Loop Cost Estimate for 73,000 ft^2 School

Option	Tons	Bore Feet	Cost	Total
Central Loop	154	27,720	$194,040	**$194,040**
Six Loops				
Class. Wings	26 each	4680×4	$131,040	
Off./Lib.	13.5	2430	$ 17,010	
Caf./Kit./Gym	36.5	6570	$ 45,990	**$194,040***
44 Loops				
Classrooms	3.5 each	630×32	$141,120	
Office	6	1080	$ 7,560	
Library	7.5	1350	$ 9,450	
Cafeteria	18	3300	$ 23,100	
Kitchen	10	1800	$ 12,600	
Gym	17	3000	$ 21,000	**$214,830**

* No change vs. central since all zones peak in the afternoon.

A high-density polyethylene (HDPE) piping cost estimator tool has been developed and is presented on page 5 of this newsletter to assist in the preliminary design phase. The table below was generated from piping layouts for the three options. The cost of the central loop is higher despite the lower cost for the central pump(s) and drive compared to the multiple circulators used in the Six-Loop and 44-Loop designs.

Interior Piping Cost Estimate for 73,000 ft^2 School

Component	**Central**	**Six-Loops**	**44-Loops**
6" HDPE Pipe & Fittings	$22,890	-	-
4" HDPE Pipe & Fittings	5,660	-	-
3" HDPE Pipe & Fittings	31,440	25,780	-
2" HDPE Pipe & Fittings	7,390	11,180	4,900
1½" HDPE Pipe & Fittings	6,640	6,040	17,580
1¼" HDPE Pipe & Fittings	15,690	15,960	17,960
Isolation Valves (88)	3,120	3,120	3,120
Zone Valves (44)	4,530	-	-
10 hp Pump (2)	5,200	-	-
VS Drive & Sensor (1)	4,000	-	-
Check Valves (44)	-	1,960	-
Circulator Pumps (44)	-	14,740	15,620
Interior Piping Totals	**$106,560**	**$ 78,510**	**$ 59,180**

The net result is that the two non-central loops were lower in overall total cost. This analysis demonstrates central loops are not always the least cost option. However, the reader is encouraged to conduct similar analysis for other building types that may have more compact floor plans, multiple floors and/or greater diversity of loads than this example building. The results for these buildings may indicate a central loop is warranted.

Total Loop Cost Estimates for 73,000 ft^2 School
(Heat Pump and Duct Cost not Included)

	Central	**Six-Loop**	**44-Loop**
Ground Loop	$194,040	$194,040	$214,830
Interior Piping & Pumps	$106,560	$ 78,510	$ 59,180
Total	**$300,600**	**$272,550**	**$274,010**

Loop Contractors and Design Tools

Commercial Building GCHP Loop Contractors

Please send names of other commercial GHP contractors.

A&E Drilling Services, Greenville, SC 864-288-1986
Alabama Geothermal, Trussville, AL 205-661-9143
Ash Drilling, Lebanon, TN, 615-444-0276
Ball Drilling, Austin TX, 512-345-5870
Michael Barlow Drilling, Joppa, MD 410-838-6910
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
C&W Drilling, Columbiana, AL 205-669-0228
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
Douglas Exploration, Douglas, WY, 307-358-3125
Donamarc Geothermal, Union Town, OH, 330-896-4949
Earth Energy Engineering, Big Stone Gap, VA 540-523-2283
Energy Systems, Pensacola, FL, 850-456-5612
Enviro-Tec, Cresco, IA, 800-728-6187
Ewbank & Associates, Enid, OK, 405-272-0798
Falk Brothers, Hankinson, ND 701-242-7252
Gedney-Moore, King of Prussia, PA, 610-354-9843
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
Geothermal Loop Services,
Geothermal Services, Mays Landing, NJ 877-394-4689
Geothermal Energy Management, Savannah, GA,912-964-7486
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
Jensen Well Company, Blair, NE, 402-426-2585
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
Pruitt Drilling, Moab, UT, 435-259-6290
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 410-879-3588
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
Jesse Yoakum Well Drilling, Cleveland, MO, 816-899-2561

Cost Estimator for Interior HDPE Piping

Table 1. Site Installed Cost for SDR 11 HDPE
(Based on 10 ft. Height and 3 Hangers/10ft.)[1]

Nominal Diameter	Cost ($/ft.) Uninsulated	Cost ($/ft.) Insulated[2]	Max. GPM $\Delta h \leq 4$ ft/100’
1”	10.90	16.30	8
1¼”	12.30	17.90	15
1½”	13.95	19.75	22
2”	15.10	21.00	40
3”	17.10	24.65	110
4”	21.55	29.90	220
6”	30.70	44.25	600
8”	41.45	52.95	1200
10”	64.20	77.20	2200
12”	80.60	95.30	3500

1. Add 10% for 14 ft. height and 20% for 18 ft.
2. Closed cell foam insulation (1”-6”), Fiberglass with jacket (8”-12”)

Table 2. Fitting Cost Equivalent Lengths ($$L_{eqv}$)
SDR 11 - High Density Polyethylene

Nominal Diameter	90° Elbow	Tee	Reducer (One Step)	Flange Adaptor
1”	2.3	3.0	-	-
1½”	2.3	3.2	2.0	-
2”	2.3	3.3	2.4	3.5
3”	3.5	4.6	2.7	4.0
4”	3.2	4.7	2.8	4.0
6”	5.0	6.4	3.3	4.1
8”	9.1	8.7	3.9	4.1
10”	10.6	13.8	3.3	3.6
12”	12.7	15.6	3.4	4.1

Example: Estimate the cost of running an uninsulated header pipe 150 ft. at a height of 10 feet above the floor. The pipe must handle 100 gpm and have two tees and three elbows.

The right column of Table 1 indicates a 3” tube (@ $17.10) is required to handle 100 gpm with a head loss lower than 4 ft./100 ft. (per ASHRAE Std. 90.1). The equivalent length for each 3” tee is 4.6 ft. and elbow is 3.5 ft. The equivalent length (based on cost) for the pipe run and the resulting cost are,

$L_{eqv} = L + 2 \times L_{eqv(Tee)}\, 3 + L_{eqv(L)} = 150’ + 2 \times 4.6 + 3 \times 3.5 \approx 170’$
Cost $\approx 170’ \times \$17.10$/ft. $\approx \$ 2907$

(Want a cost estimator for steel pipe? Let us know.)

Letters, Comments, Questions, & Suggestions

Well Test Interpretation

We are in the process of reviewing the results of a flow test of a well, which will be supplying water to an open loop system. This well has a static water level of 37 ft. A summary of the flow test results shows a flow of 75 gpm with a drawdown of 14.5 ft, 125 gpm at 25.3 ft and 175 gpm at 35.3 ft. The well is 310 ft deep.

In this area of the state, there are two aquifers present one a water table aquifer and the other an artesian aquifer. The water table aquifer has been declining and wells completed in it are subject to more stringent monitoring and reporting. Is there a simple way to tell from this data in which type of aquifer this well was completed?

There are several ways to determine what type of aquifer a well is completed in. One method is to analyze the flow test results. Confined or artesian aquifers tend to have a constant "specific capacity" - an index arrived at by dividing the production rate by the drawdown. Using your data, these values would be 5.17 gpm/ft at 75 gpm, 4.94 gpm/ft at 125 gpm and 4.95 gpm/ft at 175 gpm. For practical purposes, all three values could be considered to be equal at approximately 5 gpm/ft. This behavior is indicative of a confined aquifer. Unconfined or water table aquifers have a specific capacity that varies with flow, decreasing as production is increased**.**

The depth may offer some support for the confined aquifer also. Unconfined aquifers are often relatively shallow. Confined aquifers normally have a confining layer of low permeability material (silt, clay, etc) over the top of the aquifer. The sequence is often unconfined aquifer, clay layer, confined aquifer. The depth of the well in this case is sufficient for this situation to exist.

If it is possible to obtain a copy of the well completion report, there may be information there to confirm the type of aquifer. Drillers sometimes must report when water is encountered during drilling. For a well completed in a water table aquifer, the static water level will be the same as the depth at which water was first encountered. For a well completed in an artesian aquifer, the water level will be above (by an amount equal to the artesian head possessed by the aquifer) the depth at which water was first encountered. This assumes that the well was completed in a way that does not allow the confined and unconfined aquifers to mix (required by most regulatory agencies).

The completion report may list the formation through which the well penetrates. Often aquifers are identified by the type of rock, sand, gravel, clay etc in which they reside. Identification of the formation materials the well is completed in and the comparison of this to the description of regional aquifers available in the literature (the USGS publication mentioned elswhere in this issue for example) can confirm the indications from the other parameters discussed above.

The SEER of Ground Source Heat Pumps

How do you calculate an equivalent SEER from a ground source heat pump EER?

You are invited to view ARI Standard 210/240 for air source equipment to fathom the complexity of SEER. Although GSHP-EER calculation is simple, predicting the performance of various ground loop types (which is necessary to determine the seasonal efficiency) is difficult. Generating **a single number** that would be a reasonable indicator for a variety of loop types and climates would be extremely difficult.

The recommendation is to base comparisons on a bin method program <u>that you develop yourself</u> rather than one provided by a manufacturer, utility, or an "independent" agency funded by a manufacturer or utility. Spreadsheets and the availability of flexible bin weather data (like BinMaker Plus) ease the burden of this task. It is critical to use actual performance data of equipment that meets the needs of the building space for latent capacity, fan static pressure, and auxiliary power using actual air or water temperatures (including the extremes). Air source SEER and ground source EER will not do this.

For example, we compared a 15 SEER air source heat pump with a 15 EER GSHP (with a vertical loop) using Chicago and Atlanta weather data (*ASHRAE Transactions*, Vol 98, Pt 2, BA-92-9-3). In Chicago the GSHP used 9120 kWh per year and the ASHP used 13,500 kWh. Can we then assume?

$$SEER(GSHP) = \frac{13{,}500}{9{,}120} \times SEER(ASHP) = 1.48\, SEER(ASHP)$$

Probably not, since in Atlanta, the values are;

$$SEER(GSHP) = \frac{7540}{6070} \times SEER(ASHP) = 1.24\, SEER(ASHP)$$

SEER and EER also mask performance at extreme conditions. In Chicago, the ASHP had peak winter and summer demands of 18.9 & 4.1 kW compared to 8.5 & 2.9 kW for the GSHP.

The discrepancies exist because SEER is a "weighted" average efficiency using rather mild weather data. The table below is the bin temperature data used for 2-speed heat pump SEER. So SEER is based on 661 hours when the outdoor temperature is below 80°F and only 74 hours when it is above 90°F. Also, the GSHP Standard (ARI 330) uses a temperature of 77°F, which would require a large loop in many climates.

ARI 210/240 Bin Temperature Distribution for Cooling SEER

Temp.	**67°F**	**72°F**	**77°F**	82°F	87°F	92°F	97°F	102°F
Hours	**214**	**231**	**216**	161	104	52	18	4

⇑

Indoor Rating Point Temperature = 80°F

There is no simple answer to this question. We feel development of program to predict energy use in residential and light commercial applications would be less troublesome and provide more meaningful results than a GSHP-SEER.

Meetings, Publications, and Information Sources

How Do They Know What's Down There?

Fear of the Unknown Beneath the Surface has caused more than one HVAC engineer to balk at the concept of ground source heat pumps. However, there is a surprisingly large amount of information available from ground water maps and geological surveys. In some states this information is being transferred to web sites. More detailed information is likely to be available for purchase at reasonable costs. For example a 128-page ground water availability publication with 93 pages of well log information and chemical analysis for Tuscaloosa County (Alabama) costs only $7.00. You may want to sample the web sites listed below as examples of what is out there (or down there).

"Ground Water Atlas of the United States"
http://wwwcapp.er.usgs.gov/publicdocs/gwa

Idaho water well completion reports
www.idwr.state.id.us/info/water/drilling/wl_srch.htm

Oregon water well completion reports
http://dechutes.wrd.state.or.us/apps/gw/

Meetings & Seminars – 1999/2000

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

Oct. 20-22, Geothermal Heat Pump Consortium Annual 1999 Meeting , Atlanta, GA 888-255-4436 or 202-508-5500

Nov. 5, One-Day Seminar for Engineers, Roanoke, VA, American Electric Power/ASHRAE, 502-773-4353

Nov. 15-19, Train-the Trainer Workshop, IGSHPA, Stillwater, OK, 800-626-4747 or ***www.igshpa.okstate.edu***

Dec. 3-6, National Ground Water Association Convention, Nashville, TN 800-551-7379 or ***www.ngwa.org*** (a Geothermal Heat Pump Workshop will precede the meeting on Dec. 2-3)

Feb 5-9, 2000 ASHRAE Annual Meeting, Adams Mark Hotel, Dallas, TX. 404-636-8400 or www.ashrae.org

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

Geothermal Heat Pumps in Commercial Buildings – Empirical Studies (Symposium SE-99-20 Papers from 1999 Meeting)
A New Comparison of Vertical Ground HEX Design Options
Implications of Measured Building Loads on GHP Sizing
Benchmark for Performance: GHPs in Lincoln Public Schools
Comparing Maintenance Costs of GHPs in Lincoln Schools

Geothermal Heat Pumps in Commercial Buildings – Analytical Studies
(Symposium SE-99-21 Papers from 1999 Meeting)
Energy Use of Ventilation Air Options for GSHPs
Non-dimensional Pumping Power Curves for WLHPs
Transient 2-D Finite-Volume Model for the Simulation of Vertical Ground HEXs
Short Time Step Response Factors Model for Vertical HEXs
A Preliminary Evaluation of the DOE2.1Eground Vertical Well Model using Maxey School Measured Data

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

"Ground Water Scaling Potential Maps", 1999. **(New)**

"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

International Energy Agency Heat Pump Centre

IEA Heat Pump Centre Newsletter, Vol. 17, No. 1/1999, Special focus on: "Ground-Source Heat Pump Systems"
http://www.heatpumpcentre.org

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)

"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)

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

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

The Source - IGSHPA Newsletter

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

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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 5).
- You have verifiable cost data you want to share.

Send information and requests to:

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Outside the Loop

A Newsletter for Geothermal Heat Pump Designers and Installers

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

- Ground Loop Testing
- Impact of Conductivity Errors
- Ground Water Site Evaluation
- Non-Central Loops for Lower GCHP Costs
- Letters – Well Tests, A GSHP SEER?
- GSHP Loop Contractors
- Cost Estimator for Interior HDPE Piping
- How Do They Know What' s Down There?
- GSHP Manufacturers & Suppliers
- Publications and Meetings

GEOEXCHANGE

Back issues of *Outside the Loop* can be accessed on the web site of the Geo-Heat Center in Klamath Falls, Oregon. The address is:

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

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