Outside the Loop

A Newsletter for Geothermal Heat Pump Designers and Installers

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Developments in Ground Conductivity Testing

Several requests have been received from readers to address the issue of in-situ thermal conductivity testing of potential GCHP sites. The tests involve drilling a test bore, insertion of a typical vertical ground heat exchanger, loading of the loop with a constant heat source, and the determination of conductivity from the change in loop temperature.

Developments during the last two years have significantly improved the capability of predicting ground thermal properties and ground loop design accuracy. An additional benefit of these tests is that drilling conditions determined during the installation of the heat exchanger can be provided to loop contractors. This information is critical to providing an informed bid price for installing the ground loop. **Ground conductivity testing helps minimize two of the most common barriers to affordable loops; overdesign and high contractor pricing to cover unknowns in the ground.**

There are debates regarding details that will fine-tune the test procedures when they are resolved. Although ASHRAE has approved a project to evaluate and enhance the procedures, it will be at least 18 months before the project is complete. The good news is that instead of debating if a certain formation has a conductivity of 1.0 or 1.4 Btu/hr-ft-°F, testers are now discussing if the value is 1.21 or 1.29 Btu/hr-ft-°F. Additional good news is that a $\pm$10% uncertainty in formation conductivity will typically result in less than a $\pm$5% uncertainty in loop length requirement which will impact equipment capacity by less than 1% if high efficiency heat pumps are specified. (Details of this calculation will appear in the next issue of *Outside the Loop*.)

One issue is the length of time the test should be run. Proponents of 12-hour (or less) tests, that are based on the line heat source solution, claim they can screen data to arrive at accurate values even when there are minor heat input variations. Other methods suggest longer tests are necessary. The focus of debate is the impact of the near bore properties. The figure on the following page shows temperature profiles from the center of a test bore out into a typical formation.

The profile for a "12-Hour" test is compared with a "48-Hour" profile in a soil with a 1.5 Btu/hr-ft-°F conductivity, a 250 ft. x 5 in. bore, and a 4.5 kW source. The bore grout conductivity for the 12-Hour test is 0.4 Btu/hr-ft-°F while the grout for the 48-Hour test is 1.4 Btu/hr-ft-°F. Note the large temperature gradient in the bore (66.5 to 90°F) for the 12-Hour test

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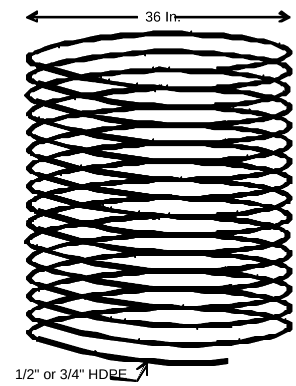
Large Diameter Bore Coils

An alternate to conventional U-tube designs for vertical ground coupled loops has recently emerged in California. Coiled piping (reportedly 1/2" or 3/4") is inserted in shallow (~50 ft), large diameter (36") boreholes. The configuration of the loop piping is much like a slinky suspended from one end so as to form a cylinder with an outside diameter slightly smaller than the borehole.



The larger diameter and the much lower heat rate through the tube wall and fill material contributes to the potential for enhanced performance relative to conventional U-tubes. The large diameter of the hole could allow the use the native material for fill since there would be less problem with bridging. Since it is difficult to hold the piping evenly distributed against the bore wall, spacers must be used. They must be strong to remain intact during the backfill operation. If the coil piping is separated from the borehole wall or "bunched up", heat transfer will be substantially reduced.

Performance of this configuration and how to evaluate it with available design software is a frequent question. GchpCalc, version 3.1 can, according to the developer, be used to evaluate the borehole design described above. The actual diameter of 36" and a high fill material conductivity (to simulate a low thermal resistance between the pipe and the ground) are input. As an example, a small office building with a peak load of 30 tons and 850 full load cooling hours and 250 full load heating hours was used. Key input values were soil k of 1.2 Btu/hr-ft-F and a ground temperature of 61°F. The following table summarizes the results of both the large borehole design and a U-tube loop design for this building.

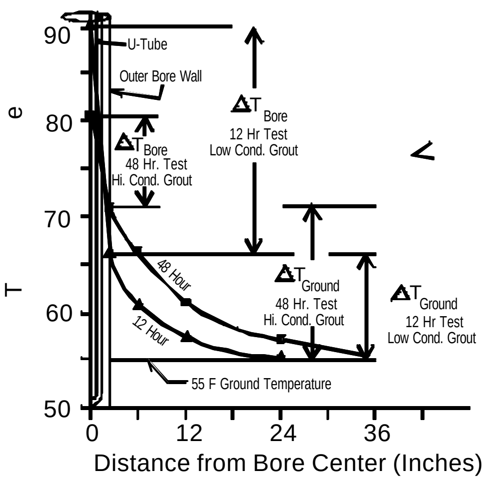
In any situation in which bores are placed in a grid pattern, interference occurs which reduces the effectiveness of the

Continued on Page 2

Design Issues and Tools

Ground Conductivity Testing (Continued)

compared to the soil temperature change (55 to 66.5°F). The relative amount of temperature rise across the ground is much higher for the 48-Hour test with the high conductivity grout. Since the amount of temperature rise in the loop due to the bore hole effects is reduced, the accuracy in deducing thermal conductivity of the soil is improved. Also, the heat has moved farther out into the formation and into soil that has not been disturbed by the U-tube installation. Drilling methods typically inject a drilling fluid (wet clay) or compressed air (warm, dry) into the formation near the bore. The ground near loop must also be given time to recover before the test is started. This is especially true if cement based grouts, which give off heat when curing, are used.



Temperature Profiles in Ground Conductivity Tests

The ASHRAE research project should address these issues. In the interim, the following recommendations are suggested.

1. The heat rates should be near the expected peak loads on the U-tubes (15 to 25 watts per ft. of bore), should be constant and maintained from 12 to 48 hours.
2. The thermal resistance of the bore (pipe & grout) should be minimized so that the measured temperature rise is a strong function of the thermal properties of the soil.
3. The depth of the test bore should be near the expected average length of the ground loop.
4. The test should not begin for 24 hours after the loop has been inserted. This time should be extended for 72 hours if cement based grouts are used.
5. Test times of 36 to 48 hours should be considered if large amounts of drilling mud or air are used during drilling or if low conductivity (< 0.75 Btu/hr-ft-°F) grouts are used.

Correction: The high density polyethylene pipe pressure rating table appearing on page 2 of the Winter 1999 edition of *Outside the Loop* had an error. SDR 13.5 pipe is rated at **111 psig** at 90°F rather than **11 psig** as listed in the Table. Thanks to Toni Boyd of the Geo-Heat Center for spotting the goof.

Large Bore Coils (Continued)

Borehole Length Requirement -Ft/ton (with 80% Diversity)

	Conventional U-Tube		Large Bore	
	5" Bore, 1" SDR 11		36" Dia., 3/4" DR 11	
	Yr 1	Yr 10	Yr 1	Yr 10
5x6 grid @ 20'	188	220	54	114
1x30 grid @ 20'	186	202	47	66
1x30 grid @ 40'	-	-	42	51

individual boreholes. Heat that cannot be transferred away from an individual bore due to the interference is stored in the ground near that bore. The greater the spacing between the bores and the greater the depth of the bores, the greater is the volume of ground in which this heat can be stored. In cooling dominated climates, an upward temperature "creep" over a period of years will result. If the ground loop design does not take this effect into account, entering water temperatures will rise year by year and compromise system performance. The unusual grid arrangement (1 x 30) and large spacing highlight the sensitivity of these designs to interference between bores.

The software simulates this interference effect by providing two values for the length requirement, one for the first year of operation and one for the 10th year of operation (at which point most systems will have reached thermal equilibrium). The shallow depth of the large diameter design is more strongly influenced by adjacent borehole interference. When spaced at 20ft. in a 5x6 grid, the conventional U-tube design requires 188 ft of borehole per ton to produce an 85°F EWT in the first year and 220 in the 10th year to produce the same EWT. The large diameter design produces the same EWT at 54 ft/ton in year 1 but requires 114 ft/ton in year 10. Orienting the bores in a single row and/or spacing them at 40' reduces the impact of the thermal interference on the large borehole design

In conclusion it appears that the large borehole design does offer the prospect for substantially reduced length requirement relative to the commonly used U-tube arrangement. Design of the ground loop must carefully consider the impact of interference and the installation must be accomplished in a way that does not compromise the position and spacing of the piping. Applications involving soft drilling conditions (with stable borehole walls), and non-grid type ground loops would be most suitable for this design. Due to the heavy impact of interference, designers should not draw conclusions about the performance based on early year data. However, in naturally porous soils, the negative impact of long-term interference is mitigated by water percolation through the formation.

Caution is warranted since major obstacles exist in addition to the heat storage problem. The first problem is increased head loss, which leads to larger pumps and reduced system efficiency. Second, the higher heat rates in the soils may tend to dry the formation and lower conductivity. Thus, rainfall may be necessary to regenerate the loop fields. Finally, if the bores are covered by the same environmental regulations as U-tubes, there will be some very wealthy grout and pipe vendors.

CEMENTITIOUS GROUTS 101

By Marita L. Allan, Brookhaven National Laboratory

Grouts used to backfill boreholes for vertically oriented ground source heat pumps (GSHPs) can be divided into bentonite or cement-based. Concerns have been expressed about shrinkage, excessive heat of hydration and poor bonding to U-loop with some cementitious grouts. By use of fillers and admixtures, together with suitable mix proportioning, the properties of cementitious grouts can be improved. The New Jersey Department of Environmental Protection recently approved use of a superplasticized cement-sand grout for use in consolidated and unconsolidated formations following an injunction on the use of unfilled cement grouts. This article outlines the basics of cementitious grouts.

Materials

In its simplest form cementitious grout consists of ordinary Portland (ASTM Type I) cement and water. This is often referred to as neat cement grout. Variations on the simplest grout include different cement types, addition of bentonite, partial replacement of cement with mineral admixtures (supplementary cementing materials), addition of retarders or accelerators, and use of water reducing agents. Neat cement grouts have relatively low thermal conductivity (typically 0.46 to 0.50 Btu/hr· ft· ^{o}F) making their use for GSHP applications limited. By adding filler materials such as silica sand the thermal conductivity can be increased up to 1.1 to 1.5 Btu/hr· ft· ^{o}F depending on proportion.

The properties of cement grouts are controlled primarily by the water/cement ratio. This includes viscosity, hydraulic conductivity, strength, durability, and shrinkage. Thermal conductivity is also affected by water/cement ratio, particularly if the grout dries out since excess water is evaporated and the resultant porous material has a lower thermal conductivity. A good quality cementitious grout requires minimization of the water/cement ratio.

The behavior of fresh, or unhardened, grout is critical since this will determine the ability to mix, pump and place the grout with conventional equipment. In addition to the strong influence of water/cement ratio, the viscosity of grout can be altered through the use of chemical admixtures. Water reducing and superplasticizing (high range water reducing) agents can be used to reduce the water demand while retaining low viscosity. Consequently, the water/cement ratio can be reduced and this is beneficial for such properties as thermal conductivity, shrinkage resistance, strength, hydraulic conductivity and durability. Superplasticizers are more effective than regular water reducers. These admixtures are covered in ASTM C 494 and ASTM C 1017. The effectiveness of superplasticizers decreases with mixing time. The sequence of superplasticizer addition also exerts a significant effect on grout rheology. Superplasticizers can act to increase bleed and shrinkage, particularly if overdosed.

Many groundwaters and soils contain levels of soluble sulfates that are detrimental to the integrity of Type I cement-based materials. This potential problem can be overcome either through partial replacement of Type I cement with, for example, blast furnace slag or by substitution with a sulfate resistant cement (Type II or V).

Bentonite (impure sodium montmorillonite) is a common additive and is used primarily to improve grout stability, reduce bleeding and reduce segregation of sand. Apparent viscosity and cohesion increase with increasing bentonite content. Superplasticizers have reduced effect with high bentonite content grouts. High proportions of bentonite increase set time and reduce the strength of grouts. Bentonite can be difficult to mix uniformly with water, particularly when using a paddle mixer as is common in the GSHP industry. Use of a high shear mixer may obviate the necessity for bentonite and this is discussed further below.

In addition to increasing thermal conductivity, sand also has the benefit of reducing shrinkage and improving mechanical properties for equivalent water/cement ratios. Cement-sand grouts have lower heat of hydration when compared with neat cements. It is important that silica sand used to enhance thermal conductivity and impart other beneficial properties to grout should consist of a wide and well-graded range of particle sizes and be well rounded as opposed to angular or flaky. Sand that is too coarse will tend to segregate and cause pumpability problems whereas very fine sand will increase the water demand and limit the proportion of sand that can be added to the grout. The exact gradation of sand that can be used successfully in grout will depend on the mixing and pumping equipment. Research at BNL has found that sand between 75 μm and 2.36 mm (Sieve Numbers 200 to 8) works well with a superplasticized cement grout mixed in a paddle mixer. This is similar to concrete sand except that the coarse material (i.e. retained on Number 8 and 16 sieves) is not used. Use of mineral admixtures such as silica fume, fly ash or blast furnace slag may alter the gradation and proportion of sand that can be used.

Mixing and Pumping

The GSHP industry tends to use low shear, paddle mixers for mixing grouts. The order of addition for cement-sand grouts with this type of mixer is typically water, bentonite, superplasticizer, cement and sand. It is more common in the geotechnical and structural grouting arenas to use high shear or colloidal mixers. These are more efficient than paddle mixers and may permit reduction of water/cement ratio, decreased superplasticizer dosage and increased sand proportion. Also, it may be possible to omit bentonite in the grout formulation with such a mixer. In either case, it is preferable to use a grouting unit that consists of a mixer and a separate agitator tank. With this arrangement grout is transferred from the mixer to the agitator tank where it is continuously stirred as it is stored or pumped. It is important to always keep the grout moving as cementitious grouts, particularly those containing bentonite, tend to be thixotropic and will form a gel on standing. Furthermore, keeping the grout mobile prevents segregation of sand. The use of an agitator tank simplifies this requirement.

Cement-sand grouts are best pumped with either piston or ram type pumps. Progressing cavity pumps may experience excessive wear. A 1¼" tremie tube is recommended for cement-sand grouts. The grout must be placed from bottom to top and the tremie tube must always be kept below the surface of the grout as it is withdrawn.

Quality Control

Every batch of freshly mixed grout should be measured for specific gravity prior to pumping. This requires use of a mud balance available from companies such as Baroid and the test procedure is given in ASTM D 854-83. The specific gravity is sensitive to water/cement ratio, sand/cement ratio and uniformity of mixing. Measuring flow time in accordance with ASTM C 939 can also be performed to check for grout pumpability and uniformity

It is recommended that samples of grout should also be taken for future laboratory thermal conductivity testing. The grout should be poured into a leakproof container, the dimensions of which depend on the equipment that will be used to measure thermal conductivity. The grout samples should be sealed or covered with plastic for 24 hours and maintained at temperature as close as possible to 20-25^{o}C. After 24 hours the samples should be demoulded and immersed in a water bath at 20-25^{o}C to cure for at least 7 days prior to testing.

General Information on Cementitious Grouts

- Kosmatka, S.H., Cementitious Grouts and Grouting, Portland Cement Association, 1990.
- Domone, P.L.J. and Jefferis, S.A. (Eds), Structural Grouts, Blackie Academic and Professional, Cambridge, 1994.
- Houlsby, A.C., Construction and Design of Cement Grouting, John Wiley and Sons, New York, 1990.

Information on Cementitious Grouts for GSHPs

- M.L. Allan, Thermal Conductivity and Other Properties of Cementitious Grouts, International Ground Source Heat Pump Association Technical Conference, Stillwater, May 1998.
- M.L. Allan and S.P. Kavanaugh, "Thermal Conductivity of Cementitious Grouts and Impact on Heat Exchanger Length Design for GHPs", *International Journal of HVAC&R*
- S.P. Kavanaugh and M.L. Allan, "Testing of Enhanced Cement Ground Heat Exchanger Grouts", *ASHRAE Transactions*, Vol. 105, Pt. 1, Atlanta, 1999.
- M.L. Allan, "Thermal Conductivity of Cementitious Grouts for Geothermal Heat Pumps", FY 97 Progress Report, BNL 65129, Nov. 1997.
- M.L. Allan and A.J. Philippacopoulos, Thermally Conductive Cementitious Grouts for Geothermal Heat Pumps: FY 98 Progress Report, BNL 66103, Nov. 1998.

Recipes of Thermally Enhanced Grouts

Cement based grouts

54 lbs. Cement + 200 lbs. Silica Sand* + 1.04 lbs. of 200 mesh Sodium Bentonite + 21 Fl. ounces of Superplasiczer + 6.2 Gal. of Water ⇒ 19 gal. of grout with a TC of **1.4 Btu/hr-ft-F**.

*Sand Gradation for Cement-Based Grouts

Sieve No. Size (μm)	8 (2360)	16 (1180)	30 (595)	50 (297)	100 (149)	200 (75)
Percent Passing	100	95-100	55-80	30-55	10-30	0-10

Bentonite based grouts

50 lbs. Bentonite + 23 gallons of Water ⇒ 27 gallons of grout 20% solids with a ther. cond. (TC) of **0.43 Btu/hr-ft-F**.

54 lbs. Bentonite + 100 lbs. Silica Sand* + 15 gallons of Water ⇒ 24 gal. of 58% solids grout with a TC of **0.65 Btu/hr-ft-F**.

54 lbs. Bentonite + 200 lbs. Silica Sand* + 17.5 gal. of Water ⇒ 30 gal. of 64% solids grout with a TC of **0.85 Btu/hr-ft-F**.

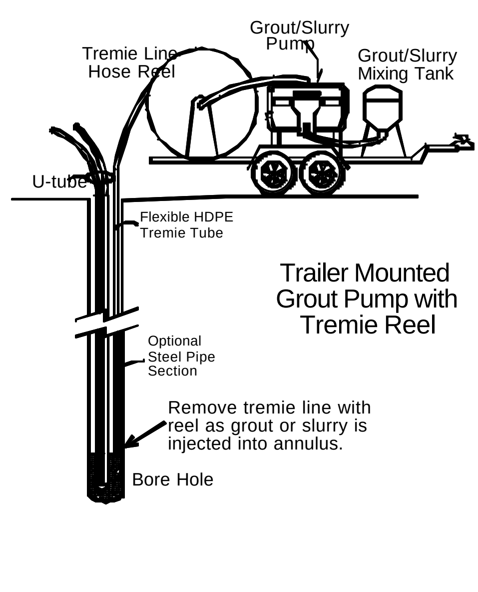
54 lbs. Bentonite + 350 lbs. Silica Sand* + 21.5 gal. of Water ⇒ 41 gal. of 69% solids grout with a TC of **1.15 Btu/hr-ft-**F.

54 lbs. Bentonite + 600 lbs. Silica Sand* + 25 gallons of Water ⇒ 56 gal. of 76% solids grout with a TC of **1.45 Btu/hr-ft-F**.

*Sand gradation varies by manufacturer.

Volume Required to Backfill U-Tube Boreholes
Gallons per 100 Feet of Bore Hole

	Diameter of Bore							
U-tube Dia.	3.5"	4.0"	4.5"	5.0"	5.5"	6.0"	6.5"	7.0"
3/4"	**41**	**56**	**74**	**93**	**114**	**136**	**163**	**191**
1"	-	**51**	**69**	**88**	**109**	**133**	**154**	**186**
1-1/4"	-	-	**60**	**80**	**101**	**124**	**150**	**177**
1-1/2"	-	-	-	**73**	**94**	**117**	**143**	**170**



Products, Services, and Installation Innovations

Commercial Building GCHP Loop Contractors

Please send names of other commercial GHP 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
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
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 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
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 410-538-7722
Venture Drilling, Inc. Tahlequah, OK 918-456-8119
Van and Company, Duncan, OK, 580-252-2205
Virginia Energy Services, Richmond, VA, 804-358-2000

Þ Þ Þ More Contractors Þ Þ Þ

Pointy-Headed Professor & Friends Descend from Ivory Tower and Go Below $10/ft^2$ Barrier

Chuck Remund is a professor of Mechanical Engineering at South Dakota State University and he will do just about anything to get someone to use ground source heat pumps. He has trained contractors, done research, argued, taught classes, written papers, indoctrinated his 7-year old son, argued some more, sold thermal grout, coerced a fellow professor to design ductwork and stamp drawings, and talked a guy out of a comfortable (but boring), high-paying job to start a geo-company to put in twice as many hours for less pay.

The company, GRTI, has even done some engineering design work. One example of a recently completed project dipped well below the magical $10/ft^2 barrier. The facility is a 26,000 ft^2, 58-ton athletic facility in Sisseton, SD, which consists of a double gym, weight room, wrestling room, and two locker rooms. The ground loop is 39 bores at 200 ft. each grouted with thermally enhanced bentonite (of course). Ventilation air is heated by electric resistance with SCRs controllers, which use input from four CO_2 sensors. The cost summary was:

Ground Loop	$ 54,600
Heat Pumps (58 Tons)	38,800
Duct Work	50,000
Piping/Insulation	6,500
Pumps	4,500
Ventilation Units	3,800
Electric Heaters (70 kW)/Cabinets	5,100
CO_2 Sensors (4)	4,800
Grills, Louvers & Registers	6,000
Exhaust Fans	1,200
Labor	25,000
Taxes	6,600
Total	**$ 206,900**
$/ft^2	**$ 7.96/ft^2**
$/ton	**$ 3,567/ton**

Innovations Displayed at IGSHPA Conference

Call 800-626-4747 for a list of vendors at the conference.

- U-tube Spring Clips to push HDPE tubes to outer bore wall and reduce thermal resistance caused by low TC grout.
- Enhanced bentonite grouts (TCs = 0.65 to 1.45 Btu/hr-ft-F)
- Circulator pumps with epoxy coated housings & impellers.
- Higher efficiency heat pumps
- Improved pump for thermally enhanced grouts.
- All HDPE vault/header for large loop fields and Quick-Connects for heat recovery units with PEX tubing.
- Pre-fabricated HDPE piping networks

More Loop Contractors

Virginia Service Co., Virginia Beach, VA, 757-468-1038
Winslow Pump & Well, Hollywood, MD, 301-373-3700
Yates & Yates, Columbia, KY 502-384-3656

Letters, Comments, Questions, & Suggestions

To Insulate or Not to Insulate? (Interior GCHP Pipe)

We have been installing GCHP systems in the Austin area for a number of years without insulating the interior piping. The loops are warm in the summer and are never below 50°F in the winter. Is it necessary to insulate the lines above the ceilings to prevent moisture condensation?

Should I be worried in Texas?

Dear Should I,

The cooling mode temperatures of GCHP piping in southern climates are well above the dew point temperature of the room air. So there should be no condensation of water on the outside of uninsulated piping during the cooling season. The period of concern is during the winter operation when the loop temperature is 50°F or less. If high-density polyethylene (HDPE) is used, moisture condensation is unlikely on uninsulated piping with normal room air conditions with loop temperatures above 45°F. Metal piping should be insulated if temperatures are below 50°F. Here is an example calculation that your design engineer should be able to perform.

A 4-inch, SDR 11 HDPE pipe carries 50°F water through a room at 70°F/50% relative humidity. Is insulation necessary to prevent condensation?

A psychrometric chart indicates the dew point temperature of the room air is 50°F. Therefore, if the outside temperature of the pipe wall (t_o) is less than this value, condensation will occur. To determine the pipe wall temperature, first find the heat loss per unit length of pipe.

$$q/L = \frac{t_{room} - t_{water}}{R_i + R_p + R_o} \quad where\ R_i << R_p\ \&\ R_o,$$

$$R_p = \frac{\ln d_o/d_i}{2\pi k_p} = \frac{\ln 4.5''/3.68''}{2\pi\ 0.22 \frac{Btu}{hr-ft-F}} = 0.146 \frac{hr-ft-F}{Btu}$$

$$R_o = \frac{1}{h_o \pi d_o} = \frac{1}{1.5 \frac{Btu}{hr-ft^2-F} \pi \frac{4.5''}{12\ in/ft.}} = 0.566 \frac{hr-ft-F}{Btu}$$

$$Thus\ q/L = \frac{70 - 50\ ^\circ F}{0.146 + 0.566} = 28 \frac{Btu}{hr-ft}$$

The temperature of the outside pipe wall is,

$$t_o = t_{room} - q/L \times R_o = 70^\circ F - 28 \frac{Btu}{hr-ft} \times 0.566 \frac{hr-ft-F}{Btu}$$

$$t_o = 54^\circ F.\ Too\ warm\ for\ condensation!$$

Note: This example calculation is conservative since indoor humidity levels during cold weather will likely be lower than 50%. Thus, dew point temperatures will be lower than 50°F.

Well Pumps – Lineshaft or Submersible

We are designing an open loop system for an office building in Nebraska. It is a 225-ton system and we will be pumping approximately 340 gpm. Static water level in the well is 76 feet. Our pump rep is suggesting that we use a lineshaft driven pump. We were planning on a submersible. Can you comment on the relative advantages/disadvantages of the two types?

Picking Pumps in Plattsmouth

Dear Picking Pumps,

Either type of pump could be used in this case but it is likely that the submersible will be less expensive. Lineshaft pumps are generally suited to large industrial/municipal applications at high (>350 - 400 gpm) pumping rates. They are somewhat more efficient than submersibles but not sufficiently so to impact the decision. Lineshaft pumps rotate at slower speeds (nominal 1800) compared to submersibles (3600) and as a result are more tolerant of sand. Due to the long rotating shaft connecting the motor and the bowl assembly, a straighter well is required and this should be reflected in a tighter specification for plumbness and alignment in the well specification. At the static water level in your well, an open type lineshaft should not be used. To assure adequate lubrication at start up an enclosed lineshaft (with water or oil lubrication) should be used. As a result of the above ground motor location, wells with lineshaft pumps are normally equipped with well head structures for protection of the motor.

Submersible well pumps are the choice for most GSHP applications. For the flow rates involved in these systems they are typically 20% to 50% less first cost than lineshaft pumps and they require no surface structure. Rotating at a nominal 3600 rpm they are more sensitive to sand in the production stream than lineshaft pumps. If variable speed is to be used, submittals verifying the motor manufacturer's awareness of this fact should be required. It may be necessary to equip the motor with an auxiliary cooling shroud and electronic compensation for drive-to-motor length may be necessary depending upon depth. Submersibles are more voltage sensitive than surface motors and cable selection should be carefully considered. Submersibles should always be equipped with a foot valve to assure that the motor starts under load (full column of water). This prevents momentary thrust reversal that can damage the motor.

Obviously, the nature of the submersible precludes any routine maintenance since all the components are below grade. Regular monitoring of motor current is advisable for both submersible and lineshaft equipment. For systems served by a single well it is useful to store a spare pump and motor on site for submersibles or a spare pump (bowl assembly) for lineshaft type pumps.

Meetings, Publications, and Information Sources

Meetings & Seminars - 1999

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. 3-4, Two-Day Seminar for Engineers, Portland, OR

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

August 1-3 – Architect & Engineer Seminar, Holiday Inn, Gatlinburg, TN, (7.75 LUs & 7.75 – 9.3 PDHs), 606-367-5839

August 23-25 – Energy '99: An Energy Efficiency Workshop & Exposition, FEMP, DOD, GSA – 800-395-8574, ***www.energy.ee.doe.gov***

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
(Symposium 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 (510-934-4212)

Heat Pump News Exchange – Quarterly Newsletter

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

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

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

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

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

International Energy Agency Heat Pump Centre

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

Heat Pump Systems for Single Room Applications" (Workshop Proceedings - Dec. 1998, Final Report - Jan. 1999)
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)

"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)

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)

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)

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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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Warning – Be Advised - Warning

We will soon be making our mailing list available to our sponsor and to other GSHP professionals. We expect the list will be used to send advertisements or announcements. Please contact us by June 30, 1999 if you want your name removed from this list. At that time, we can provide the list to anyone requesting it at no charge.

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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