

The SOURCE

IGSHPA Newsletter

Volume 12, Number 2

March/April 1999

An Opportunity for Drillers Interested in GeoExchange

By Allan Skouby, Geo Pro, Inc.

Inside...

An Opportunity for Drillers Interested in GeoExchange... 1

Trane Donates Heat Pumps to OSU 3

Register Today for Security Tomorrow 3

More Comments on In-situ Borehole Thermal Conductivity Testing 4

More articles and advertisements are appearing for geoexchange (a.k.a. ground-coupled heat pump and closed-loop geothermal heat pump) applications. The technology is very simple, which is one of the reasons for its growing popularity. The system typically consists of packaged water-to-air heat pumps which are connected to an engineered plastic piping (thermally fused high density polyethylene) system which is buried in the ground where low-grade thermal energy is transferred from the building to the earth in summer months and from the earth to the building in the winter months. Typical temperature change of the fluid (water or water-antifreeze solution) through the buried piping system ranges from 6°F to 15°F, depending on the system's flow rate and whether the system is in the heating or cooling mode. The maximum temperature encountered within a year should be about $25 \pm 5^\circ\text{F}$ above the normal ground temperature during the

cooling season, while the minimum temperature should be approximately $15 \pm 5^\circ\text{F}$ below normal ground temperature in the heating season. This low-grade thermal energy is compressed at the heat pump, which in turn heats or cools the building and, in some cases, supplies the domestic hot water needs.

The buried plastic piping system is known as a ground loop heat exchanger. The size (number and depth of total boreholes) of a commercial ground loop heat exchanger will be determined by a mechanical engineer, and will be related to the thermal load of the building, the geographic conditions, and the thermal characteristics of the site. Vertical bore depths range from 50 to 600 feet, depending on drilling conditions and the contractor's capabilities. It is not uncommon to encounter commercial projects with as many as several hundred boreholes on a single project.

Geoexchange drilling contractors are typically responsible for drilling the

vertical bore (while complying with state and local regulations), installing the polyethylene U-bend assembly, backfilling per the design specifications, providing the necessary excavation for the supply and return line to and from the building, thermally heat fusing the U-bends to the manifolds and headers, and flushing and purging the completed vertical ground loop. Most specifications call for the installation contractor to be IGSHPA accredited.

A major obstacle to the widespread acceptance of this technology is its initial cost. It is commonly believed that lowering the initial cost of a geoexchange system will dramatically enhance consumer acceptance. To the consternation of some well drillers, cost reduction has become focused on the ground loop installation.

Reducing Costs While Increasing Profits

When a system has been designed with conventional

—continued on page 6



**International
Ground Source
Heat Pump
Association**

490 Cordell South, Oklahoma State University,
Stillwater, OK, 74078-8018
Phone: 1-800-626-4747
Fax: (405)744-5283
Web site: <http://www.igshpa.okstate.edu>

IGSHPA ADVISORY COUNCIL

- Dan Ellis, Chair
ClimateMaster
- Bill Dean, Vice Chair
WaterFurnace International
- John Manning, Secretary
Water Source Supply Company
- Billy Abner, East Kentucky Power Coop.
- Phil Albertson, Ditch Witch
- Larry Eitelman, Florida Heat Pump
- Morris Lovett, OG&E
- Scott Jones, Econar Energy Systems Corp.
- Frank Migneco, GPU Energy
- David Phillips, Addison Products Company
- Ron Robertson, Exelon Energy Services
- Phil Schoen, Geo-Enterprises, Inc.
- Chris Smith, Florida Heat Pump
- Steve White, Phillips Driscopipe

IGSHPA STAFF

- Executive Director, Jim Bose
- Assistant Director, Lisa McArthur
- Director of Research, Marvin Smith
- Development Engineer, Randy Perry
- Training Coordinator, Fred Jones
- Publications Coordinator, Robert Jones
- Special Projects, Jim Netherton
- Conference Coordinator, Heath Chelesvig
- Unit Assistant, Shelly Fitzpatrick
- Senior Secretary, Melanie Tarlton
- Financial Assistant, Brenda Marlow
- Mailroom Clerk, Kelli Hill
- Student Assistants, Mandy Means and Mandy Barbee

The Source is published bimonthly by OSU International Ground Source Heat Pump Association, 490 Cordell South, Stillwater, OK, 74078-8018, as a service to the membership. Send questions, story ideas, photos, and comments to Editor, *The Source*, c/o IGSHPA, or call 1(800)626-4747. Visit our web site at <http://www.igshpa.okstate.edu>.

Copyright 1999 by the Board of Regents for the Oklahoma State University Agricultural and Mechanical College, all rights reserved.

Use of copyrighted material is permitted, provided the reprint credits IGSHPA and *The Source*, and a copy of the reprint is sent to the IGSHPA office.

Bulletin Board



New Trainers: the latest group of IGSHPA-accredited trainers! They are, from left to right, Richard Moore, *Earth Energy Technology & Supply, Inc., Marietta, OK*; Rick Nash, *Bergerson-Caswell, Inc., Maple Plains, MN*; Mike Milwee, *Alabama Power Company, Verbena, AL*; John Jackson, *Alabama Power Company, Mobile, AL*; and Steve Paiewonsky, *HydroDelta Corporation, E. Stroudsburg, PA*.

WaterFurnace recently announced its new line of full-condensing, multi-function units, Synergy3. The line combines the benefits of forced air heating and cooling with the comfort of radiant floor heating.

Available in three sizes—4, 5, and 6 tons—each system is engineered to meet the demands of a structure in any climate. Synergy3 units come with white epoxy powder coated cabinets and are equipped with Copeland Scroll® compressors, microprocessor controls, and ECM2 variable-speed blower motors. The line is safety listed with ETL and ARI 330 performance rated for efficient operation in cold climates.

For more information, call WaterFurnace at 800.436.7283.

IGSHPA would like to extend apologies to the following members that were inadvertently left out of the 1998-99 Membership Directory:

F. Steven Bauman and F. Gordon Craig
Geothermal Services, Inc.
5435 Harding Hwy, Box 427
Mays Landing, NJ 08330
craigtest@worldnet.att.net
Phone: 609-625-5433
Fax: 609-625-4306

Phil Bisesi
Advanced Energy
909 Capability Drive, Ste 2100
Raleigh, NC 27606-3870
pbisesi@advancedenergy.org
Phone: 919-857-9000
Fax: 919-832-2696

Peter Millar
Energy Solutions
Box 8954
Truckee, CA 96162
Phone: 530-582-0458

Cary Smith and Marc Eckels
Sound Geothermal
Rt. 3, Box 3010
Roosevelt, UT 84066
Phone: 435-722-5877
Fax: 435-722-5089

Scott Wilkes
NESCO INC
301 Oakhurst Road
Wilmington, NC 28405
swilkes@aol.com
Phone: 910-392-9821
Fax: 704-843-3647



Trane Donates Heat Pumps to OSU

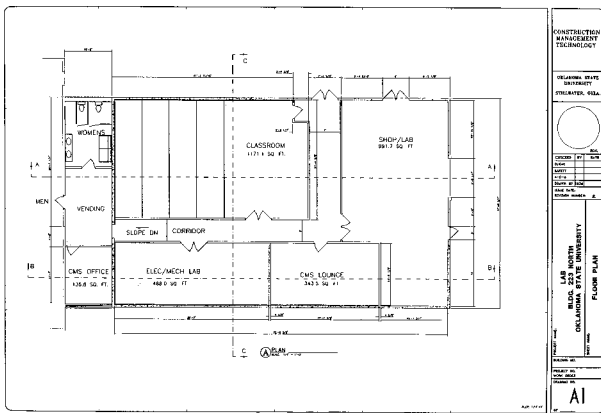
Trane recently donated 73 WPHD0287s, 2 1/2-ton units to the Oklahoma State University Division of Engineering Technology. Dr. Marvin Smith, director of geothermal research within the division, has identified ten of these units for ongoing research purposes. The OSU Fire Protection and Safety Technology Department is developing a plan to utilize several units in their soon-to-be constructed laboratory.

The Construction Management Department of OSU will use six Trane units in two projects. One project is the construction of a new lab. Scheduled for completion in the year 2000, the Construction Technology Lab is designed

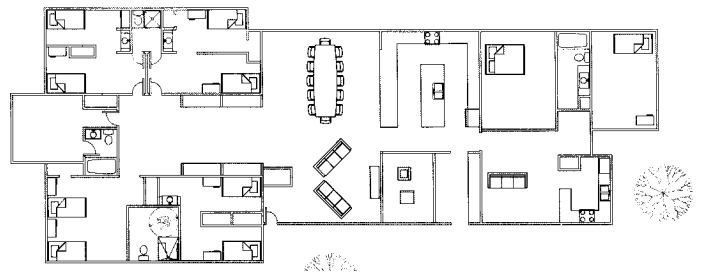
with three zones requiring 2 1/2 tons each. This 3000 square foot concrete double-tee building is located on the OSU campus. Construction students and faculty will have use of a new classroom, lab, and shop space (see design).

Construction Management's second project is with the Lions Club of Oklahoma. Construction documents and CAD students at OSU are preparing plans and specs for a new 4000 square foot "Ranch Home" for the Lions Club Boy's Home. This home has three zones and will use three Trane heat pumps (see design). Eight boys and two house parents will live in year-round comfort as they enjoy heating and cooling from pond loop source heat pumps.

IGSHPA would like to extend a BIG THANK YOU to TRANE and their Waco Business Unit employees, Jay Severance, VP and general manager, Roger Meyer, marketing manager, and Howard Newton, applications manager, for their generous contribution to OSU.



The plans for OSU's construction management lab.



Lions Club Boy's Home design.

Register Today for Security Tomorrow

A tornado sweeps through a small town leveling everything in its path. Government buildings, commercial businesses, and homes are destroyed. One such home belongs to Mr. Smith. His home is gone along with any record of his geothermal heat pump system. To start the rebuilding, Mr. Smith contacts the builder who constructed his home. Unfortunately, the builder is no longer in business. When Mr. Smith calls his heating/air service contractor, he finds them gone as well. Where does Mr. Smith go now? He only vaguely remembers where the pipe is buried in the back yard; or is it the front yard? How will a new builder know where to re-establish his system?

Although melodramatic, this is the kind of situation a geoechange customer could experience. For almost a decade now, IGSHPA has had the answer to Mr. Smith's problem. If Mr. Smith's contractor and/or installer of his geothermal system had participated in IGSHPA's Registration Program, he would have a hotline (1-800-626-4747) to call for help. For the small fee of \$25.00, Mr. Smith's system record could have been permanently stored

at the IGSHPA headquarters. Upon request, IGSHPA could have provided him with a chart of his system, including information on grout type, grout brand, and type of hole backfill material used. IGSHPA also could then refer him to several contractors in his area. IGSHPA could help him find the resources to rebuild his system efficiently.

IGSHPA's Registration Program is easy to participate in for geoechange professionals. The first step is to order, or download from the IGSHPA website (<http://www.igshpa.okstate.edu>), official application forms. The second step is simply to complete one form for each installation. When completed, the form should be mailed along with a check for \$25.00 to IGSHPA. The staff at IGSHPA then informs the customer and their utility provider that the system has been registered. The customer is asked to affix the Registration Label to his/her unit.

IGSHPA records and stores the registration information in two secure locations, permanently. For a nominal investment, any geoechange customer can be registered today for peace of mind and security tomorrow.

More Comments on In-situ Borehole Thermal Conductivity Testing

By Jeff Spitler, Simon Rees, and Cenk Yavuzturk; Oklahoma State University

Two recent articles (Skouby 1998, Smith 1999a) in *The Source* have discussed in-situ thermal conductivity testing. For very practical reasons, there is one hot button issue related to in-situ thermal conductivity testing—how long should the test be? The authors have recommended 50 hours as a minimum test length. Yet, we are well aware that a shorter test would be highly desirable even if some small, but acceptable, loss of accuracy resulted. This article is aimed at explaining how and why we came up with the 50-hour recommendation, and will look briefly at what the possibilities are for a significantly shorter test.

Work at OSU on in-situ thermal conductivity testing began in 1995. The initial work was funded by the NRECA, with Peyton Collie as project monitor. This work involved the design, fabrication, and testing of the test apparatus, and development of an analysis procedure. The graduate student who did most of the work, Trey Austin, covered the apparatus design and analysis procedure in his thesis (Austin 1998), which is now available on the World Wide Web.

We originally attempted to use the line source method described by Mogensen (1983) and used by Smith (1999a). The method uses an approximate analytical solution for a constant-heat-output line source in an infinite medium to develop a relationship between the slope of a temperature rise-log time curve and the thermal conductivity. This method has the advantage of being very simple, but in practice there are often significant problems associated with determining the correct value of the slope or derivative. As demonstrated by Austin (1998), any small perturbation in the power input or flow rate can cause a significant variation in the estimated ground thermal conductivity. Likewise, sudden changes in the weather can cause a small perturbation in the power input to the ground, which in turn can cause a significant variation in the estimated ground thermal conductivity. These problems led us to abandon the method. Smith (1999b) continues to use the method, but with a great deal of care in manually selecting time periods when the power input and flow rate are nearly constant. The linear line source method curve in the plot that appeared in the last issue of *The Source* was the result of this procedure.

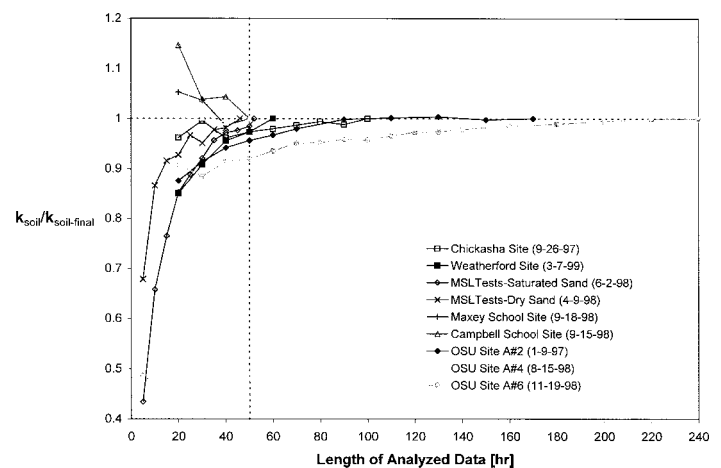
After abandoning the line source method, we went on to investigate parameter estimation based methods. With parameter estimation, various inputs, especially the ground thermal conductivity, are adjusted systematically to a

numerical model of the borehole and surrounding ground so as to minimize the differences between the actual temperature response and the model-predicted temperature response. The ground thermal conductivity that gives the minimal difference between the two responses is the estimated value.

With parameter estimation, any number of parameters might be estimated simultaneously. Initially we attempted to only estimate the ground thermal conductivity. However, the estimate of the ground thermal conductivity is highly sensitive to the borehole resistance. Since, in current practice, it is almost impossible to know where the U-tube is positioned in the borehole, it is difficult to accurately determine the borehole resistance a priori. We concluded the resulting errors were unacceptably large, and therefore went to a parameter estimation with two parameters: ground thermal conductivity and grout thermal conductivity. In this case, the grout thermal conductivity serves as a surrogate for several other parameters, especially the U-tube position. Also, at the time Austin was finishing his thesis, the numerical model was not satisfactorily accurate during the first 12 hours and we decided not to use the temperature response from the first 12 hours as part of the objective function for adjusting the input parameters.

Subsequently, the numerical model was significantly refined and so we now use the entire data set. To determine how long of a test length to recommend, we

Figure 1





investigated a number of cases where we had tests as long as a week. The estimated thermal conductivity generally converges at some point—we looked for a time that would usually give us a result within $\pm 5\%$ of the converged estimate. To demonstrate this, in Figure 1, we have plotted a set of normalized soil conductivity estimates from nine different in-situ tests. All of the estimates are divided by our best estimate of the converged value or the estimate obtained at 50 hours if the test was only 50 hours in length. With one exception, all the tests give estimates of the ground thermal conductivity within $\pm 5\%$ of the converged value at 50 hours.

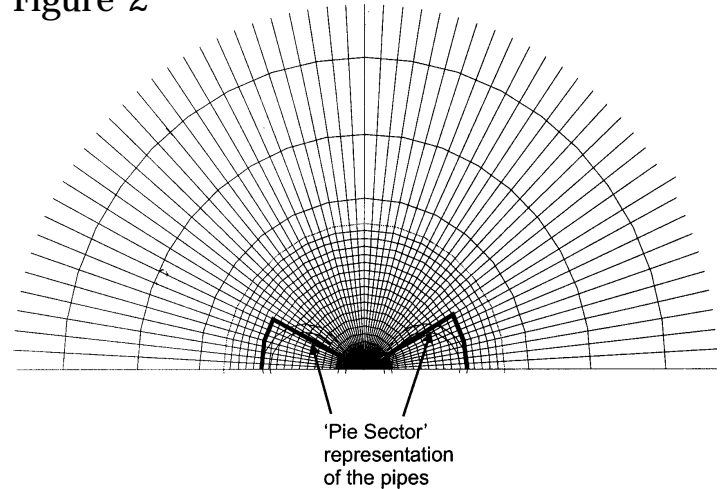
Could the tests be shorter while still taking advantage of the two-parameter estimation procedure? Of course, but with some additional loss of accuracy. There is clearly a trade-off between accuracy and length of test. If the test is only 20 hours in length, then the results for our nine tests are all within $\pm 15\%$ of the converged estimate. However, as the test length is further decreased, the error grows quickly. We should note that using a shorter test length is not always conservative, as several tests that approach the converged estimate from above demonstrate.

Could the tests be shorter with another analysis procedure? Possibly. We've already discussed the limitations of the line source method. The main reason the two-parameter estimation procedure takes so long is that it takes time to resolve the differences between the effects of the ground thermal conductivity and the effects of the borehole resistance, or grout thermal conductivity. If a single-parameter estimation could be used, it should converge much more quickly. In order to make use of a single-parameter estimation, we would need the following:

- 1) Grout with known thermal conductivity.
- 2) Thermal characteristics of pipe well known.
- 3) Good estimate of convection coefficient in the pipe.
- 4) Control of the U-tube placement in the hole.
- 5) Constant diameter borehole.
- 6) Highly accurate representation of the borehole geometry in the numerical model.

The first three items can reasonably be achieved. It is not at all clear whether items 4 and 5 are feasible to achieve in the field. The 6th item, the numerical model, has been developed here at OSU. The numerical model used in the original work used a polar grid system that required the pipe geometry to be approximated by a pie sector in the grid (see Figure 2). An improved model has now been developed that uses a boundary-fitted grid system that is much more flexible and can accurately represent the U-tube pipe geometry. Details of the grid around the borehole are shown in Figure 3. This makes the calculation of the heat fluxes and temperatures inside the borehole much more accurate. This is important for prediction of the borehole response near the beginning of the in-situ test and should lead to better parameter estimations.

Figure 2

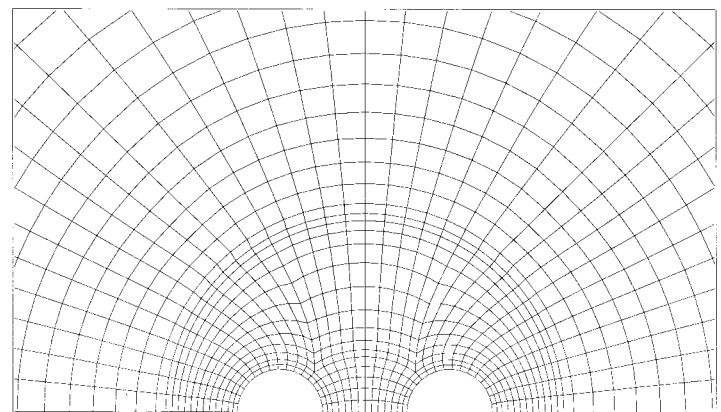


The numerical model polar grid with a pie sector approximation of the U-tube pipe geometry.

This improved numerical model has been used to estimate the soil conductivity from experimental data taken from the medium-scale borehole test facility at OSU. This facility consists of a 4' x 4' x 48' box filled with sand saturated with water and with an 5' aluminum tube at its center to represent a borehole. The U-tube position is closely controlled inside the tube and grouted in place. Smith used the data from this experiment in his recent article (Smith 1999a). Estimations of the saturated sand conductivity have been made using different amounts of data up to 52.5 hours using the two-parameter method developed by Austin et al and also with a one-parameter method. Estimating only one parameter assumes the grout conductivity, U-tube position, and borehole size to be accurately known.

The results of these parameter estimations are shown in Figure 4 along with the results previously published by Smith for the line-source method. The results for the two-

Figure 3



The numerical model boundary fitted grid showing the improved representation of the borehole and U-tube geometry.

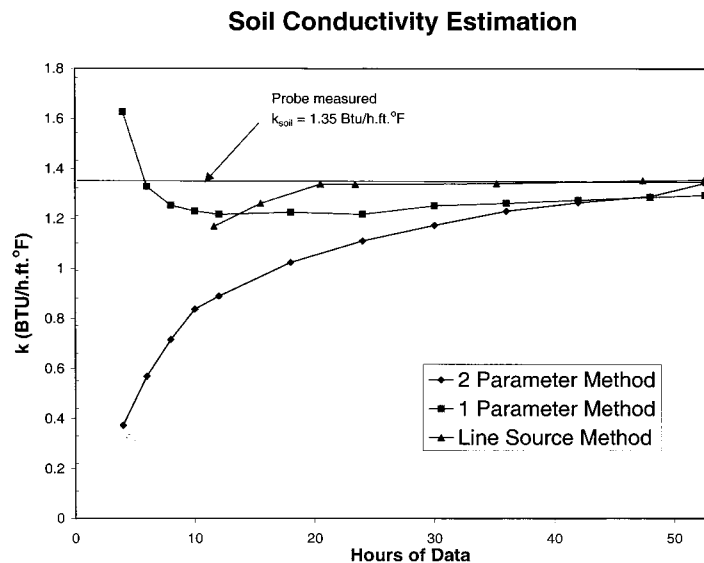
—Spitler, from page 5

parameter method steadily increase as more data are used and approach a consistent value towards fifty hours of data. The results for the one-parameter method however, approach the independently measured value much more quickly, in a similar manner to the line-source method. It should be noted that, unlike the line-source method, the results of both the one and two-parameter methods do not rely on judgements by the user in selecting the data—the procedures are fully automatic.

It is encouraging that the one-parameter conductivity estimation method performs so well on test data of shorter duration. However, it should be emphasized that using this method requires the grout conductivity, U-tube position, and borehole size to be accurately known. In practice, although the grout conductivity may be reasonably well defined, the position of the U-tube in the borehole cannot be controlled, and the size of the borehole may vary along its depth depending on drilling conditions. Therefore, we do not recommend its use in the field. The two-parameter conductivity estimation method we have previously recommended is able to compensate for variations in borehole size and U-tube position automatically by simultaneously estimating the effective grout thermal conductivity.

However, further research, under field conditions, needs to be done to investigate effective means for controlling the U-tube position, sensitivity of the single-parameter estimation method to actual borehole diameter, and

Figure 4



Results of soil thermal conductivity estimates using test data of different duration. Three sets of results are compared with the independently measured value, (a) the numerical two-parameter method (Austin 1998), (b) a one-parameter estimation method, and (c) the line-source method results (Smith 1999a).

whether or not measuring the grout volume would provide a sufficiently accurate estimate of the borehole diameter. If these research tasks are completed successfully, we will look forward to being able to recommend a test and analysis procedure that allows for much shorter tests!

References

- Austin, W. A. 1998. "Development of an In-Situ System for Measuring Ground Thermal Properties." Master's thesis. Oklahoma State University. Stillwater, Oklahoma. (Also available at [HYPERLINK http://www.mae.okstate.edu/Faculty/spitler/Austin_thesis.pdf](http://www.mae.okstate.edu/Faculty/spitler/Austin_thesis.pdf))
- Austin, W., C. Yavuzturk, J.D. Spitler. 2000. "Development Of An In-Situ System For Measuring Ground Thermal Properties." Submitted for publication in the ASHRAE Transactions.
- Mogensen, P. 1983. "Fluid to Duct Wall Heat Transfer in Duct System Heat. Storages." Proceedings of the International Conference on Subsurface Heat Storage in Theory and Practice. Swedish Council for Building Research. June 6-8.
- Skouby, A. 1998. "Thermal Conductivity Testing." *The Source*. November/December 1998. p. 5.
- Smith, M. 1999a. "Comments on In-situ Borehole Thermal Conductivity Testing." *The Source*. January/February 1999. pp. 3-5.
- Smith, M. 1999b. Personal communication. March 1999.
- Yavuzturk, C., J. D. Spitler, S. J. Rees. 1999. "A Transient Two-Dimensional Finite Volume Model for the Simulation of Vertical U-Tube Ground Heat Exchangers." Accepted for publication in ASHRAE Transactions, Vol. 105, Part 2.s

—Skouby, from page 1

bentonite grout specified as the backfill material for the entire bore column, the drilling contractor has an opportunity to introduce a new thermally enhanced bentonite-based grout that can reduce the ground loop heat exchanger cost while increasing the profit margin on that project. This new thermally enhanced bentonite grout has the ability to reduce standard designs from 15 to 30%, depending on the thermal characteristic of the specific jobsite. This is done while maintaining the same or better environmental protection that conventional bentonite grouts are known for.

When awarded a contract, the contractor should approach the engineer and suggest changing grouting materials to reduce total required bore lengths. This change will allow the contractor to reduce the total installed cost while increasing total profit margin.

—continued next page



In a recently awarded project, the design engineer specified that bids be submitted for the project with both conventional grout (bore lengths specified by the engineer) and thermally enhanced grout (again, bore lengths specified by the engineer reflecting the calculated reduction). The awarded bid reflected a savings of approximately \$200 per installed ton (12,000 Btu/h) with the thermally enhanced grout. Had the project been designed and specified with conventional grout, the awarded contractor would have had an opportunity to point out to the engineer the performance advantages of the thermally enhanced grout, and could have lowered the cost of the project while having an opportunity to retain some of the savings as additional profit.

This approach will help grow the technology while improving profits for cutting-edge contractors. Using this opportunity will help the contracting community defend its position within the industry and prove there is a mutually beneficial way to reduce system costs without requiring drilling contractors to reduce their profitability.

Required Investment

The manufacturer has designed this new grouting material to be very user friendly. Contractors will find its handling characteristics are more reliable than many of the popular conventional grouting materials commonly used today. It will, however, require some special equipment in order to insure maximum profitability.

The material is currently supplied as a two-part field mix and is designed to be mixed using 54 pounds of bentonite base (one bag) with 200 pounds of thermal enhancement compound (either four 50# bags or two 100# bags) and 17.5 gallons of fresh water. This 254-pound dry mixture will yield 30.2 gallons of a ultra-high solids (63.5%) product. Due to its slightly abrasive nature, it will require a piston style grout pump and is recommended to be mixed with a paddle type mixer.

For contractors that have not previously invested in a dedicated grout mixer and pump, there will be a need to invest in one that can handle at least 40 gallons of capacity.

Actual field experience indicates that a high quality, heavy-duty, dedicated grout mixing/pumping system is well worth the money in saving time and labor when handling this thermally enhanced grouting material.

Opportunity Summary

This new thermally enhanced bentonite-based grout has the potential to reduce vertical ground loop heat exchanger cost by 10 to 20% while maintaining critical environmental integrity. A progressive drilling contractor has an opportunity to convert projects where conventional grouting materials were specified and keep a portion (or all) of the savings associated with this new material.

By initiating interest in this thermally enhanced grouting material, the drilling contractor has the opportunity to help promote geoechange while proving that contractors can work with this technology to reduce costs. If the drilling contractor can't make money installing geoechange systems, there won't be contractors to support this industry. This new thermally enhanced grout provides a win-win situation for the drilling contractor and the geoechange industry!

For more information or design assistance, contact Allan Skouby, GeoPro, Inc., (972) 390-8097. 

Special Notice: Design Engineers

When Thermal Grout 85 is specified and installed on a commercial project, **GeoPro, Inc.** now offers:

- Ground loop design assistance on your first commercial GeoExchange system!
- Three FREE thermal conductivity analyses per commercial project!
- On-site technical support and training!

For more information on this offer, call GeoPro, Inc., at (972)390-8097, or e-mail us at allanps@aol.com

WF Ad from Jan/Feb