"Ground Source Heat Pump Systems – Putting the Earth to Work for You"
April 21, 2011

Following are answers to questions from the viewing audience that were not answered during the webcast due to time constraints:

1. **The first speaker said that the ground conditions (i.e, deep) could only be determined by drilling. However, for a horizontal ground source/sink system, would ground-penetrating radar techniques be helpful in designing horizontal systems?**

   Perhaps – I've heard of research into the use of ground-penetrating radar that might be helpful, but, as of yet, nothing brought to practice.

   Jeff Spitler

2. **Pump energy is often very high. What are the recommendations for managing it?**

   This is primarily a design issue. Let me just refer you to what Kirk said in his second talk – first in Ground-Source Heat Pumps – Design of Geothermal Systems for Commercial and Institutional Buildings, published by ASHRAE in 1997, Steve Kavanaugh and Kevin Rafferty give benchmarks for pumping efficiency on a grading scale: A- Excellent, B – Good, etc. To get an A grade the pumping power should be 5 hp /100 tons cooling capacity or less. In SI units, that would be about 11 W pumping power per kW cooling capacity. In order to achieve this, according to Kirk, well fields should have pressure drop below 25 ft of head (75 kPa) and the overall system pressure drop should be below 60 ft. of head (180 kPa) and preferably below 50 ft of head (150 kPa).

   Jeff Spitler

3. **Would you have any concerns using lake water already delivered to a facility, as the facility is a large city Raw Water Treatment Plant? History shows incoming water temp max and min to be 98°F and 40°F.**

   Assuming the heating and cooling loads are small relative to the water flow, the lake water should be an excellent heat source and sink. But lake water is likely to cause (at the least) biological fouling of the heat exchangers, so an isolation heat exchanger, e.g. plate frame heat exchanger might be called for.

   Jeff Spitler

4. **Is there any benefit to utilize a buffer tank to naturalize the temperature of the ground water source heat pump?**

In general, the benefit gained is probably not worth the extra investment cost. I did look into this once as a class exercise, assuming a well mixed tank and my recollection is that, for a residential system, you had to get to a tank on the order of 8 m^3 or 2000 gallons before you started to see a significant difference in the diurnal temperature swing. But even then, the actual effect on energy consumption was pretty small, so it was hard to imagine that it would be worth the cost and lost space associated with putting such a tank in your basement.

Jeff Spitler

5. **How do you really get heat transfer thru a plastic pipe?**

Ground heat exchangers rely on having a relatively large surface area to get a sufficiently high UA value. It would be nice to have a higher conductivity pipe, but the ground would be the next limiting factor in the design, so there is a limit to how much benefit we can get from increasing the conductivity.

In the 1940s, there was a flurry of activity in the ground source heat pump field using metal pipe. Leakage was a significant problem and one of the reasons the technology fizzled out. In the 1970s, that problem was solved using high density polyethylene (HDPE) pipe, which will last a half century or more.

Jeff Spitler

6. **What happens at the end of the 10-year design? Do the temperatures continue to rise?**

The simulation results are based on a pure conduction analysis for the same building loads occurring year after year. And this is a heavily cooling dominated building, which would be very likely be served by a hybrid GSHP system. But, yes, in this case, the temperature will rise very slightly from year to year. In practice, it is likely to be difficult to detect such a small temperature rise. For our example, from the 10^{th} year to the 11^{th} year, the maximum heat pump EFT increases by less than half a degree Fahrenheit or about a quarter of a degree Celsuis. The annual increase decreases each year. But you can check with a design tool how much additional temperature rise would be expected.

Jeff Spitler

7. **What is the recommended number of years to design your wellfield with a known maximum entering temperature?**

Ten to twenty years would be commonly used durations for design calculations.

Jeff Spitler

8. **Has there been any research on applying slant directional drilling making multiple bore holes radially from a single point?**

This has been done in Sweden with specialized drill rigs that can be brought into the basement of a building. And over 25 years ago, a Swedish PhD student, Per Eskilson, developed g-functions that could be used to analyze such configurations. But I've never seen much interest in North America.

Jeff Spitler

9. **Not much was said about horizontal systems. Notwithstanding your aversion to rules-of-thumb, is there any quick and approximate way to determine how much horizontal ground area is needed for a ground energy exchange system?**

While I think it's quite possible for a local contractor to come up with a rule-of-thumb for residential applications, I don't have any quick approximate ways to do it – it would depend quite a bit on local ground temperatures and ground properties, for starters.

Jeff Spitler

10. **On a hybrid system, can you do nighttime free cooling with the tower to pull waste heat out of the borefield and keep from overheating the field?**

    Yes. Control strategies for hybrid ground source heat pump systems have been an active area of research for several years.

    Jeff Spitler

11. **Does a geothermal system have limits on how far the night set back temperature can be set to?**

    Probably! The thing that I've noticed in design of ground heat exchangers is that it's quite easy to specify a night setback temperature control schedule in a building energy analysis program. But if all the heat pumps are set to come off of setback at the same time, and they all run at near full capacity for an hour, it is possible to create an undesirably and unnecessarily high peak load that drives the ground heat exchanger size and cost upward. In practice, for a building with lots of heat pumps, it might be a good idea to stagger the thermostat schedules.

    Jeff Spitler

12. **Have any studies been done on how many hours a balanced system will operate within acceptable water loop temperature ranges without even circulating water through the ground loop?**

    I'm not aware of any.

    Jeff Spitler

13. **You have specified that the vertical bore pipe be tested and air sealed in the factory. Is this required since it will be difficult to keep the charge in the pipe during transportation? What is the alternative?**

    Keeping the charge in the pipe is generally not a problem if it is sealed properly. Usually when you cut into the pipe there is a release of pressure. My recommendation is to re-pressurize any pipe that does not have a factory seal to the rated pressure. Then recheck it after three hours. Don't use it unless it holds the static air pressure.

    Kirk Mescher

14. **How does methanol compare to glycol for freeze protection?**

    Methanol and glycols both work well. Methanol is much more corrosive and corrosion control is more difficult. Glycols have a little more pumping penalty but, in appropriate concentrations work well and can be corrosion inhibited.

    Kirk Mescher

15. **Grout appears to be an excellent insulation layer which is counter to the needs of a heat exchanger. Drillers complain about equipment wear with adding sand to the grout. Is a simple sand backfill acceptable depending on soils? Please discuss grouting and thermal conductivity. (Darren from Omaha)**

The thermal conductivity of Bentonite is .43 any thermally enhanced grout will be .85+. Most states require that loop wells be sealed from the surrounding aquiver with a bentonite slurry, thermally enhanced grout or cementuous grout. Proper grout pumps and grouting techniques will seal the loop well from the surrounding native structure.

The plastic pipe is a hindrance to heat transfer. Thermally enhanced grout has proven to better connect the pipe to the native soils and improve heat transfer. The purpose for all of this is to protect the ground water from any contamination and to connect the heat transfer mechanism to the native ground. This all reduces BORE RESISTANCE.

Sand, pea gravel etc can Bridge leaving gaps in the heat exchanger, increasing bore resistance and does not offer any ground water isolation protection.

Kirk Mescher

16. **What happens if a leak is notices – either during installation, or over time? Are repairs possible or does that loop need to be abandoned?**

Any leaks I have seen have been at the u loop connection at the header. That does not mean that u loops cannot leak. If a u loop does leak, it will simply need to be abandoned (pinched off and disconnected. Header leaks can be repaired by fusing the pipe properly during a repair.

Kirk Mescher

17. **What pipe size you used in case where the thermal conductivity is up to 3?**

The largest loop pipe I have used is 1 ½" and that is where I would go. One must consider the length of the bore in evaluating this question and the load profile from the building. TC is but one component of ground loop heat exchanger design.

Kirk Mescher

18. **For the Washington School Case Study – clarify typical TC values – 3 is very high.**

Typical TC is 1-2 in this area. Due to the water in the formation, a higher than normal TC was experienced.

Kirk Mescher

19. **Any considerations to evaluate the cost benefit analysis when you account for water treatment of borewater?**

The typical geo-exchange system is a closed loop heat exchanger and therefore is a "one shot" chemical treatment. Each year there may be a minor amount of bolstering but the treatment cost is nominal.

Kirk Mescher

20. **How much does a thermal conductivity bore test cost?**

In our area the test costs run from $3000-$5000 depending on location and if the tester needs to stay overnight etc. The total cost including the well is generally under $12,000.

Kirk Mescher

21. Several viewers have questions about GSHP software. What characteristics should the software have?

It must accept load profile in a format which is easily generated by the design engineer, accept multiple equipment MFG performance data, and be able to accommodate different bore configurations and types. Again, I will reference Kavanaugh and Rafferty and the ASHRAE chapter on geo-exchange to complete this answer.

Kirk Mescher

22. Where wells are installed below a building, is there concern of a frozen ground heaving a building?

I generally do not like wells under a building, but it depends on the design conditions for the fluid. I would suggest that the lowest water temp going to the well should be maintained above 35 to absolutely remove this problem from consideration. And, by the way, temperatures below that do not offer good system COP's and should be avoided anyway.

Kirk Mescher

23. Does the bore hole field need to be at a lower elevation than the mechanical room to facilitate purging if you are circulating at 2ft/s?

No. Elevation is a bit of a consideration but the connections are typically at the same elevation so the elevation change of the ground when purging loops which are 2-500 ft deep in the ground would typically have little impact.

Kirk Mescher

24. Please explain how to minimize the problem of inadequately deep burial of heat exchangers in horizontal heat exchanger fields.

It is my belief that they should be a minimum of 10 ft deep. One must stay well below the frost line in a location for them to be effective at all. Horizontal systems require vertical percolation of water to recharge the moisture around them. Clay at the top will stop moisture from getting down to the loops.

To minimize the problem,

1. *Understand the structure where the loops are being installed and make sure you are well below the frost line and that water from rain can get to the loops.*
2. *Make the horizontal bores as deep as practical.*
3. *Perform thermal conductivity tests on the installation and back out bore resistance factors to understand the connection with the ground.*

Kirk Mescher

25. How can you balance the heating/cooling loads to the ground? Wouldn't it depend on the actual space? Aren't the heating/cooling loads established and essentially defined prior to the heat pump design?

The desire is for the annual heat rejection to, and the heat extraction from the ground source loop to be as close to one another as possible. To do this, it may be beneficial to include more loads if possible, for example in a cooling dominated building, add the service water heating loads to the loop to better balance the heat extraction and heat rejection.

Mick Schwedler

26. How important are air purge ports at the manifold in a valve vault with larger fields?

Purging of well fields is extremely important. It is the only way that all foreign materials. These materials consist of air, plastic shavings, dirt, sand, etc. These things should be expunged from the system before water from the ground loop exchanger is allowed to enter into the building. Otherwise air binding, contamination in strainers, filters and heat exchangers within the mechanical equipment will result. A clean system is necessary for long life and trouble free operation.

Kirk Mescher

27. Economizer requirements are not based on unit size, but zone sizes. If the min is 54,000 BTU, but you have two 36,000 btuh units serving the space, then you need an economizer. Correct?

The ASHRAE 90.1 economizer requirements are based on system size. 90.1 also defines the term system. The 90.1 Users Manual gives examples of when economizers are or are not required.
Example 6-MM in the 90.1-2007 User's Manual states,

> *"…if two sets of economizer devices are required (as would be the case, for instance, if the two air-handlers did no share a common mixed air plenum), each air handler would be considered an individual system and economizers would not be required."*

Please consult the standard and User's Manual of the proper vintage (2007 or 2010) to determine if your specific system is required to have an economizer

Mick Schwedler

28. How does GSHP compare to efficient centrifugal chillers for cooling? (Andy from Huntsville, AL)

This comparison must be done by making a full system and energy analysis for the specific project in its location. Both systems can be very energy efficient if designed well. For the chilled water system it may be desirable to follow the ASHRAE GreenGuide suggestions to reduce flow rates (and subsequent pumping energy) by increasing both chilled and condenser water temperature differences.

Mick Schwedler

29. What pipe material is typically used in the underground portions?

High density poly-ethylene pipe is normally used in the ground-source loop.

Mick Schwedler

30. In extreme cold climates, is there an additional heat source for GSHP?

In projects located in cold climates it may be beneficial to have a back-up heat source.

Mick Schwedler

31. What are the recommended antifreeze types if you need to use an antifreeze? Is methanol ever recommended for use in such a system? Methanol is a dangerous chemical and highly flammable; any recommendations for storage and handling of methanol?

We do not believe that ASHRAE makes recommendations concerning specific antifreeze fluids. That is the purview of the design team. With that said the most commonly used antifreeze is glycol. Information on use of secondary coolants is in the 2009 ASHRAE Handbook – Fundamentals, Chapter 31.

Mick Schwedler

32. What sort of antifreeze is recommended if it is needed? What sort of storage is needed for the antifreeze?

We do not believe that ASHRAE makes recommendations concerning specific antifreeze fluids. That is the purview of the design team. With that said the most commonly used antifreeze is glycol. Information on use of secondary coolants is in the 2009 ASHRAE Handbook – Fundamentals, Chapter 31.

As for storage, all local safety codes should be followed for all chemicals used in a system.

Mick Schwedler

33. What are some different control options for a cooling dominant climate with a hybrid GSHP cooling tower system? When does the cooling tower come on?

Operators of these systems commonly begin to use the closed circuit cooling tower in the spring. This allows the heat pumps to operate at elevated temperatures during the heating season – resulting in higher efficiency. It also reduced the loop temperature prior to the peak cooling season – resulting in better cooling efficiency. Alternatives could include operating the fluid cooler at night, then it is more beneficial due to reduced outdoor conditions.

Mick Schwedler

34. Has anyone used a geo exchange system with active beams? If so, what problems have they encountered?

We have no personal knowledge of geo-exchange systems with active beam systems. With any system humidity control, ventilation, comfort, and energy use should be examined, and the applicable ASHRAE Standards should be followed and Handbook information may be consulted.

Mick Schwedler

35. What is the relative percentage design-hour effort for GSHP systems in comparison to a traditional packaged, split, or chiller-boiler system designs?

We hesitate to give answers on design-hours. The first time any person uses a new technology there is a learning curve and it takes more time. If unfamiliar with the process, it is likely that the design of the ground loop will add to the project design time needed.

Mick Schwedler