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Geothermal or Ground Source Heat Pumps Part II: Costs and Design Considerations

COST

Geothermal or Ground Source Heat Pumps (GSHPs) are more costly to install initially than regular heat pumps but save money in operating and maintenance costs. Since outside parts of the system are below ground and protected from the weather, maintenance costs are low. Investments can be recouped in as little as three years. There is a positive cash flow, since the energy savings usually exceeds payment on the system.[1]

System installation drives the final cost and depends on whether the system will be drilled vertically underground or the loops will be placed in a horizontal fashion a shorter distance below ground. The length of the loop depends upon the type of loop configuration used; the buildings heating and air conditioning load; local soil conditions and landscaping; and the severity of the climate.

Loop style and total trench/bore length are obtained from software design. The goal is 2.5 - 3 gpm flow per ton of capacity (minimum of 2.25 gpm). The Loop circuiting is designed for low pressure drop, good heat transfer, and 1 circuit per ton of capacity in 3/4". Headers are piped in reverse return to even out pressure drop in parallel circuits

Soil type affects the necessary loop field size because different types of soil have different abilities to absorb energy. Extremely dense soils, such as rock and clay, have the ability to hold a great deal of heat and can therefore transfer more heat. Sandy soils absorb far less heat and therefore require a larger loop field. As a general rule of thumb, the drier the ground the larger the loop field required.[2]

Site conditions can require variation from "normal" design practice. Space availability may require boreholes that are closer together, but deeper. Ground conditions may dictate that holes not be deep enough to accommodate a nominal ton (12,000 BTUH) of capacity, or they can be deeper and accommodate more than a nominal ton of capacity.[3]

Larger buildings requiring more heating or air conditioning generally need larger loops than smaller buildings. Buildings in climates where temperatures are extreme generally require larger loops. The cost of drilling will vary depending on the terrain and other local factors. There will also be installation charges for electrical work, ductwork, water hook-up, and other provisions or adaptations that are required.[4] The reduced peak load requirements would allow utilities to serve more customers and to lower fixed costs per customer, thus offsetting some increased variable costs. This would result in less cost per kilowatt, since fixed investment for new capacity is high.[1]

Well fields must be designed to provide necessary heat source/heat sink capacity required by the system's heat pumps, and to allow the earth to adequately dissipate surplus rejected heat or replenish the effects of absorbed energy over an annual cycle. Grid type well field design must consider the effects of system operation over the expected life of the system. Failure to consider the long term impact of heat rejection or absorption can result in distortion of far field temperatures over time. This distortion can cause cooling dominant loop maximum temperatures to go above design parameters, reducing capacity and efficiency. On heating dominant systems, temperatures can fall below design parameters, with the same results. In extreme cases, loop temperatures can reach levels that will cause system heat pumps to be shut down by their internal safety circuit.[4]

It is critical to 'right size' the system. Systems are generally sized in tons. An undersized system will strain the reach of the desired heating and cooling needs.

This could result in high utility bills as the heat pump tries to make up for its size by using more electricity. An over-sized system can produce too much airflow at a given time resulting in extremely short run times. Short run times cause the system to cycle on and off frequently reducing its efficiency. A geothermal heat pump is expected to be 300%-400%[5] efficient, but too large of a unit causes significant decreases in this efficiency and results in higher electric bills. An over-sized unit will also have a negative effect on the comfort level of the occupants. During the hot and humid summers a short run time will cool a room but fail to remove the air's humidity. Some pieces of equipment operate for a fixed period of time and if the equipment is over-sized it can overshoot the thermostat setting causing the space to overheat in the winter and become too cold in the summer.

DESIGN CONSIDERATIONS

For a vertical ground coupled heat pump the following 'rules-of-thumb' may be applied.

- **Land -** Generally requires 250-300 ft^2 of land area/ton
- **Length** - Bore holes are typically 150 ft. to 450 ft. in length. Typical systems require 150 ft. - 200 ft. of bore/ ton of peak block load.
- **Spacing** - At 20 ft bore spacing, a shallow field of 150 ft bores requires approximately 1 acre / 100 tons of peak block load
- **Grouting** provides thermal conductivity and environmental benefits.
- 3/4" pipe - One vertical bore/ton. One circuit and 3 gpm flow per ton.
- Bore/ton: Cold climates 150 ft/ ton; Warm climates 230 ft/ ton

Pipes and Fittings:

- High Density polyethylene (HDPE)pipe
- Socket or Butt heat fusion joints are stronger than the pipe wall itself
- 3/4", 1", 1-1/4", 1-1/2", and 2" sizes common

Vertical Bore Grouting

- Grouting of Vertical Bore Holes is required
  - Seal Borehole to Protect Underground Aquifers
  - Maintain Thermal contact between pipe and ground
  - Allow movement of pipe
- Grout Types include Bentonite or Cement based or Thermally enhanced
  - Pressure Grouting from the bottom up is recommended

Pump Options:

- Redundant Alternate - Size single pump to handle complete circulation install duplicate redundant pump in parallel and control alternately
- Redundant Staged - Install two pumps in parallel that can handle load and stage them with alternating controls
- Variable speed pumps with solenoids at each unit
- Distributed pumping - Install pumps at each heat pump with single pipe system and continuous circulation

Prior to starting loop field grid design preparation the Certified Geothermal Designer[6] should:

a. Calculate heat loss and heat gain
b. Select equipment
c. Select loop design temperatures
d. Analyze thermal conductivity test(s) to determine:
   - Far field (ground) temperature, Ground thermal conductivity, Ground thermal diffusivity, Thermal conductivity test bore well logs
e. Evaluate pipe diameter options
f. Evaluate grout options
g. Define loop field space availability
h. Define borehole depth possibilities
i. Define environmental and code requirements

Part III of this series will examine the advantages and disadvantages of the various GSHPs and the importance of following International Ground Source Heat Pump Association Standards in design and installation.

[1]The International Ground Source Heat Pump Association (IGSHPA) http://www.igshpa.okstate.edu/index.htm
[2]http://www.geothermalgenius.org/how-it-works/sizing-a-geothermal-heat-pump-system-design.html
[3]Rawlings, P. Premier Issue Geo Outlook Online Earth Insights http://www.igshpa.okstate.edu/geothermal/insights.htm
[4]California Energy Commission http://www.consumerenergycenter.org/home/heating_cooling/geothermal.html#compare
[5]http://www1.eere.energy.gov/femp/pdfs/groundsource_heatpumps.pdf
[6]credentialed through the Association of Energy Engineers (AEE), with joint sponsorship by the IGSHPA and the Geothermal Heat Pump Consortium (GHPC)