Designing AE Systems

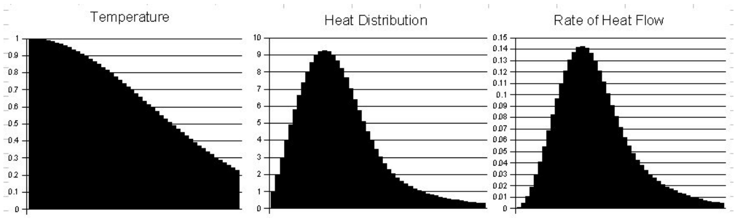
Atmospheric Energy (AE) systems are easier to design and to use than GSHP systems because you are really designing the container for holding the energy (rather like a gas tank) and you have direct control over how much energy you choose to store and over the timing of the heat injection.

The depth of the boreholes may be up to 20 times less than that for GSHP's, but against that there is a need to drill six holes as opposed to just the 1 to 4 holes that are normally needed for GSHP's.

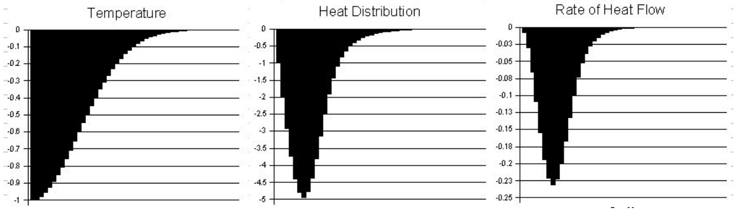
Borehole spacing The spacing between the injection holes and the extraction holes is primarily determined by the conductivity of the rock, or more precisely by its thermal diffusivity [conductivity/(density x specific heat)] (m^2/s).Typical values are:

Basalt	0.059
Granite	0.086
Gneiss	0.106
Quartzite	0.255
Clay	0.082
Limestone	0.091
Sandstone	0.143

Heat injected into a high diffusivity material spreads out quickly, which means that the spacing is increased, and since a larger mass of material is engaged the potential heat storage capacity is increased. By early winter the temperature distribution, heat distribution and the area of maximum heat flow are shown in the plot below. The outer boreholes should be located in a band of 1.5 to 1.8 times the distance from the center to the center of the heat flow peak. However, the position of that peak can be difficult to determine in advance so the design must allow for variances in the actual location. That can be accomplished by adjusting the timing of the heat injection, starting the process later in the summer if the outer boreholes are too close. In extreme cases some of the heat can be injected in the fall, using inexpensive off-peak electricity as explained below.



In the outer boreholes the temperatures fall well below the ground's ambient temperature so the graphs are mirror images of the injection graphs, but compressed because of the shorter period between the start of the process and the heat interaction. The spacing should make the positive heat flow peak from injection overlap the negative heat flow peak from the heat extraction to achieve maximum delivery of heat during the coldest part of the winter.



Borehole depth The borehole depth is determined by the efficiency of the ground heat exchanger, and also to a degree by the diffusivity of the ground. The ground heat exchangers must follow the European practice of using four tubes per borehole, high conductivity grout and tube spacers to achieve higher efficiency. The greater efficiency is possible in the first place because the ground heat flow is much higher during the period of maximum demand. The efficiency is further enhanced in AE systems by paying closer attention to thermal short circuiting between the tubes and by generating a vertical thermal gradient that improves the heat exchange efficiency. Typically the borehole depth is less than half of that required by a GSHP because of these differences, and since the boreholes are the most expensive component of such systems that results in much lower construction costs.

The borehole depth depends on the winter energy demand. For larger buildings or for multiple homes the spacing between the boreholes is not altered. You simply make the boreholes deeper in proportion, typically with an upper limit of about a dozen homes. There are other designs that can be applied to larger buildings.

The effects of water Water that is fixed in place in the ground will change the thermal properties (like conductivity and heat storage capacity) but will not otherwise interfere with the operation. If the ground is permeated with water that is flowing then that water will carry away heat that has been injected, making heat storage difficult or impossible. However, the water also brings heat to the boreholes so they will continue to function properly, and the required borehole length will be about the same because the extraction capacity per metre of length will be similar.

The more common situation is where water is flowing at one or just a few strata, for example between layers of sedimentary rocks or along a fault line. In that case, the ground that is close to those strata will have its heat replenished by the flowing water and the dry rock will continue to store heat, so the system will again function properly.

Rock is generally preferable to soil. If the soil is wet then water flow and convection will prevent heat storage, and if it is dry then soil typically has poor thermal conductivity, making it unsuitable.

The heat injection systems The primary heat injection system is an ordinary air heat exchanger, physically similar to the radiator in a car. It transfers heat that has been extracted from the air into the antifreeze solution which carries it into the ground, where the heat is transferred into the rock for storage.

There are in addition two electric heaters, one in the heat injection system and one in the extraction system. The former can optionally be used to carry out a Thermal Response Test at the time of installation (to determine diffusivity and exchange efficiency) and it can also be used to build up the quantity of heat stored in the fall, particularly if the AE system has been installed too late in the year to inject summer heat.

The second electric heater is installed in the heat extraction circuit, just ahead of the exchanger for the heat pump. Ontario is about to adopt a dual pricing scheme under which electric power will cost 2.7 cents at night and 9.3 cents during the day. The ground can thus be “trickle charged” at night via cheap electric power and that heat can be recovered as it is needed, for example during exceptionally cold days. These two heaters also provide insurance against situations where the heat store is undersized or the extraction boreholes are misplaced. There is often considerable uncertainty about the nature of the rock before the holes are drilled so this feature makes it unnecessary to over-design the system just in case the rock is not what was expected.

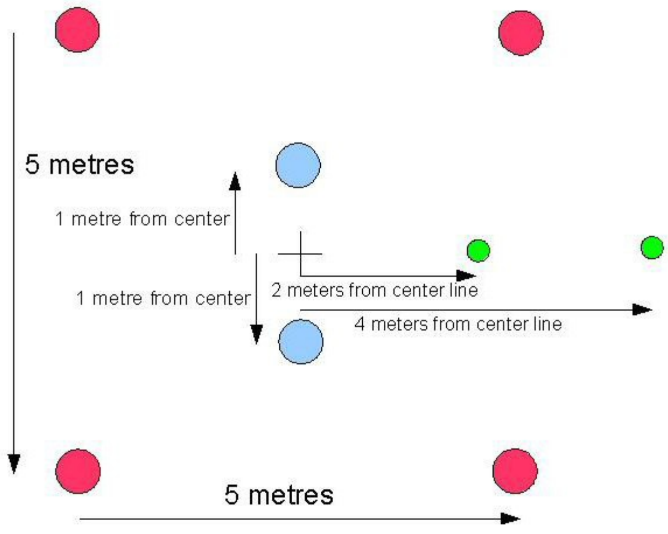
Time of installation An AE system can be installed at any time of the year, although the preferred time is in the spring, allowing for the normal heat charge step. If the system is installed later in the year any air-heat deficit for that initial year can be made up by the normal heat stored in the ground (as with a GSHP) plus the electric heat that can be injected, so for that first year there is only a modest cost penalty.

Heat pump design The heat pump itself is identical to those used for ground source heat pumps. It will operate with much higher efficiency because there will always be sufficient heat supplied to its heat exchanger, even during a long winter cold spell, and because the input temperature will be higher, resulting in a higher COP.

Controls The user has a large degree of control over the system. The air-heat exchange can be adjusted to control the amount of heat that is injected into the ground. The timing of that injection can be adjusted to optimize the timing of the heat arrival at the extraction sites. The electric heaters can be utilized to handle exceptional circumstances as described above. If there are changes made to the building the heating system can be adjusted to handle those changes. Even long term climate changes can be accommodated.

In areas that have milder winters, for example on the BC Coast or in much of the US, there is less need of storage, and in those areas heating systems commonly draw heat directly out of the winter air. In such circumstances the AE system can be operated as a hybrid system, using direct air-heat on mild winter days and stored heat on cold days, resulting in a smaller and less expensive heat storage system.

Costs The heat in the summer air is free and is abundant in all parts of Canada. The use of AE systems not only provides a massive source of energy that is presently not utilized but it also provides a means of achieving conservation and demand management on a large scale. For the homeowner the benefits are stable and very low heating and cooling costs at a much lower capital cost than other renewable energy alternatives like GSHP's or solar power.



A typical layout for the boreholes (shown with two extra holes drilled for temperature profile tests)

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