Balancing Power and Energy Outputs

In systems that store or extract heat from the ground the system designer has to meet two separate objectives :

(1) It must provide sufficient power to heat the building on the coldest winter day, and
(2) It must provide enough energy to heat the building throughout the winter

Quite commonly both requirements are compromised by using another heat source to supplement the heat pump's output, for example via an electric heating coil or a natural gas furnace. Even when the heat pump meets all of the heating requirement most of the time, there is still a big penalty to pay because it implies that the COP jumps from a substantial value, perhaps 3.5, right down to 1.0, so there is a heavy power drain and a rapid diminution of the effectiveness of the system. However, for the purposes of this discussion we will assume that the system has been designed so that it never requires such a supplemental heat source.

Cold countries vs. warmer ones In a cold country like Canada GSHP's typically use deep boreholes containing rudimentary heat exchangers, such as simple U-tubes that lack spacers to hold the tubes against the borehole walls and employing grouts that have relatively low thermal conductivity.

In warmer countries, as in central Europe, double U-tube or coaxial heat exchangers are more commonly used, along with the other measures that boost the heat extraction efficiency of the heat exchanger.

Both designs meet their respective objectives. In a cold country the winter energy demand is greater so the heat exchanger extracts heat from the surrounding ground, creating a thermal well that grows until the power capacity (Objective 1) becomes the limitation. Using double U-tubes etc. does not provide any advantage because the power limitation is the consequence of inadequate heat flowing through the surrounding ground. The solution has therefore been to drill deeper holes and economize on the heat exchangers, which may have an extraction capacity of only 20 watts per metre.

In a warmer country the winter energy demand is much smaller but it can still get cold enough to require a substantial power output, so the extraction efficiency is the more important factor. Moreover, the borehole need not be as deep if that efficiency is higher, and since drilling the borehole is the most expensive part of the construction cost it is more economical overall to spend more on the heat exchanger to reduce the drilling cost.

The power capacity of the heat exchangers can range up to 90 watts per metre. This is one of the reasons why GSHP's are more commonly used in Europe than in Canada.

Combining power and total energy requirements
AE systems address both requirements, making it possible to use relatively short ground heat exchangers that meet Objective 1 and that still meet Objective 2. Like the European heat exchangers they use four tubes to double the heat exchange surface, plus spacers and high conductivity grout. However they further improve on the efficiency by reducing the thermal short circuit between the upflow and downflow tubes, and they create a thermal gradient in the ground that makes the extraction more efficient because as the fluid rises in the tube the surrounding ground temperature also rises, maintaining a constant heat flow along the length of the tube. These revisions are expected to increase the power extraction rate to 115 watts per metre, but that has not yet been experimentally demonstrated (Sept. 2008).

Improving the heat exchanger efficiency is a waste of effort and money if there isn't sufficient heat in the ground to begin with. It is absolutely essential to ensure that the rate of ground heat flow is always sufficient to maintain the power extraction objective. In an AE system that need is met by providing a central heat store from which the heat flows into four external heat extraction wells. There is a substantial amount of heat (extracted from the air) in that central area and the geometry of the heat flow pattern becomes stable as the winter progresses so the heat flow from the center to the extraction boreholes is never starved. Moreover, because most of the heat is coming from the center the diameter of the thermal well stabilizes, so that too is capable of supplying more heat throughout the winter.

To meet Objective 2 the designer needs to calculate the amount of heat that is available from both the central area and the four extraction wells. If you know the temperature of the ground that is a simple calculation involving the density and specific heat of the ground material, but since this temperature changes with position and time the calculation requires a finite increment analysis procedure.

Conclusion People who build traditional GSHP's in cold countries often find it difficult to believe that such large improvements in power and energy supply can be achieved with AE systems that use very similar components. However, injecting heat into the ground to meet Objective 2 is a simple process, and with that heat flowing into the more efficient extraction tubes Objective 1 is equally achievable.