Column

Observations on ground-source heat pump systems in North America and Scandinavia

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Ground-source heat pump (GSHP) systems are commonly used to provide energy-efficient heating and cooling for residential, commercial, and institutional buildings in both North America and Scandinavia. Since the 1970s, there have been active research programs in both Sweden and the USA. Over time, there has been significant knowledge exchange going on between the two countries in such areas as methods for analysing and modelling GSHP systems and measuring ground thermal properties. Nevertheless, as an American researcher who has been traveling back and forth between the two countries for twenty years and who recently spent a year in Sweden, I find that there is a remarkable lack of knowledge about the differences in how the technology is applied between the two countries. This works two ways – not only do researchers from one continent not understand how the technology is applied in another continent, we often don't understand what is unique or different about our own technological solutions. In hopes of mitigating, at least slightly, these misunderstandings, I offer the following observations about ground source heat pump systems in North America and Scandinavia.

Perhaps it is a trivial observation, but residential buildings in Scandinavia seldom use mechanical cooling while in much of North America both residential and commercial/institutional buildings require both heating and cooling. This certainly explains some of the differences, such as American use of reversible heat pumps. Perhaps it also indirectly explains the near-universal preference of Scandinavians for quiet hydronic heating systems while Americans tend to accept more noise from their heating and cooling systems.

Whatever the cause, residential ground source heat pumps are predominantly water-to-air in North America and water-to-water in Scandinavia. In both regions, ground source heat pumps use a water/antifreeze mixture circulated through ground heat exchangers as the source for a vapor compression heat pump cycle. Beyond that commonality, there are quite a few differences, some of which are summarized in Table 1 for typical residential GSHPs. To be sure, advances in technology are ongoing – e.g. GSHPs that have dedicated domestic water heating have recently become available in North America.

For commercial heat pump applications, it appears that distributed heat pump systems predominate in North America and central heat pump systems are predominant in Scandinavia.

When I started looking into Scandinavian residential heat pumps, it took some digging to understand how domestic hot water heating is done – with a water-to-water heat exchanger rather than a refrigerant-to-water heat exchanger. But the most surprising difference from my perspective is not the technology per se, but the availability of data from manufacturers. For design of ground heat exchangers, it is necessary to quantify the heat transferred to and from the ground and in North America, simple equation-fit models of heat pumps are often used to translate the heating and cooling loads met by the heat pump to heat extraction and rejection rates imposed on the ground. In North America, development of such

Characteristics	North America	Scandinavia
Source medium	Water/antifreeze mixture	Water/antifreeze mixture
Load medium	Air	Water
Domestic water heating capability	Limited to water heating with desuperheater; coincident with compressor operation.	Integrated domestic hot water (DHW) tank.
Internal valves	Refrigerant-reversing valve switches between heating and cooling mode.	Diverting valve switches hot water from heat pump condenser between radiators (for house heating) and outer shell of DHW tank.
Data availability	Manufacturers provide tabulated data sets and correction factors sufficient for developing equation fits of performance that can be used in ground heat exchanger design.	Only one or a few data points are provided by manufacturer.

Table 1. Some characteristics of typical ground-source heat pumps used in North America and Scandinavia.

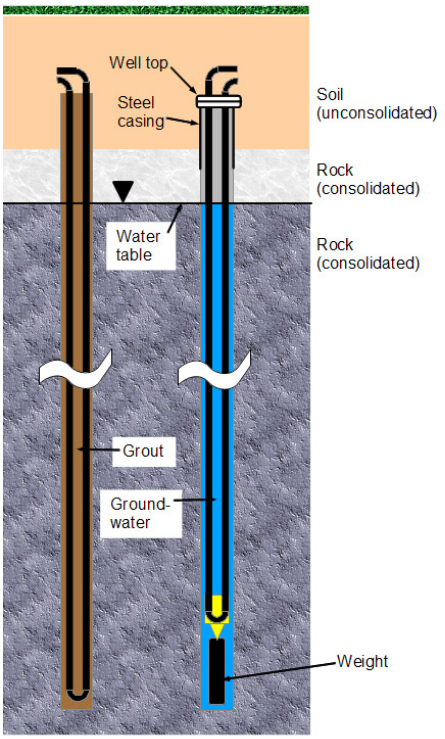

Figure 1. Different types of boreholes.

equation-fit models is supported by the availability of rich data sets (typically 60-150 combinations of flow rates and entering fluid temperatures) provided by manufacturers for each heat pump model. In Scandinavia, manufacturers provide only one or a few data points, rendering development of such an equation-fit model impossible. From my perspective, this is a hindrance to ground heat exchanger design.

For the most part, boreholes in North America (Figure 1, left) are backfilled with grout in order to protect any groundwater at lower depths from surface pollutants. Because of the often shallow bedrock and high groundwater levels in Scandinavia, boreholes are generally constructed like water wells, with steel casing lining the borehole down into the bedrock. Then the U-tube is weighted and suspended in the borehole. (Figure 1, right.)

Groundwater-filled boreholes tend to perform well, with low thermal resistance, though the thermal resistance varies with heat transfer rate and annulus temperature. While it is difficult to make comparisons of different technologies in different countries, groundwater-filled boreholes in Scandinavia are significantly more expensive to install than grouted boreholes in the USA. In some Scandinavian locations (e.g. the west coast and south of Sweden) where the distance to bedrock is high, the cost of groundwater-filled boreholes can be prohibitive and grouted boreholes might be considered.

Borehole heat exchangers tend to be deeper in Scandinavia, with the average borehole depth being 171 m in 2013[1]. I'm not aware of anyone compiling such statistics for North America, but my impression is that the average would be closer to 80 m, though in recent years we've started to hear more about much deeper boreholes.

One other observation is that in North America where geological conditions are similar to Sweden, standing column wells are often used. These may have potential for Scandinavian application. Likewise, in those regions in North America, it may also be feasible to use groundwater-filled boreholes with suspended U-tubes for some applications.

The differences in heat pump technology and ground heat exchanger design as utilized in North America and Scandinavia are substantial. Some differences are inherent, due to climate and geology, but others deserve further investigation.

References

[1] Gehlin, S., Andersson, O., Bjelm, L., P.G. Alm, and J.E. Rosberg. 2015. *Country Update for Sweden*. Proceedings World Geothermal Congress 2015, Melbourne, Australia, April 19-24, 2015.