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| Abstract Example/Template |  |

**Calculation Tool for Effective Borehole Thermal Resistance**

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Ground source heat pump systems are energy-efficient and environmentally-friendly means of providing building heating and cooling. Design of the ground heat exchangers for these systems can be challenging for several reasons including estimation of the borehole thermal resistance. The borehole thermal resistance – that is, the thermal resistance between the fluid in the U-tube and the borehole wall – is a key performance characteristic of a closed-loop borehole ground heat exchanger. Lower borehole thermal resistance leads to better system performance. Since the original identification of the concept of borehole thermal resistance by Mogensen (1983), there have been numerous methods proposed for calculating this in the case of grouted boreholes. Either a single or double U-tube heat exchanger involves multiple eccentrically placed cylinders within another cylinder and therefore leads to difficulties in analyzing the conduction heat transfer problem. Therefore, a number of simplified methods, which are usually accurate only over a narrow range of geometries, have been developed. The multipole method developed by Claesson and Bennet (1987) is accurate over a wide range of geometries, but is mathematically challenging to implement.

For ground-water filled boreholes, several authors have shown that the borehole thermal resistance can vary with both heat transfer rate and annulus temperature due to variations in the buoyancy-driven flow and heat transfer. However, no convection correlations have been available until recently and therefore designers have had to rely on thermal response tests for similar boreholes.

When a thermal response test is used to measure borehole thermal resistance it inherently includes the effects of internal heat transfer between tubes in the ground heat exchanger, and is referred to as the effective borehole thermal resistance. Hellström (1991) developed analytical relationships between the local borehole thermal resistance and the effective borehole thermal resistance.

An Excel/VBA spreadsheet was developed that contains an implementation of the multipole algorithm and can calculate resistance using any order multipole for grouted boreholes. For groundwater-filled boreholes, we utilize a recently published correlation (Spitler, et al. 2016) for the natural convection in the borehole annulus. The effective borehole thermal resistance can be determined using either of Hellström’s formulations.

This paper presents a new tool for calculation of borehole thermal resistance for both grouted and groundwater-filled borehole ground heat exchangers. It avoids the use of simplified models for grout resistance and is the first tool to be able to calculate borehole thermal resistance for groundwater-filled boreholes based on an experimentally-determined convection correlation.

Please keep abstract to one page.