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GROUND THERMAL CONDUCTIVITY TESTING: EFFECTS OF GROUNDWATER ON THE ESTIMATE.

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ABSTRACT

Heatpumps are increasingly used as an economical and sustainable source of heating and cooling for buildings. A heatpump tranfers thermal energy, from a relatively low temperature to a high temperature, with a very high efficiency. Efficiencies of 4 or more are common, where for every kW of electricity 4 kW of heat or cool is provided. Due to this, the EU and also many individual countries, view heatpump technology as a sustainable technology that helps achieving the long term goals of reducing primary energy use and greenhouse gas emmisions. Although there are other systems, we consider here exclusively the use of the ground by closed-loop heatexchangers to a maximum depth of ca. 200 meters.
Although the ground source heatpump is a proven technology, already in use for over 40 years in Europe and the US, the design is by no means straightforward. Especially when trying to achieve higher heat transfer rates, with a limited area for the groundsource heatexchanger installation, many design parameters become critical. Especially the site-typical ground thermal conductivity is a critical parameter, as it affects the design substatially and is difficult to estimate from geological information (drill logs and soil type specific conductivities) only. In view of this, several In Situ Geothermal Response Tests have been developed [1,2,3].
The purpose of an In Situ Geothermal Respons Test (GRT) is to estimate the ground thermal conductivity and borehole reistance of a groundloop heatexchanger used for heating and/or cooling buildings. Test results consist of a measured temperature response (increase or decrease, depending on the test) to an imposed power load. The test results are interpreted acoording to a line-source approach or with the use of a numerical model. In the fist case the power load is required to be constant throughout the test.
However, it should be recognized that the In Situ test does not necessarily test the ground thermal conductivity only, other factors influence the results as well. Especially groundwater effects may be important.
Groundwater can affect the ground thermal conductivity estimate in two manners. First of all, the naturally occuring groundwaterflow will transport groundwater with an undisturbed ground temperature. This groundwater may recharge the store (or, in the case of a high temperature heat seasonal heat store, deplete the store of injected thermal energy). In the Response Test this effect can be noticed as the test result will not converge to a stable estimate of ground thermal conductivity, but will tend to increase with time. We conducted two controlled experiments, one with and one without induced ground water flow. The results of this test establish that the change in the response curve can actually be attributed to groundwaterflow. Subsequently the results were used to calibrate a numerical model with which several groundwater flow regimes can be evaluated.
Another effect are local convection currents, generated by the energy pulse. These convection currents will be generated normally only during heat-injection and will especially influence the borehole resistance. We, for instance, observed increasing thermal conductivity estimates with test on the same borehole when power rates were increased. We also noted differences between unsaturated and saturated boreholes on the same location. Currently we are elaborating a numerical model to study and quantify those effects.
It is evident that the evaluation of the Geothermal Response Test results, in view of possible groundwater effects, is important. This is especially the case when the values are used as specific *thermal conductivities* for a location. When using the results for a design, the effect is not directly a problem as long as the test temperature bandwith is comparable to the operating temperatures in the groundloop. Understanding and quantifying the effects of natural groundwaterflow and convection will enable us to incorporate these effects explicitely in the groundloop design procedure. Using that information higher energy fluxes can be accomodated with confidence by the engineer, without compromising the longevity of the system.

[1] Austin, W.A. (2000). Development of an In-Situ System and Analysis Procedure for Measuring Ground Thermal Properties. ASHRAE Transactions 106.

[2] Van Gelder, A.J., Witte, H.J.L., Kalma, S., Snijders, A. and R.G.A. Wennekes (1999). In-situ Messungen der thermische Eigenschaften des Untergrunds durch Wärmeentzug. IN: T. Hitziger (Ed): OPET Seminar “Erdgekoppelte Wärmepumpen zum heizen und Klimatisieren von Gebäuden. 109 pp.

[3] Eklöf, C. and S. Gehlin (1996). TED – A mobile equipment for Thermal Response Tests. Master’s Thesis 1996: 198E. Lulea University of Technology, Sweden.