Thermal Conductivity Measuring Method for Water Filled Open Boreholes

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Abstract

For designing of Ground Source Heating Systems (GSHS) Thermal Response Tests (TRT) are used for a long time. TRTs generally provide a profound basis for the final implementation of a GSHS. They obtain the effective thermal conductivity and thermal resistance of a borehole. Until today several TRT types have been introduced and defined as Geothermal Response Test (GRT), Enhanced GRT (EGRT), Constant Heat Flux TRT (chTRT), Constant temperature (ctTRT) etc.. These models mainly focus on closed heat exchangers in shallow boreholes. However, recent developments in medium depth drilling technologies make deeper boreholes more economic. Furthermore, advanced methodologies for obtaining thermal conductivities in deep and open boreholes are progressing. In this study, we introduce a new simple thermal conductivity obtaining methodology that can be used for deep and open boreholes. Generally, TRTs are applied with the circulation of water inside pipes or immersing probes in water. In case of water circulation in deep boreholes, different heat flux values will be attributed to different layers. Moreover, by introducing a constant heat flux similar to conventional TRT into water-filled boreholes or water-filled pipes, convective movements of water will occur and thermal conductivities cannot be obtained. However, immersed probes as a heat source might prevent water convection cells inside a pipe or a borehole. In deep boreholes, the heat flux is depended on the thermal conductivity of each layer. Thus, deep boreholes require a discrete heat introduction into every single layer of different thermal conductivity in order to keep the temperature constant. The thermal conductivity of each layer can be approximated and integrated over the total length of a deep borehole. This effect is analytically and numerically investigated in this study.

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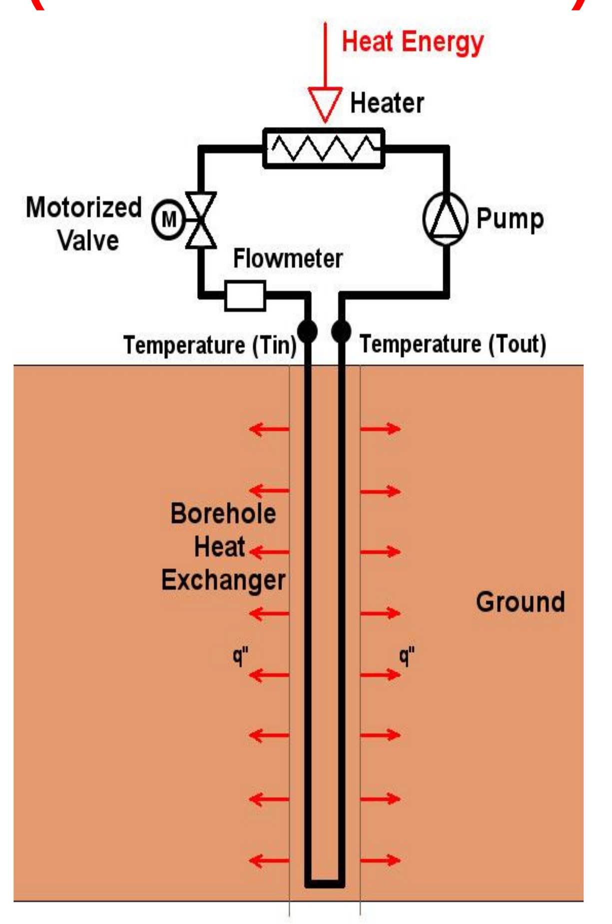
Highlights

- Probe TRT method is applied for determining thermal conductivity.
- Constant temperature is used to avoid convective movements of water.
- Thermal conductivities of layers are predicted from the slope of inverse of heat power in log time axis.

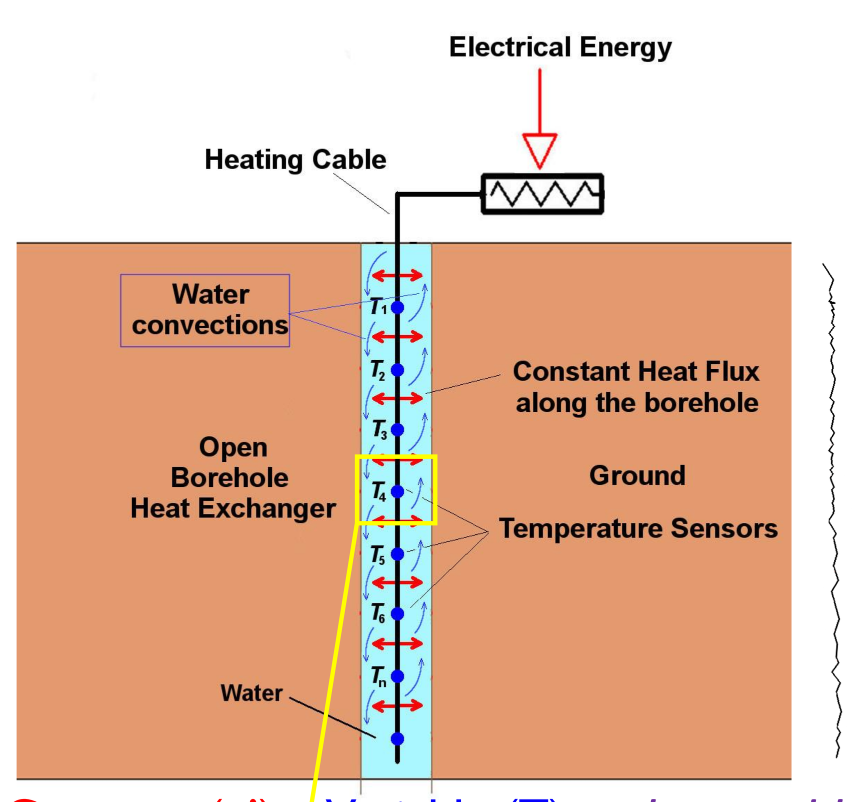
Methodology

Conventional TRT (Constant Heat Flux)



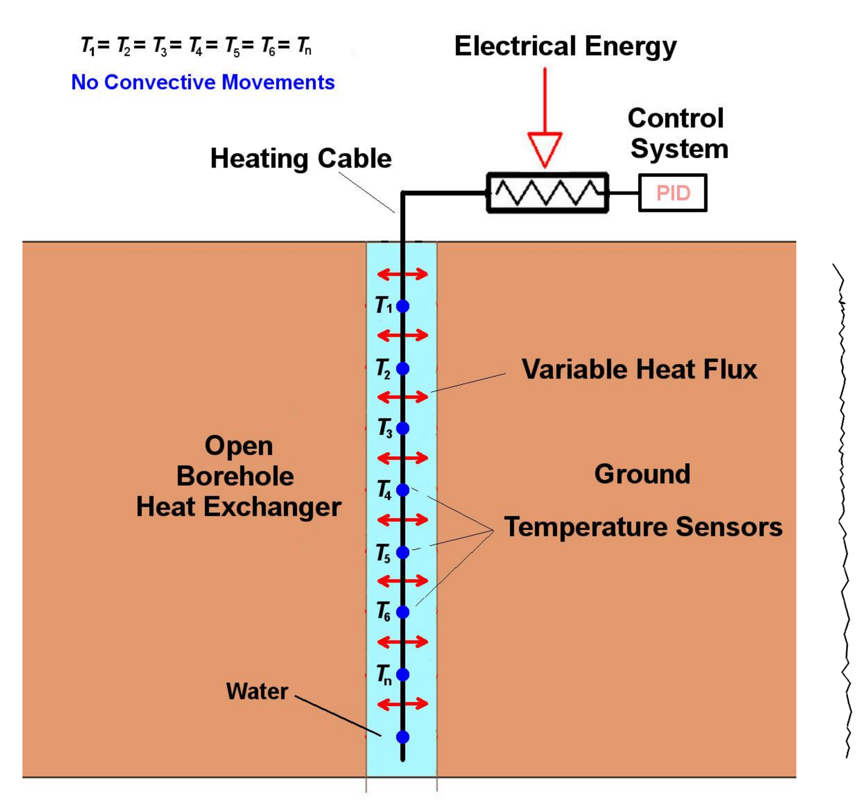
Constant (q') + Variable (T) ⟶ *k*

Constant Heat Flux in Probe Method

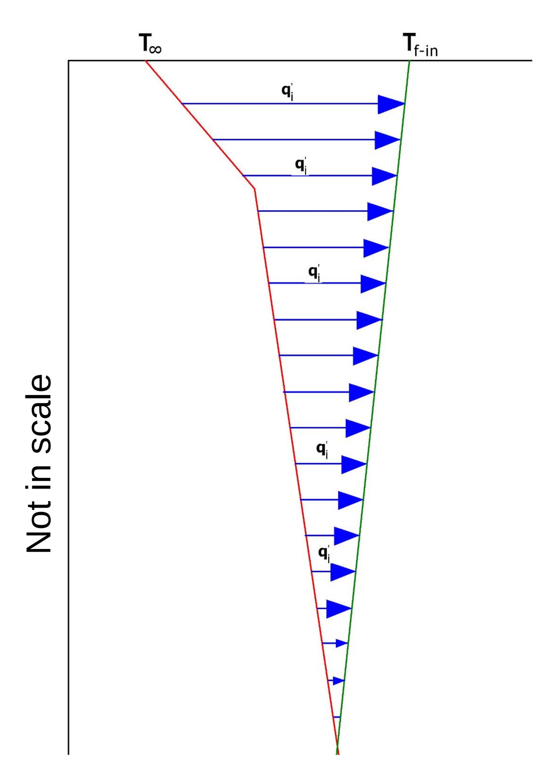


Constant (q') + Variable (T) ⟶ *layered k*

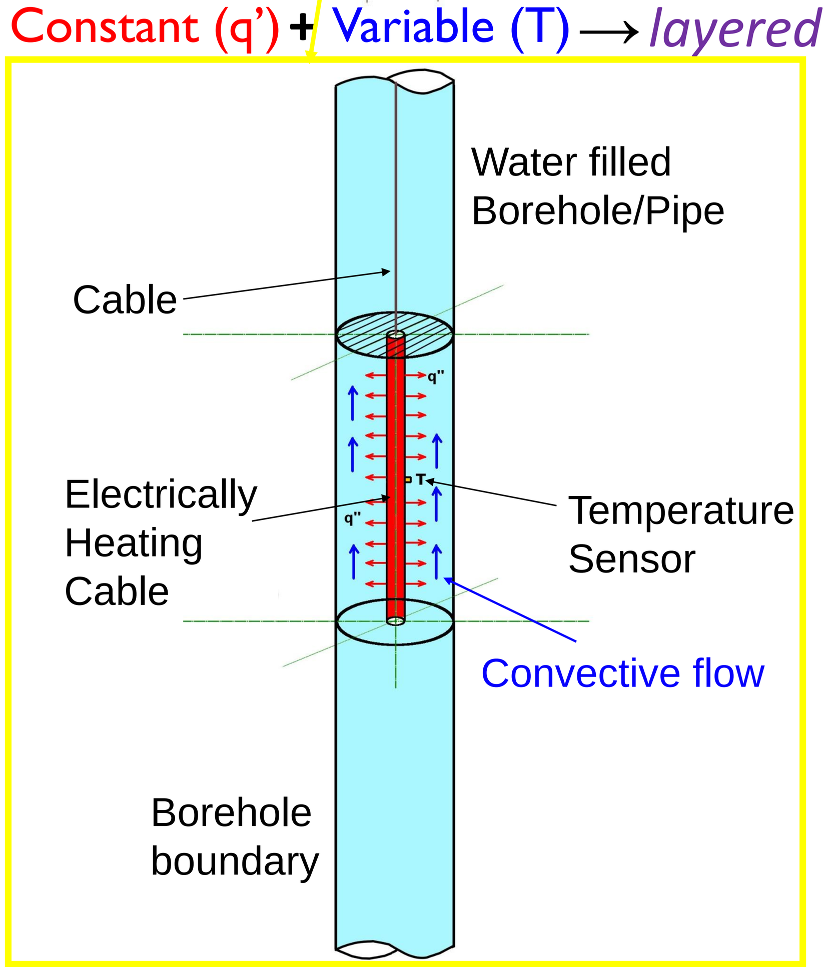
Constant Temperature in Probe Method



Constant (T) + Variable (q') ⟶ *layered k*



In conventional TRT heat fluxes along the borehole are not same.



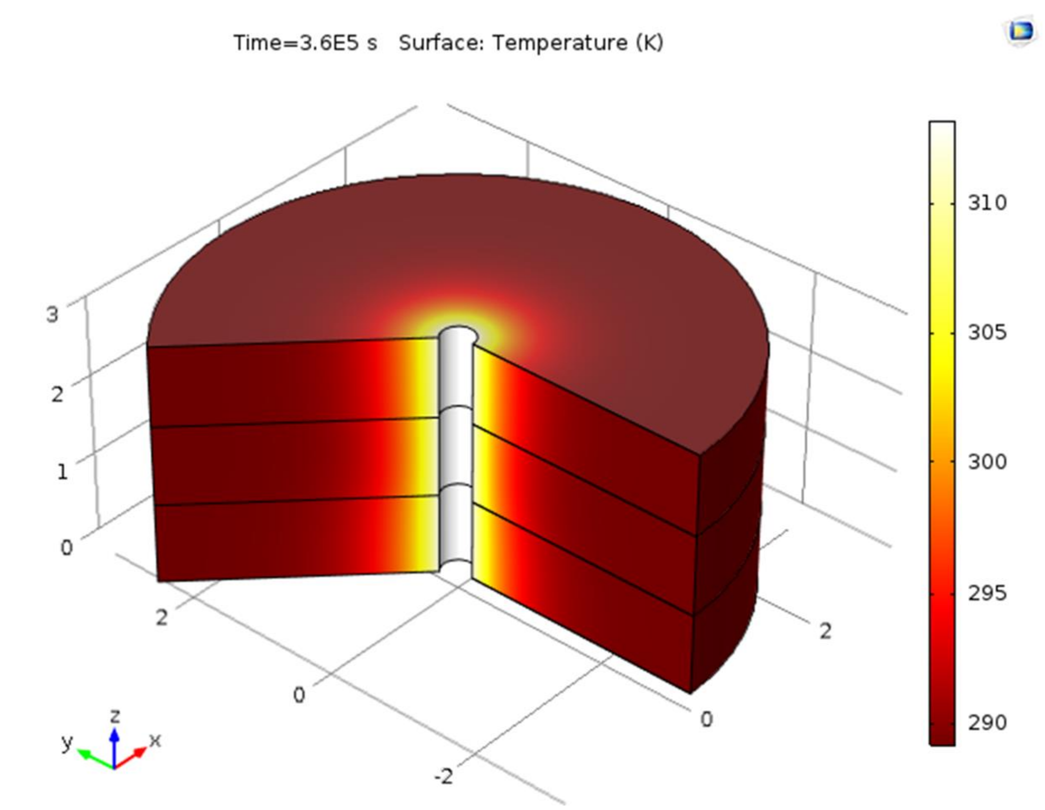
$$k = \frac{2.303}{4.m.\pi.(T_w - T_0)}$$

Aydin et.al. 2017

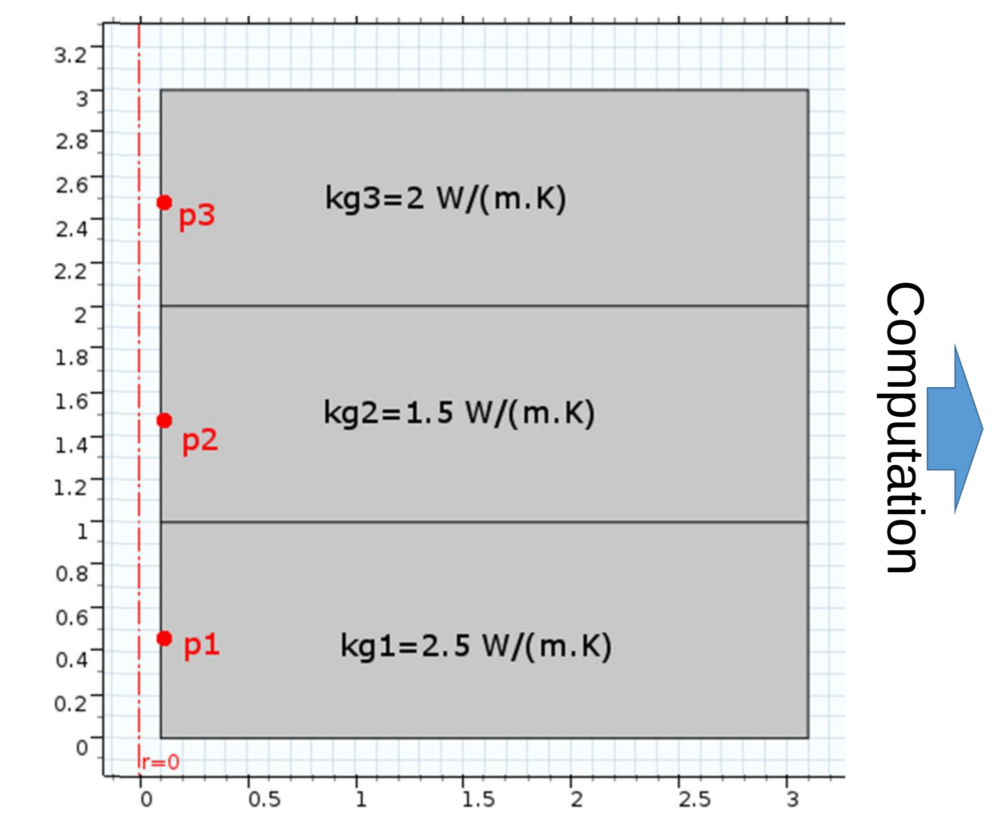
k – Thermal Conductivity [W/(m K)]
m – Slope of changings inverse of heat flux during the test (1/q)
T_w – Water Temperature
T_0 – Undisturbed Ground Temp.

Modeling & Results

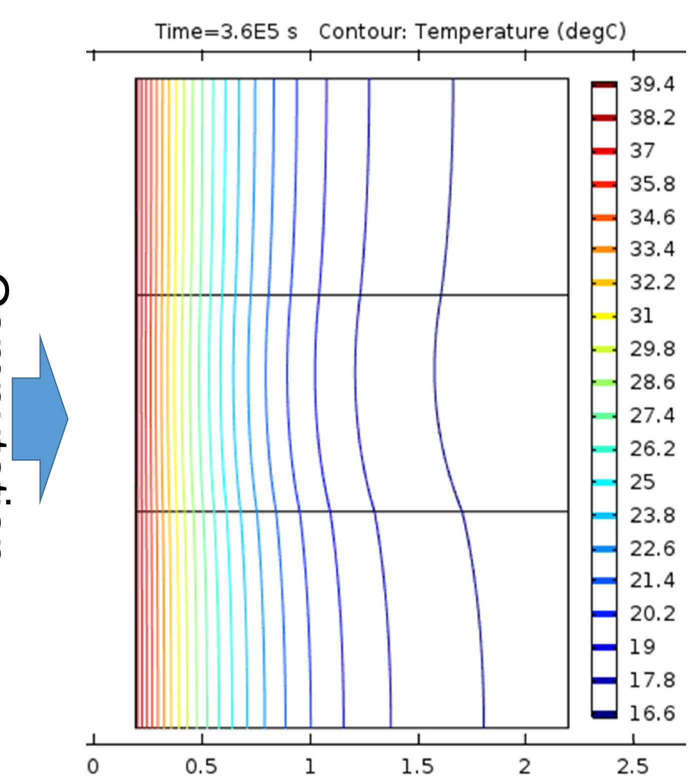
A numerical model is built for validation of the method.



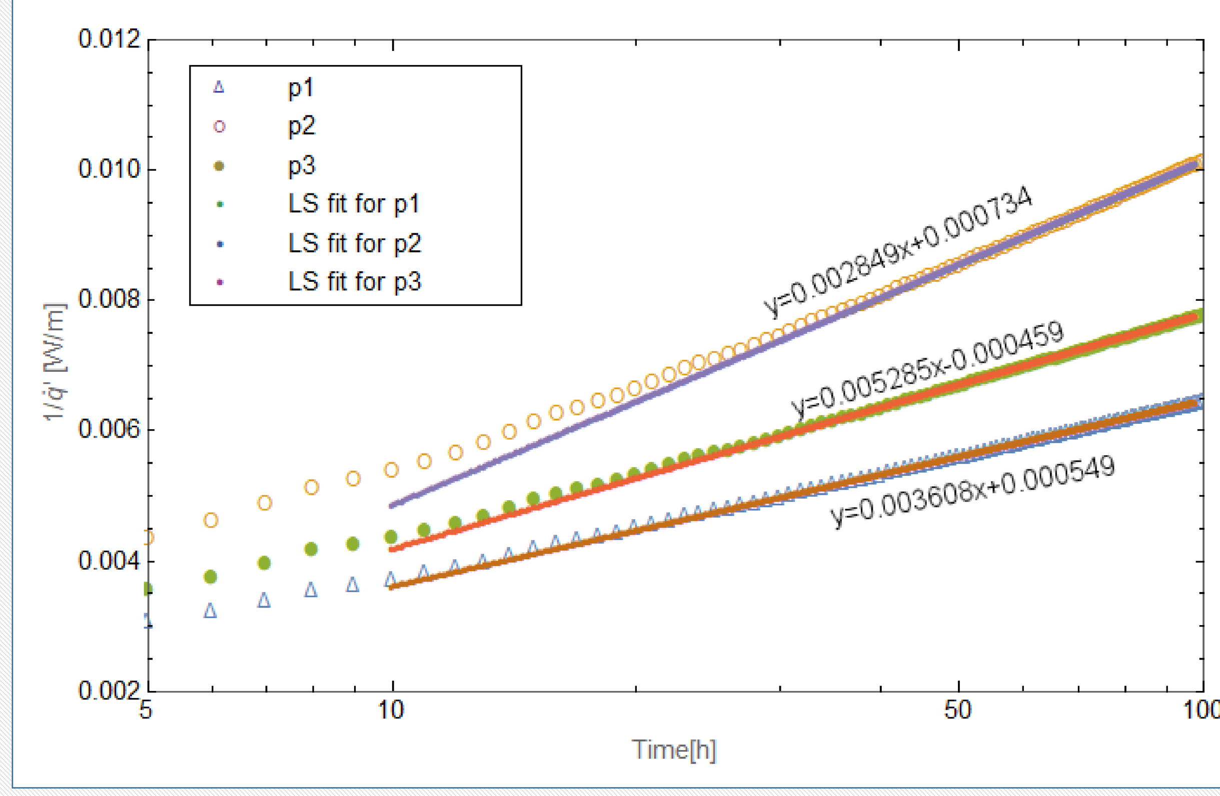
In COMSOL Multiphysics 2D-Axial Heat Transfer modul is used.



In the model different *k (therm. cond)* values entered for different layers.



Temperature distribution.



The model is run for 100 hours simulation. After solution is completed, heat flux magnitudes ($\dot{q}_n$) are calculated from observation points of p1, p2 and p3. Inverse of $\dot{q}_n$ values in logarithmic time axis show linear trend. From the slopes, k values are calculated as shown in table:

	T_w	T_0	m	k	% Dev
p1	40 ºC	16 ºC	0.002849	**2.68**	7.2
p2	40 ºC	16 ºC	0.005285	**1.44**	4.0
p3	40 ºC	16 ºC	0.003608	**2.12**	6.0

Conclusions

- Constant temperature probe method is developed for determining layered thermal conductivities of ground.
- Method is validated with numerical modeling.
- This method can be used for determining thermal conductivity for water filled open boreholes and middle deep boreholes.

Ref : Aydin, M., Onur, M., Sisman. A., 2017. A New Method for Constant Temperature Thermal Response Tests, 42. Workshop on Geothermal Reservoir Engineering, Stanford University / USA, 13-15 February 2017.