

Improvements of U-pipe Borehole Heat Exchangers



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Outline

- Ground Source Heat Pumps
- Borehole Heat Exchangers: Importance and Design parameters

Undisturbed Ground Temperature Profile
Borehole Thermal Resistance
Ground Thermal Conductivity

- Experiences with Borehole Heat Exchangers

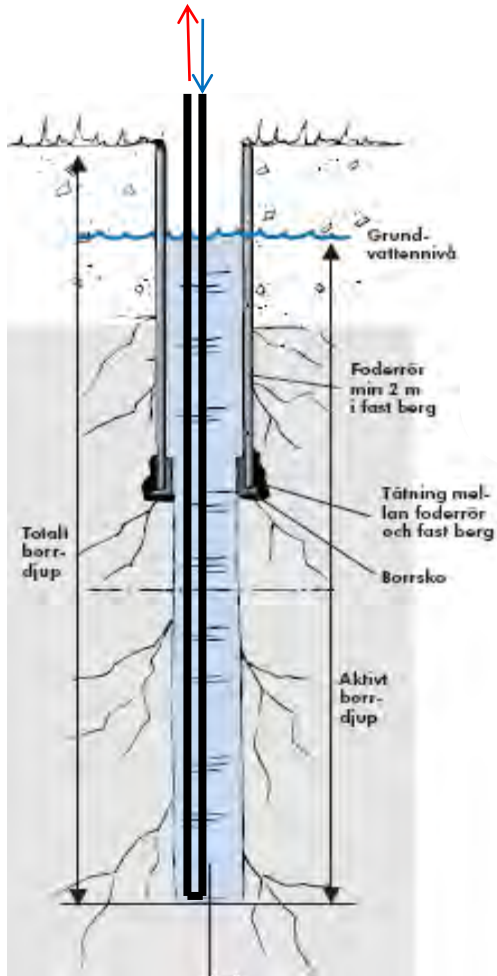
U-pipe
Coaxial
Thermosyphon



EFFSYS 2

Effektivare kyl- och värmepumpssystem

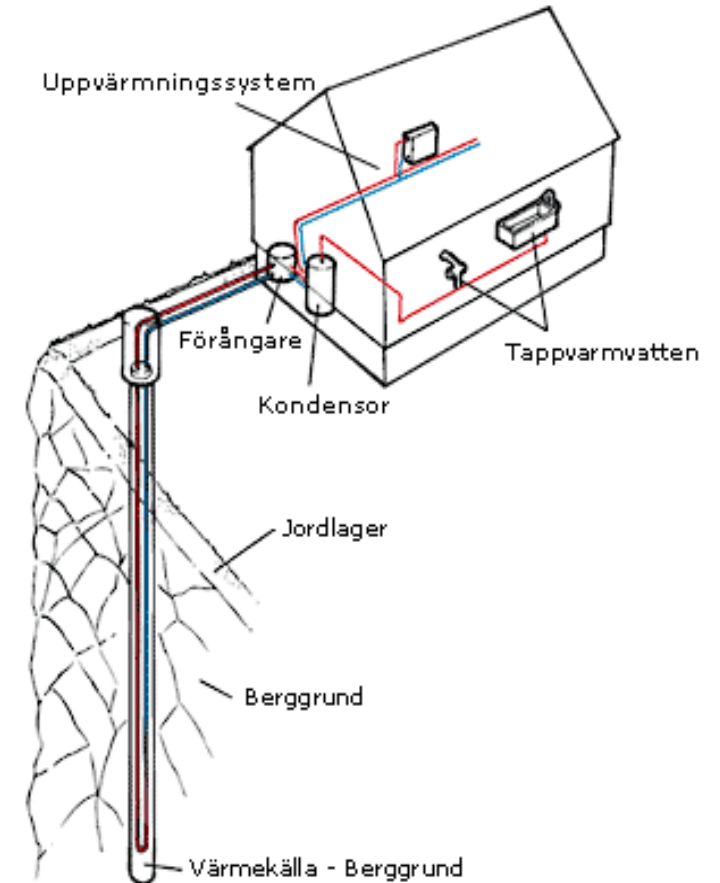
Ground Source Heat Pumps (GSHP)



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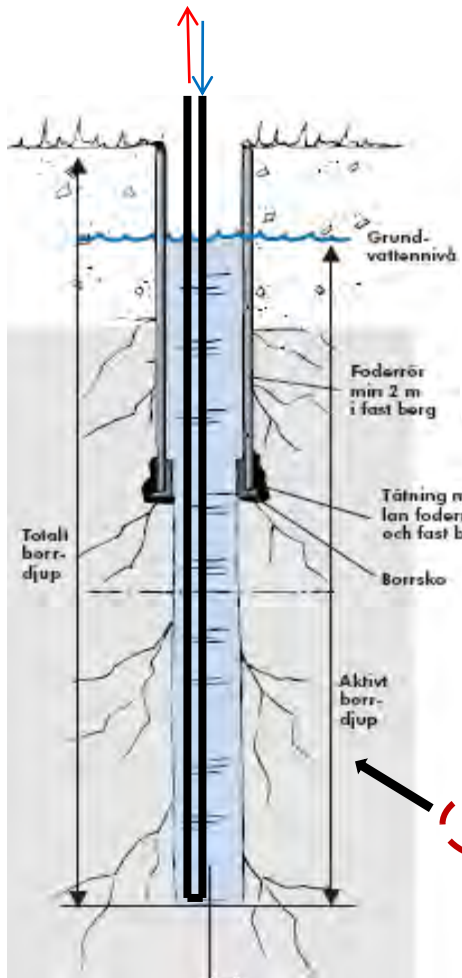
- Very common method for heating and cooling buildings
- Common method to exchange heat with the ground

“Borehole Heat Exchangers” (BHE)

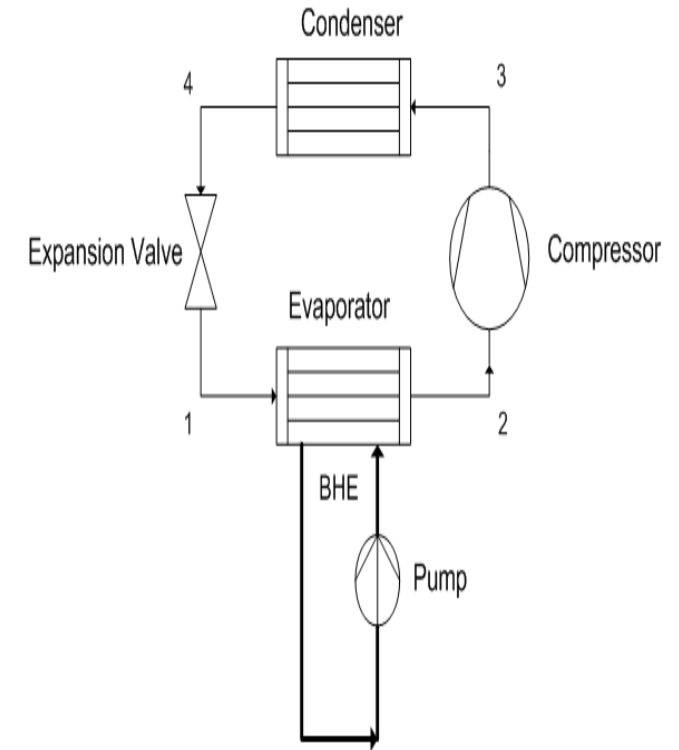
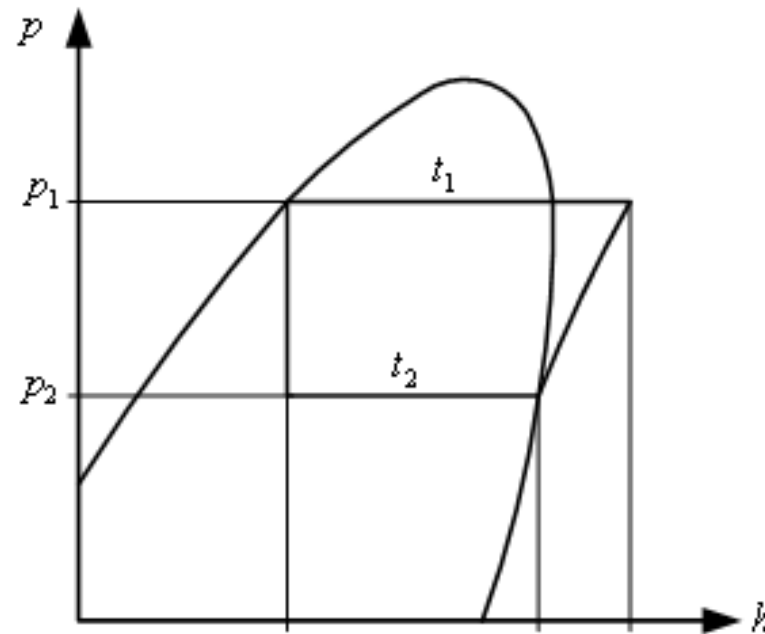


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Importance of BHE design



- Identify methods for reducing the ΔT between the rock and the fluid



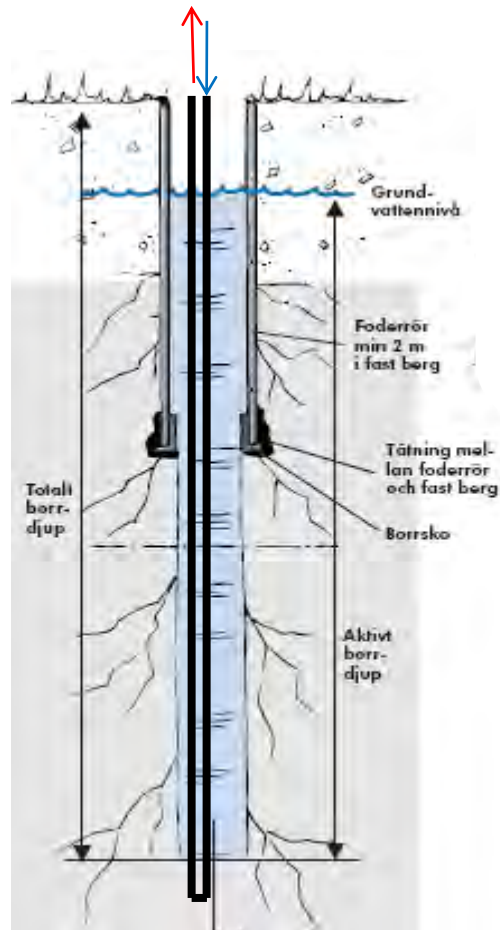
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Borehole Heat Exchanger (BHE)



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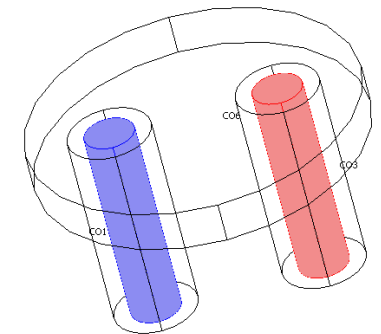
www.svepinfo.se

- Three parts to be considered

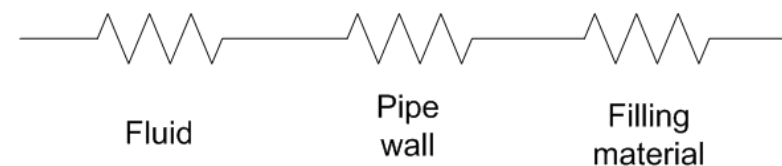
Secondary Fluid

Tubes

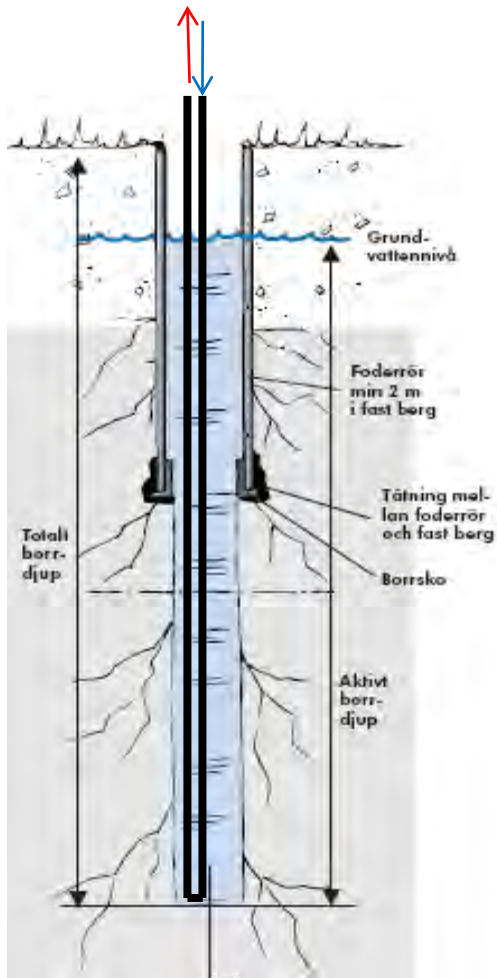
Filling material



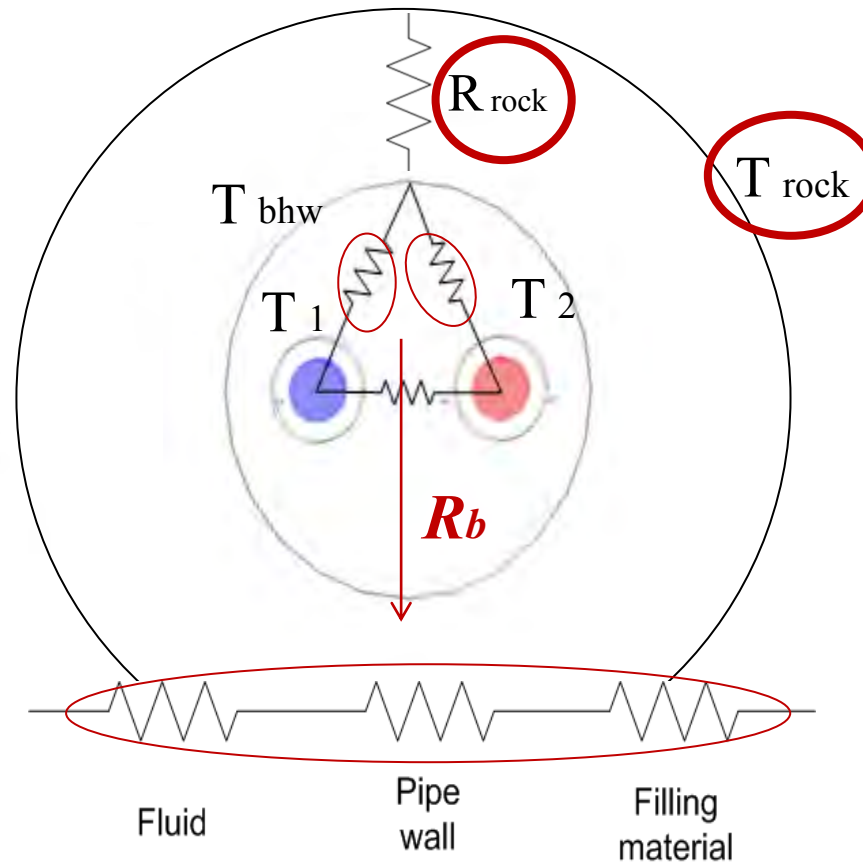
- Thermal resistances that must be minimized



Borehole Heat Exchanger Design



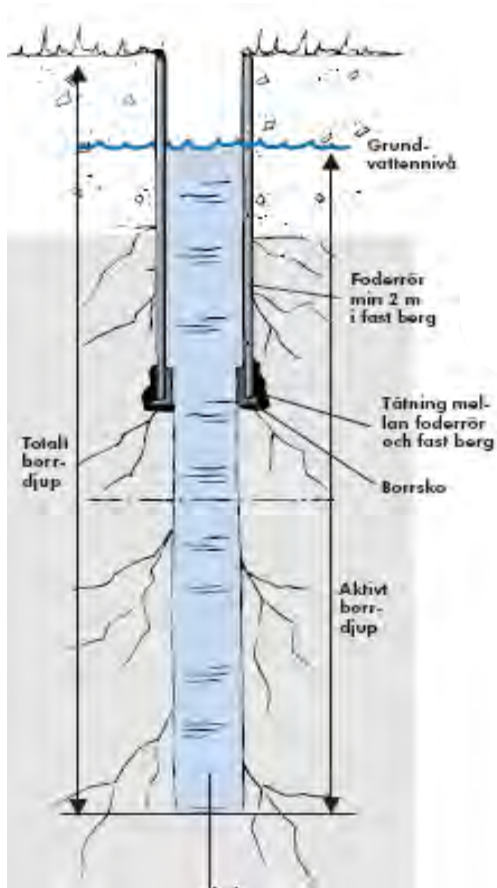
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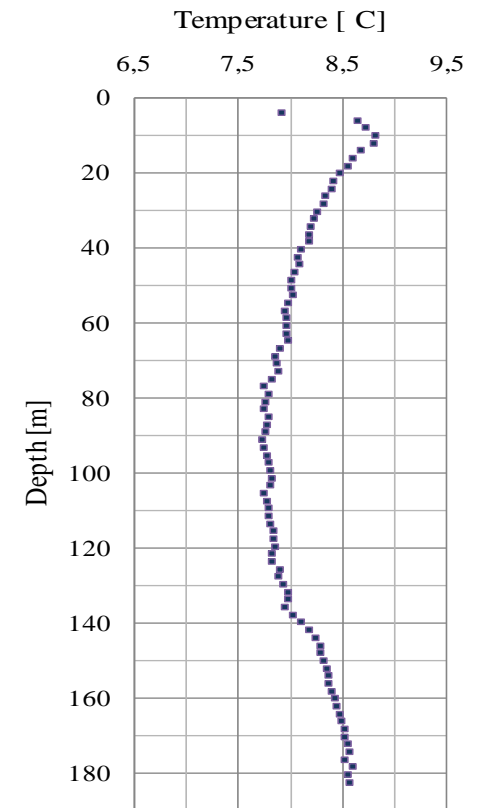
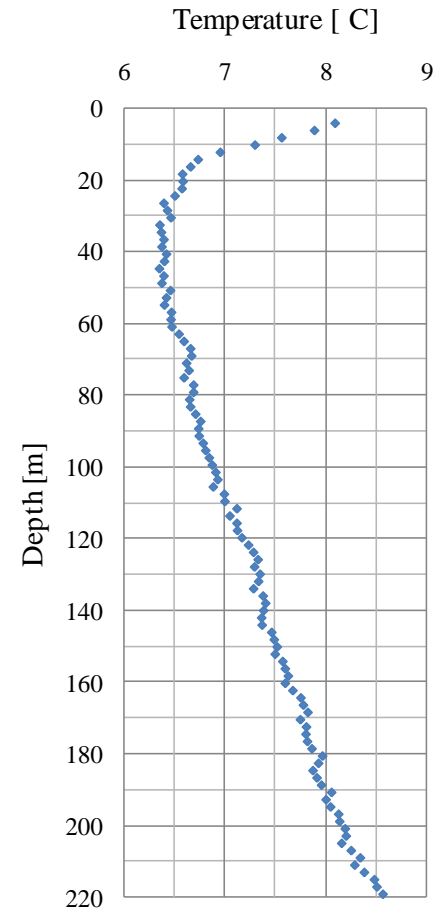
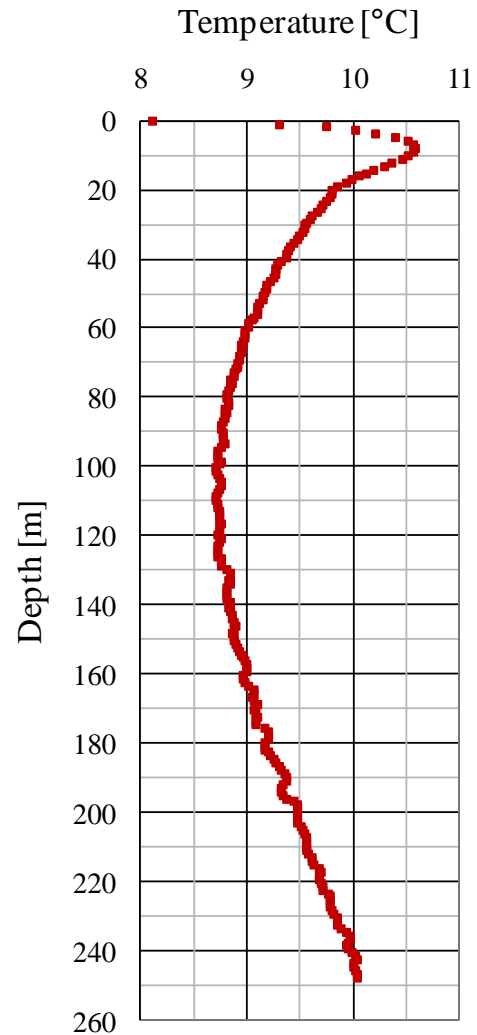
$$R_b = \frac{T_f - T_{bhew}}{q'}$$

- Undisturbed Ground Temperature

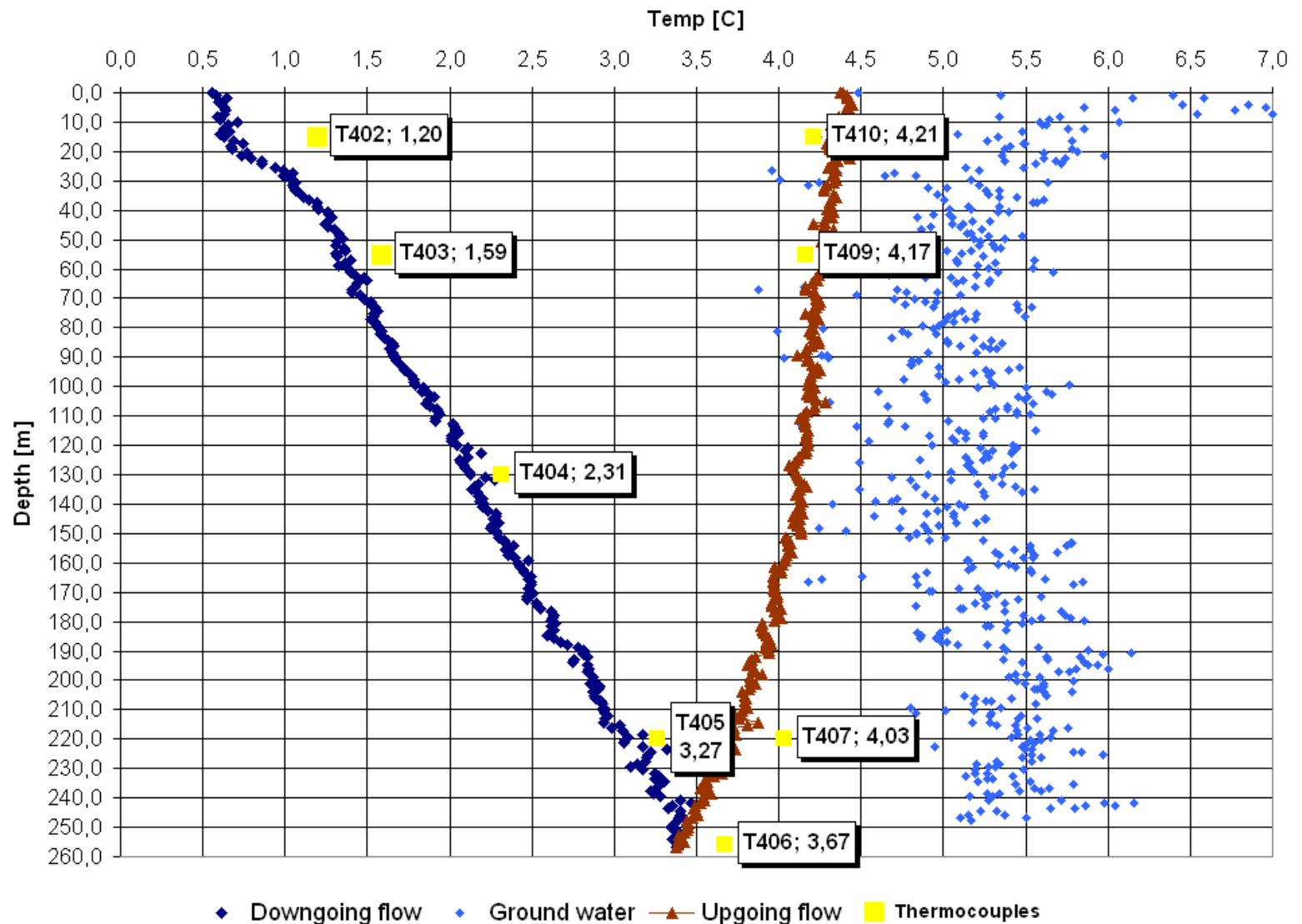
Ground temperature profile



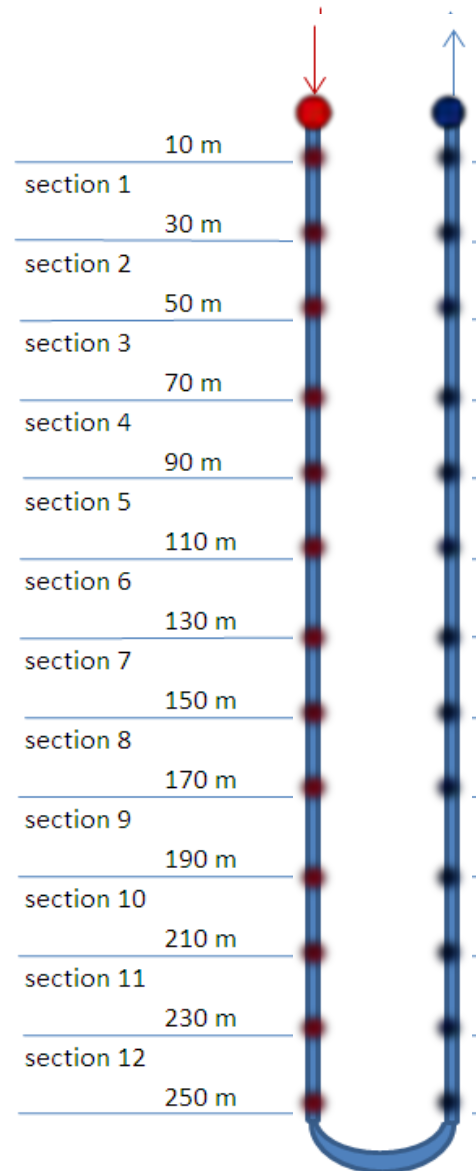
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Distributed Temperatures in BHEs



Distributed Thermal Response Test (DTRT)



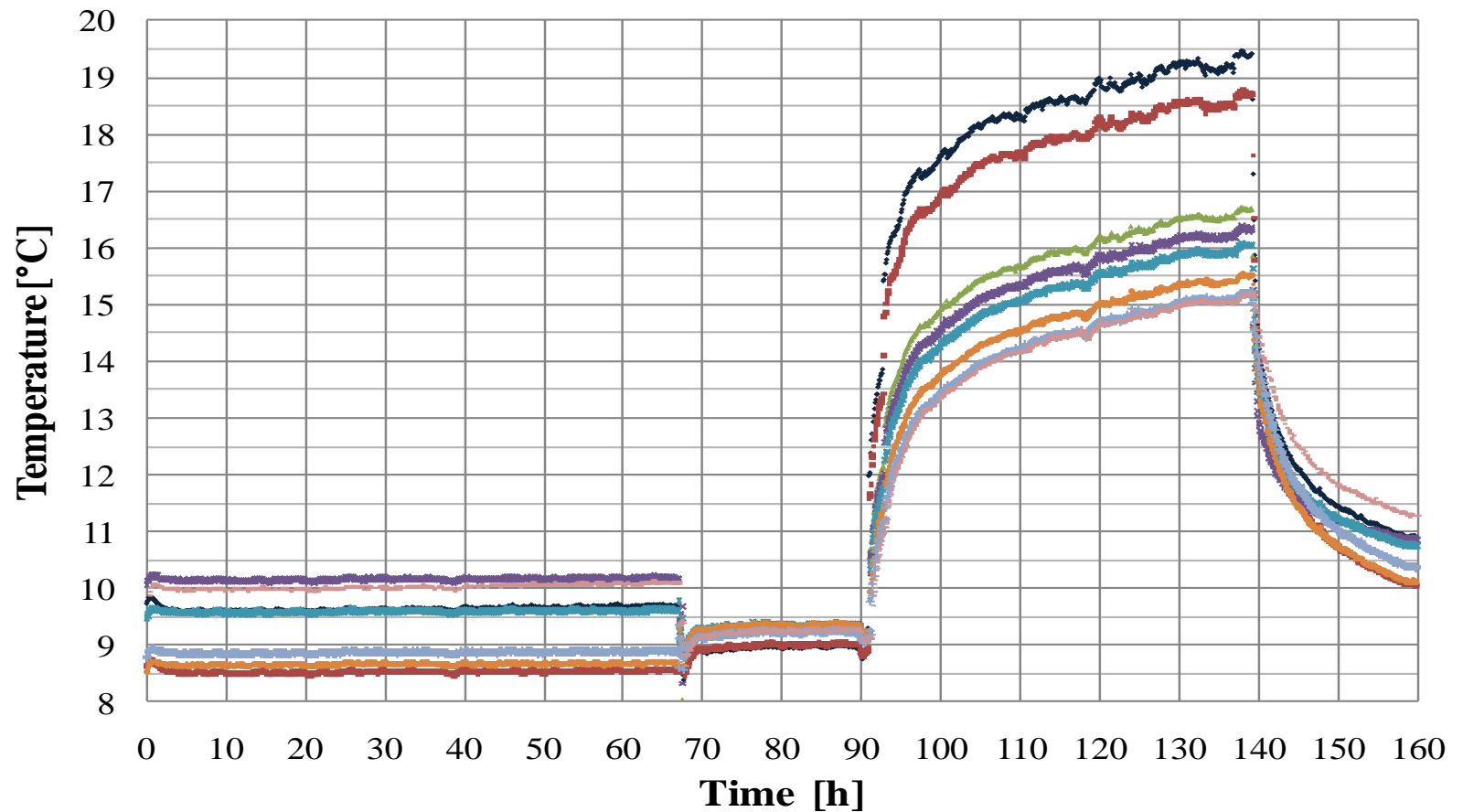
$$T_f - T_g = \frac{q}{L} \left[R_b + \frac{1}{2\pi\lambda_{rock}} \int_{\frac{r_{bh}}{2\sqrt{at}}}^{\infty} \frac{e^{-\beta^2}}{\beta} d\beta \right]$$

- **R_b** and **λ_{rock}** are determined at different instances along the borehole



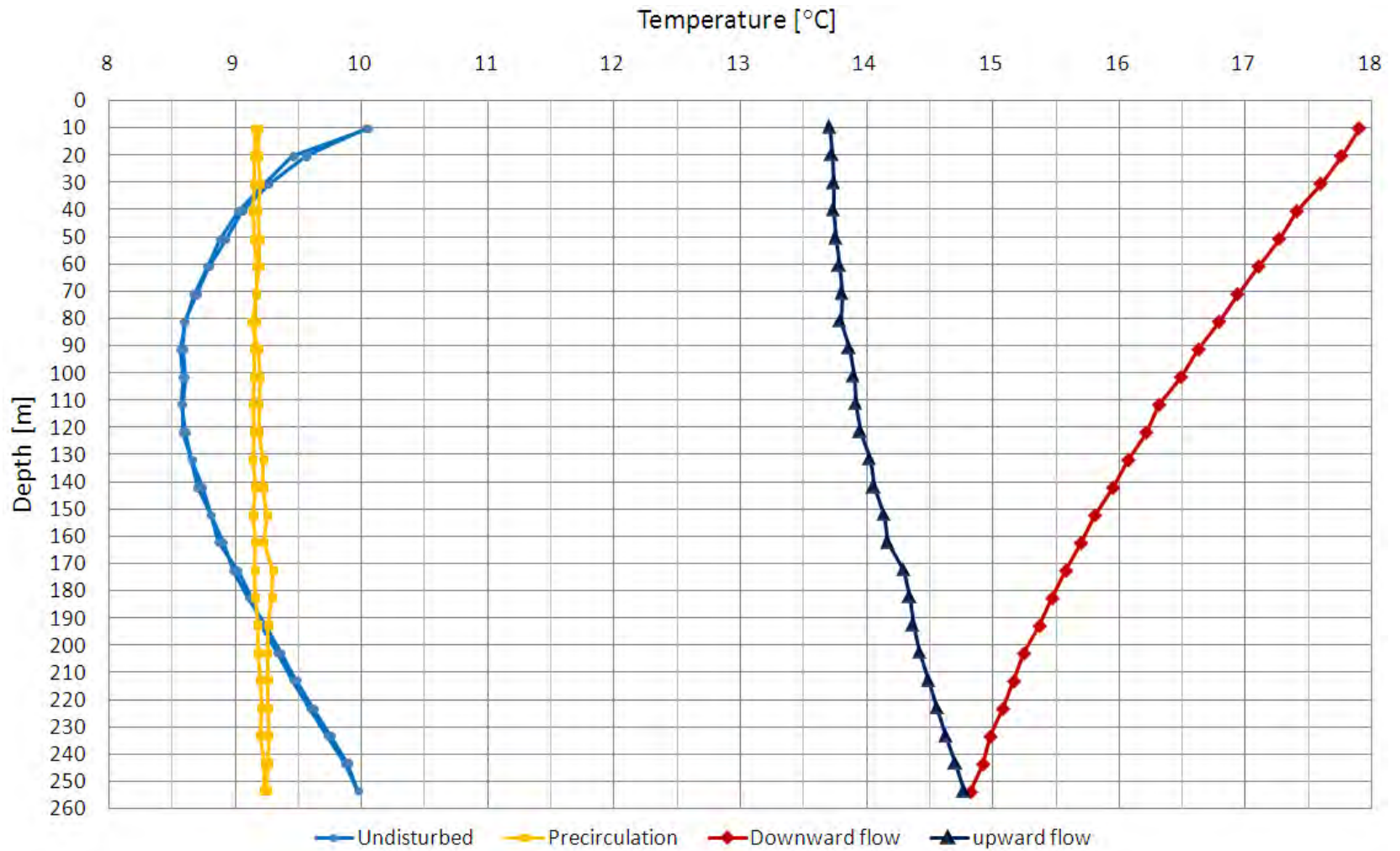
Distributed Thermal Response Test

- Temperatures at different depths during four phases of a DTRT



- 15m down
- 55m down
- 220m down
- bottom
- 220m up
- 130m up
- 55m up
- 15m up

Average Temperatures during DTRT

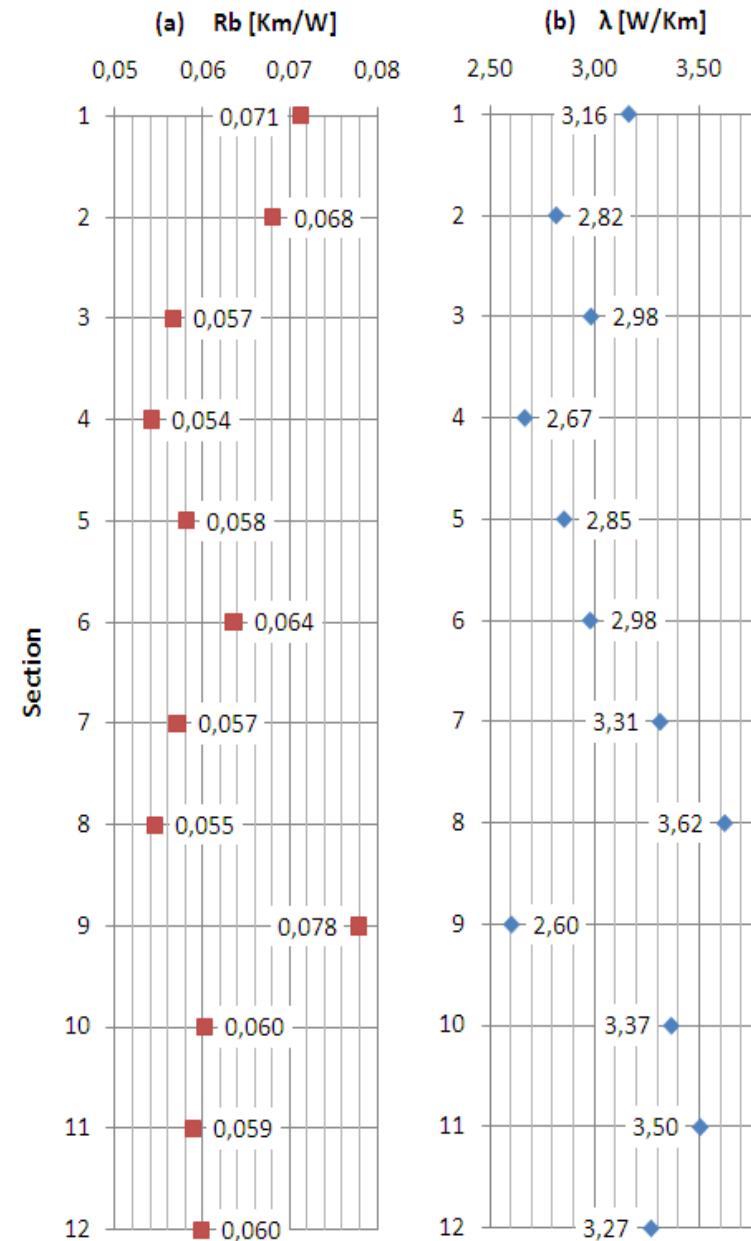
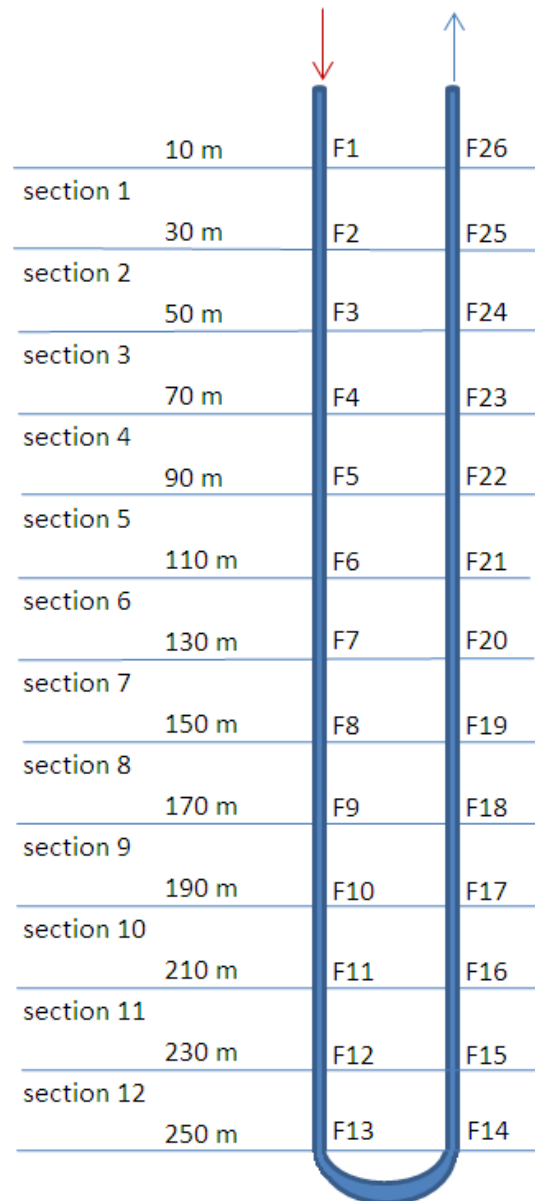


DTRT results

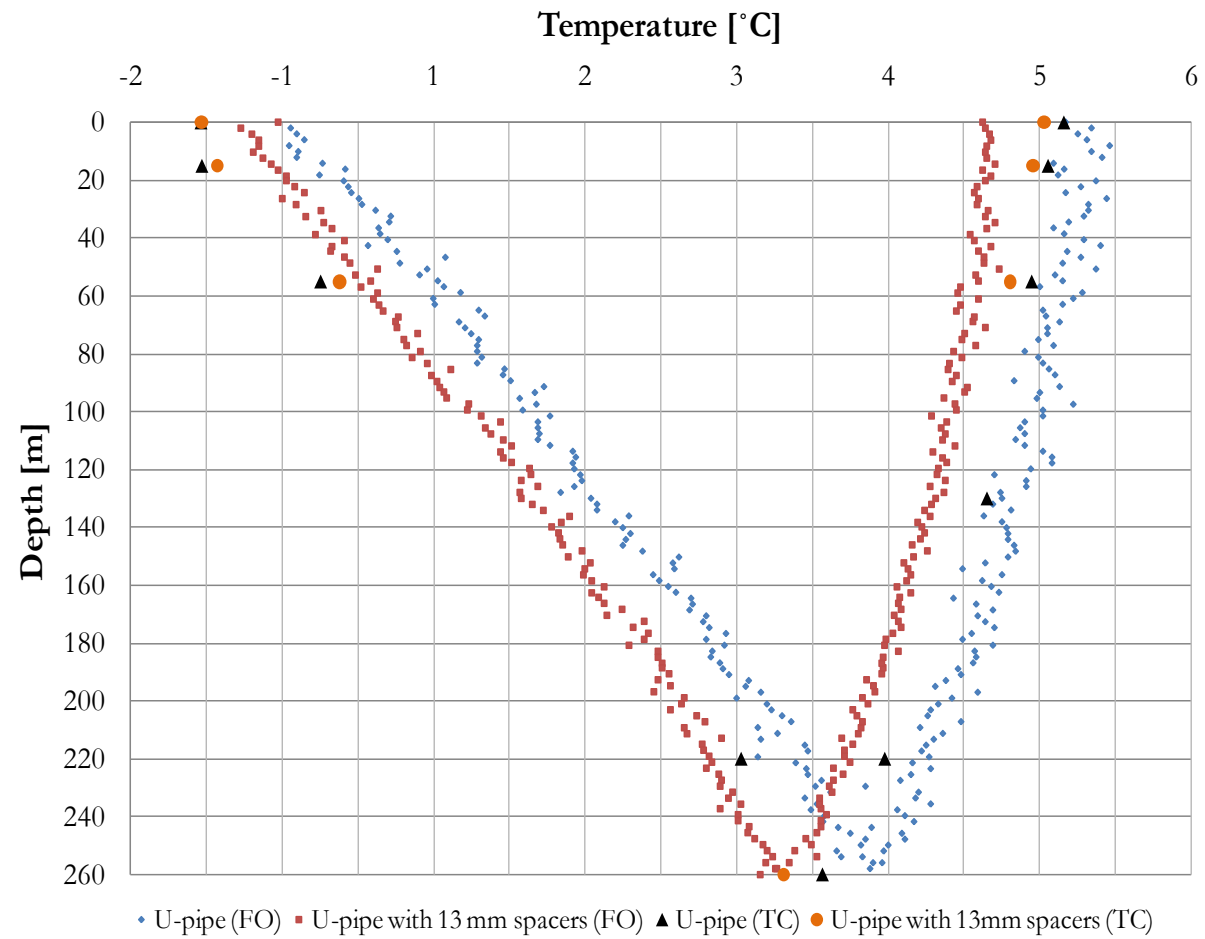


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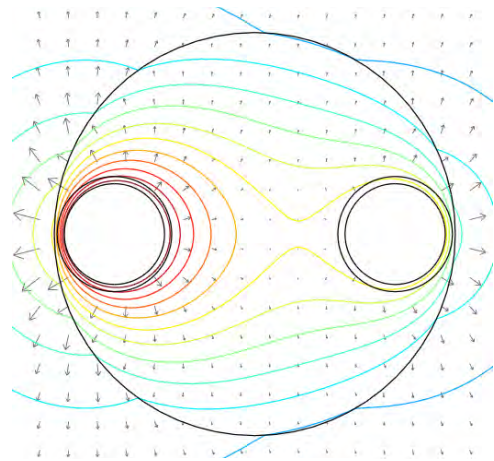


U-pipe with and without spacers

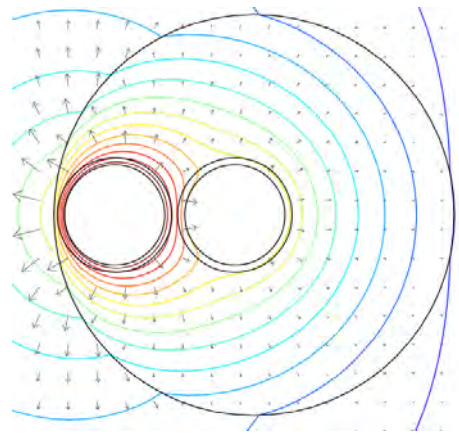


FO: Fiber optics; TC: Thermocouples

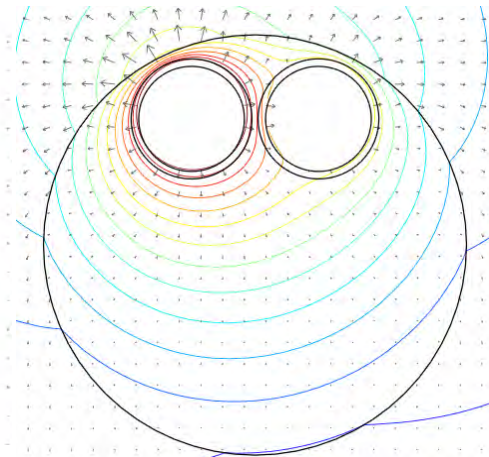
Shank position in U-BHEs



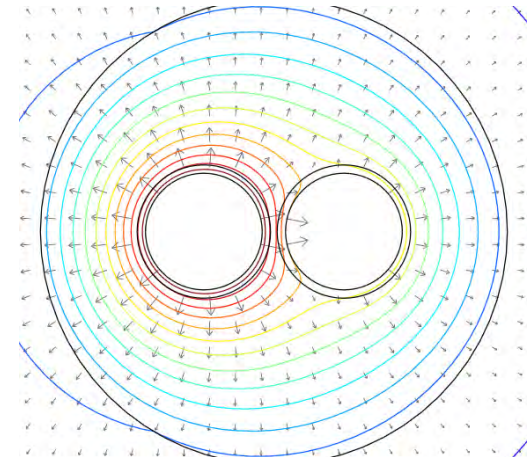
Pipes apart



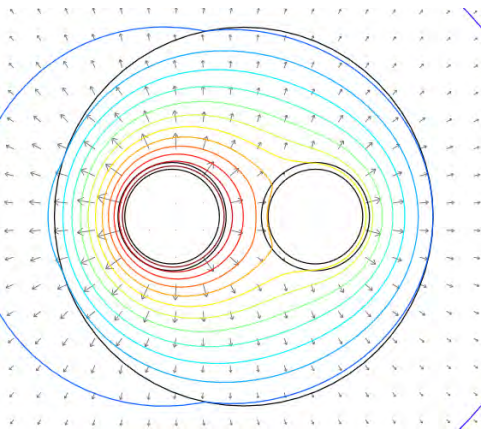
Pipes together
aside



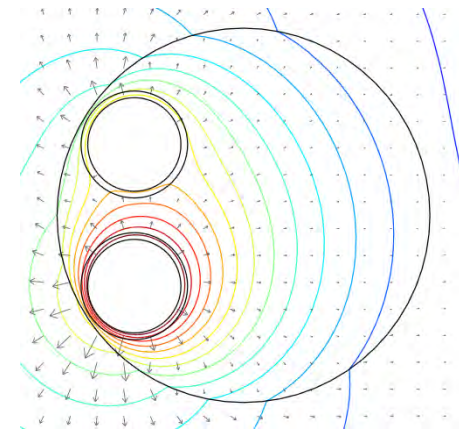
Pipes together
aside 2



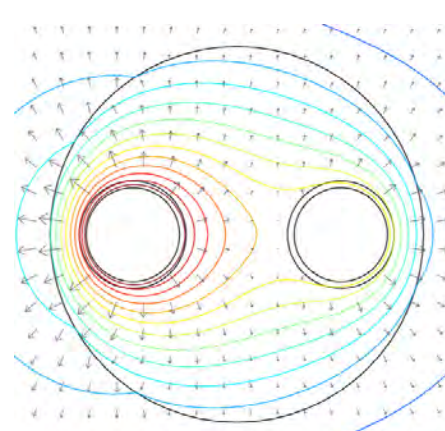
Pipes together
centered



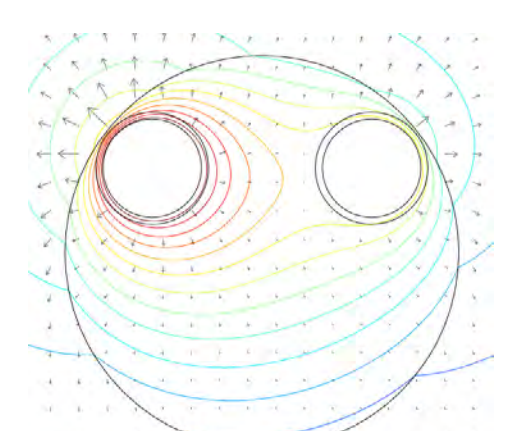
13 mm spacers
centered



13 mm spacers
aside



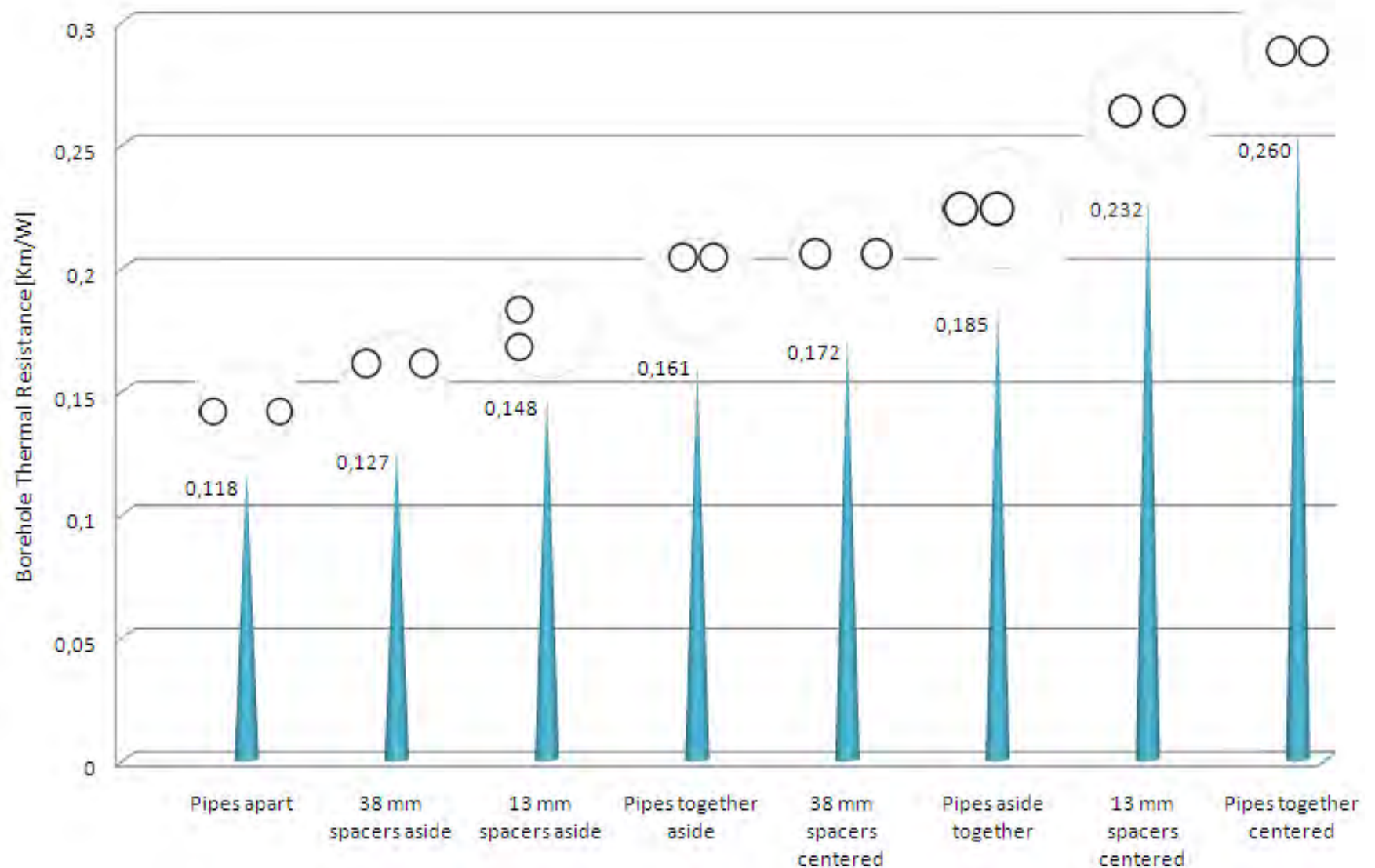
38 mm spacers
centered



38 mm spacers
aside



U-pipe – with and without spacers



Coaxial Designs - TIL

- TIL (Thermal Insulated Leg)

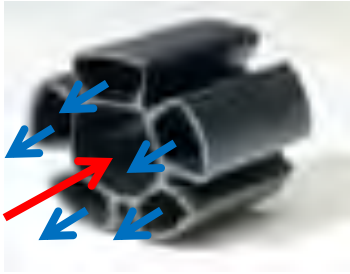


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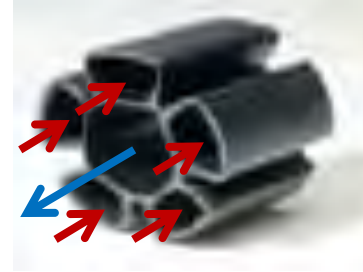
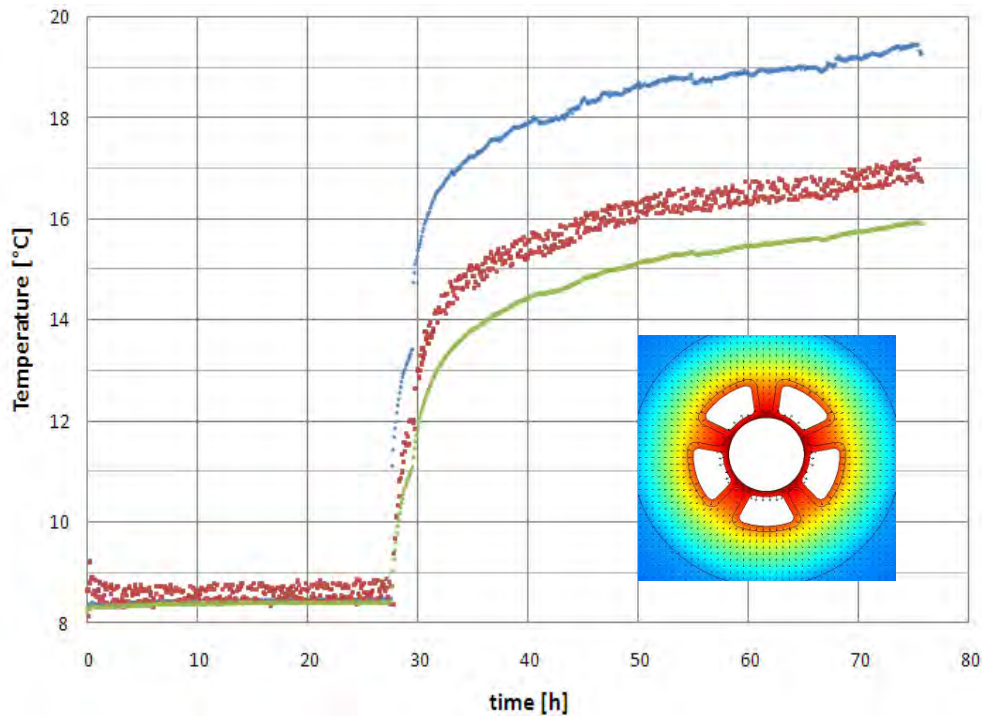
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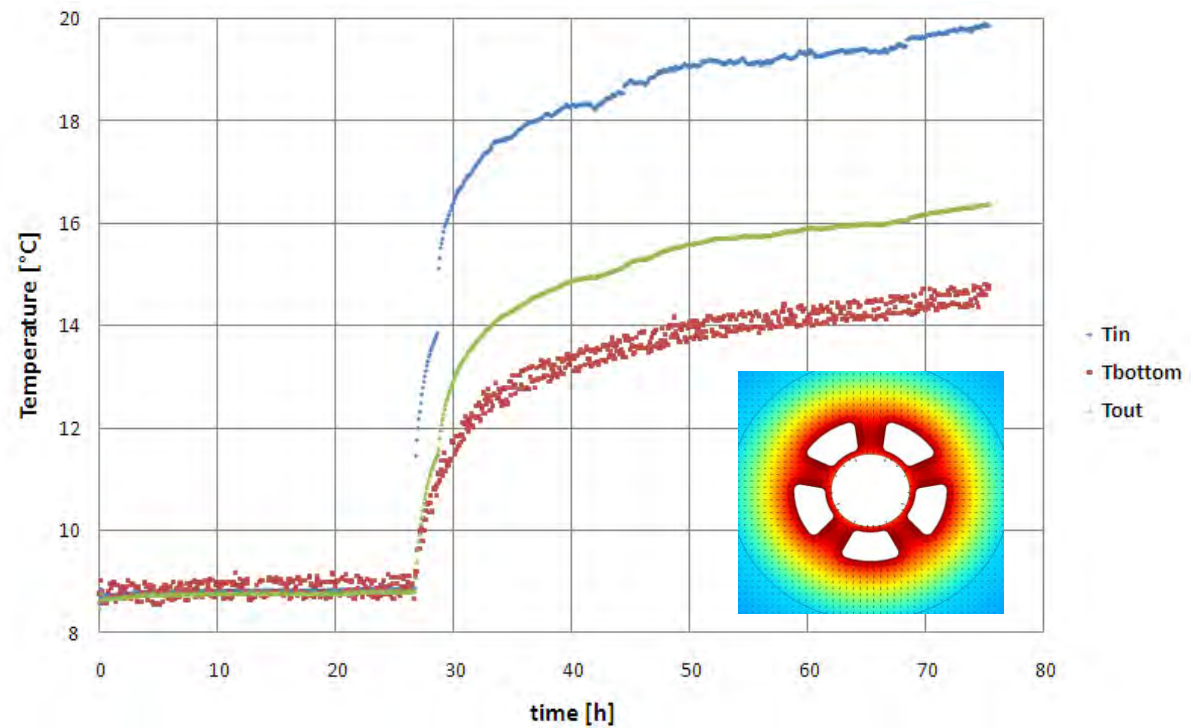
Coaxial designs – 5 trapezoidal channels



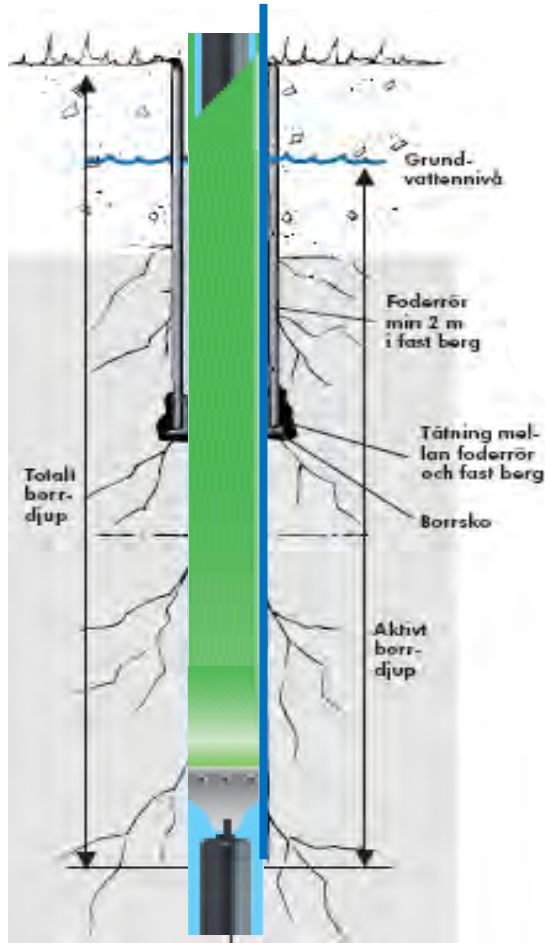
TRT1



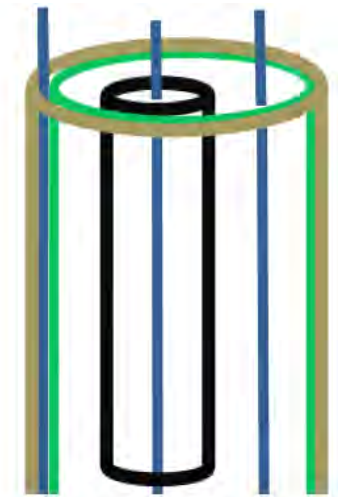
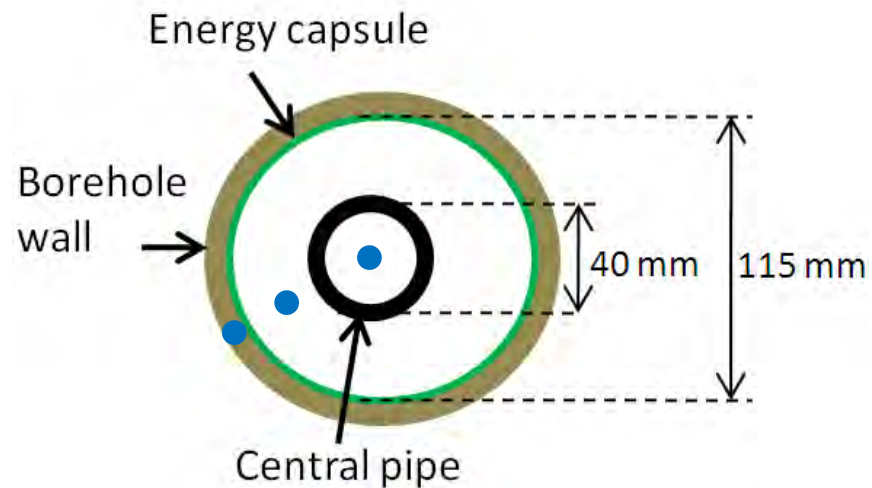
TRT2



Coaxial Designs - Annular



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www.pemtec.se



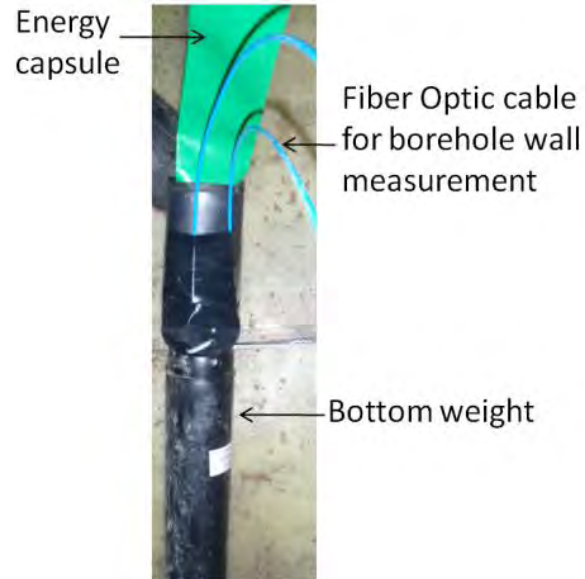
- Fiber optic cable
- Energy capsule
- Borehole wall

Annular coaxial installation

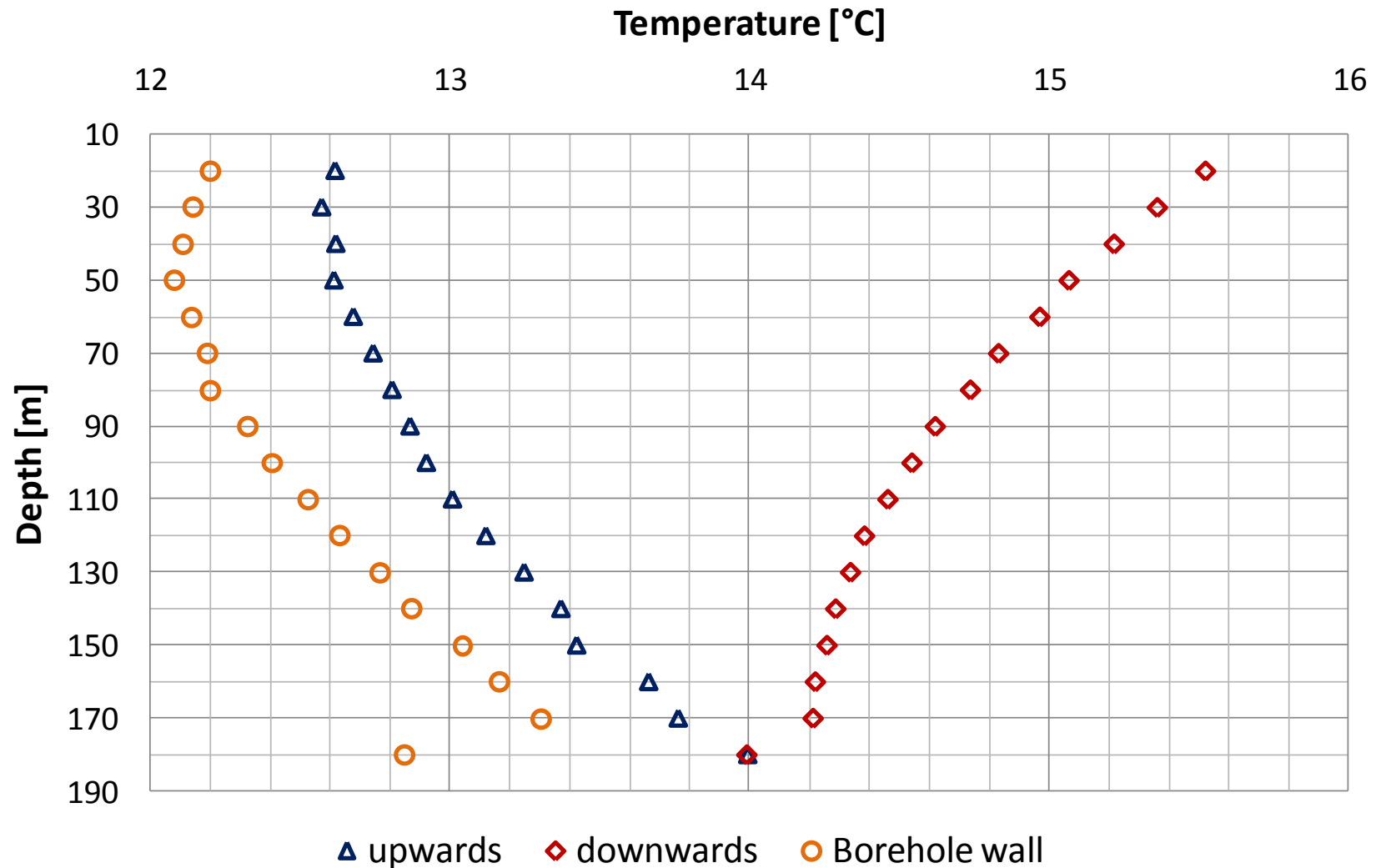
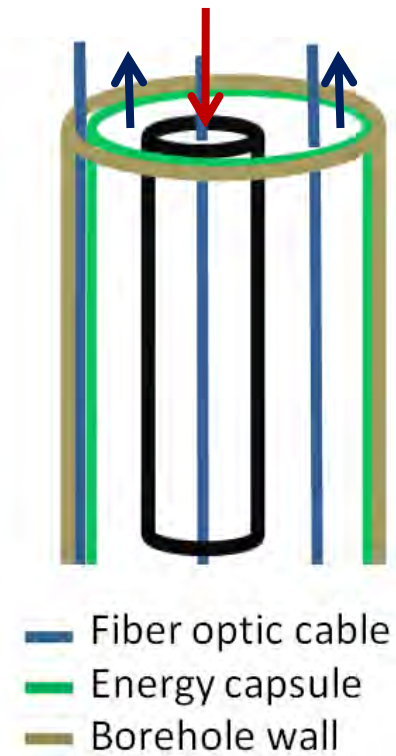


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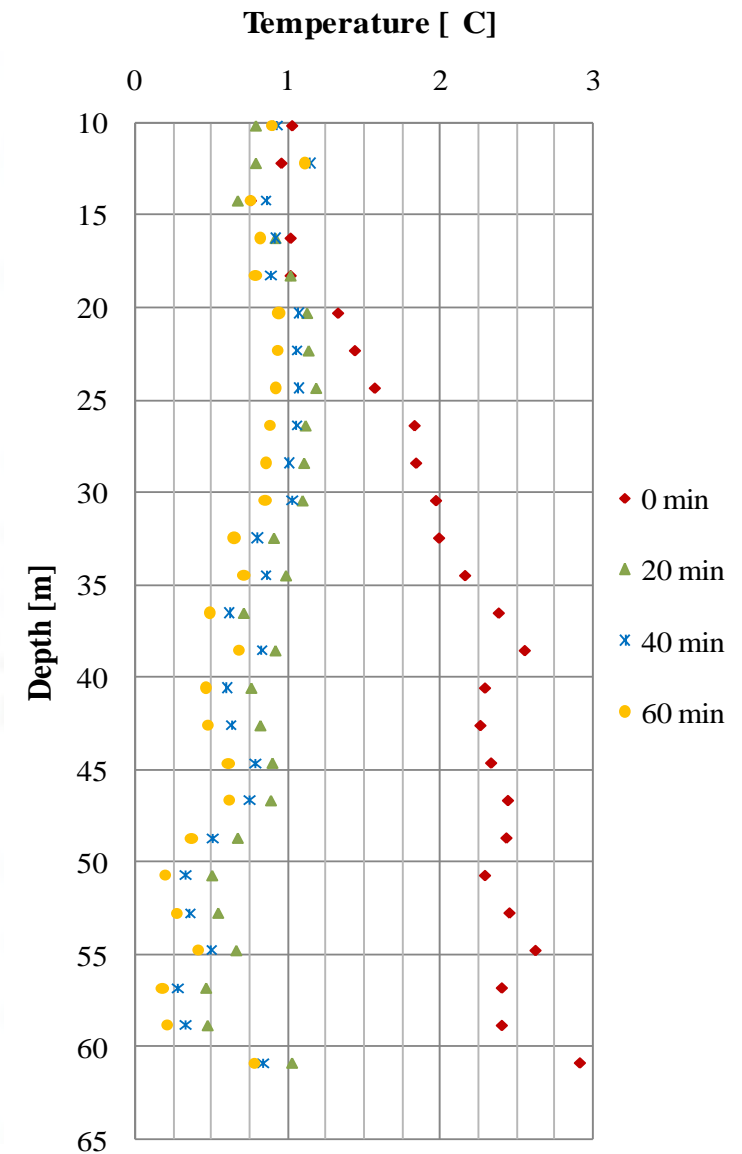
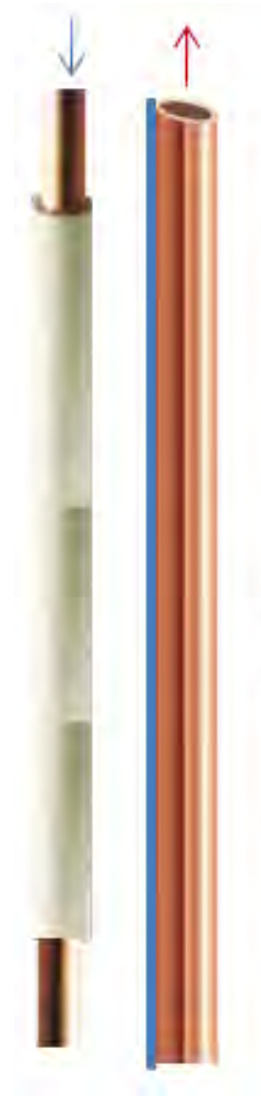
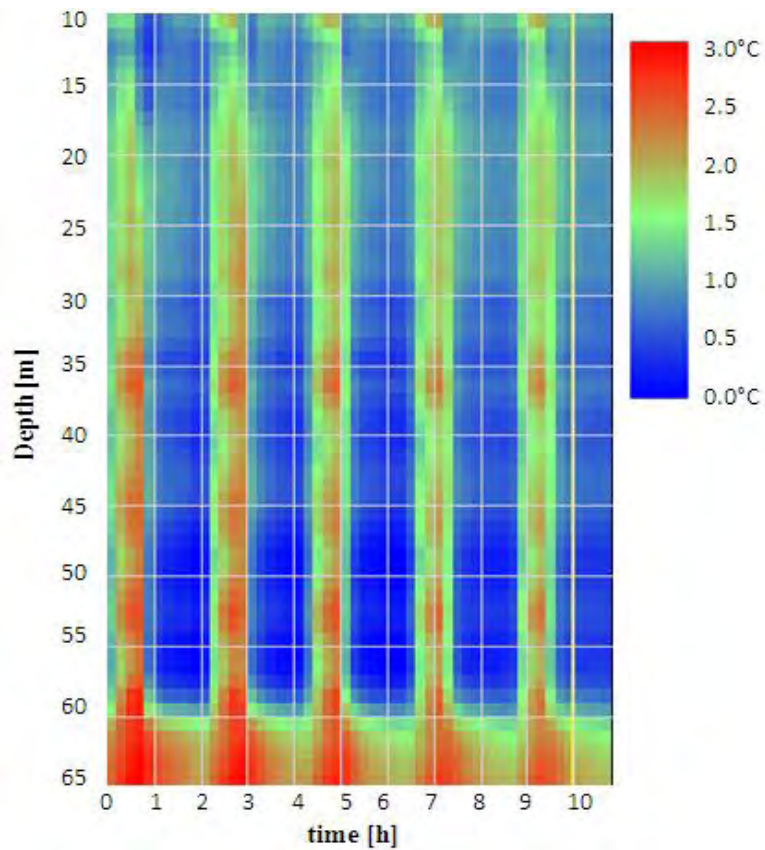


First DTRT in Annular Coaxial BHE



CO₂ – Termosyphon U-pipe BHE

No circulation pump



Thank you!

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Improvements of U-pipe
Borehole Heat Exchangers

JOSÉ ACUÑA

Licentiate Thesis in Energy Technology
Stockholm, Sweden 2010



KTH Industrial Engineering
and Management