Modelling the separatus heat exchanger

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Separatus is a novel type of heat exchanger designed to reduce the investment cost of geothermal borefields — and you can calculate its performance directly using GHEtool! This article explains the development of the current theoretical model behind the separatus system within GHEtool.

> ***!Note***
> *This article focuses on the theoretical foundations of the separatus model. If you're looking for practical guidance on how to use GHEtool to model these systems, you can read the blog post on the separatus website.*

What is separatus?

The separatus heat exchanger was developed in 2023 by Dietmar Alge, Jana Walker, and Stefan Geser, building on the concept of split-pipe technology. It is based on a standard pipe with a diameter of 51 mm, but with an internal spacer installed to separate the hot and cold fluid streams.

By using this design, drillers only need to install a single pipe instead of the traditional two or four pipes (as used in single or double U-tube configurations). This significantly reduces installation time and borehole diameter, which leads to a lower investment cost of the geothermal borefield.

Image of the separatus heat exchanger.

Model development

Developing a model for a new product is always a challenge — one can either opt for a highly detailed simulation or take a more practical, engineering-based approach. For separatus, the latter path was chosen. The team developed a model for their heat exchanger based on the geometry of a single U-pipe, which is the closest existing model in terms of geometry, and then tuned the parameters based on real-life measurements.

Below, the experimental setup and the two key measurements are described. This is followed by a discussion of the final calibrated single U-pipe approximation, which has been implemented in GHEtool.

> ***!Note***
> *The model described below was developed by separatus to enable simulation of the innovation using Earth Energy Designer. The GHEtool implementation is based on the same original assumptions. Later in this article, future updates to the model are also discussed.*

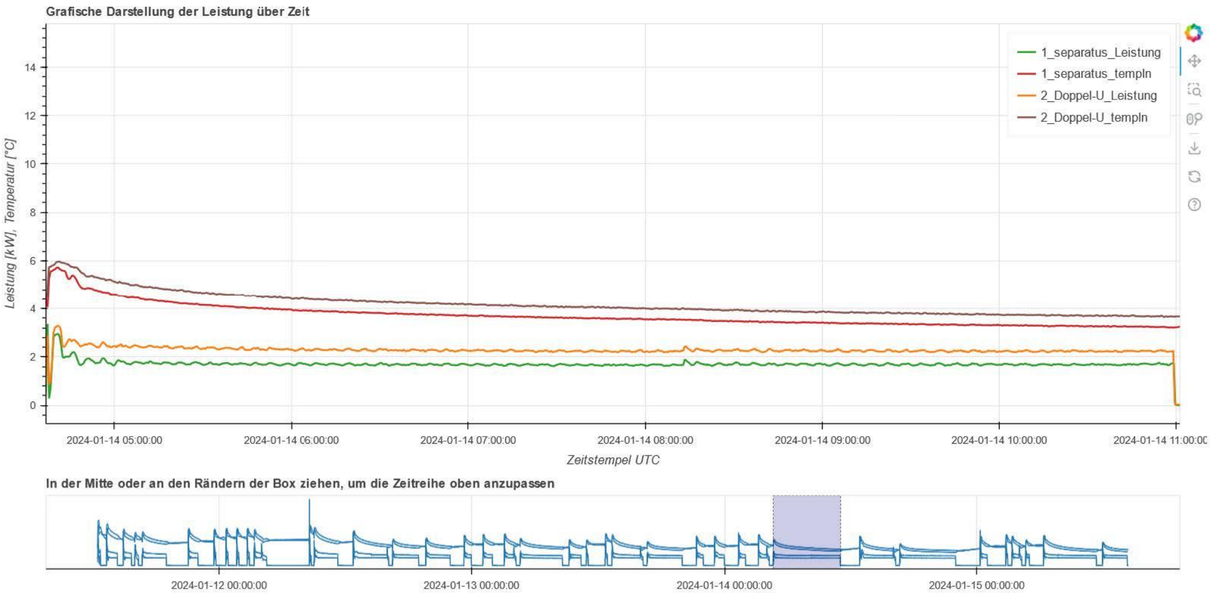
Experiment description

The test site for the experiment was in Altach (Austria). Three boreholes of 70 m each were drilled of which one of them was filled with a double DN32 heat exchanger and another with the separatus one. By means of extra valves in the manifold, the heat pump could be connected to both or either one of these boreholes, making it easy to compare their thermal performance.

> ***!Note***
> *During installation, an issue occurred with the grout backfilling of the double U-tube borehole. It is assumed that this borehole was not properly backfilled over the whole depth. Since Altach has a relatively high groundwater level and flow, this may have been advantageous for the thermal performance of the double U-tube borehole.*

Equal flow rate measurement

In the first test, both the double U-tube and separatus probes were connected to the heat pump for a duration of 97 hours, each with a nominal flow rate of 1100 l/h. The results, shown in the graph below (zoomed in on the longest continuous runtime of the heat pump), highlight the thermal performance of both systems.



Measurements for an equal flow rate.

As seen in the graph, the power extracted from the double U-tube (Doppel-U_Leistung) is higher than that of the separatus probe (separatus_Leistung), with values around 2.27 kW and 1.74 kW respectively. Both outputs remained fairly constant over the 6-hour measurement window.

Assuming the equivalent borehole thermal resistance for the double U-tube is 0.12 mK/W, this corresponds to a borehole thermal resistance of 0.156 mK/W for the separatus configuration. This relationship stems from the fact that, over short timescales, the ground temperature can be assumed constant, meaning the thermal power is inversely proportional to the effective borehole thermal resistance.

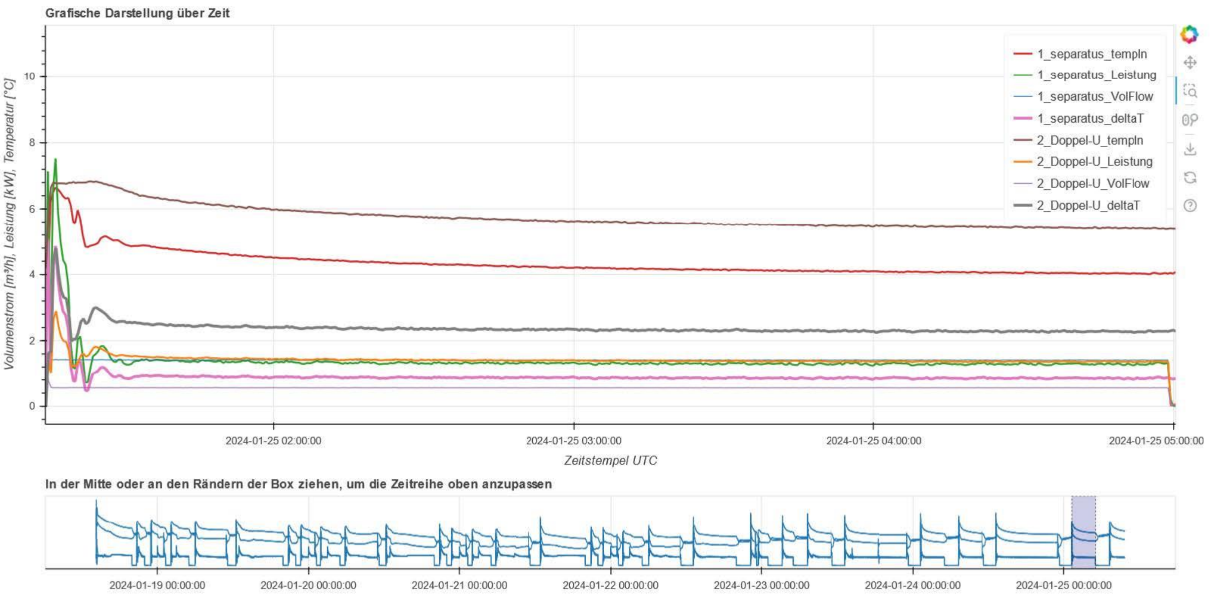
> ***!Note***
> *If you're not familiar with the concept of effective borehole thermal resistance, you can read our detailed article on the topic here.*

Equal heat transfer measurement

To further evaluate the performance and reverse engineer the effective borehole thermal resistance, a second test was conducted, this time with a constant heat transfer rate. The flow rate for the double U-tube was reduced to 550 l/h, placing it in the laminar flow regime, while the flow rate for the separatus probe was increased to 1400 l/h, corresponding to a transient flow regime.

This setup resulted in equal heat extraction from both boreholes, as shown in the graph below, which again focuses on the longest continuous operation period (about 4 hours).

!Note
If you're not familiar with the differences between laminar, transient, and turbulent flow in geothermal systems, check out our article on flow regimes [here](#).



Measurements with an equal heat extraction rate.

Although both systems delivered nearly the same heat extraction, the temperature difference (deltaT) between the fluid inlet and outlet was smaller for the separatus probe. This is expected due to the higher flow rate, which results in a smaller temperature drop across the heat exchanger.

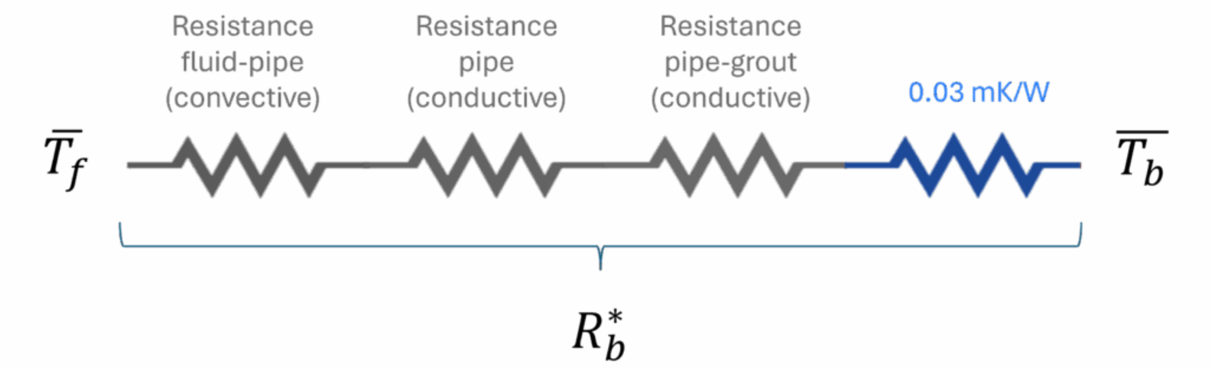
Results

The results of the previous simulation were used to reverse engineer the parameters of a single U-tube that would result in the same effective borehole thermal resistance as measured for separatus. This was done using a trial-and-error approach, under the assumption that the borehole was fully grouted.

The closest match was achieved with the following parameters:

- Pipe diameter: 35.74 mm
- Wall thickness: 3 mm
- Pipe-to-centre distance: 18 mm

To model the additional thermal interaction between the hot and cold legs of the separatus probe—caused by the internal separation wall—an extra contact resistance of 0.03 mK/W was added.



Thermal resistances with extra contact resistance.

> ***!Note***
> *Due to its design, separatus has more thermal interaction between the hot and cold legs than a typical single U-tube. To account for this in the model, an additional resistance must be introduced. This resistance is in series with the fluid-pipe, pipe, and pipe-ground resistances (as explained in our article on effective borehole thermal resistance, which you can find here). Based on trial-and-error calibration against the measured data, a contact resistance of 0.03 mK/W was found to best represent the observed performance.*

What's next?

The model described above provides an engineering-based approximation to simulate the thermal behaviour of the separatus probe. While it offers practical usability, it is based on a few simplifications:

- The pipe geometry is modelled as a single U-tube, with the diameter chosen so that the cross-sectional area matches that of the separatus pipe.
- An additional correction factor was introduced to simulate the additional thermal interaction between the hot and cold sides inside the pipe, but this was based on a single measurement.

Since the model is calibrated using real-life measurements, it can be considered reliable when used under conditions similar to the experimental setup—particularly within the turbulent flow regime.

To broaden the model's applicability and accuracy, Enead and separatus are now collaborating to develop a new, more comprehensive model. This updated version will be based on the actual geometry of the separatus heat exchanger and will allow for more precise predictions of borehole thermal resistance under a wider range of conditions (e.g. different borehole diameters, fluid regimes, etc.). Thanks to the availability of additional measurement data, this next-generation model can also be calibrated with greater accuracy.

Conclusion

This article explained the model development of the separatus heat exchanger. The current model is built upon the framework of a single U-tube and has been calibrated using real-world measurements of the separatus system. A clear path forward has been set, with the aim of transitioning to a more geometry-based model that allows for accurate simulation in a broader range of use cases.

References

- Watch our video explanation over on our YouTube page by clicking here.