Pressure drop and pump energy in GHEtool Cloud

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For an efficient borefield design, you have to pay close attention to both the pressure drop and the pump energy consumption. In this article, we will explore the latest additions to GHEtool Cloud to help you with the hydraulic design of your borefield.

> ***!Note***
> *This article builds further on our article related to the theory of pressure drop calculations. If you have not read it, you can check it out here.*

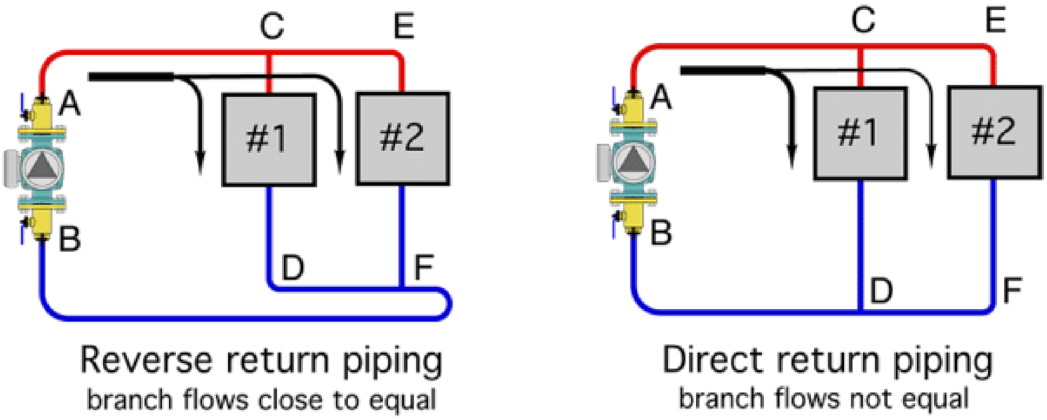
Pressure drop across the borefield

Although there are many different ways in which boreholes can be hydraulically connected, the pressure drop of the entire borefield can be easily calculated based on one central assumption: we want every borehole to have the same flow rate (so that it can exchange the same amount of energy with the ground). To achieve this, you must ensure that all boreholes in your field experience the same pressure drop, so that the fluid does not have a preferential path with lower resistance. This means that the pressure drop of your entire system will be defined by the borehole where it is the highest, and all other boreholes will be calibrated to have the same pressure drop so that the flow rate through all of them remains equal. This is what is called a **hydraulically balanced system.**

The total pressure drop across this worst-case borehole can be calculated as the sum of the pressure drop across the **vertical part** of the borehole itself and the pressure drop from the borehole to the central borefield collector, i.e. the **horizontal pressure drop**.

Horizontal pressure drop

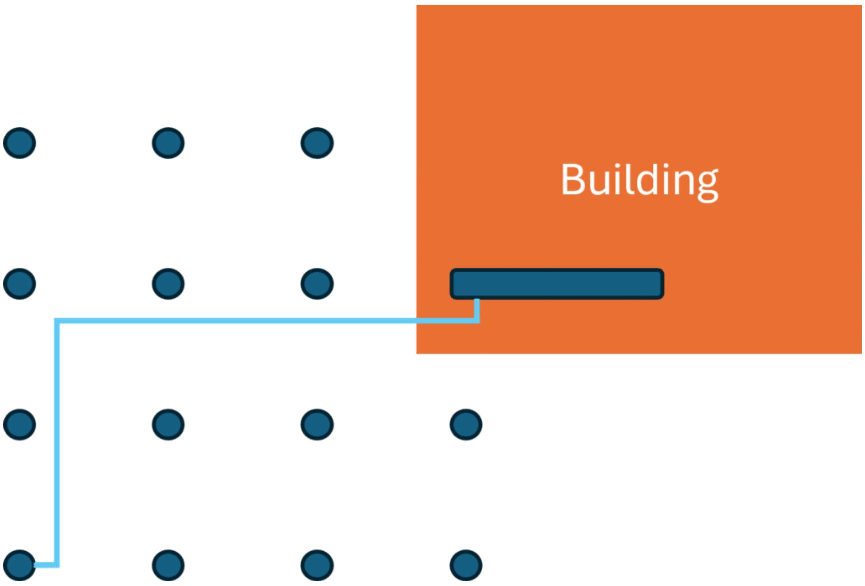
There are many different ways in which boreholes can be hydraulically connected: they can be connected in series or parallel (check our article on this topic here), different horizontal pipe diameters can be used, multiple subcollectors can be implemented, or combinations of all of the above. Each of these systems has a different hydraulic characteristic and deserves its own article. However, most systems can be modelled as boreholes connected individually (or in a series group) to a central borefield collector.



Example of Direct and Reverse Return Systems (source: https://www.pmmag.com/articles/100205-when-and-how-to-use-reverse-return-piping)

> ***!Stay tuned***
> *At the moment, it is not yet possible to model parallel hydraulic connections, where multiple boreholes are connected in parallel on a single horizontal pipe in a direct return system or reverse return system (i.e. Tichelmann). This is because the distance between parallel-connected boreholes also needs to be considered, as the flow rate is not the same through every part of the horizontal circuit. This feature will be added in a later update—stay tuned!*

The image below shows an example of a borefield with 14 boreholes. The borehole with the longest horizontal connection is the one in the bottom left. Hence, the pressure drop for this borehole will determine the pressure drop across the entire borefield.



Example hydraulic configuration with the longest horizontal connection. The boreholes are spaced 6 m apart.

Example with GHEtool Cloud

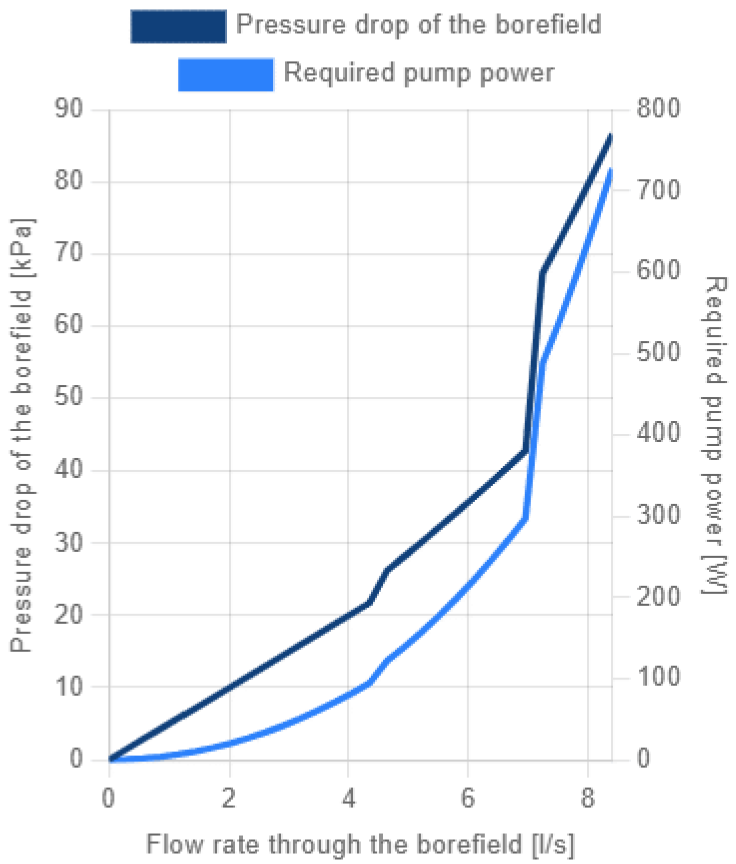
To calculate the hydraulic behaviour of your borefield, you need to use a dynamically calculated borehole thermal resistance (see the 'Thermal Resistance' tab). If you do so, you can select the option to calculate the pressure drop and pump energy under the 'General' tab.

Let us now further specify the example above. Let us assume a water-MPG mixture with 25% MPG and a flow rate of 0.3 l/s. The boreholes are 150 m deep, with a double DN32 U-tube heat exchanger. The horizontal connections are made with a slightly larger DN40 diameter to reduce losses.

Let us enter the flow rate of 4.2 l/s for the entire borefield in the 'Fluid data' section under the 'Thermal Resistance' tab.

Assume all parallel

If we assume that all boreholes are connected individually to the main collector, we can set the series factor to 1. The results of this simulation can be seen below.



Pressure drop and required pump power.

You can see two main jumps, identifying the transition between laminar and turbulent flow (as was explained in our previous article).

The first, smaller jump, is the transition of the horizontal pipe from laminar to turbulent flow. This occurs because a DN40 pipe, used for the horizontal connection, transitions to turbulence (or the transient zone) faster than the double DN32 pipe inside the borehole. The second jump, occurring at around 7 l/s flow rate, marks the point at which the entire borehole also becomes turbulent.

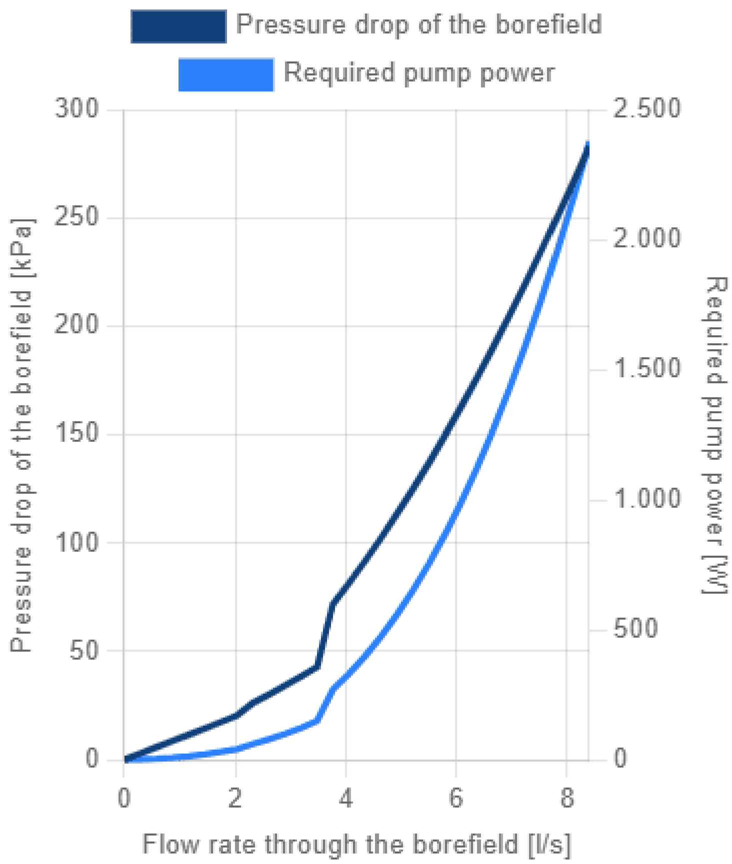
The numerical results for this case are as follows:

- **Pressure drop across one borehole** : 17,37 kPa
- **Pressure drop of the borefield**: 21,04 kPa
- **Flow rate through the borefield**: 4,2 l/s
- **Required pump power**: 88,367 W
- **Estimated pump energy**: 220,98 kWh/year

You can see that the pressure drop of the entire borefield is slightly higher than that of a single borehole due to the horizontal piping. Both are calculated at the design flow rate of 4.2 l/s for the entire borefield. At this design point, the pump should provide 88 W for the system to function as intended and will consume approximately 220 kWh/year of electricity.

Per two in series

To enhance the thermal behaviour, we can opt to connect boreholes in series. If we connect them in groups of two, the flow rate through each borehole doubles, reducing borehole thermal resistance. However, the pressure drop and required pump power increase dramatically, as seen in the figure below.



Pressure drop and required pump power (series factor 2).

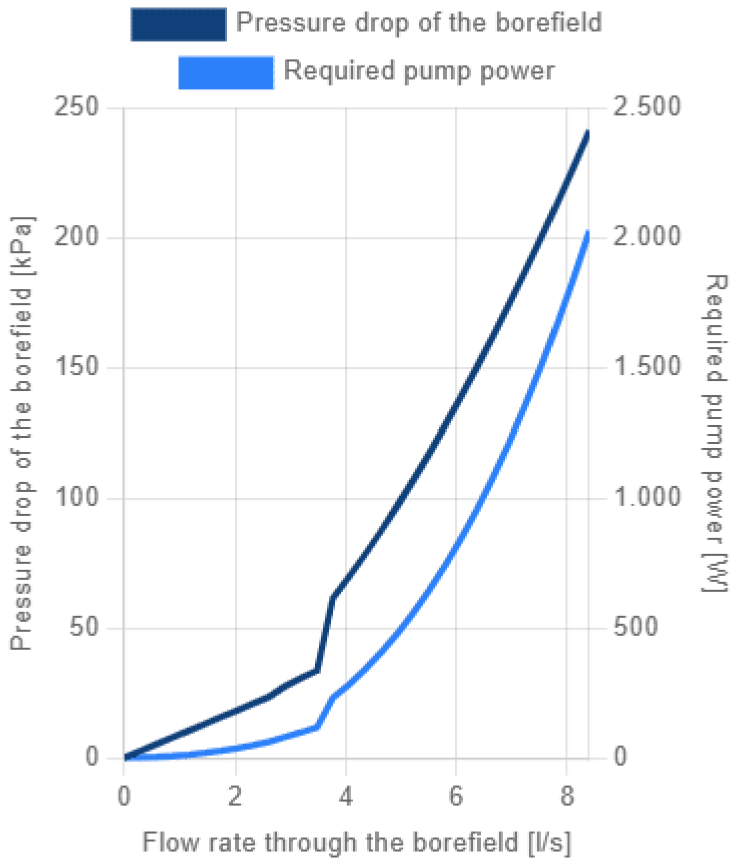
The figure above shows that the entire system is now turbulent, leading to the following numerical results at the design point:

- **Pressure drop across one borehole** : 67,18 kPa
- **Pressure drop of the borefield**: 86,65 kPa
- **Flow rate through the borefield**: 4,2 l/s
- **Required pump power**: 363,922 W
- **Estimated pump energy**: 861,55 kWh/year

Due to the highly turbulent nature of the horizontal piping, the pressure drop of the borefield is now significantly higher than in the borehole itself. As a final step, we can increase the pipe diameter of the horizontal piping to DN50 to reduce losses in this part of the system.

DN50 for horizontal connections

If we want to achieve the same thermal behaviour while reducing pump energy consumption, we can increase the diameter of the horizontal piping, bringing the pressure drop of the borefield closer to that of the borehole itself. The results are shown below.



Pressure drop and required pump power (series factor 2 and DN50).

- **Pressure drop across one borehole** : 67,18 kPa
- **Pressure drop of the borefield**: 73,98 kPa
- **Flow rate through the borefield**: 4,2 l/s
- **Required pump power**: 310,735 W
- **Estimated pump energy**: 735,64 kWh/year

The pressure drop across one borehole remains unchanged, as expected, but losses in the horizontal pipes are reduced, lowering the required pump power from 363 W down to 310 W. Although this effect may seem small in this example, it can be highly significant in larger borefields, where the horizontal distances are comparable to the vertical ones.

Conclusion

In this article, we explored how GHEtool Cloud can assist with the hydraulic design of borefields. We demonstrated how different horizontal pipe diameters affect the pressure drop, and we discussed the impact of series connections on borehole thermal behaviour. With this new feature, we aim to empower you to design even more efficient borefields, ensuring that the pump can effectively deliver the designed flow rate.

References

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