

# Modelling the MuoviELLIPSE

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As of today, the MuoviELLIPSE from Muovitech is available in GHEtool Cloud. In this article, we shed light on the mathematical model behind this elliptical probe, covering both the fluid dynamics and the internal heat transfer within the borehole.

## MuoviELLIPSE

The MuoviELLIPSE is, as the name suggests, an elliptical heat exchanger developed by Muovitech. Like its counterpart, the TurboCollector, the MuoviELLIPSE features multiple small fins along its inner surface. These fins are oriented alternately in clockwise and counterclockwise directions along the length of the pipe. Acting as passive turbulators, they are designed to induce turbulent flow behaviour at lower flow rates, thereby enhancing heat transfer.

In standard smooth pipes, the transition to turbulence typically begins at a Reynolds number of around 2300. However, due to the internal geometry and elliptical shape of the MuoviELLIPSE, turbulence is initiated at approximately  $Re = 1850$ .



*Image of the MuoviELLIPSE.*

## Model development

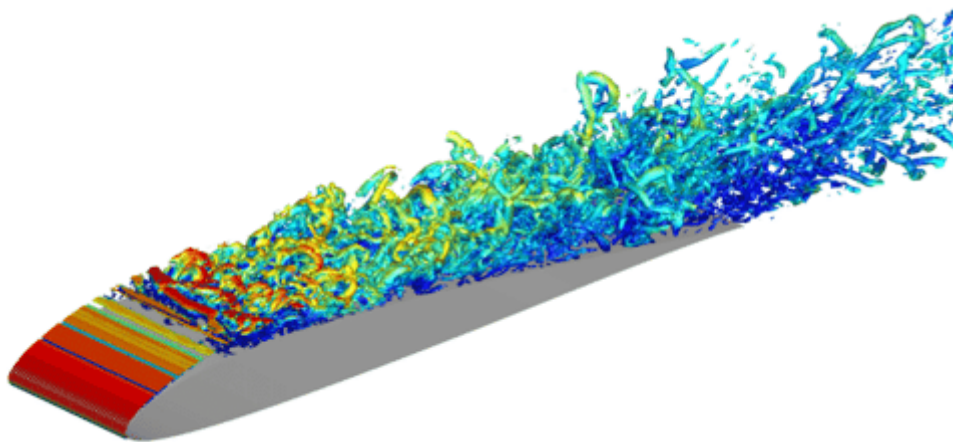
As is clearly visible, the MuoviELLIPSE differs from traditional smooth round pipes in two ways:

1. The fluid behaviour inside the probe is affected by the internal fins and the elliptical shape.
2. The heat transfer outside the probe, but within the borehole, is influenced by its irregular geometry.

To model the MuoviELLIPSE correctly, both aspects must be considered. The first aspect is addressed using Computational Fluid Dynamics (CFD), and more specifically Direct Numerical Simulation (DNS), and is discussed first. The heat transfer within the borehole is then calculated using the Boundary Element Method (BEM).

## Computational Fluid Dynamics

Computational Fluid Dynamics (CFD) is one of the most important fields in engineering today. It is used to simulate fluid behaviour in chemical plants, optimise the shape of aircraft wings to maximise lift, assess the aerodynamic performance of vehicles, predict wind turbine output, and much more. When it comes to modelling the thermohydraulic behaviour of the MuoviELLIPSE, CFD is the preferred method.



CFD simulation of a wing. (Source: (Marten D., 2020))

### **!Note**

*The thermohydraulic simulation of the MuoviELLIPSE follows a similar methodology to that used for the development of the TurboCollector model. For more information on the methodology employed, the reader is referred to [this article](#). As with the TurboCollector, the fluid dynamics results were generated by Niklas Hidman (2026), whose article is referenced below.*

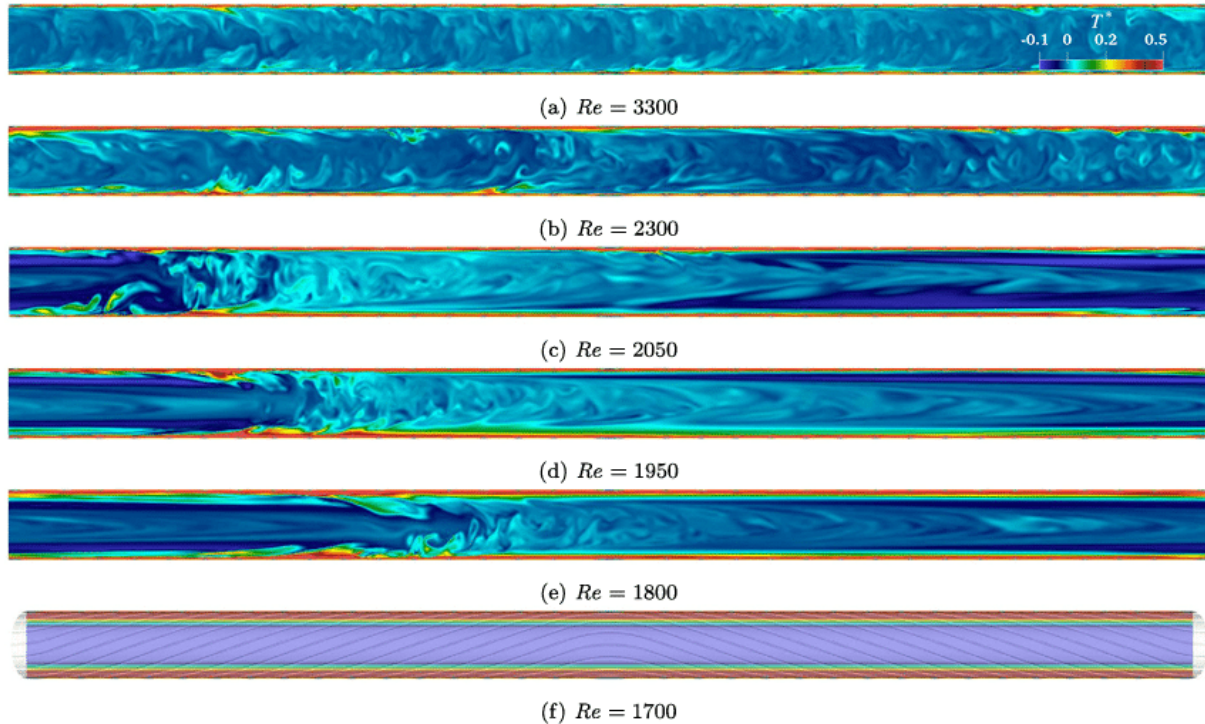
Within the field of CFD, there are various approaches to modelling turbulence, ranging from simplified and computationally efficient methods such as Reynolds Averaged Navier Stokes (RANS) and Large Eddy Simulation (LES) to the highly computationally demanding Direct Numerical Simulation (DNS). Using DNS, fluid behaviour is resolved down to the smallest spatial and temporal scales, allowing even the finest turbulent structures to be captured.

Since the fins that induce turbulence are themselves relatively small, only DNS is capable of accurately capturing the true thermohydraulic behaviour of the MuoviELLIPSE.

Below, the result of such a DNS simulation for a pipe with internal fins is shown (Hidman et al., 2026).

**!Note**

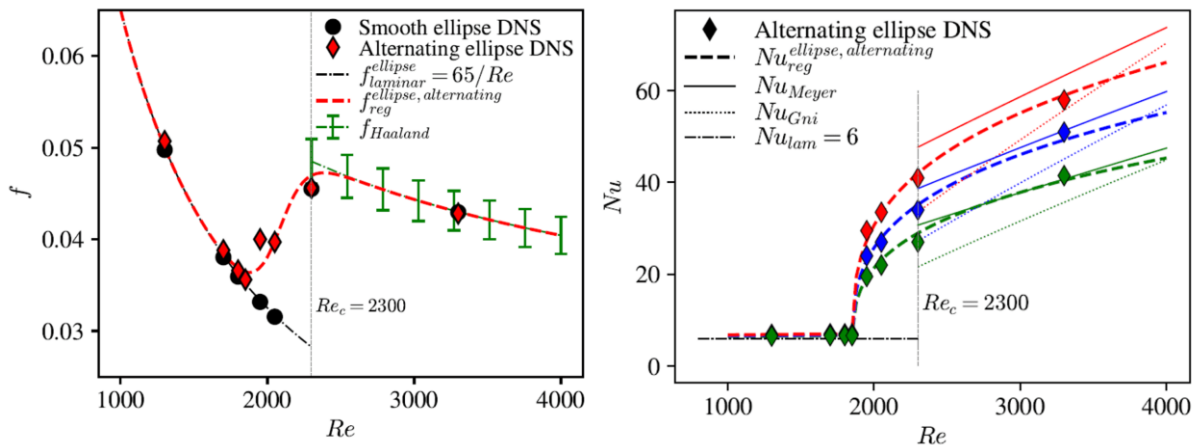
Although the results shown below are taken from Hidman et al. (2026) and relate to the TurboCollector, the same principles also apply to the MuoviELLIPSE.



CFD (DNS) simulation of the TurboCollector. (Source: (Hidman et al., 2026))

In the image above, the first CFD simulation was performed for a Reynolds number of 3300, corresponding to fully turbulent flow. By systematically reducing the Reynolds number in the simulation, the flow gradually transitions out of the turbulent regime and enters a transitional regime characterised by local flow disturbances, as illustrated by the case with  $Re = 1800$ . For Reynolds numbers below 1700, the flow regime becomes fully laminar.

For the MuoviELLIPSE, the transition from laminar to transitional flow occurs at approximately  $Re = 1850$ , compared to the traditional value of around  $Re = 2300$  for a smooth pipe. This behaviour can be observed in the two correlation graphs shown below.



DNS simulation results for both the friction factor (left) and the Nusselt number (right). (Source: (Hidman N., 2026))

The graph on the left shows the friction factor (more information can be found here) as a function of the Reynolds number for both a smooth elliptical probe, which serves as a reference, and the MuoviELLIPSE. It is clear that, at a Reynolds number of approximately 1850, the probe with internal fins begins to deviate from the smooth pipe behaviour and moves towards the friction factor associated with turbulent flow. Once the flow becomes turbulent, it follows the familiar decreasing trend with increasing Reynolds number.

The same behaviour can be observed when examining the Nusselt number, which is a measure of convective heat transfer. At the transition threshold of approximately  $Re = 1850$ , the Nusselt number increases sharply, indicating a significant enhancement in heat transfer. As a result, the effective borehole thermal resistance decreases, as will become clear later in this article.

**!Note**

*Note that, for the Nusselt number, multiple simulations were performed for different Prandtl numbers, indicated by the various colours. A detailed explanation of the Prandtl number is beyond the scope of this article, but for geothermal applications it typically ranges from approximately 20 (green) to 75 (red), depending on the fluid properties, such as the type of antifreeze used, and the fluid temperature.*

The results show that the observed increase in heat transfer at the transition to turbulent flow occurs across the entire range of relevant Prandtl numbers.

**Boundary element method**

The second challenge in modelling this pipe is accounting for its elliptical shape. For traditional smooth circular pipes, the internal heat transfer equations can be solved analytically. However, this is no longer possible for non-circular geometries.

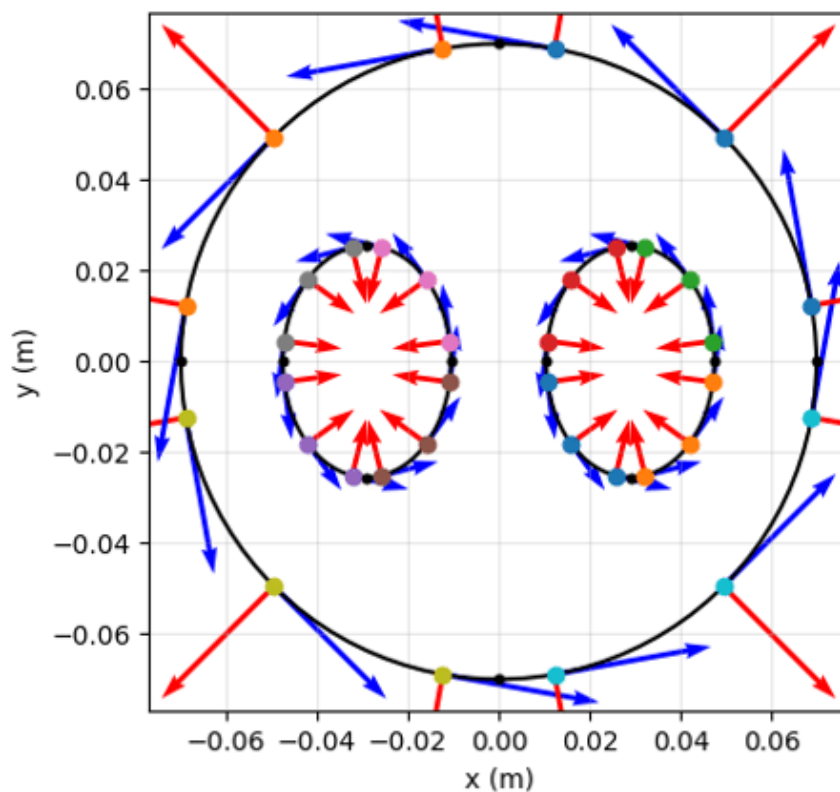
To overcome this limitation, a numerical approach in the form of the Boundary Element Method (BEM) was employed.

**!Note**

*The application of the Boundary Element Method to shallow geothermal borefields was inspired by and co-developed with Prof. Massimo Cimmino.*

The Boundary Element Method (BEM) is a numerical technique used to solve linear partial differential equations (PDEs), such as those governing heat transfer. In the present case, it transforms the original two-dimensional problem into an equivalent one-dimensional problem defined along the boundaries of the pipes and the borehole wall.

Put simply, rather than solving for the entire temperature field within the borehole, it is sufficient to solve an equivalent heat transfer problem along the pipe surfaces and the borehole wall. This concept is illustrated graphically below.



*Graphical representation of the Boundary Element Method (thanks to M. Cimmino).*

In the figure, the different points represent the nodes at which the heat transfer equations are solved. The arrows indicate the tangential and normal components of the heat transfer. By discretising the pipe geometry in this way, it becomes possible to accurately account for the true elliptical shape of the probe.

The main drawback of the BEM is that it is computationally intensive and therefore too slow for direct use within GHETOOL. To make the model sufficiently fast for practical simulations, an Artificial Neural Network (ANN) is trained using the results of the high-fidelity BEM simulations.

This approach combines the best of both worlds: an accurate, geometrically representative model for calculating heat transfer within the borehole and an ANN that enables these calculations to be performed efficiently within GHEtool.

***!Note***

*Artificial Neural Networks (ANNs) are already used within GHEtool to accelerate the calculation of g-functions, which form the basis of the methodology used to determine the required size and depth of a borefield. For more information the reader is referred to [this article on the topic](#).*

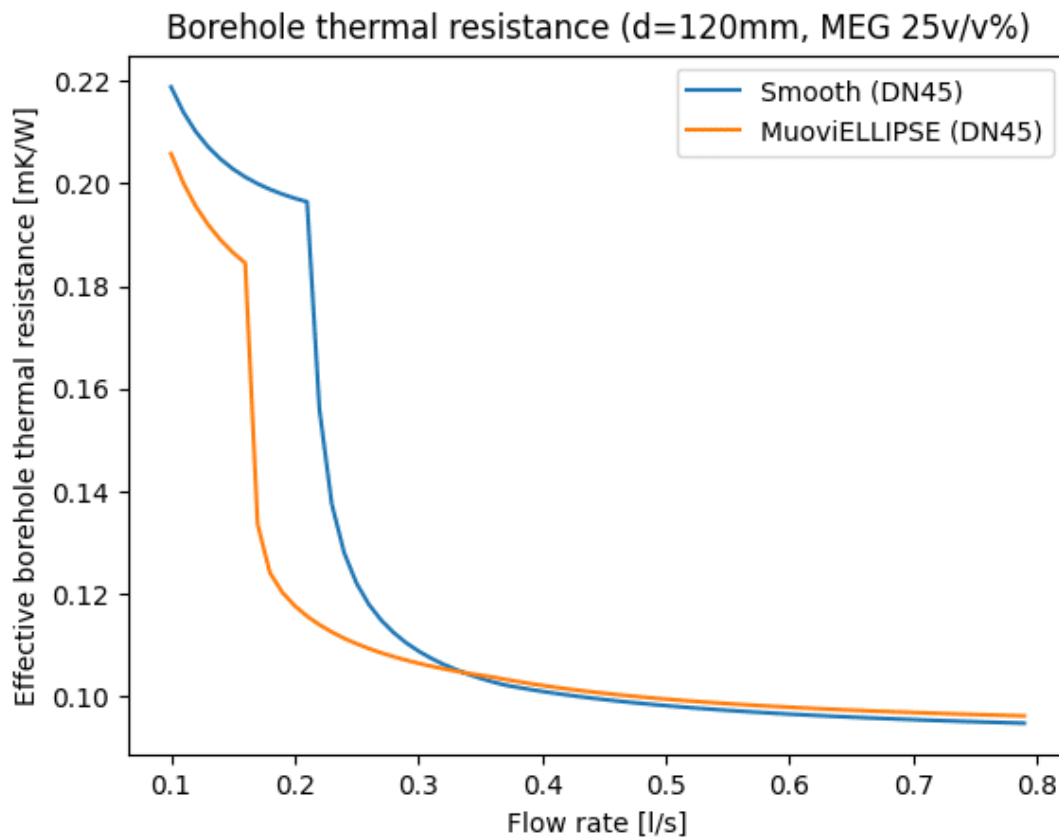
Based on the models discussed above, the effective borehole thermal resistance and pressure drop of the MuoviELLIPSE are examined below.

## Simulation results

Using both the correlations for the friction factor and the Nusselt number as well as the BEM, the effective borehole thermal resistance and the pressure drop curves for the MuoviELLIPSE will be discussed below.

### Effective borehole thermal resistance

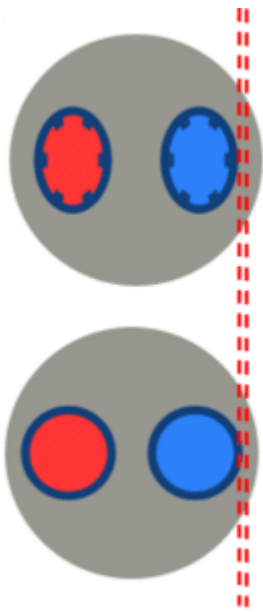
In the graph below, the effective borehole thermal resistance is shown for both the MuoviELLIPSE DN45 (PN16) as well as the smooth DN45 circular probe as a comparison. The graph is created using a borehole diameter of 120mm and MEG 25v/v% for both probes. The pipe length is 100m and the grout has a thermal conductivity of 1.5 W/(mK).



*Effective borehole thermal resistance for a MuoviELLIPSE DN45 and its smooth circular equivalent.*

The sudden jump towards a smaller borehole resistance, indicating the transition from a laminar towards a transient flow, occurs sooner for the MuoviELLIPSE than for the smooth alternative. This is due to the internal fins that enhance the turbulence already at lower flow rates.

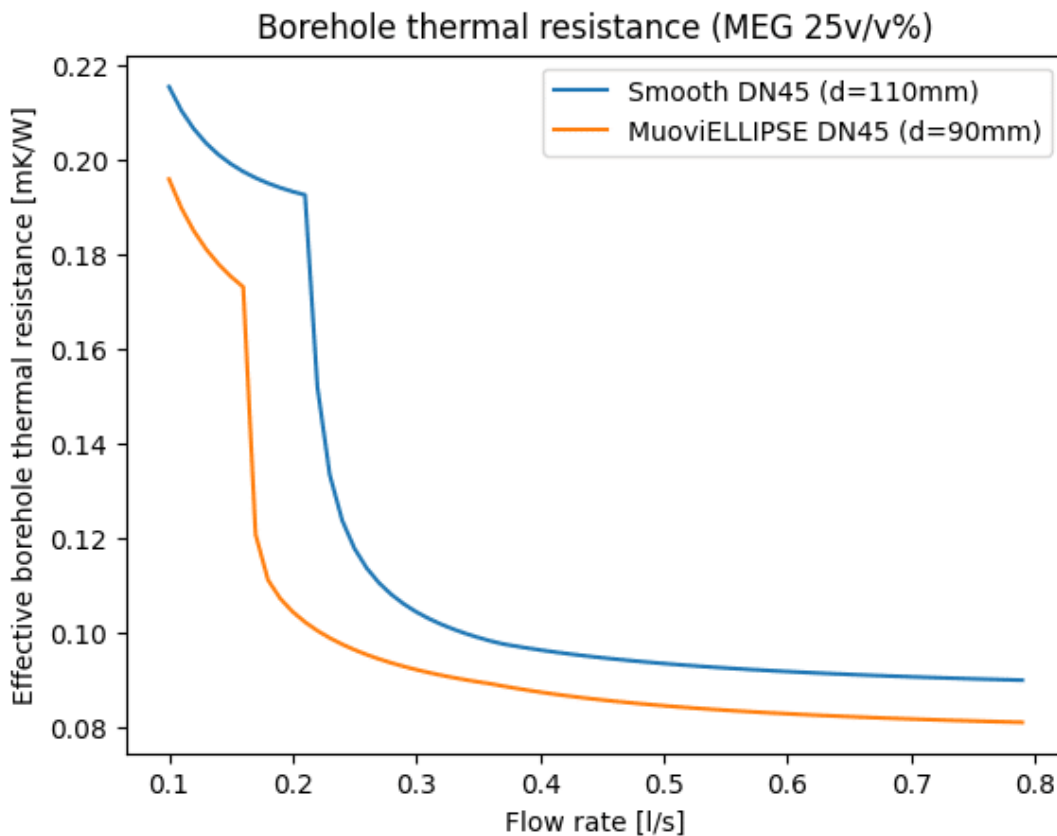
What is also noticeable, is that for a fully developed turbulent flow, the effective borehole resistance for the MuoviELLIPSE and the smooth reference converges, with the circular probe having a slightly better borehole resistance. This is because, as is shown in the cross-sectional view below, the circular pipes are slightly closer to the borehole wall than the elliptical ones.



When the fluid is turbulent, the grout resistance becomes more and more important in the overall borehole resistance and having your pipes closer to the wall is hence beneficial.

The advantage however when working with an elliptically shaped probe, is that one can install it easier in boreholes with as smaller diameter. As is visible in the cross-sections above, the MuoviELLIPSE has more 'space' to move around, so it could potentially be installed in a slightly smaller borehole. The comparison between a circular DN45 probe in a 120mm borehole and the elliptical one in a 90mm is shown below.

*Cross-sectional view of a 120mm borehole with both a MuoviELLIPSE DN45 and a circular DN45.*

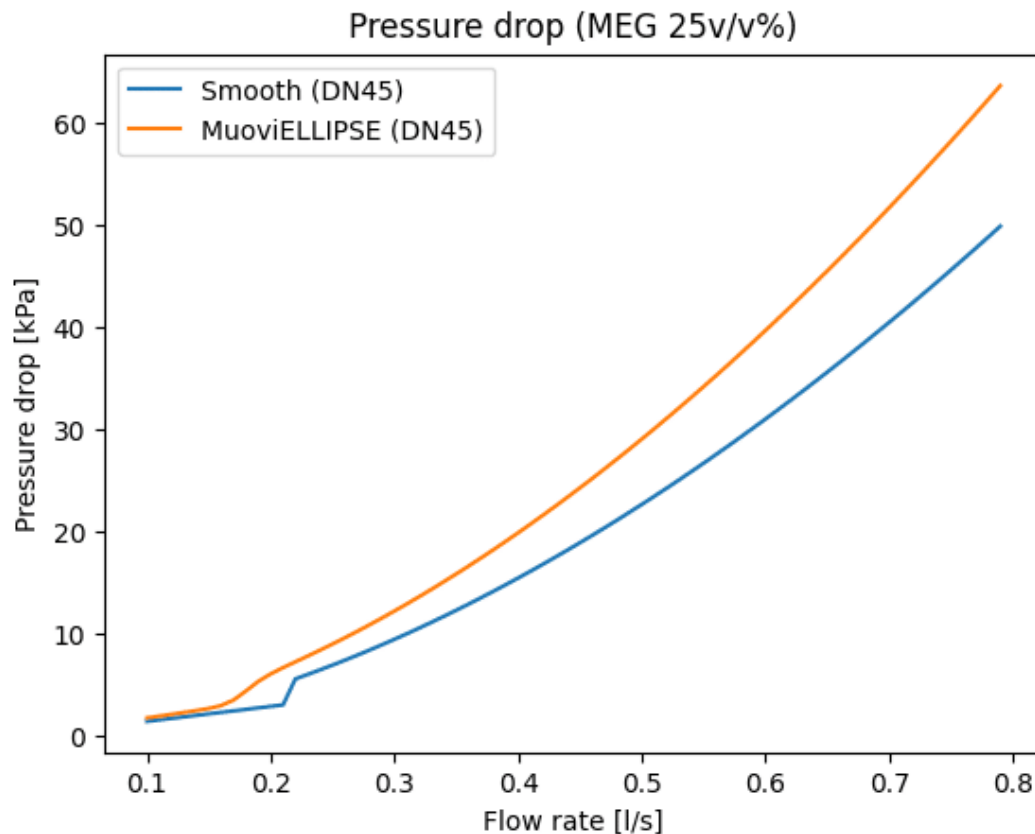


*Effective borehole thermal resistance for a MuoviELLIPSE DN45 and its smooth circular equivalent for respectively a borehole diameter of 90mm and 120mm.*

In the graph above, the transition towards turbulence still occurs at the same location, but now, the MuoviELLIPSE outperforms the smooth pipe for all flow rates, due to the smaller borehole diameter and hence the smaller grout resistance.

## Pressure drop

In the graph below, the pressure drop for both the MuoviELLIPSE DN45 and its smooth circular DN45 reference is shown.



*Pressure drop for the MuoviELLIPSE DN45 and its smooth circular equivalent.*

One can see that the pressure drop increase starts faster for the MuoviELLIPSE than for the circular pipe. This is because, just as with the TurboCollector, the enhanced turbulence at lower flow rates comes at the cost of an increased pressure drop. Besides that, a clear difference in pressure drop between the elliptical and circular pipe is visible.

This is because the hydraulic diameter of both probes is not identical. The circular DN45 PN16 probe has an internal diameter of 36.8 mm whereas the hydraulic diameter of the elliptical probe is 34 mm. This smaller diameter means a slightly higher flow velocity for a given flow rate and hence also a higher pressure drop.

### **!Note**

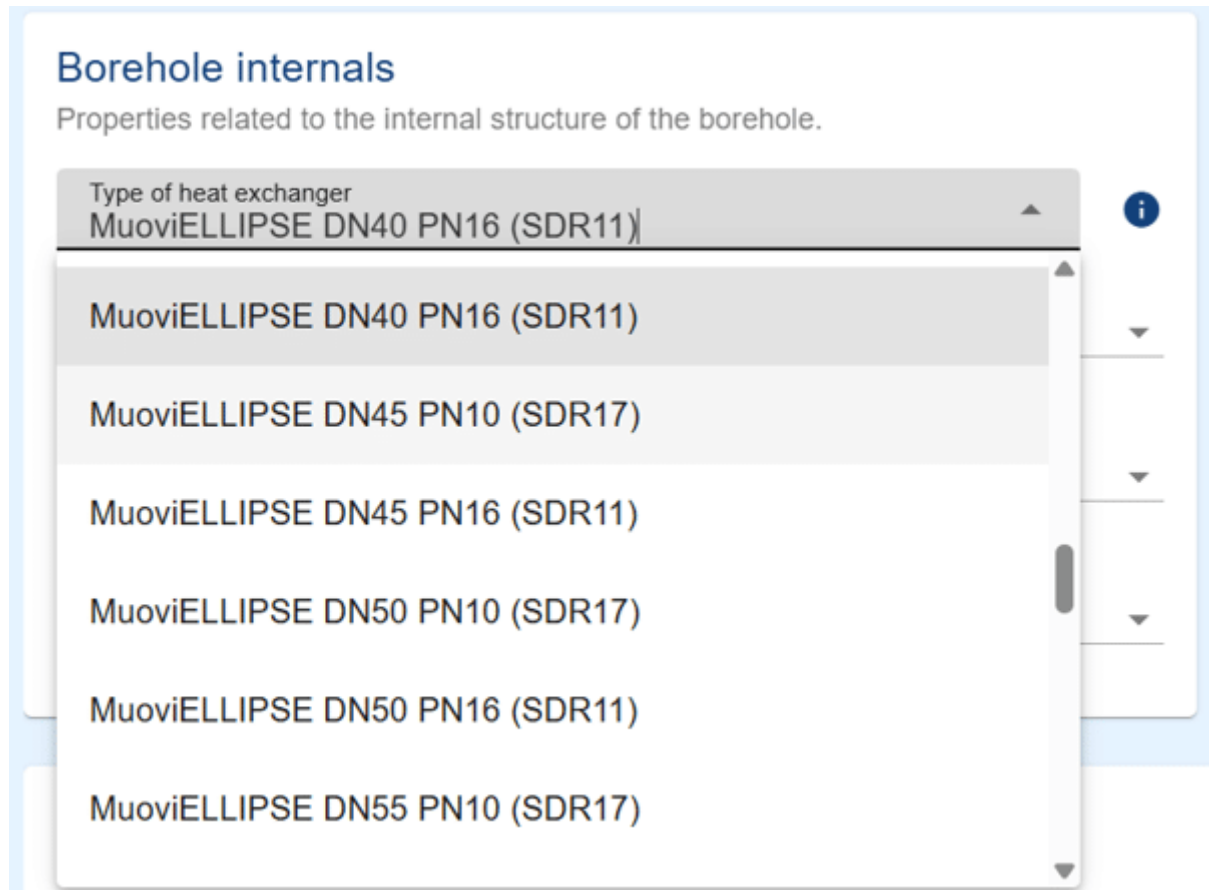
*The hydraulic diameter is a concept used to model non-circular geometries by defining an hydraulic diameter that would give them the same hydraulic properties as a circular pipe. This hydraulic diameter is defined as:*

$$D_h = \frac{4A}{P}$$

where  $D_h$  is the hydraulic diameter in (m),  $A$  is the cross-sectional area in ( $m^2$ ) and  $P$  is the wetted perimeter of this area in (m). Since the ratio is slightly smaller for an elliptical probe than for a circular one, the hydraulic diameter is hence a little bit smaller.

## MuoviELLIPSE in GHTool

From today onwards, the different MuoviELLIPSE (ranging from DN32 to DN63, both PN10 and PN16) are available in GHTool Cloud under the 'borehole internals' tab. Try it out today!



Print screen of the MuoviELLIPSE in GHTool Cloud.

## Conclusion

This article discussed in detail the mathematical modelling of the MuoviELLIPSE, based on the recent work of Hidman N. (2026) for the heat transfer inside the probe as well as the boundary element method, to account for the elliptical shape.

It was shown that the clockwise and counterclockwise rotating fin design creates a transient flow starting at around  $Re=1850$ , whereas the transition to a turbulent flow in a smooth pipe starts only at around  $Re=2300$ . Due to its elliptical shape, it is possible to install this probe in a smaller borehole diameter enhancing the effective borehole thermal resistance.

The friction factor is higher for the MuoviEllipse in the range  $1850 < Re < 2300$  due to the induced turbulence, but it converges towards the smooth pipe solution in both the laminar and fully turbulent regimes. However, due to the smaller hydraulic diameter due to the elliptical shape, the overall pressure drop stays higher than the circular counterpart.

## References

- Watch our video explanation over on our YouTube page by clicking [here](#).
- The article by Niklas Hidman can be found [here](#).
- More information on the boundary element method can be found [here](#).



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