EED - Frequently Asked Questions

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The latest version of this document is available at
https://buildingphysics.com/download/eedfaq.pdf

EED - Frequently Asked Questions

A collection of frequently asked questions has been assembled in this document. They are organized according to the most fitting submenu heading in the program.

The following documents may also be of some assistance:

- TUTORIAL EXAMPLES FOR EED v4
- Notes from Geotrainet Course in 2016 showing some test cases with comparisons to measured data
- Explanation to SPF in EED
- A "textbook"-file from the international summer school in 2001
- One of the papers cited in the manual from 1997 with conclusions of EED
- A general paper on GSHP from 2003, with reference to EED
- Paper that presents the first version of EED 1994
- Eskilson Ph.D.Thesis (1987).pdf
- Hellström Ph.D. Thesis (1991).pdf

Contents

1 General questions

Q.
I have downloaded the EED User Manual and after some study of it I have some questions to which I would be most pleased to receive your replies and observations. I should explain that I have developed an interest in applying BHES to UK conditions where the technology to date is largely ignored (GeoScience excepted).I would like to understand the mathematical basis for the so-called g-functions, and how they are calculated and incorporated into EED. I understand that they were originally formulated by P Eskilson in his Doctoral Thesis at The University of Lund (1987), and subsequently incorporated into the EED simulation model, apparently in a more simplified form. Most of the references are to internal reports published by Lund University by Eskilson and later workers. Is it possible for you to send me any papers explaining these functions in detail and how they feature now in EED?

A.
The g-functions are implemented in the EED program as they were formulated by Per Eskilson. Per Eskilson calculated g-functions for about 40 different configurations and for each configuration several different values of the dimensionless ratio between borehole spacing and borehole depth were used. All g-functions have since been recalculated to include shorter time-scales for 797 different configurations were the ratio between spacing and depth can be varied between 0,02 and 0,5. The theory of the g-functions is explained in Eskilson's doctoral thesis that can be downloaded from www.buildingphysics.com. The borehole thermal resistance is explained in more detail in the thesis be Hellström. Thus, thesis can be found at the same site.

Q.
In the example design in the EED Manual it seems that equal rates of extraction/injection are applied to each borehole, obtained by dividing the monthly and peak net totals by the total number of boreholes (4 in the example). Is this a correct interpretation of EED and if so, is an equal rate of heat extraction/injection applied to all boreholes in any selected configuration?

A.
No, that is not the how the g-functions in EED have calculated. The simplification assumed in the g-function formulation is that all boreholes have the same fluid temperature, so the heat transfer rates will vary between (and along) the boreholes. The fluid temperature used is the mean value of inlet and outlet fluid temperature. We have found this to be a good approximation and certainly better than assuming equal rates from all boreholes.

The g-functions have been calculated using a simulation model called Superposition Borehole Model that allows for various different loading conditions:

1. borehole wall temperatures the same for all boreholes – heat transfer rates calculated

2. heat transfer rate per meter borehole (heat flux) the same for all boreholes – borehole wall temperature calculated
3. total heat transfer rate (for all boreholes) given – common borehole wall temperature calculated (g-functions)
4. given inlet fluid temperature and fluid flow rate (boreholes may be coupled in series or parallel or combination of these, there may also be different hydraulic systems with different loading conditions) – outlet temperatures and heat transfer rates calculated
5. as number 4, but total heat transfer rate and flow rate are given – (required) inlet fluid (and resulting outlet) fluid temperatures are calculated. In this model the boreholes can be placed arbitrarily and also non-vertical. Load conditions can be varied (and mixed) with any time-step. (The SBM model is currently an old-fashioned FORTRAN program running in batch mode). Running EED and SBM for the same configuration and load conditions give the same results.

Q.
Does EED account for tilted (with an angle) boreholes?

A.
No, EED only allows for vertical boreholes. You can however use the mid-point of the effective length of the borehole as an approximation. The “mid-point” is at half of the depth of the borehole. In this case we consider that all boreholes are at least straight, when angled (not in a curve like in oil or deep geothermal). So, if you draw a plan of the borehole field with the location on surface and extrapolate the relative position of the boreholes at final depth, the “mid-point” is just in the middle from the top to the bottom point, seen either from top or from the side. For the distance of boreholes at this mid-point, the boreholes in the upper half are closer to each other (I reckon only outward angles make a sense anyway), and in the lower half have more distance. So giving the mid-point as “spacing”, you have the average distance. As written, this is not exact, but a good approximation. We have however an inhouse model (SBM) that accounts for tilted boreholes. Let us know if you need help with calculations.

Q.
Wir arbeiten für die Auslegung von Erdwärmefeldern mit dem EED-Programm. Hierzu stellt sich folgende Frage:

Kann eine räumliche Temperaturausdehnung für ein Erdsondenfeld (ohne Grundwasser) mit dem o.a. Programm simuliert bzw. dargestellt werden. Es geht um die Beeinflussung eines benachbarten Sondenfeldes durch eine geplantes Sondenfeld in einem Genehmigungsverfahren. Hier wird ein entsprechender Nachweis verlangt.

A.
EED ist ein gegenüber numerischen Simulationsmodellen vereinfachtes Verfahren, in das Ergebnisse aus solchen Simulationen über die g-Functions eingehen. Daher kann nur die Temperatur in den Sonden, nicht die Ausbreitung berechnet werden. Entsprechend schnell ist die Berechnung.

Für die Temperaturausbreitung eignet sich als Abschätzung z.B. die Formel nach Guernsey, die in VDI 4640 Bl. 2 abgedruckt ist. Ansonsten muss mit numerischen Modellen wie FEFLOW gearbeitet werden.

Q.
EED does not account for the convective heat transfer with regional groundwater flow in the surrounding ground. To some extent, this limitation may be counted as the worst case scenario, because the convective heat transfer heat/cold withdrawal will alleviate heating/cooling peeks. However, we may overestimate the number of wells and increasing the cost because of this limitation. In this case, the use of models accounting for groundwater heat transfer (FEFLOW, TOUGH, other) may be beneficial. What, in your opinion, is the criterion which allows to judge if the groundwater flow should be taken into account? What do you think of the EED applicability for cases with intensive groundwater flow?

A.
EED uses a purely conductive approach, because the inclusion of groundwater flow requires much more input parameters and a much more complex calculation. EED is intended as a fast and easy method for the typical ground source system. If you suspect there might be a high influence of moving groundwater, a full hydrogeological model is required to get precise answers (and the hydrogeological investigations to determine the exact input parameters, too). To my experience, consistent with field observations, the way to use EED in areas with regional groundwater flow is the following:

For the short-term behavior (“peak load”), the influence of groundwater flow is negligible. Only with extreme Darcy-flow, there is a slight impact (the Darcy-flow is the only interesting value, as it includes the amount of water that passes the BHE, not just the velocity). I had a student do a thesis with a comparison of EED-results to results from a groundwater model (TRADIKON-3D, only used internally at the university), and the results showed just that: no or negligible short-term impact. For the long term, there is a substantial impact, as groundwater carries heat to and from the BHE. For single BHE or small numbers, I use the temperature values of the 2nd year as a reference; because of the groundwater, these temperatures will not be exceeded over the years. For large BHE fields, there is only a shift of the temperatures inside the field, so the impact is much smaller, and I calculate like in the purely conductive mode. NB: This are hints to use EED in cases it is not exactly intended for. There might occur misjudgments by the user, for which the developers cannot be held responsible. EED does a purely conductive calculation, for exact determination of groundwater impact, use other relevant software.

Q.
We work with geothermal activation of concrete energy piles. Recently I bought a license of EED3, but the available manual gave no hint how to set parameters in EED 3 to calculate these cases. Do you have some information with which parameter sets it is possible to work with energy piles of e.g., 1,20 m diameter, 10 m depth, a distance of 1,50 m center to center and different U-pipe variations to optimize output? One line of piles can contain up to 100 single piles. I would

appreciate very much to know how to set the EED-parameter, since in different reports people report to have used EED to solve these questions.

A.
EED can be used for energy piles with up to 3 loops in one pile (triple-U), as long as some criteria are given:

1. Pile diameter not more than ca. 1/10th of pipe length, with a maximum of about 1,5 m.
2. Pile distance minimum 1/10th of pipe length (only for narrow piles!)

In your case, the pile diameter is a bit too large, and the remaining soil between adjacent piles (0,3 m!) tends to be much less than the pile diameter. I doubt that EED will give an accurate prediction of temperatures in this case.

In general, the input for an energy pile reads as follows (example):

- borehole heat exchanger type: triple-U
- borehole depth: 10 m
- borehole diameter: 800 mm
- contact resistance pipe/filling: 0 (m,K)/W
- (pipe as you wish)
- shank spacing: 500 mm (Diameter of iron re-enforcement cage!)
- filling thermal conductivity: Concrete (ca. 1,6 W/m/K)

If you want to model a single line with 100 piles, just use the g-function for a single line of 25 (maximum for line), and divide the bas- and peak-loads by 4. The difference in thermal response of a line of 25 to longer lines is negligible.

Q.
Do you provide training courses?

A.
Within academic co-operations, courses may be free (travel and accommodation will have to be provided); for commercial purposes, there are courses depending on time and topic (only EED, EED and GSHP design, and any other additions you might wish), and on the time needed for travel to the course venue.

Q.
I want to know if you have some files such as CD to demonstrate the process of using the software except user manual.

A.
In the user manual the process of design is shown using an example. The software is intended as a tool for GSHP designers, so a basic knowledge of the systems is of course required. This cannot be taught by using a CD-ROM. If you have specific questions concerning the use and operation of EED, please do not hesitate to contact us. If you need a basic teaching, a course might be required.

Q. [2021]
Can you give me details about the EED model? Is it based on the (ILS) infinite linear source? If not, which model is utilized?

What are the limitations in the use of EED for simulation period and hourly simulations? According to the ILS model, hourly simulations cannot be simulated and simulation period should not exceed 7 years for a 100 m BHE.

A.
The infinite line-source model (ILS) calculates the radial thermal process in a plane (two-dimensional). There are three-dimensional effects, such as end effects including exchange with the ground surface. The EED model uses g-functions precalculated using the SBM model, which is a fully three-dimensional model (x,y,z) based on super-positioning of numerical axisymmetric cylindrical solutions (r,z) for each borehole (vertical or inclined).

The model is further described in Per Eskilson's thesis.

There are no limitations in simulation time provided boundary conditions, undisturbed ground temperature, are not changing during this time. If there is a gradual heating of the ground, or precisely the average undisturbed ground temperature along the borehole, this gradual temperature increase should be added to the calculated results.

Q. [2021]
Curious if your EED software will work in Australia with Australia climate data?

A.
Of course EED will work with Australian climate.

The impact of climate is in the load curves (which should be calculated according to Australian data and practice) and the undisturbed ground temperature. The default monthly load distribution as installed would not be applicable, obviously.

2 Ground Properties

The figure below illustrates how the initial ground temperature is used in the program. The program generates a linear temperature gradient *ΔT/Δz* based on the input data of ground thermal conductivity *λ* and geothermal heat flux q_{geo} according to the relation:

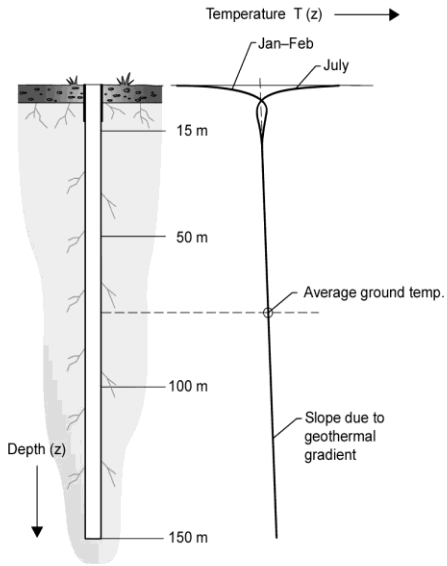
$$q_{geo} = \lambda \cdot \Delta T/\Delta z \quad \rightarrow \quad \Delta T/\Delta z = q_{geo} / \lambda$$

The ground temperature variation *T(z)* with depth *z* can now be written as:

$$T(z) = T_0 + (\Delta T/\Delta z) \cdot z$$

where T_0 is the ground surface temperature.

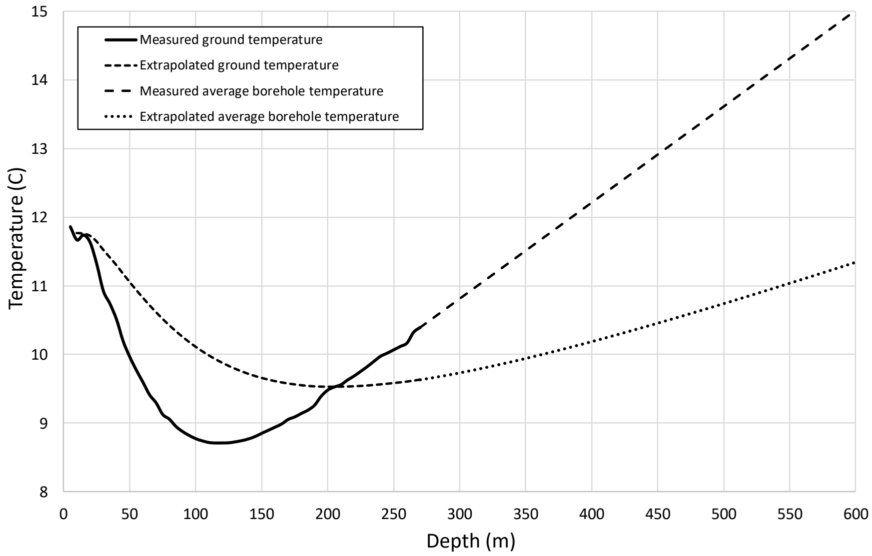
The program then uses the average value, the temperature at mid-point of the active borehole, as the initial ground temperature



Borehole with vertical temperature profile in the ground.

If a test borehole has been drilled at the proposed site for the geoenergy project, it is possible to make a measurement of the vertical temperature profile after a certain time period allowing for the disturbances caused by the drilling operation to vanish.

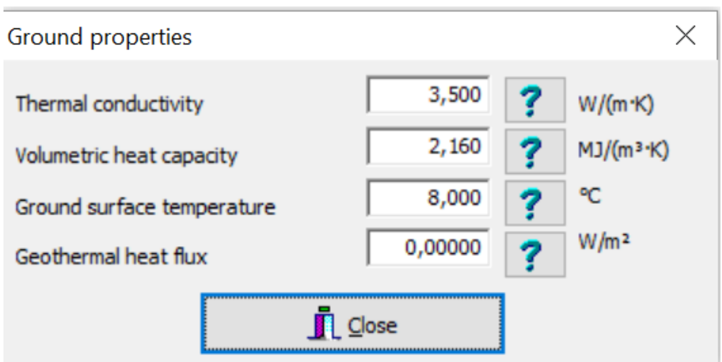
The graph below provides an example of a measured and extrapolated vertical temperature profile in Central Stockholm. Here, the influence of heat losses from building foundations at the ground surface reaches a depth of about 150 m. Below this depth there is a fairly linear temperature increase with depth. The temperature profile below 265 m has been extrapolated based on a linear regression of measured temperatures in the interval 180-265 m. The corresponding average borehole temperature has been estimated based on these values.



Graph of measured and extrapolated vertical temperature profile in Central Stockholm. The corresponding average borehole temperature has been estimated based on these values

A thermal response test will also provide an average initial ground temperature along the active borehole.

In the case that the average initial ground temperature is known, this value should be written in place of the “Ground surface temperature” and the “Geothermal flux” value should be put to zero.



Q.
I have a question about “ground properties”, you have listed many values of the ground. I want to know if these are average of all layers in the ground. The values are only sorted by the type of the rock in EED.

A.
If you know the ground profile with depth, you can take the weighted average between the relevant rock types. Let me give an example:

You may have a 120-m-borehole in (from top) 20 m of sand, then 50 m of limestone, and until final depth another 50 m of marl. The individual values are:

- sand, saturated 2.4 W/m/K
- limestone, massive 2.8 W/m/K
- marl 2.1 W/m/K

Now you do the weighed average:

20 m / 120 m x 2.4 W/m/K = 0.40 W/m/K
50 m / 120 m x 2.8 W/m/K = 1.17 W/m/K
50 m / 120 m x 2.1 W/m/K = 0.87 W/m/K

And the sum of the values gives you the value over the borehole length with 2.4 W/m/K.

Q.
How can the "Geothermal heat flux" be obtained?

A.
The geothermal heat flux within Europe usually is obtained from an atlas issued by the European Commission containing a set of maps showing this value. It has to be calculated from measurements in boreholes, by taking a temperature profile with depth and measuring the thermal conductivity of the ground. For a GSHP project, you would not do that. If you do not have similar maps (check e.g. with the International Geothermal Association http://iga.igg.cnr.it), there are two ways to deal with it:

Take the default value (or a value between 0.06 W/m^2 and 0.07 W/m^2). This is valid for most places on earth, outside geothermal anomalies.

If you have a measured average value over the borehole length (e.g., from the preparation of a Thermal Response Test), type in that value as ground surface temperature, and set the geothermal heat flux to 0.0. This is the most exact way, however, the final depth of the borehole should not differ much from the depth of the borehole the value was measured in. The value may vary in a region e.g., where deep faults and thermal waters occur (geothermal anomalies).

Q.
Where can I get values of geothermal heat flux of Toronto, Canada from. I read FAQ in which you have mentioned that we can take default value of geothermal heat flux between 0.06 and 0.07. Please mention the units for these values. If I am using English units what will the values be then.

A.
The EED databases by now yield only European values for site-specific parameters. There are some values for the rest of the world, of course, typically provided by geophysical institutes at universities and geological surveys. In case there is no further information, I suggest using the average value of 0.06 W/m^2 (ca. 0.02 btu/(hr*ft^2)). For areas in the Canadian shield (Northern Ontario), a lower number of ca. 0.015 btu/(hr*ft^2) would be reasonable, for the Western regions a slightly higher value.

Q.
Concern # 1
I have obtained following parameters from In-Situ Thermal Conductivity Test:

Calculated Thermal Conductivity = k = 1.0 Btu/ft.h¢ªF
Calculated Thermal Diffusivity = 0.01625 ft^2/hr

Based on above parameters, I have calculated Ground heat Capacity as follows:

Calculated Thermal Diffusivity = 1.000/0.01625 = 61.5 Btu/ft^3¢ªF

(Please confirm whether I calculated correct or not?)

Concern # 2
I have soil temperatures at various locations of Canada at depth of 150 cm. Could I use those values of temperature at depth of 150 cm in EED 3.13 as Ground surface temperature?

Concern # 3
I am sure un-disturbed ground temperature is different from Ground Surface Temperature. Please mention formula or equation used by EED 3.13 to calculate it at various depths.

Concern # 4
We normally take services of a company to drill test borehole to find thermal conductivity as well as thermal diffusivity of ground. Would you please suggest us how could we calculate the Geothermal heat flux from test borehole?

Concern # 5
I have picked following values from In-Situ Thermal Conductivity Test:

Power Input = 4166 watts.
Borehole depth = 185 feet.
Btu/hr/ft = 4166 x 3.41/185 = 76.8

Since, I don't have a Geothermal heat flux value, so I put 76.8 as ground surface temperature and set geothermal heat flux to 0.0. Did I do correct or not?

A.
Concern #1:

We do not need thermal diffusivity as input for EED. This value is calculated as

thermal diffusivity = thermal conductivity/(density x specific heat capacity)

Where the thermal conductivity and the volumetric heat capacity (=density x specific heat capacity) is given in EED.

Concern #2:
Temperature at 1-2 m depth is so close to mean surface temperature that you can use these values without further correction.

Concern #3:
EED is calculating the temperature at half the depth of the borehole, as reference for the calculations. Temperature is rising slightly towards depth, according to the geothermal heat flux and thermal conductivity, and this increase is calculated starting from the ground surface temperature.

Concern #4:
To measure the geothermal heat flux, you need a vertical temperature log in the borehole, at a stable situation several weeks after drilling (the drilling process heavily disturbs the temperature distribution). With the known thermal conductivity and the temperature difference over the borehole depth, you can calculate the geothermal heat flux. Remark: This is normally not done for GSHP installations, there you use either estimated data, or in case you have a test, the procedure described in concern #5.

Concern #5:
There is no way to calculate the ground surface temperature from the heat input. I reckon that is a misunderstanding. As you have given the test result in the appendix, just use the value given there for the ground temperature: 10.9 °C or 51.6 °F, and set the geothermal heat flux to 0. Please be aware that that value only is valid for a depth in the range of that of the test borehole, i.e., some 180-190 ft !

Q. [2021]
I have a doubt about parameter « Ground surface Temperature » in Ground properties. Do I put the surface temperature of the city or the real ground temperature, for example when we have a thermal response test (with an average ground temperature)?

A.
A few remarks:

The Ground Surface Temperature is the mean annual temperature at ground surface (i.e. just beneath ground surface); normally it is the same as the annual mean air temperature, however, in regions with long duration of snow cover, "ground surface temperature" is some 1-3 K higher than mean annual air temperature.

The undisturbed ground temperature is calculated as an average over the borehole length, using the surface temperature as a start and calculating the temperature at depth using the geothermal gradient and the ground thermal conductivity.

So, the ground surface temperature is not the same as the mean ground temperature, as due to the geothermal gradient, the temperature increases towards the depth. So the mean ground temperature is calculated from the average annual surface temperature (which exists in ca. 10-15 m depth, all year round) and the geothermal heat flux, which together with thermal conductivity of the ground and borehole depth gives the mean temperature over a certain borehole depth. Unless you do not set the value for geothermal heat flux to zero, the mean ground temperature will always be higher than the ground surface temperature, the difference will be larger with deeper holes.

In case you use measured data from a Thermal Response Test, you can enter the value and set the heat flux to zero. However, in this case the result is only correct for boreholes with the same depth as the borehole the Thermal Response Test was done with.

A remark: When measuring ground thermal temperatures in a borehole, be sure to wait some time (typically >2 days) after the drilling is completed, as you will have thermal disturbance from the drilling. Doing several measurements in a row and checking for a stable temperature might allow using an earlier value.

Some more general remarks:

ALL the values in the EED database are only meant as an assistance to the users, and to give an idea of generally acceptable and plausible ranges of values for the input parameters. While the data for plastic pipes or antifreeze fluids are rather accurate and representative for the specific material given, any values on ground thermal parameters, on ground temperature and geothermal heat flux are merely an approximative default, in case no other values obtained more closely to the site are available. The main intention with giving values for ground temperature at all was to warn users throughout Europe that a general value of 10 °C (cf DIN EN 15450 !) is not suitable for all of Europe, where ranges from 3-4 °C in Northern Sweden to 18-20 °C in Greece can be found. Hence for ground parameters and temperature, it is always advised to use data from TRT, other measurements or local maps whenever existing.

Concerning the ground surface temperatures, the values where obtained as average regional temperatures from meteorological atlases, to provide a general values as said above. Thus "Berlin" means the region centered on Berlin, not a specific spot inside the city. Such specific data from given points on the map would not help in any way in finding a representative value for a spot in the region, and the EED databases obviously cannot provide for a higher spatial resolution.

It is well known that cities create a kind of "heat island" effect not only concerning air temperature, but also underground. Already in the 1980s measurements showed that e.g. in Cologne the groundwater temperature underneath the city was about 5 K higher than outside. These effects, including others like elevation, have to be taken into account when using a regional value for a specific spot.

The data on geothermal heat flux were obtained similarly from the geothermal atlases of the EU. The decision was made to use surface temperature and geothermal heat flux in order to obtain the average ground temperature for different BHE depth at the same site (important for the determination of required borehole depth).

However, when keeping the BHE depth at the value of the TRT, measured values of average ground temperature can be used, with geothermal heat flux set to 0.

3 Borehole and heat exchanger

Q.
Is the mass flow rate of the carrier fluid also a constant value for all boreholes in a multiple configuration: or is it only included as a parameter to calculate the Reynold's number and Borehole Resistance?

A.
It is only included to calculate the borehole thermal resistance. However, the flow rate for individual boreholes ought to be fairly similar in order for one borehole thermal resistance value to be representative for all boreholes.

Q.
I have seen in the presentation that we need to enter information about annual energy load variation, peak loads and flow rate in m^3/s. I don't see anything about the temperature difference between entrance and exit in the borehole.

A.
The temperature curves given are the mean temperatures in the borehole heat exchangers (BHE), i.e., the mean value between inlet and outlet. This reflects the behavior of the BHE to the borehole and the outside ground, not the temperature development along the BHE axis. The value for flow rate (m^3/s) is required for calculating the Reynold´s number, which has an impact on heat transfer inside the pipes and thus on borehole thermal resistance. If hourly calculation is used, the flow rate value is used to calculate entering and exiting fluid temperatures.

Q. [2021]
I am usually using EED v4 for research purposes. After carefully reading the "EED manual v4", "EED manual v3" and "EED v4 examples" I still have doubts about the exact definition of the Fluid Temperature (Tf). The most accurate definition found in the "EED manual v4" is: "The calculated resulting temperatures are the mean fluid temperatures (Tf) inside the pipe, at half of the depth of the borehole". I understand this definition for a single BHE. But for a multi-BHEs field, what Tf represent?

If we consider a filled rectangular configuration, 3 x 3 boreholes with only heat extraction (schematically represent below).

X1	X2	X3
X4	X5	X6
X7	X8	X9

Tf represent the mean fluid temperature inside the pipe of the borehole X5 at half of the depth or is it the mean fluid temperature of the 9 boreholes at half of the depth? Indeed, one can expect that in the long term Tf of borehole X5 is much lower than that of the other BHEs.

A.
Indeed, EED in all its versions delivers only one value for the fluid temperature for all boreholes. This is the average among the different BHE in center and periphery of a BHE field. No values for individual BHE are given (besides for g-function 0, a single BHE, of course).

This approach is well suited for the practical application of EED in the design of BHE installations. However, it might not be satisfactory for research purposes.

If you want to know the exact temperatures at individual BHE, a numerical simulation using e.g., FEM is best suited. My personal experience here is with FEFLOW. Btw., the validity of the EED average temperature result has been shown several times when comparing to the average of temperatures from FEFLOW simulation, and also when comparing to monitored data from existing project. I Hope that helps, even if you might not be happy with the approach in EED, destined for quick and easy design of BHE installations.

Q. [2021]
I have a question about using EED in simulating multiple borehole fields at the same time.

We are studying an urban area in Helsinki that consist of about 20 neighboring residential districts. Every district has around 10 000 - 20 000 m2 residential apartments.

Each of the districts could potentially have a 10 to 40 pcs. borehole field (300 m deep).

We need to study how these the individual borehole fields affect each other in terms of heat flow. For example, does the adjacent borehole fields limit the amount of energy that can be produced with geothermal heat pump systems for each district etc.

We are currently considering how to simulate this kind of case.

Would you say that EED could be the right or wrong software for this kind of case? Do Have you any experience of such a case?

A.
EED is not suitable for estimation of influence between multiple borehole fields as the individual borehole fields have different energy loads and there is no way to describe that in EED (in the current version).

The temperature field around a borehole field has to be estimated (for instance the average temperature influence at the boreholes of configuration *n* due to the boreholes at of different configurations *m*).

This is fairly straightforward using the SBM program directly.

However, what could be done is to simulate a worst-case scenario where all fields have maximum loads at the same time using EED. For that, a large total field - or a combination of 2 fields working simultaneously - could be checked, with setting the distance between the fields equal to the BHE distance within the fields.

Anyway, if the distance between fields is more than say 20 m, and there is no groundwater flow, the influence over the next 25-30 years will be negligible.

Q. [2021]
I would like to know if it is possible to use the software to calculate a cold local heating network. So, i mean a central geothermal field with decentralized geothermal heat pumps in the houses. When it is possible, how is the SPS considered? Or can I use the software only for one heat pump?

A.
When planning a "cold" heating network (i.e., using a water loop to provide a low-temperature heat/cold source to individual heat pumps), the operation characteristics and SPF of individual heat pumps can hardly be used for dimensioning.

For such system, neither the maximum (i.e., the sum of the peak loads of all heat pumps) nor the annual distribution of the individual heat pumps are relevant. The maximum is lower than the sum of peaks, as rarely all heat pumps will operate simultaneously. Hence a factor is used to assume the maximum simultaneous peak load

(Diversity Factor, or "Gleichzeitigkeitsfactor" in German), typically in the range of 0.7 to 0.8.

A water loop system thus has to be considered as a system of its own with own characteristics. The resulting ground-side load of this system (including any heat input from cooling or other heat sources like waste heat), has to be calculated or simulated. Some of the operation of heating/cooling might result in heat transfer inside the water loop, with only a small net impact on the BHE system.

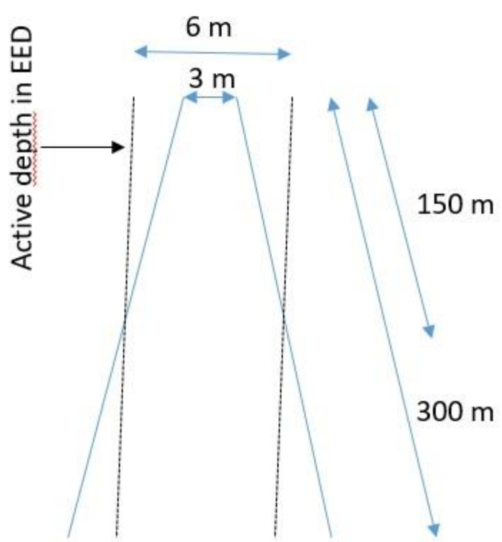
Such calculations will result in a file of required heat supply by the ground system (or heat uptake when cooling). Depending on the type of calculation/simulation, a ground-side load file will result, preferable with hourly load values.

This load file then can directly be used as input for EED, setting SPF to "direct" in both heating and cooling, and setting DHW to 0 (as that will be also included in the ground-side load file). An hourly load file could be read directly by EED 4.x, superseding all input in "base load" and "peak load". This is definitely the best way to calculate larger systems!

Using the sums of individual heat pumps as input for dimensioning a water loop system will always result in a much oversized BHE field.

Please be aware that this is a question of general behavior of water loop systems, and not of handling EED. The burden of generating meaningful input data is always with the user, we can only advise which type of data is suitable.

Q. [2021]
I have question concerning tilted BHEs. If the total length of tilted BHE is for example 300 m according to the attached fig, what is then the active BHE length one should use in simulations? Is it still 300 m or length of vertical plan cut from the surface to the BHE bottom which is then less than 300 m (black line in the fig)? Effective spacing between BHEs is the distance between mid-points but I am not sure what length I should use for each BHE.



A.
Of course, the "real" length has to be used, in the example 300 m. The important factor is the exchange from pipes to ground, and that is dependent on the length of the borehole, not the vertical distance from surface to the depth plane of the borehole bottom.

In vertical boreholes, both values are the same, so this question usually does not arise.

However, it is important to observe the long-term behavior, which is controlled by the volume affected. Here the g-functions are used - but EED does not offer such functions for inclined (titled) boreholes, as opposed to the predecessor software TFSTEP in the 1990s. The main reason is that the automatic search for the required borehole depth would not work that way.

Hence for inclined boreholes, an approximation must be made using the respective g-function (for vertical boreholes), and setting the distance to the average distance over depth (i.e., 6 m as in the graph above).

The approach suggested by the user for choosing the g-function and BHE distance is basically correct, but will remain an approximation, albeit an acceptable one.

For a more exact solution, the short-term behavior (i.e., peak load) can be taken from a calculation with the BHE length along the BHE axis, and the long-term behavior (base load) from a calculation with reduced BHE depth (vertical distance from surface to depth plane of borehole bottom) and mean borehole distance, in order to not overstate the affected ground volume.

Q. [2021]
For some time I am struggling with the comparison between my calculation and that ones in EED when it comes to the flow and the characteristics. I know have discovered that EED is taking the dynamic viscosity and specific density of the medium @ -10°C? Is there a specific reason knowing most systems variates between 2°C and 10°C.? This gives a huge difference in the Reynolds number and has repercussions on the depth calculation as result. Do you have more info on this topic?

A.
EED is taking the viscosity and density values as stated in the respective database on heat carrier fluids, or any other value you enter in the input fields in submenu "Heat carrier fluid".

In the database, values for water are given at different temperatures up to 95 °C (for heat storage systems), and for ethanol, typically used in Scandinavia, values for -5 to +20 °C are provided, for several mixing ratios.

For glycol, the values given in the database refer to -5 °C, which is about the worst-case scenario for most GSHP. In case you want to have the calculation done at other temperature levels than provided in the database, simply type the respective values (e.g., from tables from manufacturers) into the fields in the submenu, and they will be taken when calculating.

Q. [2021]

English

For thermo-hydrodynamic numerical modeling, I need the monthly heat extraction in MWh. In the monthly calculation with EED, this heat extraction is specified in MWh in the result file for the month. This information is missing in the hourly calculation. You earlier recommended that I calculate the heat extraction in MWh using the following formula

Total drilling meters [m] * extraction rate [W/m] * hours per month [h] = heat extraction in Wh

I was able to understand and reproduce the results of the monthly EED calculation, but with the hourly EED calculation only the extraction rate [W/m] of the peaks is given in the result file. However, I need the extraction rate [W/m] of the base load, as this is largely responsible for a long-term temperature change in the soil and therefore thermo-hydrodynamic numerical modeling is required for both. How can I determine the extraction rate [W/m] of the base load with an hourly calculation or why is this not documented in the result file?

A.

The distinction between base load and peak load was originally made in EED in order to record both the long-term influence and short-term operation at maximum power with only 12 power levels (months). Base and peak loads within EED are specifically defined (see manual) and accordingly not exactly what is otherwise understood by this in heating systems. Rather, base load means the monthly withdrawal (more precisely the withdrawal work), peak load means a maximum performance of the duration to be specified in the input data.

When calculating with hourly values, the concept of this EED-specific base and peak load is no longer relevant. Since there is a single value for every hour, this "peak load" is automatically recorded in the respective hours with maximum output, and the sum of the monthly hourly output (output per hour in kW corresponds to kilowatt hours) gives the monthly work, i.e., the "base load" in Meaning of EED.

Therefore, there are no values for base load in the output file.

If the option is used to perform an hourly calculation with the "old" approach (12 months base and peak load), then the result from the monthly summation of the hourly values should correspond to the respective monthly base load from the input data. If, on the other hand, a data file with hourly values is read in (for which the hourly calculation is actually intended), then all entries for work and performance in the base and peak load menus are obsolete and are not taken into account in the calculation.

The long-term temperature influence then results directly from the calculation with an hourly data file.

Q.

German

Für eine thermohydrodynamische numerische Modellierung benötige ich den monatlichen Wärmeentzug in MWh. Bei der monatlichen Berechnung mit EED wird im Ergebnisfile für den Monat dieser Wärmeentzug in MWh angegeben. In der stündlichen Berechnung fehlt diese Angabe. Herr Blomberg hat mir empfohlen, den Wärmentzug in MWh mit folgender Formel zu berechnen

Gesamtbohrmeter [m] * Entzugsleistung [W/m] * Stunden pro Monat [h] = Wärmentzug in Wh.

Die Ergebnisse bei der monatlichen EED-Berechnung konnte ich somit nachvollziehen und reproduzieren, aber bei der stündlichen EED-Berechnung wird nur die Entzugsleistung [W/m] der Spitzen im Ergebnisfile angegeben. Jedoch benötige ich die Entzugsleistung [W/m] der Grundlast, da diese maßgeblich für eine langfristige Temperaturveränderung im Boden verantwortlich ist und deshalb beider thermohydrodynamische numerische Modellierung erforderlich ist. Wie kann ich die Entzugsleistung [W/m] der Grundlast bei einer stündlichen Berechnung ermitteln bzw. warum wird diese nicht im Ergebnisfile dokumentiert?

A.
Die Unterscheidung in Grundlast und Spitzenlast war bei EED ursprünglich gemacht worden, um bei nur 12 Leistungsstufen (Monate) sowohl den langfristigen Einfluss als auch kurzfristigen Betrieb mit Maximalleistung zu erfassen. Grund- und Spitzenlast innerhalb EED sind dabei speziell definiert (s. Manual) und entsprechend nicht exakt dem, was sonst bei Heizungsanlagen darunter verstanden wird. Grundlast bedeutet vielmehr der monatliche Entzug (genauer die Entzugsarbeit), Spitzenlast ein Leistungsmaximum von in den Eingabedaten zu spezifizierender Dauer.

Bei der Berechnung mit stündlichen Werten ist das Konzept dieser EED-spezifischen Grund- und Spitzenlast nicht mehr relevant. Da für jede Stunde ein einzelner Wert vorliegt, ist in den jeweiligen Stunden mit Maximalleistung diese "Spitzenlast" automatisch erfasst, und die Summe der monatlichen Stundenleistung (Leistung pro Stunde in kW entspricht ja Kilowattstunden) ergibt die monatliche Arbeit, also die "Grundlast" im Sinne von EED.

Daher gibt es in der Ausgabedatei keine Werte für Grundlast.

Wird die Option verwendet, eine stündliche Berechnung mit dem "alten" Ansatz (12 Monate Grund- und Spitzenlast) durchzuführen, dann sollte das Ergebnis aus der monatlichen Summierung der Stundenwerte dem der jeweiligen Monats-Grundlast aus den Eingabedaten entsprechen. Wird dagegen ein Datenfile mit stündlichen Werten eingelesen (wofür die stündliche Berechnung eigentlich vorgesehen ist), dann sind alle Eingaben für Arbeit und Leistung in den Menüs Grund- und Spitzenlast obsolet und werden nicht in der Berechnung berücksichtigt.

Die langfristige Temperaturbeeinflussung ergibt sich dann direkt aus der Berechnung mit einen stündlichen Datenfile.

Q2. [2021] Follow up question for above question
English
Thank you for your quick and detailed answer. According to VDI 4640 sheet 2 are the temperature limits on the heat transfer medium when entering to be assessed in the EWS or outlet from the heat pump. This temperature according to the EED manual as LWT (leaving water temperature) or in the Temperature graphs designated as Tf_out (Chapter 3.8 EWT and LWT). According to earlier answer, this temperature is only calculated by EED if you choose the hourly calculation method. With the monthly Calculation is not calculated Tf_out. Therefore, I am forced to perform hourly calculation with EED. With the monthly calculation "only" Tf is calculated by EED, which is not for evaluation according to VDI 4640 Sheet 2 can be used as the temperature to be assessed. In my calculation I did not import a separate file, but the Automatically convert monthly heating distribution from EED into hourly values to let. To check I have a

monthly calculation iteratively with the almost identical key figures (probe configuration, probe length) are determined to the Check heat extraction in MWh / month. As a result I have a lot get different values. The extraction power [W / m] of the base load is plausible. However, this procedure is very time consuming and awkward.

>The long-term temperature influence then results directly from the calculation with an
>hourly data file.

Does that mean I have to do the EED automatic conversion of Use monthly to hourly dates to do the monthly withdrawal work to determine MWh / month? Also export via "Show chart with resulted load file "-> edit graphic -> data -> export as Excel file and then calculate monthly sums from the hourly values? That would be a very awkward way.

A2.
If you only have the monthly data anyway, you do not need the hourly calculation at all to solve your problem. The file with Tf_in and Tf_out is only a work relief, so that one does not have to add or subtract 8760 times half the temperature spread.

With monthly values you determine the difference between the fluid mean temperature and the inlet temperature in the probes (= outlet from heat pumps) directly for the coldest and warmest month. To determine the required probe length, you can also change the target temperature to be maintained; With a spread of 3 K and a minimum inlet temperature in the probes of -3 ° C (frequent case in Germany), set the minimum temperature to be maintained to -1.5 ° C (corresponds to -3 ° C + (3 K / 2)).

The procedure is described in the tutorial for the first example (p. 6). I attach the file as it can be downloaded from the website under "Tutorial".

I am sure that this path does not seem so awkward. The path via the output data file is only intended for hourly input files.

Q2.
German
vielen Dank für Ihre schnelle und ausführliche Antwort. Gemäß VDI 4640 Blatt 2 sind die Temperaturgrenzwerte auf das Wärmeträgermedium beim bei Eintritt in die EWS bzw. Austritt aus der Wärmepumpe zu bewerten. Diese Temperatur wird laut Manual von EED als LWT (leaving water temperature) bzw. in den Temperaturgraphen als Tf_out bezeichnet (Kapitel 3.8 EWT and LWT). Nach Ihren Angaben wird diese Temperatur nur vom EED berechnet, wenn man die stündlichen Berechnungsmethode wählt. Bei der monatlichen Berechnung wird Tf_out nicht berechnet. Daher bin ich gezwungen die stündliche Berechnung mit EED durchzuführen. Bei der monatlichen Berechnung wird "nur" Tf von EED berechnet, welche nicht zur Auswertung gemäß VDI 4640 Blatt 2 als zu bewertende Temperatur herangezogen werden kann.

Bei meiner Berechnung habe ich keinen separaten File importiert, sondern die monatliche Heizverteilung von EED automatisch in stündliche Werte umrechnen lassen.

Zur Überprüfung habe ich eine monatliche Berechnung iterativ mit den fast identischen Kennzahlen (Sondenkonfiguration, Sondenlänge) ermittelt, um den Wärmeentzug in MWh/Monat zu überprüfen. Im Ergebnis habe ich sehr verschiedene Werte erhalten. Die Entzugsleistung [W/m] der Grundlast ist plausibel. Jedoch ist diese Vorgehensweise sehr zeitaufwendig und umständlich.

>Die langfristige Temperaturbeeinflussung ergibt sich dann direkt aus der Berechnung
>mit einen stündlichen Datenfile.

Heißt das im Umkehrschluss ich muss die von EED automatische Umrechnung von monatliche in stündliche Daten verwenden, um die monatlichen Entzugsarbeit MWh/Monat zu ermitteln? Also Export über "Show chart with resulted load file" --> Graphik bearbeiten --> Daten --> Export als Excel-File und dann aus den stündlichen Werten Monatssummen berechnen? Das wäre ein sehr umständlicher Weg.

A2.
wenn Sie sowieso nur die Monatsdaten haben, benötigen Sie die stündliche Berechnung überhaupt nicht für die Lösung Ihres Problems. Der File mit Tf_in und Tf_out ist nur eine Arbeitserleichterung, damit man nicht 8760 mal die halbe Temperaturspreizung addieren oder subtrahieren muss.

Bei monatlichen Werten bestimmen Sie den Unterschied zwischen der Fluid-Mitteltemperatur und der Eintrittstemperatur in die Sonden (= Austritt aus Wärmepumpen) einfach direkt für den kältesten und wärmsten Monat. Für die Bestimmung der benötigten Sondenlänge kann man gleichermaßen die einzuhaltende Zieltemperatur verändern; bei einer Spreizung von 3 K und einer minimalen Eintrittstemperatur in die Sonden von -3 Â°C (häufiger Fall in Deutschland) setzen Sie die einzuhaltende Minimaltemperatur auf -1,5 Â°C (entspricht -3 Â°C + (3 K / 2)).

Das Verfahren ist im Tutorial gleich beim ersten Beispiel beschrieben (S. 6). Ich hänge den File an, so wie er unter "Tutorial" von der Website heruntergeladen werden kann.

Ich bin sicher, dass dieser Weg nicht so umständlich erscheint. Der von Weg über den Ausgabedatenfile ist nur für stündliche Eingabefiles gedacht.

Q. [2021]
I have a question regarding the temperature levels that EED calculates:

For Example: EED shows me that the mean fluid temperature during a 100 kW (from ground) cooling period is 11 °C

CASE 1.
Let us assume that the cooling system of the building is designed so that the dT over the ground loop is 3 K. With design dT = 3 K this would mean that the inlet temperature (into the ground) would be 11+(3/2) = 12.5 °C and outlet temperature 11-(3/2) = 9.5 °C.

CASE 2.
Let us assume that the cooling system of the building designed so that the dT over the ground loop is 8 K. With design dT = 8 K this would mean that the inlet temperature (into the ground) would be 11+(8/2) = 15 °C and outlet temperature 11-(8/2) = 7 °C.

THE PROBLEM:
Now I have the same cooling power from ground (100 kW) with two different fluid temperature levels (12.5/9.5 °C and 15/7 °C) also in the CASE 2. the outlet fluid temperature level from the ground loop is 7 °C which seems quite low or even unrealistic.

THE QUESTION:
Can I somehow handle this kind of study with EED? Can I somehow study how different design temperature levels affect the free cooling power available from the ground?

A.
The representation of inlet/outlet temperature as you show in case 1 and 2 is of course correct. And case 2 shows why we refrained from showing the explicit inlet/outlet temperatures - there are simply to many variations of input parameters to the circuit to do that in a simple way.

Maybe one day EED will have a module to deal with that...

For now, the answer is that the actual temperature difference always is a result of the interaction of the machinery in the building with the BHE, and the flow rate in the circuit as a further variable.

A deeper (longer) BHE will allow for a larger difference. Heat pumps usually are designed to have 3-4 K temperature difference over the evaporator circuit, and that is rather stable, as the flow velocity is designed accordingly (there might be more variation when multi-stage heat pumps and single-stage circulation pumps are used). This 3-4 K fit well with the most BHE in use.

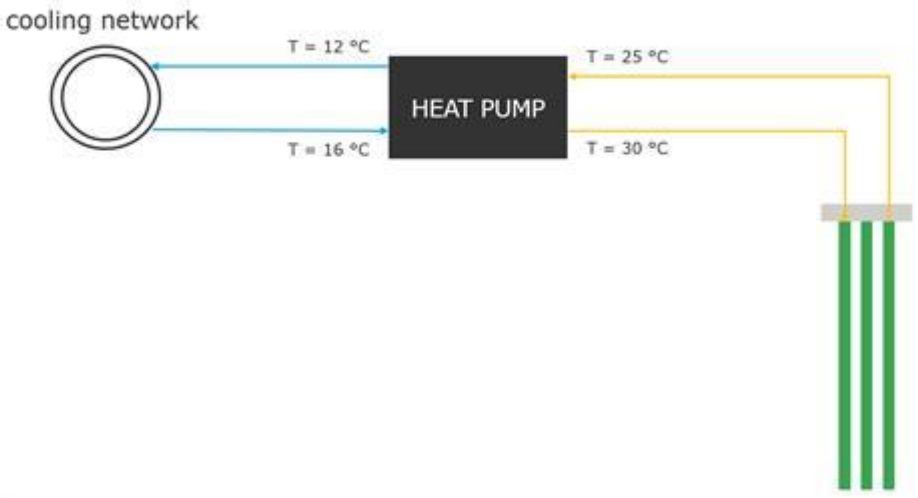
When considering the cooling case (heat pumps in reverse or water-cooled chillers), usually the water cooling circuit (which is the ground circuit with BHE) will be run with a circulation flow again resulting in some 3-4 K difference, so basically the same situation as in heating mode (your case 1).

In case the circulation flow is comparably lower with same load, the temperature difference would go up. And then a new equilibrium would be established between BHE and building equipment, the BHE not reacting with exactly the same temperature difference as the chiller creates.

I personally feel comfortable with designing systems based on the 3-4 K range between inlet and outlet, and for systems with planned higher temperature difference I just use the more conservative value obtained with using 3-4 K. This may not be the optimum, but is what is possible to do with EED.

Q. [2021]
I have a question regarding how to use EED in estimating borehole field behavior in active cooling.

By active cooling I mean that there is a heat pump so that the condenser side is connected to ground loop and evaporator side is connected to building cooling network (see the picture below).



Can I simulate this kind of situation with EED by inserting the cooling energy from heat pump evaporator as a cooling load in EED, and using an SPF-value for the heat pump?

And then I could just plot the average fluid temperature and make sure that during base load it does not exceed (30+25)/2 = 27.5 (see the picture).

A.
What you describe is exactly the idea behind the calculations with cooling load in EED. Setting cooling SPF to "direct" means direct cooling, putting a number (e.g. 5) will add the heat from the compressor drive to heat inserted into the ground, just as in your graph.

In the tutorial (https://buildingphysics.com/download/exampleseed.pdf) this is shown in example 3, with a small house in Greece, but it of course works analogously in larger buildings and other climates, as long as active cooling is required.

Whether you chose the base load temperature or the peak load temperature for sizing the allowed maximum should be derived from the respective case in question.

For hourly calculation I often use direct cooling in EED, but prepare an input file by adding the compressor drive to the heat injected for hours with active cooling. This allows for systems that temporarily use active cooling, but e.g., start with direct cooling in late spring.

I am sure it is worthwhile to have a look at the tutorial mentioned above, which is free for download from the EED website https://buildingphysics.com/eed-2/. There are also the input data files for the examples for download.

Q. [2021]
I use EED for the first time. I have been used to use Feflow which is over dimensioned for small projects and feasibility fast calculations. Could you give some details on EED's computational approach?

As far as I understand, input power K and flow Q are required. I suppose flow is not only used to calculate Reynolds number but also transferred energy.

Delta T between input and output depends on K and Q. In real conditions Q fluctuates over time and the heat pump devices fit on a constant delta T. So, I do not understand how to adjust my value of Q to get realistic results representing the real transfer of energy. I have been used with Feflow to input Q and K.

A.
Actually, the heat input/extraction is only calculated using the thermal power. The temperature difference inlet/outlet is not considered at all, hence the results as mean temperature between inlet and outlet.

The flow rate (Q) is required to calculate the borehole thermal resistance, by determining the Reynolds number, as you assume.

FEFLOW offers more options here, however, when using the BHE module in FEFLOW, the calculation of the BHE as such is very similar to that inside EED.

Q. [2021]
Recently we have gotten several requests from clients that needed some more complex BHE models to see how their BHE systems would behave with respect to groundwater flow and other BHE systems close by. I have found a way to make such BHE models in FeFlow (which we use for all sorts of groundwater-based analyses).

I have done a quick test to see how much a single BHE, modelled in FeFlow, would differ from the same BHE, modelled in EED. Obviously, getting a result out of EED is extremely fast compared to FeFlow, but I did find that I get much less extreme fluid temperatures (by min-max by 3-4 degrees, same for the baseload temperatures) when modelling with FeFlow. It seems that the heat transfer from the ground to the circulation fluid is much more effective in FeFlow.

The BHE parameters in FeFlow are very similar to EED, so I am wondering what makes the difference. Have done, or do you know of any benchmark testing that has been done to compare FeFlow results with EED? I know that these are completely different modelling techniques, but I would have expected them to yield much similar results (maybe within 2 degrees C).

A.
As I was just working on some calculations for an energy pile field (close the Dutch border in NW-Germany, btw.), I used this to make a comparison of FEFLOW and EED - a reason why this response took more than a week.

The energy piles are not BHE, of course, and test the limits of both EED and the BHE-module in FEFLOW. However, with a diameter of 380 mm and depth of 17 m, it is still inside what I would accept (ratio length/diameter about 50).

There is no groundwater flow assigned in this model in FEFLOW (no gradient), as EED does not represent groundwater flow at all.

Below is a graph with the first 2 years (operation starting in January), with full-time cooling load in summer and half-time heating load in winter.

Below is also shown a horizontal and vertical cut of the FEFLOW result after the 2nd summer, showing the grid used (extending further outside than shown in the graphs, of course, to avoid boundary effects). The temperatures at the bottom and top are set to the initial surface temperature and the slightly higher temperature at 38 m depth, considering the geothermal gradient. A simulation w/o BHE-loads had been made first to achieve a steady-state thermal field in vertical direction.

The temperature predictions of EED (base load in winter) and FEFLOW-3D are reasonably close.

FEFLOW-2D is a bit different, as it does not work with the BHE-module, but an equivalent cell size instead.

A direct comparison of EED and any FEM-simulation is rather difficult, as the simulation is affected by so many minor differences in the input parameters, grid design and types of solutions. In particular, the way the energy loads are assigned in the BHE-module in FEFLOW is somewhat tricky and bound for mistakes.

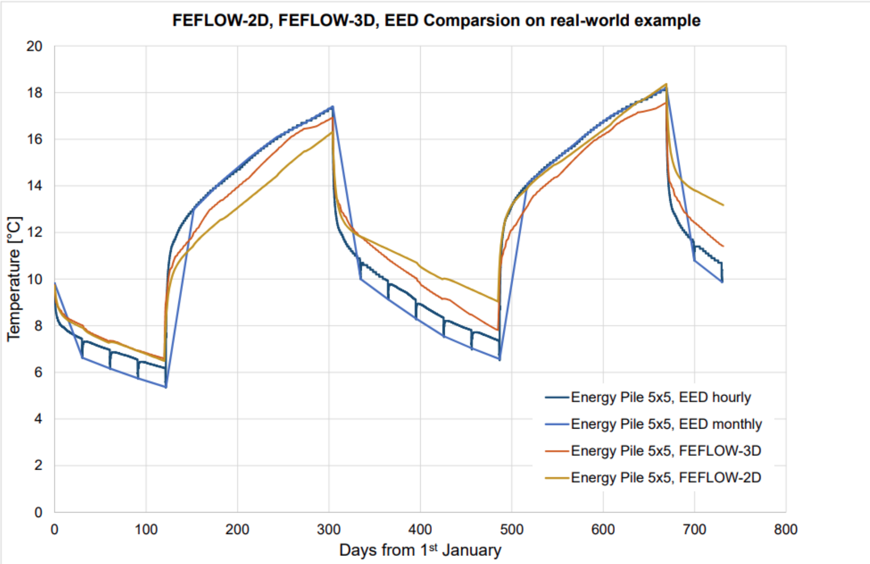
You can also see in the curves the way EED assigns the base and peak loads. The hourly calculation was done with creating an hourly file from the monthly data, showing the peak load assigned at the end of each month. This approach was used in the earlier versions of EED to ensure the system will work at full capacity even after the monthly extraction had already been done. Hence it is a worst-case scenario, which might not show up when using hourly data provided by a building simulation or from monitoring.

I reckon the differences at the BHE are due to the overall FEM-grid and data input (e.g. the "worst-case" approach of the EED peak loads), and not the BHE-module as such.

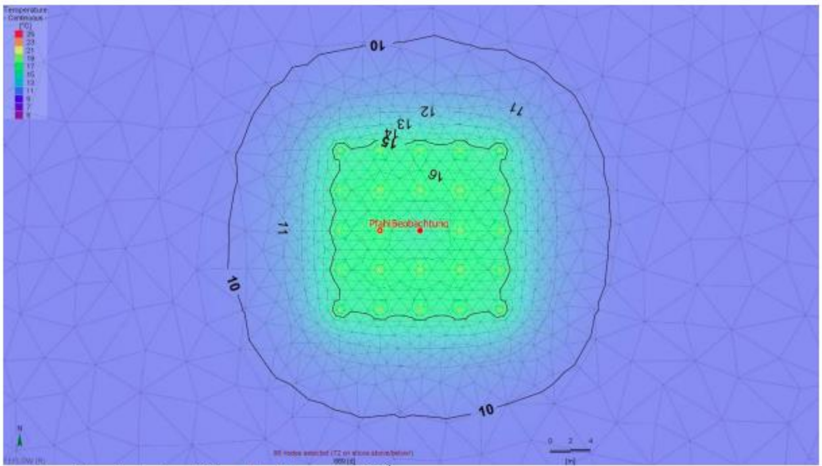
We often use a combination of EED and FEFLOW:
- EED for first size estimates and later overall sizing.

- FEFLOW, with a given overall sizing, for investigating behavior between BHE, temperature development around the BHE-field, and influence of groundwater.

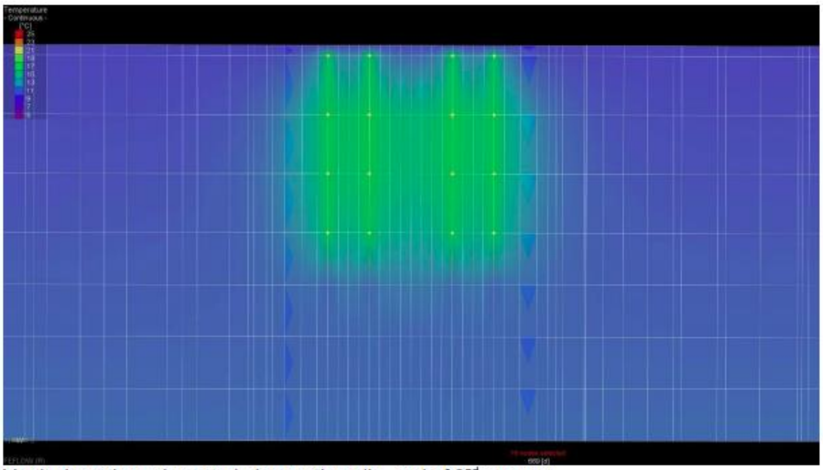
This might be also iterative, with some more quick EED trials in between and further FEFLOW simulation.



FEFLOW 3D



Horizontal cut at about 8 m depth, end of 2nd summer


Vertical cut through central observation pile, end of 2nd summer

Q. [2021]
We have a question regarding one of the values in the datasets used in EED. Specifically, the viscosity of ethylene glycol.

Ethylene glycol is one of the most-used heat carrier fluids in ground heat exchangers, at least here in the Netherlands. Often the value as recorded in EED (0.0052 kg/ms) is used.

When we look at other sources for the viscosity of ethylene glycol (25% dissolved in water at a temperature of 0 °C), a lower value of between 0.0032 to 0.0038 seems more appropriate.

The difference doesn't seem much at first, but it has a significant influence on the Reynolds number, and in turn in our assessment of the - laminar or turbulent - type of flow.

How has the viscosity of the ethylene glycol solution been determined? Do you have the source available?

Do you recommend the value as recorded in the EED dataset?

A.
The original databases for EED have been built upon manufacturer data of materials in the 1990s, and have been updated when required (such update was done recently on pipe diameters, with the wall thickness of 32 mm HDPE in SDR 11 changed from 2.9 to 3.0 mm, according to developments in the standards).

It looks like also the antifreeze database needs some makeover now. In datasheets today often the kinematic viscosity is given instead of the dynamic viscosity (kin. visc. = dyn. visc. / density).

I checked with recent data for Antifrogen N (now from Clariant, in the time of the original database development from Bayer), and found in their curves a value of ca. 4 mm2/s for kin. viscosity, which would mean 0,0042 kg/(m*s) for dyn. viscosity.

Differences might stem from the fact that the materials sold are not pure monoethylene, but just based on it, with other ingredients (e.g., corrosion inhibitors) present.

The EED-databases always can give just a general value, and whenever possible, data from the actual material to be used in the installation should be applied.

So, whenever you have better data, just use it - and we will strive to keep the EED databases as accurate as we can manage.

Q. [2021]
According to the old version 3 manual, the depth of the borehole is 20-200m. Is it still valid for version 4.20?

A.
The original versions of EED v2 had a limitation of 200 m, and there was an error message for deeper boreholes. Version 3 and 4 handles deeper boreholes but we advise the depth to be 10-300 m, in order to allow for some energy piles and

deeper BHE. Over 300 meters, the error will increase.

Important is also the ratio between spacing and depth that may vary between 0,02 and 0,5. This means that if you have a borehole with 300 m depth, the spacing can be between 6 and 150 m. EED checks the input for this.

The EED program assumes that the undisturbed temperature, taken as an average over the borehole depth remains constant during the whole operation. In a short energy pile arrangement, there will typically be a significant annual variation imposed by the boundary conditions above the ground (basement, slab-on-the-ground, outdoor temperature).

Q. [2021]
We have drilled many 300 m holes in the Faroes and in April a new rig will be put in service which can drill down to 430m.

A.
The EED program can be used to depth of at least 500 m under reasonable operating conditions (heat extraction rate, fluid flow rate). The program assumes that an average initial temperature along the borehole can be used which means that the actual temperature gradient is not used (but employed to calculate the average value). This introduces a very small, but conservative error. For reasonable operating conditions and a 500 m borehole the error is less than about 1 %.

Q. [2021]
Today I am looking at a hole with a depth of 280 m where the water level inside is at a depth of 70 m, which mean that we have two different Filling Conductivity (Air in the upper part and Water in the rest). How shall I configure the Borehole?

A.
The heat transfer properties in the upper (air) and lower part are quite different. In the air-filled part there will conduction (thermal conductivity 1/60 of the waterfilled part), natural convection of air and some radiation between plastic pipes and borehole wall. I recommend neglecting this part. Assume that the active part is 280-70 = 210 m and remember to insert your estimate of initial average temperature between the depth 70-280 m as ground surface temperature in the first menu. Set geothermal heat flux to 0. Considering the situation with very low heat transfer in the borehole in the upper part, the heat balance for the ground will skewed if the whole borehole length is included with an average borehole resistance for the whole borehole.

4 Borehole thermal resistance

Q.
What is the difference between “thermal resistance fluid/ground” and “effective borehole thermal resistance”? Which parameters do they depend on?

A.
“Fluid/ground´” thermal resistance gives the thermal resistance between fluid and borehole wall perpendicular to the pipe axis (it does not include the effect of heat transfer between downwards and upwards flow channel)

“Effective borehole thermal resistance” includes the effect of heat transfer between downwards and upwards flow channel.

Q.
When I select “Use constant values” in the sub-menu concerning thermal resistances in the bore hole, how is the individual thermal conductivity (filling, pipe etc.) used?

A.
When “Use constant values” is selected, then properties of the borehole heat exchanger design, fluid, pipe and filling are not used.

Q.
What should the “internal” in the sub-menu concerning thermal resistances in the borehole be filled with?

A.
There are two ways of providing information about the heat transfer properties between the circulating heat transfer fluid and the borehole wall, either by specifying the design and the properties of the materials involved (heat carrier fluid, flow rate, pipe, filling material and contact resistance) or by giving a constant value for the borehole thermal resistance. The thermal short-circuiting between the downward and upward flow channel can cause substantial reduction of the thermal performance of the borehole heat exchanger. The thermal resistance between the upward and downward channel is called the internal thermal resistance. If you the option of calculating the borehole thermal resistance, you will get a reasonable value of the internal thermal resistance as a result. The value of the internal thermal resistance will influence the calculated fluid temperatures only if the box “Account for internal heat transfer” in the menu “Borehole thermal resistance” is checked.

Q.
I have question about the thermal resistances in your output file and I can’t find an answer either in the manual or in the FAQs. In the output file various thermal resistances are listed:

THERMAL RESISTANCES
  Borehole therm. res. internal   0.2248 K/(W/m)
  Reynolds number   9907

Thermal resistance fluid/pipe	0.0053 K/(W/m)
Thermal resistance pipe material	0.0787 K/(W/m)
Contact resistance pipe/filling	0.0000 K/(W/m)
Borehole therm. res. fluid/ground	0.1026 K/(W/m)
Effective borehole thermal res.	0.1028 K/(W/m)

The meaning of some of them are clear, some not, so these are the questions:

Q1: How are “Borehole therm. res. internal” and “Effective borehole thermal res.” defined and what are the differences? Why is “Borehole therm. res. internal” larger than “Effective borehole thermal res.”?

Q2: Why does the sum of “Thermal resistance fluid/pipe” + “Thermal resistance pipe material” + “Contact resistance pipe/filling” + “Borehole therm. res. fluid/ground” not result into the “Effective borehole thermal res.”?

It would be very helpful to have a figure or a description explaining how these resistances are defined.

A.

A1: Let us for simplicity consider the case of a single U-pipe with the two shanks placed in a symmetric position. The local borehole resistance is calculated in a plane perpendicular to the borehole axis.

There is a filling material with a thermal conductivity λ_f. The surrounding ground has a thermal conductivity λ_g. The borehole radius is r_b.

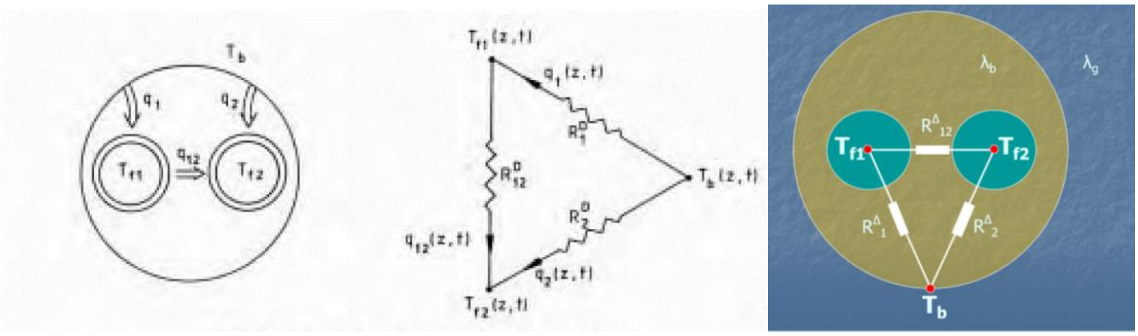
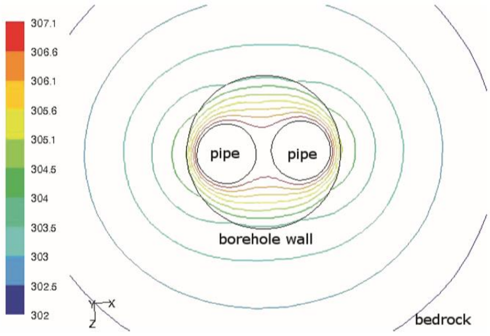


Figure shows the heat transfer circuit for a single borehole

There are two fundamental cases:

1. The fluid in both shanks have the same temperature T_f (T_{f1}=T_{f2}). The temperature on the borehole wall will vary along depending on the proximity of pipes and the thermal conductivity of the surrounding ground. The average borehole wall temperature is T_b.



Ref: Anna-Maria Gustafsson, 2010.

An example of the isotherms around the borehole.

A steady-state heat transfer calculation using the so-called multipole method gives a heat flow q_p from each shank. The total heat flow from the two shanks becomes $q=q_p+q_p$.The total resistance between the fluid and the outer radius is defined by:

$$R_b = (T_f-T_b)/q$$

2. There is a temperature difference between the two shanks. In the fundamental antisymmetric solution the two shanks have the temperature $+T_f$ and $-T_f$ respectively. A steady-state heat transfer calculation gives a heat flow q_{12} between the two shanks. The internal thermal resistance R_a is defined by:

$$R_a = (T_f-(-T_f))/q_{12}=2T_f/q_{12}$$

The effective borehole resistance R_{beff} is defined by the difference between the mean fluid temperature $T_{fm} = (T_{fin}+T_{fout})/2$, where T_{fin} and T_{fout} are the fluid temperatures in and out of the borehole, and the average borehole wall temperature T_b. The heat injection rate $q = Q/H$ where Q is the total heat injection rate to the borehole and H is the active borehole length.

$$R_{beff} = (T_{fm}-T_b)/q$$

The R_{beff} takes into account the local borehole resistance R_b and the short-circuiting effect between the shanks due to the finite value of R_a.

A2: “Thermal resistance fluid/pipe”, “Thermal resistance pipe material, and “Contact resistance pipe/filling” refers to the local heat transfer through one shank. They can be added to one “pipe” resistance R_p. The heat flow rate is then q_p and the resulting difference between fluid temperature T_f and the temperature T_p in the filling material adjacent to the pipe becomes:

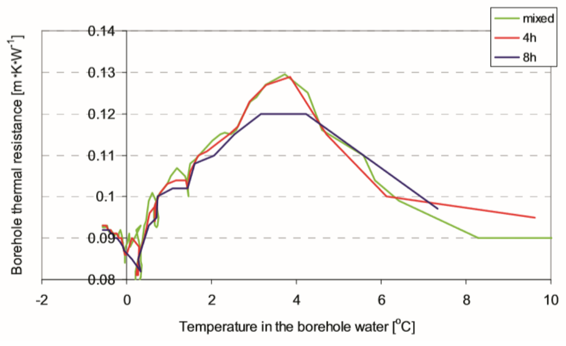
$$T_f-T_p = q_p * R_p$$

The “local” borehole thermal resistance between fluid and ground includes the resistances from the pipes and the resistance through the filling material. The resulting borehole thermal resistance R_b is a function of the pipe resistance R_p, the pipe radius, the shank spacing, the filling thermal conductivity, the borehole radius and the ground thermal conductivity. The effective borehole heat transfer takes into account also the thermal short-circuiting effects due to the temperature difference between the shanks. The short-circuiting effects depend on the internal borehole resistance, the flow rate and active borehole length.

Q.
How is the influence of natural convection in groundwater-filled boreholes handled in EED?

A.
This topic has been studied for about 20 years and there no easy general solution to the problem has yet been found. The correlations to measured data that have been made are limited to specific geometric situation, such as a single U-pipe with 40 mm pipe diameter in a borehole with 140 mm diameter in a certain temperature range or time-consuming CFD-calculations of specific geometries.

The natural convection depends primarily on the temperature-dependent water properties, the specific heat transfer rate and the geometric layout of the borehole heat exchanger. The heat transfer results in a temperature difference between the outside of the pipes and the borehole wall. The ensuing density differences drive the natural convection and the flow resistance is due to the viscosity of the water. The figure below illustrates the general behaviour. Density differences are small around 4 °C where water exhibits a density maximum. At higher temperatures the viscosity is lower and offers less resistance. At lower temperatures the density differences increase and eventually the borehole water may freeze, which causes convection to cease but replaces water with ice (thermal conductivity 2,1 W/m,K).



Ref: Anna-Maria Gustafsson, 2010

Example of computed borehole resistance at different borehole water temperatures

At the moment there are basically two approaches used to estimate the borehole thermal resistance in groundwater-filled boreholes. The first method assumes an annulus where the inner pipe has the equivalent diameter of the multiple pipe arrangement in the borehole. The heat transfer is then estimated based on published formulas for heat transfer in an annulus (Hellström and Kjellsson 1997, Gustafsson 2010, Schwencke 2013). The second approach is to use the conduction layer theory and fit the coefficient against field data (Spitler et al, 2016; Spitler et al, 2016).

The user is referred to the references below for more details.

References:

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Schwencke A. (2013). Analyse og modellering av dype energibrønner. NTNU, Trondheim, Norway.

Spitler J.D. et al. (2016). Calculation Tool for Effective Borehole Thermal Resistance. CLIMA 2016 - proceedings of the 12th REHVA World Congress, Aalborg University, Aalborg, Denmark.

Spitler J.D. et al. (2016). Natural convection in groundwater-filled boreholes used as ground heat exchangers. Applied Energy 164 (2016) 352-365.

Q. [2021]
I am a doctoral student and working on issues related to borehole heat exchangers. I would like to ask about some calculations used in EED. I mean exactly formulas for calculating thermal resistances).

At first, I would like to consult on the internal borehole thermal resistance formula taken from manual:

$$Rb_{in} = \frac{T_f - (-T_f)}{q_{12}} = \frac{2 \cdot T_f}{q_{12}}$$

Where: T_f – feeding temperature q_{12} – a steady-state heat transfer between two shanks

I would like to ask:

Q: Which formula was used to calculate a steady-state heat transfer between two shanks?

A: The formula considers the local two-dimensional heat transfer problem in a plane perpendicular to the axis of a borehole with two shanks of a single U-pipe where one shank has the temperature T_a and the other shank has the temperature $-T_a$. The problem is solved analytically using the Multipole method. The result of the calculation is the heat flow q_{12} (W/m) between the two shanks. The thermal resistance R_a between two pipes is defined by temperature difference T_a-($-T_a$)=$2T_a$ divided by the heat flow q_{12} similar to the formula above. This is explained in section 8.4.4 of Hellström (1991) where explicit high-accuracy formulas for R_b and R_a are given using the first-order multipole. EED uses the Multipole method with 10 multipoles the calculate the resistances. This well-defined heat transfer problem can also be solved numerically by FDM or FEM methods, which will yield the same result.

I assume that your questions concern how these resistances relate to the overall heat transfer of the whole borehole to the surrounding ground.

EED uses the concept of an effective borehole thermal resistance R_b^* , which is defined by the relation:

$$\bar{T}_f - \bar{T}_b = \frac{Q}{H} \cdot R_b^*$$

where $\bar{T}_b$ is the average temperature of the borehole wall. The total heat injection rate is denoted Q (W) and the active borehole depth is H (m). The average fluid temperature $\bar{T}_f$ is defined by:

$$\bar{T}_f = \frac{1}{2} \cdot (T_{fin} + T_{fout})$$

Note that $\bar{T}_f$ is the average value of the inlet and outlet fluid temperature. It is not the average fluid temperature along the flow channels in the borehole.

The total heat injection rate Q is related to the fluid properties, flow rate V_f and the difference between inlet and outlet fluid temperature by:

$$Q = \rho_f c_f V_f (T_{fin} - T_{fout})$$

This relation is used to remove the explicit dependence in the inlet and outlet fluid temperatures.

In the idealized case of a uniform borehole wall temperature, the effective borehole thermal resistance R_b^* can be expressed as:

$$R_b^* = R_b \cdot \eta \cdot \coth(\eta)$$

where η is given by formula 8.88 in Hellström (1991). The nomenclature is given for a so-called Δ-circuit (See Figure 8.2). For small values of η the effective borehole thermal resistance is given by the following approximation:

$$R_b^* \approx R_b + \frac{1}{3} \cdot \frac{1}{R_a} \cdot \left(\frac{H}{\rho_f c_f V_f} \right)^2$$

For the case of a uniform heat flux at the borehole wall, the effective borehole thermal resistance R_b^* becomes:

$$R_b^* = R_b + \frac{1}{3} \cdot \frac{1}{R_a} \cdot \left(\frac{H}{\rho_f c_f V_f} \right)^2$$

Q: Where can I found a feeding temperature records taken to this formula in EED? If this is not possible, which formula was used in this case?

With reference to Hellstrom – Ground Heat Storage Thermal Analyses of Duct Storage Systems (1991) I found this formula:

$$\frac{1}{H} \int_0^L [q_1(z) + q_2(z)]\, dz = \bar{q}(t) = C_f V_f [T_{fin}(t) - T_{fout}(t)]/H \qquad (\mathrm{W/m}) \qquad (8.85)$$

But we do not have information about Tf_{in} and Tf_{out} from EED. It is correct formula for this case?

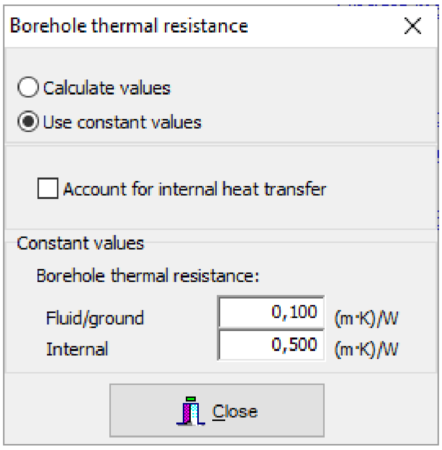
If not, which formula is correct?

A: The relations for the effective borehole resistance are used in EED where the explicit dependence of the inlet and outlet temperatures is removed and represented by the flow rate dependence.

The formulas have been used to successfully relate measured TRT data to flow rate and borehole depth dependence.

Q. [2021]
I have a small question regarding borehole thermal resistance from TRT data (dT/q), however, I was wondering with which data this exactly corresponds to in EED.

Should we use constant values (coming from TRT), where the borehole resistance fluid/ground equals our Rb from a TRT test? However, I would think internal heat transfer is taken into account by a TRT (since it’s an in practice test). However, how should I fill in a Rb of e.g., 0.0891 W/mK in this case?



A.
The evaluation of a thermal response test usually gives the thermal conductivity of the ground, the effective borehole resistance Rbeff (including the thermal short-circuiting effect) and the average undisturbed temperature along the borehole.

In EED the effective borehole thermal resistance Rbeff is either calculated based on detailed description of the borehole heat exchanger design specified in the "Borehole and heat exchanger" submenu or by specifying a constant value of the local borehole resistance Rb and the internal resistance Ra in the "Borehole thermal resistance" submenu.

To input the measured Rbeff value:
1. Go to the "Borehole thermal resistance" submenu.
2. Write the measured value in the "Borehole thermal resistance: Fluid/ground" box
3. Unclick "Account for internal heat transfer". The value in the "Borehole thermal resistance: Internal" box will not be used.

A more detailed explanation for this and an approximate way to adjust for other flow rates, fluid temperatures and borehole depth is also described in Chapter 8 in this document.

Q. [2021]
I need to know how to use borehole heat exchanger resistance results of TRT onto EED. I have a global resistance value from TRT (here Rb 0,074 m.K/W). How do I introduce this into EED

A.
The contact resistance pipe/grout is usually 0, if a borehole is well grouted.

To enter the borehole thermal resistance, you need to use the respective sub-menu "Borehole thermal resistance" and tick "Use constant values". Now you can enter the rb measured in TRT (if you wish - this limits the validity of results to exactly the type of BHE tested). The easiest is to un-tick the box "Account for internal heat transfer" and enter the value from TRT in "Fluid/ground", to have only the measured value being considered. Then it does not matter what is in "Internal".

Personally, I usually do some calibration of the rb using variations in grout thermal conductivity and shank spacing when calculating the value, until I get the same result as in the TRT. That allows me to change BHE geometry (e.g., borehole diameter), if required, and the result for temperature development will be valid also for the new BHE.

Q. [2021]
Could you send me an example file for TRT calibration and a detail on the way you proceed?

A.
there is no specific input file for the calibration. It is just a variation of the unknown parameters in the BHE input menu.

Well known values are:
- diameter of borehole
- depth of borehole
- type of BHE (1-U, 2-U, coax)
- diameter and wall thickness of pipes
- material of pipes (usually HDPE, 0,42 W/(m*K))

These parameters are kept with the known values.

Possibly less well known variable values are:
- grout thermal conductivity (depends a lot on good mixing and injection)
- shank spacing (unless spacers are used)

Thus, you vary the values for grout and shank spacing somewhat until the result for the effective borehole thermal resistance matches the measured values from the TRT.

Make sure the flow regime (turbulent/laminar) is the same for TRT and for calculation (and for the final design), and adjust the flow rate in calculation to achieve the same regime as during TRT.

5 Energy loads – SPF, base and peak loads

Q.

I am a registered user of the EED software. Over the last several months I have been through evaluation of EED modelling results performed by another consultant. In April I sent some questions to Burkhard and got very exhaustive answers. Thanks again for that. On a new spin of analysis I came across a parameter which proved to be very important: SPF. There is no explicit explanation of this parameter in the manual. I did a sensitivity test and found that altering SPF for Heating from 3 to 1 and for cooling from 4 to 1 impacts simulation results extremely.

I searched the Internet but was unsuccessful in finding the definition of “seasonal performance factor” in relation to ground heat pumps, looks like this is not a common term. Could you please provide an explanation of SPF and methodology of its calculation?

In my case I have monthly heating and cooling loads defined which, to my understanding is enough to set the energy transfer model. Why SPF play a role in this situation?

A.

The seasonal performance factor SPF is quite common here in Europe, in German language under the name Jahresarbeitszahl and with the abbreviation JAZ in Switzerland and the sign beta in Germany (s.a. VDI 4640, the relevant German guideline). It is in fact an annual integrated COP.

The measurement of SPF is done by monitoring the electric power consumption of heat pump and ground-side circulation pump, and the heat / cold output of the heat pump towards the building. In the heating-only version we use mainly here in Germany, we do this over a full year; in heating/cooling you would do it over the respective season. In Germany, officially now another value has been introduced, the Jahresaufwandszahl, which is just: Jahresaufwandszahl = 1 / Jahresarbeitszahl.

Methods how to estimate these values for a given heating system and house are shown in a new guideline VDI 4650.

Now to the relevance of SPF: EED uses the heating and cooling load of the building as input. This was done because most contractors have to determine this values anyway. The load towards the ground, however, is different; it is higher in cooling mode, and lower in heating mode, because the heat pump evaporator always has lower thermal capacity than the condenser. This difference results in the SPF. To simplify this for standard applications, we allow the SPF to be stated as an annual average. We already some time ago started discussion on including a heat pump module and manufacturer’s performance charts, to calculate SPF/COP for each month.

For the experienced user, who knows the heat transferred to and from the ground, and who wants to state this explicitly, we have the option to click the box “Direct” in the “Base load” submenu. This is further described in the manual.

On Google, a simple search for “seasonal performance factor” returns plenty of relevant entries, with SPF or HSPF (Heating Seasonal Performance Factor, for the heating season only).

Q.
Ist mit der Jahresarbeitszahl wirklich die Jahresarbeitszahl des Gesamtsystems gemeint (die ja eigentlich erst im Feldversuch bestimmt wird, wenn es bereits zu spät ist) oder aber der COP der Wärmepumpe am für die Auslegung herangezogenen Betriebspunkt?

A.
Grundsaetzlich ist die Jahresarbeitszahl gemeint. Sie muss hier im Vorfeld aber aus den zu erwartenden Betriebsdaten (bzw. den für die EED-Berechnung angestrebten Soletemperaturen) und den Herstellerangaben der Leistungszahl (kurve) angenommen werden. Falls Sie darin keine Erfahrung haben, bietet VDI 4650 eine Methode zur Berechnung.

Q.
I want to know how to obtain the value of “SPF”, in the case of direct cooling, the SPF=10000 in summer, and SPF=2.12 in winter. The difference between summer and winter is so large, why?

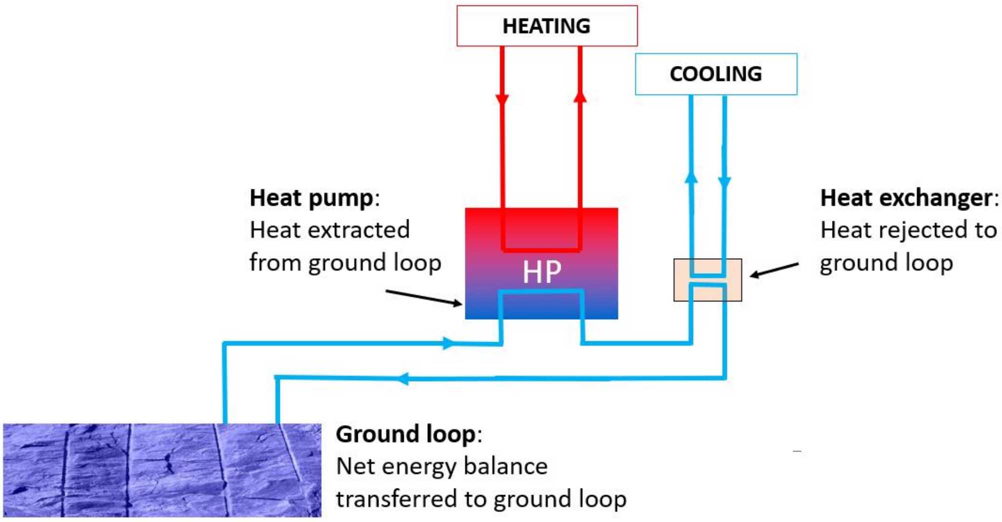
A.
The value of 10000 can be used to indicate the heating/cooling loads are directly transferred to the ground side. This is the case e.g. in direct cooling, when no compressor is in operation. However, in the practice, there is a SPF of 20-40 in direct cooling, because circulation pumps have to be operated; this does not in the same way influence the ground, so we have used an SPF value of 10000 in earlier versions of EED. In later versions of EED you can achieve this in better way by clicking the “Direct” box.

In general, the SPF is calculated as the amount of heat or cold produced during a season divided by the amount of electricity required to run the heat pump over the same time. In direct cooling, there is no heat pump, so we use the method described above.

Q.
I’ve got for a review an EED case where the user (the HVAC company) has specified monthly heat and cool base loads, as well as peak heat and cool loads for each month of the year. In the program manual, you refer to the Linden sample case, where the system several months works for heating only and several months for cooling only, which make complete sense to me. However, in the files which I am sending to you, the engineer was inputting heat and cool loads simultaneously and getting outputs from the model (please take a look at the attached input and output files). My question is the following: the EED input allows simultaneous input heat and cool loads. However, the BTES hole cannot

simultaneously reject and extract heat (the BTES system cannot work in heating and cooling mode simultaneously). I would presume, that the algorithm adds monthly heat and cool loads with different signs and after that simulate the impact of the algebraic sum with one sign throughout the month (heat extraction if heating mode is prevailing and heat injection if cooling is prevailing). Am I right?

A.
Yes, you are perfectly right. And that is what in fact happens in reality, at least in a short distance from the pipe. Short-term variations from heating to cooling do not affect ground temperature, as the process is slow, and only the net impact over a longer time span will count. For larger plants, most of the short-term alternations between heating and cooling not even reach the ground, as they cancel each other out in the system loops.



The figure shows a simple system with simultaneous heating and cooling loads.

Q.
How does the program calculate peak heat loads and peak heat loads? Why are they added at the end of the month to calculate maximum and minimum temperatures?

A.
The base load tells the long-term story, i.e. the development of the ground temperature and thus fluid temperature in response to the heat extraction and injection. This is where real loads of heat are shifted in and out of the ground. The peak load is there to check if the maximum required load over a continuous operation time of some hours can be extracted or injected under the general long-term development. As we do monthly calculations, no temperatures are given for days other than the end of the months (or the beginning of the next, which is the same). Putting the peak load to the end of the month usually means

a worst-case scenario. The energy amount of the peak is not added to the monthly development, not to increase the base load by mistake.

The most critical loads for design are:

1. energy loads for heating and cooling. These loads determine the energy balance for the ground and the ground temperature evolution over time.
2. peak heating power in the winter – most critical time is usually january-march. This gives you the minimum fluid temperature.
3. peak cooling power in the summer – most critical time usually august (-september). This gives you the maximum fluid temperature.

The peak heat load occurs during the situation that results in the maximum value of the net heat extraction from the ground loop considering simultaneous heating and cooling loads during a month.

The peak cool load occurs during the situation that results in the maximum value of the net heat rejection from the ground loop considering simultaneous cooling and heating loads during a month.

The DHW (District Hot Water) energy load is important for the whole year, but DHW peak power is not important for the maximum fluid temperature in the summer.

Q.
In the third line of base load, you have a “Ground”, and under that there is an “Update”, I do not understand what is the meaning of this line?

A.
This column contains the balance of actual heat extracted from the ground loop due to heating and the actual heat rejected to the ground loop, as calculated from the load values and SPF values. You cannot access this column directly.

Q.
I have total heating as well as cooling load, water flow rate in boreholes, as well as inlet water temperature in boreholes. Please tell me how could I get the outlet temperature from borehole heat exchanger now? I want to know how the ground will behave in my case. This is very important because outlet temperature from ground will be the inlet temperature of HVAC equipment.

A.
In EED, the inlet water temperature is not considered as an input parameter. All the temperature calculations are done as a deviation from the undisturbed ground temperature that is calculated using values given in the “ground properties” submenu as input.

The resulting temperature is the mean fluid temperature, which is the average of the fluid temperature entering and exiting the borehole. Typically in heating mode the EWT (which is the temperature out of the borehole into the heat pump) is ca.

1.5-2.0 °C higher, the return temperature the same value lower than the mean temperature. In cooling mode, EWT is ca. 2 °C lower than the mean, return higher. As you wrote, this values depend upon flow rate, but also borehole depth, pipe diameter, filling, shank spacing, etc. In the old Lund PC DOS programs from the late 1980s, a program INOUT allowed for calculation of these temperatures, once the system design was done. In EED version 4 these temperatures can be displayed if hourly values are used. Note that you can convert monthly and peak loads to hourly values in the submenu “Hourly calculations”. However, the flow rate specified in submenu “Borehole and heat exchanger” and does not vary with time.

Q.
Can you give me some detailed information about the base load and peak load. Could you tell me the reason why you separated the base load and peak load. When we have calculated the total heating /cooling load, how can we confirm the values of the base load and the peak load?

A.
This question refers to the engineering practice, and not to the EED operation. Therefore, we only can tell what you need for EED:

The base load is the total amount of heat/cold required in a month (in MWh), either given directly as a monthly value, or as a total over the year and a monthly percentage (see manual). This value controls the long-term behavior of the system over the year.

The peak load is the maximum heating or cooling output required during the coldest (or hottest) day of the month, given in kW, and the expected duration during this day, in hours.

If you want to know how to get these values for a given building, please consult your HVAC planners.

Q. [2021]
I am slightly confused about peak loads. How would I know what the peak load hours are per month for say a 4 bedroom property? I assume the output would be the maximum power of the heating system for winter months, but I don't know how to find out the duration at its peak.

A.
Please see Q/A above.

So, this is a kind of information we cannot give, but a HVAC engineer should be able to at least estimate.

As a default, for the worst case, 24h at full heat pump capacity can be assumed for Dec-Feb. But it makes more sense to estimate something between 12 and 18 hours, depending on the heat pump capacity compared to the building heat load (usually the heat pump is slightly more powerful than the building load). With bivalent heat pumps or those with an electric backup (electric boiler), the 24h are more adequate, as they might actually run for full days without stopping.

Q.
Ich habe mir die FAQs mal durchgelesen, weil ich ein Verständnisproblem mit den Peak-Loads habe. “The peak load is the maximum heating or cooling output required during the coldest (or hottest) day of the month, given in kW, and the expected duration during this day, in hours.” Wenn ich also jetzt zB für Januar 10kW und 24h eingebe, dann bedeutet das nicht, dass in allen 31 Tagen 24h Maximalleistung erbracht wird, sondern EED nimmt diesen Peak nur als Hinweis für Minimaltemperaturen. Sehe ich das so richtig?

A.
Die peak load wird natürlich nicht an allen 28-31 Tagen eines Monats angesetzt (dafür gibt es ja die Base load), sondern nur an einem Tag. Dies ist rechnerisch immer der letzte Tag eines Monats, da dies bei fortschreitender Abkühlung den worst case darstellt. An allen anderen Tagen wird die durchschnittlich Monatsleistung erbracht, die peak load am letzten Tag dann aber nicht zur monatlich entzogenen Wärmemenge dazugerechnet (sonst wäre diese ja um den Betrag dieses einen Tages höher).

Q.
Sind bei Eingabe der Dauer der Spitzenlasten tägliche Wärmepumpenlaufzeiten gemeint? Dann käme ich beim “Linden”-Beispiel aus dem Handbuch auf etwa 3360 Volllaststunden, während sich in der Grundlast bei 29030 kWh/a und einer Wärmepumpen-Heizleistung von 17 kW etwa 1700 Stunden ergeben. Für die Bestimmung der minimalen Fluidtemperaturen scheint mir das von entscheidender Bedeutung zu sein, denn die meisten Wärmepumpen schalten ja bei -5°C Soleeingang ab – zumindest in der Voreinstellung. Bedeutet “mittlere minimale Soletemperatur -5°C” eigentlich, dass bei 3° Spreizung die Sole im Vorlauf -6,5°C und im Rücklauf -3,5°C hat? Wenn ein Monatsmittel gemeint ist, könnte es also auch sein, dass die Temperaturen im WP-Eingang temporär -5° unterschreiten und die Wärmepumpe dann abschaltet, bis die Sole sich wieder “beruhigt” hat?

A.
Spitzenlasten sind nicht die täglichen, sondern die maximal an einem Tag vorkommenden Stunden (also am kältesten bzw. bei Kühlung am wärmsten Tag des jeweiligen Monats. Wichtig ist dabei eigentlich nur die maximale Leistung/Laufzeit im Monat mit der kältesten Soletemperatur aus Grundlast. Nur gelegentlich kommt es vor, dass das absolute Temperaturminimum im zweitältesten Monat, aber bei größerer Spitzenlast auftritt (analog auch für Kühlung). Die restlichen Monate dienen letztlich nur noch dazu, eine Schöne Kurve für die Graphik zu bekommen – auslegungsrelevant sind sie dann nicht mehr.

Die Betriebsstunden Linden stimmen dann wieder. Ihre Annahme zu mittlerer Fluidtemperatur und Eintritts-Austritts-Temperatur ist korrekt.

Q.

Müssten nicht bei einer WW-Bereitung über die Wärmepumpe auch im Sommer Spitzenlasten angesetzt werden? So, wie ich das bislang alles verstanden habe, kann die WP ja nur unter Volllast laufen oder eben gar nicht (abgesehen vielleicht von den neuen modulierenden Nibe-Pumpen).

Wie sie sehen, bin ich weder Thermodynamiker noch TGA-Planer. Leider bekommt man als Bohrbetrieb von den Auftraggebern (im EFH-Bereich zumeist Heizungsbauer) nur selten (bzw. nie) Lastprofile geliefert. Was Volllaststunden sind bzw. dass das eine Rolle spielt, wissen die meisten gar nicht. In der Regel bekommen wir den Wärmebedarf aus dem EnEV-Nachweis auf den Tisch oder auch nur eine Quadratmeterzahl und müssen bereits für die Angebotserstellung einer Sondenbohrung die Wärmepumpe selbst auslegen. Mit viel Glück ist bereits klar, welche WP es sein soll. Nun ist mir das Vorgehen vieler Bohrunternehmen (wir sind recht neu am Markt) nicht so ganz geheuer, grundsätzlich mit 50 W/m zu rechnen. Deswegen haben wir EED gekauft, um auch im EFH-Bereich wenigstens mal nachrechnen zu können, zumal die Wärmeleitfähigkeiten in der VDI ja etwas differenzierter angegeben sind als die Entzugsleistungen. Die Diskrepanz zwischen EED und VDI ist nun allerdings recht frappierend (wie mir nach Lektüre Ihres diesbezüglichen Artikels jedoch bereits im Vorfeld des EED-Erwerbs klar war), ein Bohrmeterbedarf auf der sicheren Seite kaum am Markt durchzusetzen. Mal schauen, wie wir damit umgehen werden. Zumindest wollen wir keine Wärmequellen errichten, die nach Ablauf der Gewährleistung den Geist aufgeben.

Noch einmal zurück zu meinen Fragen bzgl. der Lastverläufe: kennen Sie vielleicht eine Quelle, in der es so etwas wie Standardprofile für Wärmepumpen (Wohnhäuser, Neubau und Bestand) mit Spitzenlasten und Laufzeiten gibt, die vielleicht auf Erfahrungen bzw. Feldversuchen basieren und die als Eingabegrößen für EED dienen könnten?

A.
Auch im Sommer sind bei WW-Bereitung zumindest Grundlasten anzugeben. Da der Untergrund da aber insgesamt wärmer ist als im Winter (weniger Wärmeentzug), kann auch WP-Vollast für 1-2 Stunden da nichts mehr Groß bewirken. S.o. zu den Kurven in der Graphik…

Q.
bei unserer Tagesarbeit mit EED ist uns eine Ungereimtheit aufgefallen, wofür wir keine Erklärung finden.

Die monatliche Verteilung der Heizlast wird in EED standardmäßig von November bis Januar mit 56,40% des Gesamt-Jahresbedarfs angegeben. Bei einer Gegenkontrolle haben wir diese Verteilung auch in vorliegenden geologischen Gutachten wiedergefunden. Entgegengesetzt dazu nimmt eine Berechnung lt. ENEV §3 von November bis Januar den Gesamt-Jahresbedarfs mit 81,00% an. Resultierend würden in einem aktuellem Fall lt. EED-Verteilung ~380 m abgeteuft. Wenn wir die Monatsverteilung der ENEV in EED übertragen, errechnet das Programm aber ~500m. Wir berechnen jede Anfrage (auch kleine Gebäude) mit EED. Die Frage ist nun, welche Verteilung wir annehmen sollen.

Des Weiteren die Frage, was würde bei einer Bemessung lt. VDI 4640 passieren – das Problem würde überhaupt nicht sichtbar.

A.
EED ist ein internationales Programm, das in vielen Ländern eingesetzt wird. Die Verteilung der Heizlast auf die einzelnen Monate stammt aus praktischen Erfahrungen und Monitoringdaten aus den 1990er Jahren. Sie ist lediglich als Vorschlag gedacht, wenn man keine anderen Vorgaben oder Daten hat (Default).

Wenn Sie z.B. in Übereinstimmung mit EnEV (oder anderen nationale Regeln) rechnen wollen, dann müssen Sie natürlich die dort getroffenen Vorgaben einhalten, und die Default-Werte in EED ggf. entsprechend ändern.

Bei größeren Anlagen empfiehlt es sich sowieso, nicht die monatliche Verteilung zu nehmen, sondern die jeweils auf den Monat entfallenden Wärmemengen direkt aus der Berechnung des Wärmebedarfs zu übernehmen.

Zur Frage VDI 4640: In der Version von 2001 sind sowieso nur recht grobe Richtwerte angegeben, Feinheiten wie die monatliche Verteilung der Heizlast kommen gar nicht vor. VDI 4640-2:2001 garantiert auch keine optimalen Anlagen, die Richtwerte stellen lediglich sicher, das keine Anlagen gebaut werden, die vollkommen unbrauchbar sind. Anders ist es mit dem Entwurf VDI 4640-2:2015, bei dem fuer kleinere Anlagen mit EED berechnete Werte verwendet werden, es also bei Einhaltung der Anwendungsgrenzen keine Diskrepanzen geben sollte (die endgültige Version VDI 4640-2 neu wird für Anfang 2019 erwartet).

Q. [2021]
I've got a question about the peak load for heating in EED. I understand from the FAQ that the peak load is the following: ”The peak load is the maximum heating or cooling output required during the coldest (or hottest) day of the month, given in kW, and the expected duration during this day, in hours."

Now let us say I have a heat pump of 150kW with a COP of 4. For the peak heat power in EED, should I fill in the power at the condenser (150kW) or the power at the evaporator (112,5kW) and why?

A.
The peak load is always calculated the same way as the values in base load, i.e. with the input in the "SPF" fields in the base load sub-menu. See page 26 in the EED 3 manual (https://buildingphysics.com/manuals/EED3.pdf) for reference. In your case, if SPF= 4 is stated in the base load fields, this will also be used for peak load, and you should insert 150 kW for peak load. If "direct" is ticked in the SPF field, the ground side / evaporator side will be addressed, and you should insert 112.5 kW.

Q. [2021]
We recently started to use EED software and we need a little help form you which refers to input data for simulation are cooling and heating load.

Normally we get annual energy and monthly profile from HVAC designer and there is almost always no available data for peak loads, although these data essentially affect the results.

For our complete consideration of this issue, I would like to ask you to help us to understand it better.

On the one hand, we have defined the energy needs of the building, and on the other hand we have the operating mode of the heat pump.

The operating hours of the pump depend not only on the thermal losses/loads of the building (building quality), but also on the type of facility. If we have accumulation within the building (underfloor heating / cooling) and the warm/cold water buffer in the installations with the heat pump, the number of pump working hours is reduced and significantly differs from the number of hours needed for heating or cooling of the building.

For heat pumps that operate with a non-inverted type compressor, the system is run at the specified temperature in the buffer. The heat pump maintains this temperature and in this sense there is no influence of base or peak loads for the amount of extracted energy from the ground.

A.
The reason for distinguishing between base and peak load is in making the usually available building data compatible with the ground-side calculation routine.

In most cases, you just get the annual heating/cooling demand, and the peak demand at the coldest/hottest moment (usually equivalent to the maximum output of the chosen heat pump). Everything else is not available in many cases, but influences nevertheless the ground temperature development.

Thus, even in the case you describe with a buffer, kept at temperature by the heat pump, there is a ground-side peak load, at least in the definition used within EED:

- Base load is the heat/cold generated during a full month, for the calculation divided by the numbers of hours in the month, and represents a steady heat transfer at monthly average value.

- Peak load is the maximum heat extraction/injection that occurs continuously over a number of hours.

The peak load in the case with the buffer would be the nominal heat pump heating/cooling output, adjusted with the respective SPF (or directly the heat extraction/injection), over the maximum number of hours the heat pump is operating continuously. On a mild day, the heat pump might just be running twice a day for 1 hour each time, while on a colder day it could be e.g. 8 times for 1.5 hours or 4 times for 3 hours, depending on the size of the buffer. And on the coldest day it might even be one time for 22 hours continuously.

For a heat pump with 30 kW maximum heating output, the peak load values in the respective month would be:

- mild day, 30 kW and 1 h

- cold day, 30 kW and either 1.5 h or 3 h

- coldest day, 30 kW and 22 h

This peak load calculation is important as the temperature development is different if times of thermal recovery are present versus longer.

As an example, a scenario of a sequence of 1.5 hours operation, 2 hours stop, 1.5 hours operation will give a different end temperature than a scenario with 2 hours stop and 3 hours operation.

The issue is not encountered when using the hourly load file option as provided in EED 4, as all the required input will be part of the load file.

The problem is that in many cases the building HVAC engineers will not be able to provide such an expected/simulated load file.

Hence the monthly base load / peak load option is kept as an option in EED 4.

Q. [2021]

I have a question about peak load cooling. The contractor did a simulation in EED and sent me their calculations. In the peaking load they used 1h for every month. Which seemed strange/not realistic to me. I responded that they should use something like:

- May	2h
- June	4h
- July	8h
- August	8h
- September	2h

They replied that this was their reasoning:
"The reason why we used 1h/month is because direct cooling will be used through a heat exchanger. In the calculation software we've tried to replicate passive cooling (= direct cooling). The software is actually made for active heating and cooling. The time display is only used to simulate the maximum temperature. If we use more than one hour, temperatures above 18Â°C will appear on the graph, which is the maximum temperature for passive cooling. We also assume that there will always be a demand for cooling (because of the ICT rooms etc.).So we can still run the heat exchanger of the passive cooling system to bring the soil back to temperature."

My question to you is, is this a valid reason to put everywhere 1h for each month?

I've never seen/used this method for passive cooling.

A.
The software is NOT made for active cooling only. You have the option to transfer heat directly from or to the ground by ticking the box "direct" under the SPF-field in the base

load menu. In the example you sent, an SPF of 1000 was entered, which comes close to direct; such a remedy is not required, just click on "direct". For the peak loads, the same value as given in the base load menu is assumed, incl. a direct heat transfer if the box is ticked.

I do not share the reasoning of the contractor. This only would work if the direct cooling were not required and cooling is just shut off once temperatures from the ground exceed the limit of, say, 18 Â°C.

What is said there is that cooling is primarily considered in the aspect of re-heating the ground to balance the winter heat extraction. Hence there might be a separate cooling system for peaks, and the actual cooling from the ground is close to the base load, and spread over a long time period.

If you want to make direct cooling work at any time, a larger field would be required to accommodate the peak cooling load over several hours (maybe >10 h on hot summer days) without exceeding the technical temperature limit for direct cooling.

The hours you suggest for peak cooling seem quite realistic to me.

So, unless they do not want to cool during peak periods, they would have to add these hours in the peak cooling load menu and re-calculate the BHE field, which will need to be somewhat larger.

Q. [2021]
There seems to be a bug between the options “Annual energy and monthly profile” and “Monthly energy values”. If I switch between these two options, with the same input of energy, load, etc. the numbers at the bottom of the page are changing. I mean, heating numbers are becoming cooling numbers and vice versa. In this case, the load is similar, so not much is changing, but it seems to be wrong, nevertheless.

A.
This is only the default values, there is no way for automatic toggling back and forth...

Q. [2021]
On my current project I have different flows for cooling and heating. In EED I cannot use this, so the simulation is not accurate because it is based on wrong input.

A.
Indeed, different flows in heating and cooling mode will have some influence (and mean in practice different pumps, or pumps with controllable flow). This operating regime was not anticipated when we discussed EED first.

As long as the difference will not result in a flip from turbulent to laminar or vice versa, it can be neglected. Would have an influence on the Tin and Tout temperatures in any case, but not much on the borehole thermal resistance unless flow regime changes.

To add that into EED would only make sense for hourly values, were flow rate could be an extra input column.

With monthly values, EED does not know for which time of the month which flow rate would prevail, and in calculation both heating and cooling might be simultaneous. A check for the peak load (heating or cooling?) might work, but not for base load.

Q2. [2021] Follow up on last question:

We are dimensioning both cooling and heating separately, in which we'll try to optimize both. I don't know how other companies calculate this or how it is organized in other countries, but in the projects we have, the cooling and heating flow is almost always different. One is with an active heatpump, the other is free flow (passive cooling). An example is this case I have right now: 12 m^3/h for heating and 3 m^3/h for cooling, both for all boreholes. This is quite a difference and will indeed be visible in the temperature (difference) of the fluid. At the end of the cooling or heating season, I thinks this will make a difference in the capacity of cooling/heating without exceeding the preselected boundaries. I think, with that view, it would add to the value of the output if we know both for cooling and heating if it is turbulent, or, if not, how far it is off the right Reynolds number.

A2.
You are definitely right in what you say. Here are some more comments:

The problem with different flow rates for heating and cooling is that in the monthly data input, we do not know within each month when heating and when cooling occurs. That might be clear in January and July, but e.g. in April/May both might occur. Hence the best option in such case would be to do two calculations, one with the heating flow rate and one with the cooling flow rate, and take the min/max temperatures according to respective regime.

We could think in adding the flow rate as input for the hourly calculations. Flow rates, in particular in larger systems, do not change quickly, so one value over one hour is fine.

But from where should the user get hourly flow rate data? Most building design programmes just give the hourly load in kW, not any flow rate. One solution could be a building-specific curve linking flow to load, i.e. from the pump control strategy. In consequence, this option does make sense only, imho, when using data from monitoring.

Thus knowing one heating and one cooling flow rate could be a compromise, and taking the respective flow rate according to the net ground-side heat load in a certain hour being positive or negative.

Anyway, I doubt the effort to implement that would be justified.

Q. [2021]
I have a question regard the Peak Load-input in EED. I have noticed that it uses the SPF-value specified in the Base Load-tab.

Isnt the COP at Peak Load lower than the SPF-value? Since the SPF is the mean COP over the year, and is the sum of small time segments

in which the supply temperature is lower than for instance 55 degC at peak load?

Is there a special reason why you choose to only use SPF-value and not COP at Peak Load?

A.
The current version of EED uses one annual average value of SPF for both the base

and the peak load. The program also uses one annual average value of SPF for hot water production.

We are of course aware of the fact that the heat pump COP varies with both heat pump evaporator side temperature and condenser side temperature during the year.

It would of course be handy if the program included performance data for the heat pump/cooling machine used and the demand side temperatures for heating and cooling. We are working on developingÂ the program in this direction while keeping the functionality of a quick execution time.

The currently available alternative is to do the conversion from demand side loads to ground loop loads externally, e.g., using an Excel spreadsheet. This can be done for both monthly loadsÂ + peak pulse and hourly loads. You should then check the "Direct" boxes (heating and cooling) in the submenu "Base Load".

Q. [2021]
I am currently working on a large-scale geothermal project that once again requires your EED software. However, there are solar panels on this project, which will discharge into geothermal probes. My question is: How to take into account the solar discharge in the geothermal probes with the software ?

Is it possible to add the energy injected into geothermal probes by solar panels in the basic cooling demand ? Or is there another way ? Because I didn’t see any solar discharge in the sample files. More and more of the projects we are working on combine low enthalpy geothermal energy with other forms of energy production.

A.
The input category "cooling" can be used to address any heat injection into the ground, e.g. from solar thermal. In this case, it is important to click the "direct" box for cooling in the base load sub-menu.

Then different options exist to specify the heat injection:

a) by monthly loads (base load) and peaks (peak load). In this case the peak loads should not be forgotten, as a solar thermal panel usually has a high output over few hours per day, and low or none for the rest. (Btw., the option for annual heat and monthly distribution makes little sense for most heat injection tasks.)

b) by reading an hourly data file into EED (from version 4.0 on). Such data files are usual for larger solar thermal plants, when meteorological data, site location and exposion, and solar panel area are used as input for simulation of heat production.

The option with hourly load data is very versatile and allows input from different heat sources, with a net/total value given for each hour.

Generally, only the heat input is considered, not the temperature of that heat. Hence it is important to check that the resulting temperature in the BHE is below the temperature the heat transport medium has while injecting heat into the ground. For solar thermal panels that should be no problem, with high supply temperatures; it is more an issue e.g. for direct cooling.

With solar heat or waste heat, it is always important to check the pipe materials in the loops are suitable for the targeted high injection temperatures! Otherwise, a buffer tank with mixing (pre-cooling) might be required. Standard PE is usually not an option for these cases.

It should also be considered that heat injection in summer and building cooling at the same time are not compatible.

Q. [2021]
We have a project where it is clear that we can't cover the whole heating energy need with gshp (or otherwise in a another building we are not able to load all extra heat to the ground in the summertime). If we know the max number of boreholes, can we somehow simulate the maximum energy from boreholes? How is it done? I couldn't find any examples.

A.
EED calculates the fluid temperature for a given load and given configuration/borehole depth, or the borehole depth for a given load/fluid temperature constraint/configuration.

It does not directly calculate the load for a given fluid temperature constraint/configuration/borehole depth. So, you need to try different loads and see what fluid temperatures you will get for your specific configuration/borehole depth.

Q. [2021]
I have a problem using EED in a new project. Please let me ask in German:

Bei einem Standort in Aalen soll eine modulierende NIBE-Wärmepumpe eingesetzt werden. Der Modulationsbereich geht von rd. 2,5 kW bis 13,5 kW. Der Heizwärmebedarf vom Gebäude wurde mit rd. 12.000 kWh/a berechnet. Im kältesten Monat liegt der Heizwärmebedarf bei 3.100 kWh. Daraus kann ein mittlerer täglicher Heizwärmebedarf von rd. 100 kWh abgeschätzt werden. Mit einem ausreichend dimensionierten Pufferspeicher reicht eine Heizleistung der Wärmepumpe von rd. 8 bis 10 kW aus.

Bei der Eingabe in EED wird zwischen Grundlast und Spitzenlast unterschieden. Die Grundlast kann ich aus der EnEV-Berechnung entnehmen. Schwieriger ist für mich die Festlegung der Spitzenleistung der Wärmepumpe. Mein Ansatz wäre jetzt aufgrund der Modulation mit einer Spitzenlast von 8 kW zu rechnen oder kann ich die Spitzenlast aufgrund der Modulation vernachlässigen. Welchen Weg können Sie mir bei der Dimensionierung mit EED empfehlen? Vielen Dank für Ihre Hilfe im Voraus.

A.
Of course a peak load must be used, as that might occur at a certain time. A modulating heat pump does reduce the power in part-load conditions, but for peak, it will need to work at full capacity. Or, in the case given, at the full capacity required after a buffer storage takes some of the load.

In the specific case, the peak load should not be the maximum capacity of the heat pump (13.5 kW), but the remaining peak load of 8-10 kW when considering the buffer.

The idea of the user to use 8 kW as peak thus seems correct. For the hours of peak load duration, the effect of the buffer storage has to be considered, spreading the maximum load required by the building over a longer time span.

For larger projects with modulating heat pumps, or cascades of heat pumps, a building simulation might be done, and the hourly data input in EED 4 offers an ideal tool to process the load output of such simulation!

Q. [2021]
I've a hypothetical scenario where only base load and JAZ is given for the year. Peak loads are not considered in the input. For determination of the size of the heat pump it's I need do define the peak load that can be achieved by a certain BHE configuration. The only parameters that I get from EED (Version 3.2) are mean fluid temperatures. Furthermore, by reading the FAQ I've seen that flow rate is calculated for Reynolds only.

So, is there any option to calculate the peak load that is extracted from the ground to define the size of the heat pump? I think dividing monthly demand by total operating hours might be wrong as this is as phase with high and low load are averaged only.

Or is multiplication of specific heat extraction rate an option? If I got it right this calculated only if peak loads are entered.

Or is there any way to back-calculate the differential temperature between inlet and outlet?

A.
This is a tricky one. There is no direct way to calculate the maximum heat pump evaporator capacity within EED. The only correct way would be to use some estimated peak load values, check for the temperature, and do some iterations to find the maximum peak load that fits the desired temperature development.

The methods you have considered only give some approximation.

For calculating the temperature difference between inlet and outlet, the flow rate and heat extraction can be used easily, with the specific heat of the fluid (ca 4.18 kJ/kg for water, less for antifreeze mixtures; these values are given in the EED database for heat carrier fluids.
The formula: Delta T (K) = heat rate (kW) * 3.6 / spec. heat (MJ/m3/K) / flow rate (m3/h)

Q. [2021]
I am currently carrying out modeling on a geothermal probe field for a building located at an altitude of 1700m
Heating power: 123 kW
Cooling power: 93 kW

The thermal response test gives us a value of 5.568 W / mK, but I noticed that according to the standards (SIA 384/6…), it is customary to reduce the usable power per meter of probe according to the altitude of the building.

Is it possible to consider the altitude of the building with EED software?

A.
This is more a question on general understanding of BHE design, not on the use of EED.

The altitude is not a direct input parameter for simulations and calculations like EED. It however influences other input parameters, mainly the heating load of the building and the undisturbed ground temperature.

The altitude is only relevant as direct input in some simplified design tables and nomograms like in SIA/SN 546 384/6 or VDI 4640-2.

Hence when you use EED with the correct input parameters for the building load (which has to be determined by taking into account the specific climatic conditions at 1700 m asl) and for the undisturbed underground temperature (which you should have from the TRT), no further adjustment needs to be done.

A caveat is given when using the database for ground temperatures within EED. These values refer to the elevation of the cities stated, and can be lower on mountains in the respective region. The values from the database are helpful when now other info is available, but need to be considered and adjusted in the way described in the Manual and Tutorial. It is always better to use a measured value from TRT, if available.

Finally, two remarks on the TRT result stated:

a) It is strange to see a value stated with 3 digital decimals, like 5.568 W/(m*K). Of course, such values can be calculated, but both the operation and the evaluation of a TRT do not allow for more accuracy than about 1 decimal place, i.e., 5.6 W/m*K). I prefer not to trust a value given with such high (and surely not real) accuracy.

b) There are very few rocks with a thermal conductivity greater than 5 W/(m*K), just some Gneiss, Quartzite, Rock Salt etc. It is more likely that the result includes some effect of flowing groundwater. A sequential analysis can help to verify that (cf. VDI 4640-5, available in bilingual German/English).

Using 5.6 W/(m*K) without verifying if that value is justified by the rock type might lead to a substantially undersized BHE plant.

6 Solve

Q.
In the ‘Solve mean fluid temperatures’ mode, the fluid temperature can get below freezing point of the carrying liquid or can go over the temperatures expected to come from the building while in cooling mode. In the attached output, the maximum temperature in cooling mode goes over 93 C, while the real maximum temperature coming from building will be 40 C (from condenser)? I presume, in this mode the algorithm has an imperative to extract/inject the specified temperature and have no constraints. For this, having the fluid specific heat capacity and flow speed through the pipe, the program iteratively finds the appropriate temperature which would provide prescribed heat extraction/injection still balanced with the thermal capacity and conductivity of the BTES system (using the linear source solution similar to the Theis solution for groundwater). Am I right?

A.
Almost. In the ‘Solve mean fluid temperatures’ mode, the program calculates the temperature response to a given amount of heat injection/extraction variation, using the thermal parameters (specific heat, thermal conductivity) of the ground, pipes, etc., and the geometric influence of pipe grids as contained in dimensionless thermal response function called the g-function. There is no consideration of the maximum or minimum temperatures a system can cope with; this is for the user to check and to make the system accordingly. In the “Solve required borehole length” mode, these temperature limits can be stated explicitly.

For your case, of course the temperatures are far out off any reasonable limits. When you look at the specific heat extraction rate for peak cooling, it exceeds 150 W/m! Here values between 20-80 W/m are normal, in respect to the thermal conductivity in the underground on site. The system is just to small for a peak cooling load in excess of 1.5 MW.

Some other observations of your case:

1. The ground thermal conductivity of 1.9 W/m/K is low, this is a value e.g. for wet clay. When drilling in your area , you may have some clay, sand, till, etc., but with the borehole reaching down to 180 m depth, there ought to be a good deal of hard rock with higher thermal conductivity. So I would expect a higher value. Such a low value of course means higher extremes than with higher conductivity; please check.

2. For a drilling depth of 180 m, the distance between holes of 4.3 m is rather small. Considering usual deviations from the vertical, there is a very good chance for a driller to hit a BHE installed before.

The g-functions are based on fully three-dimensional numerical solutions of the heat conduction equation assuming the same borehole wall temperatures for all boreholes. The resulting heat transfer rate along the boreholes will vary according geometric conditions such as borehole diameter, depth, spacing and number and configuration of boreholes. The borehole wall temperature at every moment is matched so that the sum of each borehole heat flow equals the prescribed total heat flow. This means that the changing ground temperature may result in gradually less favorable ground temperatures in the vicinity of some boreholes. If a (infinite or finite) line source approach is used then all the heat flux on the borehole wall will not change with time.

One point usually is the most difficult to bring across: EED is a very fast tool to get sound layouts for borehole heat exchangers, or to play quickly with various alternatives in a pre-design phase. With this as a goal, it is not made to cover every aspect. The major limitation is the purely conductive approach. So for choosing EED for a specific task, you should know what you want to use it for (and I meanwhile use it much more often than any other tool).

Q.
Wenn ich EED die minimale Bohrlänge berechnen lasse und dabei als Grenze -14°C Soletemperatur(Quelltemperatur) – auch unter Berücksichtigung der Peaks – eingebe, erhalte ich dann ein technisch mögliches Ergebnis? Die Einsatzrenzen einer WP liegen ja bei -5°C – 25°C, müssten aber meiner Meinung auch kurzzeitig tiefere Temperaturen “ertragen” können.

A.
Rechnen kann man natürlich alles, selbst die Grenze von -273 °C wäre hier kein Problem. Praktisch geht das natürlich nicht. Für sinnvolle Temperaturgrenzen finden Sie in VDI 4640 oder bei den WP-Herstellern Angaben.

In einem Teststand habe ich 1985 bereits eine Erdwärmesonde bis auf -13 °C Austrittstemperatur heruntergefahren, um die Grenzen auszutesten. Die 22-kW-WP von Siemens hat das klaglos mitgemacht, tiefer kam sie nicht mehr. Leistungszahl in diesem Betriebszustand etwa 1,5. Sinnvoll ist das also nicht. Auch bei Direktverdampfern (z.B. mit Ammoniak) hat man vor einigen Jahren so tiefe Temperaturen propagiert, um Bohrmeter zu sparen. Neben den Umweltauswirkungen (großer Gefrierradius) ist dabei auch die Arbeitszahl unbefriedigend, wie ich auf langes Nachbohren auf Tagungen herausfinden konnte.

Q.
zur Angabe der jährlichen min Temperaturen: sind damit die Temperaturen vor dem Wärmeentzug oder nach dem Wärmeentzug durch die Wärmepumpe gemeint ?

A.
Die Temperaturen sind grundsätzlich als mittlere Soletemperaturen angegeben, d.h. als Mitteltemperatur in der Erdwärmesonde. Die Temperaturen des jeweils zur Wärmepumpe zurueck und dann wieder in die Erdwärmesonde fließenden Wärmestroms liegen somit um je die halbe Temperaturspreizung im Solekreislauf über bzw. unter dieser Temperatur (die Spreizung in einer typischen Wärmepumpenanlage liegt bei 3-4 K). Die Spreizung ist von der Durchflussmenge, dem Solegemisch etc. abhängig und kann somit nicht immer angegeben werden. Wir haben übrigens dennoch vor, für einfache Fälle eine

Berechnung der resultierenden Ein- und Austrittstemperaturen in das z.Z. in Bearbeitung befindlichen Update zu EED zu integrieren. Sie werden bei Verfügbarkeit benachrichtigt.

Q.
Angabe der jährlichen max Temperaturen (free cooling): sind damit die Temperaturen im Vorlauf oder im Rücklauf der Erdwärmesonden gemeint? s.o.

– sind Angaben zur Temperaturspreizung (Heiz- bzw. Kühlbetrieb) möglich?

– Freikühlbetrieb: werden Eingangs-Temperatur hinterlegt, damit die maximale Temperatur berechnet werden kann oder spielt die Eingangstemperatur ab einer bestimmten Länge der Erdwärmesonden keine Rolle mehr?

A.
Die absolute Eingangstemperatur wird nicht eingegeben, sie kann natürlich im Einzelfall höher sein. Bei Temperaturen bis etwa 30 Grad Celsius spielt das keine Rolle. Bei Anlagen mit hoeheren Temperaturen, wie sie z.B. in Wärmespeichern wie Neckarsulm-Amorbach vorkommen, ist EED sowieso nur begrenzt einsetzbar; dabei handelt es sich um Sonderanwendungen, die auch von ökologischer Seite ausführlich geprüft werden müssen, eine numerische Modellierung ist dabei m.E. unerlässlich. EED kann dabei nur als Vorplanungsinstrument dienen. In den üblichen Fällen erdgekoppelter Wärmepumpen liegen die Eintrittstemperaturen in das Erdreich zwischen minimal etwa -5 °C im Winter und rund 20 °C (oder etwas darüber) im Sommer. Bei direkter Kuehlung sind 20 °C sowieso nicht zu ueberschreiten.

7 Output

Q.
Could you please send me calculation details for SPECIFIC HEAT EXTRACTION RATE [Btu/(h·ft)]?

A.
It is the heat rate extracted from the ground divided by the total length of borehole heat exchangers (in EED, the monthly value for peak heat load re-calculated for the ground side using the SPF, and then divided by total BHE length). An example in SI:

Peak Heating load in February	15 kW
SPF	4
Heat extraction rate on ground side	11.25 kW
Total BHE length	225 m

Specific heat extraction rate = 11250 W / 225 m = 50 W/m

The same for English units, in BTU/hr and ft instead of W and m.

Q.
1) I have seen in the presentation that we need to enter information about peak loads, annual energy distribution and a flow in m^3/h. I don't see anything about the temperature difference between entrance and exit in the borehole. The graphs after calculation give an average temperature + maximum and minimum values that should correspond to the maximum and minimum average temperatures according to the peak kW. Can you help me with this?

2) We have a tricky calculation to do. We have a heat pump that will only produce cold and will release 70 kW in the ground (10 m^3/s). We might have a very exceptional use of a generator during 48 hours that will need to reject an overall (heat pump + generator) 210 kW to the ground with 20 m^3/h. How can we handle this in EED since the m^3/h will be very different when the generator is on? I was thinking of doing it in two steps with EED:

– First the heat pump alone during 20 years with 57 kW and 10 m^3/h to get the maximum temperature of the ground over the period.

A.
1) The temperature curves given are the mean temperatures in the borehole heat exchangers (BHE), i.e. the mean value between inlet and outlet. This reflects the behavior of the BHE to the borehole and the outside ground, not the temperature development along the BHE axis. The value for flow rate (m3/h) is required for calculating the Reynold´s number, which has an impact on heat transfer inside the pipes and thus on borehole thermal resistance.

2) What you describe is exactly the way I would do it myself. In a case for only heat injection into the ground, you will see a temperature increase over the years, and probably you will need a very large installation to cope with this over a longer

period. In such a case, it might be wise to use the winter cold for getting some of the heat out of the ground again, e.g. by just pumping the fluid through a dry air cooler. Such a “cold storage” system can reduce the required BHE length greatly, and often is more economic than a pure cooling option (heating up the ground only).

Q. [2021]

I have a question about the output of the EED software. In the basic example in attachment, the mean temperature of the base load after 25 years in January is -2,57°C.

What exactly does this temperature mean? Could you explain this more in detail? For example, is this the temperature of the flow going to the building so this is the “available” temperature for the heat pump? If I set boundaries for this temperature, it is good to know for what this is.

A.
The calculated resulting temperatures are the mean fluid temperatures (Tf) inside the pipe, at half of the depth of the borehole.
See manual for v4 p. 39 at
https://www.buildingphysics.com/manuals/EED4.pdf

Also search for “EWT” in this document.

8 How to input data from a Thermal Response Test

Q.
Our company deals with “BTE problems“ so we purchased your software EED 3.12 some months ago. It seems to be very useful and user-friendly. But there are some things connected to borehole thermal resistance which we do not understand to.

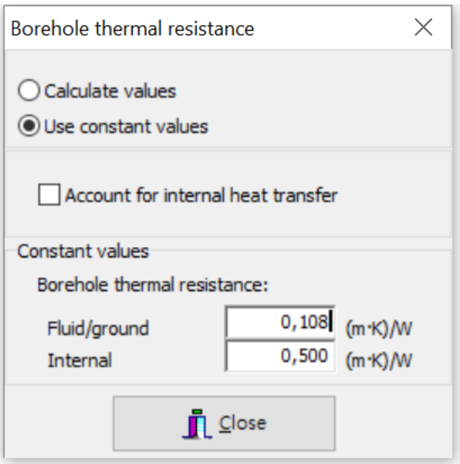
We found that thermal resistance of borehole depends on volumetric flow rate of brine (affecting the Reynolds number). Is it possible to use measured value of thermal resistance which we got from TRT to calculations in EED? During TRT there was totally different volumetric flow than it will be in borehole connected to heat pump. How much is thermal resistance of borehole affected by volumetric flow of brine?

A.

The standard evaluation of a thermal response test gives the effective thermal conductivity of the ground and the effective borehole thermal resistance of the borehole heat exchanger. The value of the effective borehole resistance includes the effect of thermal short-circuiting and it depends on fluid thermal properties (temperature-dependent), flow rate and depth of borehole. In the case of groundwater-filled boreholes there is an additional dependence on specific heat transfer rate. Differences between the thermal response test and design conditions have to be taken into account.

To use the measured value of the effective borehole thermal resistance:

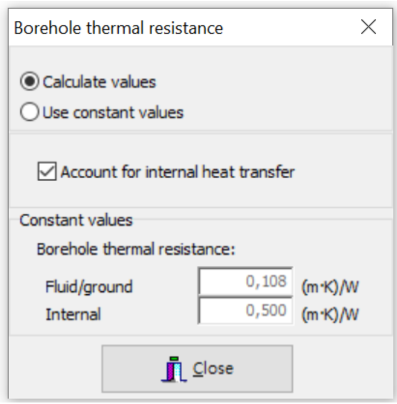
1. Go to menu “Borehole thermal resistance”
2. Check “Use constant values”
3. Uncheck “Account for internal heat transfer”
4. Insert your measured effective borehole thermal resistance value in the box “Fluid/ground”
5. The value for Internal is not used if “Account for internal heat transfer” is unchecked



Example of using measured effective borehole thermal resistance obtained from a thermal response test.

To study the effect of a change in fluid properties and flow rate it is recommended to use EED to obtain a reasonable match with measured data:

1. Go to menu "Borehole thermal resistance"
2. Check "Calculate values"
3. Check "Account for internal heat transfer"



4. Go to menu "Heat carrier fluid"
5. Give fluid properties at the fluid temperature used in the thermal response test
6. Go to menu "Borehole and heat exchanger"
7. Set the parameters for your borehole heat exchanger. Usually there are the same uncertainties with regards to actual shank spacing and/or filling thermal conductivity. Vary those values within reasonable limits (start with shank spacing) and match the calculated effective borehole thermal resistance (see the calculated data in the output window) with the measured borehole thermal resistance at the flow rate used in the thermal response test.
8. Go to menu "Heat carrier fluid"
9. Give properties at desired fluid temperature of design case
10. Go back to menu "Borehole and heat exchanger"
11. Vary "Volumetric flow rate"
12. Study the variation of "Effective borehole thermal resistance" in the "Design Data" output file

Q.

Unser Büro arbeitet seit einiger Zeit mit dem Programm EED. Zudem führen wir seit etwa 2 Jahren Thermal-Response-Tests durch. Nun habe ich bei der Umsetzung des aus dem Test berechneten thermischen Bohrlochwiderstandes in der EED Simulation das Problem, dass im EED unter „Borehole thermal resistance" als „constant values" zwei Parameter – „Fluid/ground" und „Internal" abgefordert werden, aus dem TRT jedoch nur ein Wert (Rb) berechnet wird.

Ich würde mich sehr freuen, wenn Sie mir einen Hinweis geben könnten, wie ich den im Test berechneten thermischen Bohrlochwiderstand im EED umsetzen kann. Für Ihre Unterstützung bedanke ich mich im Voraus und verbleibe mit freundlichen Grüßen

A.
Der mit dem Responsetest gemessene und über die bekannte Formel ermittelte Wert entspricht etwa dem Wert “Fluid/Ground”. Der Wert “Internal”, der den Wärmeaustausch zwischen den einzelnen Rohren beschreibt, ist grundsätzlich höher und kann bei dem Default wert von 0,5 K/(W/m) belassen werden. Er geht in den Gesamtwert (“effective” im Ausgabefile *.out) nur sehr gering ein.

Q. [2021]
I have two small questions about the values concerning "Thermal borehole resistance" when a TRT test has been conducted.

The total borehole resistance value is 0,187K/(W/m).

I understand this is the value I have to input in the Fluid/ground box? But what to input in the box below "Internal". Is this value of 0,5 W/m.K an automatic estimate, or how should I interpret this?

I have two test results of TRT tests of 2 boreholes on the same site with a slight difference in design of the pipes (spacers used vs no spacers used.) The values we got for thermal borehole resistance are resp. 0,143 W/m.K and 0.141 W/m.K.

Is it too easy to say that the difference of using spacers or not is only 1,4% on the design of total boreholes?

This might be more of a designer question, but if you could give me your opinion on this, I would be most grateful.

A.
the only way to input borehole thermal resistance (Rb) from TRT is "fluid/ground" box. This works as the internal resistance is usually negligible when using the standard temperature difference of about 3 K created by the heat pump (and usually almost the same at inlet and outlet of the BHE). The value of 0.5 (m*K)/W is a default that works well as long as delta is in the 3 K range. For thermally enhanced grout and very slim boreholes, you might lower the value to some 0.1-0.2 (m*K)/W. In any case, the final result for BHE length and fluid temperatures will be virtually the same.

You can check that within EED. When calculating Rb, and having ticked the box "account for internal heat transfer", the respective value is calculated. It is >0.5 for a single-U-BHE and old, standard grout with <1 W/(m*K), and about 0.2 for a double-U-BHE with thermally enhanced grout.

The final difference in effective Rb is in the 4th decimal digit only.

A more elaborate input would be required for high delta T inlet/outlet, which might occur when using solar heat or waste heat injection for UTES.

My suggestion for input of TRT data is to either have a sufficiently high value for "internal" (<0.5) or to un-tick the box "account for internal heat transfer", while supposing this aspect is already covered within the TRT data and evaluation.

Concerning the issue of spacers, this depends very much on borehole diameter. In a slim borehole, the difference with or without spacers will be small, as the pipes will be in almost the same place.

In a borehole with large diameter, spacers will have more impact, provided the spacers push the pipes considerably closer to the borehole wall. The effect will also be more pronounced with grout of low thermal conductivity, and less with thermally enhanced grout.

So, I am not too much surprised to see a small advantage only. Again, EED can be used as a tool to investigate that.