

## Program for Heat and Flow Calculations of Geothermal Heating Plant in Cooperation with Heating Network

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### ABSTRACT

Authors introduced practical solutions for heat distribution in municipal heating network, supplied from geothermal heat plant operating with geothermal heat exchanger. Heat and flow calculations include: geothermal water extracting system, geothermal heat exchanger and system of geothermal energy utilization consisting of peak load boiler, high and low temperature users. Computer program simulates variability of many parameters, regarding to users requirements and localization. It provides the choice of the most effective solution after taking into consideration following criteria: maximum utilization of temperature difference and minimal number of bypass used in a system. Program can find application for installations in design stage, existing or being modernized. This work illustrates the influence of floor heating on effectiveness of geothermal energy utilization, and the influence of heating network temperature on effectiveness of geothermal energy utilization.

### 1. INTRODUCTION

Theoretical method of heating network calculation, consisting of low and high temperature heat receivers is introduced in this paper. Analysis of different combination possibilities with proper by-passes is carried out on the basis of elaborated method. It will allow to choose the most advantageous solution of the connections for given assumptions taking into consideration the maximal utilization of geothermal heat.

Investigated heating network is supplied from geothermal heating plant, which includes geothermal heat exchanger and peak boiler.

For each group of heat receivers a corresponding characteristic will be formulated and the type of used regulation will be given.

Analysis of different connections between heat receivers, having various characteristics and geothermal heating plant is carried out by connecting them in all possible configurations.

With the purpose to systematize the calculations two various types of nodes, receive nodes and transmit nodes, connected with the help of bypasses, were implemented.

Transmit nodes are placed at the outlets from heat receivers, they let the cool water in municipal heating network (bypasses). Receive nodes collect return water from the municipal heating network, they are installed at the inlets to heat receivers as well as at the geothermal heat exchanger.

Additionally heated water from geothermal heat exchanger is directed to the node number 2.

Analysing program selects from all feasible combinations those which are the most energetically effective. The main determinant is the biggest amount of heat energy transferred in geothermal heat exchanger. Connections in a network and the flow rate of heating medium are the subjects to the optimisation.

### 2. PROGRAM

Introduced program was written in Object Pascal programming language in programming environment of Delphi 8 .Net for Windows Win32 and .Net platform ([www.borland.com](http://www.borland.com)).

Program was tested on the server equipped in 2 processors Xeon 2.8GHz and 1024MB RAM memory with installed system Windows 2003 Server based on the specification 1 placed below.

#### Specification 1, computer for calculations.

2 Processors type: Xeon DP 2.8GHz  
Memory: RAM 1024MB ECC  
HDD: SCSI U320 (transfer 320 Mb/s)  
Controller RAID: Adaptec SCSI RAID 2010S  
Main board: Intel® SE7501HG2  
Housing: Intel® „Hudson III”  
Double network: Intel® PRO 1000+ Server  
Installed operation system: Windows 2003 Enterprise Server.

Calculations of the program take at least 4 hours on the tested computer. One of program's procedure was illustrated in a Figure 2. Running of program calculations is based on 3 stage operations: loading of the data, carrying out calculations, choosing the most effective calculations from the results. Main windows of the program are published in Figures 7-10.

Program is doing all tasks fully automatically and without errors. Loading of the data is possible in window “Data”. In this window all the data describe completely assumptions for calculation.

Calculations are realized in a window “Calculation”. This window also visualize the progress of calculation during the program is running.

Optimization takes place in a window “Optimization”. The effect of optimization procedure is an output file with the most effective results of heating network combinations. In this file the values of each parameter describing the network state as temperature, medium flow rate and heat flux are included.

### 3. CHARACTERISTIC POINTS

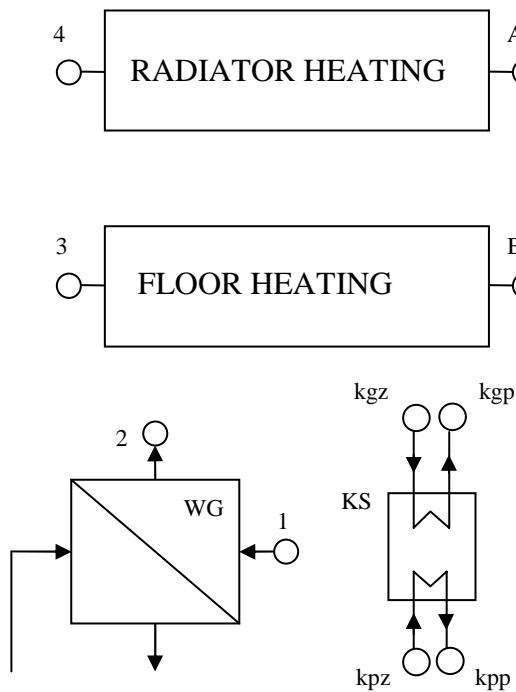


Figure 1. Schema with calculation nodes.

There are two type of nodes, transmit nodes and receive nodes. Two groups of such junction are combined by bypasses, which number as well as combination are mathematically optimized.

Nodes in points from 1 to 4 are receive nodes, they are supplied by the fluid from calculation by-passes. For a given node, output temperature and volume flow are obtained form the calculation procedures.

Points A and B are transmit nodes. They are at the outlets of heating water streams from the heat receivers. The value of the volume flow rate at this points is obtained on the basis of heat demand quantity and outside temperature.

In the Fig. 1. nodes for the basic calculation elements were presented.

Points kgz (supply of the peak boiler with the hot water for radiator heating), kgp (return water from peak boiler for radiator heating), kpz (peak boiler supply with water for floor heating), kpp (return water from peak boiler for floor heating) are not distinguished in calculation. Peak boiler is treated as the whole, supplying the needed heat to municipal heating network to satisfy the user's requirements.

### 4. FOUR CALCULATION LEVELS

Program in the first calculation step fixes the amount of water leaving the receiver for given outdoor air temperature  $T_z$ .

If the calculated configuration of the heating network is K:A1,B1 it means, both streams from the heat receivers will be directed to geothermal heat exchanger, in the following sequence, first the stream from point A (radiators) and than from B (floor heating receivers) according to the record order A1,B1.

After the first calculation the heating network is presented in the Fig. 3.

The amount of the fluid from receivers might be bigger than the capabilities of geothermal heat exchanger, in such a case there is a need to use a by-pass and continue the calculation.

During next phase of calculations the water amount in points A and B is being reduced, concerning the quantities which have been directed to the geothermal heat exchanger before.

Calculations of the next level do not deal with geothermal heat exchanger, because its capabilities in combination K:A1,B1 are fully over.

The results from calculation may look as follows K:A1,B1 A2,B3 (see Fig. 4) depending on the principle of the highest effect of energy utilization by receivers.

If the sum of volume flows in a network is lower than the amount of fluid at the outlet side of receivers after the second stage of calculations, than calculations are continued until the amount of the water from heat receivers will run out. There is a limitation regarding the maximum occurrence with the number of 4, it means calculations are carried out for 4 pairs of by-passes. One calculation process is one pair of by-passes.

For by-pass calculations all 4 receiver points are taken into consideration.

In such a way all thermodynamic parameters of the network are calculated.

Each combination is possible to be written as K: A1,B1 B2,A3 or K: B1,A1 B2,A3.

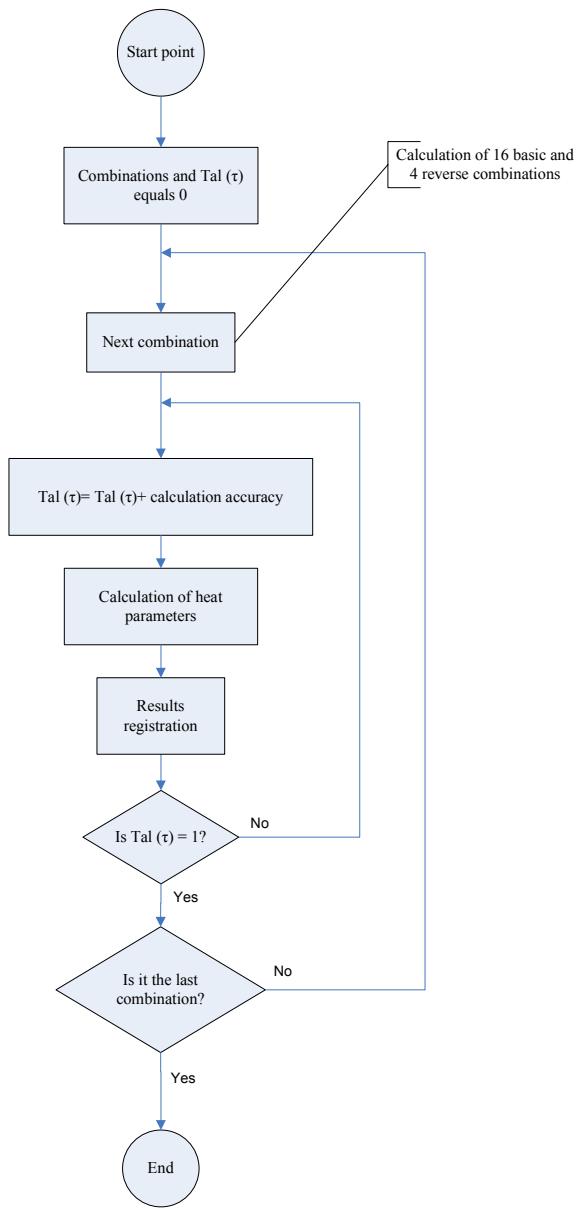
#### 4. 1 First stage calculation algorithm.

With the aim to visualize the process, first level calculation algorithm was presented in Fig. 2. Every next stage of calculation will be exponentially complicated.

### 5. CALCULATION EXAMPLE

For introduced input parameters calculations were done by the program and the diagrams shown in Fig. 5 and Fig. 6 were generated.

$T_{g\max}$	= 50	[°C]
$T_{gp}$	= 50	[°C]
$T_{pp}$	= 30	[°C]
$T_{gz}$	= 95	[°C]
$T_{pz}$	= 60	[°C]
$\rho_s$	= 1	[kg/dm <sup>3</sup> ]
$Cp_s$	= 4.18	[kJ/kgK]
$T_{z\min}$	= -16	[°C]
$T_{zg}$	= 12	[°C]
$\rho_g$	= 1.08	[kg/dm <sup>3</sup> ]
$cp_g$	= 3.8	[kJ/kgK]
$V_{g\max}$	= 150	[m <sup>3</sup> /h]
$V_{g\min}$	= 50	[m <sup>3</sup> /h]
$Q_{comax}$	= 8000	[kW]
$\tau_0$	= 4368	[h]



**Figure 2. Algorithm: First level of calculation.**

## 5. CONCLUSION

As presented in the diagrams generated from the calculated results, the contribution variability of low- and high temperature heating causes big changes in a heat amount utilized from geothermal resources. We can follow the influence of geothermal conditions on the heating system behavior as well as how the heat receivers types and regulation type create the shape and internal parameters of municipal heating network.

Computer program after simulation provides the most effective solution taking into consideration the biggest amount of geothermal heat utilized and minimal number of bypasses installed in a municipal heating system. Program can find application for installations during design stage, existing or being modernized.

In the future program will contain more components as heat pumps, various receiver types, different regulation types, and authors foresee a possibility of cooperation with OR Cycle and Kalina Cycle for stream generation.

## NOMENCLATURE

- Symbols at the figures and diagrams
 

KS	– Peak boiler
WG	– Geothermal heat exchanger
Variant O2	– Heat flux for 75% radiator heating and 25% floor heating contribution in total heat demand.
Variant O3	– Heat flux for 50% radiator heating and 50% floor heating contribution in total heat demand.
Variant O4	– Heat flux for 25% radiator heating and 75% floor heating contribution in total heat demand.
Variant O5	– Heat flux for 00% radiator heating and 100% floor heating contribution in total heat demand.
$\bar{\tau}$	– Reduced time
- Symbol of combination number
 

K: A1,B1  
 K: A1,B2 A3,B3  
 K: A1,B2 A3,B3 A4,B2  
 K: means combination of bypasses used in a network.  
 Ax, By or By,Ax - Configuration of bypasses.  
 Number x - describes the number of the node, where the by-pass from point A is connected.  
 Number y - describes the number of the node, where the by-pass from point B is connected.
- Symbols used during calculations
 

$T_{zmin}$	– Minimum calculated external temperature occurring in a given climatic zone [°C]
$T_{sw1}$	– Temperature at the inlet of the network water stream to geothermal heat exchanger [°C]
$T_{sw2}$	– Temperature at the outlet from geothermal heat exchanger [°C]
$T_{gmax}$	– Temperature of hot geothermal water supplying geothermal heat exchanger [°C]
$T_{gz}$	– Maximum temperature when the heating is on [°C]
$m$	– Mass flow rate [kg/s]
$\rho_g$	– Geothermal water density [kg/dm <sup>3</sup> ]
$\rho_s$	– Density of municipal water [kg/dm <sup>3</sup> ]
$c_{p_g}$	– Specific heat of geothermal water [kJ/kgK]
$c_{p_s}$	– Specific heat of municipal water [kJ/kgK]
$T_{gmax}$	– Temperature of geothermal water [°C]
$V_{gmax}$	– Maximum volume flow rate of geothermal water [m <sup>3</sup> /h]
$V_{gmin}$	– Minimum volume flow rate of geothermal water [m <sup>3</sup> /h]
$T_{gz}$	– Temperature required to supply radiator heating, high- temperature receivers [°C]
$T_{pz}$	– Temperature required to supply floor heating, low- temperature receivers [°C]
$T_{gp}$	– Water temperature at the outlet from radiator heating receivers [°C]
$T_{pp}$	– Water temperature at the outlet from floor heating receivers [°C]
$Q_{comax}$	– Total heat demand [kW]

$\tau_0$  —Number of heating period hours in a year [h]  
 W —Heat capacity [kJ/K]

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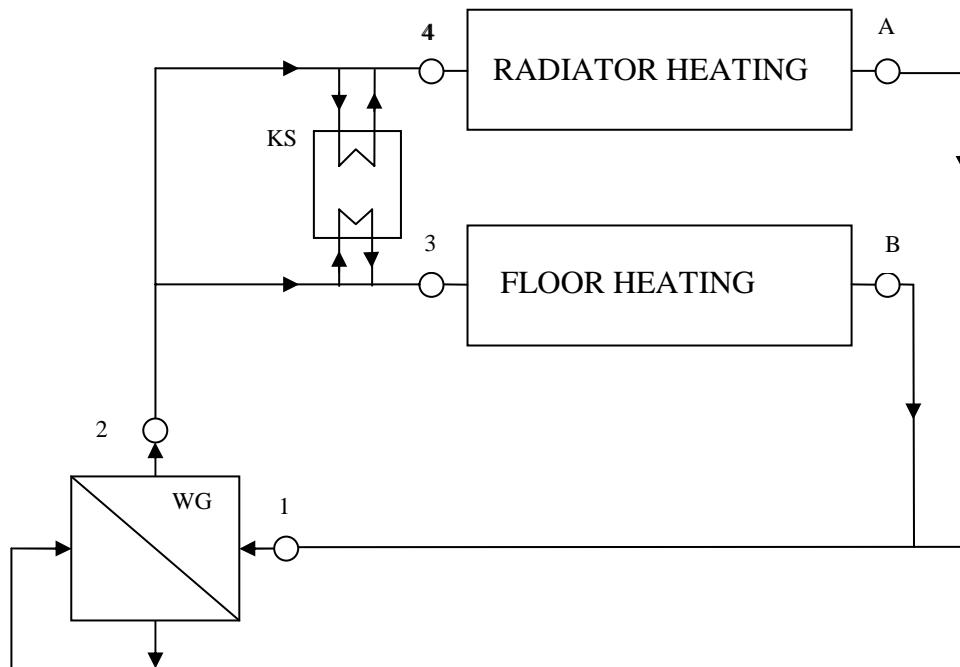


Figure 3. Network schema described by combination K:A1,B1.

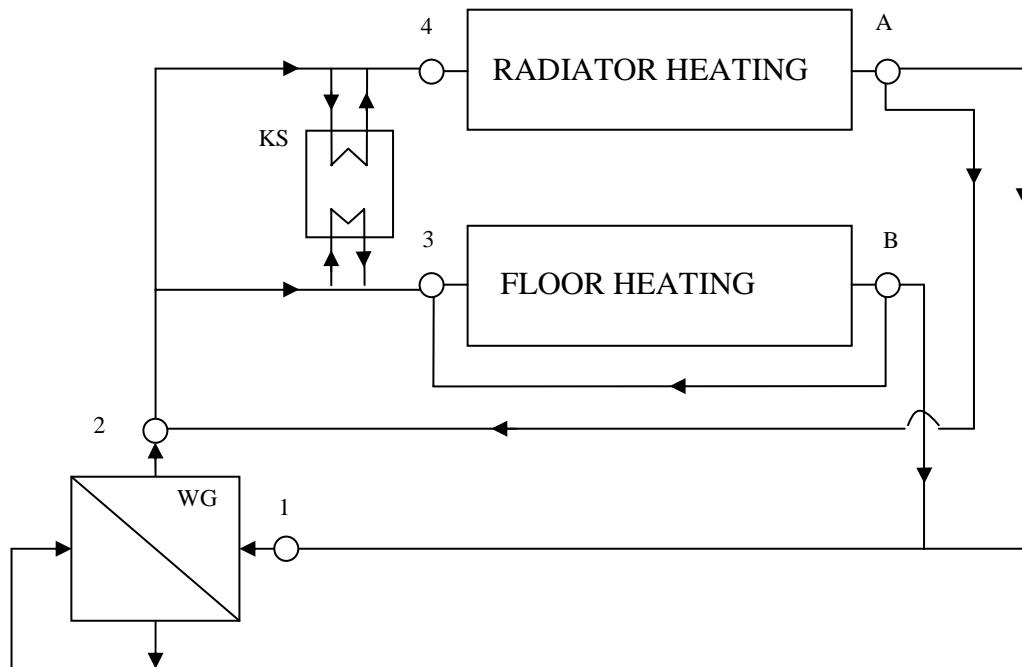


Figure 4. Network schema described by combination K:A1,B1 A2,B3.

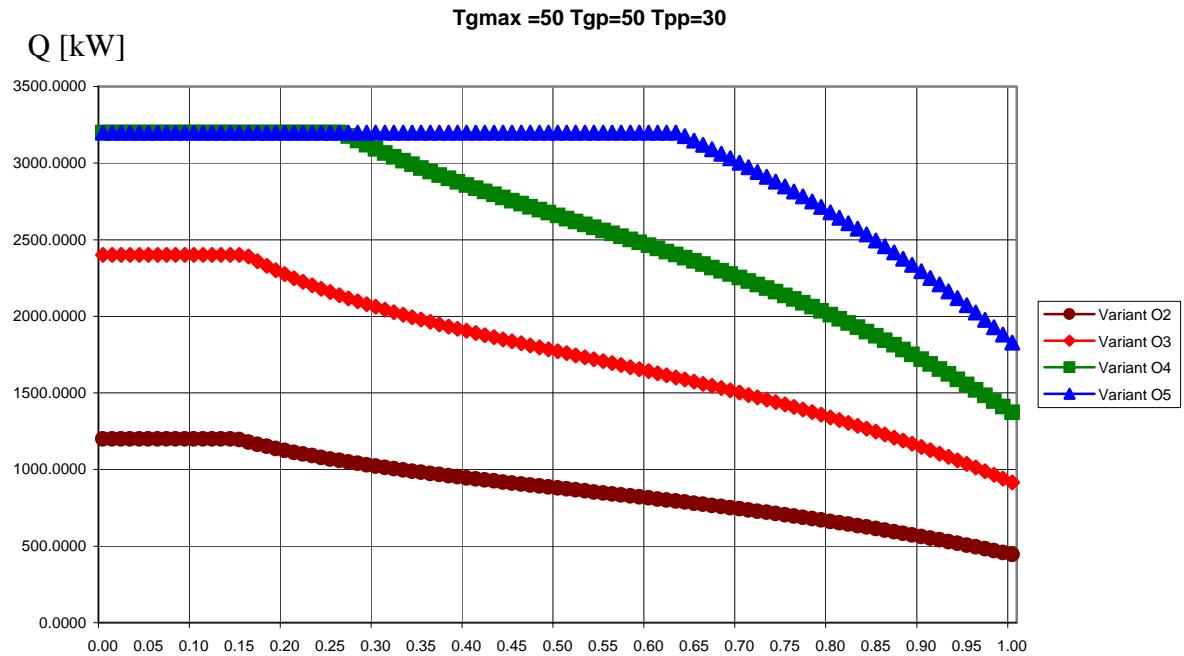


Figure 5. Heat flux for each variant during heating period for parameters  $T_{gmax} = 50$  °C,  $T_{gp} = 50$  °C,  $T_{pp} = 30$  °C.

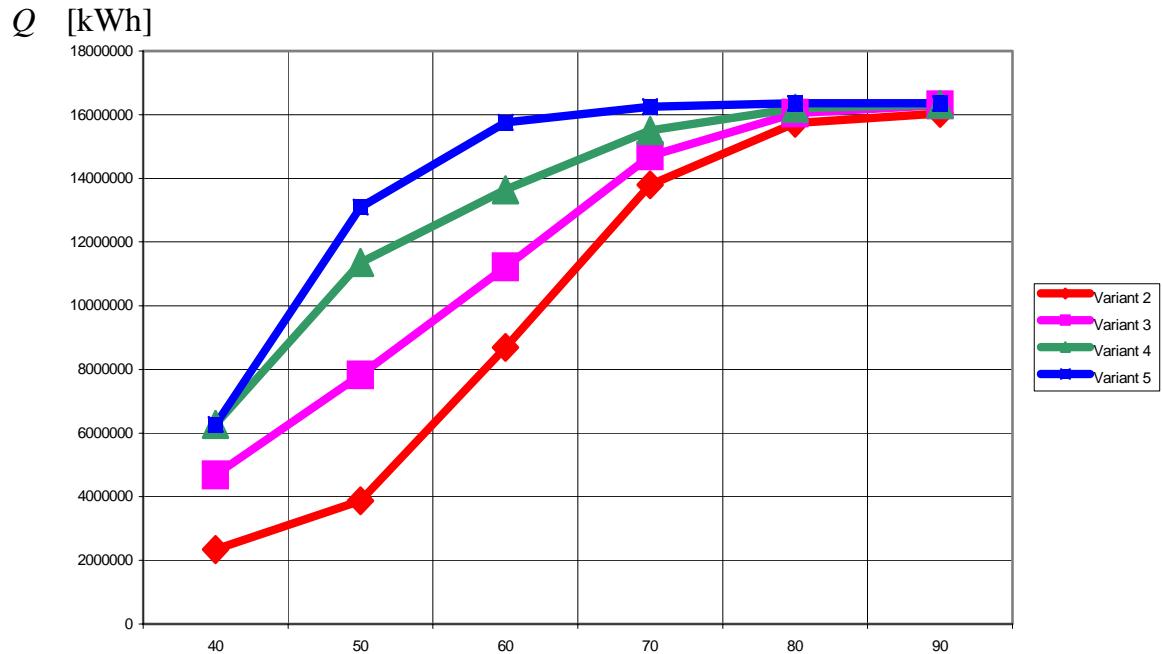


Figure 6. Heat amount gained from geothermal water as the function of geothermal water temperature and variant of low- and high temperature heating contribution by assumed constant temperature  $T_{gp} = 50$  °C.

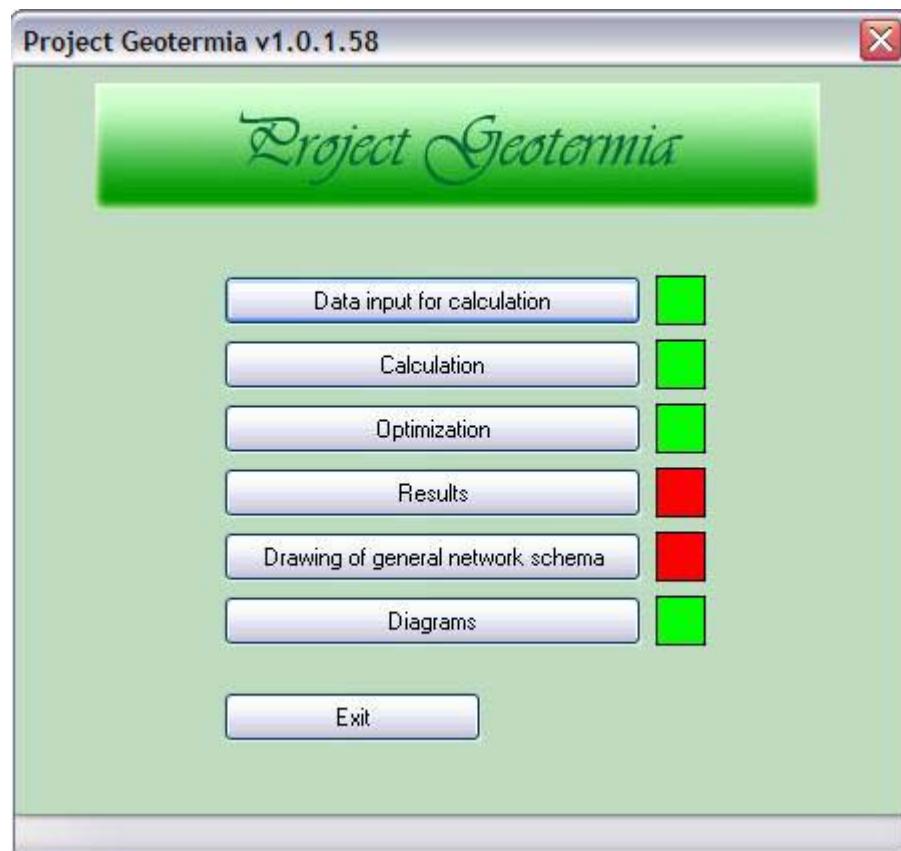


Figure 7. Main window of the program.

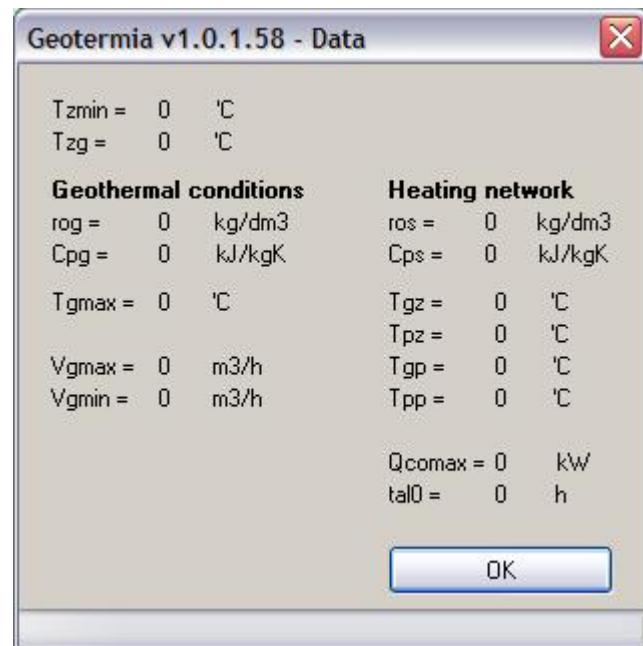


Figure 8. Window "Data" for loading the calculation data.

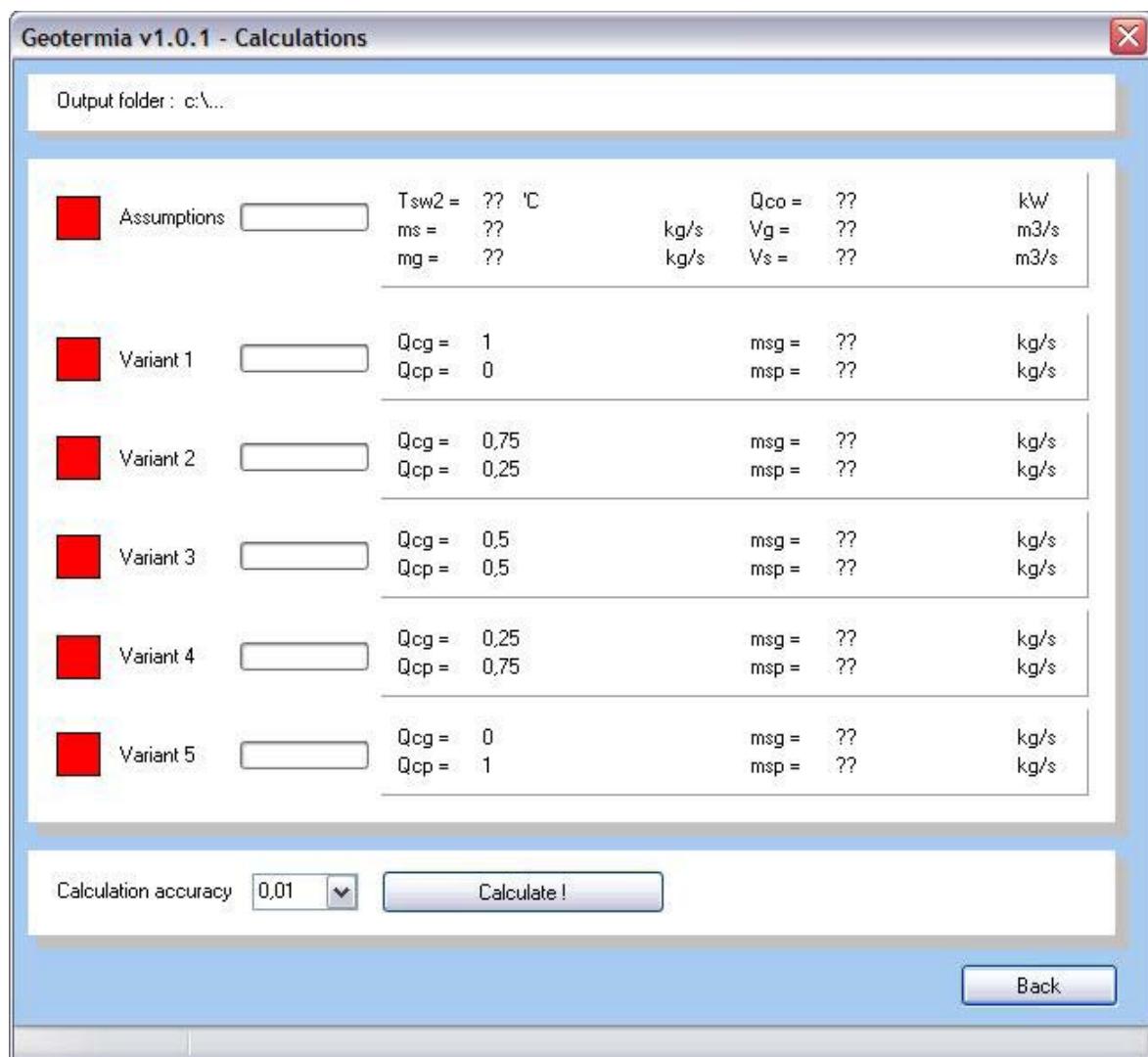


Figure 9. Window "Calculation" where program calculations are running.

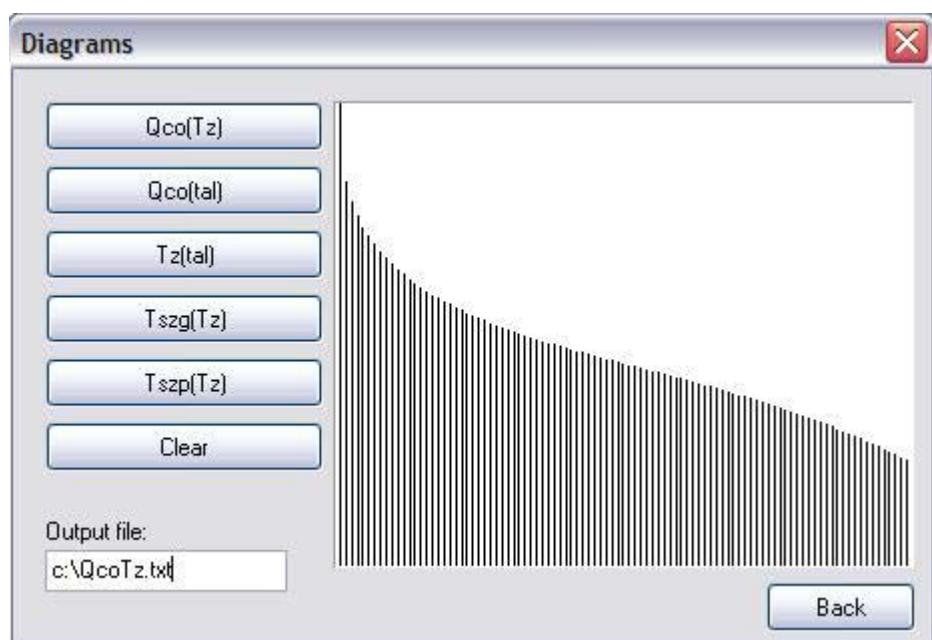


Figure 10. Window "Diagrams" visualizing general diagrams for calculations with the help of calculation functions.