GEIE
Route de Soultz
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Production (Thermosyphon)

Test 05jul05 at GPK4

Preliminary Interpretation with HEX-B

Internal Technical Note

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GEOTHERMAL ENERGY HYDROGEOLOGY ENGINEERING NUMERICS

1. Aims

On 4th July 2005 a 2 day production test has been carried out at GPK4. Production was enabled only by buoyancy (thermosyphon). This study aims at an interpretation of the measured values at wellhead/surface for pressure, flow rate and temperature using the PT-profile simulator HEX-B. Specifically:

- Interpretation of the measured temperature by comparison with calculated values with the HEX-B.
- Calculation of the pressure at the casing shoe to determine the productivity index PI [l/s/MPa]

2. GPK4 production (thermosyphon) test 05jul04

Figure 1 shows the test data from the thermosyphon test at GPK4. For the following calculations with HEX-B it is assumed that the values of "Q_out_separator" represent the total (liquid) flow rate from GPK4.

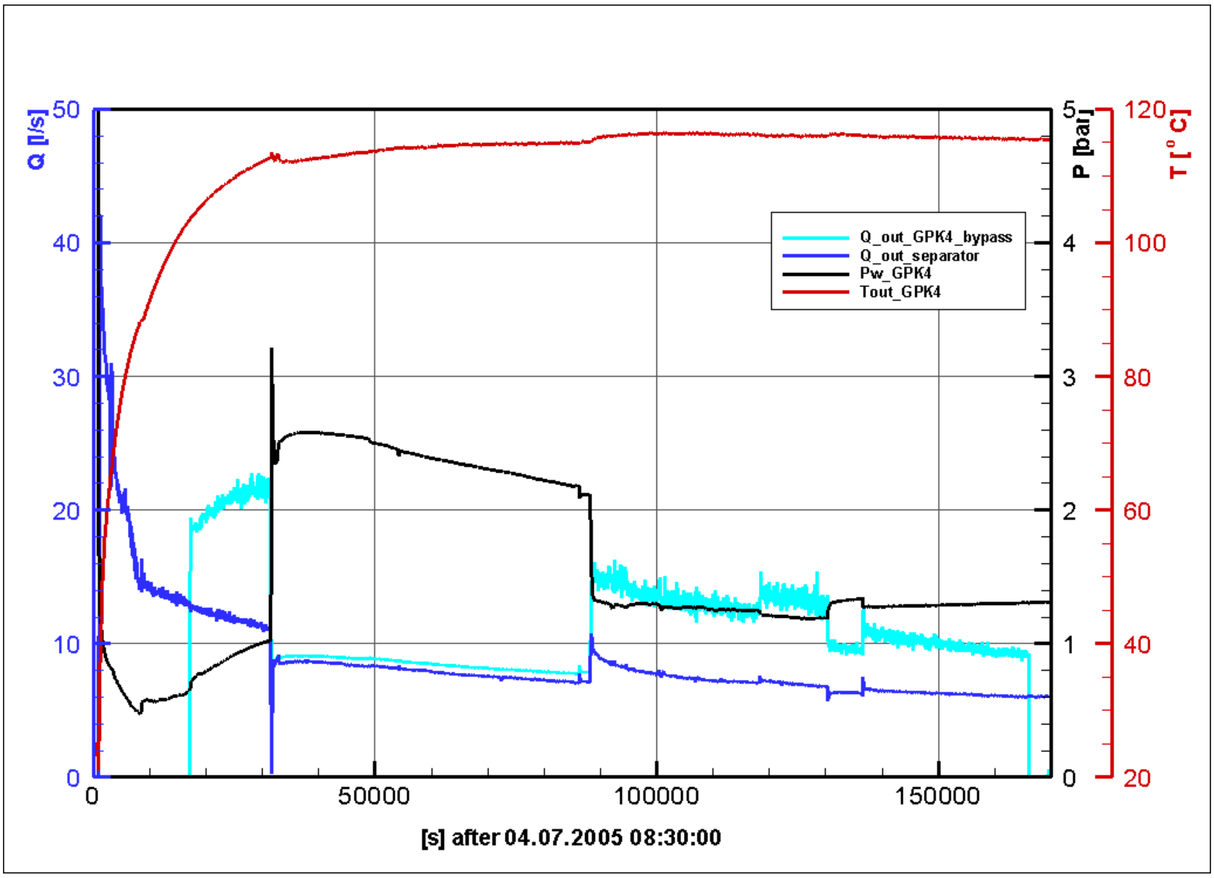

Figure 1: Measured data of test 05jul04, thermosyphon production test at GPK4.

3. HEX-B model of GPK4

HEX-B was developed originally as a PT-calculator for injection. The borehole model used for 05jul04 is based on an injection calculation used earlier for GPK4 that accounts even for the open borehole section.

3.1. Original model for injection

A flow log for the open hole section of GPK4 was not available. Table 1 shows the fracture-frequency in the OH section of GPK4, which has been determined from the UBI log. We assume, that a flow log would indicate fluid losses into the rock matrix with identical percentage as the fracture-frequency. This leads to a corresponding distribution of flow rate for each of the defined borehole section.

Table 1: Fracture-frequency from the UBI log in GPK4 in the OH section zone and corresponding flow rate percentage

Depth-interval	**Fracture-frequency**	**Fracture-frequency %**	**Flow-rate %**
until 4800 m	0	0.0	100.0
4800 - 4900 m	7	17.1	82.9
4900 - 5000 m	10	24.4	58.5
5000 - 5100 m	7	17.1	41.5
5100 - 5200 m	11	26.8	14.6
5200 - 5300 m	6	14.6	0.0
Total	41	100.0	

Based on these assumptions the borehole model for injection calculation consists of 9 sections (Table 2). The sections and values for the thermal properties are taken from the borehole models for GPK2 and GPK3, below the casing shoe sections with the specific flow losses are defined (sections 4-9).

Table 2: Borehole/rock model in HEX-B for GPK4 injection

Bore hole parameters						Rock mass parameters	
Depth section MD [m]			Inner radius [m]	Flow rate [% of injection rate]	Average wall roughness [mm]	Thermal conductivity [W/m K]	Specific heat capacity [J/m³K]
Nr	from:	to:					
1	0	1500	0.11	100	0.15	3	$2.2\ 10^6$
2	1500	3800	0.11	100	0.15	4	$2.2\ 10^6$
3	3800	4756	0.11	100	0.15	3	$2.2\ 10^6$
4	4756	4800	0.108	100	1	3	$2.2\ 10^6$
5	4800	4900	0.108	83	1	3	$2.2\ 10^6$
6	4900	5000	0.108	59	1	3	$2.2\ 10^6$
7	5000	5100	0.108	42	1	3	$2.2\ 10^6$
8	5100	5200	0.108	15	1	3	$2.2\ 10^6$
9	5200	5260	0.108	5	1	3	$2.2\ 10^6$

3.2. Model for production

The production process can be simulated with a reversed flow under the following limitations:

- Specific points of inflow into the borehole with different temperatures and NaCl-molalities cannot be defined so far. Therefore the borehole model reaches only from the surface to the casing shoe where a constant mixed temperature enters the borehole from below. With regard to the temperature development in the borehole this approach may be appropriate.

- The calculated pressure does not include the buoyancy forces and the friction losses in the open hole section. This may be significant since the open hole section is the roughest part of the borehole.

For the production a reduced borehole model was used in HEX-B (see Table 3).

Table 3: Borehole/rock model in HEX-B for GPK4 production

Bore hole parameters						Rock mass parameters	
Depth section MD [m]			Inner radius [m]	Flow rate [% of injection rate]	Average wall roughness [mm]	Thermal conductivity [W/m K]	Specific heat capacity [J/m^{3}K]
Nr	from:	to:					
1	0	1500	0.11	100	0.15	3	2.2 10^6
2	1500	3800	0.11	100	0.15	4	2.2 10^6
3	3800	4756	0.11	100	0.15	3	2.2 10^6

An inflow temperature at the casing shoe of 185 °C and the measured values for flow (Q_out_separator) and pressure (Pw_GPK4) have been used for the production simulation. As initial conditions the undisturbed values for the temperature and NaCl-molality have been used (Figure 2).

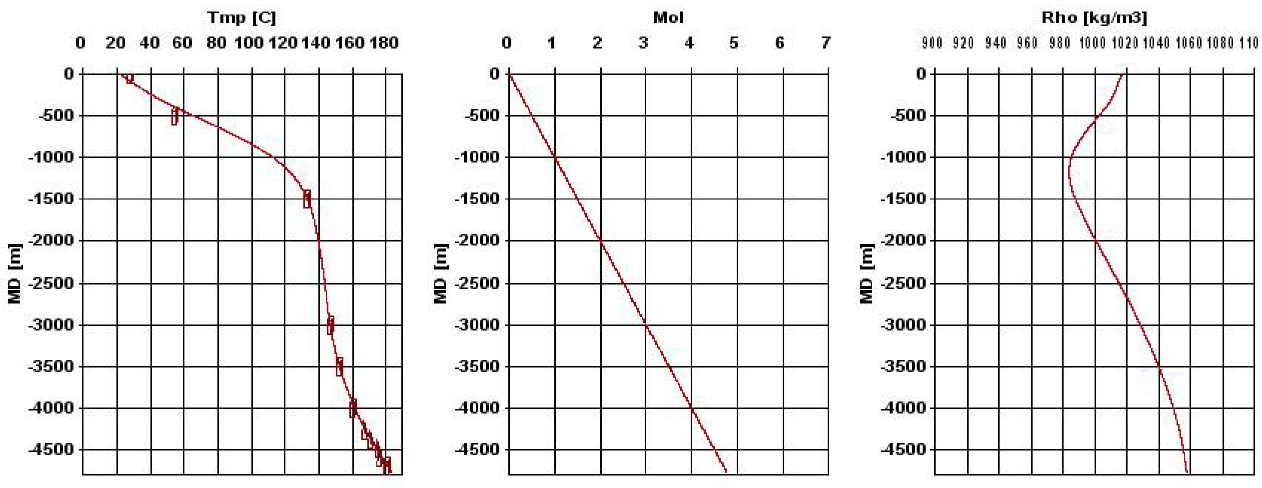

Figure 2: Assumed initial profiles GPK4 for temperature and NaCl-molality and for the corresponding density. The red dots in the left graphic indicate measured temperature values.

4. Results

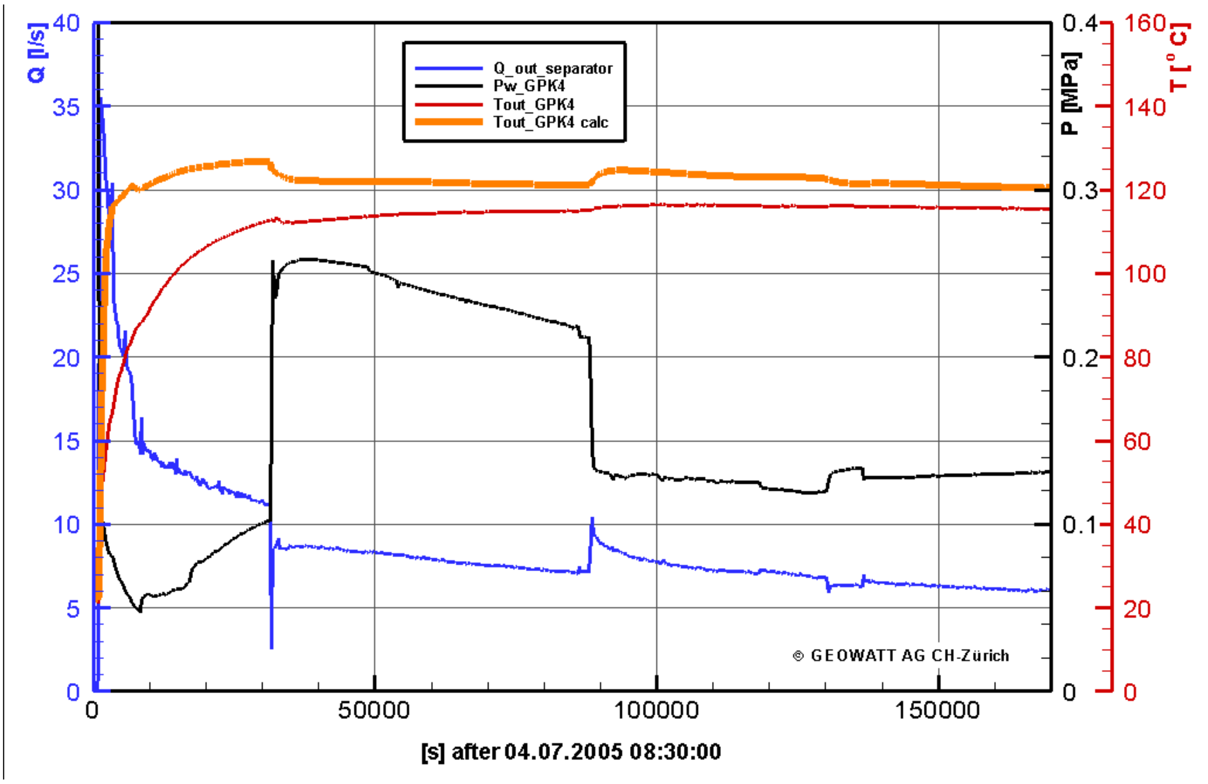

Figure 3: Calculated temperature of test 05jul04 (orange line) at GPK4.

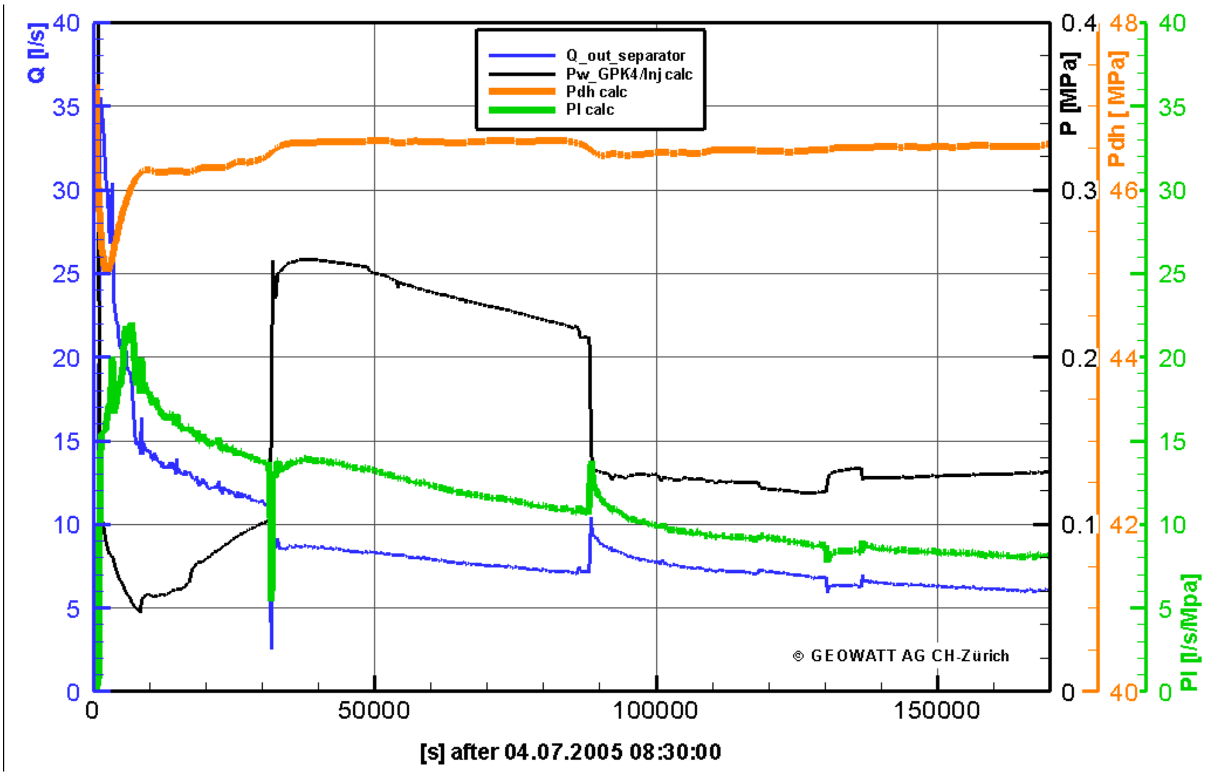

Figure 4: Calculated Pdh@4756 MD (orange line) and Productivity Index PI (green line) of test 05jul04 at GPK4.

5. Observations/Remarks

- The calculation assumes the original initial temperature profile in GPK4 (Figure 2). The inflow into the open hole section is assumed to have 185°C mixed temperature at the casing shoe. The sensitivity of this value to the calculation has not yet been checked.

- During 05jul04 the temperature at the casing shoe is likely to be lower than 185°C. From these preliminary results, a even 10-15°C cooler environment can be assumed due to various stimulation tests carried out in September 04 and February/May 05. Furthermore, a different temperature of the initial water column within the borehole to the ambient rock temperature is ignored by these calculations. Therefore the calculated production temperature curve increases more rapidly than the measurements. The initial borehole column is replaced about 8600 s after the test started. At long-term the calculated temperature will approach the measured values.

- Assuming that the fluid has been kept in a liquid state all during the test and the "Q_out_separator" values represent the total liquid production rate, the effect of the decrease of the flow rate between 30'000s and 90'000 s to the measured temperature of 1K is remarkably small (Figure 3).

- The productivity index approaches a value of 8 l/s/MPa after 2 days (Figure 4), however continues decreasing.

- Future sensitivity calculations (for example with cooler inflow temperature,..) are intended.

- Most likely, the thermosyphon effect can be improved by forcing an initial upward flow. This would cause a more effective heating of the water column. Probably, even a temporary use of a production pump could be beneficial.