

EEIG
Route de Kutzenhausen
F-67250 Soultz

Low Rate Injection Test 04Sep08

GPK4

Pressure, Temperature, Injectivity Index and Fracture Failure Pressure

Calculation with HEX-B

24. September 2004

Ref. 017/TN17.4b/TM



S W I S S
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1. Content

- A. Numerical completion of measured pressure and temperature at 4700 m depth
- B. Determination of initial injectivity index [l/s/MPa] of GPK4
- C. Fracture failure pressure in GPK4

2. Numerical calculations

2.1. Initial State GPK4

The following initial values have been defined (Figure 1):

- Temperature: Derived from the temperature-log 06.07.2004 09:51:32, corrected to fit the values measured on 06.09.2004
- NaCl-molality: A linear function with depth to fit the pressure values taken on 06.09.2004:

$$\text{Mol}(z) = 0.91\text{E-}3 * z$$

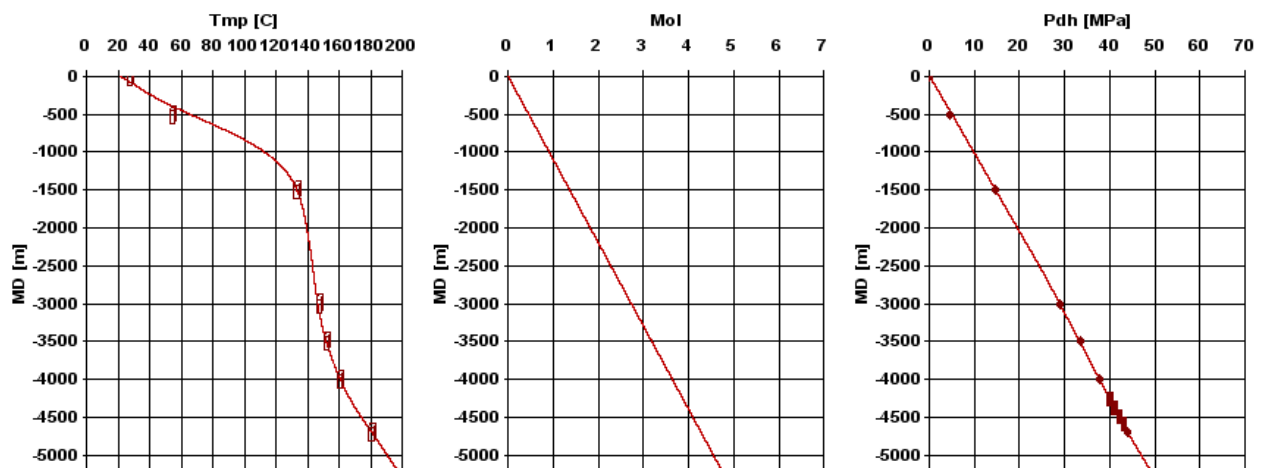


Figure 1: Initial values for the temperature and the NaCl-molality in GPK4. The red line indicates the calculated initial state; the red signs indicate the measured values taken on 06.09.2004

2.2. Specific parameters set in HEX-B

The borehole model consists of 9 sections (Table 1). 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 (Table 2).

Table 1: Borehole/rock model in HEX-B for GPK4

Bore hole parameters						Rock mass parameters	
Nr	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]
	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

A flow log for the open hole section was not available. Table 2 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 flow rate for each of the defined borehole section.

Table 2: 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	

The time steps of the calculation have been chosen as 800 s.

3. Results

3.1. Pressure and Temperature at 4700 m

The calculated pressures and temperatures are in good agreement with the values measured at the start and the end of the test. The accuracy of the calculated downhole values for the data gap between 60'000 s and 340'000 s can be assumed as ± 1 K for the temperature and ± 0.5 MPa for the absolute pressure (Figure 4). The maximum downhole pressure has been reached when the injected brine arrived the observation depth at 4700 m (Figure 2 and Figure 3).

3.2. Initial Injectivity Index at GPK4

The resulting injectivity index for this test has stabilised at a value of 0.15 l/s/MPa (Figure 5). The increased injectivity index at 90000-95000 s during an higher injection rate may be an indication of the compliant behaviour of the fractures.

3.3. Fracture Failure Pressure in GPK4

The failure pressure of the fractures intersecting GPK4 have been predicted by a projection of the GPK3 values to the trajectory of GPK4. During the low rate injection test the pressure profile in the open-hole section has exceeded only some values near 5000 m MD (Figure 6).

Nevertheless microseismic events have been recorded during the test in a wide depth range. Events at depth range of the open-hole section occurred after 24 hours the test started. It can be assumed that the pressure front has already exceeded the vicinity of the open-hole section. Therefore the pressure in the borehole at depth and time an event in the vicinity of the borehole occurs (radius from the borehole < 100 m) can be defined as the failure pressure of a corresponding fracture. Since most of the events have been located below GPK4 only 6 failure pressures have been determined (Figure 7).

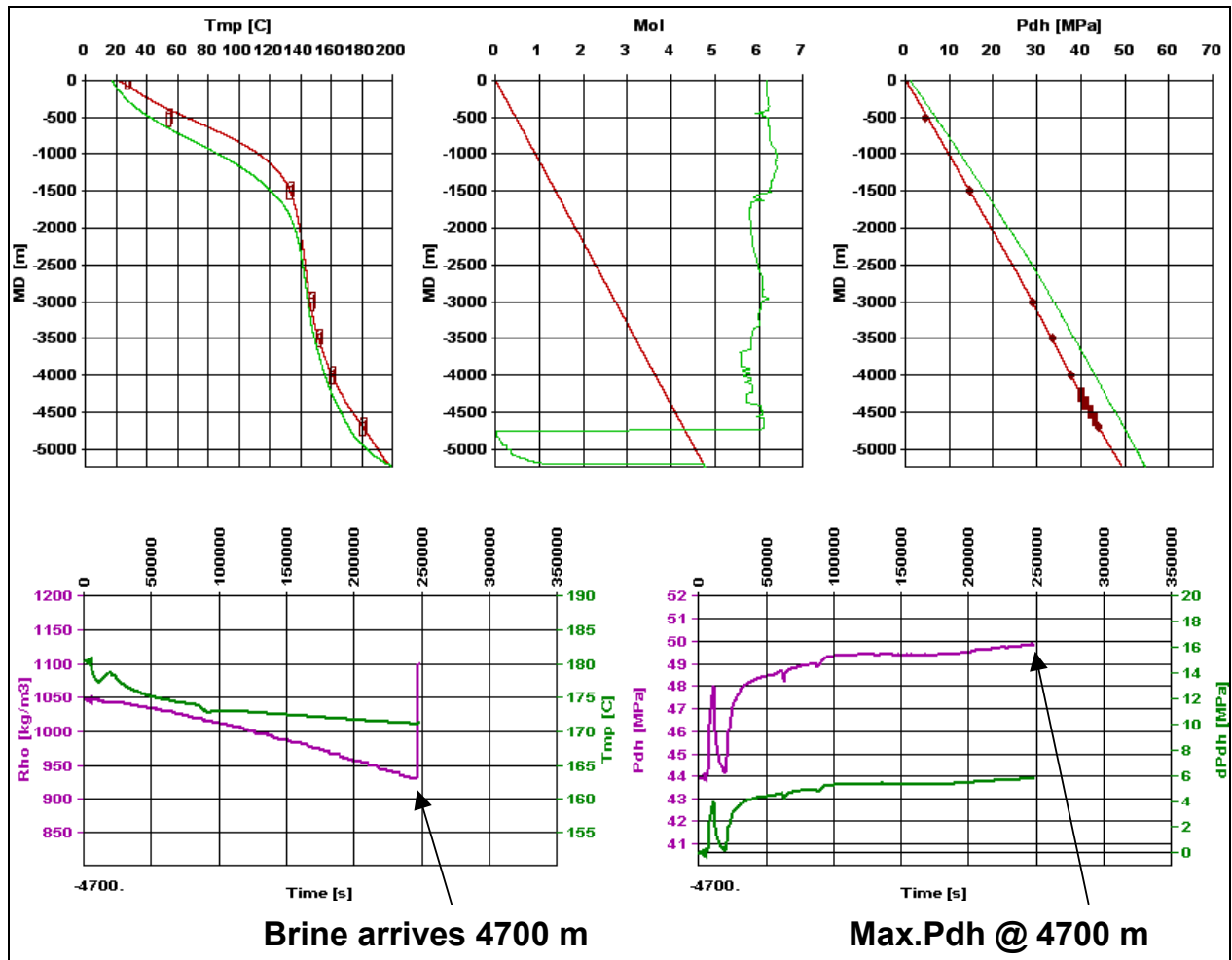


Figure 2: State in GPK4 when the injected brine arrives MD= 4700 m. Purple line at left: density Rho; Purple line at right: absolute downhole pressure Pdh.

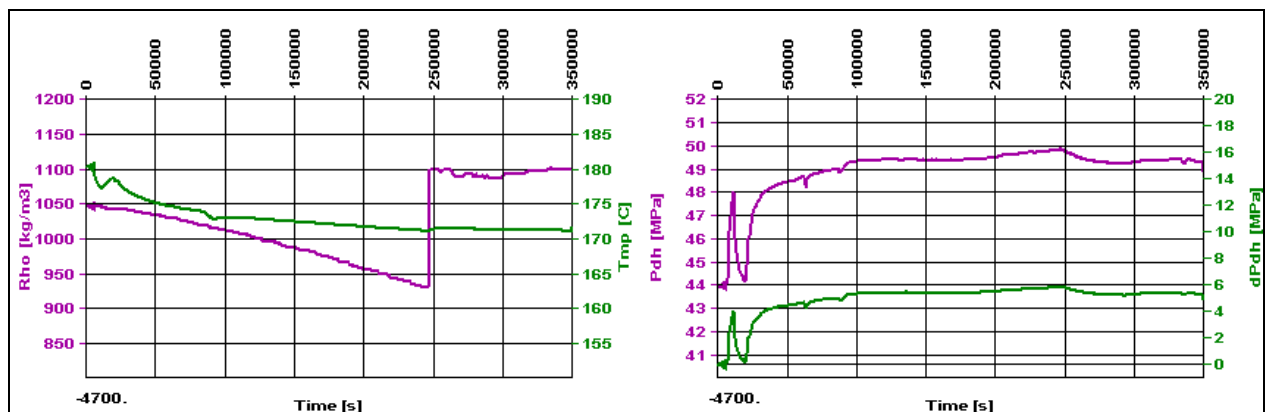
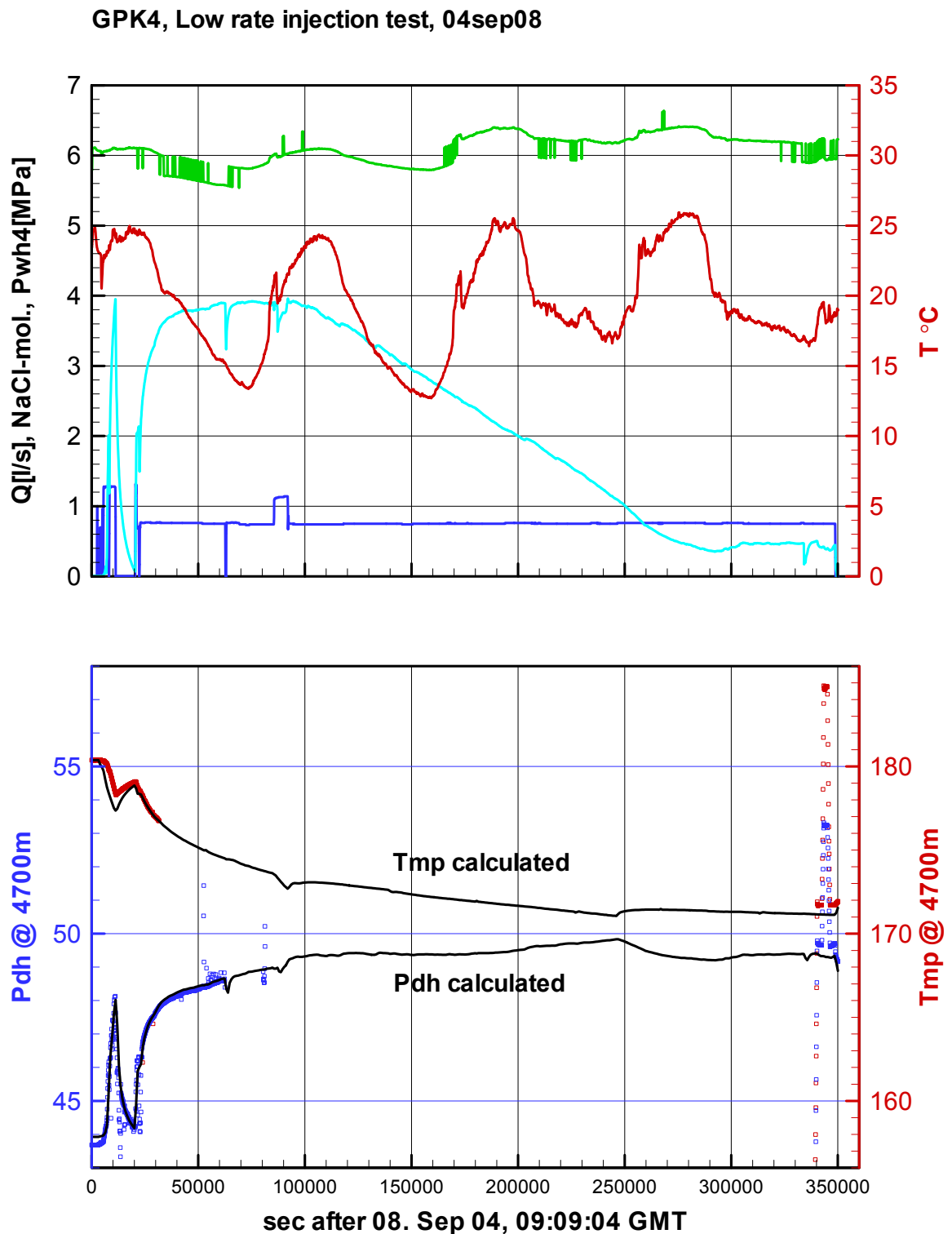


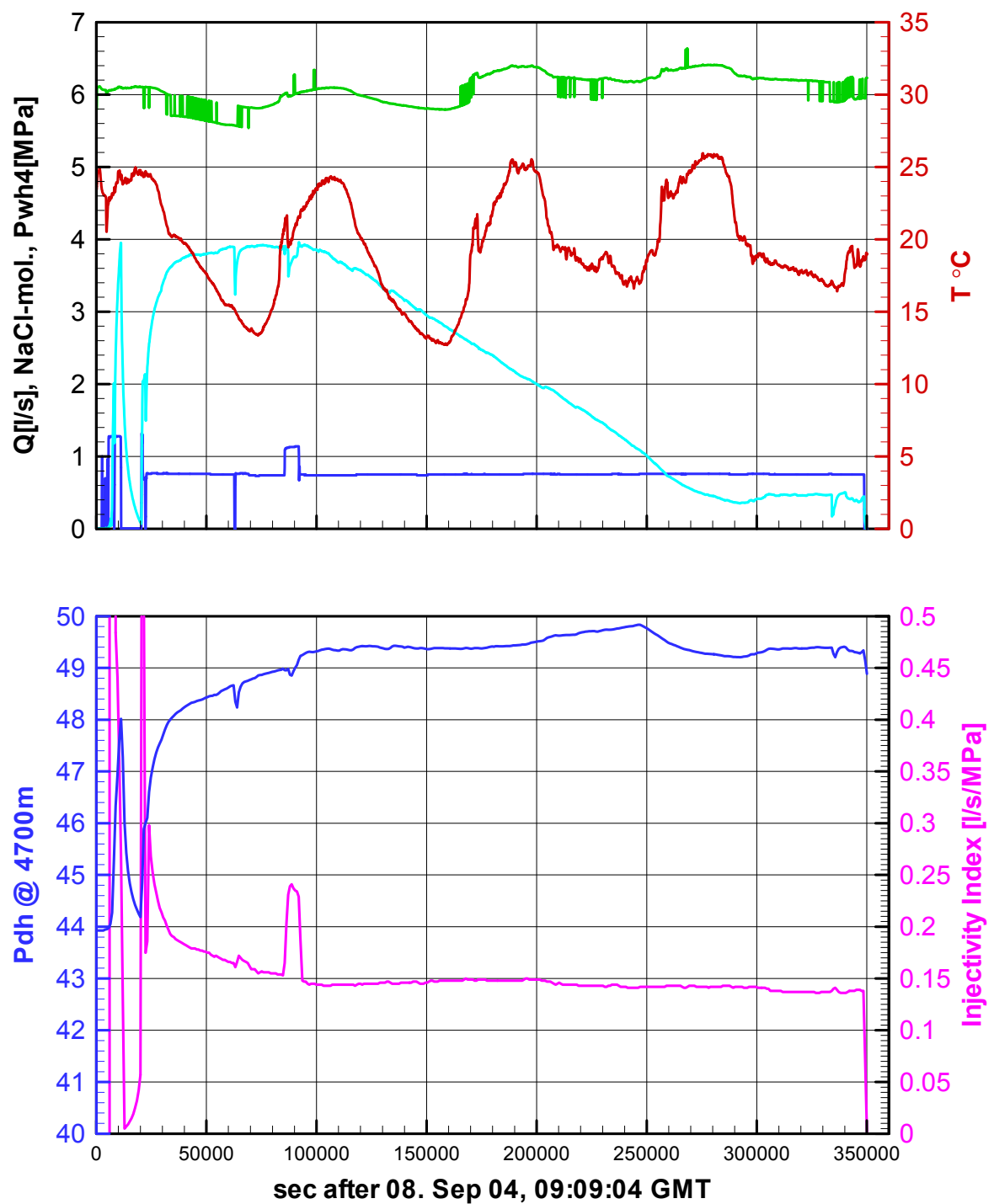
Figure 3: State at MD=4700 m after the injected brine passed.



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Figure 4: Top: Measured wellhead data during injection, Below: Measured (dots) and calculated values for temperature and pressure at 4700 m depth in GPK4

GPK4, Low rate injection test, 04sep08



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Figure 5: Top: Measured wellhead data during injection, Below: Calculated values for the downhole Pressure at 4700 m and the Injectivity Index II [l/s/MPa]

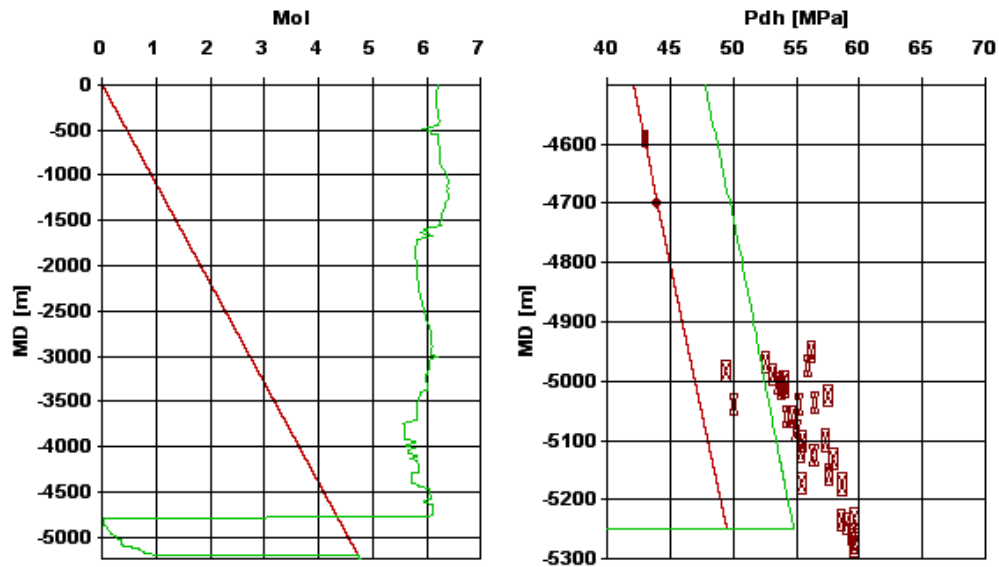


Figure 6: State of NaCl-molality and pressure in GPK4 in the moment the injected brine passed the depth of 4700 m (ca. 250'000 s after start of the test). The pressure profile has roughly reached the maximum values. Generally the projected failure pressures from the GPK3 stimulation test 03may27 (red signs at left) have not been exceeded.

1. Projection of Failure Pressures from GPK3 Test 03may27 to the Trajectory of GPK4
2. Failure Pressures of GPK4 Low Rate Injection Test 04sep08

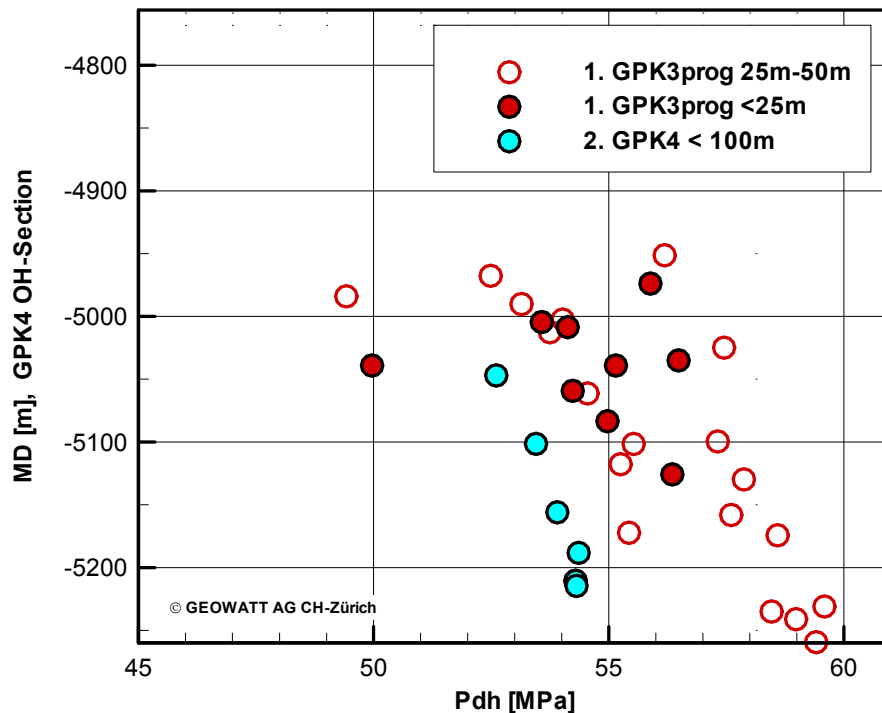


Figure 7: Projected failure pressure from GPK3 tests (red) and values determined from the GPK4 low rate injection test 04sep08 (blue).