Prognostic simulation of reinjection - Research project geothermal site Neustadt-Glewe / Germany

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Introduction

For the first time after political and economical changes in Germany a hydrothermal site was put into operation in December 1994.

Due to prevailing conditions extraordinary in Central Europe (reservoir temperature 99°C; 220 g/l salinity) the project Neustadt-Glewe is supported by a comprehensive research program. The wells concerned (a doublet with an internal distance of 1.400 m) open the porous sandstone aquifer with an average thickness of about 53 m in a depth of 2.240 m.

One point of interest was the pressure and temperature behavior over a period of 10 years considering the fluid viscosity changes due to variable injection temperature. For means of reservoir simulation and prognosing the injection behavior the simulator code TOUGH2 was used.

Long-term behavior of injection

Far field simulation is important in long-term operation. Transient and non-isothermal effects are the reservoir temperature and viscosity change and their influence on the well head pressure. For means of reservoir simulation a three-dimensional model was used. The aquifer is totally characterized by 6 horizontal layers. For consideration of the heat transfer with caprocks the full three-dimensional characterization as well as the semi-analytical solution were investigated. Due to symmetry only the half of the basic pattern has to be considered. The model made use of 2640 elements, 7246 connections and 12 time depending sinks and sources. The time steps are variable.

The initial conditions of temperature and pressure within the layers are determined by the geothermal gradient of 0.04 K/m and gravitation.

Figure 1 illustrates the time varying flow rate due to the transient heat demand. Additional, after five years operating, the regime of exploitation will be changed due to provided enlargement of district heating demand.

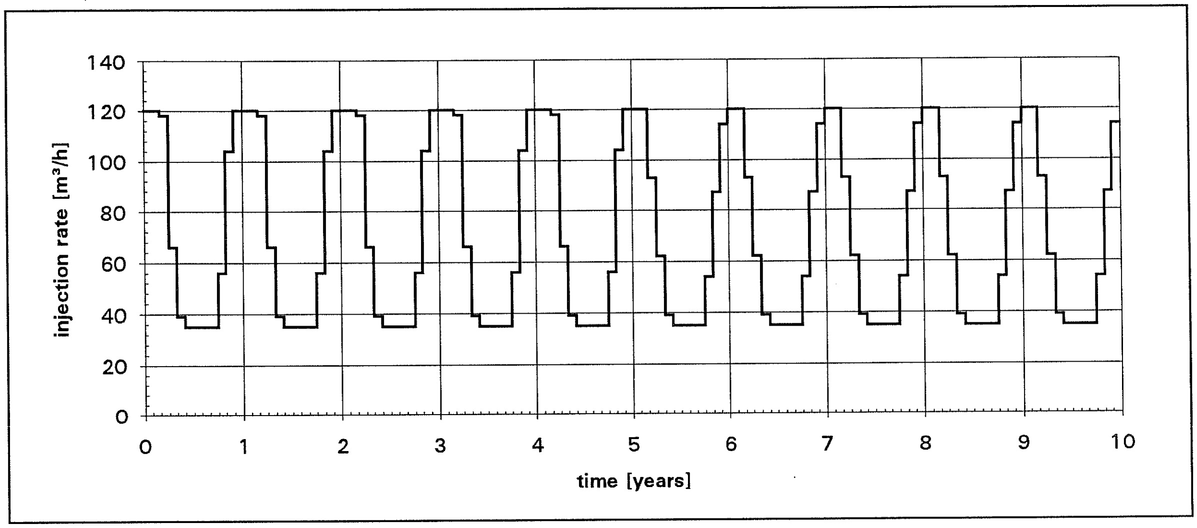

Fig. 1: Provided injection flow rate over a 10 years period

Figure 2 illustrates the time varying injection and sandface temperatures. The dash line characterizes the injection temperature. The sandface temperature line calculated is slightly smoothed due to numerical effects. Wellbore storage effects had been neglected.

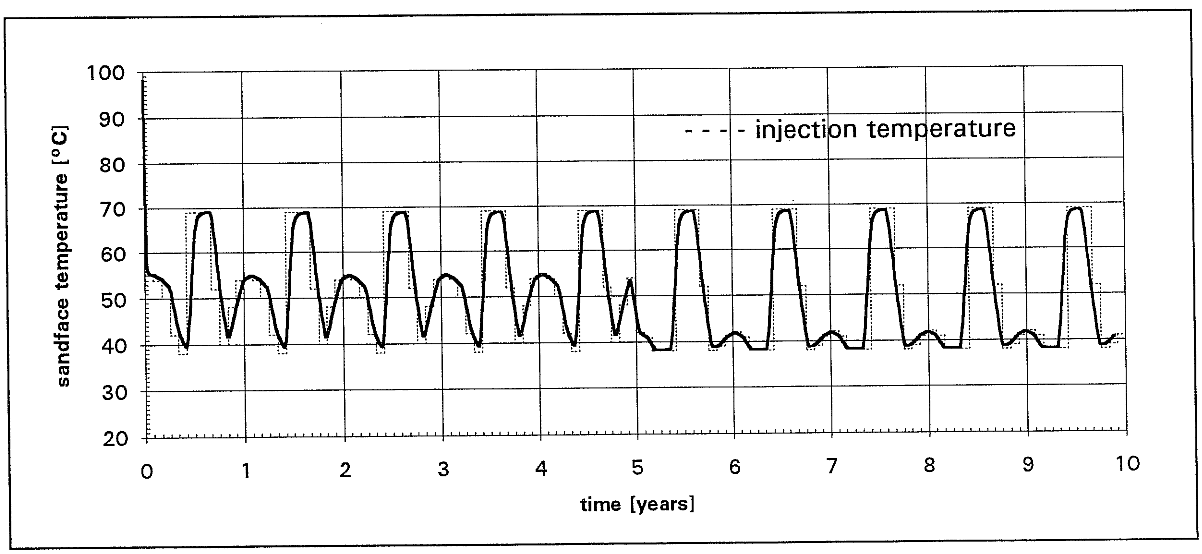

Fig. 2: Injection and calculated sandface temperature in the injection well

The calculated pressure response over this period is given in figure 3. The pressure increase due to reservoir cooling was proved to be controllable.

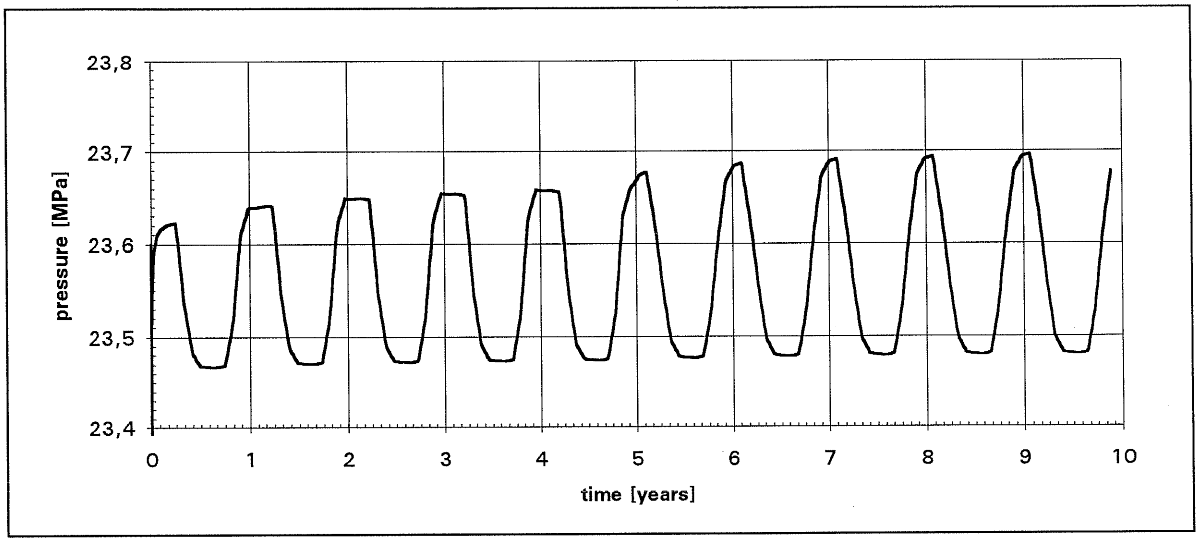

Fig. 3: Calculated pressure response over 10 years period

The results calculated were compared to results given by the simulator code CFEST (Gupta et. al /1/). The pressure behavior is similar, although the absolute values cannot be compared due to neglecting the salinity in the TOUGH simulation.

Consideration of salinity

With the help of the EOS7-module /2/ it became possible to consider the salinity of thermal water. The clipping of the input-file *NGbrine* for TOUGH-simulation neglecting the complete time-control-description is given in figure 4.

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*NG06brine* Research project geothermal site
ROCKS----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
POMED          2650.        .22     9.E-13     9.E-13     9.E-13        2.2      905.7
MATRX          2650.        .01     9.E-18     9.E-18     9.E-18        2.0      707.5

SELEC----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
    2
     0.1E6         20.       1150.

MULTI----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
    2    3    2    6
START----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
PARAM----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
  4 999      9910000000000002 47
       0.0 3.12000E8        -3.      2.6E5A2113          9.81
     1.E-2     2.E-2      3.E-2      4.E-2      5.E-2      6.E-2      7.E-2     2.2E-1
     5.E-1      9.E0      9.E1      1.E2       1.E2       7.E2       9.E3       2.E4
      2.E4      5.E4      6.E4      1.E5      2.6E5      2.6E5      2.6E5      2.6E5
     1.E-4
           23.60E6                    1.                   98.
TIMES----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
    1    1
  1.560E8
GENER----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
A2113BRI 1                  126       COM22
0.0                       1.E0          1.E1           1.E2
               *
               *
       1.6595              0.1        1.6595            0.1
               *
               *
       2.50E5         2.50E5        2.50E5         2.50E5
               *
               *
A7129BRI 6                  126       COM2
0.0                       1.E0          1.E1           1.E2
               *
               *
      -1.6595             -0.1       -1.6595           -0.1
               *
               *

INCON----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8

ENDCY----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
MESHMAKER1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
XYZ
        0.
NX       33
   5000000.    50000.      100.       100.       100.       100.       100.       100.
       100.      100.       50.        49.         2.        49.        50.       100.
       100.      100.      100.       100.       100.       100.       100.       100.
       100.      100.      100.        49.         2.        49.       100.     50000.
   5000000.
NY       10
        50.      100.      100.       100.       100.       100.       100.       100.
     50000.  5000000.
NZ        8
       100.       4.5        9.         9.         9.         9.        4.5       100.

ENDCY----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
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Fig. 4: Input-file for EOS7-simulation

In figure 5 the results of calculated pressure response for pure and mineralized water over an one-year-period are compared. The calculated pressures are proved to be in agreement with test- and first operation-results.

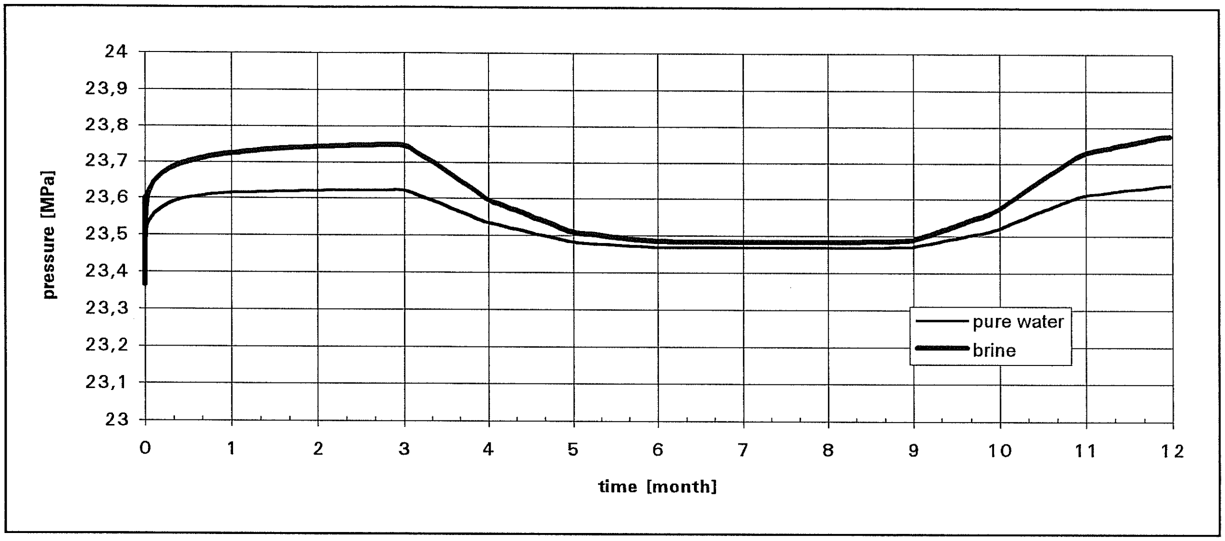

Fig. 5: Comparison of calculated pressure response for pure and mineralized water

Conclusion

In German geothermal activities pressure responses due the reservoir cooling in long-time reinjection prognosis were neglected in the past.

The TOUGH2-code is proved to be fairly suitable to consider the viscosity-density-change in injection wells for prognostic simulation of long-term-behavior of reinjection.

References

/1/ Gupta, S.K. et al.: Coupled Fluid, Energy, and Solute Transport (CFEST) Model: Formulation and User´s Manual
Technical Report BMI/ONWI-660, Office of Nuclear Waste Isolation, Battelle Memorial Institute,Columbus, OH 1987

/2/ Pruess, K.: EOS7, An Equation-of-state Module for the TOUGH2 Simulator for Two-Phase Flow of Saline Water and Air, LBL-31114