HOCLOOP - Case Well for modelling CO_2 based circulation fluids

In order to investigate the change in performance when replacing water by using CO_2 as the heat transfer fluid, the following case well is suggested:

Figure 1. presents the trajectory of the reference well. The well is vertical from the surface to about 4000 m depth, and the well turns to a long horizontal well, the horizontal section is at 4.5 km vertical depth, so the total depth of the well is nearly 10 km. Table 1. presents the geometrical characteristics of the well and the completion string inside the well.

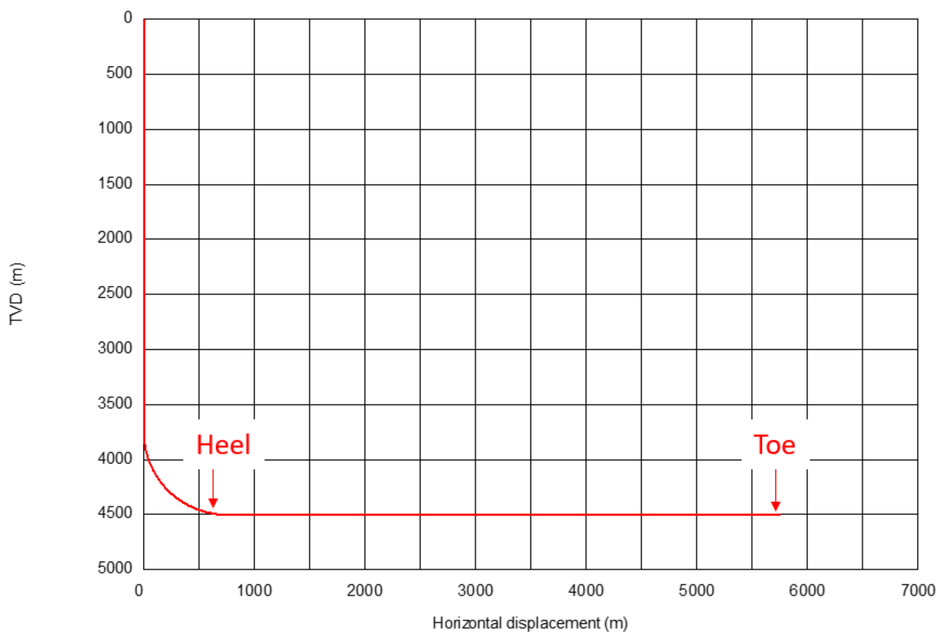

Figure 1. Well trajectory for the reference well.

	Unit	Value
Total measured depth of the well	m	9928
Vertical depth for the horizontal section	m	4500
Original rock temperature at 4500 m TVD	°C	172.5
Geothermal_Gradient	°C/Km	35
Injection_Temperature	°C	30
Rock_Density	kg/m3	2542
Rock_Heat_Capacity	J/kg-K	1085
Rock_Conductivity	W/m-K	2,44
Tubing_ID – inner diameter of the tubing from top to bottom	mm	85 (3 3/8")
Tubing_OD – outer diameter of the tubing from top to bottom	mm	160 (6 5/16")
Casing_ID – inner diameter of the well from top to bottom	mm	224 (8 13/16")
Casing_OD	mm	244 (9 5/8")

Table 1. Geometrical data and formation properties for the reference well.

Figure 2 and 3 presents the results of the temperature in the circulating water and the thermal power production from various flow rates of the circulating water in the loop. As can be observed, the output temperature decrease with increasing flow rate. An increase in the flow rate will also increase the thermal power output. However, normally there is a limitation in how low the output temperature can be for the return fluid to be useful.

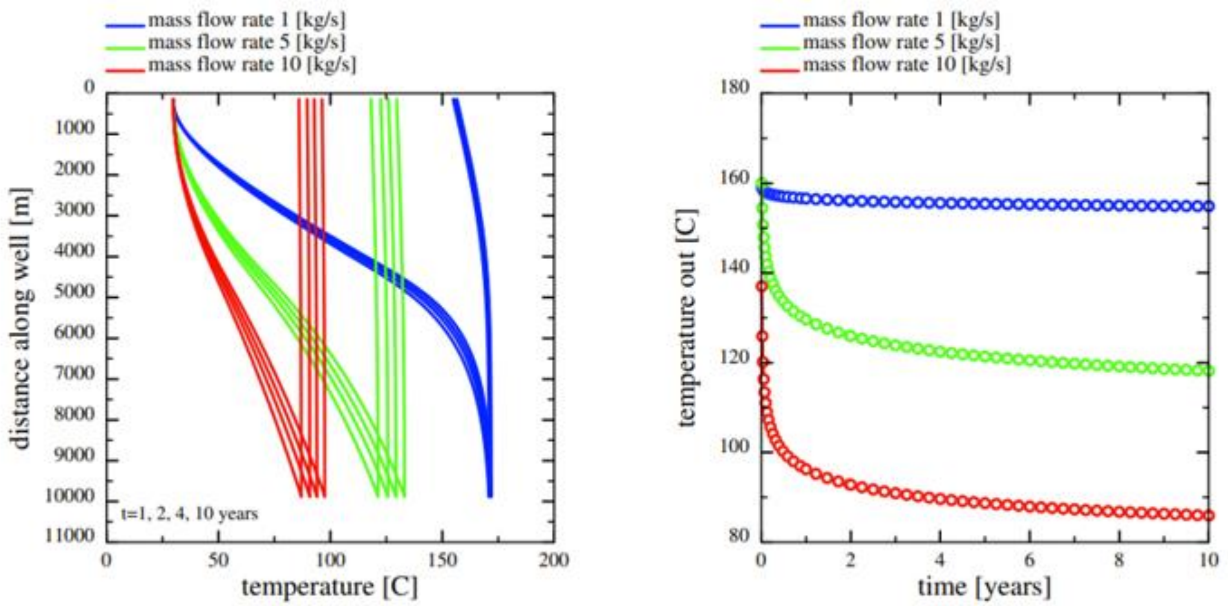

Figure 2. Circulating fluid temperature, dependency on the water flow rate.
Left: Temperature in the circulating fluid in the well. Right: Temperature out vs time.

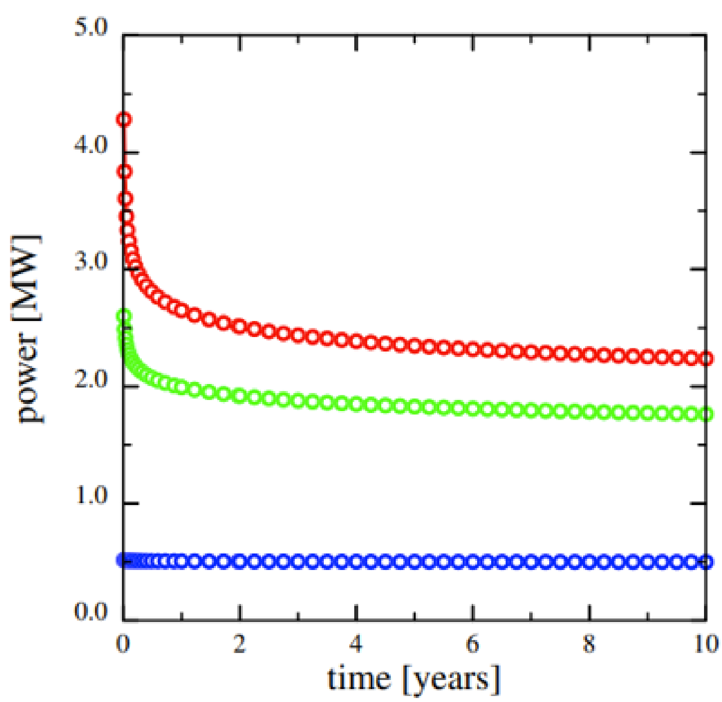

Figure 3. Thermal power production as a function of time for various water circulation flow rates.

The challenge can be formulated as follows:

CO_2 has a specific heat capacity in the range 0.66-0.85 kJ/kg K, see for example: https://www.engineeringtoolbox.com/CO2-carbon-dioxide-properties-d_2017.html, whereas water has a specific heat capacity of 4.2 kJ/kg K. It is therefore expected that the thermal power extraction from the rock will be comparable for water circulating with a rate of 5 kg/s as for CO_2 circulating with a rate of 25 kg/s, assuming the same temperature for the fluids entering the well.

1. Model the circulation performance using CO_2 in the circulation loop at a circulation rate of 25 kg/s, assuming the same inlet temperature at surface (35 C) and the same inlet temperature to the production tubing at the bottom of the well (120 C, after 10 years).
   Note for the calculations:
   Since CO_2 will increase temperature and pressure on its way from earth surface down to the heel of the well, one should assume the water and CO_2 to have the same temperature at the heel of the well.
   Since CO_2 will expand and thereby reduces its temperature and pressure on the way from the toe of the well and up to earth surface, one should assume the water and CO_2 to have the same temperature at the toe of the well.

2. Model the CO_2 performance with varying flow rates, as above for water. Calculate the temperature and pressure at stable conditions after 10 years for:
   - Wellhead inflow at surface
   - Heel of well, at around 4500 m depth
   - Toe of well, at 9928 m depth
   - Wellhead outflow at surface.

3. Describe and quantify the potential for electricity production when letting the hot pressurized CO_2 returning from the well be used directly on a turbine generator.