DESTRESS

Demonstration of soft stimulation treatments of geothermal reservoirs

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St1 Deep Heat Project: Hydraulic stimulation at 5-6 km depth in crystalline rock, hydraulic properties and lessons learnt

St1 Deep Heat Project started in 2014. With its two deep wells extending to 6.2 - 6.4 km depth, located in Espoo, southern Finland, it is the world's deepest industrial geothermal energy project. The aim is to build an EGS (enhanced geothermal system) at a depth of about 5-6 km. The project is a pilot aiming at exploring the technical and economic feasibility of geothermal energy in the crystalline rock conditions of Finland for production of thermal power to a district heating network. Due to the demands of the district heating, the aim is to produce hot fluid at about 100° C and re-inject it to the formation at 50° C. The 100° C temperature goal requires drilling to about 6 km depth. The extreme depth level sets significant challenges for drilling and hydraulic stimulation, as well as controlling of induced seismicity. So far (2020) the project has drilled a 2 km deep completely cored pilot hole (OTN-1), and two deep wells, OTN-2 to 6.2 km and OTN-3 to 6.4 km. Hydraulic stimulation has been carried out in the deep wells in 2018 and 2020 to improve hydraulic conductivity. In 2018 about 18,000 m^3 of fresh (tap) water was injected into OTN-3 in five 100-200 m long stimulation stages at 6.0-6.4 km depth. During stimulation, wellhead pressures, flow rates and induced seismicity were continuously monitored and recorded. Hydraulic conductivity of the reservoir was estimated from stimulation pressure and flow rate data. A major observation is that conductivity is pressure-dependent due to elastic response of the fractured medium on increased pore pressure. At the highest applied wellhead pressures of 700-900 bar conductivity increased to about 10^{-9} … 10^{-8} m/s. Leak-off pressure of fractures is about 520 bar at 6 km. However, when the wellhead pressure was relaxed by about 200-300 bar, conductivity decreased by about one magnitude according to the stimulation pressure data. Pre-stimulation leak-off test data and post-stimulation long-term monitoring of shut-in pressures in OTN-3 allowed estimation of the low-pressure conductivity, which appears to be of the order of $5 \cdot 10^{-11}$ m/s. It is considered to represent the natural level of hydraulic conductivity in the reservoir.

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