HDR INVESTIGATIONS DOWN TO 400 m DEPTH IN CRYSTALLINE ROCKS AT FALKENBERG

Kappelmeyer, O., Geothermik Consult GmbH,
D-3000 Hannover 1 / FR Germany

In a granite massif in NE Bavaria/FR Germany in the depth range down to 400 m an artificial heat exchange system with an extension of more than 25000 m^2 was stimulated by hydraulic fracturing. The stimulated fracture was intersected by six additional boreholes up to 80 m distance from the frac initiation. These intersection boreholes provided access to the fracture system at different distances between injection point and extraction point during circulation and allowed systematic experimental investigations on the hydraulic, mechanic an thermal behavior at various pressure stages. Appropriate models extend the results to greater depth with regard to HDR systems in deep rock sections.

The hydraulic experiments comprised:

- the change in fracture width, fracture transmissivity, and fracture volume as a function of fluid pressure
- the hydrodynamic pressure losses in the fracture for laminar and turbulent flow
- the water losses from the fracture into the rock.

The following results were obtained:

Fracture width, fracture transmissivity and fracture volume changed nonlinearly with increasind and decreasing fluid pressure. Fracture width was 0.2 - 0.5 mm at hydrostatic pressure (corresponding to an effective normal stress of 18.5 bar) and 1.0 - 2.0 mm at frac extension pressure (corresponding to about - 3 bar effective normal stress). These fracture widths were measured between straddle packes in the intersection holes at different distances from frac initiation. The transmissivity of the fracture ranged from some D·m at hydrostatic pressure to some 100 D·m at frac extension pressure. The noulinear relationship between fracture width and fluid pressure is explained by a model describing the deformation of asperities on the fracture surfaces.

Most of the total pressure drop occuring in the fracture during circulation originates at the inlet and the outlet immediately around the boreholes. The hydrodynamic pressure drop at the inlet and the outlet borehole increased nonlinearly with increasing flowrate for flowrates higher than a critical value of about 0.5 l/s. The results for injecting and venting differed only slightly in the range of the investigated flow rate (0.1 - 7 l/s) but the differences seem to increase at higher flowrates. The observed relationship between pressure drop and flowrate is explained by assuming a turbulent region around the boreholes that expands with increasing flowrate. Due to this turbulent energy losses much higher fracture transmissivity is needed to operate a Hot Dry Rock system than is calculated from laminar flow models. To achieve flowrates up to 100 l/s through a single fracture a transmissivity of some hundred D·m is required.

The water losses at stationary conditions increases linearly to the fluid pressure within the fracture. At frac-extension pressure loss rate was 0.8 l/s. The loss rate did not increase after frac-extension. It is concluded that water was lost over one or a few single joints into a large confined or an unconfined aquifer. Though fluid losses are a site specific quantity, the results indicate, that it is questionable to describe fluid losses by homogeneous models.

The investigations at the Falkenberg HDR test site were performed by researchers from various Universities and research institutes. The results are published in: "Terrestrial Heat from Impervious Rocks - Investigations in the Falkenberg Granite Massif - " compiled by Kappelmeyer, O. & Rummel, F. (1987) Geol. Jb. E 39, pp. 252, Hannover