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Well Integrity Analysis in a High Temperature Geothermal Well using Distributed Temperature Sensing Behind Casing

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SUMMARY

Within this study, a fiber optic cable was installed behind the anchor casing of a high temperature geothermal well in Iceland. The aim was to study the integrity of the cemented annulus during load changes, i.e. temperature and pressure changes during fluid production. Fiber optic distributed temperature data were acquired during installation/cementation, flow testing as well as during a subsequent shut-in period. Temperature data from the cementation were used to analyse the cement quality. During the onset of a flow test, measured temperatures in the annulus increased by more than 200°C. From the data a process influencing the well integrity could be identified.

Introduction

Structural wellbore integrity is essential for a safe and sustainable provision of energy from geothermal systems. Adapting monitoring technologies to observe and analyse processes otherwise undetected can help to optimize expensive work-over activities, but can also prevent a severe hazard for human lives and neighboring wells. Within this study the fiber optic distributed temperature sensing technology was tested for monitoring the structural integrity of a cemented annulus in a conventional high temperature geothermal well in Iceland. Prior to the field experiment, a suitable optical fiber for deployment was selected (Reinsch and Henninges 2010) and a fiber optic cable was manufactured. In 2009, this cable was installed down to a depth of 270 m behind the anchor casing of well HE-53 in the Hengill geothermal field, SW Iceland. Temperature data was acquired during cementation and during flow testing of that well as well as during the following shut-in period.

Field Data

Temperature profiles acquired during the cementation were used to quantify the amount of cement deposited and thereby the cement quality in each depth interval. The results compare reasonably well with data from conventional acoustic CBL logging (Reinsch, 2012). During flow testing, DTS measurements were performed for a period of two weeks (Reinsch *et al*. 2013). During this time the wellhead temperature increased to about 240°C, whereas maximum temperatures of 230°C were measured in the annulus. A constantly increasing wellhead temperature was observed. Within the annulus, however, decreasing temperatures were observed at the shoe of the conductor casing in about 60 m depth shortly after the onset of the flow test. Successively, decreasing temperatures were detected in adjacent depth intervals. The effect migrated along the wellbore axis with a speed of 5-10 m/100 h and lasted for a few hours in each depth interval.

Discussion

Having evaluated the cement quality from DTS data during the cementation, the thermal excursion within the annulus during flow testing was analysed. Using numerical simulations, it could be shown that one possible process to cause a thermal excursion like the one observed, can be attributed to a degradation of the cement integrity. The large temperature increase (>200°C) led to a rising vapor pressure of the pore fluid in the cement sheath of the casing. Due to the thermal expansion of the casing, mechanical stress is applied to the cement. As soon as the stress exceeded the strength of the cement, small fractures could evolve, opening a fluid pathway to trapped pore fluid within the cement. At elevated temperatures, the pore fluid could easily evaporate, consuming thermal energy and thus leading to the observed temperature decrease.

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