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Soultz-sous-Forêts: GPK-2 production well integrity after more than 15 years of operation

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ABSTRACT

Economic feasibility of a geothermal power plant relies on continuous and constant operation of the geothermal loop. Constraints of operational performance like unscheduled shut-down periods, intense maintenance operations and follow-up costs reduce their reliability. Once geothermal wells are drilled and completed they are considered in most cases as fixed equipment of the geothermal loop designed for a service life of twenty and more years. When it comes to maintenance issues, well casings are most difficult to access after completion and if required, work-over operations are time-consuming and costly. To make sure that the wells are fully operable, regular inspections of casing integrity are performed at Soultz. Casing integrity of the inner casing of GPK-2 was evaluated amongst other wells in July 2015 by ultrasonic measurements, gamma-ray detection and camera inspection.

After more than fifteen years of operation, the calculated wall thickness of the GPK-2 9"5/8 casing shows a maximum loss of 2.2 mm within the first 500 m which indicates a corrosion rate of less than 0.2 mm at production conditions. Down to approximately 300 m, GR values are low and show a higher variation which indicates a strong heterogeneity of the scaling layer at the pipe interior. This finding was confirmed by camera inspection.

GPK-2 inner casing interior is mainly covered with scales. Frequently, parts of the scale layer are mechanically removed by LSP installation/de-installation and logging operations which leave long vertical scratches on the pipes. There is no indication at all for scale spalling due to subscale corrosion processes. During the camera logging, no holes or other signs of casing integrity impairment was discovered. Down to 120 m uniform corrosion is frequently visible and to the final logging depth uniform corrosion is visible only randomly.

1. INTRODUCTION

The EGS site Soultz-sous-Forêts is located at the western rim of the Upper Rhine Graben (URG), ~50 km in NE of Strasbourg, France. It operates a naturally fractured granitic reservoir percolated by Na-Cl-Ca brine with Total Dissolved Solids (TDS) up to 100 g/L. Geothermal brine is produced at 160°C/20 bars and is re-injected at 70°C/18 bars. For power production, an Organic Rankine Cycle (ORC) was installed with an estimated gross capacity of 2.2 MWe at 35 L/s. At Soultz, three geothermal wells were operated successfully as a triplet with one production well, GPK-2, and two injection wells. All geothermal wells of the Soultz site were completed with API mild steels, N80 and P110 which show low-rate uniform corrosion of <0.2 mm per year at Soultz operating conditions (Baticci, 2009 and Baticci et al. 2010). Recently, casing integrity of GPK-2 was investigated in the framework of a regular inspection and evaluated.

1.1 GPK-2 History

GPK-2 is the Soultz main production well. Initially, it was drilled in 1995 down to 3880 m and deepened to 5080 m in 1999. For this deepening the 9"5/8 and the 7" casing were removed but afterwards partly reused for GPK-2 well completion (Baumgärtner et al. 1999). The inner casing down to 500 m consists of a 9"5/8 and down to 4440 m of a 7" casing. From 1995 to 2009 basically production tests and well developments were performed. Geothermal loop operation started in 2010 with a long term production test of 11 months and continued with power production in 2011 for several months. In 2012, GPK-2 was operated only during a short time circulation of several weeks and in 2013 it was used for brine production for seven months. In between these operations, long-term shutdown periods occurred including prior well-killing by NaCl-brine for pulling and re-installation of the production pump.

1.2 GPK-2 Monitoring

Once geothermal wells are drilled and completed they are considered in most cases as fixed equipment of the geothermal loop designed for a service life of twenty and more years. When it comes to maintenance issues, well casings are most difficult to access after installation and if required, work-over operations are time consuming and costly. To make sure that the wells are fully operable, regular inspections of casing integrity are performed at Soultz.

Casing integrity of the inner casing of GPK-2 was evaluated amongst other wells in July 2015 by ultrasonic measurements, gamma-ray detection and camera inspection. Ultrasonic measurements were compared with the 2005 results.

2. RESULTS OF THE GPK-2 LOGGING OPERATIONS

Table 1 summarizes the performed logging operations in GPK-2 and the respective logging interval. Due to the prior well killing of GPK-2 the water level was 67 m below ground. The camera system is limited to 60°C and therefore the logging depth was restricted to 224 m.

Table 1: Logging depth of the respective well logging operation in GPK-2, June and July 2015

Logging Tool	Ultrasonic	Gamma-Ray	Camera
Logging Depth [m] below ground	67 – 507	0 – 507	0 – 224
Date	June 2015	June 2015	July 2015

2.1 Ultrasonic and Gamma-Ray Measurements

GPK-2 casing integrity was measured by using an USI*tool (Ultrasonic Imager Tool, USIT, *Mark of Schlumberger) specifically designed for casing inspection including corrosion detection and monitoring, detection of internal or external damage or deformation and casing thickness analysis for collapse and burst pressure calculations (Schlumberger, 2004). Another possible method of casing inspection is multifinger Caliper logging which provides information about inner diameter, shape of the casing and surface roughness by mechanical scan of the casing interior. This method is e.g. used in the Paris Basin for well inspection where high corrosion rates are present (Ungemach et al., 2002 and Lopez et al., 2010). For casing inspection at Soultz this method was not used due to the low corrosion rates and thin deposits of barite scale in the wells. Ultrasonic logging provides more detailed information concerning casing wall thickness and allows reprocessing of the collected data.

Ultrasonic measurements require a liquid dominated environment for optimum ultrasonic wave transmission. Therefore, the casing interval above the water level, which was at 67 m below ground, could not been investigated. Basic principle of well logging by ultrasonic imager is the transmission of ultrasonic pulses which interact with casing material and, if present, cementing at the casing exterior. Decay and frequency of reflected pulses are detected and processed to calculate inner and outer casing diameter, casing wall thickness and quality of cementing. Ultrasonic measurements were supported by additional Gamma Ray (GR) measurements which is a simple method for barite scale detection in the Soultz wells due to their NORM character (Scheiber et al. 2012). Level and variation of the GR signal allows interpretation of scale homogeneity and scale accumulation.

Original wall thickness (pink line), measured wall thickness (blue line) and recalculated wall thickness (dashed blue line) of GPK-2 are displayed in Figure 1 as a function of depth below ground level. Additionally, normalized GR values are shown (green line). After more than fifteen years of operation, the calculated wall thickness of the GPK-2 9”5/8 casing shows a maximum loss of 2.2 mm within the first 500 m which indicates a corrosion rate of less than 0.2 mm at production conditions. Down to approximately 300 m, GR values are lower and show a higher variation which indicates a strong heterogeneity of the scaling layer at the pipe interior. This is caused by repeated de- and reinstallation of the downhole production pump and due to this action the scales were frequently part wise scratched from the pipe interior. Below 300 m the scale layer becomes more and more homogeneous and GR values increase. Interestingly, at the same depth the measured wall thickness decreases but the calculated wall thickness shows only minor variations.

The ultrasonic pulses carry to types of information

(1) wall thickness by resonant frequency and

(2) internal and external radius by transit time and amplitude.

The *USIT signal* (blue line) is based on wall thickness by resonant frequency and the *USIT calculated* (blue dashed line) is based on the internal radius which was subtracted from the external radius. Re-calculation served as a check for the automatic software evaluation of the wall thickness. The scaling layer on the pipe interior interferes with the ultrasonic pulses and gives misleading interpretation of the wall thickness.

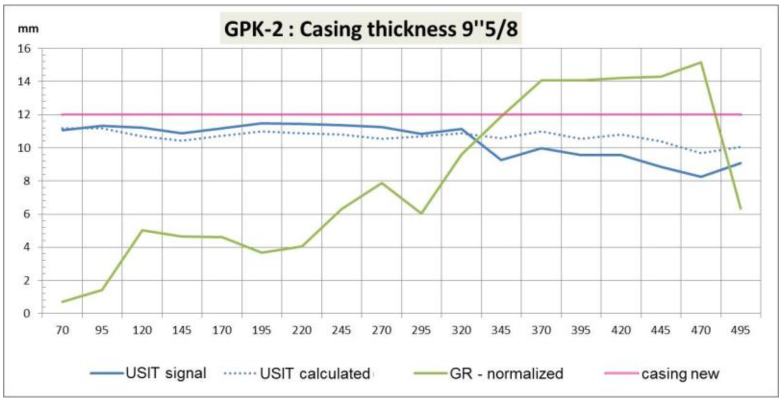

Figure 1: 2015 GPK-2 USIT and GR measurements: Pink line: original wall thickness. Blue line: measured wall thickness. Dashed blue line: recalculated wall thickness. Green line: Gamma-ray normalized.

2.2 Camera Inspection

For camera inspection, the High Definition (HD) system Supervision SVC110SV was used. Due to its temperature limitation of maximum 60°C logging was limited to a depth of 224 m. The camera logging was mainly performed to investigate the zone between 0 – 67 m which was not possible to investigate by USIT due to well-killing and resulting low water level. GPK-2 inner casing interior is mainly covered with scales. Frequently, parts of the scale layer are mechanically removed by LSP installation/de-installation and logging operations. There is no indication at all for scale spalling due to subscale corrosion processes. During the camera logging, no holes or other signs of casing integrity impairment was discovered. Concerning corrosion features, the well can be divided in two sections:

A) 0-120 m: Uniform corrosion is frequently visible, Figure 2.

B) 120-224 (final logging depth): uniform corrosion is visible only randomly, Figure 3.

Between 23 to 40 m depth, small scale pits, <0.5 cm, and worm like features occur with a high density. Partwise they seem to penetrate into the casing with maximum depth of 1-2 mm. Scales cover the inner casing only randomly. This section should be monitored closely during following logging operations.

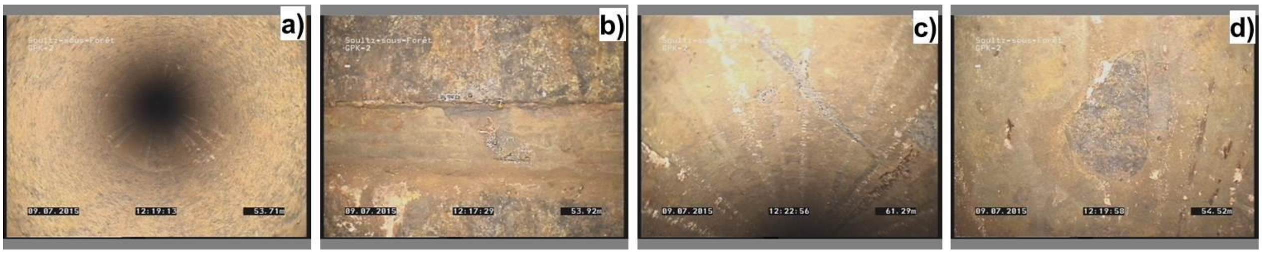

Figure 2: Casing interior of GPK-2 above the water level between 53 and 62 m. *a)* View into the well. *b)* Casing joint. *c)* Casing wall covered with scalings. *d)* Scale on casing wall.

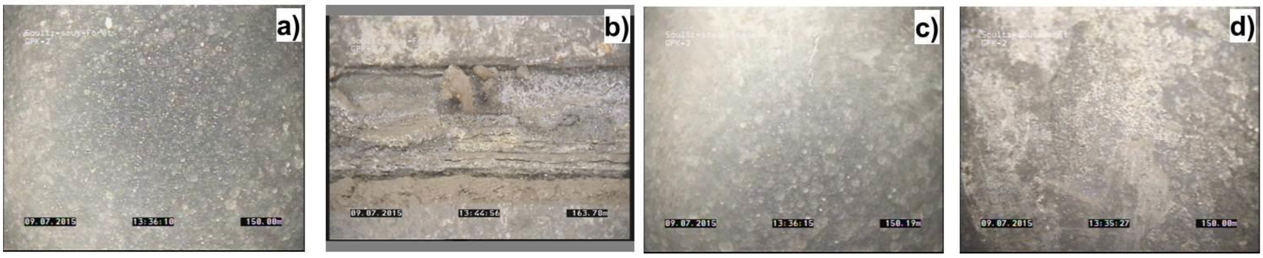

Figure 3: Casing interior of GPK-2 below the water level between 150 and 163 m. *a)* View into the well. *b)* Casing joint. *c)* Casing wall covered with scalings. *d)* Scale on casing wall.

4. CONCLUSIONS

Casing integrity of the inner casing of production well GPK-2 was evaluated amongst other wells in July 2015 by ultrasonic measurements, gamma-ray detection and camera inspection. After more than fifteen years of operation, the calculated wall thickness of the GPK-2 9”5/8 casing shows a maximum loss of 2.2 mm within the first 500 m which indicates a corrosion rate of less than 0.2 mm at production conditions. Down to approximately 300 m, GR values are low and show a higher variation which indicates a strong heterogeneity of the scaling layer at the pipe interior. With increasing homogeneity of the scale layer a significant interference with the ultrasonic pulses come along which result in misleading interpretation of the wall thickness.

Camera inspection confirmed that the GPK-2 inner casing interior is mainly covered with scales. Frequently, parts of the scale layer are mechanically removed by LSP installation/de-installation and logging operations which leave long vertical scratches on the pipes. There is no indication at all for scale spalling due to subscale corrosion processes. During the camera logging, no holes or other signs of casing integrity impairment was discovered. Down to 120 m uniform corrosion is frequently visible and to the final logging depth uniform corrosion is visible only randomly.

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