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A BOREHOLE SIMULATION AUTOCLAVE SYSTEM

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ABSTRACT

In order to permit testing of newly designed tools under controlled HDR geothermal site conditions prior to expensive running downhole, a high pressure / high temperature borehole simulation autoclave system was developed. The autoclave has an internal length of 7.8 m, an internal diameter of 165 mm (6-½"), and can be pressurized up to 150 MPa (21750 psi) and heated up to 200 °C (392 °F). Pressure and temperature can be held constant within 1 per cent of their maximum values. The autoclave has an inside mounted 7-conductor cable-head and electrical feed-thrus, as well as various hydraulic inlets or outlets at various positions to enable tool operation of almost any kind during testing.

So far, more than 100 tests were carried out on logging tools, drilling equipment components, packer systems, fibre optical cables, corrosion test chambers or even cement samples for completion of geothermal wells. The tests demonstrated that in some cases, even a non-adequate O-ring may be the reason to ruin a development worth of several thousands Euro if the tool was used in-situ without previous laboratory testing.

INTRODUCTION

Deep boreholes are expansive probes into the earth crust. The recent VSP-logging in the Soultz boreholes has demonstrated again, that logging tools at geothermal sites are often exposed to loading conditions up to their technical limits. Therefore, geophysical exploration in such boreholes requires most reliable and well-tested systems such as logging tools, geophones, fluid and gas samplers, or packer systems to withstand to the hostile downhole environment at great depth. Testing such downhole equipment under controlled laboratory conditions prior to running downhole tests is particularly important for newly developed tools as experienced for testing in the German deep drilling project KTB, the ocean drilling project ODP, or in the European HDR geothermal deep drilling projects. Since access to existing commercial laboratory autoclave testing facilities is limited in Europe, MeSy has developed a borehole simulation autoclave system in 1988 available to all deep drilling project participants and research organizations active in the development of new borehole testing or drilling systems.

BOREHOLE SIMULATION AUTOCLAVE FACILITY

Essential details of the borehole simulation autoclave facility are shown in Figure 1, which can be described as follows (Hegemann and Rummel, 1995):

- The autoclave consists of a 8 m long heavy duty steel pipe with an outer diameter of 280 mm and an internal diameter of 165 mm (6-½") for testing tools with a maximum length of 7800 mm.
- The steel pipe can be heated by an external furnace of 20 kW power which allows a heating-up rate between 2 °C/hour and 25 °C/hour. External insulation guarantees good heating efficiency with minimum thermal losses.
- Both, the top and bottom caps of the autoclave contain high pressure / high temperature seals, and several hydraulic and electric feed thrus. In addition, a 7-pin Gearhart Owen type 1-½" OD cable head can be installed inside the autoclave which permits tool operation under the specific test conditions. Cross-over to other cable heads are available.
- The pressurization and heating units enables to control and monitor pressure and temperature within 1 per cent of the maximum conditions of 150 MPa and 200 °C. These maximum conditions are in accordance with the approval from the German Safety Authority (TÜV), which regularly inspects the autoclave system. Built-in safety installations (burst disc valves and temperature limitation) guarantee not to exceed maximum values.
- The autoclave is housed in a 10 m deep well of 1.5 m diameter which allows access to electrical and hydraulic inlets and outlets prior and after the tests. During testing the autoclave room is not accessible. Pressure and temperature at various autoclave positions are monitored fully digitally and remotely.

SUMMARY OF AUTOCLAVE TESTS

Since 1988, more than 100 tests at high temperature and high pressure conditions (partly also with He - or CO_2 - gas) were conducted. This includes:

- Tests of single - and multipacker - systems of different diameters and different rubber compositions to investigate the deformation behavior.
- Tests of newly developed borehole tools (magnetometer, susceptibility tool, borehole televiewer, 4-axis accelerometer, fluid-sampler, focused resistivity tool, 3-component geophones, 6-arm caliper, γ-ray density and radar tools) and tool components (tool housings consisting of steel or glass fibre, cable head cross-over).
- Test of newly developed drilling equipment (e.g. vertical drilling systems).

– Test of newly designed corrosion test cambers.
– Long-term corrosion and degradation tests on fibre optical cables for temperature and pressure monitoring.
– Long-term hydration tests on deep drilling cement samples.

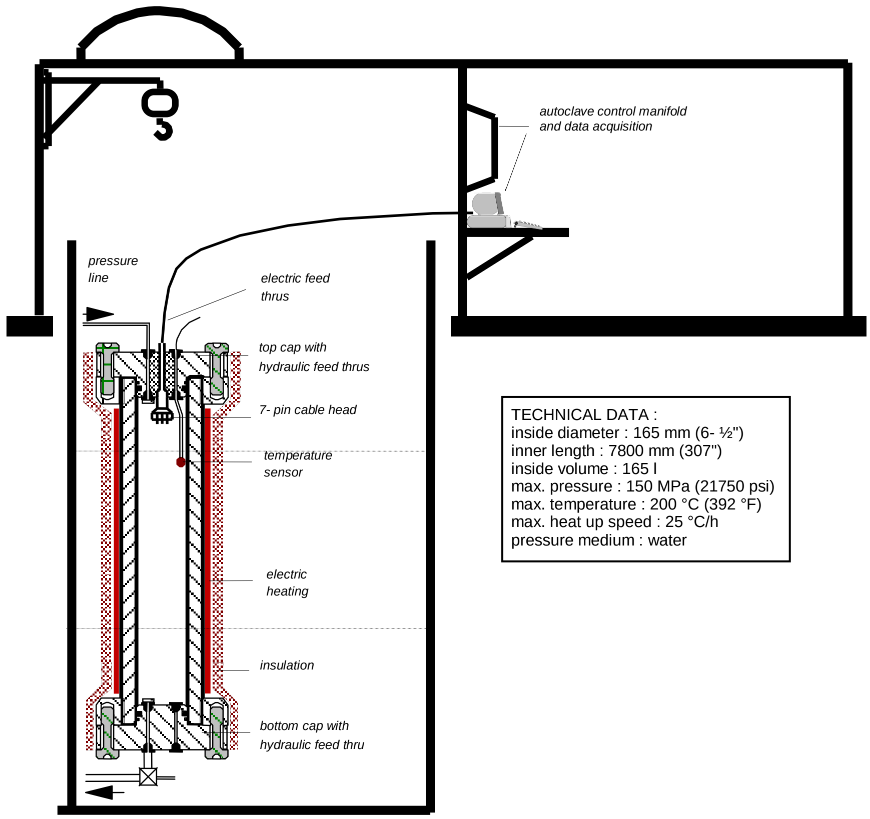

Fig. 1: Schematic drawing of the borehole simulation autoclave facility.

As an example, the test arrangement for the long-term corrosion experiments on high-temperature glass fibres against the formation fluid of the Soultz boreholes is shown in Figure 2 (GTC Report, 2004). Different fibres (e.g. pyrocoat and hermetic pyrocoat) were installed in thin stainless-steel coil tubings with an OD of 3 mm consisting of corrosion-resistant alloys such as incoloy 825, inconel 626, or SS316L. In order to protect the autoclave pipe against the salty formation fluid, the thin tubings were placed in steel pipes of OD 22 mm, which contained the formation fluid. A high viscous gel on the open sides of the steel tubes was used to prevent a mixture of the formation fluid with the water in the autoclave. Fibre optics cable functioning was constantly conducted by connecting the glass fibres with the temperature device DTS 800 during the tests. After some initial short pressurization tests, the corrosion and degradation was investigated in a long-term test with the downhole conditions of 5 km depth with a pressure of 50 MPa and a temperature of 193 °C during a period of 6 weeks. The pressure and temperature record of such a test is shown in Figure 3.

During testing, the attenuation along the two fibres was measured and compared with reference measurements as an indication of degradation processes. After testing, the steel tubing was investigated by detailed material testing. In summary, no significant corrosion and degradation was observed on both, the thin stainless steel tubings and the glass fibres.

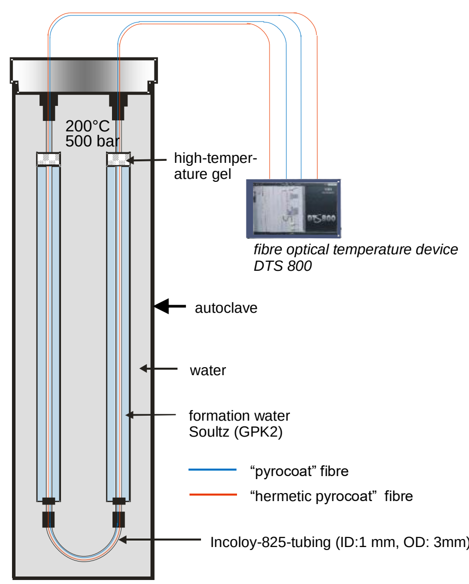

Fig. 2: Schematic test arrangement for corrosion and degradation tests on fibre optical cables (not on scale).

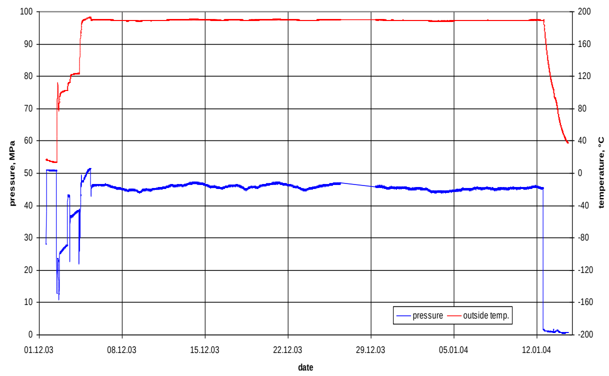

Fig. 3: Pressure and temperature record of a corrosion and degradation test on fibre optical cables.

CONCLUSION

As experienced from more than 100 tests in the borehole simulation autoclave system, numerous faults in tool design were identified. In some cases even a simple O-ring in the tool housing would have been the reason to ruin a new development worth of some hundred thousands Euro if the tool was not tested prior to its in-situ operation.

The borehole simulation autoclave is offered to any scientific researcher or geotechnical organization involved in logging tool development at effective costs with respect to public funding.

ACKNOWLEDGEMENT

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The corrosion tests on fibre optical cables were conducted in collaboration with the project partner GTC, Karlsruhe.

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