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Thermodynamic Modeling and Simulation as part of the Flooding and Recompletion Project of Salt Cavern Ll. Torup TO-8, DK

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Abstract

The gas storage caverns at Ll. Torup, Denmark, have been built in the 1980s in the course of the energy crisis as part of the Danish Energy politics. Since 2007 the gas storage facility in Ll. Torup is operated by Energinet.dk Gas Storage. After more than 20 years of gas operation Energinet.dk considered the flooding and recompletion of the seven gas storage caverns at Ll. Torup starting with cavern To-8 in 2011. The completion operation is mainly motivated by safety reasons, i.e. installing state of the art equipment such as a surface controlled subsurface safety valve (SCSSV) and new sealing elements (packer). The flooding of the gas filled salt caverns is a necessary preparatory operation. Such kind of refurbishment will become more and more important to cavern operators in the coming years, since a number of storage caverns in Europe have reached a lifetime of several decades.

KBB Underground Technologies GmbH (KBB UT) was asked for planning and technical support of the whole campaign in Ll. Torup comprising flooding, recompletion and gas refill. After the first step of installing a flooding string under gas pressure the gas filled salt cavern was discontinuously flooded by injecting freshwater via the flooding string. During the flooding of the gas filled cavern the gas/liquid interface rose and the gas was compressed leading to an increase of the temperature. In the subsequent step the gas was withdrawn from the cavern via the annulus between gas production tubing and flooding string and therefore pressure and temperature decreased. Switching from gas withdrawal to freshwater injection became more frequent with on-going flooding operation. With less gas in the cavern the rates of pressure and temperature in the cavern increased extraordinarily and with it the risk of damaging the last cemented casing shoe. In order to solve this conflict of increasing pressure rates at the end of the flooding and to stay within rock mechanical recommendations KBB UT accompanied the process by thermodynamic simulation.

This simulation has to account for more than commonly applied models provide, which are used for gas storage in salt caverns. The amplitude between high and low temperature is damped due to the heat transfer between the gas and the surrounding rock salt. Therefore, the heat transfer has to be considered to get reasonable results. However, the flooding process cannot be computed with currently available salt cavern simulation tools, because they do not consider the heat generation due to the gas compression from the arising interface. Therefore, KBB UT had to model these additional effects and extended the thermodynamic simulation software PVT3. This software has been developed in-house at KBB UT in the recent years to simulate the thermodynamic state of the gas filled salt caverns.

During the project the simulation results were compared and calibrated to match the operational data of the first flooding steps, while the flooding was on-going. By this the simulation enabled to optimise the later flooding steps without violating the rock mechanical limitations and gave the basis for a reliable trading prognosis for the gas which was produced during the flooding operations.

Key words: Caverns for Gas Storage, Caverns for Liquid Storage, Computer Modeling, Instrumentation and Monitoring, Rock Mechanics