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Research Project Report RR2015-1

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Renewable Energy Storage in Salt Caverns

- A Comparison of Thermodynamics and Permeability between Natural Gas, Air and Hydrogen -

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EXECUTIVE SUMMARY

In several countries worldwide the usage of sustainable energy sources is increasing and according to planning will reach a significant share of the total energy mix. A major challenge is the integration of renewable electricity sources into the grid due to a divergence of production and consumption in time and space. In this context various options for the large scale storage of energy are under development including compressed air energy storage and hydrogen storage in salt caverns.

In order to facilitate the transfer of know-how in the field of natural gas storage in salt caverns to compressed air and hydrogen storage ESK has been contracted by SMRI to investigate the general differences in the thermodynamic behavior and the permeability of rock salt for natural gas, hydrogen and compressed air.

The work has been carried out by ESK and its subcontractor TU Bergakademie Freiberg and is summarized in this research project report. The main results are:

- The investigated properties are the critical points, compressibility factor, density, specific heat capacity, adiabatic index, Joule-Thomson coefficient, dynamic viscosity and water saturation content. The thermodynamic properties of natural gas, hydrogen and air differ significantly from each other. A different thermodynamic behavior of storage caverns for these gases has to be expected.
- The main impact on cavern storage operation is the compressibility factor determining the working gas volume, the rate of pressure change at the last cemented casing shoe, the pressure spreads at the well head and the flow velocities in the tubing.
- A different long-term development of the cavern temperature and the cavern temperature spreads of caverns containing hydrogen, air or natural gas can be caused by their different specific heat capacities.
- Hydrogen shows very low or negligible pressure difference between cavern and well head under all simulated conditions due to its low density and viscosity. In low diameter tubings air shows the highest dynamic pressure losses, so for fast cycling compressed air energy storage large diameter tubings are required.
- The cavern shape and size affects all gases in the same way, so for the selection or design of a cavern for air or hydrogen storage from a thermodynamic point of view the same criteria can be applied as for natural gas storage caverns.

- To determine the differences in permeability 5 samples from the location Staßfurt, Germany were measured for hydrogen, methane and nitrogen (as substitute for air) using a transient two-chamber test rig. The method of measurement is a proven technology and the experimental setup was calibrated by measuring a blank sample with no permeability.
- During the measurements a progressive decrease of the permeability is observed for all samples and gas types, which can be attributed to an increasing compaction of the samples. Depending on the compaction time (24 h – 1 300 h) the measured permeabilities range from 4.9 E-18 m^2 to 4.4 E-23 m^2.
- The main result of the measurements is that practically no difference in the permeability of rock salt for natural gas, hydrogen and air could be observed. Any difference in the permeation rates of the gases through a portion of rock salt (given that there are permeation paths existing) results only from their different viscosities. Thus, rock salt can be expected to be suited as geological barrier for hydrogen and compressed air as it has been verified for natural gas for several decades.

The obtained results from this research project contribute essentially to enhance the understanding in the relevant thermodynamics and rock salt permeability associated with hydrogen and compressed air storage in solution mined salt caverns. The project has, therefore, significantly improved the competitiveness of salt cavern storage technologies in the field of renewable energy management.