Renewable energy storage in salt caverns

SMRI Project Sponsors' Summary

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Numerous industrial countries in Europe, North America and Asia are undergoing a transition from fossil and nuclear energy to renewables. Because wind and solar power boast the largest scope for major expansion, but both generate energy dependent on the weather rather than demand, there will be a major demand for large capacity storages – particularly if renewables make up a large portion of the energy mix. The main solutions are compressed air energy storages and hydrogen storages solution mined in rock salt. SMRI supports this development by implementing complementary research projects.

Even though some storages of this type are already under operation, a great deal of R&D is still required, particularly in the case of hydrogen: this mainly concerns the thermodynamic operational behaviour of the storage caverns, and verification of the integrity (tightness) of the enclosing rock salt formation.

The findings in this report are divided up into research into the thermodynamic operational behaviour, including determining the thermodynamic material data, and the permeability of the rock salt when exposed to different gases (nitrogen, methane and hydrogen) under high pressure.

The *first part of the investigation* looking at the thermodynamic operational behaviour is a calculation of the relevant thermodynamic material parameters of hydrogen in the relevant pressure and temperature ranges, followed by a graphic presentation and discussion. This provides the SMRI membership with a complete, reliable and practice-orientated compilation of this data for the first time.

This establishes the basis for the subsequent part: a comparative numerical simulation of the operational behaviour of a high pressure gas storage cavern with either natural gas, compressed air or hydrogen. This makes it possible to carry out a sensitivity analysis looking at 15 cases to determine the influence of the different parameters, such as operating behaviour (seasonal to strongly fluctuating), cavern volume/depth/geometry/location, as well as tubing diameter. The evaluation of the results revealed that although the maximum and minimum values of the temperature and pressure vary depending on the type of gas – especially because of the difference in compressibility values – the basic behaviour is ultimately very similar. This even applies under very severe operating conditions. This proves that compressed air or hydrogen caverns can be used without any major problems to balance out strongly fluctuating wind and solar generation cycles.

The *second part of the investigation* looks at the influence of the stored gas on the permeability of the rock salt – in other words, on the integrity during storage operations. Earlier tests, and long term operational experience in particular, revealed that rock salt is technically tight with respect to natural gas under in-situ conditions. Cylindrical rock salt samples in a specially configured test apparatus were used to measure the permeability of the rock salt when exposed to pressurised natural gas, nitrogen or hydrogen. As expected, the permeability of the sample begins to decrease when exposed to the stress because extraction and storage of the rock salt sample under atmospheric pressure causes the sample to deconsolidate, and the fabric of the rock salt therefore heals slowly when pressurised again in the apparatus.

The crucial and positive finding from this research project was that as compaction and healing approach the in situ conditions, the permeability of the samples is independent of the nature of the test gas in a first approximation. This proves that undisturbed rock salt is also technically tight with respect to hydrogen.

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