

SOLUTION MINING RESEARCH INSTITUTE

105 Apple Valley Circle
Clarks Summit, PA 18411, USA

Telephone: +1 570-585-8092
Fax: +1 570-585-8091
www.solutionmining.org

**Research
Report
RR2010-01**



*High Frequency Cycling of Gas Storage Caverns:
Phase I: Development of Appropriate
Lab Tests & Design Criteria*

**Dirk Zander-Schiebenhöfer,
KBB Underground Technologies GmbH
Hannover, Germany**

12 October 2010

7 Summary

Currently high frequent cycling operations for gas storage caverns in rock salt are discussed by operators very often. Thereby the intension is not only to have more pressure cycles per year but also a most flexible layout for operations. Additionally high rates for pressure changes are requested. However, a precise or detailed illustration of planned operations in terms of pressure versus time is mostly not available in advance.

Contrary to this, rock mechanical safety analysis for such kind of gas storages has to be based on well-defined boundary conditions in terms of minimum and maximum cavern pressures as well as maximum rates for pressure changes during withdrawal and injection. Also the assumptions regarding the temperature regime have to be precise. Further, recommendations due to rock mechanics investigations include restrictions for operations at near minimum cavern pressures.

As a result of communications among the cavern industry some key parameters of intended future operations have been identified. These are the possibility to operate more than one cycle per year – as it is common according to the so called seasonal operation mode – and to increase the permitted rate of change of the internal cavern pressure.

By comparing the resulting impacts on the rock salt mass surrounding the caverns due to the different operation modes – seasonal versus high-frequent – the needs for further research can be pointed out in terms of additional and/or extended testing of rock salt in the laboratory as well as necessary future developments in the modeling process and/or extension of the assessment criteria with appropriate limiting design values.

The main findings can be summarized as follows:

- There is a need for cyclic creep tests, whereby mechanically applied loads and temperatures are changed. It is proposed to perform these tests uncoupled because currently cycling mechanical loads and temperatures simultaneously seems not to be advisable.
- The mechanism of internal damage due to cyclic temperature changes is not understood very well at the moment. This can be improved by large scale hollow cylinder tests, where temperature and pressure in the inner hole can be controlled independently from the applied stresses and temperature.

- The integrity at the casing shoe is of special interest, if high frequency cycling of pressure is supposed to be operated. Especially the tightness of the interfaces between rock salt, cementation and casing should be studied in a laboratory test using large scale specimens.
- Rock mechanical modeling for high frequency cycling of storage caverns in rock salt should be based on models coupling thermodynamics and rock mechanics. In doing so the interactive influence of the gas fill in the cavern and the rock mass can be considered.
- Material laws applied within the theoretical modeling process will have to consider internal damage variables in order to provide a design variable.
- Assessment criteria have to include the results and findings of the additional laboratory work. These assessment criteria will have to include an indicator for internal damage with a limiting design value.

With regard to the current state of knowledge it is proposed to focus additional laboratory testing on

- strength tests at low temperatures (0 to 20°C)
- cyclic loading tests (stress and/or temperature cycling) and
- appropriate tests for studying damage mechanisms and/or damage cumulation during cyclic loading due to stress and temperature.

Specifications of proposed laboratory tests are summarized in appendices A to E. If it is not possible to carry out the complete volume of proposed tests, the cyclic loading tests (mechanically and thermally) are of key interest in order to generally understand the deformation behavior under cyclic loading. For further optimization of a multi-cyclic operation the damage mechanisms have to be studied in order to determine permissible ultimate states of material integrity.

Boundary conditions of these tests should be adjusted to thermal and mechanical loading conditions of a typical gas storage cavern. A cavern with a roof at about 1,000 m depth is suggested in this regard. Subsequently and based on the results of the preceding tests conditions according to caverns at shallower and/or deeper depths could be considered in additional tests.