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Cavern Well Abandonment Techniques Guidelines Manual

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0 Summary

Introduction

The research activities conducted by SMRI in recent years on cavern sealing and abandonment (CSA) revealed that it is basically feasible to permanently seal a brine-filled cavern in homogeneous salt structures like salt domes and thick bedded salt formations where stability and integrity are ensured almost exclusively by the rock salt. In these cases and when complying with location-specific conditions no uncontrolled brine expulsion is expected to take place into the cover rock, into drinking water aquifers or at the surface.

As a logical next step towards developing CSA procedures for specific caverns, SMRI engaged Kavernen Bau- und Betriebs GmbH (now KBB Underground Technologies GmbH) to elaborate a general manual for planning and implementing CSA measures in practice.

This manual is not conceived as a list of binding regulations, but rather as a basis upon which operators and engineering companies can develop their own CSA concepts for specific caverns as required.

Task

Based on the previous results of basic research performed on behalf of SMRI, the task was to elaborate a practice-oriented technical concept for CSA measures. This concept must fulfill the following requirements:

- Long-term protection from contamination of drinking water aquifers and the escape of brine and/or flammable and/or environmentally hazardous storage product residues at the surface
- Long-term stability of rock mass surrounding cavern
- Maintenance-free
- Application of tried-and-tested methods and materials as far as possible

- Affordability
- Acceptable by the authorities

The main sections in this manual are as follows:

- Assessment of well and cavern pre-sealing conditions
- Replacement of storage fluid with brine or water in the case of storage caverns
- Assessment of minimum waiting time before plugging
- Performance of waiting period for temperature equalization until plugging can commence
- Cavern plugging concepts for both storage and brine production caverns
- Monitoring after complete cavern sealing & abandonment
- Costs

Basic CSA concept

In the first phase of developing a concept, analysis was carried out of the practical experience and regulations existing for oil and gas wells, with the aim of integrating this experience where possible into the CSA concept for caverns. German and Texas regulations were looked at. The analysis concluded that this experience and the regulations are only of limited applicability to cavern boreholes. In addition regulations for monitoring abandoned caverns in the Netherlands and in Poland were considered.

An important aspect when designing a borehole plug is selecting the section of the borehole in which to install the decisive plug for guaranteeing long-term sealing. The options for suitable sections are:

- Option I: Lower end of the last cemented casing string if the cementation is proven permanently tight
- Option II: Cavern neck (open hole) if suitable bore hole section present below the casing shoe
- Option III: Window milled in the lower section of the last cemented casing to provide an optimal bond between the cement and the rock, and not rely on existing cementation.

The CSA concepts for all options consist of the following main phases:

- Replacement of storage fluid with brine or water in the case of storage caverns
- Performance of tests and calculations to estimate site-specific rock mechanical, thermal and hydraulic characteristics
- Waiting until the necessary temperature equalization has taken place between the brine and the surrounding rock
- Cavern abandonment (work over activities for plugging cavern well)
- Surface monitoring

Assessment of location-specific conditions

SMRI has proven the basic feasibility of abandoning a sealed brine-filled cavern. However, this must be confirmed for an individual cavern or at least for a representative cavern in a cavern field. This particularly involves the estimation of the minimum necessary waiting period for temperature equalization and the long-term pressure build-up over time after plugging as a result of brine re-heating and convergence.

This usually requires numerical modeling which must be based on location-specific data (geology, well data, rock mechanics, salt permeability, and operational history).

Replacement of product or blanket

Brine or water can be used to displace liquid products from liquid storage or cushion gas from gas caverns. Brine is preferred because use of water will alter cavern conditions and may alter casing seat.

In the case of hydrocarbon products or blanket, an important aspect is cleaning the borehole to remove hydrocarbon residues to ensure that an optimal bond is created between the borehole wall and the cement plug.

Activities during waiting time

One of the main question marks is the waiting period required after flooding the cavern with cold brine or water; in special cases it may be reasonable to pre-heat the brine or water before injection for reducing waiting time. This involves analyzing the benefits of reducing the waiting time against the extra energy costs.

Cavern plugging concept

Independent of bore hole section selected for the location of the decisive plug, the section above the plug is to be completely cemented.

Either way, it is essential to ensure that an optimum bond is achieved which guarantees the long-term safe plugging of the compressed brine in the cavern.

In general all of the equipment in the borehole such as production strings and packer / tailpipe assembly in the case of gas caverns should be removed before installing the plug.

The borehole must also be properly cleaned because it is likely that HC blanket or product residues will accumulate in the roof of the cavern and in the borehole during the waiting period.

Then the installation of the actual plug can commence:

OPTION I: DECISIVE PLUG FOR SEALING WITHIN LAST CEMENTED CASING

A pre-condition for selecting Option I is confirmation of the tightness of the cementation around the last cemented casing. Setting the cement plug also assumes successful setting of a cement retainer or bridge plug and overlying cement bridge. The borehole can then be cemented to the surface.

OPTION II: DECISIVE PLUG FOR SEALING WITHIN CAVERN NECK (OPEN HOLE)
BELOW LAST CEMENTED CASING

A pre-condition for selecting this option is a cavern neck of adequate length and suitable cross-section to enable an open hole packer to be set within the open hole, followed by the setting of a cement plug of adequate physical length to create a safe plug.

OPTION III: DECISIVE PLUG IN WINDOW MILLED IN CASING

This option does not depend on the cementation around the last cemented casing or the geometry of the cavern neck. In the first phase, a bridge plug is installed in the vicinity of the casing shoe. The window is then milled above the installed plug in the casing string through the cementation to the salt formation. The borehole can then be cemented to surface.

ADDITIONAL TASKS:

The following applies whichever of the options is selected: cutting the casing adequate below ground level, setting a concrete slab, dismantling the well head and other installations on the cavern pad, and renaturizing the cavern pad, paths and field lines.

In some instances¹, however, regulators require leaving the casing above ground and affixing a placard to the casing for identification and subsidence monitoring requirements

No ranking or recommendation of the best solution for locating the plug is possible when comparing the pros and cons of the different options. The optimum solution

¹ for example Kansas, USA

depends on the local conditions as well as the requirements laid down by the operator and the authorities.

A qualitative comparison of the costs involved in the different plugging measures for a model cavern reveals that the costs are largely independent of the option finally selected.

Costs

The costs for cavern abandonment divide up into the below stated tasks:

- Preparation including work over activities
- Flooding with brine or water
- Optional: Pre-heating the water/brine for flooding
- Waiting period for balancing out temperature differences
- Plug construction including workover
- Well head and pad deconstruction and renaturization
- Post abandonment monitoring
- Engineering

On request of SMRI no numbers for costs have been included, since the actual costs will depend on the specific situation (type of cavern, duration of waiting time, country, actual reason for compiling costs – building reserves or need for abandonment).

Another reason why to do without costs are the two tasks *optional preheating of brine or water* and *waiting period*. The actual costs for both tasks will depend to a large extent on the assumptions made, e.g. temperature difference during heating, energy costs, length of waiting time (years, decades). This does not allow to present reasonable numbers e.g. for a sample case.