## 1. Abstract

Advanced geomechanical design and control instruments for salt cavities should consist of in total four main elements. With respect to the schematic visualization shown in Fig. 1 the four elements are indicated by

(1) lab tests to analyze the material behavior as well as to decide the limit values,

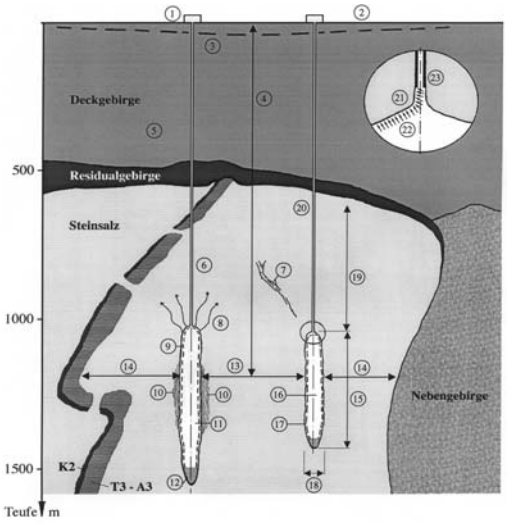
(2) a cavern design concept to prove static stability, tightness and acceptable surface subsidence,

(3) a cavern operation supervision program to control the permissibility of operation pattern and

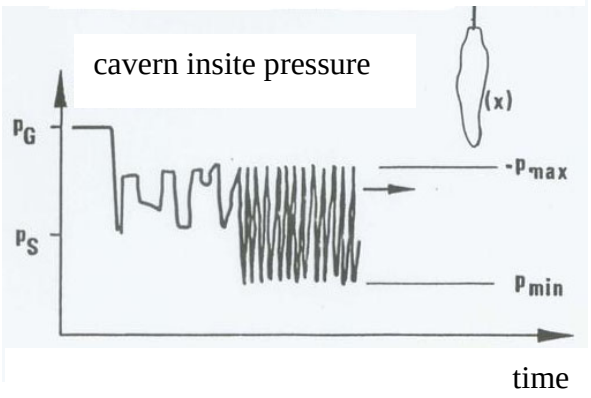
(4) a cavern abandonment simulation program to analyze the environmental safe abandonment.

lab tests

cavern design concept




cavern operation supervision program




cavern abandonment simulation program

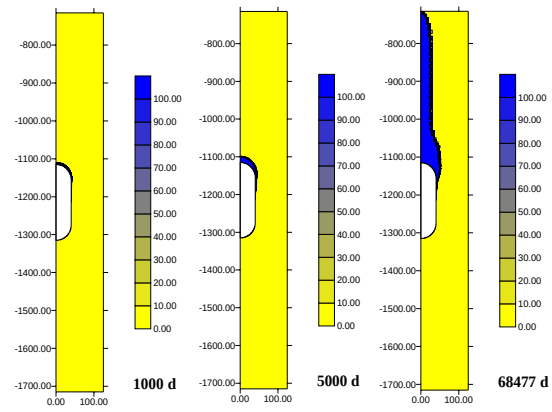



Fig. 1: Geomechanical design and control instruments

The permissible operation pressure of cavities is determined by rock mechanical calculations considering geological and material parameters such as stratigraphy, density, primary formation stress and temperature state, strength and creep behavior of the rock mass as well as configuration parameters like cavern height and diameter, distance between neighbor cavities and thickness of roof and pillars. Additionally, the rock mechanical calculations, carried out on the basis of recognized design methods, include evaluation criteria for the following design parameters to ensure the stability, usability and tightness of the cavities:

- permissible minimum internal pressure ($minp_i$)
- permissible maximum internal pressure ($maxp_i$)
- permissible pressure rate for gas injection $+\dot{p}_i$
- permissible pressure rate for gas release $-\dot{p}_i$
- permissible effective strain related to the internal pressure $\varepsilon_v$ ($p_i$)
- permissible duration of operation pressure in reference to the pressure level $p_i(t)$
- required internal pressure as well as dedicated operation time for recreation of rock mass quality

Therefore, the interaction between the minimum and maximum permissible operation pressure, the allowable duration in reference to the pressure level, the permissible pressure rate for release and injection of gas as well as cavern convergence are particularly important for the load bearing behavior of the surrounding rock mass.

As mentioned above, the permissible effective strain related to the internal pressure is one of the important design parameters to ensure the cavern stability. Generally the reason to limit the permissible effective strain of the rock mass is founded by investigations about the deformability of rock salt until creep rupture occurs. From lab tests it is well known, that the sample deformation observed without breakage depends to the minimum principle stress. The effective strain itself is a time-dependent value which could be calculated only by taking into account the total operation pattern as well as the transient and stationary creep rate. Therefore a comparison between the permissible effective strain determined as a result of the cavern design concept and the actual effective strain as a result of the realized operation pattern could not be done without a more ore less complex computation. To ensure the compliance of the design criteria, daily documentation and monitoring are required.

Additionally, with the increasing demands of a less seasonal but more cyclic operation pattern of the cavities with frequent turnover and a high deliverability there is a necessity for a computer aided equipment for quick online calculations of the permissibility of a foreseen

operation pattern or to reply quickly to inquiries regarding gas availability and storage capacity.

Similarly to the effective strain the convergence depends on the operation pattern. The convergence itself directly affects the total capacity of working gas as well as the permissible pressure rate for gas injection respectively for gas release. Therefore inquiries regarding gas availability and storage capacity could not be answered without a more ore less complex computation. To ensure the compliance of the design criteria, daily documentation and monitoring are required.

Because all of the design parameters fixed by the geomechanical design concept to ensure the stability, usability and tightness of cavities must be fulfiled simultaneously on the one hand and the increasing demands of a less seasonal but more cyclic operation pattern of the cavities with frequent turnover and a high deliverability otherwise, there is an increasing necessity for monitoring the compliance of design parameters as well as to satisfy different demands requested by the gas operator.

This paper deals with a new program called COSP (Cavern Operation Supervision Program) that has been developed to compute, control and document the permissibility of realized respectively calculated or planned operation patterns using the cavern specific design criteria on the one hand and to answer inquiries regarding future gas availability and storage capacity on the other hand. The program takes into account cavern specific data such as

- cavern volume
- depth of casing shoe
- cavern convergence in reference to the internal pressure
- cavern specific design criteria learned from the rock mechanical calculation
- compressibility of gas.

The data input necessary to perform calculations for assessment of permissibility of operation patterns, gas availability, storage capacity as well as the data input to control and document realized operation patterns in practice is reduced to a pair of variables, “internal pressure” and “related time”.

Possible data input procedures are numerical, graphical or ASCII-import. Visualization of the calculated or realized operation patterns as well as the analysis and documentation of the related permissibility are automatically done by the computer program in terms of predefined plots and worksheets. For further processing of the computed data an ASCII-export is available, if needed.

The different features available by the program and its capability will be demonstrated by execution a demo version available freebie. To create a site specific release of the program it is necessary to implement into the source code the dependencies between convergence, strain, internal pressure and operation pattern as well as the rock mechanical design criteria from the individual location. Particular demands regarding input and output of data, design of windows and available menus could be created regarding to the individual requirements.