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**Development of a New Criterion for the
Determination of the Maximum Permissible Internal
Pressure for Gas Storage in Caverns in Rock Salt**

Final Report

by

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9. Summary

Beginning with a state of the art review on criteria for the evaluation of safety at maximum internal cavern pressure state for gas storage caverns in domal rock salt designed for seasonal storage, a new criterion has been developed. It evaluates safety on the basis of a boundary condition for usability. The limiting state is equated to that point in time when the infiltration of the storage medium into the rock mass starts and can not be prevented from continuing.

This is defined by a combined infiltration / safety criterion, describing the onset of infiltration qualitatively if the internal cavern pressure exceeds the level of one of the two components of the local stress state acting perpendicular to the spreading direction of the infiltration process, with the spreading direction of the infiltration being normal to the cavern wall in the vicinity of the cavern. The quantitative measure is given by the minimum extent of a closed safety zone surrounding the cavern where the two stress components of the local stress state in the rock mass, which are acting perpendicular to the spreading direction of the secondary induced infiltration, exceed the internal cavern pressure by a certain level.

Carrying out a sensitivity study including the main influencing factors on the rock mass state at maximum internal cavern pressure reveals that the developed criterion works, giving a qualitative and quantitative measure for the specific state to evaluate.

From that study it can be stated that the main influences on safety at maximum internal cavern pressure are associated with initial conditions such as the primary stress state (densities of the overlying rocks, depth of the cavern), the geometrical layout parameters (shape of cavern roof, height of the chimney between cavern roof and casing shoe) and site location factors (pillar width).

The operating history conditions assuming a typical seasonal storage have a medium (time period at preceding minimum internal cavern pressure) to small (minimum pressure level) and very small (pressure drop down rate, level of preceding operations) effect on safety at maximum internal cavern pressure state.

Provided the material parameters for a suitable material law describing the response of rock salt under loading and unloading are determined with adequate accuracy, the studied influencing factors depending on material behavior have very small influence on the stress state in the rock mass at maximum internal cavern pressure (comparison of different material laws). But if the assumed set of material parameters is not representative, the change in safety conditions will be apparent in the sense of a declined or even non-existent safety zone (s. variation of material quality). Creep response of rock salt itself has a medium influence on safety at maximum internal cavern pressure state.

From an engineering point of view the time-dependent response of rock salt under unloading can be neglected, bearing in mind the initial assumption of an operating history for seasonal storage of gas. Recovery of creep will be very slow and therefore the stress state will not change remarkable within the time periods that have to be considered within this scope.

The recommended new criterion for the determination of the maximum permissible internal pressure for gas storage caverns in domal rock salt has been developed on the basis of the experience and scientific work recovering the past 20 years. The results of the present research project demonstrate that the safety at maximum internal cavern pressure can be evaluated by this criterion taking into account the various different influencing factors of geometry and location of the cavern, primary state of stress, material behavior of rock salt and the operating history.

The safety margins for the recommendation of the maximum gas pressure in the cavern naturally can only be fixed specific to the actual location of that cavern, and considering the whole set of influencing factors. They strongly depend on the experience of the consulting engineer.