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Stability Analysis of Natural-Gas Storage Caverns in Salt Formations

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Abstract

Predicting rock salt behavior is crucial for an accurate and reliable design of underground storage caverns in salt formations, and specifically to ensure the stability and integrity of these underground spaces throughout project's entire operational life. This assessment should consider nonlinear and time-dependent behavior for rock salt under complicated loading conditions. Furthermore, as cyclic gas pressure and temperature changes must be integrated into the analyses, the application of suitable numerical methods is indispensable.

Different stability criteria are available to evaluate salt instability, including "No Tension", "No Tensile Effective Stress" and "No Dilation". These criteria, respectively, mean that no main stress and no effective tangential stress can be tensile. Also, no dilation can occur at cavern walls when considering a specific dilation criteria. To maintain cavern stability, all these criteria must be satisfied. In this study, numerical modeling has been performed utilizing LOCAS, a 2D axisymmetric finite-element code, to assess the effect of various operating and geometrical parameters on cavern behavior.

This paper will offer an overall assessment of the behavior of salt caverns used for natural gas storage. Specific loading scenarios will be considered first. Then, thorough parametric and sensitivity analyses will be used to investigate the impacts of the geometrical parameters (cavern depth, shape and volume) and operational parameters (max/min pressure, cycle's number, cycle's period and gas injection temperature) on the behavior of salt caverns.

This study shows that dilation occurrence is more likely to happen within the first cavern life cycle when pressure drops to the minimum level. As for the potential of tension occurrence in the surrounding rock, this is more likely to happen by increasing number of operation cycles, especially in the upper one-third of the cavern wall. Finally, it is seen that cavern depth and minimum cavern internal pressure are even more important influences on the salt cavern behavior.

Key words: Caverns for Gas Storage, Cavern Operation, Cavern Design, Computer Modeling