Paper to SMRI Fall Meeting Berlin (D) – Oct. 2004

Pneumatic fracture tests and numerical modeling for evaluation of the maximum gas pressure capacity and the effective stress conditions in the leaching horizon of storage caverns in salt diapirs

Schreiner, Wolfgang[1], Jäpel, Gernot[2] and Popp, Till[1]

[1] Institut für Gebirgsmechanik GmbH, Friederikenstraße 60, 04279 Leipzig, Germany

[2] Untergrundspeicher- und Geotechnologie-Systeme GmbH, Berliner Chaussee 2, 15749 Mittenwalde/Mark, Germany

The in situ stress is, in addition to the design and the physical characteristics of the cavity, and installed equipment, the most significant factor determining the total gas storage capacity, e.g. the maximum volume of gas that can be stored in an underground storage facility. In many cases, however, it is adequate to assume that the maximum permissible gas pressure is equal to the minimum salt formation pressure. Its magnitude is determined by the overburden and Poisson's ratio, as has been proved by UGS Mittenwalde with pneumatic fracture tests for many caverns in Germany resulting in a storage pressure gradient of 0.190 - 0.205 bar/m (around 85% of the lithostatic pressure due to safety reasons).

In contrast, under domal salt conditions the in situ stress in the salt can be different, i.e. the three principal stresses are not equal due to the fact that salt driven by its lower density flowed upward to form diapirs and pierced overlying units. Because the salt passed upward through overlying sediments with lower densities (2.05 g/cm^3), in a first assumption, the resulting storage pressure gradients should be significant lower than in bedded salt formations, i.e. in the order of 0.18 bar/m. However, a case study in a salt dome of northeast Germany with pneumatic frac tests at various depths between 900 and 1.400 m documented that the measured minimal stress values are significantly higher, i.e. 1.0 – 1.5 MPa, than the estimated lithostatic pressure.

As a valuable basis to interpret the in situ measurements we conducted simulated laboratory pneumatic frac tests on cylindrical salt samples from the investigation site at various confining pressures. Because the measured higher frac values could not be referred to an effect of additional tensional strength of the salt we favour an interpretation based on higher confinement in horizontal direction of the salt diapir. This view has been successfully confirmed by numerical modelling of the temporal evolution of the stress state in the salt structure over geological time scales (> 10^6 a) including: (1) stratigraphy surrounding the dome, (2) approximate dome geometry, (3) depth depending temperature and (4) effects of glacial overburden during the last ice ages (10^5 - 10^4 a) resulting in a definition of a so called halokinetic additional stress component. According to these results the maximum gas pressure in the storage caverns was allowed to be set 10 bar higher than based on conventional design criteria.