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Geomechanical Analysis of Pressure Limits For Thin Bedded Salt Caverns

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ABSTRACT

Bedded salt formations are layered and interspersed with non-salt sedimentary materials such as anhydrite, shale, dolomite, and limestone. The “salt” layers themselves also often contain significant impurities. In comparison to relatively homogeneous salt domes, therefore, bedded salt cavern development and operations present additional engineering challenges related to the layered, heterogeneous lithology, differential deformation and bedding plane slip between individual layers, and larger lateral to vertical cavern dimensions.

This paper summarizes results from a recently concluded research project sponsored by the Gas Research Institute. The project effort included a geologic and geomechanical review of three major bedded salt basins in North America (the Permian Basin, the Michigan Basin, and the Appalachian Basins). We evaluated the geologic settings for these bedded salt deposits, and we reviewed geomechanical aspects for typical lithologies encountered. Given that background and insight, we next investigated analytical and numerical methods to estimate the geomechanical response of caverns in such settings to pressure cycling.

The primary limit on maximum cavern pressure is the fracturing pressure for the weakest lithology encountered by the cavern. We present analytical equations describing the influence of heterogeneous bedding layers on stresses in the subsurface. Varying mechanical properties will lead to varying horizontal stress, and hence varying fracture pressure. We illustrate this process with 3D geomechanical models of caverns in bedded salt.

A second potential constraint on gas storage operations is the pressures at which bedding plane slip or mechanical damage may be induced in heterogeneous layers surrounding the cavern or in the overburden. Bedding plane slip at the cavern boundary can lead to lateral gas migration, while bedding plane slip in the roof and caprock can lead to well damage and to roof caving. We present a theoretical review of stresses induced by pressure cycling, and analytical and 3D geomechanical modeling of various cavern configurations to illustrate the pattern and magnitudes of shear stresses induced around varying geometries. Parametric simulations are presented to illustrate the relative influences of cavern height to diameter ratio, non-salt interbed number and thickness, and salt and non-salt roof-beam thickness on cavern deformation and bedding plane slip.