

3-D Cavern Enlargement Analyses

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Abstract

Three-dimensional finite element analyses simulate the mechanical response of enlarging existing caverns at the Strategic Petroleum Reserve (SPR). The caverns are located in Gulf Coast salt domes and are enlarged by leaching during oil drawdowns as water is injected to displace the crude oil from the caverns. The current stability criterion adopted by the SPR limits the diameters of caverns relative to the width of the pillar of salt between caverns. This typically allows for 5 drawdowns (leaches) and roughly doubles the capacity of the caverns. As a base case, 5 leaches were modeled over the next 25 years which is roughly the remaining operational life of the reserve. In order to define the maximum allowable cavern size for SPR, 13 additional leaches were then simulated until caverns approached coalescence.

The cavern field approximated the geometries and geologic properties found at the West Hackberry site. The data collected over nearly 20 years enabled extensive comparisons to analysis predictions. The analyses closely predicted the measured surface subsidence and cavern closure rates as inferred from historic well head pressures. This provided the necessary assurance that the model displacements, strains, and stresses are accurate. However, the cavern field has not yet experienced the large scale drawdowns leaching being simulated. Should cavern enlargement occur in the future, either through oil drawdowns or intentional enlargement to create more underground volume, code predictions should be further validated with actual field behavior at that time.

The simulations were performed using JAS3D, a three dimensional finite element analysis code for nonlinear quasi-static solids. The results examine the impacts of leaching and cavern workovers, where internal cavern pressures are reduced, on surface subsidence, well integrity, and cavern stability. The results suggest that the current limit on cavern size may be extended, but some mitigative action may be required later on to the wells and surface structure due to large subsidence strains. The caverns are predicted to be mechanically stable up through 15 drawdowns which enlarges the current 11 MMB cavern volume up to 91 MMB. Historically, expansion studies for the SPR focused on increasing storage capacity by either adding new caverns or sites to the reserve. Enlargement of existing caverns may provide an economical means to achieve added site capacity and still retain an adequate number of drawdowns.

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