Solution Mining Research Institute; Fall 2006 Technical Meeting
Rapid City, South Dakota, USA, October 1-4, 2006

Analysis of Simple Cavern Shapes for the Strategic Petroleum Reserve

Steven R. Sobolik and Brian L. Ehgartner

Geosciences and Environment Center, Sandia National Laboratories, Albuquerque, New Mexico, USA

Abstract

The U.S. Strategic Petroleum Reserve (SPR) stores crude oil in 62 caverns located at four different sites in Texas (Bryan Mound and Big Hill) and Louisiana (Bayou Choctaw and West Hackberry). The petroleum is stored in solution-mined caverns in salt dome formations. The SPR sites are varied in terms of cavern structure and layout. Some sites, such as the Big Hill site, are characterized by a cavern field of reasonably uniform cavern dimensions (radius, height, shape, and depth) and spacing. Other sites, such as Bayou Choctaw, are characterized by diverse cavern characteristics.

This report presents computational analyses to determine the structural integrity of different salt cavern shapes. Three simple characteristic shapes are evaluated for increasing cavern volumes and compared to the baseline shape of a cylindrical cavern; these shapes include caverns with enlarged tops, bottoms, and mid-sections. The results address pillar to diameter ratios of some existing caverns in the system. The intent of these calculations is to develop some guidelines to predict cavern performance and damage in salt, utilizing the three-dimensional modeling capabilities of high-performance analytical codes and sophisticated material models. As salt fracturing is known to have occurred at underground storage sites similar to SPR, it is necessary to be able to understand the effects of cavern shape and size on cavern stability, and to be able to predict such behavior under a given set of pressurization and cavern geometry conditions.

Several three-dimensional models using a close-packed arrangement of 19 caverns have been built and analyzed using a simplified symmetry involving a 30-degree wedge portion of the model. A stratigraphy based on the Big Hill site has been incorporated into the model. The caverns are modeled without wells and casing to simplify the calculations. These calculations have been made using the power law creep model. The four cavern shapes were evaluated at several different cavern radii against four design factors. These factors included the dilatant damage safety factor in salt, the cavern volume closure, axial well strain in the caprock, and surface subsidence. The relative performance of each of the cavern shapes varies for the different design factors, although it is apparent that the enlarged bottom design provides the worst overall performance. The results of the calculations are put in the context of the history of cavern analyses assuming cylindrical caverns, and how these results affect previous understanding of cavern behavior in a salt dome.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Key words: Cavern Design, Caverns for Liquid Storage, Computer Modeling, DOE (US Department of Energy), Louisiana, Rock Mechanics, Salt Domes, Strategic Petroleum Reserve, Texas