Solution Mining Research Institute Spring 2011 Technical Conference

Galveston, Texas, USA, 18 – 19 April 2011

Analysis of the Stability of Large-Diameter Caverns for the Strategic Petroleum Reserve

Steven R. Sobolik and Brian L. Ehgartner

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. Most of the caverns at these sites were built as vertical cylinders of reasonably uniform cavern dimensions (radius, height, shape, and depth) and spacing. However, several caverns at these sites, particularly those constructed prior to SPR ownership, are characterized by diverse cavern characteristics. Sometimes these unusual cavern shapes present technical problems due to the resulting increased subsidence and shear stresses. Cavern 6 at the West Hackberry site has an unusual dish-like shape with a large rim around the circumference. The diameter of Cavern 6 at the ceiling ranges from 1120 to 1240 feet. It is also in close proximity to Cavern 9, which is hourglass-shaped. Because of the shape of the cavern and the creep behavior of salt, Cavern 6 is prone to wellbore casing failures caused by tensile strains. In addition, Cavern 6 has a greater potential for tensile cracking of salt at the perimeter of the cavern during a period of increasing pressure, such as at the end of a workover procedure.

This report presents a case study of how computational analyses may be used in conjunction with site data to advise site operations responding to a wellbore casing failure. One of the wells in Cavern 6 was recently compromised. SPR operations instituted a workover procedure to allow repair of the well casing. To minimize the amount of creep-induced loss in storage capacity, the field operators wish to increase the pressure in Cavern 6 to normal operating pressure as quickly as possible after completion of the well repair activities. However, results from preliminary analyses created a concern about the rate at which Cavern 6 could be repressurized; if the pressure is increased too much or too quickly, tensile cracking at the perimeter of the cavern may occur, particularly in that portion of the cavern closest to Cavern 9. To provide guidance to field operators, additional geomechanical calculations were performed to determine the structural integrity of Cavern 6 in response to different pressurization rates and maximum pressures. The calculations utilized a realistic three-dimensional model of the geometries of the caverns, and high-performance analytical codes using a multi-mechanism deformation material model. The results of the calculations indicate a significant effect of pressurization rate on the stress response of the surrounding salt, suggesting that a conservative approach be used for repressurization. These analyses resulted in operational guidance to the SPR that permits increasing the pressure quickly to an intermediate value to minimize storage loss, and then slowly increasing the pressure to a maximum operating pressure. These calculations indicate how high-performance geomechanical analyses may be used to support field operation activities and assure cavern integrity.

Key words: Caverns for Liquid Storage, Cavern Operation, Computer Modeling, Instrumentation and Monitoring, Louisiana, Rock Mechanics, Salt Domes, Strategic Petroleum Reserve, Well Casing