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Research Report 2013-02

SMRI Research report RR2013-2

"High Frequency Cavern Cycling—Phase 2-B: Extensional Cyclic Fatigue Testing of Salt"

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EXECUTIVE SUMMARY

The Solution Mining Research Institute (SMRI) inquiries into cyclic loading effects on salt were formalized in the original SMRI Request for Proposals (RFP) 2010-01, which specified a comprehensive (but exploratory) laboratory testing program [Zander-Schiebenhöfer, 2010] to evaluate the effects of both thermal and mechanical cyclic loading of salt. Cavern storage operators are frequently asking for operation patterns characterized by more frequent cycling of internal pressures (daily to monthly). To some cavern operators, this higher frequency loading is apparent in the challenging operation schemes with fast daily cycles of loading and unloading required for compressed air storage (CAES). The scope of the original testing program outlined in RFP 2010-01 was very broad; consequently, a smaller, more fundamental approach was undertaken. The first step in that fundamental approach was completed in 2012 by a joint research effort between RESPEC and Clausthal University of Technology (TUC) [Mellegard and Düsterloh, 2012] that focused on the most significant aspects of the cyclic loading topic at that time; namely, the effect of cyclic mechanical loading under a compressional state of stress.

The results of the testing in 2011 indicated that applying cyclic mechanical loadings on the salt did not cause any appreciable change in the salt behavior that could not already be characterized using noncyclical loadings. In other words, the salt was not more prone to damage (microcracking) under cyclic loading than it was under static loading at comparable stress levels. This conclusion was considered robust, because the same laboratory testing results were obtained independently by both RESPEC and TUC.

The previous research addressed the cyclic loading of salt, but all of the testing was performed under a state of triaxial compression, and triaxial extension was not considered. Triaxial extension differs from triaxial compression in the relative magnitude of the principal stresses. In simple laboratory terms, triaxial compression can be defined as when the axial stress is greater than the lateral stress; whereas, triaxial extension can be defined as when the lateral stress is greater than the axial stress. Compressional stress states usually exhibit higher strength than extensional stress states, but how this difference might affect cycling test results is not well defined. The impact of triaxial extension stress states needed to be considered because the stress state in the salt surrounding a cavern opening will range from compression to extension depending on geometry and operating conditions. The current study documents the results of additional cyclic loading triaxial extension tests performed to assess what effect the change in stress state may have on the cyclic loading behavior.

Cyclic loading tests were performed on two cylindrical specimens of Avery Island domal salt by using load paths that incorporated triaxial extension stress state conditions. The load cycles had a period of 2 days, and the test duration was approximately 1 month (approximately 15 cycles). Both tests were performed at a temperature of 30°C. The test specimens were recovered from the same borehole at the Avery Island Mine in Louisiana, U.S.A. that provided the

previous compressional specimens. The general test protocol was kept the same as was used in the previous compressional studies to aid in evaluating the effect of extensional cyclic loading. In both tests, the volumetric strain remained near zero, which indicates that the specimens were not dilating. This means that cyclic loading in extension is no more prone to damage than cyclic loading is in compression, at least for this salt and these test conditions.

The general conclusion that can be drawn from testing performed over the last 2 years is that cyclic loading does not make the salt more prone to dilation than static loading conditions. This conclusion applies regardless of whether or not the stress loading is characterized as triaxial compression or triaxial extension. This conclusion has the most significance for operators who require a large number of cycles in a year; e.g., CAES caverns. A disclaimer to the general conclusion is that the scope of testing is limited. For example, testing has only been conducted on a limited number of small, crystal salt specimens with few impurities from the Avery Island Mine in Louisiana, U.S.A., and additional test condition variables, such as the frequency and duration of the cyclic loading, could be considered. Another test condition that has not been investigated is the possible effect of cycling temperature under constant stress conditions, and this type of study should be considered in future research efforts, as recommended by Zander-Schiebenhöfer, [2010].