CAVERN ABANDONMENT FIELD TESTS IN DEEP CAVERNS

SMRI Project Sponsor's Summary

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The Solution Mining Research Institute (SMRI) has, for many years, recognized the importance to the industry of cavern sealing and abandonment (CS&A). To that end, the SMRI has supported a CS&A research program that consists of numerous research projects. This report, *Cavern Abandonment Field Tests in Deep Caverns*, represents documentation of a 5-year study of field measurements (data) and modeling (analyses). An apparent outcome of the work is that once the brine in the cavern reaches the original salt temperature, the cavern will likely attain an equilibrium condition; however, the timing to equilibrium depends on size, depth, geometry, and other natural and engineered system components.

The report provides insight toward quantification of the transient brine pressure change associated with the five mechanisms of brine pressure change identified throughout the SMRI research program:

1. The cavern pressure drop attributable to casing (or casing shoe) leaks
2. The cavern pressure rise attributable to brine heating
3. The cavern pressure change attributable to salt creep
4. The cavern pressure drop attributable to brine (micro) permeation
5. The cavern pressure drop attributable to salt dissolution.

From above, (1) is considered negligible as verified by measurements, and the long period of time that the wells have been brine-filled allows one to assume the pressure changes from dissolution (5) are negligible. Based on measurement and analyses and considering long shut-in periods, (2) and (3) dominate and may be accommodated by pressure monitoring and adjustments; further, the implied brine permeation appears to be negligible (4).

Enterprise Products Operation LLC (EPOLCC), Dr. Joe Ratigan, and the rest of the team exercised great persistence and patience in conducting the work presented in this reporting, which extends the SMRI knowledge base of the abandonment concept. Their work builds from previous SMRI CS&A research that included laboratory testing, numerical modeling, and shallow cavern field testing. The EPOLCC effort represents the next logical step to extend the SMRI CS&A concept knowledge base through this application of in situ in deep caverns. The value added of this work includes the fact that four deep caverns were continuously monitored and modeled for 5 years, which helped to develop a significant database and the following lessons learned.

By combining continuous cavern temperature and pressure measurements with analyses, one can confidently project the approximate date at which the cavern will reach the regulatory maximum conditions allowed. Cavern attributes of size, shape, depth, and edge proximity of the cavern represent important components of monitoring and analysis.

The operator must maintain a long-term (perhaps a legacy) pressure and temperature monitoring and analysis program on every shut-in cavern. Continuous cavern pressure maintenance at or below the regulatory limit may be necessary.

The consequences if a cavern is allowed to continue to build in pressure and brine temperature remain unknown. The following major results and conclusions were reached from this research effort [Ratigan, 2015][1]:

1. Continuous data collection for extended time periods is an important part of a cavern shut-in process and is challenging.
2. Wellhead pressure monitoring compares favorably with downhole monitoring.
3. Brine temperature approaching the original salt temperature may be indicative of an equilibrium condition; however, some caverns (e.g., depending on depth or size) will reach this condition more quickly than others.
4. Numerical analyses are warranted to rigorously quantify and understand relative contributions of (1)–(5), above; for example, two-dimensional numerical analyses of the type presented herein may be necessary, it is as yet undetermined if two-dimensional analyses are sufficient.

[1] **Ratigan, J. L. 2015.** *Cavern Abandonment Field Tests in Deep Caverns*, Research Report 2015-02, prepared by Enterprise Products Operating L.L.C., Houston, TX; PB Energy Storage Services, Inc., Houston, TX; and RESPEC, Rapid City, SD, for Solution Mining Research Institute, Clarks Summit, PA.