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Research Report 2019-2

SMRI Research Report RR2019-2:

"SPR Flow-Induced Deformation Field Test"

(Data Analysis for a Field Test to Advance Understanding of Flow-Induced Deformation in a Cavern Brine Hanging String)

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10 July 2019

EXECUTIVE SUMMARY

A field test intended to measure flow-induced dynamic displacement and permanent deformation of the brine injection string in a crude oil storage cavern was executed in February 2019. Flow-induced dynamic displacement and permanent deformation in the hanging string of a solution-mined cavern have long been recognized as a potentially important phenomena that can impact cavern storage operations.

A multi-phased research program for study of flow-induced behavior of brine strings was initiated at McGill University (McGill) around 2008. The research program developed a bench-scale testing apparatus and identified that both buckling and flutter phenomena can be expected to occur in brine strings during operation. Mathematical models were developed at McGill for some flow conditions, and others are currently under development for additional flow conditions. The mathematical models have only been validated using data from a bench- scale laboratory test apparatus. The field test described in this report was the first opportunity to collect field data for validation and/or modification of the McGill mathematical models.

The field test was executed at the United States Department of Energy Strategic Petroleum Reserve facility at the West Hackberry salt dome in Louisiana. The test was performed on Well No. WH115, a single-entry crude oil storage cavern well operated by Fluor Federal Petroleum Operations, LLC. Pre- and Posttest gyroscopic surveys were run in the brine sting over the entire length of the brine injection tubing to assess the extent of permanent deformation that might have occurred as a result of the testing performed. Instrumentation was installed to measure accelerations at the wellhead and at four different depths in the brine injection tubing. The four depths were as follows:

- the depth of the production casing shoe,
- the depth of the cavern roof,
- the depth of mid-span of the tubing, and
- the depth near the end of the brine injection tubing.

The acceleration data was used to calculate the dynamic string displacements during the test, when raw water was injected in the brine injection tubing at approximate velocities of 5, 10, 15, and 20 feet/second. Oil was withdrawn at velocities proportional to, but less than the raw water in the injection tubing.

The data collected during the testing indicated:

- No significant permanent deformation of the brine injection tubing occurred.
- Brine injection tubing impacts with the production casing were apparent and increased with increasing flow velocity.
- Brine injection tubing dynamic displacement was greatest at the bottom of the string and increased with increasing flow velocity; however, unstable flutter was not observed.
- The frequency of the brine injection tubing dynamic displacement in the production casing was about 1.1 Hz and about 0.04 Hz in the cavern, indicating at least two distinct vibration modes in the tubing.

- The McGill mathematical model did not predict permanent deformation or unstable flutter over the range of flow velocities experienced during the test.

Lessons learned from this test are threefold:

- The withdrawal rate for the oil in the annulus resulted in annulus velocity that was less than the tubing velocity – particularly at the higher flow rates; ideally, future testing would attempt to match the annulus flow rate with the tubing flow rate – a condition more representative of actual operations.
- Application of the McGill mathematical model to the field test revealed the importance of knowing the friction factor in the tubing and the annulus; future testing could employ downhole pressure measurement which would allow unambiguous "back-calculation" of the friction factor in the tubing and the friction factor in the annulus.
- It would be advantageous for the McGill mathematical models to be updated to allow for two fluids – one in the tubing and another in the annulus in order to more accurately incorporate frictional forces.