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Research Report 2018-2

SMRI Research Report RR2018-2:
2018 State-of-the-Art – Flow-Induced Deformation of Hanging Strings in Solution-Mined Caverns

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20 November 2018

EXCUTIVE SUMMARY[1]

Flow-induced deformation of hanging strings in solution-mined caverns has been recognized for many decades. A mathematical model of deformation in a discharging cantilever (from the literature) was applied to the issue in the 1980s and 1990s. However, a case histories study in the early 2000s illustrated that this mathematical model was not accurately identifying velocity limits that produced flow-induced deformation in cavern brine strings. The case histories study postulated that annular flow needed to be included in a flow-induced deformation model of hanging strings to more accurately establish velocity limits.

A multiphased research program for study of flow-induced deformation in brine strings was initiated at McGill University (McGill) in about 2008. The research program developed a bench-scale testing apparatus and identified in Phase 1 that both buckling and flutter deformation modes can be expected in brine strings. In Phases 2 and 3 of the research, significant sophistication was added to the bench-scale testing apparatus and an extensive suite of tests was performed. Mathematical models have been developed for some flow conditions, and others are currently under development for additional flow conditions. The research has made many important findings, including the fact that the ratio of tubing velocity to annular velocity is perhaps one of the critical parameters in determining the mode of deformation—buckling or flutter.

The McGill research, at the conclusion of Phase 3, has not progressed to the point that a precise value of the limiting velocity can be determined for a specific solution-mined cavern well completion. However, the research has progressed to the point that the important design parameters, that can have an impact on flow-induced deformation velocity limits in the well completion, can be identified.

While research continues at McGill in Phase 4, some well-completion design changes have been strongly suggested from the research completed to date. These modifications include (1) stiff centralizers on the tubing and (2) a larger tubing diameter in the cavern depth interval than what is in the production casing[2] depth interval. The stiff centralizers would help to mitigate the impact of annular flow, and the larger tubing diameter in the cavern interval would increase the bending stiffness of the tubing.

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[1] Note regarding the SMRI "Sponsor Summary" for this research report: Joe L. Ratigan, the author of this report, was the SMRI Project Sponsor for the research conducted at McGill University that is summarized and interpreted herein. As such, this report fulfills the objectives of the "Sponsor Summary" and a separate summary has not been included. The reader is referred to the Executive Summary and Conclusion sections for brief comments on the applicability of this work for the SMRI membership.

[2] The production casing is the outer cemented casing that generally extends to a depth near the roof of the cavern and houses the brine string. "Product" is injected and withdrawn from the annulus between the production casing and the brine string. Brine is injected and withdrawn via the brine string.