SOLUTION MINING RESEARCH INSTITUTE

679 Plank Road
Clifton Park, NY 12065, USA

Telephone: +1 518-579-6587
www.solutionmining.org

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Uncertainty Propagation Method Applied to Nitrogen-Brine Mechanical Integrity Test Analysis

Matteo Scapolan

RESPEC, Montreal, Canada

Sophie Minas

RESPEC Consultant to WSP USA, Montreal, Canada

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Sophie Minas, RESPEC Consultant to WSP USA, Montreal, Canada

Abstract

Solution-mined salt caverns are commonly used to store liquid and gaseous products underground. Mechanical Integrity Tests (MITs) are conducted periodically to ensure that the cavern system is tight, secure, and capable of safely containing the stored product. Through this test, leakage is assessed to determine if the cavern is safe to operate, as a leaking cavern presents an unacceptable risk to the owner as well as the public.

In the US, the most commonly performed MIT is the Nitrogen-Brine Interface MIT. The Nitrogen-Brine Interface test is executed by injecting nitrogen into the annulus between the cemented production casing and the brine injection tubing and by running temperature and density logs on two occasions, separated by a specified time interval. The wellhead pressure is also measured continuously. At the conclusion of MIT logging, a calculated leak rate (CLR), comparing the total nitrogen gas volume at the test start and end is obtained along with an associated uncertainty known as the minimum detectable leak rate (MDLR).

In this paper a new approach to the Nitrogen-Brine Interface MIT analysis is developed in which a statistical tool called the “uncertainty propagation method” is implemented. The proposed approach consists of a standard CLR computation coupled with a revised procedure for the determination of the MDLR. Since the uncertainty of the CLR depends on the accuracy of the measured quantities (pressure, temperature, interface depth, test volume, etc.), it is possible to apply the uncertainty propagation method, which is widely used to compute uncertainties in quantities that are not measured directly, but rather calculated through a set of measurands.

While the traditional approach to the MDLR calculation relies only on the uncertainty in the interface detection, in this paper the uncertainty of all measured quantities is taken into account. This includes the measures used to determine the test volume (annulus area, nitrogen flow during borehole strapping procedure and interface depth) and the in-situ density (surface pressure and downhole temperature). This allows for an evaluation of all uncertainty contributions, not only determining an accurate value for the MDLR, but also quantifying the influence of each instrument uncertainty.

This paper provides an overview of the typical US Nitrogen-Brine Interface MIT, together with the new analysis method. Case study examples of storage cavern MITs are provided, comparing the traditional method to the novel approach.

Key words: MIT, Storage, Uncertainty Propagation, Error Propagation.