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Technical Conference Paper

Measuring and Modeling Hydrogen Permeability of Salt and Cemented Salt Plugs Under Cavern Operating Conditions

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SMRI Fall 2024 Technical Conference
22-25 September 2024
Edmonton, Alberta, Canada

Solution Mining Research Institute Fall 2024 Technical Conference

Edmonton, Alberta, Canada 22-25 September 2024

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Abstract

For many years, underground salt caverns have been used for the seasonal and long-term storage of natural gas, natural gas liquids, oil, and petrochemical wastes. Due to their ultra-low permeability, capability for rapid injection and withdrawal, and large storage capacity, salt caverns are considered promising for underground hydrogen storage. However, concerns persist regarding the safe containment of hydrogen when stored in salt caverns under high-pressure conditions.

This study investigates hydrogen storage in the Lotsberg bedded salt Formation by performing lab-scale hydrogen diffusion experiments on salt, cement, and cemented salt plugs under conditions typical for storage. The goal is to measure and model the rate of hydrogen leakage through the cavern wall, casing cement, and the salt-cement interface. We have developed a custom-designed experimental setup and numerical method to determine the permeability of the samples using hydrogen gas under conditions similar to those in a cavern. This setup includes a custom-built sleeve to minimize hydrogen leakage through the sleeve. Our results show that the intrinsic permeability of three studied salt plugs is 0.31 nD (3.1×10^{-22} m^2), 10 nD (1×10^{-20} m^2), and 4.3 nD (4.3×10^{-21} m^2) with Klinkenberg constants of 5 MPa (722.3 psig), 2 MPa (294.4 psig), and 1.8 MPa (265.4 psig), respectively. The intrinsic permeability of cement plug to hydrogen is 15 nD (1.5×10^{-20} m^2) with a Klinkenberg constant of 3.6 MPa (515 psig). Additionally, the cemented salt rock has permeability of 144.2 nD (1.4×10^{-19} m^2) with Klinkenberg constant of 2.2 MPa (317.6 psig). These results demonstrate that the well-engineered and placed cements are an effective barrier for the isolation of hydrogen in salt-caverns under the conditions tested. The results also highlight that the susceptible pathway for leakage likely occurs at the interfaces and future work should focus how the other interfaces such as the casing impact the risk of hydrogen leakage during long-term storage in salt caverns

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Key words: Hydrogen, Salt cavern, Permeability, Lotsberg, Pressure Pulse Decay