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A High-Level Thermodynamics Comparison of the Hydrogen Storage Capacity of Salt Caverns in Various North American Salt Deposits

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Abstract

Investment in the hydrogen economy is gaining momentum from industrial and government groups throughout the world against the backdrop of pressure to decarbonize the economy. A key component of the hydrogen economy is access to small- and large-scale hydrogen storage that will serve industries on multiple scales ranging from energy storage for one plant (such as a megawatt- [MW-] scale cement plant) to energy storage for a major population center (such as a gigawatt- [GW-] scale power plant). Underground salt caverns have been used for decades by the oil-and-gas industry for storing hydrogen. In the case of large-scale hydrogen storage, salt caverns provide unmatched economic and environmental benefits over other storage types in areas where the geology is favorable to build a salt cavern.

In this paper, the capacity of salt caverns to store hydrogen is compared for various salt deposits in North America by evaluating case studies in the following locations: Kansas, Michigan, Alberta–Deep, Alberta–Shallow A, Alberta–Shallow B–Large Volume, West Texas, Gulf–Deep, and Gulf–Shallow. The case studies represented in this paper were selected in locations based on the presence of existing salt caverns and interest shown by the industry to develop hydrogen caverns in these areas. Salt Cavern Thermal Simulator (SCTS) was used to model the thermodynamics of operating hydrogen storage caverns in the case studies. The thermodynamic models were simulated for an operating life of 30 years with one hydrogen turn per year, and minimum and maximum pressure limits were set at 0.25 pounds per square inch per foot (psi/ft) and 0.80 psi/ft at the casing seat depth, respectively. General geology in the area of interest was used to pick the top of salt and thickness of salt. Cavern dimensions were based on the salt deposit thickness and RESPEC's experience in those salt deposits.

Working thermal energy and storage density are two parameters that were examined to compare the storage capacity of salt caverns in the case studies. The working thermal energy requirement of a project and limits on the maximum size of the cavern in a salt deposit will dictate the number of caverns that are required to be developed to meet the project's energy demand. For example, an intermediate-sized energy requirement project, such as a cement plant with peak demand in MW, may only require one cavern; however, a large-sized energy requirement project, such as a grid-scale energy storage project requiring GW scale storage, may require multiple caverns. Storage density is the working thermal energy per unit volume of the cavern; a cavern with high storage density is preferred because an operator can save capital on developing and operating additional caverns in a particular deposit.

The results of this study show that an operator will benefit from building a hydrogen storage cavern field in salt strata that is thick enough to accommodate large caverns and deep enough to accommodate a large pressure range (i.e., maximum minus minimum pressure). The amount of working thermal energy increases with increasing depth of the cavern and increasing cavern size, which is largely dependent on the thickness of the salt strata. Storage density increases with depth and is a better metric of hydrogen storage efficiency as compared to working thermal energy. For similar-sized caverns at different depths, the deeper cavern will have a high storage density (i.e., more working thermal energy per unit volume of the cavern) as compared to a shallower cavern.

Keywords: Hydrogen storage; salt caverns; salt deposits; storage capacity; large-scale energy storage; thermodynamics