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SALT CAVERN THERMODYNAMICS—COMPARISON BETWEEN HYDROGEN, NATURAL GAS, AND AIR STORAGE

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Abstract

This paper demonstrates and compares thermodynamic design for the storage of hydrogen, natural gas, and compressed air in solution-mined storage caverns. The design objective focused on in this study is to determine the gas storage capacity (i.e., working gas and required base gas) for a given cavern volume. For a given cavern volume, the working gas capacities (measured in standard cubic feet) vary considerably for natural gas, air, and hydrogen. For the cavern modeled in this study, the working gas capacity for natural gas storage is about 20 percent higher than that for compressed air and about 30 percent higher than that for hydrogen storage. Although each of the gases has different heat transfer characteristics, the differences in storage capacities are mostly related to the differences in the compressibility factors of these gases.

Five storage operation and cavern design parameters were varied to determine their effect on cavern storage capacity: (1) number of pressure cycles per year, (2) gas injection temperature, (3) minimum pressure, (4) maximum pressure, and (5) cavern depth. Increasing the number of full-range pressure cycles from 1 per year to 12 per year resulted in decreasing the working gas capacities by 6 percent, 8 percent, and 11 percent for hydrogen, air, and natural gas, respectively, while the required base gas increased slightly. Increasing the gas injection temperature from 70°F to 130°F decreased the working gas capacity for natural gas storage by about 6 percent, while only reducing the storage capacities for air and hydrogen by 1 to 2 percent. For all three gases, the working gas increases about 50 percent as the minimum pressure is decreased from 0.40 psi/foot (psi/ft) to 0.20 psi/ft of depth at the casing seat. Similar decreases are seen in the required base gas. The working gas capacities for all gases increase by about 40 percent as the maximum gas pressure is raised from 0.75 psi/ft to 0.95 psi/ft of depth at the casing seat; however, base gas requirements are relatively unchanged. Increasing the top-of-cavern depth from 2,000 feet to 4,000 feet results in about a 70 percent increase in working gas, while the required base gas is nearly doubled for all three gases.

Key Words: Cavern Design, Cavern Operation, Caverns for Gas Storage, Compressed Air Energy Storage (CAES), Computer Modeling, Gas Storage, Hydrogen Storage, Thermodynamics