ABSTRACT

This paper provides the results of a two-phase study that examines the economic and technical feasibility of converting a conventional natural gas storage facility in bedded salt into a refrigerated natural gas storage facility for the purpose of increasing the working gas capacity of the facility. The conceptual design used to evaluate this conversion is based on the design that was developed for the planned Avoca facility in Steuben County, New York. By decreasing the cavern storage temperature from 43°C to –29°C (110°F to –20°F), the working gas capacity[1] of the facility can be increased by about 70 percent (from 1.2×10^8 Nm^3 or 4.4 billion cubic feet (Bcf) to 2.0×10^8 Nm^3 or 7.5 Bcf) while maintaining the original design minimum and maximum cavern pressures. In Phase I of the study, laboratory tests were conducted to determine the thermal conductivity of salt at refrigerated temperatures. Finite element heat transfer calculations were then made to determine the refrigeration loads required to maintain the caverns at a temperature of –29°C (–20°F). This was followed by a preliminary cost analysis for the converted facility. The capital cost of additional equipment and its installation required for refrigerated storage is estimated to be about $13,310,000 or $160 per thousand Nm^3 ($4.29 per thousand cubic feet (Mcf)) of additional working gas capacity. The additional operating costs include maintenance refrigeration costs to maintain the cavern at –29°C (–20°F) and processing costs to condition the gas during injection and withdrawal. The maintenance refrigeration cost, based on the current energy cost of about $13.65 per megawatt-hour (MW-hr) ($4 per million British thermal units (MMBtu)), is expected to be about $316,000 after the first year and to decrease as the rock surrounding the cavern is cooled. After 10 years, the cost of maintenance refrigeration based on the $13.65 per MW-hr ($4 per MMBtu) energy cost is estimated to be $132,000. The gas processing costs are estimated to be $2.05 per thousand Nm^3 ($0.055 per Mcf) of gas injected into and withdrawn from the facility based on the $13.65 per MW-hr ($4 per MMBtu) energy cost. In Phase II of the study, laboratory tests were conducted to determine mechanical properties of salt at refrigerated temperatures. This was followed by thermo-mechanical finite element simulations to evaluate the structural stability of the cavern during refrigerated storage. The high thermal expansion coefficient of salt is expected to result in tensile stresses leading to tensile failure in the roof, walls, and floor of the cavern as it is cooled. Tensile fracturing of the cavern roof may result in loss of containment of the gas and/or loss of integrity of the casing shoe, deeming the conversion of this facility not technically feasible.

[1] Natural gas quantities are expressed in terms of normal cubic meters (Nm^3) with reference conditions of 0°C and 0.101325 MPa and in terms of standard cubic feet (cf) with reference conditions of 60°F and 14.73 psi. Gas-related computations were made assuming a gas composition of 100 percent methane.