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Abstract

A project was conducted in the Netherlands to demonstrate safe storage of hydrogen in an underground salt cavern. This pilot represents one of the first global fast-cyclic energy system demonstrations to prove the feasibility of pure hydrogen storage using methods analogous to underground natural gas storage. Downhole completion technology was supplied including a 9 5/8-in. SP™ tubing retrievable safety valve (TRSV), 13 3/8-in. X-Trieve™ HC production packer, OTIS® RPT® No-Go landing nipples, and a material test sub. The well was exposed to hydrogen for a period of 11 months with surface pressure and temperature up to 200 bar (2,900 psi) and 42°C (149°F). The production packer demonstrated annular integrity throughout the demonstration project and even under well cycling. The safety valve was manually cycled more than 75 times with zero leakage across the high-performance rod piston seals or body connections. The safety valve was also inflow tested seven times and demonstrated performance far exceeding current oil and gas (O&G) acceptance criteria.

Following conclusion of demonstration activities, the well was de-completed and the downhole technologies, including safety valve, production packer and material test sub were retrieved for further evaluation. Initial inspection and testing activities were performed at a nearby field location and within hours of recovery from the well. The technologies were then returned to the Halliburton Completion Tools Centre of Excellence in Singapore for a more rigorous study. There, the safety valve successfully underwent a suite of testing, largely replicating that performed on a newly manufactured valve. Both the safety valve and production packer underwent post-test inspection and disassembly with observations driving new design and material-based recommendations.

The material test sub included a total of 64 pre-stressed metallic material samples (eight of which were supplied by the operator) including low-alloy steel, stainless steel, Ni- and Co-base superalloy, weldments, and coatings, which were subjected to stresses within a range of 67 to 90% yield strength. Additionally, 150 non-metallic samples including HNBR, FKM, FEPM, FFKM, PTFE, and PEEK were included. All material samples were returned to the Halliburton Material Science Centre of Excellence in Singapore for further evaluation. Metallic material samples were scrutinized through visual, LPI, laser scanning and X-ray CT methods, while non-metallic specimens underwent visual and X-ray CT with mechanical and analytical property change evaluation through FTIR (Fourier Transform Infrared Spectroscopy), DSC (Differential Scanning Calorimetry) and TGA techniques (Thermogravimetric Analysis). The outcome of this effort defined a path for future material studies which are currently under execution phase.

This paper/presentation will focus on the operational performance, post-test evaluation and recommendations related to the completion tools and material samples included in this demonstration project.

Key words: Hydrogen, Gas storage, Materials, Metallic, Polymer, Elastomer, Plastic