CASE STUDY

The Netherlands

LOW CARBON SOLUTIONS | HYDROGEN

Halliburton deploys critical completion technology for pure hydrogen storage demonstration

Performance evaluation of current completion technology and materials in hydrogen storage applications

CHALLENGE

- Evaluate underground hydrogen storage, an emergent concept with limited information and experience
- Adapt proven O&G technology for underground hydrogen storage application
- Develop thorough knowledge of how hydrogen impacts materials and elastomers

SOLUTION

- 9 5/8-in. SP™ TRSV
- 13 3/8-in. X-Trieve™ HC packer
- OTIS® RPT® No-Go landing nipples
- Material test sub

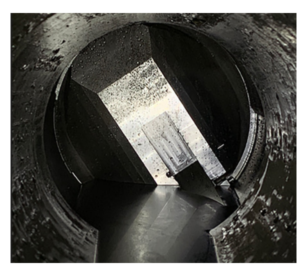
RESULT

- Accomplished safe, full-scale, underground hydrogen storage demonstration
- Successful installation, operation, and retrieval of SP TRSV, X-Trieve HC packer, and material test sub
- Exposed 64 metallic and 150+ non-metallic material specimens to hydrogen environment to support material science research in emergent field

Overview

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. Halliburton supplied completion technology that included 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 test sub contained 64 pre-stressed metallic and 150 non-metallic material specimens to examine performance under long-term hydrogen exposure. Surface pressure and temperature ranges up to 200 bar (2,900 psi) and 42°C (108°F) were observed while the packer maintained annular integrity throughout. The safety valve was 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 that far exceeded current oil and gas (O&G) acceptance criteria.

X-Trieve™ HC AHC packer recovered from the well



SP™ TRSV recovered from the well

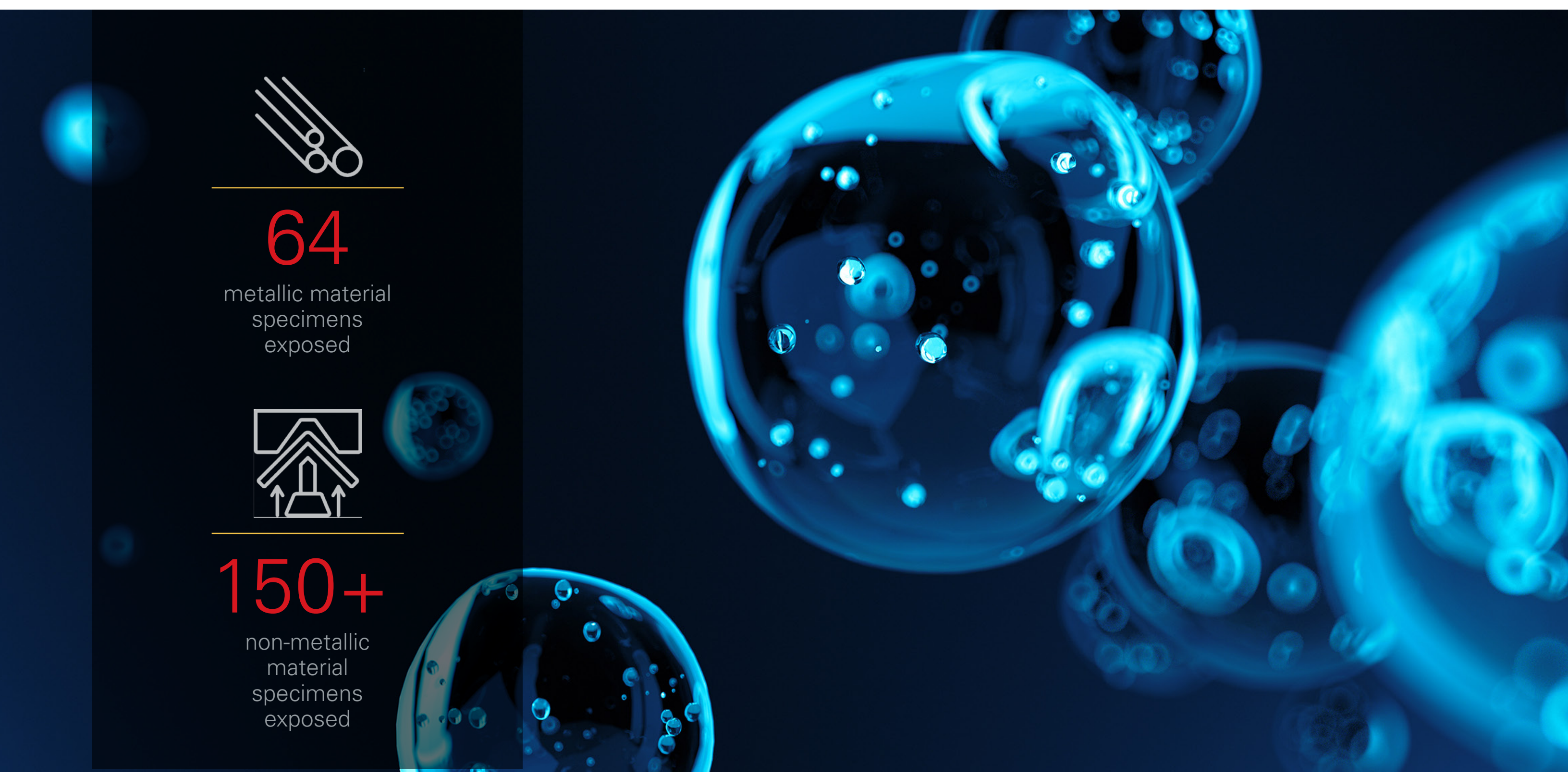
Challenge

Despite expectations for rapid growth in global hydrogen use and related storage, there are presently minimal underground hydrogen storage sites in operation; hence, information is limited. From a well-integrity perspective, the transfer of proven technology from the O&G industry and underground methane storage field to the realm of underground hydrogen storage results in several unaddressed challenges. The first is the molecular size of hydrogen. Compared to natural gas, hydrogen has a smaller molecular size, a higher level of diffusivity, and comparatively lower viscosity. Consequently, hydrogen has a higher likelihood of leakage compared to natural gas molecules. This raises concerns about the adequacy of well technologies, such as packers and safety valves.

Solution

To address these concerns and gain improved understanding of material performance during long-term pure hydrogen exposure, a collaborative effort was undertaken to conduct a comprehensive, full-scale storage demonstration. Halliburton supplied completion technology including a 9 5/8-in. SP™ TRSV, 13 3/8-in. X-Trieve™ HC production packer, and OTIS® RPT® landing nipples. Additionally, a material test sub was used to acquire comprehensive insight into the behavior of various metallic and non-metallic materials exposed to hydrogen over an extended period. The material test sub included a total of 64 pre-stressed metallic material samples (eight of which were supplied by the operator) and 150 non-metallic samples. Metallic materials included 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. Non-metallic material samples included HNBR, FKM, FEPM, FFKM, PTFE, and PEEK.

This pilot demonstration in the Netherlands not only proved the concept of underground hydrogen storage but showcased the adaptability of current well technologies



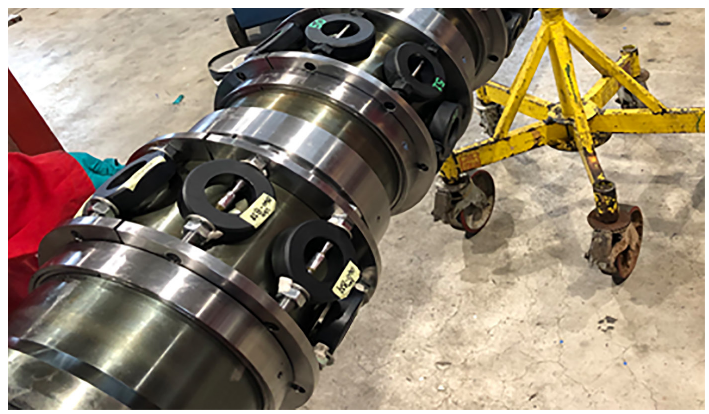
Result

During operation, surface pressure and temperatures up to 200 bar (2,900 psi) and 42°C (108°F) were observed. The production packer performed faultlessly in the well environment with zero recorded annulus pressure buildup throughout the entire demonstration period. The safety valve was cycled at least 75 times across two site visits with zero leakage from the high-performance rod piston seals or body connections. The valve was also inflow tested and demonstrated performance that far exceeded current oil and gas acceptance criteria.

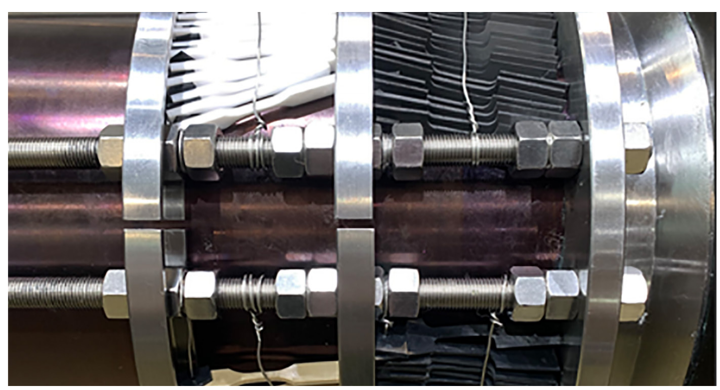
The safety valve, packer, landing nipples, and material test sub remained in the well for 12 months, which included 11 months of hydrogen exposure, before successful retrieval. The tools were returned to the operational base post-recovery, where the safety valve underwent baseline performance tests that identified zero issues with operational and seal performance. The production packer was also observed to set and release as expected. Notably, the material test sub remained intact with all material samples retained. The Halliburton-owned material samples, along with the safety valve and packer, were returned to the Halliburton Completion Tools Centre of Excellence in Singapore for further detailed evaluation.

At the Singapore Centre of Excellence, an extensive test program was executed to evaluate the operation and performance of the subsurface safety valve. The valve exhibited excellent functionality and seal capabilities under various conditions. Subsequent inspection of the packer and safety valve components yielded satisfactory results. Lastly, the material test-sub samples underwent thorough evaluation at the Material Science Centre of Excellence in Singapore, which provided Halliburton with a solid foundation and direction for further research and development in this space.

Material test sub recovered from the well.



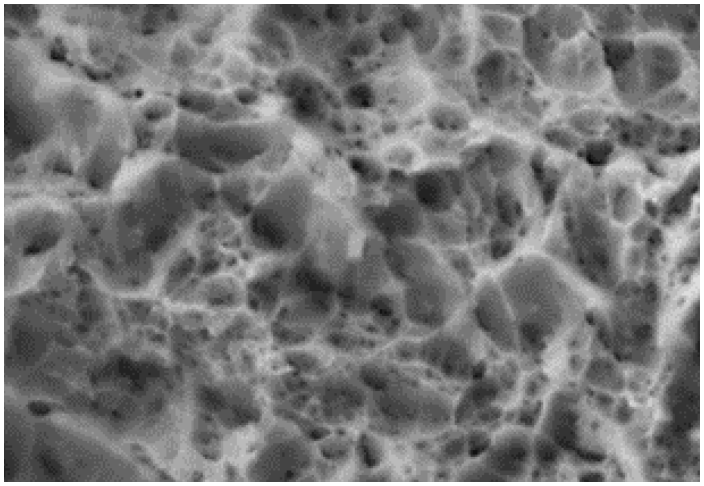
Metallic specimens mounted on material test sub



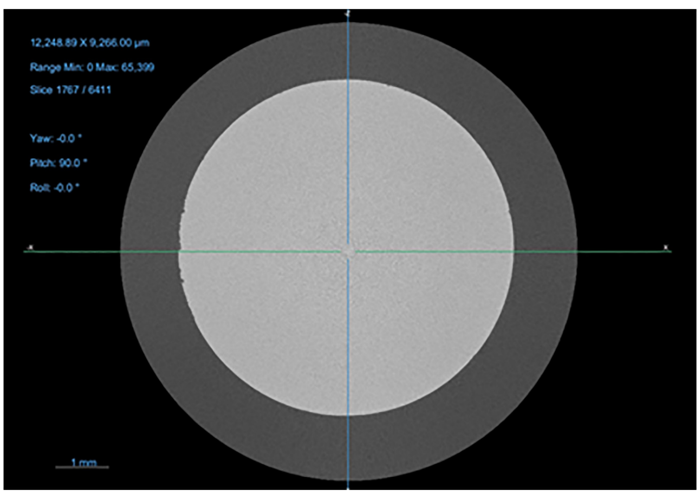
Non-metallic specimens mounted on material test sub

CASE STUDY

Full-scale demonstration of underground pure hydrogen storage using current field-proven technology from the O&G industry was safely accomplished. Additionally, the retrieved equipment and material samples from the well provide a solid foundation for further research and development activities in this emergent space.



Scanning electron microscope (SEM) image of recovered material sample generated at the Halliburton Material Science Centre of Excellence



X-Ray CT of recovered material samples

Material samples evaluated at the Halliburton Material Science Centre of Excellence in Singapore

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