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Quest MMV plan optimization resulting from increased confidence in injection well integrity based on time-lapse logging and continuous DTS monitoring

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Abstract

In August 2015, CO_2 injection commenced at the Quest Carbon Capture and Storage facility, operated by Shell Canada, on behalf of the AOSP Joint Venture (Canadian Natural Upgrading Limited, Chevron Canada Oil Sands Partnership and 1745844 Alberta Ltd.). Quest is a fully integrated CCS operation located near Fort Saskatchewan, Alberta, Canada with a capture target of approximately one million tonnes of CO_2 per year. CO_2 is injected into a deep saline aquifer, the Basal Cambrian Sandstone (BCS), at a depth of about 2 km below ground. To demonstrate containment and conformance of the injected CO_2, a Measurement, Monitoring and Verification (MMV) plan has been implemented. The Quest MMV plan uses a tiered system to assess loss of containment with Tier 1 technologies addressing critical risks using direct measurements, Tier 2 technologies addressing potential critical risks with reduced surveillance frequency and Tier 3 technologies are triggered only as a potential response to Tier 1 or Tier 2 outcomes. The adaptive nature of the MMV plan allows for changes in Tier classification of technologies and frequency of acquisition, building on the learnings from monitoring activities over time.

CO_2 or brine migration along an injector well was identified as one of the containment risks for Quest. To monitor injection well integrity, time lapse casing, cement bond, and hydraulic isolation logs were acquired together with continuous Distributed Temperature Sensing (DTS) data, downhole and tubing/casing annular pressure measurements, daily operator rounds and annual packer isolation tests. This paper will discuss the results of the time-lapse wireline logging, the related changes to the MMV plan, and new developments in DTS anomaly detection automation which can further improve monitoring of injection wells.

Time-lapse pulsed neutron logs (PNL) were acquired to verify hydraulic isolation in the near wellbore environment. It is important to understand the tool response to potentially different fluids in the wellbore between logging runs and the tool response to CO_2 in general. The development of new tools in the industry and new understanding of tool response to CO_2 improves the value of PNL data to verify containment, but also brings challenges when comparing results from different tools and different data processing workflows. The time-lapse data shows no CO_2 has migrated out of the BCS in the near wellbore environment for the three Quest injector wells, allowing for a change in Tier classification from Tier 2 to Tier 3.

Besides the PNL data, a cement bond log (CBL) was acquired on each injection well when the well was drilled and after 6 years of injection to verify hydraulic isolation. Both a reaction between CO_2 and the cement and the cool temperatures during injection

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can affect the cement quality. No deterioration in cement bond quality was detected for the three Quest injector wells, also allowing for a change in Tier classification from Tier 2 to Tier 3.

Casing integrity was verified after 6 years of injection using ultrasonic, magnetic flux, and multifinger caliper data. The combination of the tools allowed for detection of potential issues on the inside and outside of the casing, however, only the multifinger caliper provides a direct measurement while the other technologies rely in processing of the data and an interpretation of the signal. Some of the tool responses result in interpretation challenges associated with metallurgy (chrome casing in CO_2 wells), tool resolution where there is minimal corrosion, and casing manufacturing artefacts/imperfections. Low corrosion rates were determined for the Quest injection wells allowing for a reduction in logging frequency. With the requirement of a workover for the casing inspection logging, this reduction in logging frequency has a significant impact on the cost of monitoring the injection wells.

The change in Tier classification for PNL and CBL logging was made possible, not only by the good results observed with the data, but also by the presence of the fiber optic technology in each injector well, which is considered a Tier 2 technology for Quest. Data streaming is monitored, but anomaly detection has been a manual process on a quarterly basis. Automation is necessary to extract value from the data in real time. As part of an internal Shell research project a DTS anomaly detection workflow was developed. A combination of machine learning (ML) and statistics was used to detect synthetic anomalies of a simulated out of zone migration of CO_2. In the absence of real loss of containment data in Quest, parallel synthetic scenarios were modelled to mimic different types of anomalous behavior due to the presence of CO_2 outside of the designated depth interval. A sensitivity analysis was also conducted to assess both the predictability of the ML model and the detectability performance and limitations.

The analysis, based on the temperature contrast between injected cold CO_2 and the initial formation temperature, confirmed containment. The results demonstrate the method proposed is expected to be able to automatically detect a deviation in the trend of temperature as low as 0.5°C. It also highlights that warmback periods provide the most reliable results, while during injection, when the CO_2 injection rate fluctuates with variations up to 50% around its average the anomaly detection is more challenging. It has been assessed that short shut-ins or abrupt changes in the flow rates highly affect the predictability of the model and limits detection sensitivity. Further optimization of the workflow is ongoing to limit the degradation of the ML model predictions and the introduction of false positives by adding some physic-based features.

Keywords: Carbon Capture and Storage, Monitoring Measuring and Verification; Casing Integrity; Hydraulic Isolation; Pulsed Neutron Logging; Distributed Temperature Sensing; Machine Learning

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