geoconvention
Virtual Event
September 13 - 15
2021

Permanent deep fluid recovery and bubble tube system for downhole pressure measurements deployed in Aquistore, a CCS integrated project

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Summary

This paper provides an overview of the design, deployment and performance of the permanent – outside casing convey cemented in place – fluid recovery system (FRS) and surface bubble tube system of a deep monitoring well at the Aquistore geological CO2 storage project. The Aquistore site is located in south-eastern Saskatchewan, Canada, near the city of Estevan. Since 2015, 360+ ktonnes of CO_2 has be injected into a deep, highly saline aquifer at near 3.4 km depth in the Williston Basin. The injection interval is characterized by a thick sandstone aquifer of the Deadweed and Winnipeg Formations, and is overlain by the Icebox Member of the Winnipeg Formation and by the Prairie Evaporite. The measurement, monitoring and verification program of Aquistore provides an opportunity to develop and implement effective methods for monitoring CO_2 storage sites and ensure conformance of the storage process through continuous monitoring. In particular this paper will focus on the completion of the dedicated observation well, located at 150 m from the main injector, containing a fibre-optic distributed temperature system, fibre-optic distributed acoustic system, multiple pressure and temperature gauges and one FRS. The outside casing convey FRS housing was installed at depth of 3232 m. The FRS housing uses a configuration that incorporates a chamber and a system of shuttle valves. Each sampling port is connected to the surface by two stainless steel tubing/capillary lines that are connected to surface control panel. After the arrival of the CO_2 plum at the observation well, the FRS was designed to be converted to a bubble tube system – a permanent surface recording downhole pressure monitoring – through a capillary line.

Introduction

Over the last two decades, the University of Alberta, in partnership with Canadian and international organizations, has been studying carbon capture, utilization and storage (CCUS) with focus on geological storage of CO_2, including operational, verification, and environmental monitoring concepts. During this time, significant advances in downhole monitoring have been made mostly associated with the effort towards “intelligent wells” and fiber optic systems. The measurement, monitoring and verification (MMV) elements of a CO_2 geological storage project provides assurances that CO_2 has been injected and will be geological stored in an

environmentally sound and safe manner. Within MMV activities, downhole monitoring technologies (e.g. integrated observation well) provide direct and indirect measurements of the fate of geologically stored CO_2. A series of ISO standards for MMV practices for geological storage, including the associated CO2-EOR storage, highlight the importance of acquiring continues downhole pressure and temperature as part of a systematic risk assessment to ensure conformance and containment of the long-term effectiveness and security of CO2 geological storage (ISO 27914, ISO 27916, ISO TR 27913, ISO 27919). It is certain that for both value-added (e.g., CO2-EOR) and non-value-added (e.g. saline aquifers) storage projects, monitoring to detect the subsurface fate of injection greenhouse gases will be a regulatory requirement.

Identification of cost-effective technologies and methodologies will assist industry in moving forward with commercial scale projects while satisfying the desire for performance monitoring. The permanent deep fluid recovery system (FRS) and bubble tube surface equipment for downhole pressure measurements deploy in Aquistore – the first of its kind – is a game changer for long term downhole measurements for CO_2 geological storage, a component of the CCUS program. This type of monitoring technology for downhole pressure and temperature is robust with low cost of operation and maintenance. Short live of conventional downhole pressure gauges due to the highly corrosive and high temperature in-situ conditions can be a restrictive to acquire downhole pressure data for many years to decades during the operation and post closure phase for CO_2 geological storage sites.

FRS Bubble tube system in Aquistore

The instrumentation string was installed and fully cemented in a borehole of 219 mm diameter. Dual sapphire pressure/temperature sensors were installed at depth of 3305 m, and single sensors at depths of 3235 m, 3177 m, 3137 m, for a total of five sensors. The FRS sampling port was installed at depth of 3232 m. The DTS/DAS lines were installed from the surface to 2850 m depth. Additional detail description of the observation well is presented by Zambrano et al. (2015).

The bottomhole pressures can be obtained from the capillary line or bubble tube using nitrogen (N_2) as follows: pressure up tubing with N_2, accurately measures wellhead pressure and determines gas gradient for pressurized N_2. Nitrogen gas is inert, relatively inexpensive, and generally, easy to obtain. Unlike many other gases, such as CO_2, N_2 will not go through a phase change in the range of pressures and temperatures typically encountered in reservoirs (Zambrano 2012).

The FRS (patent pending) was developed at the University of Alberta. The FRS downhole housing uses a configuration that incorporates a chamber and a system of shuttle valves. The sampling port is connected to the surface by two stainless steel tubing/capillary lines (6.35 mm in diameter) that are connected to surface control panel. Bubble-tube system are conventional installed to the outside of the production tubing, for this case study the bubble-tube system was installed to the permanent capillary lines of the FRS. The surface equipment is continuously trickling a nitrogen gas downhole at near-zero velocity for measuring downhole pressure. Periodic, high flow, purges mitigate the chance of the FRS-bubble-tube plugging and are incorporated into this system. Given the thermodynamic properties of nitrogen, the permanent DTS line is used to integrate the density of the nitrogen on the lines and with the measured nitrogen surface pressure the bottom-hole

pressure at the exit point of the FRS-bubble-tube is calculated. Flow losses are mitigated by precisely controlling the injection flow rate so that it is near zero velocity. The additional benefit of the low instrument gas flow rate is that the volume of instrument gas used is also very low, thereby minimizing long-term operating costs.

This type of system is well suited for high temperature and/or harsh environments which render other pressure gauges incompatible. The upper temperature limit would be melting temperature of the capillary tubing (~1400°C). Bubble-tube system has been deployed in oil and gas installations since 1970s (Weeks 1975, Miller et al. 1979, Duncan 1995, Duncan 1997, Cassara 2008, Zambrano 2007), but the integration of DTS technology on cemented in place of capillary lines is the first of its kind for the FRS-bubble tube system deploy on CO2 geological storage site.

Results, Observations, Conclusions

The end result of this integrated system is a highly accurate bottom-hole pressure reading. Figure 1 shows the annual field comparisons of the downhole vibrating-wire pressure gauge located the injector at 3136 m depth with a corrected equivalent values at 3227 m depth (orange) and the FRS-bubble tube pressure measurements (purple) located at observation well - 150 m from the injector. The downhole pressure measurements at the observation well are in agreement with the injector. Additional work is underway to include the data set into a history match study of Aquistore, a fully integrated carbon capture and CO_2 geological storage project.

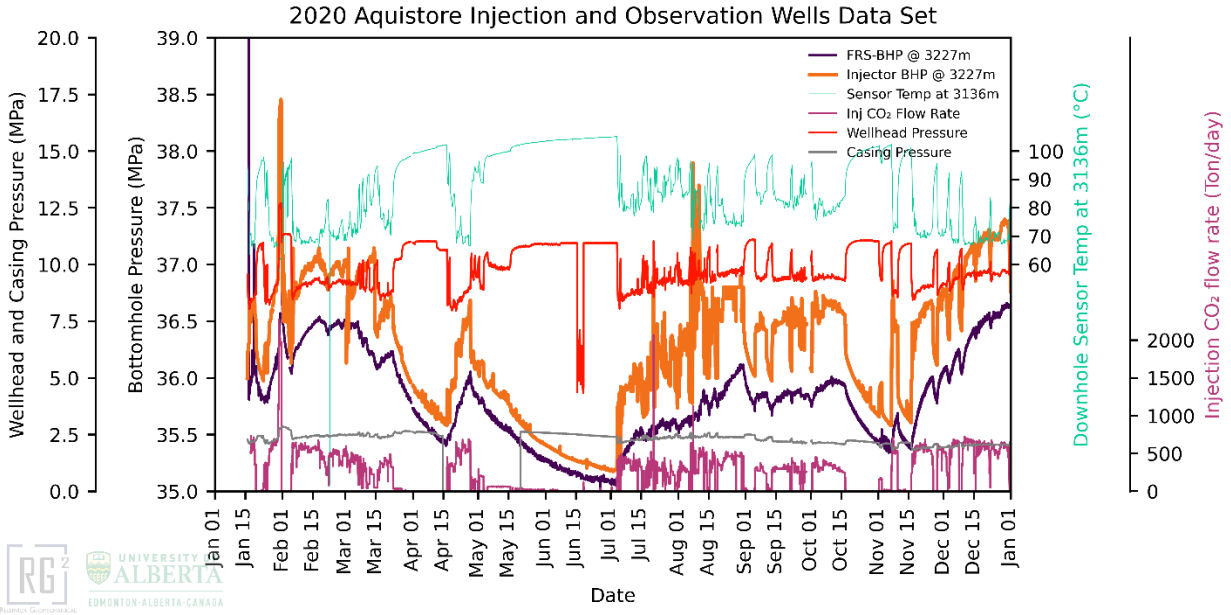

Figure 1 Aquistore Injector and observation well measurements during 2020.

Novel/Additive Information

Robust and low-cost downhole pressure measurements for long-term monitoring in harsh environments system for CO_2 geological storage or geothermal applications.

Acknowledgements

The authors thank the sponsors of the Aquistore Project for permission to publish this paper and for the funding to implement these monitoring technologies. Incremental financial support for this program was provided through the NSERC/Energi Simulation Industrial Research Chair in Reservoir Geomechanics. The monitoring technologies discussed in this paper comprise only a component of the MMV technologies deployed within the Aquistore Project. The complete MMV program has been the ongoing responsibility of the Aquistore Scientific and Engineering Research Committee comprised of Don White (chair), Chris Hawkes, Ben Rostron, Jim Johnson, Jim Sorenson, Rick Chalaturnyk and Erik Nickel.

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