Managing CO_2 Corrosion in CCS Wells: Material Selection, Design, and Operational Strategies, Lessons Learned from an SPE Workshop

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Objectives and Scope

Wellbore corrosion has emerged as a critical technical and regulatory risk for carbon capture and storage (CCS) projects in saline reservoirs, particularly for U.S. Class VI injection wells operating in CO_2-rich and potentially low-pH environments. In June 2024, the U.S. Environmental Protection Agency (EPA) Region 6 issued guidance requiring laboratory testing and/or corrosion modeling to demonstrate the suitability of well construction materials for exposure to CO_2 and saline environments, particularly when using materials below 22Cr duplex stainless steel. This regulatory action, reinforced by recent field observations such as those reported at the ADM Illinois Basin Decatur Project, where CO_2 migrated outside the permitted storage interval but remained contained below the primary confining zone, highlighted a pressing need for clearer guidance on material selection, well design, operational practices, and monitoring strategies for CCS wells.

The SPE Workshop Managing CO_2 Corrosion in CCS Wells was convened to leverage cross-disciplinary experience from operators, service companies, material suppliers, researchers, and regulators to address this need and inform practical approaches for current and future CCS developments.

Methods, Procedures, and Process

The workshop brought together subject matter experts across metallurgy, corrosion science, well design, operations, risk assessment, and regulatory oversight. Technical sessions covered: (1) CO_2 stream chemistry and impurity-driven acid formation, (2) corrosion behavior of carbon steels and corrosion-resistant alloys (CRAs) under flowing, shut-in, and transient conditions, (3) well and completion design strategies to mitigate corrosion risk, (4) laboratory testing and modeling approaches to support material qualification, (5) monitoring and surveillance techniques for early corrosion detection, and (6) remediation and workover strategies informed by field experience.

Case histories from CCS, CO_2-EOR, acid gas injection, and gas storage operations were used to compare laboratory predictions with observed field performance, highlighting both successful practices and failure modes.

Results, Observations, and Conclusions

Across multiple case histories, significant corrosion was generally not observed in active CO_2 injection wells, where operating conditions are controlled and dehydration specifications are maintained. Corrosion risk was more frequently identified in in-zone and CO_2-EOR production wells, where exposure to aqueous phases, multiphase flow, and variable operating conditions is more common.

While higher-grade corrosion-resistant alloys (CRAs), such as 22Cr and 25Cr duplex and nickel-based alloys, provide robust corrosion resistance, their cost and long lead times necessitate a risk-based material selection approach. Conventional 13Cr materials have proven insufficient in many CCS-relevant environments, although in select applications with well-defined operating envelopes, Super 13Cr has demonstrated acceptable performance.

Participants further observed that laboratory testing and corrosion modeling often predict more aggressive corrosion behavior than what is observed in the field.

Short-duration laboratory testing was found to correlate more closely with observed field performance than extended long-term tests, which can introduce unnecessary conservatism. Laboratory testing and thermodynamic modeling remain essential tools for qualifying materials below 22Cr, but must be designed to reflect realistic field scenarios.

Effective corrosion management was shown to depend on early integration of material selection with well design, proactive monitoring strategies, and clearly defined remediation plans aligned with regulatory expectations.

Significance and Lessons Learned

This workshop demonstrated that CO_2 corrosion in CCS wells is a manageable risk when addressed through integrated design, realistic material qualification, and proactive operations. Key lessons include differentiating corrosion risk across well types, designing for transient conditions, aligning laboratory testing with field behavior, planning for monitoring and intervention from the outset, and maintaining close engagement with regulators.

The collective insights provide a practical framework to support compliant, cost-effective, and durable CCS well designs as the industry scales from pilot projects to large-scale commercial deployment.