Center for Carbon Management in Energy
UNIVERSITY OF HOUSTON

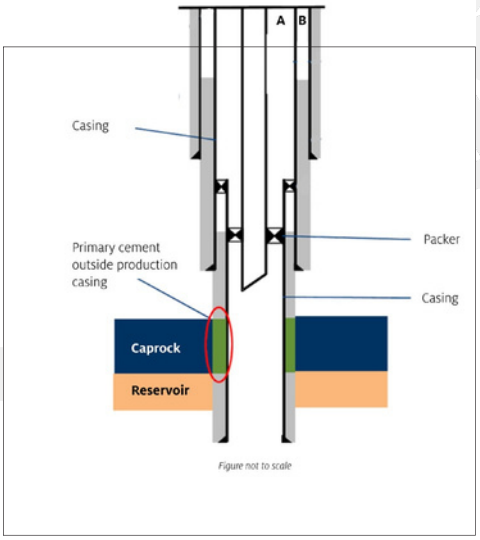
# $CO_2$ Sequestration in Legacy Oil Wells: Well Integrity

## Overview and Importance

In September 2024, Archer-Daniels-Midland (ADM) paused work at its $CO_2$ injection well at the Decatur, IL, storage facility after tests revealed a potential fluid leak. The news prompted advocacy and environmental groups to question the safety of CCUS projects.

Many older oil wells are being considered for carbon sequestration projects as they present an opportunity to reuse existing infrastructure. However, as these legacy wells were not originally designed for long-term $CO_2$ storage, it is critical to ensure that they can safely contain injected $CO_2$ over time. This makes their proper maintenance, reliable sealing, and continuous monitoring essential.

Well integrity is maintained using technical, operational, and organizational solutions, which keep the well fluids from leaking. In $CO_2$ sequestration and $CO_2$ – EOR projects, where the goal is the permanent storage of $CO_2$, maintaining a hydraulic seal is vital to avoid blowouts, and ensure the injected $CO_2$ remains securely trapped over the well's life.




Wellbore cement and casing

## $CO_2$–Cement Interactions and Degradation

When $CO_2$ mixes with water in the underground reservoir, it forms carbonic acid. This acid interacts with the wellbore cement (especially Portland cements), through a sequence of chemical reactions:

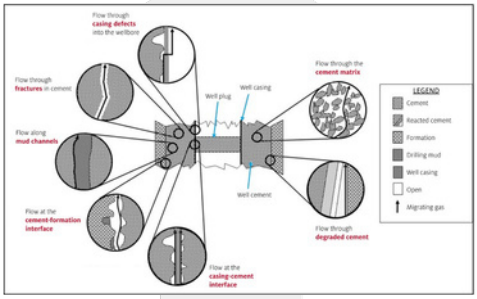
- Stage 1: Dissolution – Portlandite within the cement dissolves, initially reducing the cement's porosity and maybe even increasing its strength.
- Stage 2: Carbonation – The dissolved portlandite reacts with carbonic acid and precipitates as calcium carbonate.
- Stage 3: Bicarbonation and Leaching – The calcium carbonate eventually dissolves in a bicarbonation process, leaving behind an amorphous, porous silica zone.

**Impact:** The cement becomes permeable and prone to developing tiny cracks, ultimately compromising well integrity.

## Potential Wellbore Leakage Pathways

Fluids in the well can leak through weakness in the wellbore structure:

- Fractures within the cement itself or through a degraded cement matrix.
- Flow along mud channels left behind during primary cementing.
- Micro-annuli at the cement-formation interface or the casing-cement interface.
- Direct flow through casing defects, washouts, or failures at the well plug.




Leakage pathways at wellbore

## Mitigation Strategies and Best Practices

Specialized materials and practices are used in the $CO_2$-rich environment of wells to prevent corrosion:

- Advanced Formulations: Cements mixed with expanding agents and engineered pozzolans (such as artificial fly ash or natural volcanic ash) have lower permeability and better sealing capability.
- Alternative Materials: High-temperature durable epoxies are used in Class VI $CO_2$ injection wells.
- Risk Reduction: Using appropriate casing vs. bit size, achieving a sufficient cement bond, and ensuring adequate cement thickness extending through the reservoir's caprock minimize risk.

## Measurement, Monitoring, and Verification (MMV)

Continuous long-term monitoring of downhole cement integrity is required to detect anomalies and prevent catastrophic failure.

Cement Bond Logging (CBL): Assesses quality of the primary cement job, detects poor cement coupling, and monitors for degradation over time.

- Fiber Optics: Distributed Acoustic Sensing (DAS) and Distributed Temperature Sensing (DTS) lines in the wellbore track acoustic/ strain variations and temperature anomalies in real-time to find leakage.
- Other Methods: Pressure testing, microseismic data, and quasi-distributed pressure sensing (DPS) are also vital for overall integrity mapping.

## Real-World Field Examples

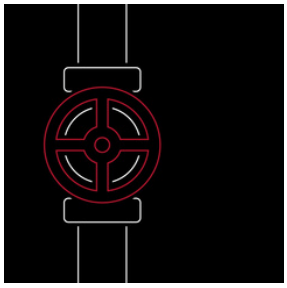
- SACROC (Permian): The Well Integrity Assessment Report from the Peterhead CCS Project highlights that Portland cement can remain viable in $CO_2$-rich environments for decades, effectively preventing $CO_2$ migration from reservoirs.
- Sleipner (Norway): In the longest-running offshore $CO_2$ storage project, Class G Portland cement used has undergone carbonation; however, this has actually plugged the pores and reduced permeability, keeping the $CO_2$ plume safely trapped, as verified by 4D seismic monitoring.
- ADM Decatur (Illinois): Standard Portland-based cement with high-performance additives was used. In 2024, a leak was detected in a deep monitoring well, a result of the well completion being corroded. Over time, the multi-zone sampling system installed inside the well failed to operate correctly, allowing fluids to migrate from the perforated zone in the injection interval to another zone above the confining zone.

Portland cement, or any type of modified recipe, must ensure long-term permanence and diligent monitoring must be deployed. This will make certain that defects are identified and resulting mitigation remedies any potential leakage.

If you have feedback or need clarification, please let us know at uhenergy@uh.edu.

# Read About UH Energy Research on CCUS

Find all Reports at
https://www.uh.edu/energy/research/papers-reports.php



## A Pivotal Moment for Enhanced Oil Recovery & CCUS

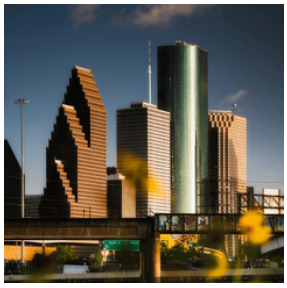
How combining carbon capture, utilization, and storage (CCUS) with enhanced oil recovery (EOR) can expand U.S. energy production while advancing carbon management.

**Charles McConnell**

## CCUS Infrastructure: Preparing for the Future of Houston

CCUS is a lynchpin to the energy transition, and Houston is at the center of commercialization aspirations. However, this isn't possible without needed investment in infrastructure, as well as a keen understanding of the road ahead.

**Charles McConnell**



## Carbon Capture, Utilization and Storage - Lynchpin for the Energy Transition

The Energy Capital of the World is poised to be the CCUS Capital of the World as well. This paper explores the Greater Houston region's unmatched advantages in leading carbon capture efforts.

**UH Energy in collaboration with the Gutierrez Energy Management Institute and the Center for Houston's Future**

## Carbon Dioxide Pipelines Explained

Researchers are exploring cutting-edge solutions to capture and transport $CO_2$ , tackling one of the biggest challenges in the building resilience.

**Paul Doucette and Mohan Vedala**

## Carbon Dioxide Pipelines: Role in Responding to Carbon Emissions

Several CCUS projects are poised to begin, which calls for a related growth in transport pipelines. But it must be done safely to protect the environment and surrounding communities. Here's how to do it.

**Paul Doucette and Mohan Vedala**