The "Green light" for scaling CO_2 storage at a global scale

Introduction

Carbon capture and storage (CCS) is identified as one of the most important actions for reaching the targets in the Paris Agreement. To play any significant part though, we will have to store most of the captured CO_2 underground.

Gradually, by establishing a multitude of wells for CO_2 -storage, in-fill drilling in mature CO_2 storage regions will be required. Accordingly, there will be occurrences with drilling of CO_2 wells in the vicinity or within existing reservoir volumes containing CO_2. Thus, new wells will be established near or penetrating in the CO_2 conductive layers.

Well control while drilling into CO_2 storage reservoirs is becoming a key safety challenge. Dense-phase CO_2 dissolves easily into drilling fluids, masking early kick signals and delaying detection of an influx. This raises the risk of a late shut-in and rapid CO_2 expansion near surface (CO_2 Blowout). After shut-in, handling CO_2 at surface adds further risks, including very low temperatures, corrosion, seal issues, and toxicity.

During phase 1 of the Project green light (Presented WCCUS 2025 #34 Well control for CO_2 wells, risk for CO_2 blowout) a well control simulator (well engineering software) for CO_2 wells has been made available for the market based on laboratory testing and software implementation from 2023-2025 with JIP partners Equinor, Shell, Eni, Ebn, CNOOC, Pions, Gassnova, Baker Hughes, Transocean, Noble, Wild well control and R&D partner SINTEF.

Project green light phase 2 addresses new knowledge gaps identified by the industry and partners. Partners: Equinor, BP, Shell, Pions, Gassnova, Baker Hughes, Noble, Wild well control and R&D partner SINTEF.

Method and/or Theory

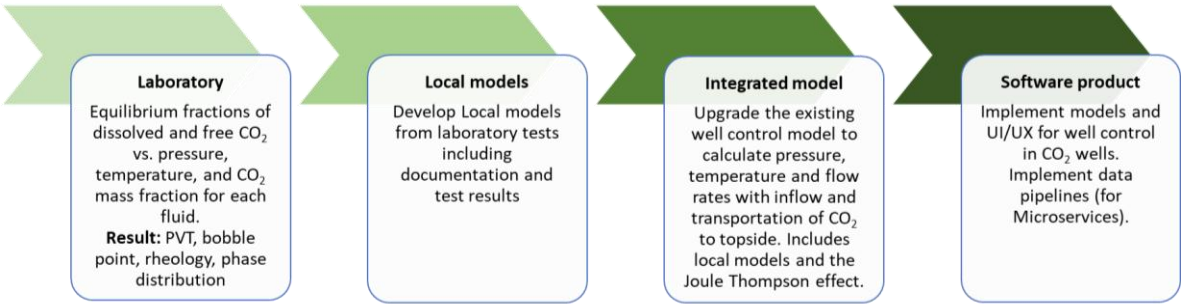
The primary objective is to develop services/software tools for safely drilling for CO_2 wells in CO_2 infill region:

- A qualified well engineering software for well control in CO_2 wells, used for planning/risk assessment prior to the drilling operation and additionally as a tool for anomaly detection during the drilling operation.
- A methodology for assessing specific drilling fluid suitability with respect to the performance of the drilling for CO_2 wells in in-fill regions.

The secondary objectives are to;

- Experimentally determine impact from CO_2 with impurities and MEG on drilling fluid properties; rheology, phase envelope and cooling impact during pressure drop
- Experimentally determine kinetics impact (both with CO_2 and methane)
- Mathematically describe the resulting rheology and thermodynamics for implementation in the Pions well control software
- Adress Relief well and blow-out kill
- Drilling simulator (topside drilling equipment) integration
- Software automation, modules for
    - Kick Tolerance
    - Bullheading
    - Choke/degassing
    - Real-time CO_2 kick detection
    - Select optimal well control strategy (AI Drilling Agent)

The activities in the project are organized related to a workflow shown below. Experimental results are reproduced individually in local models. Local models are then incorporated into an integrated multiphase (CO_2 + drilling fluids) well model so that full scenarios can be simulated (time-based/dynamic). On top of this, commercial products were developed, one "standalone" product that can be installed on a PC and one "Open API" product that can be integrated with other systems/workflows.



Examples

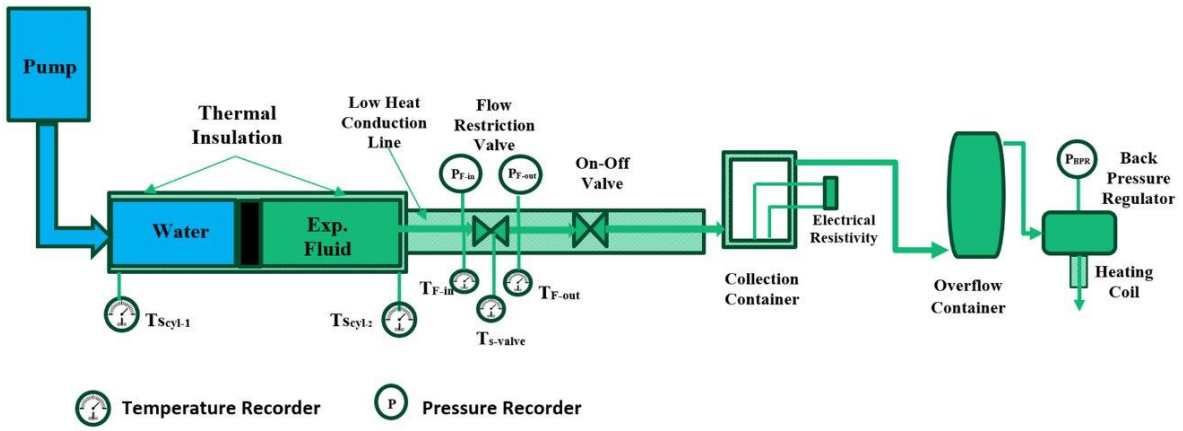


Figure 1 *Laboratory setup for Flow through a restriction for studying Joule-Thomson cooling effect*

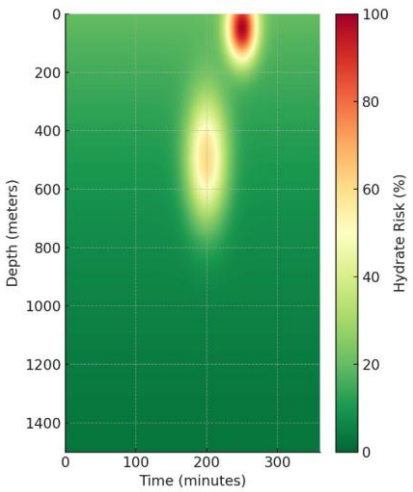


Figure 2 *Heat map for the Hydrate Risk profile showing evaluation for the whole simulation. Examples have the BOP at 500m and Choke at surface*

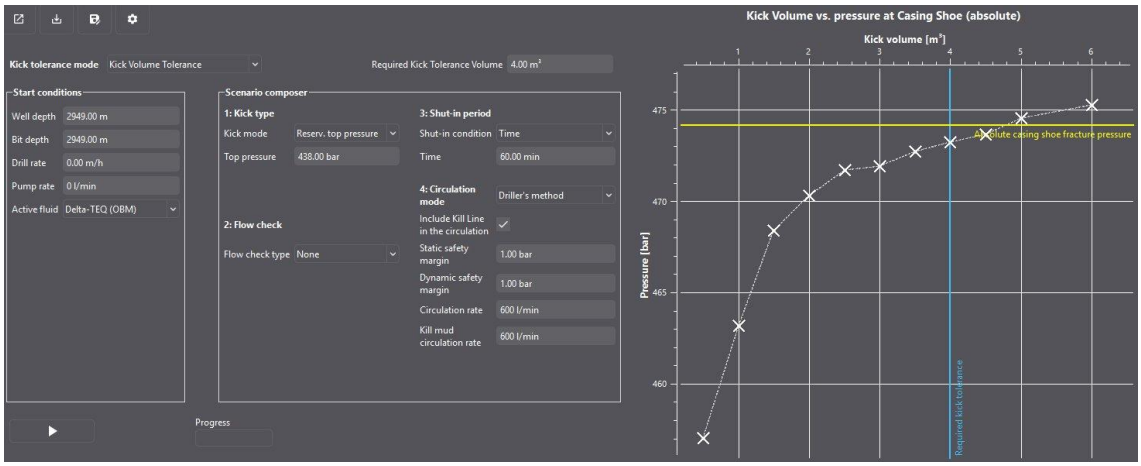


Figure 3 *CO_2 kick Tolerance simulator*

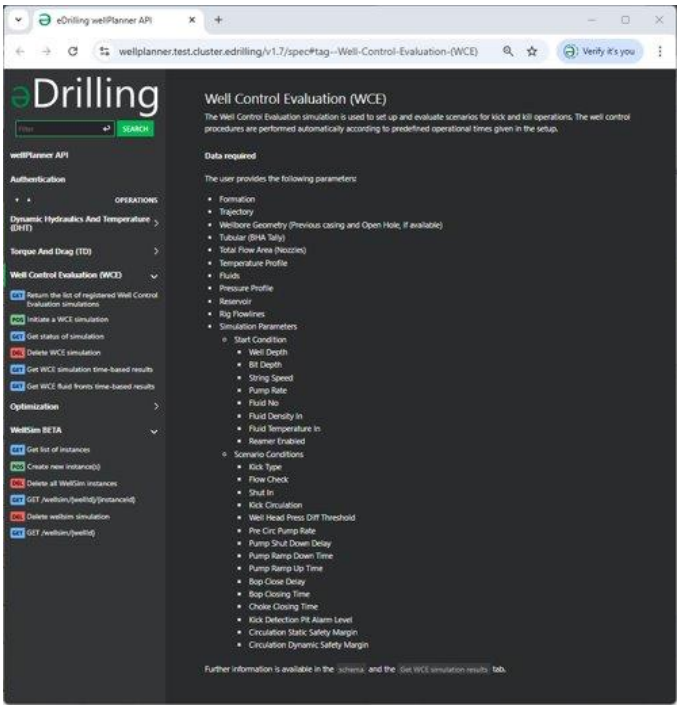


Figure 4 *World first Open API CO_2 well control simulation software (for use inside other software's)*

Conclusions

The Project green light has Milestone deliveries throughout the project period. The following results/deliveries will be presented:

- Kick detection with CO_2 compared to hydrocarbons
- CO_2 compared to Hydrocarbons expansion in open riser
- Closing BOP on a CO_2 flow, pressure and temperature impact
- Kick tolerance, comparing CO_2 with hydrocarbon
- Bullheading CO_2, examples of different well designs (including detection limits)
- Test verification, laboratory vs model (software) Benchmarking results
- Rig crew CO_2 well control Training simulator
- Use-case mapping for well control AI-Agent

Acknowledgements

Acknowledgement to the partners in the project: Equinor, BP, Shell, Baker Hughes, Wild Well Control, Noble, Sintef, Gassnova

References

The following publications and presentations have been done related to project results.

Reference	Name publication/presentation	Event
	Well control for CO_2 wells, risk for CO_2 blowout	WCCUS, Bergen September 2025
	Managing Well Control Challenges in CCS Projects	IADC Well Control Conference, Stavanger October 2024
SPE-217711-MS	CCS Well Control - Impact Of CO_2 On Drilling Fluid Performance	SPE/IADC International Drilling Conference and Exhibition 2024, Galveston March 2024
OMAE2024-128597	Integrity of Drilling Fluid as Primary Barrier for CCS Wells	OMAE, International Conference on Ocean, Offshore & Arctic Engineering, Singapore June 2024
OMAE2024-122640	Assessing Hydrate Formation Risk In Infill CCS Wells	OMAE, International Conference on Ocean, Offshore & Arctic Engineering, Singapore June 2024
SPE-223812-MS	CO_2 Well Control Scenario Prediction Using Experimentally Verified Models	SPE/IADC International Drilling Conference and Exhibition 2025, Stavanger March 2025
OMAE2025-156972	CO_2 Hydrate Inhibition in Drilling Fluid Using Mono-Ethylene Glycol (Meg)	OMAE, International Conference on Ocean, Offshore & Arctic Engineering, Vancouver June 2025