Petroc Technologies Ltd
Enhanced Hydrocarbon Recovery and CO2 Solution

CO2 Leakage Prevention Technique: A Self-Diagnosis and Self-Sealing Method

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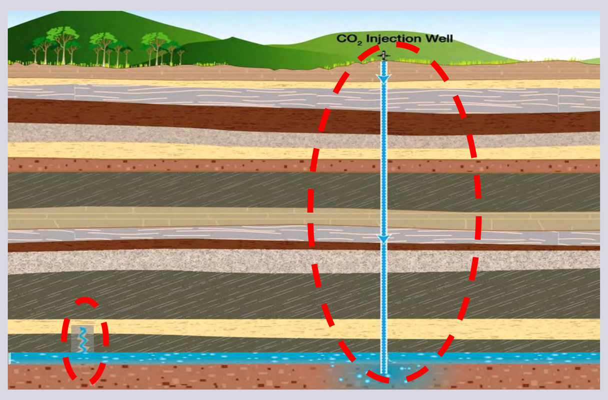
Introduction

One of the concerns for geologic storage of CO2 is that injected CO2 may leak out of the intended storage formation, to other permeable formations underground, or to the atmosphere. Additionally a leak-proof formation can develop leakage over the very large time-scale needed for permanent storage of CO2.



Petroc Technologies, has developed an innovative and unique CO2 leak prevention technique that automatically detects and effectively seal CO2 leaks from both known and unknown leakage paths in geological reservoirs. The sealing process takes place in-situ at the exact location of the leak and irrespective of leakage magnitude or timing. This, compared with other approaches, reduces the need for monitoring and intervention, making it economically a practically attractive option.

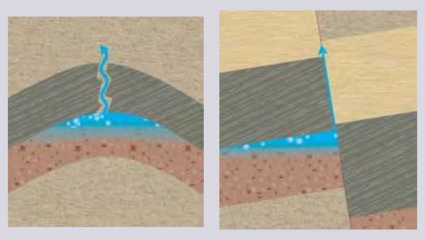


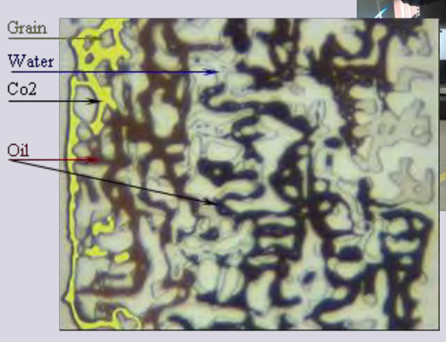
Fig. 1: Some CO2 leakage scenarios. CO2 leak could be due to lack of well integrity or somewhere in the storage site.

We have proved the technology in the Laboratory by performing different types of experiments. We have also developed different models that simulate the technique with results predicting the effectiveness of the technique in the field scale as well as matching the experimental results. There are patents in place protecting the technology.

Petroc Capabilities

Petroc offers a wide range of technical services related to oil and gas recovery and CO2 management including:
- Reservoir conditions core flood facility with in situ-saturation monitoring, performing steady-state & unsteady-state tests,
- Micromodel flow visualisation, core centrifuge,
- Fluid property measurements at reservoir conditions,
- Rock heterogeneity identification using tracer test and x-ray facility,
- Rapid and cost effective prediction of key petrophysical parameters by novel magnetic susceptibility techniques,
- Pore, core and field scale mechanistic modelling and numerical simulations.

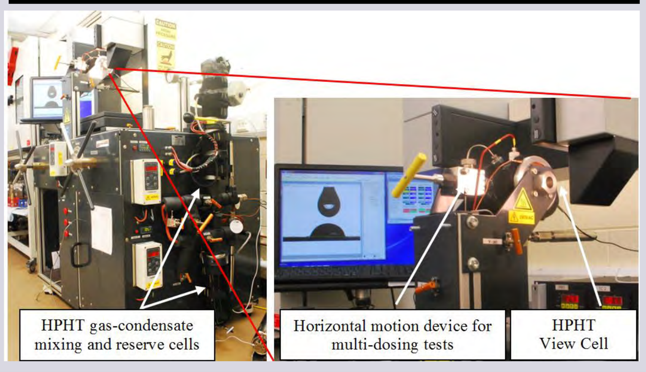
Micromodel set-up



Oil recovery by CO2

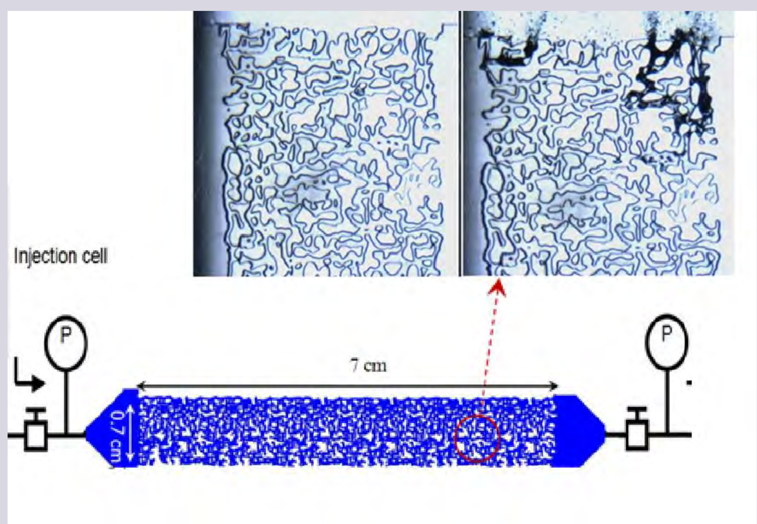
HPHT Reservoir Conditions Core Flood Facilities

HPHT Contact Angle/IFT System



Visualisation Experiments

Two-dimensional (2D) micromodel visualization experiments have revealed the mechanisms (nucleation kinetics, particle growth, particle relocation) involved in precipitation of solutes. These tests also demonstrated that a stable a durable blockage is achieved (Fig. 2). In these tests the impact of presence of water, impurities of CO2 stream and presence of a catalyst to increase the leak prevention response rate were studied.



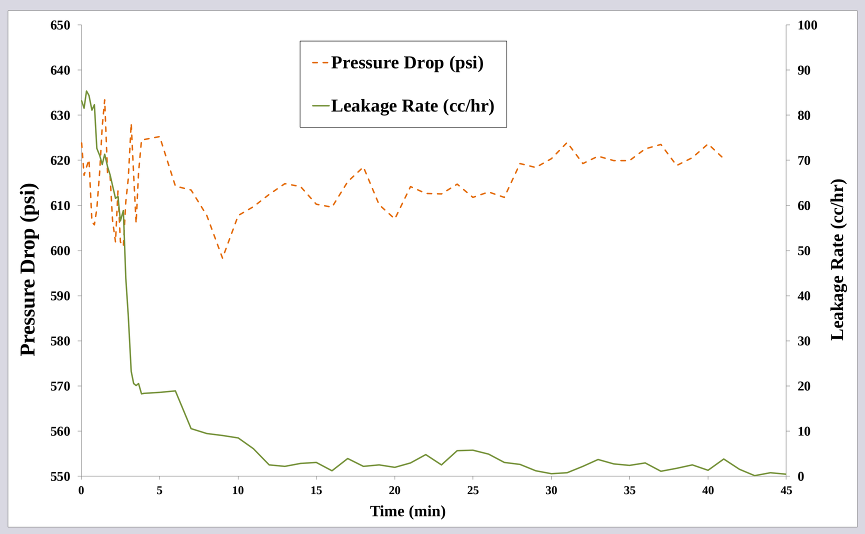


Fig. 2: The full micromodel setup illustrating the MM basic dimensions. The magnified section shows the leakage through a preferential flow path with very concentrated precipitation close to outlet. After a period of time the pressure drop across the system stabilized and the flow rate dropped to zero even after applying the high pressure drop for a long period of time.

SandPack Experiments

Sandpack facility has been used to simulate the response of the method to high leakage rates under low pressure drop scenarios typical of leakage through highly conductive fractures or fissures. It also serves as a reliable tool for fast screening of solutes as formation of blockage is favored in such high flow rate conditions.
Several such tests have been conducted using different solutes and pressure drops.

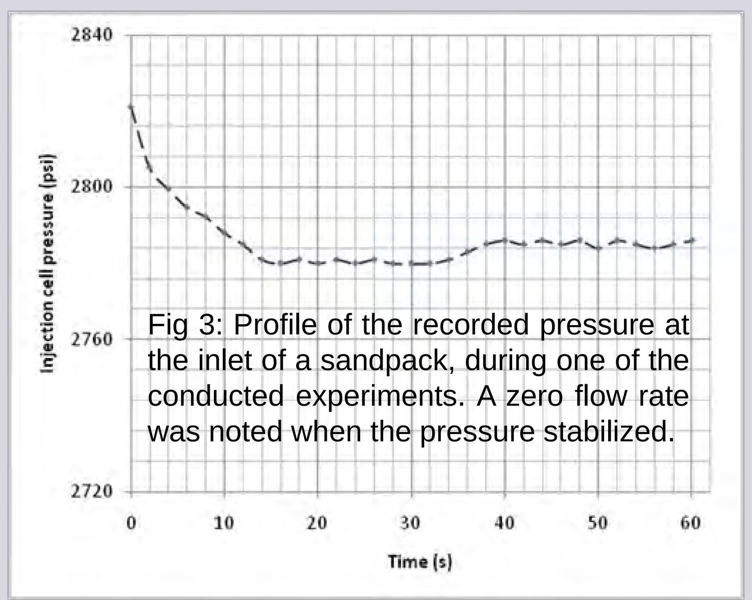


Fig 3: Profile of the recorded pressure at the inlet of a sandpack, during one of the conducted experiments. A zero flow rate was noted when the pressure stabilized.

Coreflood Experiments

Coreflood experiments are carried out for two main purposes; first, to simulate the slow rate leakage scenarios and, second, to apply the technique in real porous rocks.
Figure 4 shows that the out-face of a core has been plugged by the precipitated solid particles during a core flood experiment. At the end of this test, the permeability across the core was zero as demonstrated by the recorded flow rates in Figure 5. The durability of the seal was confirmed under high applied pressure drop and for a long period of time.
Several coreflood tests have been performed under different test conditions. The effect of solute type, leakage rate (applied pressure drop), length and type of the leakage path and presence of a catalyst to increase the blockage formation rate have been examined.

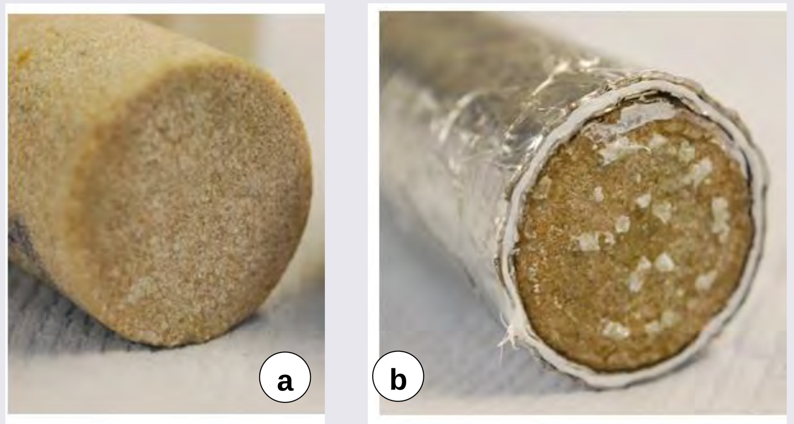


Fig. 4: The outlet face of a core (a) before the experiment and (b) after it has been blocked by the precipitated solid particles during a core flood test.

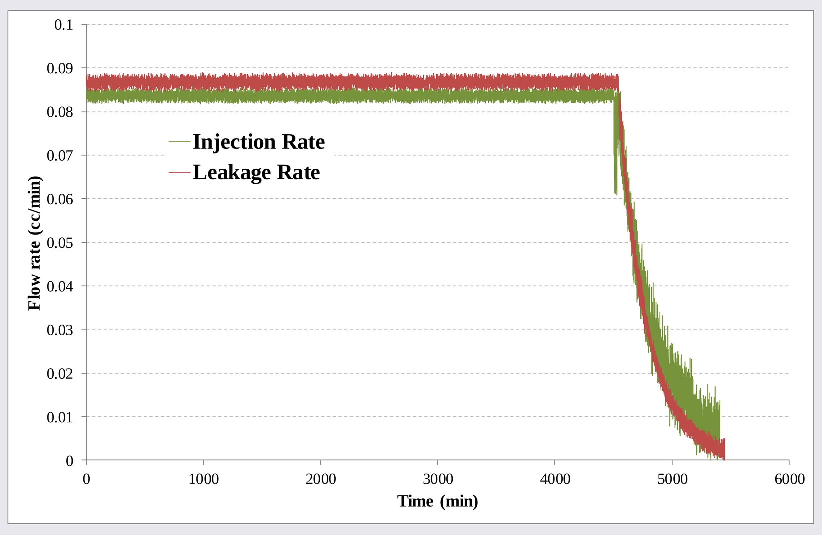


Fig. 5: Recorded injection and retract rates during a coreflood test demonstrating the efficiency of the technique.

Solubility Measurements

Solubility of different solutes in CO_2 was either obtained from the available published data and/or measured in our Lab at various reservoir conditions. These data help us to screen the solutes for a particular purpose as well as being essential for our modelling purposes.

Modelling Verifications

A well-structured modelling exercise provides a more in-depth understanding of the involved mechanisms, increases the confidence in the success of the method and reduces the numbers and types of experiments that are required under new prevailing conditions. A representative model can also be used to perform comprehensive parametric studies identifying the sensitivity of important parameters beyond the ranges tested during the experiments. Hence, to complement and generalize the experimental findings, various mathematical techniques were employed.
Benefiting from over 3-decades of experience and expertise in modelling various phase and flow behaviors processes, an in-house simulator was developed that describes the prevailing mechanisms (the kinetics of particle formation, particle growth and particle re-location) and can predict the efficiency of the technique. Figure 6 shows the predicted permeability profile when simulating the results of a coreflood experiments.
The process was also simulated using a commercial reservoir simulator demonstrating the efficiency of the technique at the feild scale as shown in Figure 7.
In our modelling approach, we have also developed a separate model that simulates the transport of the solute-CO2 solution from wellhead to the bottom hole at the sandface, if this is the preferred injection option. The model determines the solubility profile, which helps us to ensure there is no premature precipitation of the solute within the wellbore.

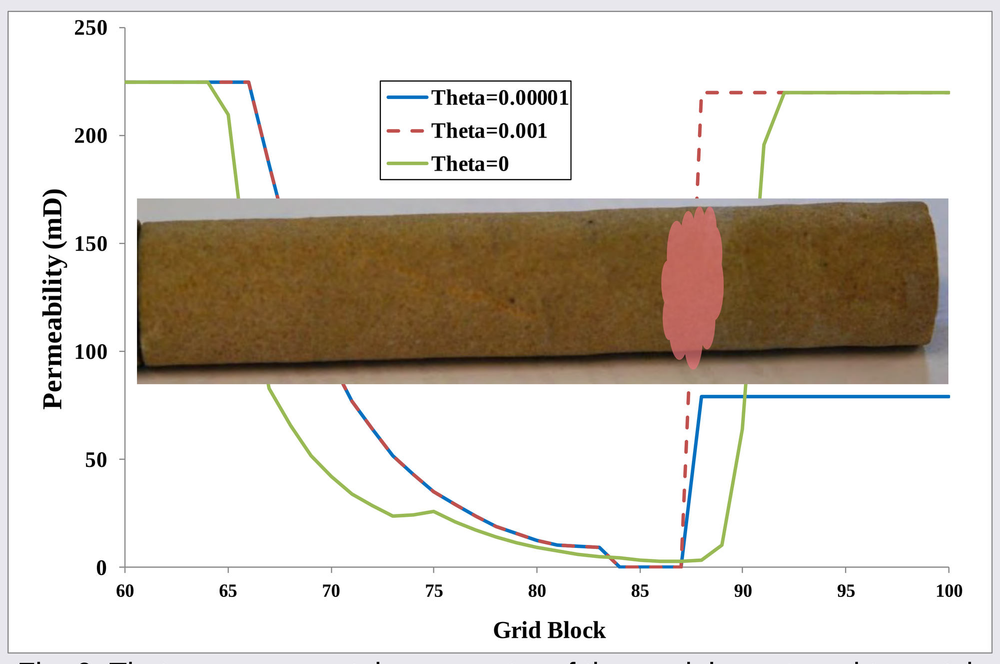


Fig. 6: Theta as an uncertain parameter of the model was tuned to match the mass balance and rate and pressure profiles recorded during the test. The trained model then successfully predicted the results of a number of other flood experiments.

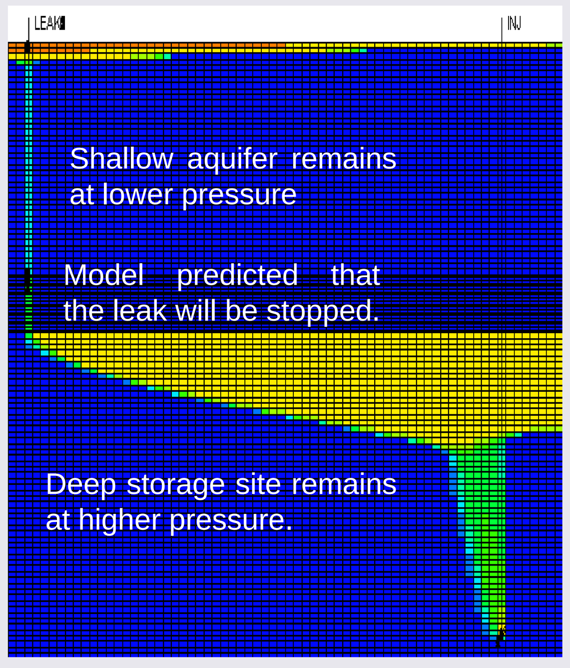


Fig. 7: Simulation of the efficiency of the technique in a leaky storage reservoir using a commercial reservoir simulator.

Awards

Scottish Proof of the Concept Award.
Shell Spring Board Award For Low Carbon Businesses.
Carbon Trust Enterprise Fast Track Award.
Scottish Enterprise Smart Award.

Patents Granted

There is a patent in place in Australia, Canada, Denmark, France, Germany, Ireland, Italy, Sweden, Netherland, Norway, United Kingdom and United States of America.