5th International Offshore CCS Workshop

Liverpool Bay CCS: Technical aspects of CO₂ storing in depleted hydrocarbon fields

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# Liverpool Bay CCS – Storage Sites Overview

<table>
<thead>
<tr>
<th></th>
<th>Hamilton Main</th>
<th>Hamilton North</th>
<th>Lennox</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fluid Type</strong></td>
<td>Wet Gas</td>
<td>Wet Gas</td>
<td>Light Oil (+ gas cap)</td>
</tr>
<tr>
<td><strong>Top Reservoir Depth (ft TVDss)</strong></td>
<td>2270</td>
<td>2590</td>
<td>2450</td>
</tr>
<tr>
<td><strong>Porosity (%)</strong></td>
<td>10-23</td>
<td>10-23</td>
<td>10-23</td>
</tr>
<tr>
<td><strong>Average Permeability (mD)</strong></td>
<td>600</td>
<td>500</td>
<td>2000</td>
</tr>
<tr>
<td><strong>Thickness (ft)</strong></td>
<td>450</td>
<td>500</td>
<td>900</td>
</tr>
<tr>
<td><strong>Initial Condition [P,T]</strong></td>
<td>97 bar, 31.6°C</td>
<td>106 bar, 29.2°C</td>
<td>112 bar, 34.4°C</td>
</tr>
<tr>
<td><strong>Start-up</strong></td>
<td>1997</td>
<td>1996</td>
<td>1996</td>
</tr>
<tr>
<td><strong>Well type</strong></td>
<td>2 Deviated 2 High Angle (+ 2 Explo)</td>
<td>3 Deviated (+1 Explo)</td>
<td>2 Deviated, 4 Horizontal 8 Multi Drain Horizontal (+ 4 Explo)</td>
</tr>
<tr>
<td><strong>RF % (@ YE 2021)</strong></td>
<td>95.2</td>
<td>93.4</td>
<td>89.4</td>
</tr>
</tbody>
</table>
CCS Subsurface Studies Workflow

- Rates/pressures from 3D dynamic model fed to CCS Subsurface Special Studies
- Evaluation of ‘storage complex’ behaviour to evaluate additional constraints on rates/pressures
- Thermal effects evaluated within each specialistic study
- Continuous iteration until no more constraints emerge from special studies outcomes
Flow Assurance

- **Flow Assurance studies objectives:**
  - Define process units and equipment to guarantee the transport within the system design constraints ($\min_t BHT = 4 \degree C; \max_t P_{flowline}$)
  - CO$_2$ behaviour across the system (from gathering point up to the storage units)

- **Technical aspects**
  - Parallel storage unit filling
  - Linking 3D dynamic model with flow assurance simulations
  - Low-P/Low-T reservoirs

- **Main outcomes**
  - Paired Flow Assurance – 3D Reservoir model
  - Surface equipment design to honour project injection rates
  - BHT safely above the limit for all the wells involved
Cap Rock Integrity

- Evaluation of cap-rock stress field under CO₂ injection via 1D analytical models
- Dataset comprising of core (2020 experiments) and log data (DTC), integrated with literature (thermal rock properties).

**Main outcomes**

- Reservoir repressurization path below the minimum horizontal stress envelope
- Injection partitioning sustainable
Thermally Induced Fracture

- Cold fluid injection into a warmer formation induces an alteration of the stress state
- Methodology standardisation w/ full integration of multiple data sources
- Technical challenges
  - Low-P, Low-T formations
  - Compositional 2D radial thermo-hydro-mechanical model: identification of a suitable numerical code

Main Outcomes
- Near-wellbore stress and temperature distributions
  - Effective stresses positive for the whole duration in each storage complex
  - Limited cooled front extension during injection operation
- No risk of tensile failure occurrence
Geochemistry (1)

- **Geochemical studies objectives:**
  - Trapping mechanism identification
  - $\text{CO}_2$ – triggered minerals dissolution/precipitation
  - $\text{CO}_2$ – induced near wellbore dry-out effects (salts precipitation) due to $\text{H}_2\text{O}$ vaporization (stripping)

- **Technical aspects**
  - Mineralogy and chemistry: formation data retrieval and experimental analysis
  - Main physical phenomena determination
  - Numerical code identification to couple fluid-dynamics and geochemistry

Main Outcomes

- Negligible CO$_2$ mineral trapping
- Limited reactivity of caprock lithology
- No threats to well injectivity recognized
Fault Stability Analysis (1)

Scope

To calculate the effective stress alteration on faults and to assess the rate partition avoiding any potential slippage occurrence.

Geomechanical Finite Element model

Faults geometry from the structural model

Dynamic Model outcomes

Stress projection on the fault surface to evaluate normal ($\sigma_n'$) and shear ($\tau$) components

$$ST = \frac{\tau}{\sigma_n'}$$

High ST Area (NO slip for $ST < \mu$)

Slip Tendency (ST) computed on fault surface at different times (t)
Main Outcomes

- 40+ faults analyzed across three storage units
- ST at the injection end ($ST_2$) always lower than initial fault ST ($ST_0$)
- No critical faults emerge from the fault stability analysis, so the risk of induced seismicity is negligible
Fault Seal Analysis

**Fault Seal Analysis study purpose**
- Validate initial contact depths
- Determine maximum CO\textsubscript{2} column height via deterministic and probabilistic approach
- Quantify maximum sustainable pressure at fault level

**Technical aspects**
- Methodology derived from exploration trap evaluation
- Low-P and Low-T formation: CO\textsubscript{2} IFT properties

**Main Outcomes**
- Deterministic and probabilistic determination of CO\textsubscript{2} column height evaluation
Conclusions and Way Forward

- For Liverpool Bay CCS project, the storage complex and FFD plan are de-risked by an extensive and robust subsurface database and by a developed suite of 3D modelling and CCUS special studies (geology, reservoir engineering, geomechanics, geochemical etc.)

- To date studies confirm the suitability of Hamilton Main, Hamilton North and Lennox to securely store at least 109 MT of carbon dioxide (base case); no criticalities are recognized.

- Some activities are ongoing/planned aiming to fully de-risk both CO₂ conformance and containment risks; study results will be included in the developed models
  - Bathymetric and 3D high resolution seismic (for overburden characterization)
  - Sedimentological study on Mercia Mudstone Group
  - Laboratory experimental studies
Thank you for your attention