SECURe
Subsurface Evaluation of CCS
and Unconventional Risks

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GOOD PRACTICE AND RISK MITIGATION
FACTSHEET #1

Carbon capture and storage:

Release of CO_2 at pressure from a well during injection

SECURe employed the Bow Tie risk assessment approach, which identifies a series of barriers that prevent a principal hazard ("top event") from occurring. This factsheet outlines recommendations, which address a single top event that can occur if control of a hazard is lost: release of carbon dioxide (CO_2) at pressure from a well during injection. It should be read in conjunction with the Participatory Monitoring Factsheet, which provides overall guidance on project construction.

The issue

Although unlikely, the potential release of CO_2 at pressure from a well must be fully assessed in all CO_2 storage projects. Such releases could result in CO_2 emissions to the atmosphere and/or impacts to ecosystems and people. Release via the well annulus could arise through the use of production wells that have not been adequately repurposed for CO_2 injection, or poor-quality and/or degradation of well engineering barriers. Well engineering assessments, appropriate material selection and monitoring provide effective barriers to prevent CO_2 release. If release were to occur, then remediation options include monitoring, operational responses, well engineering interventions, and the use of natural geological properties to slow the release. These barriers, and preventive and remedial actions are discussed in detail in the SECURe report BGS-01-R-12.

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GOOD PRACTICE REPORT

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Risk mitigation recommendations

Maintaining borehole integrity

- Operators should use **cement formulations that minimise shrinkage**, when possible. Cement shrinkage can significantly increase the probability of failure for the CO_2 injection well. Appropriate cement properties and operating conditions can be selected to reduce well failure risks by using the modelling and relationships demonstrated in D2.6. Cement formulations that lead to softer, more flexible (i.e. more ductile) cement are recommended.
- Relationships between cement properties and the impact on (1) shear cracking and (2) cement debonding (for both the formation-cement and casing-cement interfaces) and caprock leakage can help with the **design of appropriate leakage management scenarios** (D2.6). Under the right conditions, re-purposing existing wells for CO_2 injection can be done with minimal damage to the cement provided well status is known and cement properties are well-characterised.
- **Reducing the temperature shock of the cold CO_2** is the most effective way to reduce failure risks (D2.6).

Monitoring approach

- **Adaptive monitoring** is required from baseline characterisation for operational and post-operational stages of the life cycle, in order to detect any contamination events (D3.6).
- **Thresholds should be set** for hydrochemical parameters that could indicate contamination in the future (D3.6). Thresholds should be established using the environmental baseline data to calculate concentrations of parameters that would indicate excessive natural temporal variation.

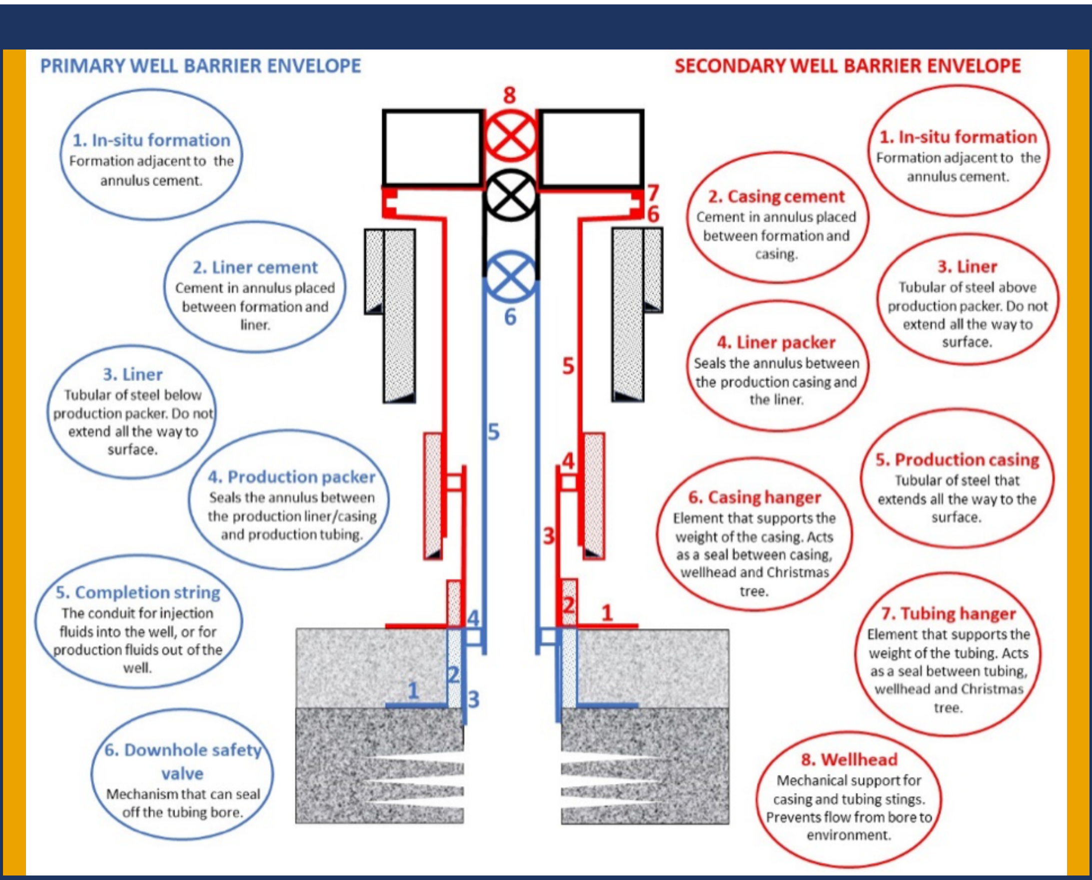

Figure 1: Simplified illustration of well barriers for a typical active CO_2 well. Primary well barrier envelope in blue and secondary well barrier envelope in red (from D5.3).

Risk mitigation recommendations (cont.)

Use of models

- **A probabilistic approach to assessing well integrity should be taken, with the goal of minimising the probability of failure.** Assessments should also provide information that will aid the communication of uncertainty in forward modelling. Research reported in D2.6 suggests that uncertainty in parameters relating to reservoir and cement characteristics can be reduced via laboratory experiments. These can test cement integrity for realistic stress states and well materials and also assess operating limits for well pressure to prevent fracturing of the cement sheath. Microannuli, or small gaps, along the well and radial fractures emanating from the casing through the cement should be considered in leakage mitigation strategies. Individual fractures may dramatically increase the leakage risk but fracture networks do not necessarily lead to a continuous, high-permeability path along the wells.
- **Effective modelling of the CO_2 containment system** should include model forecasts of well integrity. These should be based on a thorough understanding of controlling processes associated with CCS operations (D2.6). Numerical geomechanical well leakage modelling can be used to quantify the probability of well failure for a range of scenarios applicable to well re-use and new well applications.
- **Developing a risk assessment** specifically tackling the potential for catastrophic failure (e.g. well blowout) should be developed early in the project to guide site works (see D6.8).

Development of technology

- **"Remediation chemistry" should be considered as a measure** to reduce fracture permeability in and around CO_2 injection wells and the cement sheath (D5.5). This could include novel fluids that lead to mineral precipitation or polymerisation reactions ($CaCO_3$ and magnesite) when in contact with leaking CO_2.

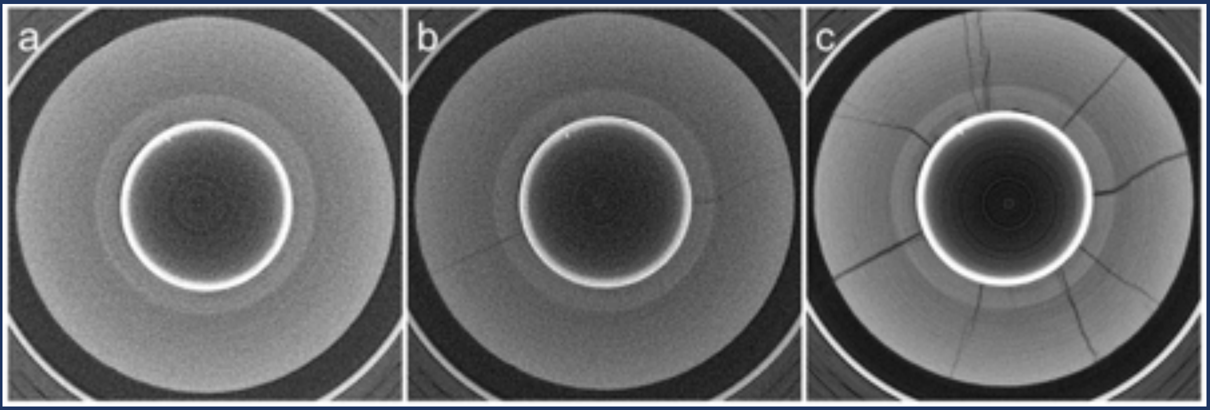

Figure 2: Well integrity: experiments show the development of fractures in the cement sheath at different casing pressures. Fractures could represent potential leak paths from the wellbore.

Detailed description:
Cross-sectional CT images of borehole cement casing taken at the same position along an experimental cell (close to the bottom of the sample), at various stages of casing pressure application: (a) casing pressure of 200 bar before fracturing occurred, (b) at 300 bar - the occurrence of the first fractures of casing pressure, and (c) cycling between 100 bar and 300 bar with CT scanning performed at 300 bar.