
Application to CO2 injection phase

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IEAGHG Well bore Integrity network
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Summary

Introduction

*Context of the study: issues for the operator*

*Purposes of the study*

Key steps of the study, main results and recommendations

*Risk assessment*

*Risk management*

*Decision support*

Conclusions

*The case study – What was achieved?*

*Operator assessment*
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Introduction: Context & Issues

- An Oil & Gas company interested in EGR by injecting and storing supercritical CO2
- The company wants to choose 3 wells out of 9 that could be suitable for conversion into injectors
- Use the well integrity as one of the criteria for the decision

OXAND & Schlumberger performed in partnership a Performance and Risk assessment (P&R™) of well integrity over the injection phase.
Introduction: Purposes of the study

On the basis of existing and available data, the general goals were:

- To propose a risk mapping for each of the 9 wells vs. potential CO2 leakage over the injection phase

- To understand the impact of variables on risk levels and identify sources of risk (e.g. contributors to CO2 migration along injection wells)

- To identify and prioritize actions for risk mitigation in terms of cost/benefit

- To use the risk as a decision criteria

- To find out 5 best wells for conversion, and to be able to justify the choice
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Well Integrity Management Workflow

Data collection
- Cement logs
- Drilling reports
- Geological profiles

Cement degradation
Casing corrosion
CO₂ migration
Initial and limit conditions

Dynamic model
- Aggressive agent concentration
- Portlandite dissolution

Well Integrity Management Workflow

Recommendations
1. Characterization/Inspection
2. Design recommendations
3. Operational recommendations
4. Monitoring recommendations

CO₂ leakage mass and probability

Risk mapping
Severity
(Consequence grid)

Best practices
Construction of static model
Wellbore: geology + well

- Geology in the wellbore environment
  - Geological formation
  - Position of aquifers
  - Pressure, temperature, fluids, ...

- Well parameters
  - Wellbore
  - Casing location and properties
  - Cement sheath geometry and properties
  - Plugging strategy

- Initial degradation
  - After 30 years of gas production
Cement degradation

- Initial state
- Cement leaching
  - Kinetics: \( e(t) = a\sqrt{t} \)
  - Permeability increase

Steel degradation

- Generalized corrosion
- Pitting corrosion
  - Kinetics: \( e(t) = b.t \)
- Annulus formation, ...

Casing erosion

- Depends on:
  - Fluid flow
  - Fluid composition, ...
- Decrease in casing thickness
Dynamic model
Degradation mechanisms & fluid transport

**Transport**
- Gas migration
- Porosity
- Capillary pressure, ...

**Micro annulus**
- Effect of
  - Thermal stress
  - Mechanical stress
- Debonding of cement

**Dry out**
- Depends on:
  - injection parameters
- Degradation of cement
  - Decrease in permeability
Simulation of gas migration along the wellbore

- **Selection of scenarios to assess risk level**
  - Combinations of well components in a certain degraded state
  - With an associated probability

- **Simulation of scenarios in SIMEO-STOR™**
  - Evaluation of well components degradation over time (30 years)
  - Gas migration during the injection period?
How to quantify the risk?

Risk = frequency x severity

- Frequency = probability of a scenario to occur
  - Frequency grid
- Severity: impact on defined targets (based on simulation results)
  - Consequence grid

Severity assessment

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<td>6</td>
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Frequency of scenarii

<table>
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<th>Min probability</th>
<th>Max probability</th>
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<td>6</td>
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</table>

(Example of risk mapping)
The consequence aims at gathering stakes involved in the project to evaluate the consequences of well integrity failure

- The stakes illustrate the responsibility of the corresponding stakeholder
- The severity level translates the magnitude of a failure

Example of stakes identified:
- Safety of people
- Pollution: air, aquifers
- Know-how
- Public opinion
- Financial (OPEX)
Define “acceptable” level of risk
- Input from the methodology user

Risk treatment achieved by
- Decreasing frequency level and/or
- Decreasing severity level

(Example of risk mapping)
Risk mapping of the 9 wells

Risk quantification

- Minimum criticity
- Maximum criticity
- Risk associated to parameters not taken into account in the model
Acceptable level of risk

Acceptable criticity level set to 7

Selection of 5 wells:
- 1st rule: well(s) with risk level equal or lower than 7
- 2nd rule: wells with maximum risk the closest to 7
  - ➔ Action to manage risk level of selected wells

![Diagram showing criticality values and acceptable risk level]
Recommend relevant actions that contribute to ensuring the acceptable level of risk for each well selected

That will clarify the uncertainties associated to the well integrity

That will treat the risk sources

Operational response: decisions tree...
Example of decision tree applied to risk treatment

Clarification of uncertainties

Workover & design actions

Operation & monitoring actions
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What was achieved?

- Use of a risk-based approach as a criterion for decision support for conversion of wells
  - Quantitative risk assessment

- Among 9 wells, 5 candidates were proposed for conversion into injectors
  - Justification / Demonstration of selection

- Actions for risk management were proposed
  - Prioritization
  - Operational response for the operator
Operator assessment

- A good overview of well integrity before and at the end of the injection period vs. uncertainties

- The consequence grid
  - The operator is able to relate a well integrity failure to a severity level (no questioning)

- The risk level as an objective metric for the project

- Demonstration / Justification of decisions
  - To the top management prior to apply any action