Active CO_2 wells: Leakage & Remediation

In order to maintain well integrity two independent well barriers shall be present at all times – this is the essence of the "two-barrier principle" from the NORSOK D-010 standard. In other words, each well barrier can be seen as a chain of connecting well barrier elements (WBE) i.e. well components such as formation, cement, packer, tubing, casing, valves etc. that constitute a well barrier envelope. There shall be at least two such independent well barrier envelopes in the well, the primary and secondary envelope, respectively, and these should not have common well barrier elements. The primary (blue) and secondary (red) envelope are illustrated in Fig.1. The main elements in the primary envelope are: (1) formation, (2) annular cement, (3) liner, (4) production packer, (5) tubing, (6) downhole safety valve. The secondary envelope contains: (1) formation, (2) annular cement, (3) liner, (4) liner packer, (5) production casing, (6) casing hanger, (7) tubing hanger, (8) wellhead/X-mas tree with valves. In addition, some possible leak pathways due to WBE failures in an active CO_2 well are indicated: internal – within the well, or external – which may reach the surface.

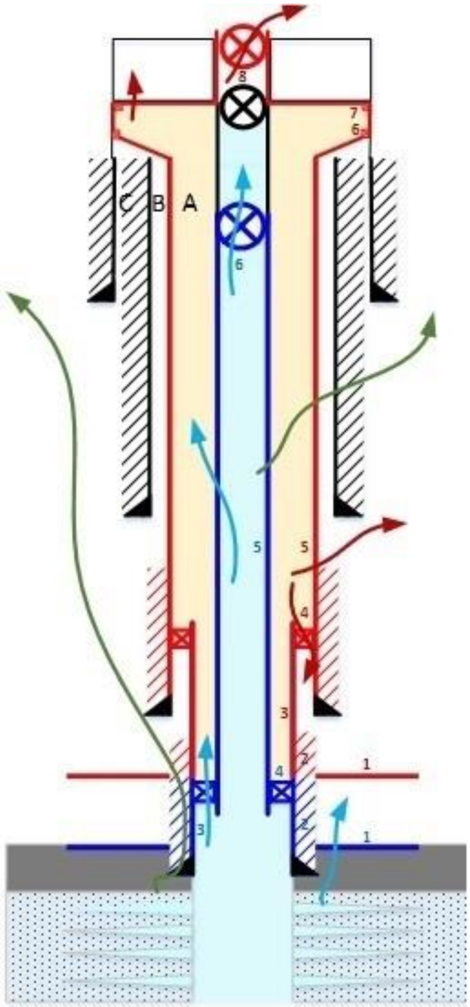

Figure 1: Schematic illustration of some possible leak pathways due to WBE failures in an active CO_2 well. Blue arrows show failure of primary well barrier envelope, red arrows show failure of secondary well barrier envelope, and green arrows show failure of multiple WBEs.

Wells are generally considered to represent the highest risk of leakage in a CO_2 storage project. Such leakages are caused by failure of one or more well barrier elements; otherwise the well integrity would be intact. An overview of causes and consequences of the main WBE failures in active CO_2 wells is listed in the Table 1. Ageing issues with cement degradation, casing corrosion and wear, and thermal loads imposed on the well infrastructure are examples of the most likely causes of well leakages. The tubing is the WBE that is by far the most likely to fail, probably due to corrosion and/or connection failures. Also the casing and the cement have a significant chance of failure.

Well Barrier Element	Causes	Consequences
In-situ Formation	Drilling-induced damage, fractures, poor bonding to cement	Fracture propagation through formation or along wellbore, may cause surface leak
Annular Cement	Mud or gas channels, microannuli, cracks	Loss of zonal isolation, pressure build-up, migration of fluids upwards
Tubing	Corrosion, erosion, fatigue, connections failure	Pressure build-up in annulus A
Casing/Liner	Corrosion, wear, collapse due to pressure, connections failure	Pressure build-up in several annuli
Downhole Safety Valve	Material degradation, corrosion	Loss of sealing ability or loss of functionality
Packer	Chemical or thermal degradation, poor sealing to damaged oval casing	Loss of sealing ability, pressure build-up in annulus above packer, or downwards fluid migration
X-mas tree	Corrosion, fatigue, poor initial design	Leakage into the environment and to the surface, if primary barrier fails

Table 1: An overview of causes and consequences of the main WBE failures in active CO_2 wells.

A wide range of technologies and methods from the O&G industry are available that can also be used for the remediation and mitigation of leakages from CO_2 wells, for example:

- Squeeze cementing - pumping cement slurry into an isolated target interval through perforations in the casing/liner to repair the primary cement job or casing/liner leaks.
- Casing repair: patching, expandable casing, welding, replacement.
- Sealant technologies for zonal isolation: pressure- or temperature- activated sealants, polymer-based gels, smart cements.

The available remediation technologies from the O&G industry will be reviewed and evaluated towards their application to CO_2 wells. As future work a number of laboratory tests are planned to examine the merits of new materials for remediation of well leakage. These materials include CO_2-reactive suspensions, polymer-based gels, smart cements with a latex-based component and a polymer resin for squeezing. If feasible, the efficiency of a CO_2-reactive suspension will be investigated in a field test at the Serbian Bečej natural CO_2 field.

Jelena Todorovic
Research Scientist
SINTEF Petroleum Research
March 25, 2015