NATIONAL PLATFORM FOR RE-USE & DECOMMISSIONING

Technology Qualification of Through Tubing Cementation (TTC) for the P&A of wells

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Jules Schoenmakers, Nexstep
on behalf of TTC Task Force Nexstep
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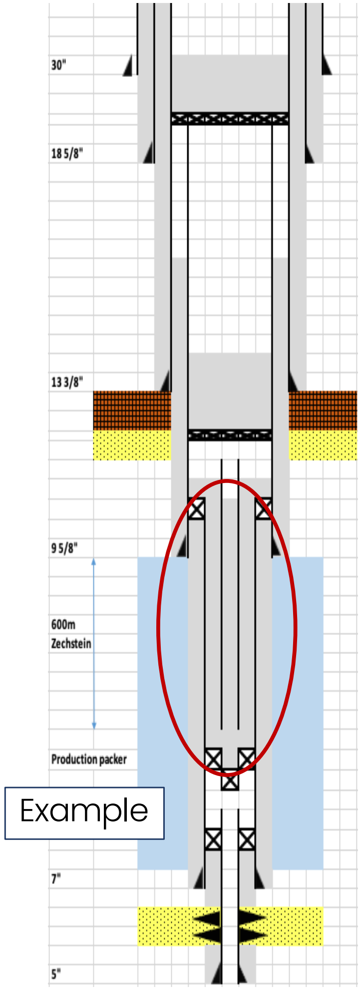


Synopsis
Through Tubing Cementation (TTC)

Technical description

- Cement tubing and A-annulus. Long cement plug.
- Used by many worldwide, incl. Netherlands in the past

Advantages:

- Faster, more efficient, less risk. Can be done rigless.
- Safer: pressure containment preserved
  Less work scope, less exposure, less handling
- Environmentally better:
  Less waste, less transport, less emission (CO2, N2), less Norm
- Complies with Dutch Mining Regulations

However:

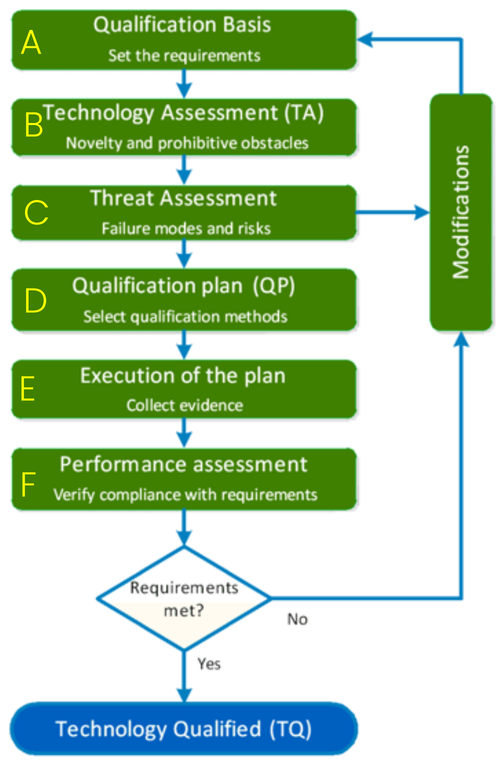
Authorities rejected TTC due to concerns of
(i) sealing quality, and
(ii) NORM*

Authorities proposed a Technology Qualification,
e.g. as per DNV-RP A203

*NORM not covered here

DNV-RP A203 standard used for TTC

- Technology Qualification methodology is a structured assessment, specified in industry standard DNV-RP-A203, see flow chart.
- Basically, it documents:
  - specification of the application envelope (A)
  - identification of key failure modes (C)
  - testing focussed on the key failure modes (E)



A Technology description,
Functional requirements
Performance targets (regulatory, industry, society)
Application envelope (see next slide)

B Components, elements, novelty
Sealing cement inside tubing, Sealing cement in annulus, Tubing, Casing
Execution technologies
Most aspects of TTC are 'proven' technology in a 'known' application.
Some aspects of TTC categorised as 'limited field history' in The Netherlands.

A Environment of use : Applications Envelope

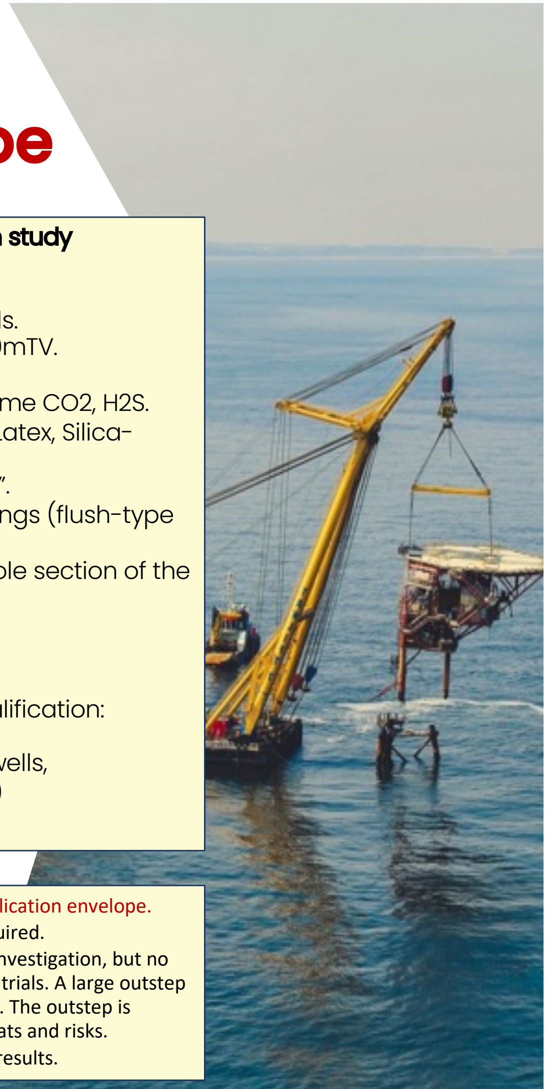
Ref	Candidate screening: Required Well Characteristics
1	Absence of Sustained Casing Pressure or flow from formations below the TTC Isolation. Remediation will require tubing to be removed.
2	Sealing casing annuli within caprock at TTC barrier depth interval.
3	Wellbore access for wireline tools to planned depth of TTC isolation
4	Absence of deep electrical or hydraulic lines at planned depth of TTC isolation, and no velocity/capillary strings in the tubing.
5	Production packer (or equivalent) has been set below or opposite the cap rock. Ability to place at least 200 m cement in annulus to mitigate contamination of cement slurry.
6	Acceptable/confirmed tubing integrity and mechanical plug rating adequate for TTC. Note: a gaslift completion requires special attention.
7	Acceptable/confirmed A-annulus integrity and rating of packer and mechanical plug adequate for TTC placement.
8	If NORM present, ability to place at least 27.5 m cement between tubing stump and geohydrological basis (below level of moving groundwater)
9	Ability to perform a meaningful verification of the location and quality of the TTC Isolation

Assumptions for Technology Qualification study

- Oil and gas production wells.
- Water-injection and observation wells.
- Depth range 100-5000mAH, 100-4000mTV.
- Inclination 0° to 20°.
- Reservoir fluids: oil, gas, brine, with some CO2, H2S.
- Cement slurry type: Portland based, Latex, Silica-blend (incl. expansion additives).
- Tubing diameter from 7-5/8” to 3-1/2”.
- Tubing with upset connectors/couplings (flush-type connections excluded).
- Single completion string along the hole section of the barrier.
- Casing diameter 10-3/4” to 7”.

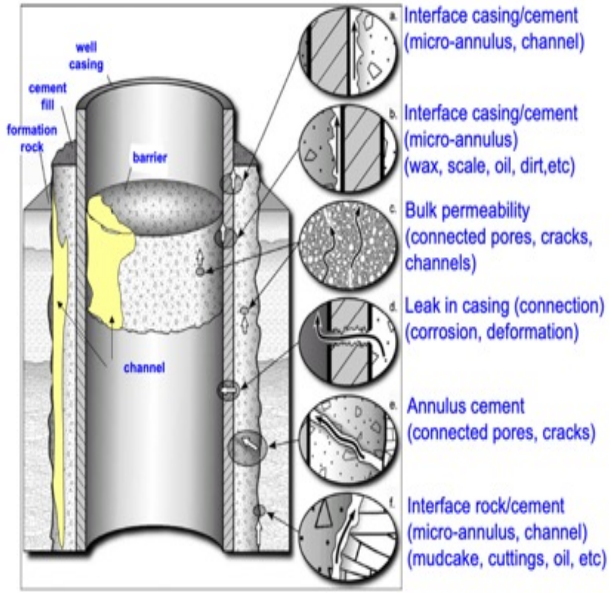
Not considered in this Technology Qualification:

- HPHT wells (>10k psi or >120degC)
- Geothermal, salt mining, and water wells,
- Wells for CO_2 injection (CCS projects)
- TTC materials other than cement



TTC may very well be suitable for wells outside the application envelope.
Additional trials with extended verification may be required.
A small outstep from previous experience requires an investigation, but no trial. A medium outstep requires one or two successful trials. A large outstep requires several successful trials to build a track-record. The outstep is determined by a novelty assessment and a review threats and risks.
The Technology Qualification can be updated with the results.

C Threat Assessment : failure modes and risks



A. Incorrect location

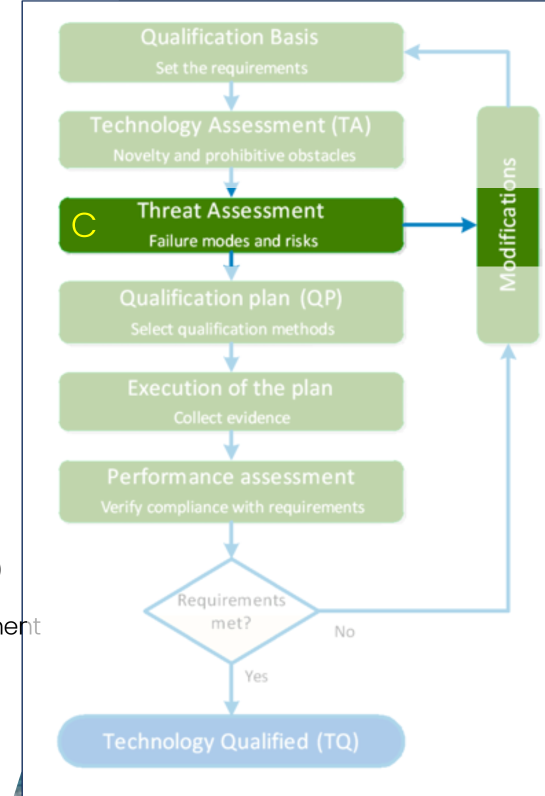
The TTC barrier is not placed opposite a suitable caprock:
1. Top of isolation is below caprock, flow through formation
2. Bottom of isolation is above caprock, flow through formation
3. Isolation moves to an incorrect position over time

B. Incorrect length

The TTC barrier length is not as required by the DMR (50m/100m):
1. Length is insufficient inside tubing
2. Length is insufficient outside the tubing
3. Length changes over time

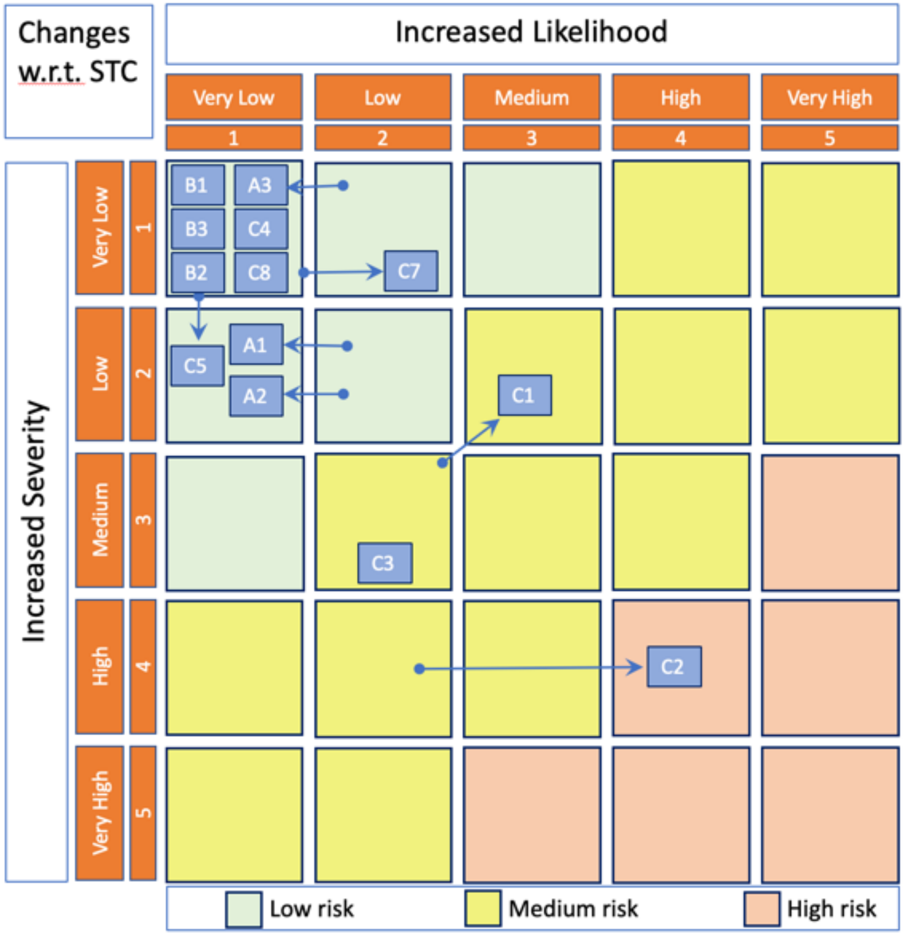
C. Leakage through the TTC barrier

Possible pathways for fluids passing through an incomplete seal
1. through micro-conduit (up/down) due to shrinkage,
2. through a conduit due to partial displacement
3. through a conduit due to free-water
4. through hard cement
5. through deteriorated steel (corrosion)
6. through deteriorated cement (corrosion, cracks, mech loads)
7. through deteriorated scale (dissolution)
8. through non-sealing components that pass through the cement

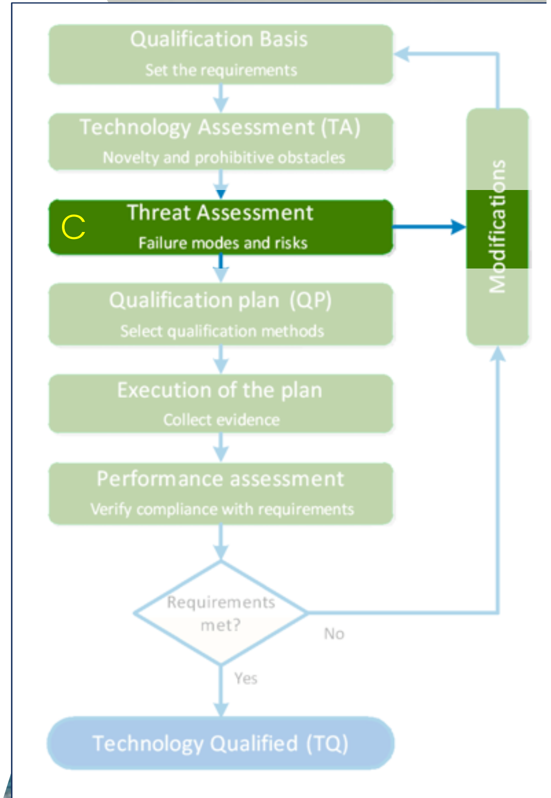


The Technology Qualification provides tables for every failure mode with consequences and risks.
It also identifies underlying causes and possible mitigation measures.

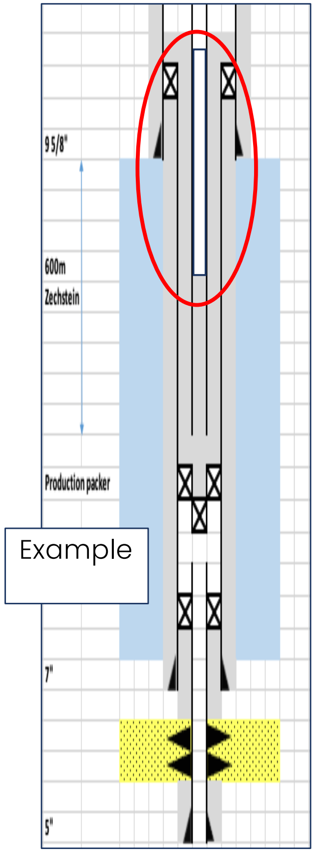
C Risk Assessment of failure modes
(relative to STC technology)



	Legend: Risk TTC vs STC
A1	Top of isolation is deeper than bottom of caprock
A2	Bottom of isolation is shallower than caprock
A3	Isolation moves to an incorrect position (over time)
B1	Length is insufficient inside tubing
B2	Length is insufficient outside the tubing
B3	Isolation moves to an incorrect position (over time)
C1	Through microchannel (up/down) due to shrinkage
C2	Through a channel due to poor displacement
C3	Through a channel caused by free-water in slurry
C4	Through hard cement
C5	Through deteriorated steel (corrosion)
C6	Through deteriorated cement (corrosion, cracks, mech loads)
C7	Through deteriorated scale (dissolution)
C8	Through non-sealing components that pass through the cement (plastics in cable)



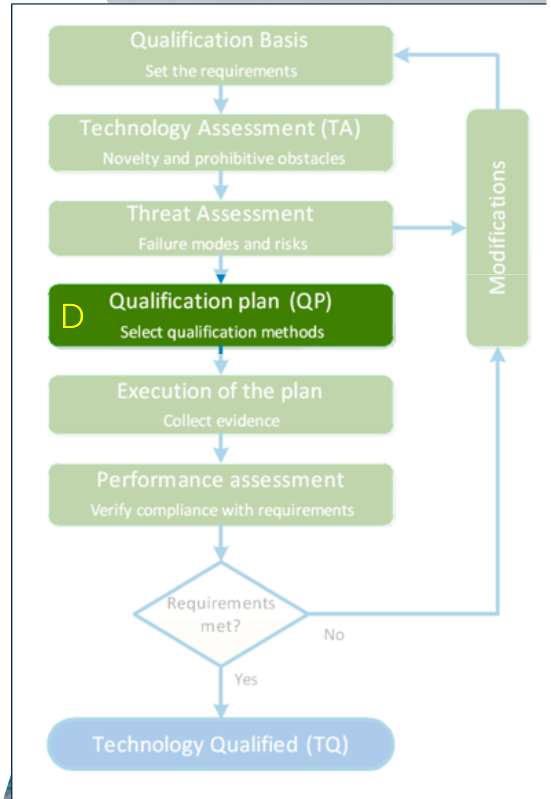
D Qualification plan for threats C2 & C3



Methods to ascertain that a seal exists in the annulus

Over-displace cement, then use:

1. Logging to indicate TOC and acoustic bond to casing
2. Pressure test through perforations to measure permeability
   (Communication test; Perf/Test; Vertical Interference Test)
3. QA/QC form
   (Quality assurance linked to the design and execution process)
4. Long term monitoring of pressures
   (little value, but often easy if time allows)



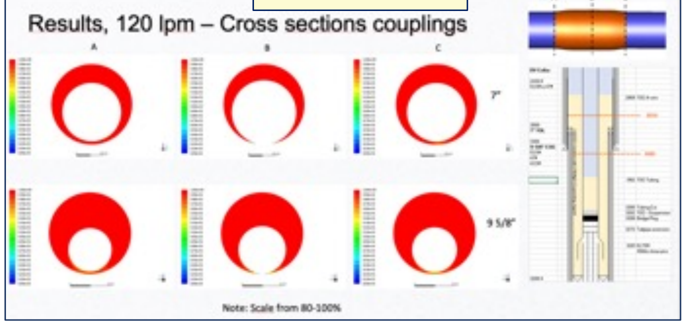
E Execution of the Qualification plan

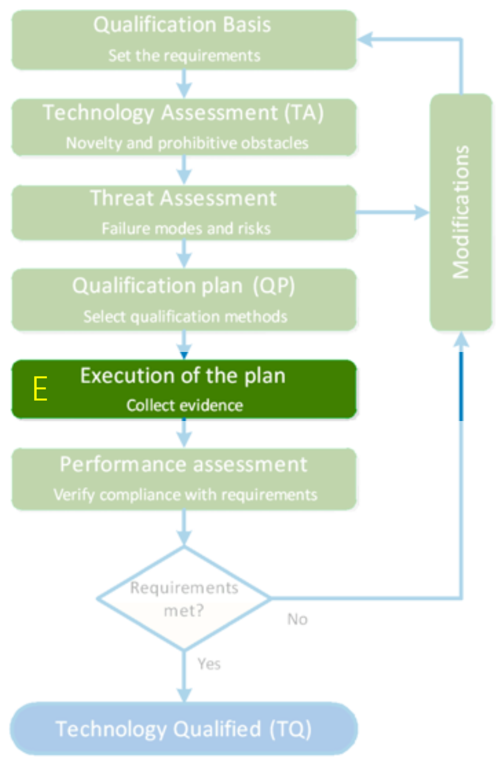
14 trials have been conducted

- Different geometry
- Different cement slurries
- Different flow rates
- Different stand-off
- Most low inclinations
- With/without agitator
- All with fluid separation darts

❖ The jobs have been simulated with state-of-the-art CFD simulations
❖ Every trial described in the document with particular learning

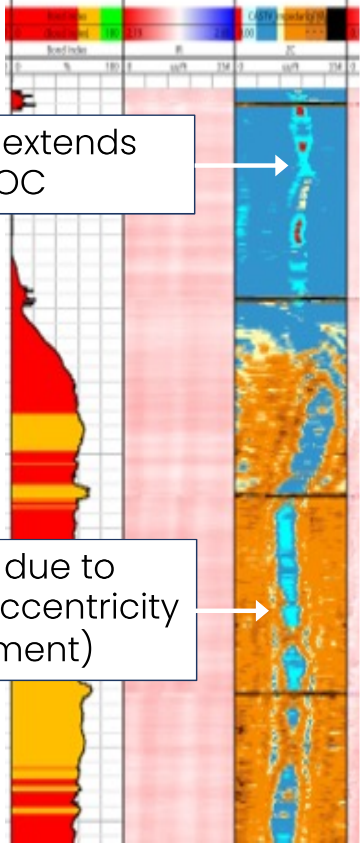
CFD simulations





E Ultrasonic logs not suitable for cemented eccentric pipes

Log TTC trial B

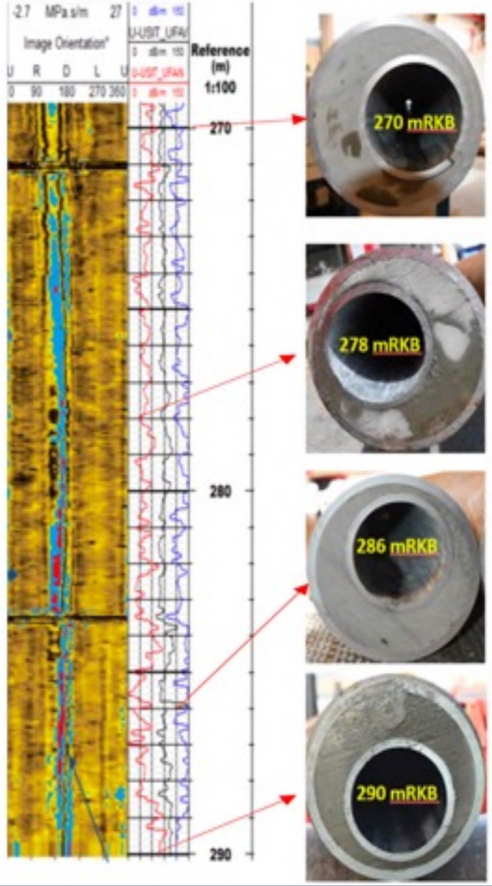


Artefact extends above TOC

Artefact due to tubing eccentricity (thin cement)

Cement log compared to retrieved pipe

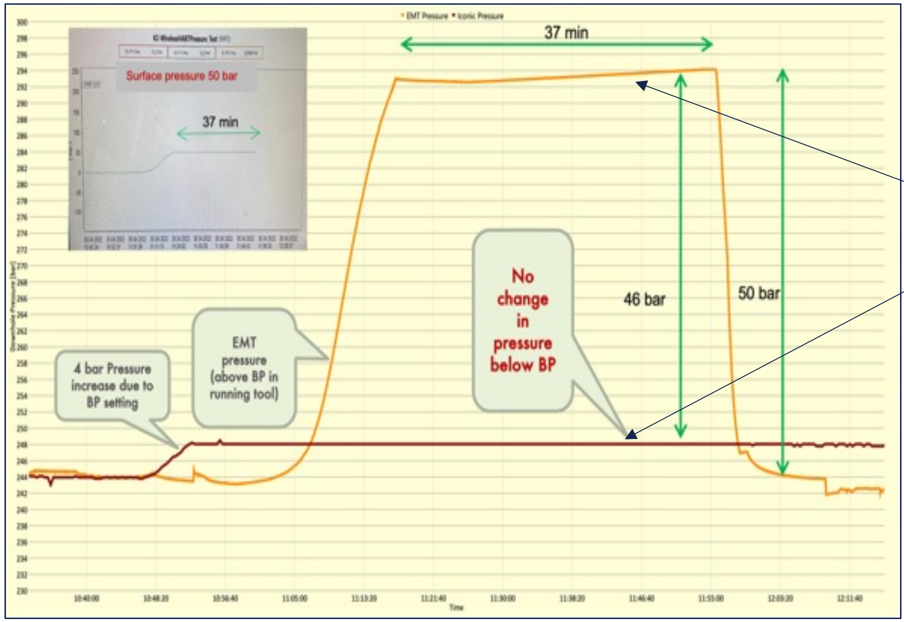
- Test a P&A technique for a specific well at Ullrigg Test Center, Stavanger (NORCE)
- Installed 6-5/8” tubing inside 10-3/4” casing. Inclination 8 degr.
- Perf’ed & Washed 260-297m
- Cemented with 1.9 s.g. Portland
- WoC 27 hr (~200 psi compr. strength)
- Drilled out inner cement at 18m/hr
- Log annulus with Isolation Scanner
  -> Good cement with apparent channel
- Pipe recovered and sectioned
  -> Visual inspection shows no channel and good cement
- Thin cement affects log signal, artefact referred to as galaxy pattern.

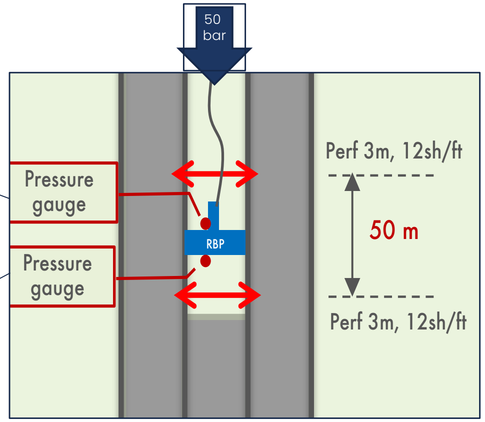


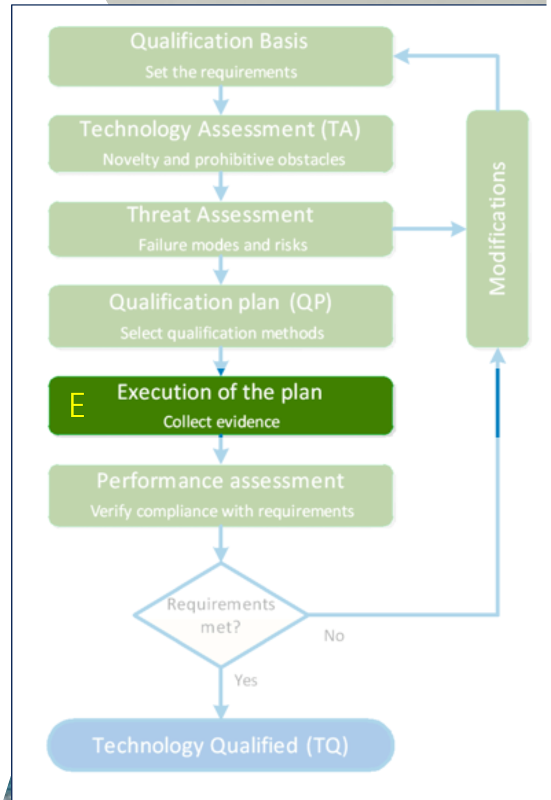
TotalEnergies

NORCE

E Example of communication test





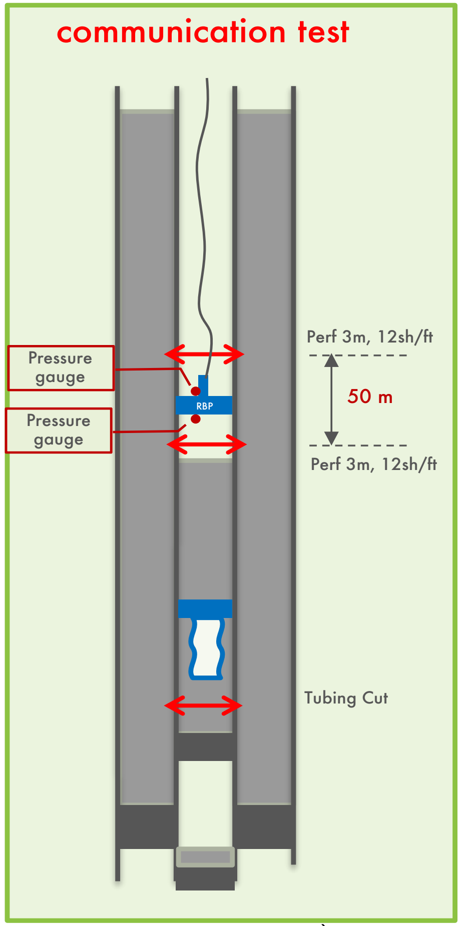


Note: in this trial, the lower pressure increased 4 bar due to the setting mechanism of the RBP., resulting in 46 bar differential

E Permeabilitty references C-test

Permeability

Permeability	
	170 mD Intact cement TPX; VIT; Duguid 2011
100 mD	100 mD Severely damaged cement (Moghadam, 2023)
	25 mD Intact cement CCl; VIT; Duguid 2011
10 mD	10^-6 to 100 mD Kang (42 Pennsylvania wells)
	0.001 – 10 mD Tao, Bryant (256 Canadian wells)
	1.7 mD; VIT; Gasda (2013)
1 mD	1 mD Mildly damaged cement sheath (Moghadam, 2023)
	0.6 mD 60% contaminated cement lab test (Le-Minous, 2017)
0.1 mD	0.1 mD 30% contaminated cement lab test (Le-Minous, 2017)
0.01 mD	Good Cement (OGUK, 2015)
0.001 mD	Intact Cement: Lab tests (Stormont et al. 2018; Bachu and Bennion, 2009; Meng et al., 2021)



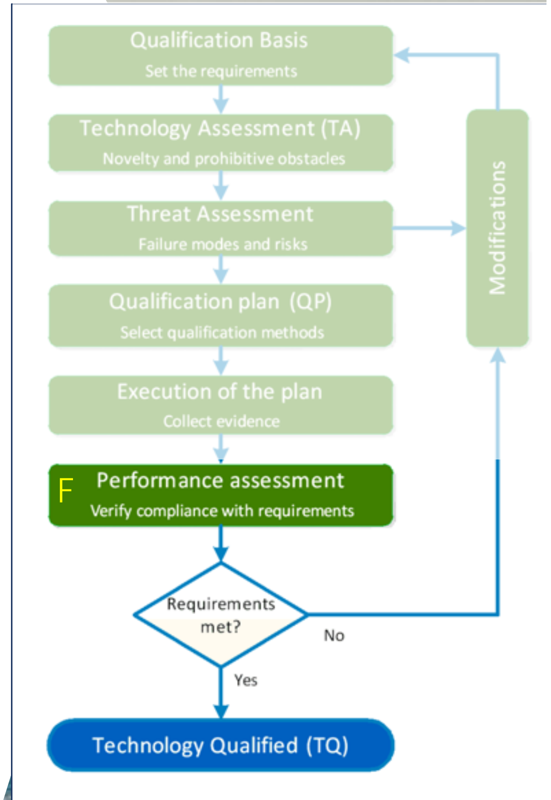
Permeability values from literature:

- Lab measurements on small specimen
  - Good Cement: 0.01 mD (OGUK, 2015)
  - Intact Cement: 0.001 mD (Stormont et al., 2018; Bachu and Bennion, 2009; Meng et al., 2021)
  - Contaminated cement: 0.1 mD for 30%, 0.6 mD for 50% (Le-Minous, 2017)
- Short sections of annulus (3-15 m long intervals, using the annulus as cross section area.
  - Duguid (2011) (2 datasets VIT): 170 mD, 25 mD
  - Gasda (2013) (3 datasets VIT): 1.7 mD
- Entire wells (often using the full well as cross section area in the calculation)
  - Kang: (Pennsylania ~42 wells): 10^-6 to 100 mD
  - Tao, Bryant: (256 wells with SCFV, Canada) 0.001 mD - 10 mD
  - Moghadam: (110 datasets in literature): 0.5-100 mD
- Simulation of consequences for a Groningen well (Moghadam, 2023)
  - Mildly damaged cement sheath along the entire well with a permeability of 1 mD:
    All scenarios show low levels of gas leakage.
    Gas plume in the freshwater aquifer is expected to be negligible.
  - A high permeability pathway along the entire well with a permeability of 100 mD:
    Can lead to significant leakage rates if a productive gas source is present.
    Dissolved methane plume can travel as far as 450 m away from the wellbore in the aquifer after 100 years.

F Performance Assessment

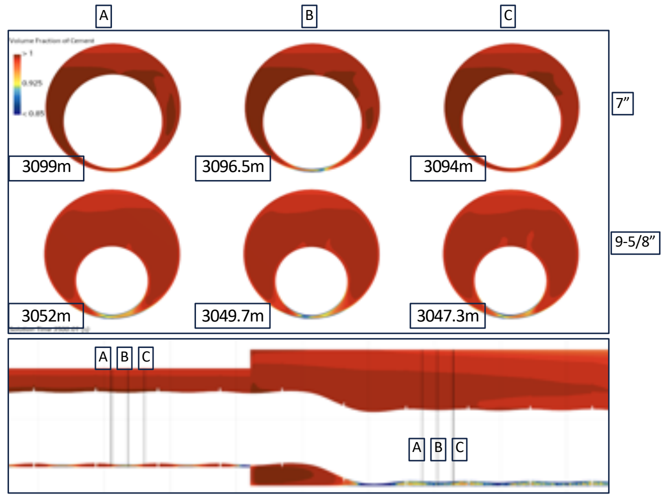
- A systematic review of possible failure modes revealed two high/medium risks of the TTC technology in comparison with stinger-based cementing technology:
  - C2 channel due to poor displacement in eccentric annulus
  - C3 free-water channel
- The extensive verification in 11 trial wells using a sensitive differential pressure test, showed that failure modes C2 and C3 do not occur.
- Heavy cement slurry effectively displaces light brine in eccentric annuli.
- An agitator is not necessary if rheology of fluids is low.
- Advanced Computer Fluid Dynamics simulation is used to analyse uncertainties in TTC jobs and optimise designs.
- Acoustic cement logging tools are not suitable for eccentric annuli Two trials were inconclusive due to logging tool artifacts.

- The TTC technology is technically qualified for the specified application envelope
- The application envelope can be extended by updating the Technology Qualification with new proof.



Further work for TTC extension

- Extend TQ applications envelope of TTC for different well configurations
- Verify ANSYS-FLUENT model for cement slurry displacing brine, so simulations can replace expensive and long-lead trials. Accelerate implementation.
  Modelling of non-Newtonian fluids with Newtonian fluid (and non-Newtonion fluid).
- Understand sealing performance of contaminated cement (bulk permeability and interfaces)
- Stability of cement columns without solid support (on viscous pills) for intermediate barriers. Fluid hierarchy.
- Dual-pipe measurement to confirm casing-rock seal
- Vessel-based cementing for small platforms (multi operator campaign)



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Thank you for your attention

Questions ?