A Next-Generation Alloy Wellbore Sealing Technology

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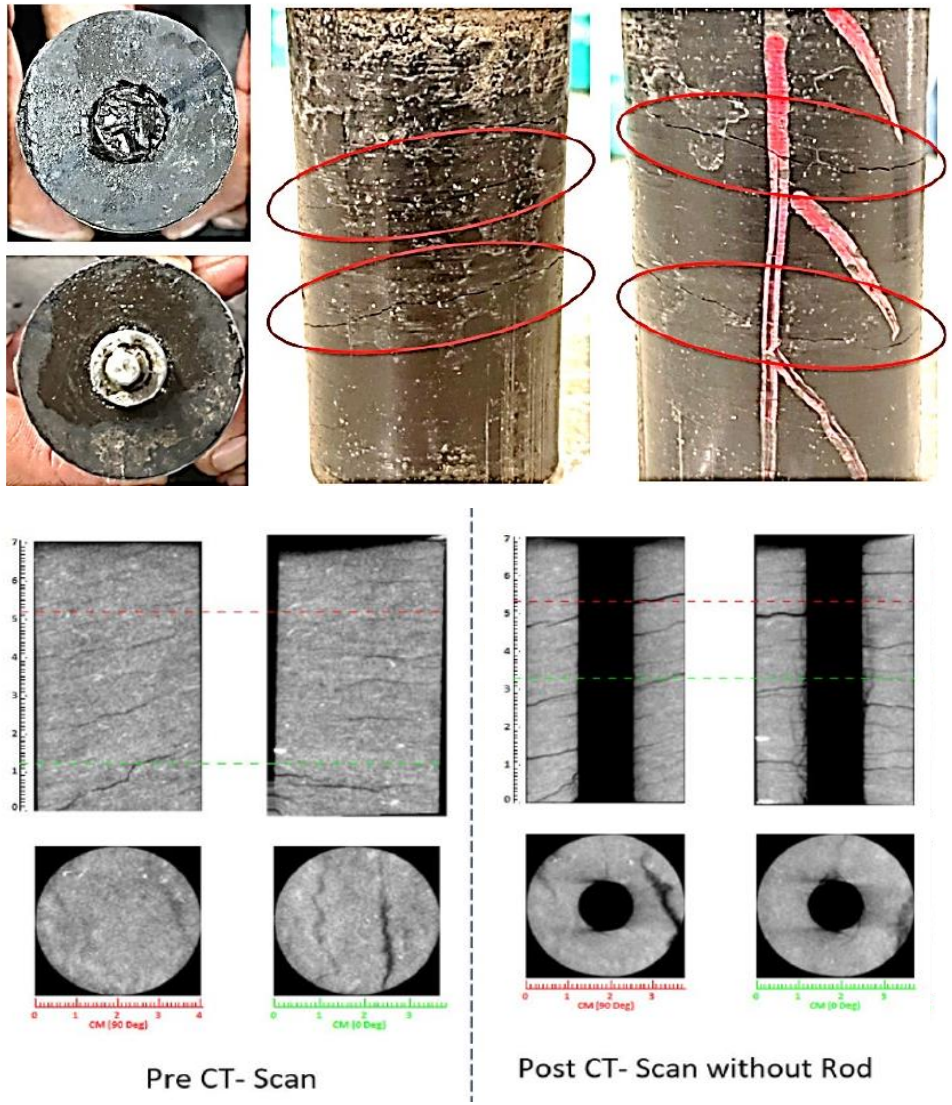
TotalEnergies requirements for a next-generation barrier

In March 2022, TotalEnergies defined a series of stringent requirements for a new kind of alloy barrier system to meet needs not currently met by the market. Barrier system must:

1. Seal and remediate a full 9-5/8” x 13-3/8” wellbore cross section, in a fully-cemented annulus rubbelized by prior slotting or perforating
2. Provide a 3,000 psi differential seal in both fluid and gas under NPNT conditions
3. Seal against flowing gas of at least ca. 1 litre/min
4. Seal in drilling mud and wellbore solids
5. Set at low temperatures, to minimise potential damage to casing/cement/caprock
6. Able to be re-melted and re-set
7. Barrier placement process to be fully controllable, monitoriable, and repeatable
8. Barrier placement to be fully verifiable, preferably using ‘conventional’ logging technologies
9. Tool able to be deployed riglessly on cable up to 4000m MD and incorporate fibre-optic sensing for real-time well monitoring and CCL for depth control.
10. Mitigate against creep and capable of providing reliable sealing for up to 3,000 years

Why close control of temperature is key to integrity

- Research into caprock behaviour sponsored by TotalEnergies and Equinor at the University of Texas has revealed:
- Moderate elevation of caprock shales can cause damage in the form of disking, cracking and delamination - see photos & IADC/SPE-208782-MS
- Excessive or poorly controlled heat can undermine barrier integrity by causing:
  - Blue embrittlement of steel
  - Damage to cement sheath
  - Damage / cracking of the cap rock
- There is a ‘sweet spot’ temperature for a given cap rock shale where the cap rock integrity can even be improved by ‘thermal hardening’
- Hence when designing long-term «permanent» barriers, **understanding the effects on the wider barrier envelope (casing/cement/formation) is critical.**



The Wellstrøm solution: controlled heating, real-time montoring and verification

- Thermal effects should not be ignored. Close control of the heat output is key to achieving robust and reliable well integrity across the full wellbore cross-section. In our view, this can only currently be achieved via electrical heating.

- It is important to design the heating cycle (with the help of thermal CFD simulation etc.) to ensure that heating stays within the thermal limits of the cap rock.

- Heating cycle can be adjusted real-time during the alloy melting process to ensure heating stays within the required limits and optimal placement. Alloy can also be easily re-melted and re-set if required.

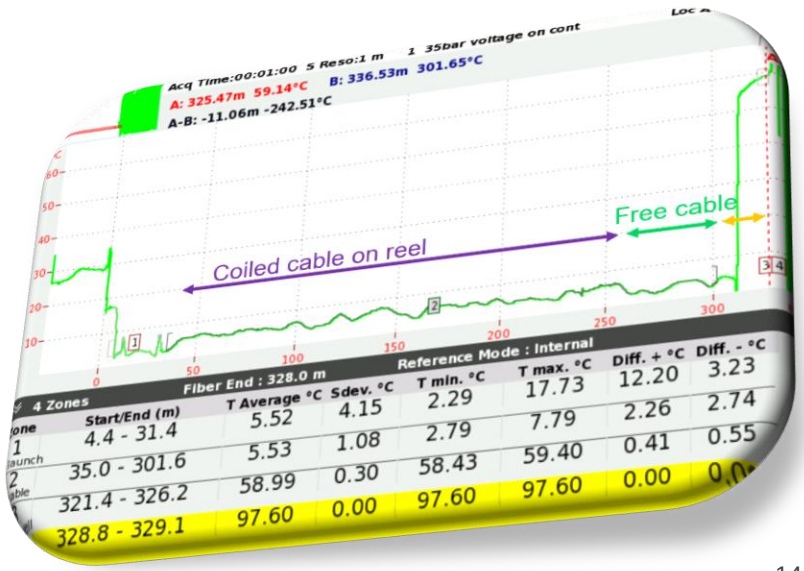
Full-scale demonstration pilot, January 2023

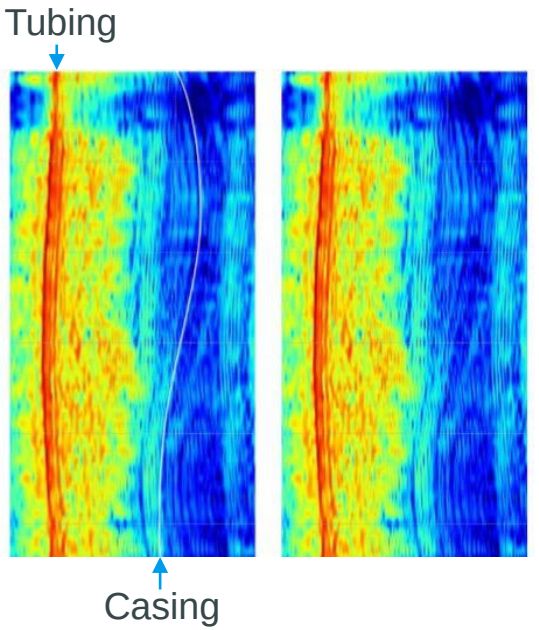
- Successfully deployed into test well on cable in 1,28 SG KCl drilling mud
- Demonstrated ability to closely control heating and setting process
- **Conclusively stopped gas migration** ~1 litre/min flowing gas
- Pressure tested successfully above in WBM & **below to 3000 psi with N2 gas**
- Monitored temperature from, downhole, surface and back to unit
- **All test objectives achieved – API TRL 6 (demonstration pilot) criteria fulfilled after only 9 months**
- Preparations currently underway for full offshore field deployment in Denmark, Q3 2023

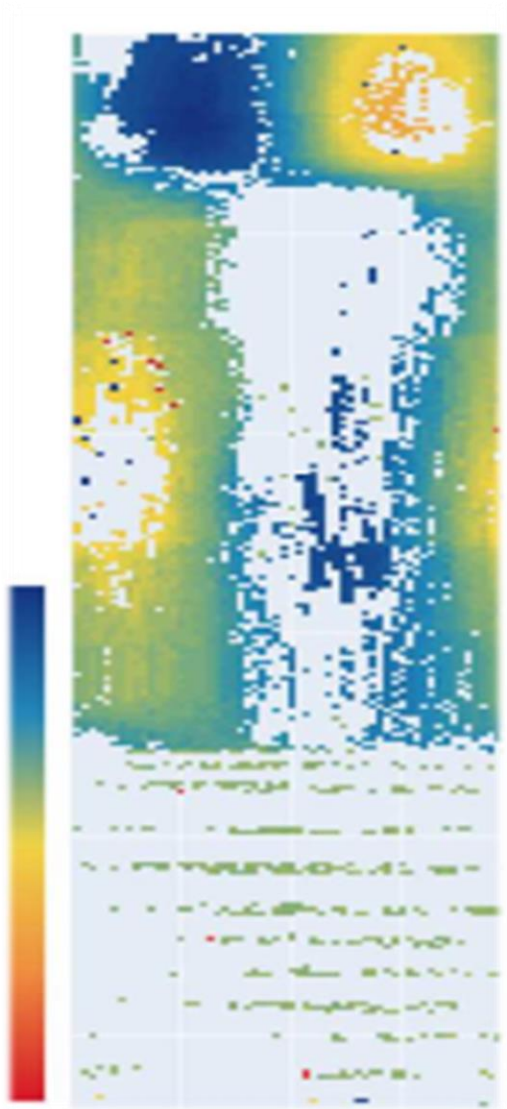
Log verification & DTS on SM fiber

Hollow mandrel logged with a 2-1/8” Ultrasonics tool´s. Promising results:

- Azimuthal map showing reflection coefficients clearly shows allloy has flowed from ‘reservoir’ above ribbed mandrel to fully immerse the ribs in alloy
- Excess of alloy volume shown to remain above the tool
- Both mandrel and 9-5/8” casing detected
- **Test demonstrates potential utility of the hollow mandrel in enabling alloy placement verification via multi-annulus logging tools.**
- First known tool with this capability

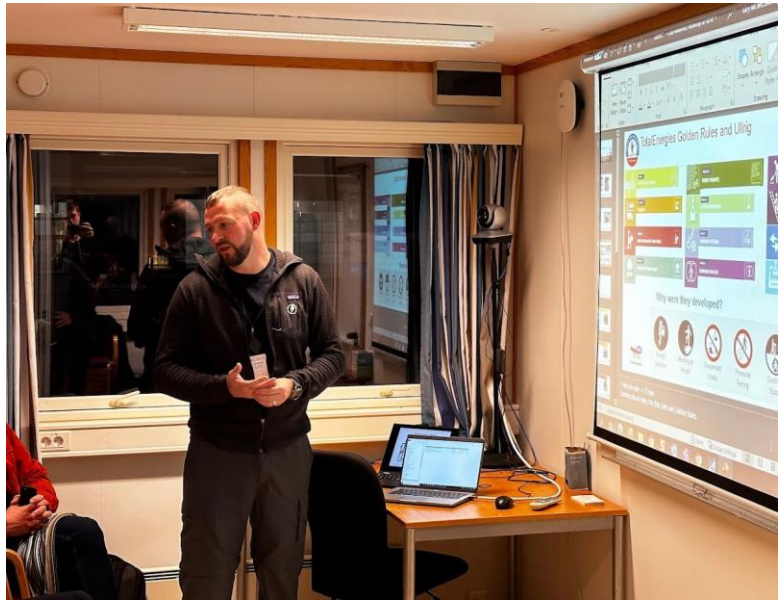


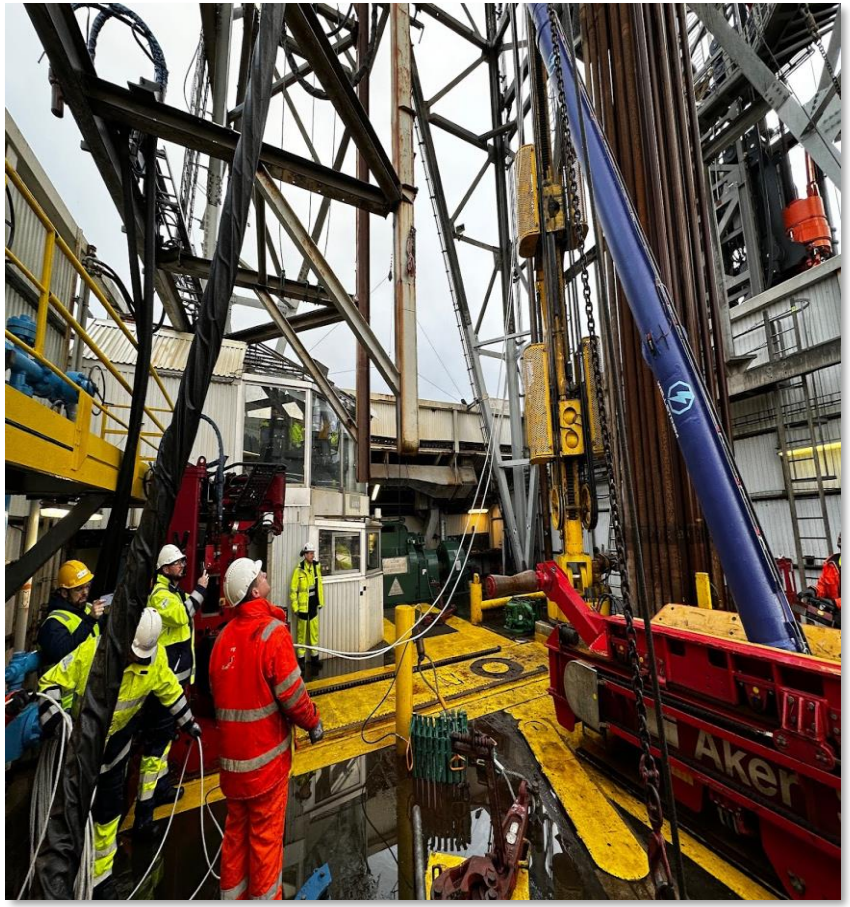


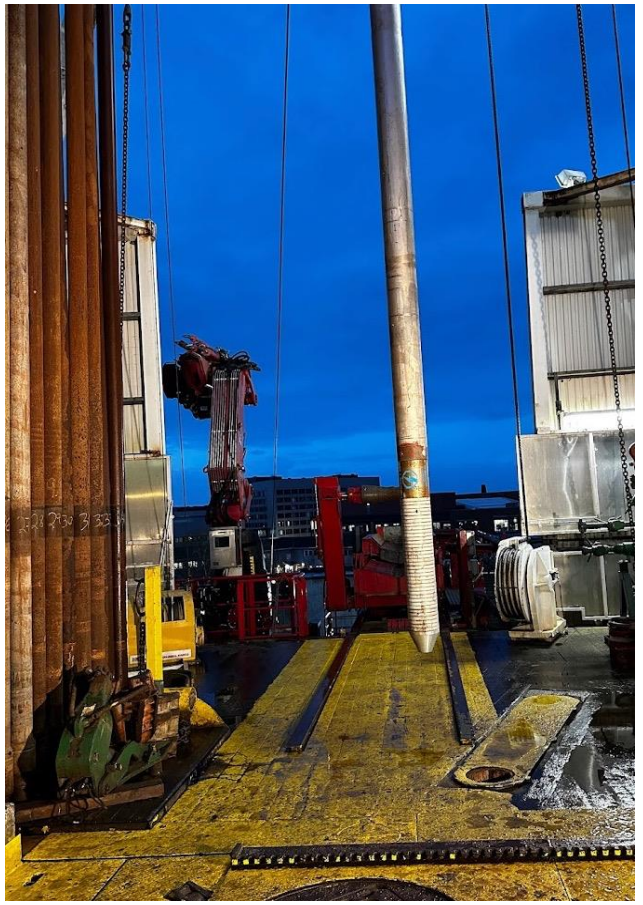


Way Forward

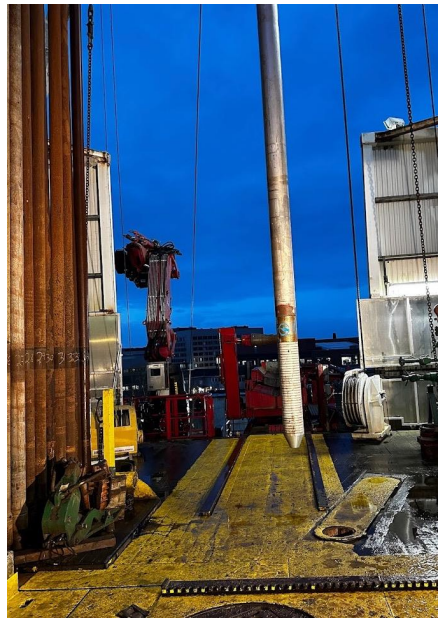
- Pursuing industrial pilot with TotalEnergies offshore Denmark Q3 2023
- **Qualify barrier P&A barrier to Norwegian PTIL, DNVGL RP-A203 & OE UK Guidelines requirements – process commencing 9th of July 2023**
- Develop through-tubing application in 2023/2024 – “T-3000”

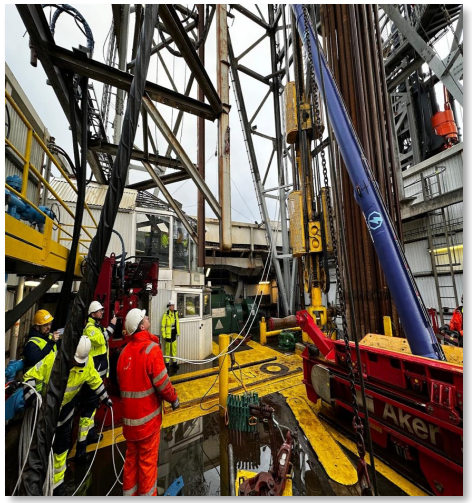


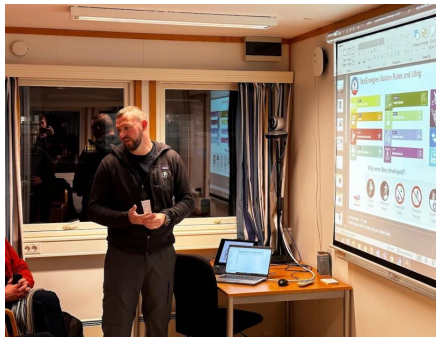




Qualification Status (API 2019)







TRL 3

2013: JIP funded development & ISO14310 V0 workshop testing

TRL 4

2015: Bureau Veritas 'Statement of Endorsement' for a 7" Alloy 80 and Alloy 150 casing plug

TRL 4/5

2016 – 2018 Independently assessed FMECA driven test programme

TRL 6

2023: NORCE, Ullrigg Test Center successful test in water-based mud

TRL 7*

Qualify barrier P&A barrier to Norwegian PTIL, DNVGL RP-A203 & OE UK Guidelines requirements

2023: System Installed (TRL 6 Field Pilot, Denmark)

Thank you for your attention

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Rig less down hole P&A

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Through-Tubing Tool introduction (Patent pending)

- Aimed first at **4-1/2”** and up to **5-1/2”** tubing sizes.
- High-performance electrical heater with temperature monitoring/logging capability
- M3 sealing materials and creep-resistant mandrel design to deliver anticipated 3000-year sealing performance
- Capable of setting plugs inside tubing/casing (via Perfs) annuli of production casings up to 10-3/4” casing
- Heater has the able to generate sufficient radial heat as to allow alloy to remain molten long enough so that it can be displaced into annuli
- Able to displace alloy into annulus and casing hydraulically or via kinetic means
- Able to set plugs in up to 60 degrees inclination
- Able to withstand up to 5000 psi differential
- Well temperature range for this plug: Low -100°