wellstrøm

SURFACE CONTROLLED ELECTRICAL SET BISMUTH PLUG

A Next-generation Fully Controllable Alloy Wellbore Sealing Technology

Gert Rege

SPE Well Decommissioning & Late Well Life in the Net Zero Era
3-5th June 2024, Aberdeen

The T-1000 goal

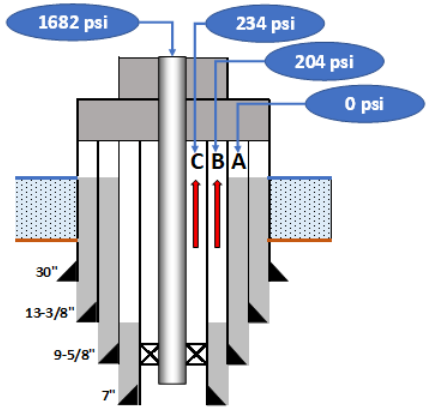
❑ **Barrier system able to remediate a well-cemented 9-5/8” x 13-3/8” casing.**

- **Set in Cemented anulus w/(mud)**
- 1 liter/min flowing gas

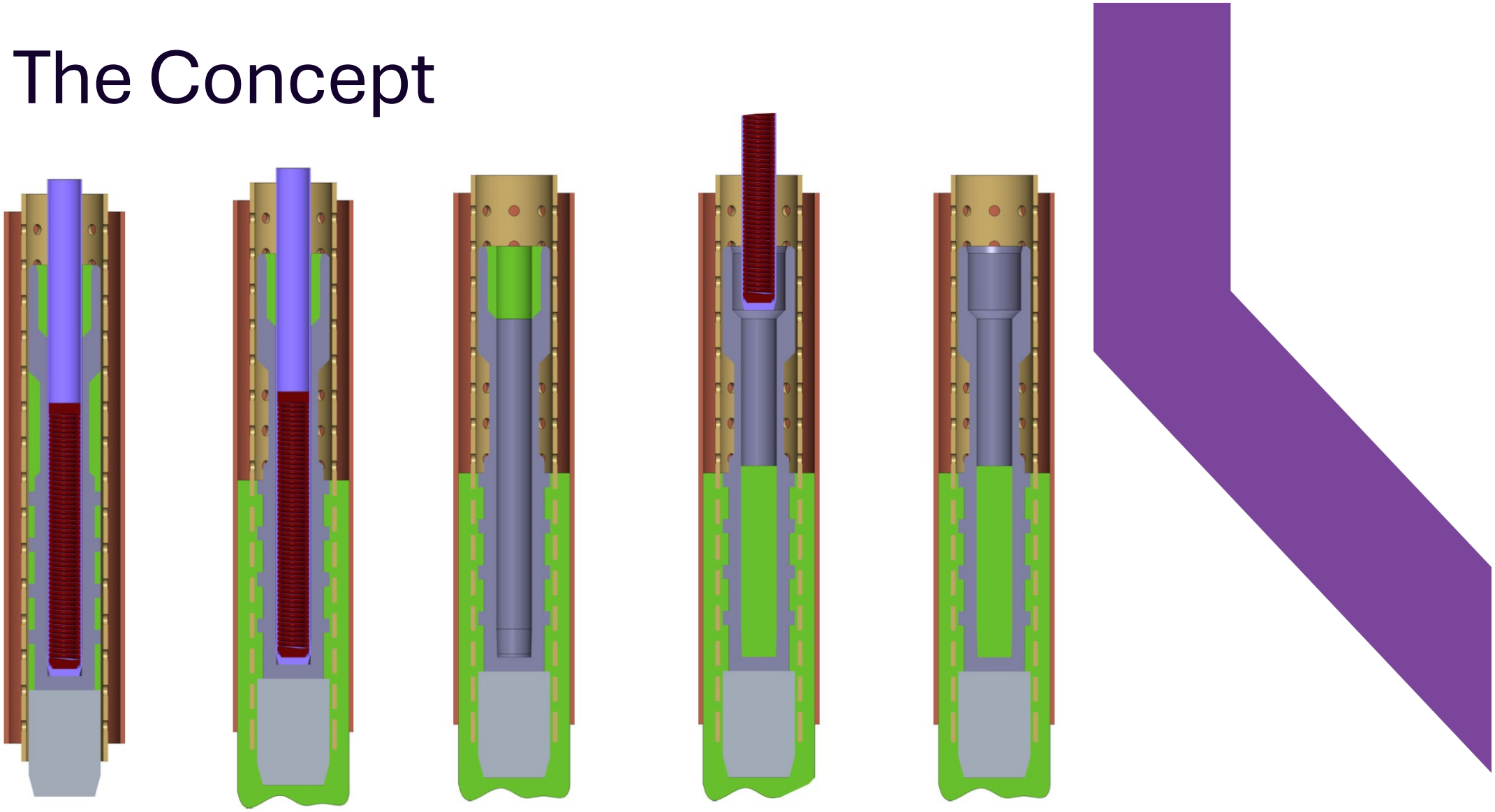
- **Set in Open annulus w/seawater**
- No flowing gas

✓ Provide a high differential seal in both fluid and gas.
✓ Can be re-melted and re-set.
✓ The process is fully controllable, monitorable, repeatable and verifiable.
✓ Alloy placement able to be verifiable by logging.
✓ Designed to mitigate against alloy creep and provide extreme longevity sealing.
✓ Able to be deployed riglessly up to 4000m

See also SPE-216616-MS for design criteria specified by TotalEnergies



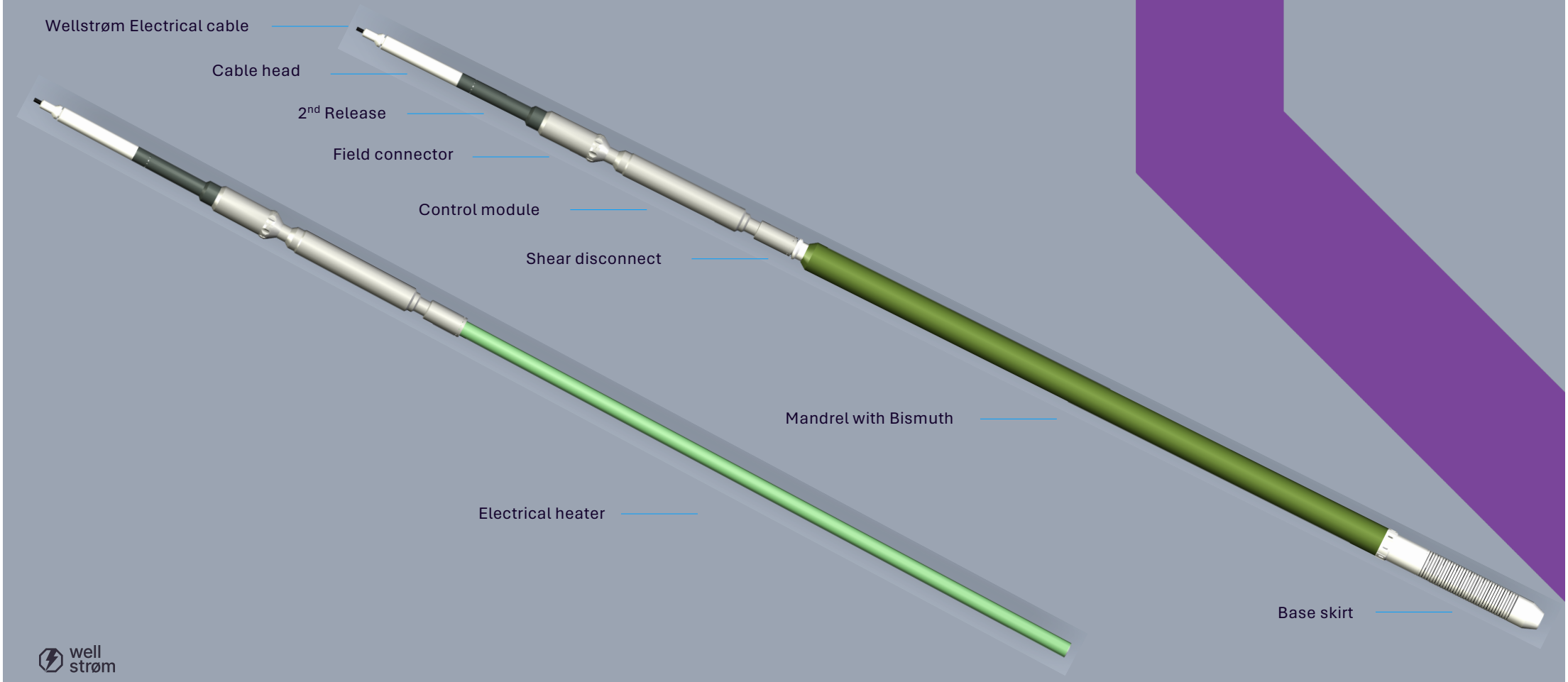
The Concept



Wellstrøm T-1000

9 5/8" x 13 3/8" csg.

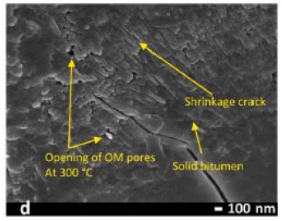
well strøm

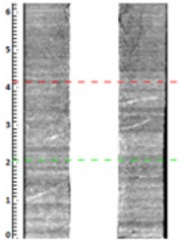


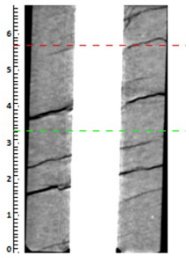
well strøm

Why electrical?

- ❑ Careful design of the heating cycle and control of the heat is important to avoid damage to outer wellbore elements.
- ❑ Electrical controlled heating with live monitoring ensures complete control of the wellbore conditions.
- ❑ Risk to outer wellbore elements:
  - ✓Steel (blue embrittlement)
  - ✓Cement (microannuli, cracking)
  - ✓Caprock (crack re-opening, diagenesis).







Excessive heating – irreversible changes and negative consequences such as shale diagenesis, mineralogical decomposition, permanent clay dehydration and fracturing – ***causing permanent loss of barrier integrity in the process.***

Intermediate *heating – thermal contraction/shrinkage, rock plastic deformation, shale re-healing/crack closure:* ***"thermal hardening"***

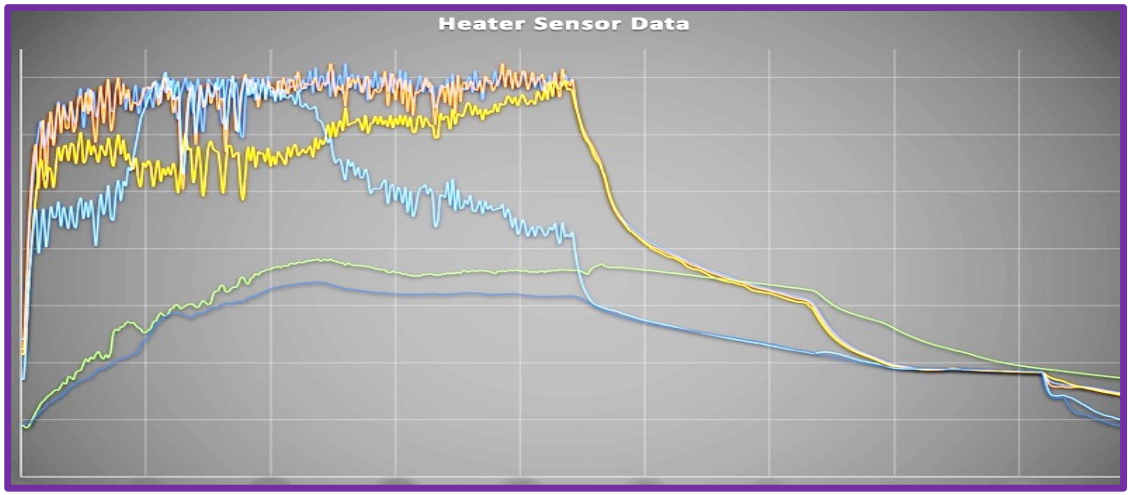
Moderate heating – thermal dilation/expansion, pore pressure elevation, effective stress reduction***, shale damage & crack re-opening***

Careful design of the heating cycle based on an understanding of caprock thermal behaviour can even ***improve caprock integrity****. Only electrical heating allows this sweet spot to be found!*

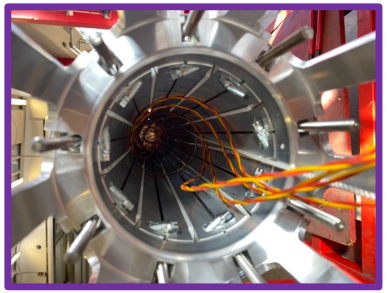
See: van Oort et al. (2024) *Thermal Stimulation of Annular Barriers for Long-Term Well Integrity*. IADC/SPE-217694-MS
Learn more this afternoon at 14:20 from TotalEnergies!

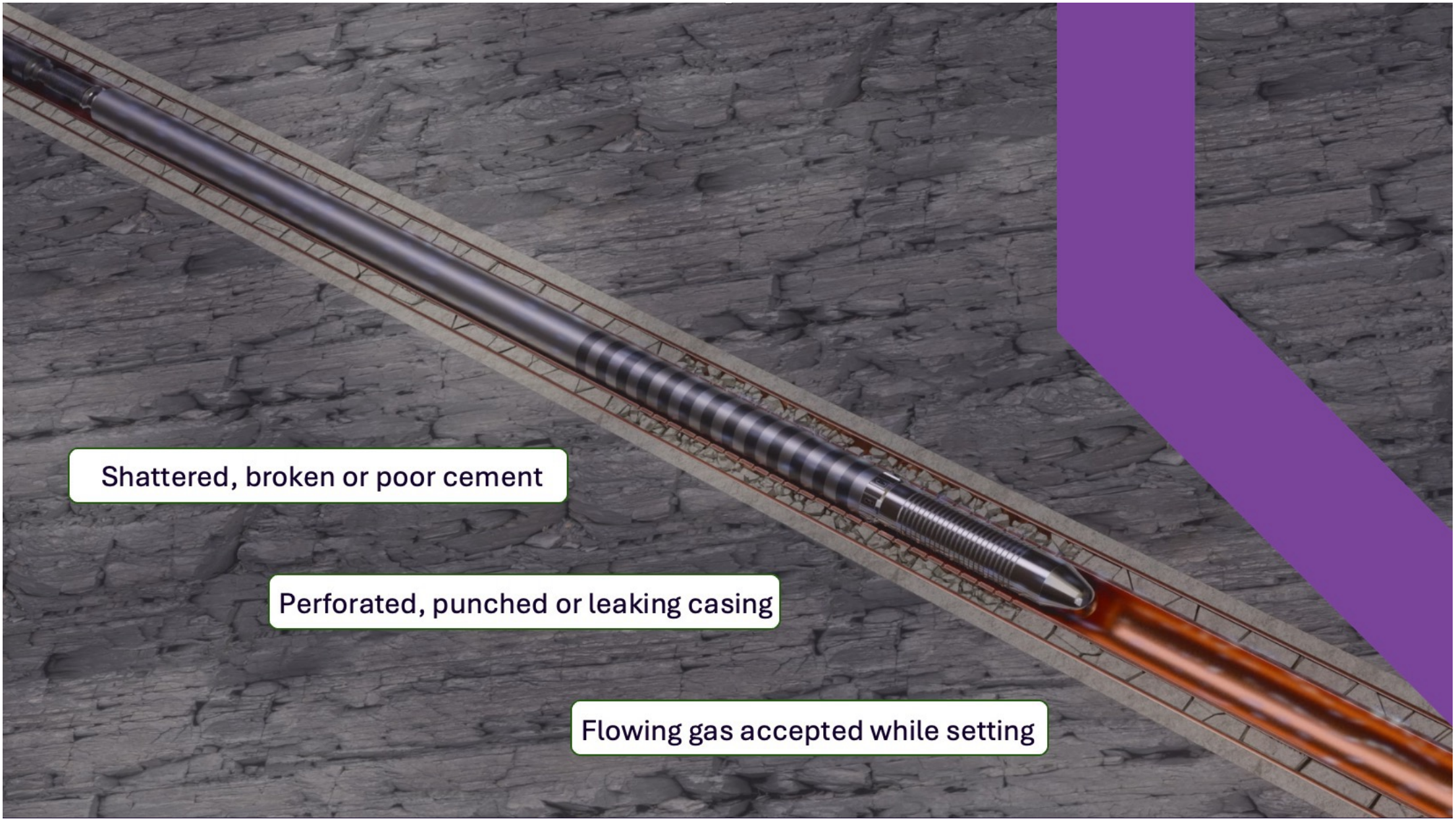
Barrier setting

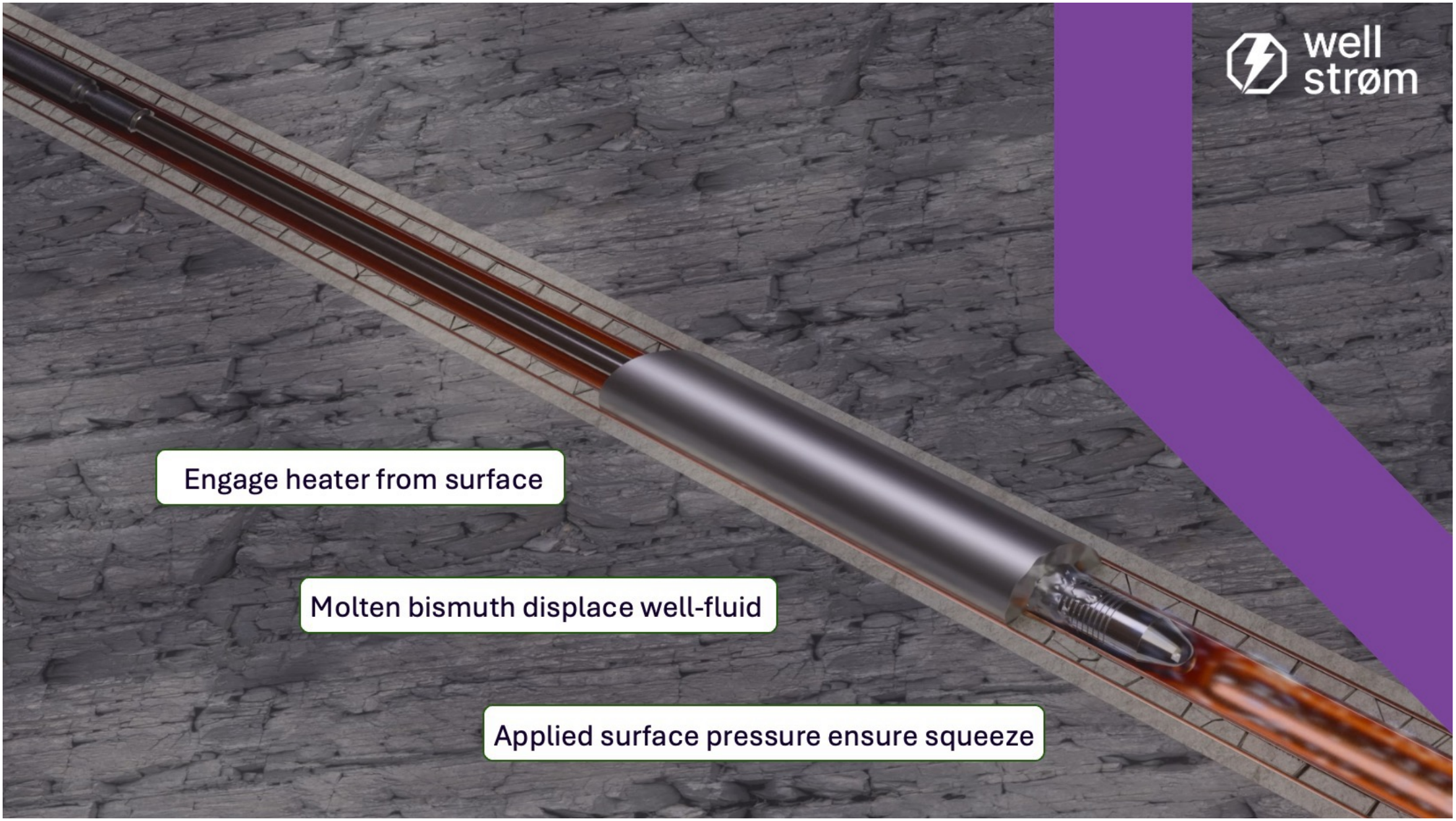
- Electrical cable deployment brings greater heater control, and monitoring capability.

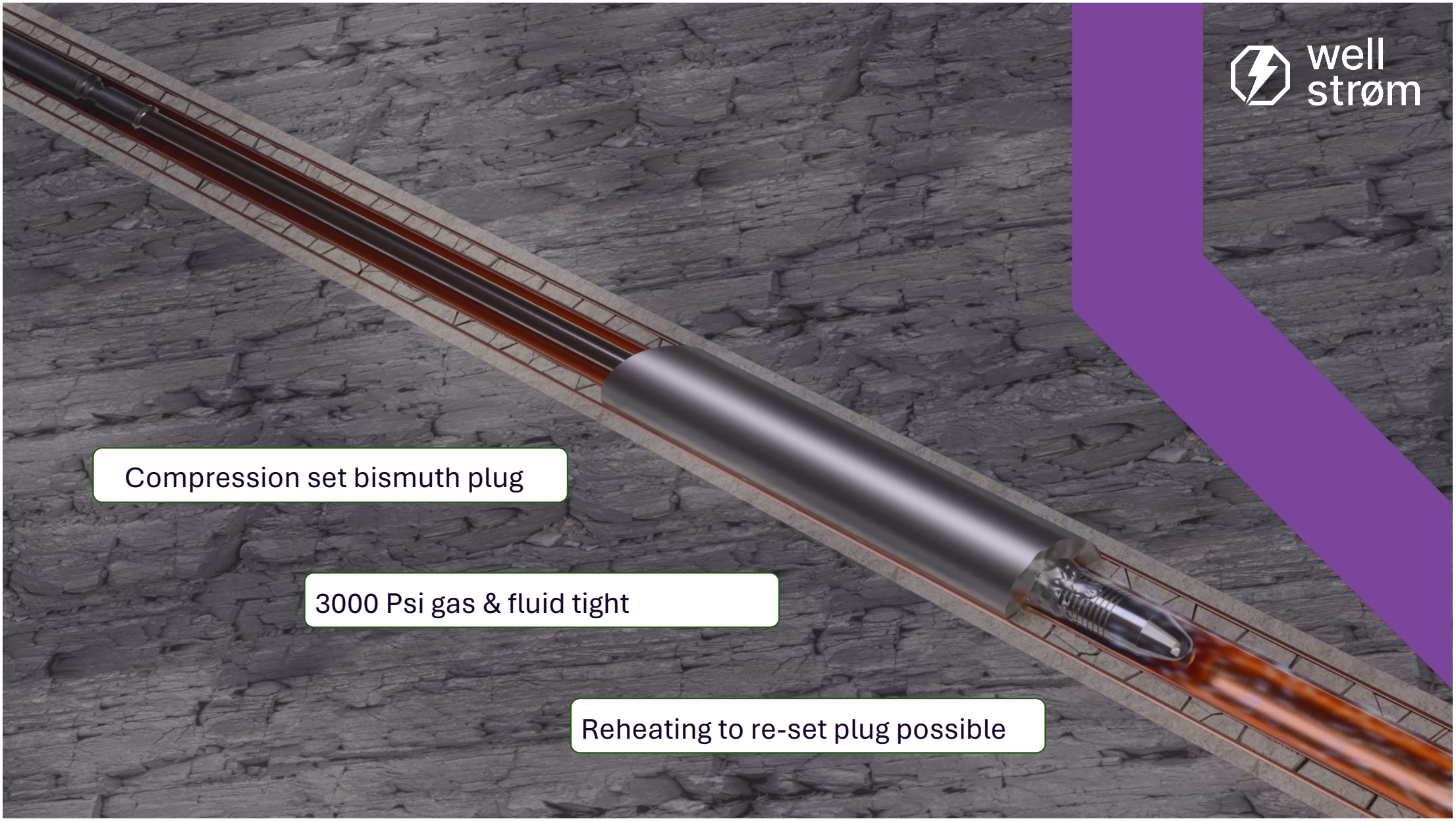


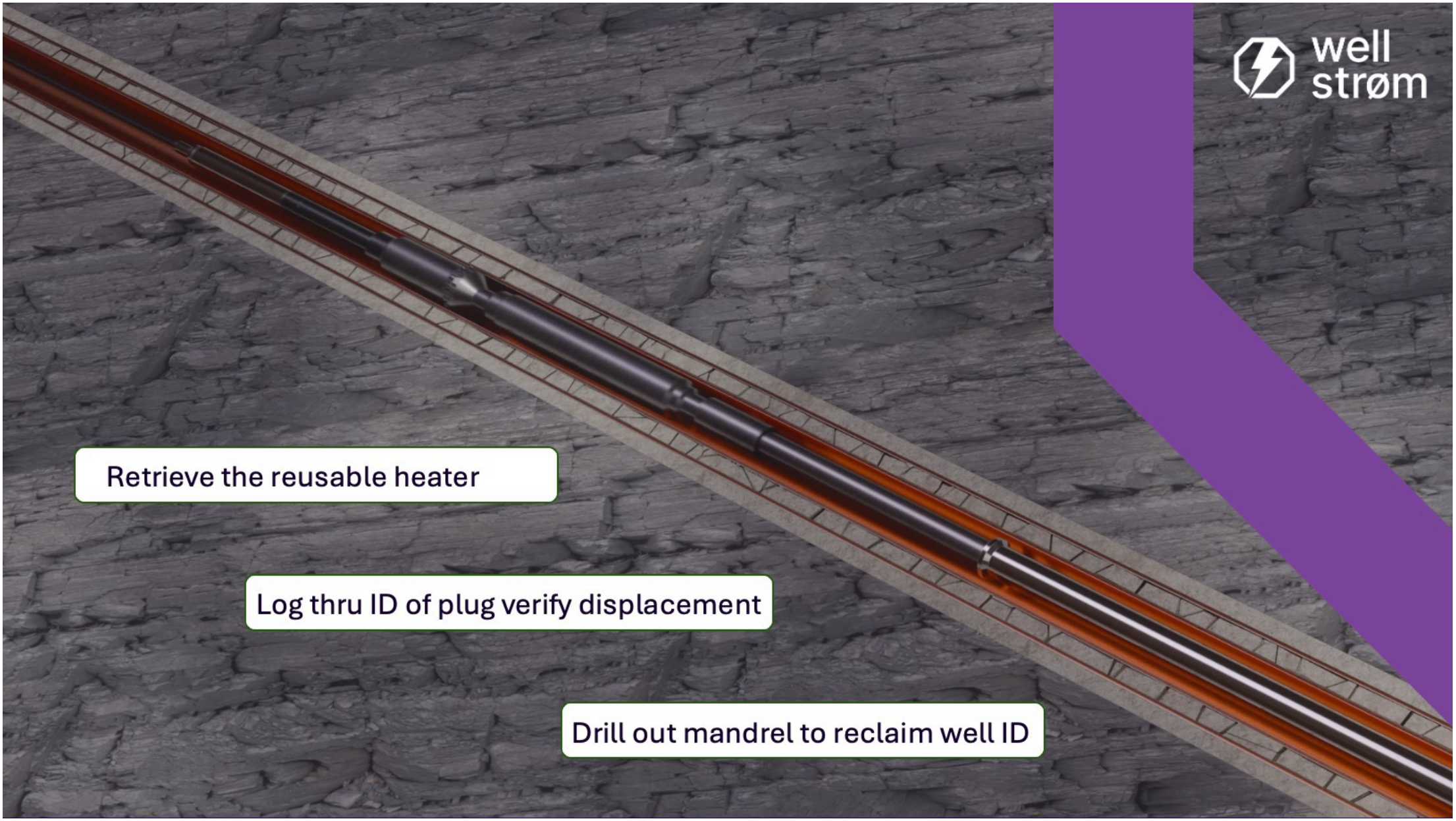
- It's important to design the heating cycle (with help of CFD simulation etc) to ensure that we don't overheat the caprock in this potentially detrimental zone.

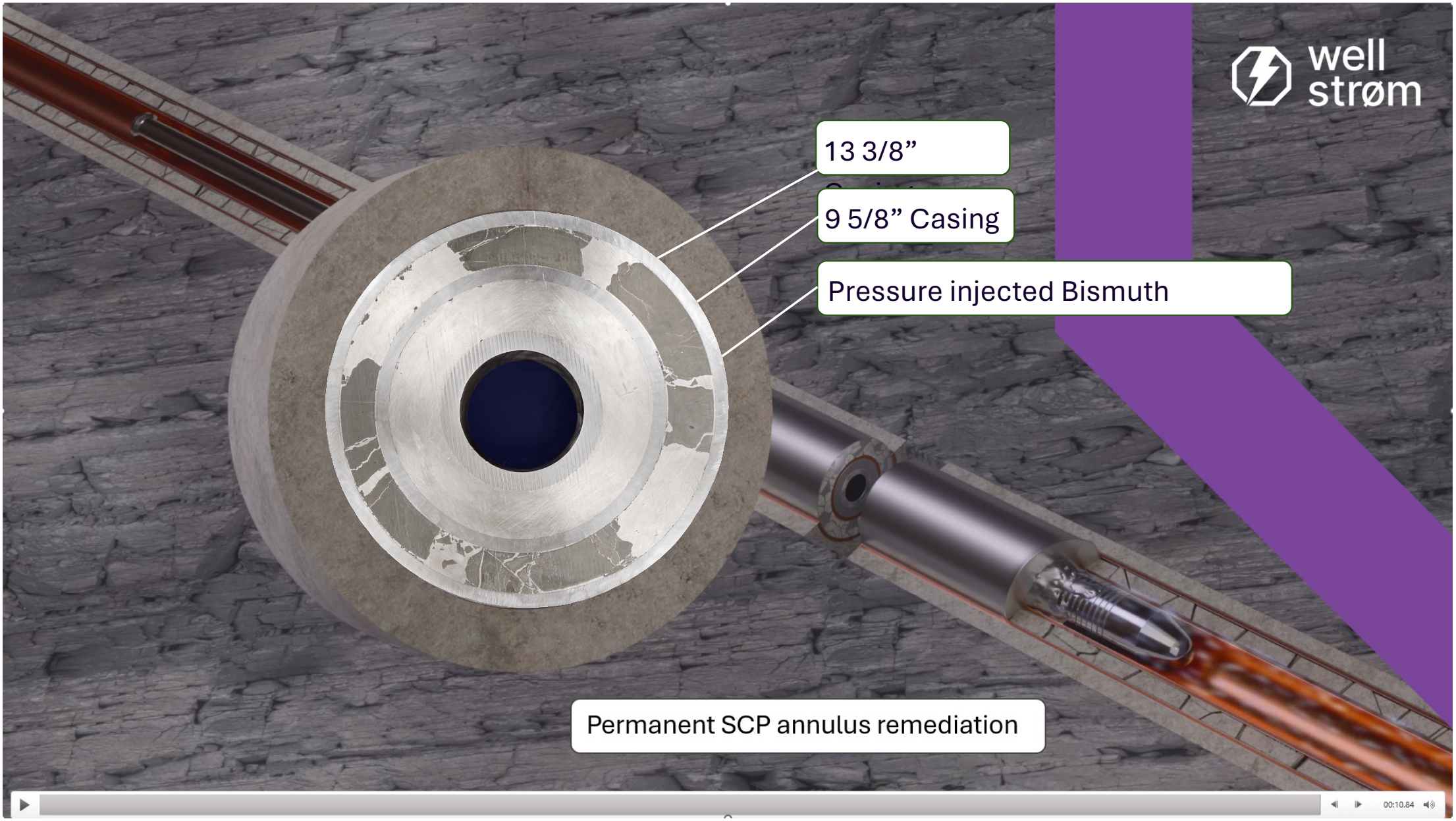



Shattered, broken or poor cement
Perforated, punched or leaking casing
Flowing gas accepted while setting


well strøm
Engage heater from surface
Molten bismuth displace well-fluid
Applied surface pressure ensure squeeze


well strøm
Compression set bismuth plug
3000 Psi gas & fluid tight
Reheating to re-set plug possible


well strøm
Retrieve the reusable heater
Log thru ID of plug verify displacement
Drill out mandrel to reclaim well ID


well strøm
13 3/8”
9 5/8” Casing
Pressure injected Bismuth
Permanent SCP annulus remediation
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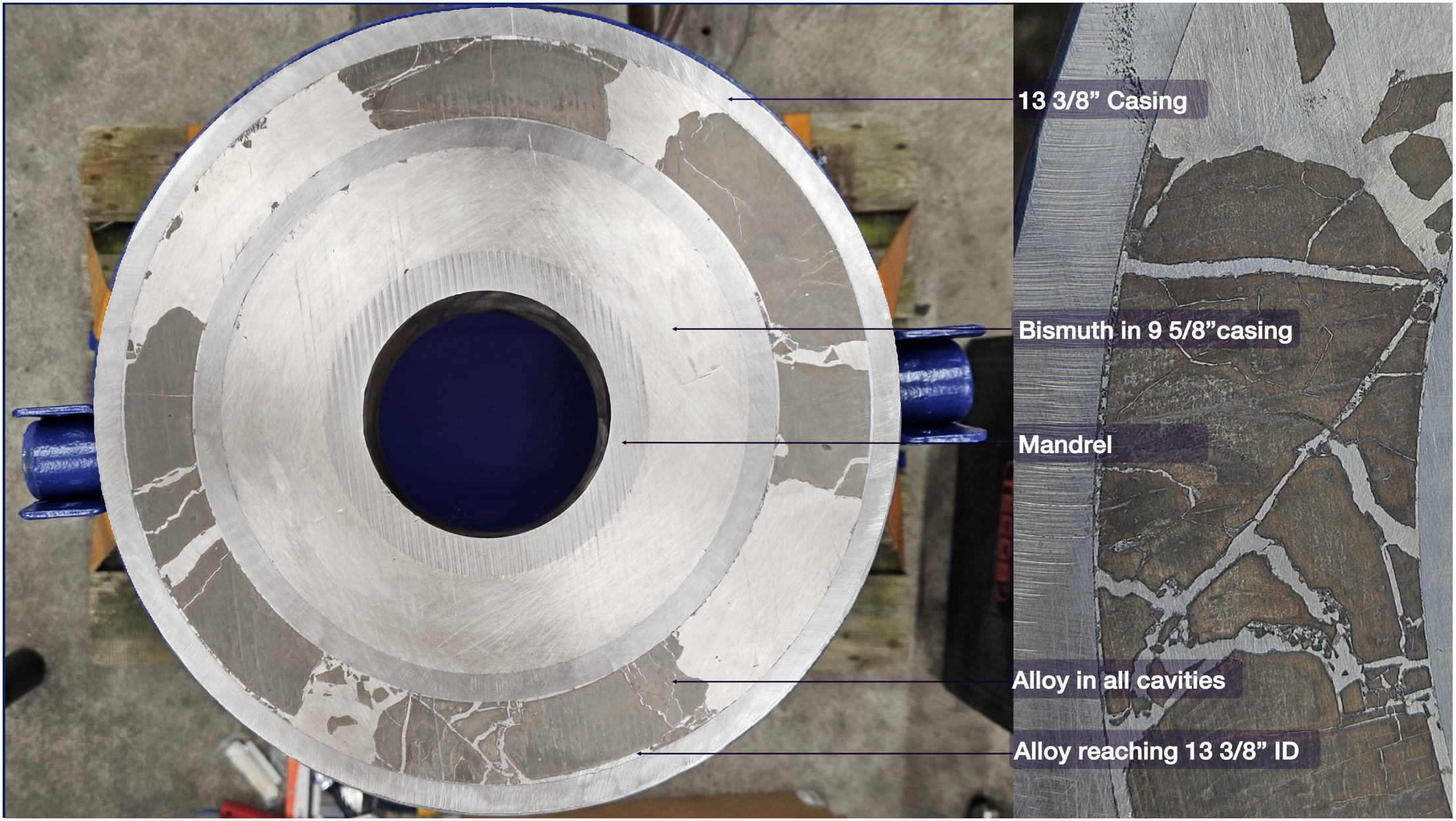
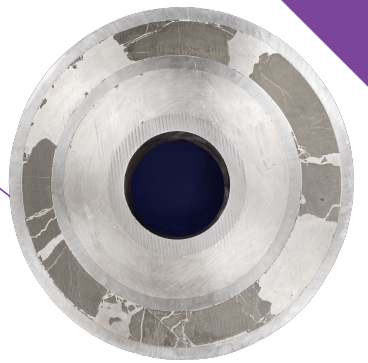

13 3/8” Casing
Bismuth in 9 5/8”casing
Mandrel
Alloy in all cavities
Alloy reaching 13 3/8” ID

Complete plug



Short Wellstrøm barrier predicted to have similar or better performance than Section Milling or PWC

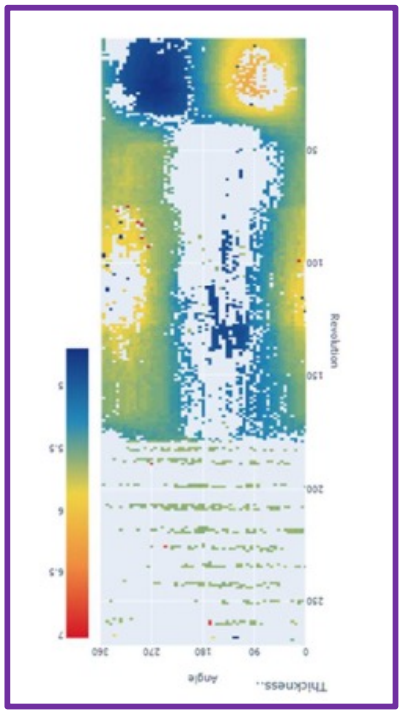
Bismuth displacing mud

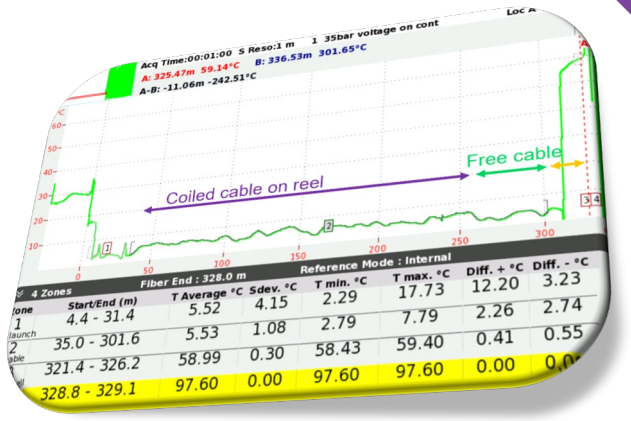
- ❑ Key challenge displacing mud from wellbore.
- ❑ Controlled steady heat do not separate wellbore fluids at the same time as the bismuth liquefy.
- ❑ Controlled steady and constant heat leaves a static system when the bismuth liquifies.
- ❑ Controlled steady heat at time of displacement do not create bubbles or uncontrolled movement of wellbore elements.

Barrier verification

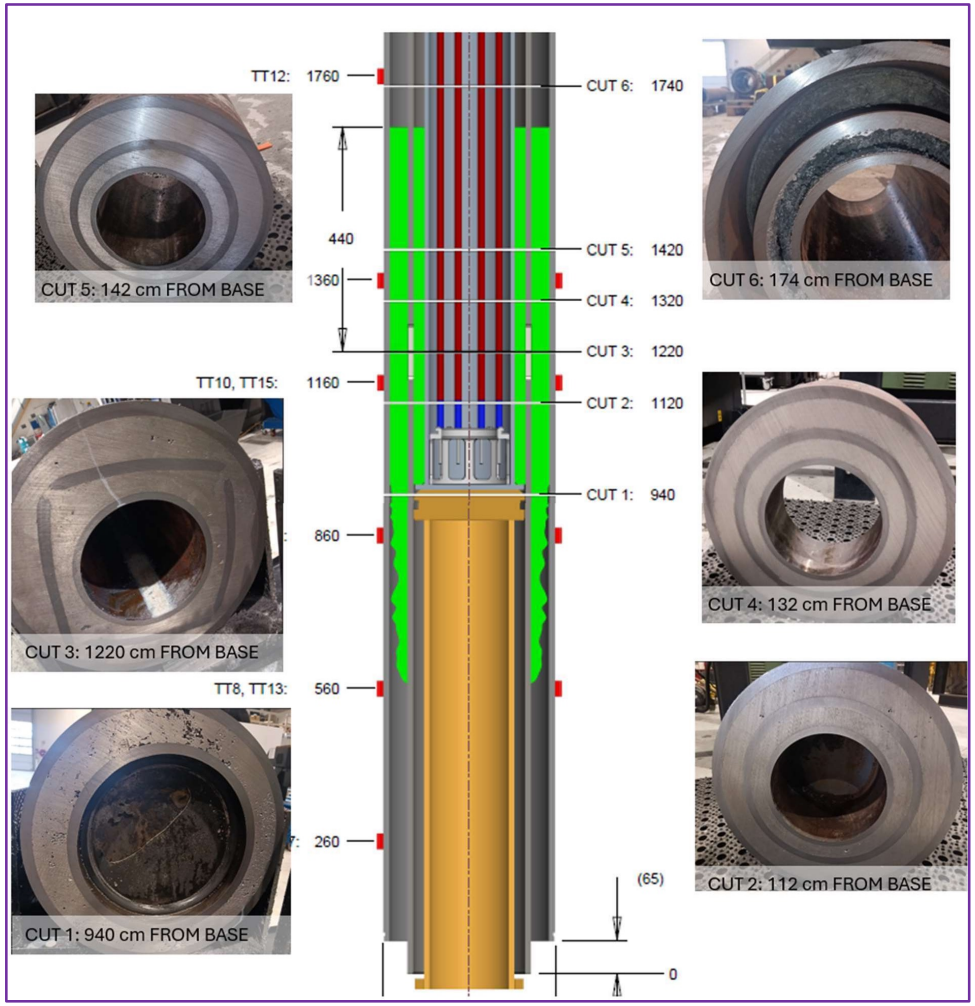
Distributed Acoustic and Temperature on Single Modus fiber

- ❑ Wellstrøm's core mission is to provide a solution that address industry concerns on barrier verification.
- ❑ Wellstrøm's barrier technology is therefore designed with verification requirements in mind, and the unique inner mandrel of the T- concept facilitates this.
- ❑ Ultrasonic testing has yielded promising results in being able to detect M3 alloys in the annulus through multiple strings.
- ❑ Incorporates verification of gas-tight seal using active downhole monitoring technology and tracer gas.

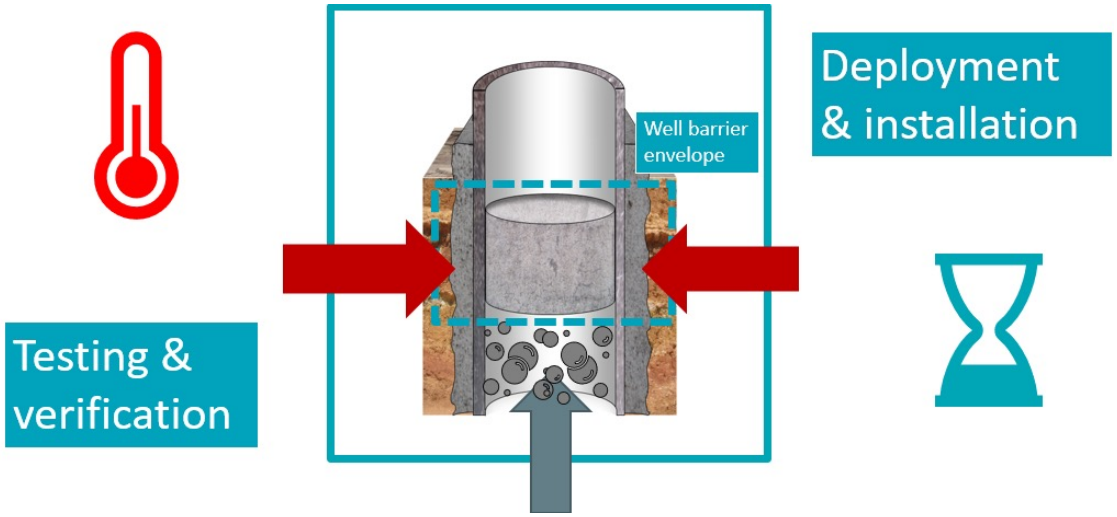


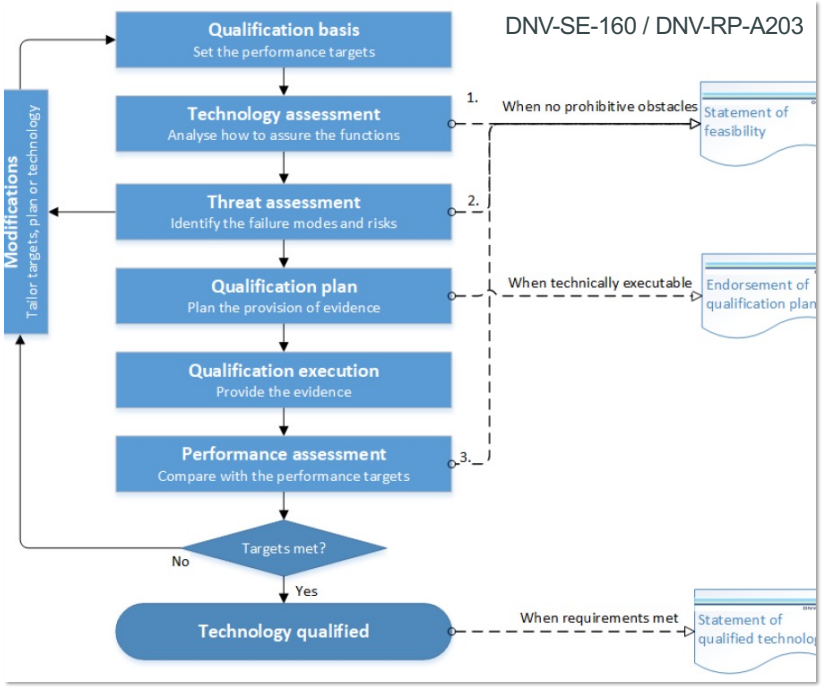


Un-cemented annulus test



Wellstrøm barrier Qualification with Astrimar and DNV





Objectives

- Qualify Wellstrom T-1000 M3 Alloy Barrier to DNV-RP-A203, OEUK (Offshore Energies UK) and NORSOK requirements.

Achievements

- Launched qualification project with Astrimar, reliability specialists in June 2023, 3 FMECA workshops held in Aberdeen
- Qualification Basis, FMECA review & Qualification Plan action workshop held 19/20th March 2024 in Pau. DNV representative present as independent observer.
- Consult Norwegian PSA April 23rd in Copenhagen + also UK NSTA & HSE

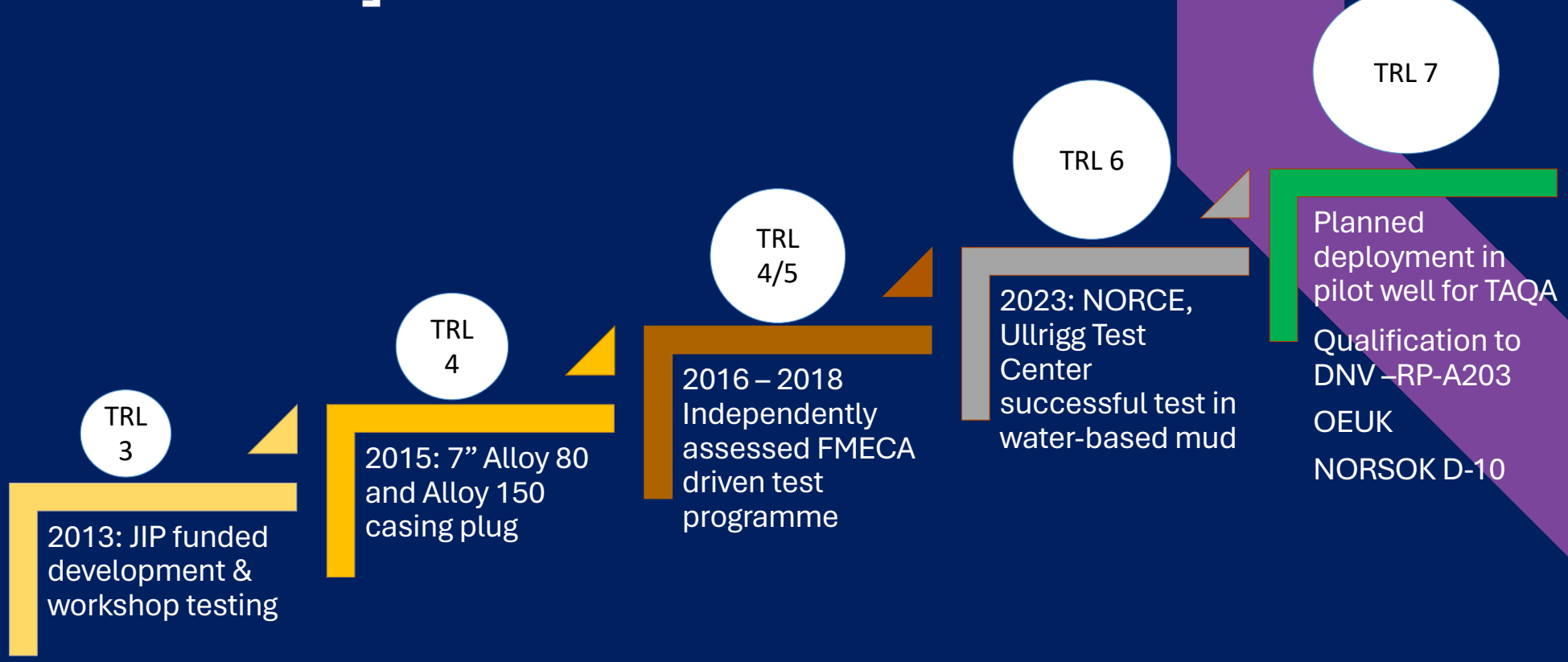
Way Forward

- Execute Qualification Plan actions as required (testing & analysis) – expected to take 18 – 24 months.

Astrimar
Reliability by Design

DNV
ADVISORY SERVICES

Qualification Status [ISO 16290]



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The story so far

❑T-1000 -trial and full-scale test
- ✓ Set plug in 1.28 SG WBM drilling fluid
- ✓ While flowing 1 liter/min gas
- ✓ Provided a high differential pressured seal @ 3000Psi gas and 3000 psi fluid.

❑Field trial for TotalEnergies September 2023 (barrier plug)
Unfortunately, postponed due to rig sequence alterations

❑Primary and Back-up equipment ready to go in our workshop
9 5/8” x 13 3/8” SCP remediation.

Optimal well temperature 15-90°C for prepared Bismuth

❑Field pilot TAQA North Cormorant, June 2024 (surface plug)

❑Further pilots with TotalEnergies anticipated 2024/25

❑WHAT NEXT?
- T-3000 – (3 ½”) 4 1/2” x 9 5/8” csg plug – Q2/Q3 2026
- T-1000 – 7” x 9 5/8” csg – TBA
- Execution of Qualification Plan with Astrimar and verification by DNV

TAQA طاقة

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SURFACE CONTROLLED ELECTRICAL SET BISMUTH PLUG

Thank you

Funded by
The Research
Council of Norway

Net Zero
Technology
Centre

Technology Driving Transition

Wellstrøm would in particular like to thank our main industrial sponsor TotalEnergies, NRC and NZTC for supporting this project

TotalEnergies