Pioneering Bismuth deployment for challenging deepwater environment in South America

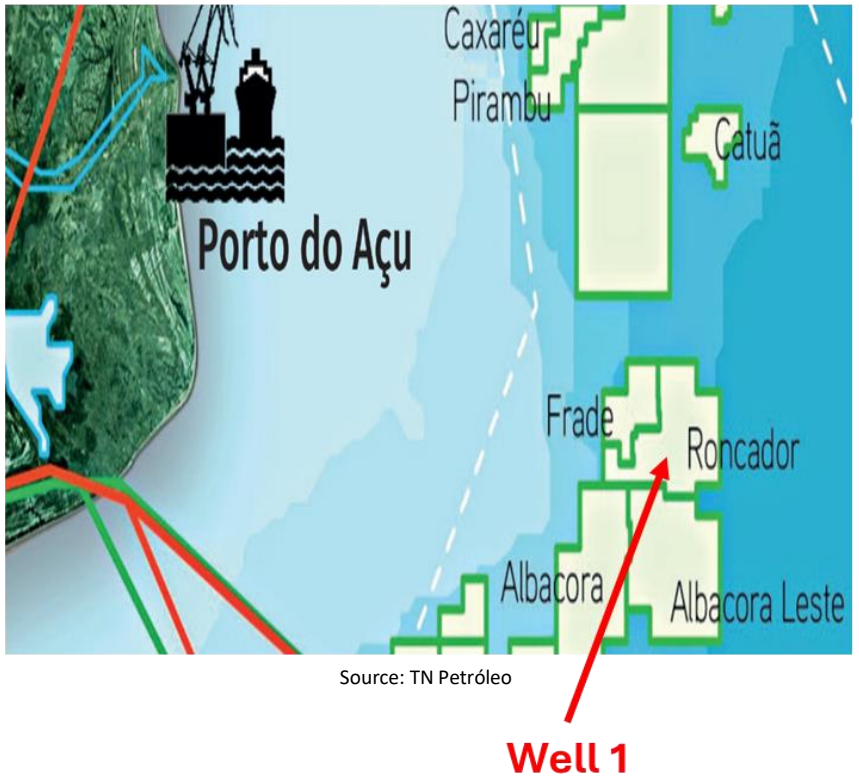
Didhiti Talapatra, BiSN; Leonardo Pacheco, Petrobras; Marcelo Victor Tomaz, Petrobras; Pedro Goncalves, BiSN; Pedro Mata/Petrobras

Bismuth plugs in Petrobras

- Large quantity of old wells to be abandoned
- Completions that were not planned to be abandoned
- Restrictions of varying diameters
- Contingency for high expansion plugs
- Partnership in the development of technologies and solutions

The Challenge:

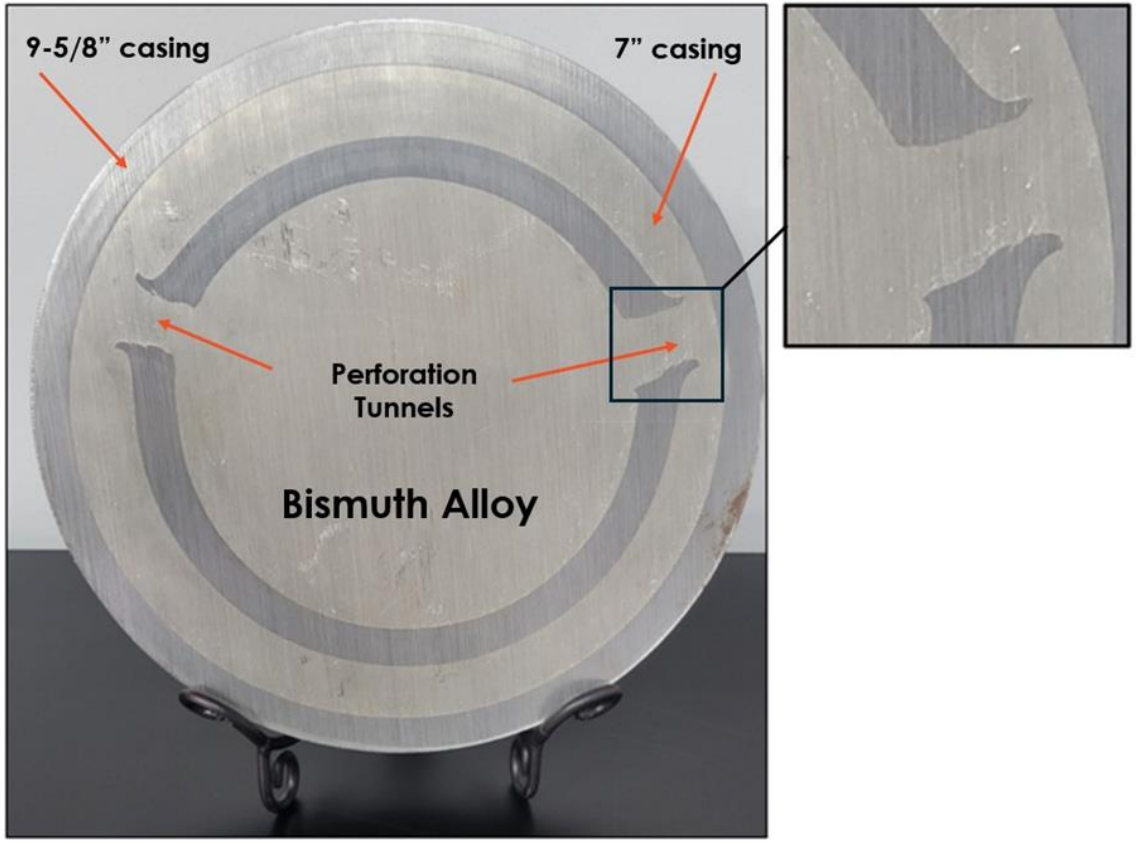
- Injection well
- Undefined communication between the injection string and the annulus
- High deviation (82°)
- Unsuccessful to isolate with conventional technologies
- Bismuth alloy barriers provided solution for achieving effective lower abandonment isolation
- First ever Bismuth alloy deployment in South America



Source: TN Petróleo

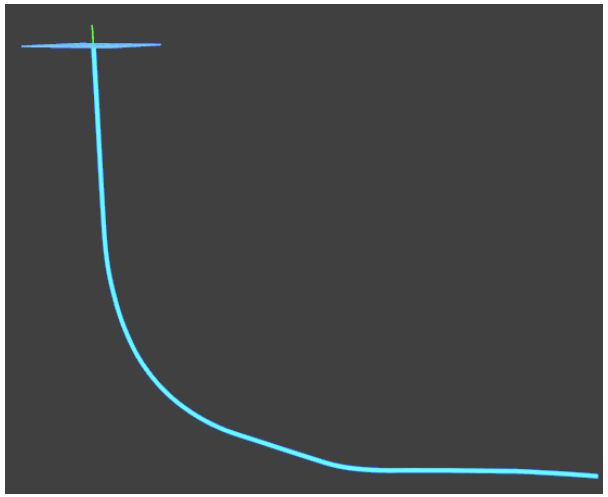
Why Bismuth ?

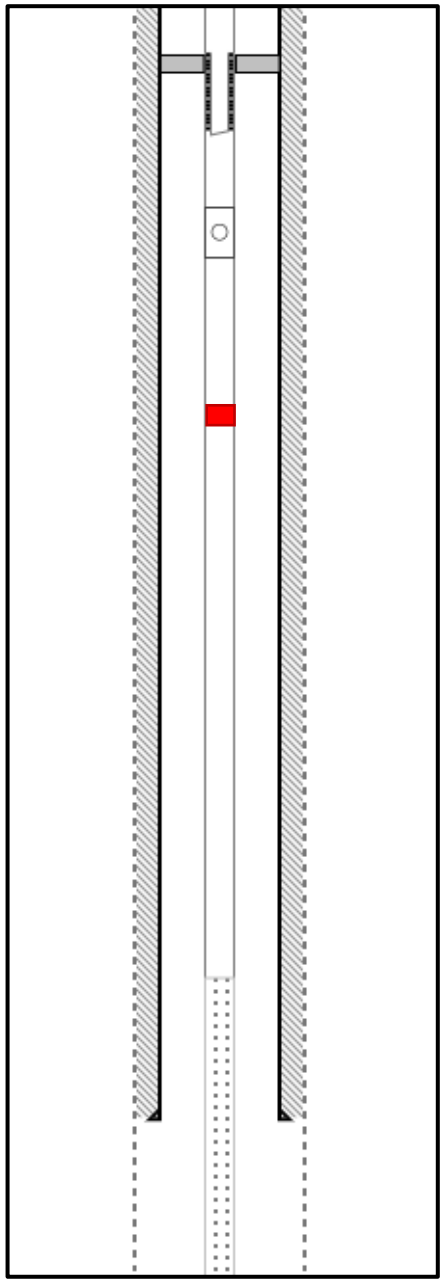
- Eternal Barrier – seals by expansion
- Impermeable to gas, no contamination – Shorter Plugs
- Not affected by CO2, H2S or acids
- High Density – heavier than steel
- Low viscosity - flows like water
- No surface pumping equipment required
- Molten metal takes shape of any sealing ID

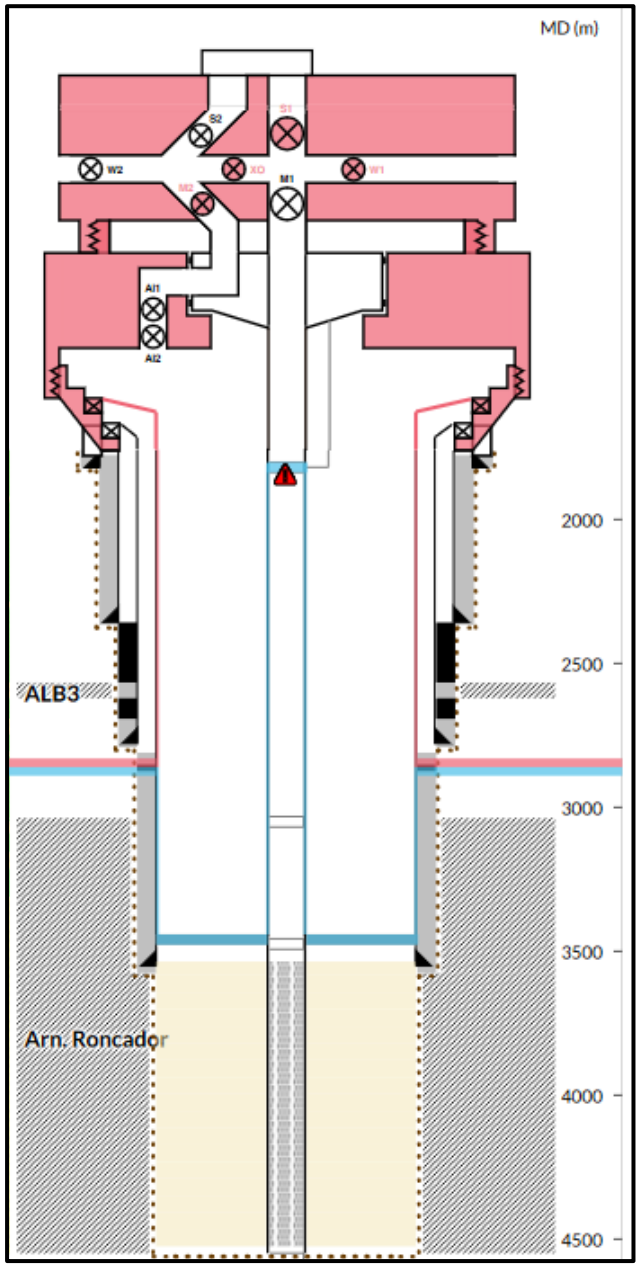


Setting Conditions:

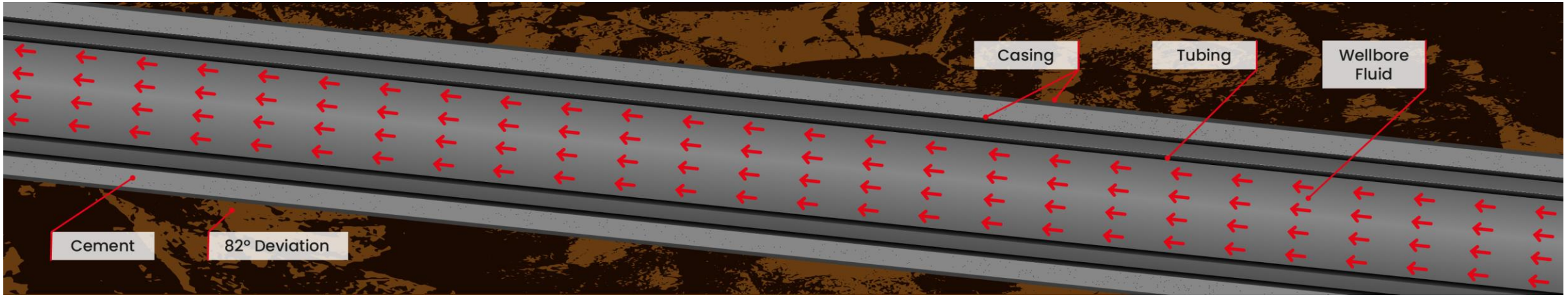
- Tubing: 5-1/2”
- Setting Depth: 3,445 m MD
- Hydrostatic: 4,890 psi
- Temperature: 61 °C
- Deviation: 82°

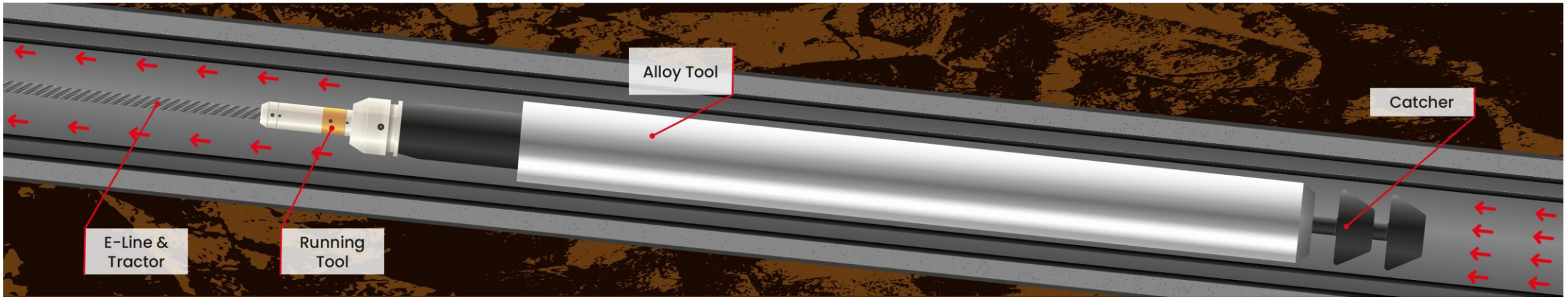






Solution: BiSN Wel-lok Tubing Seal





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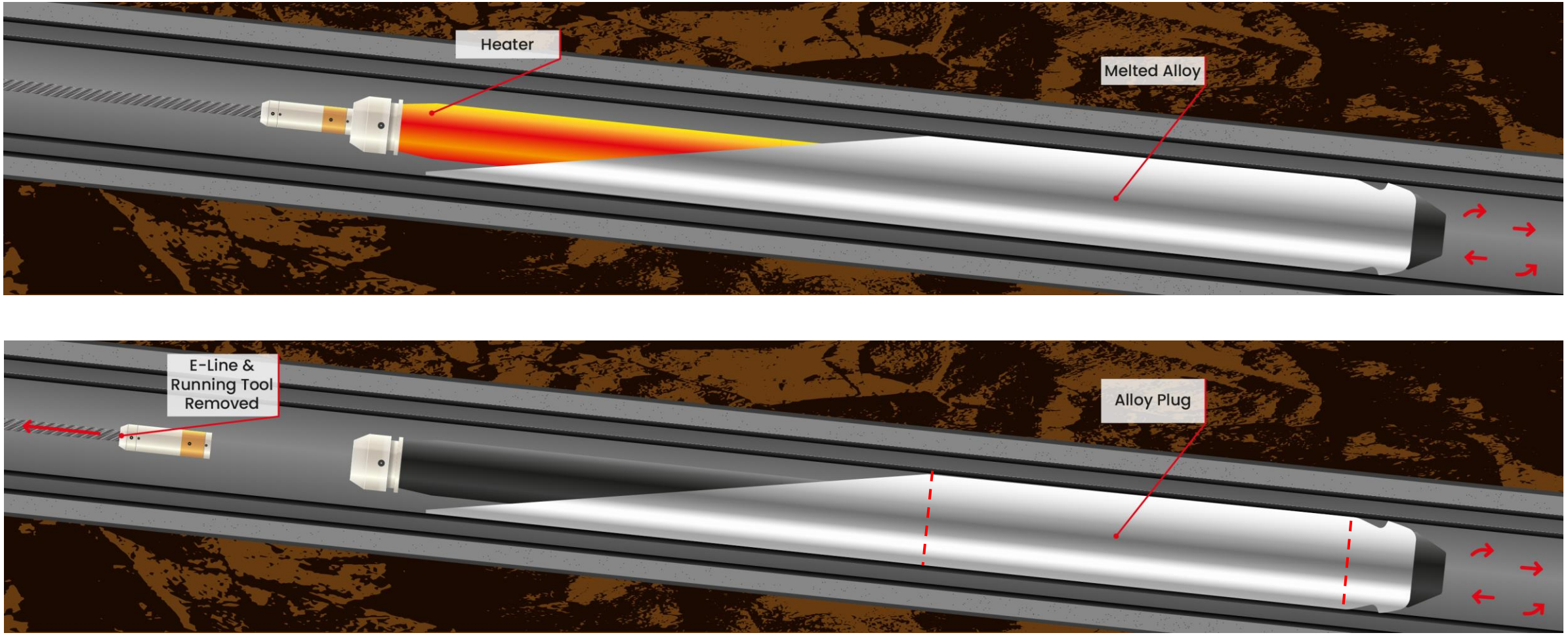
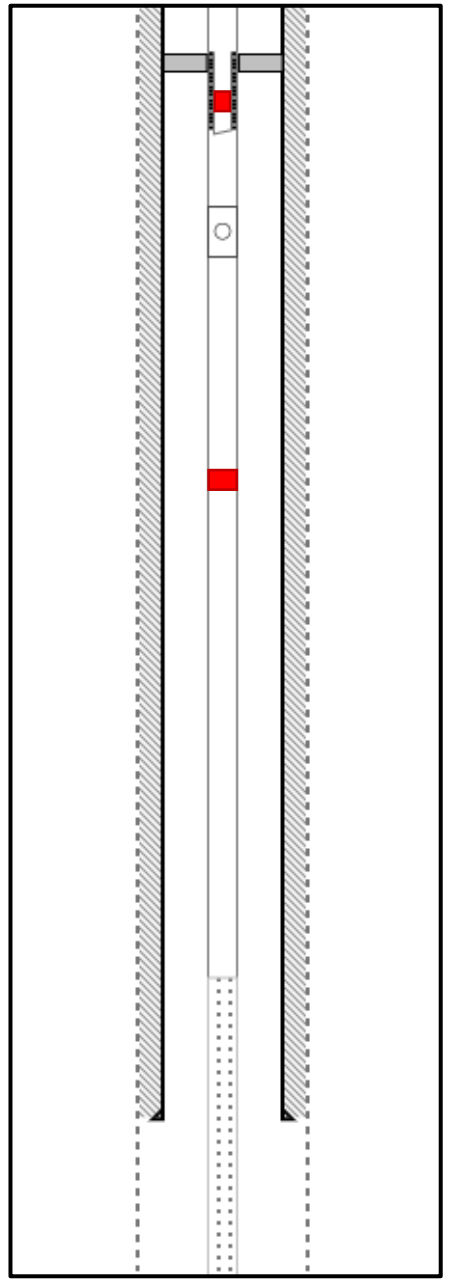
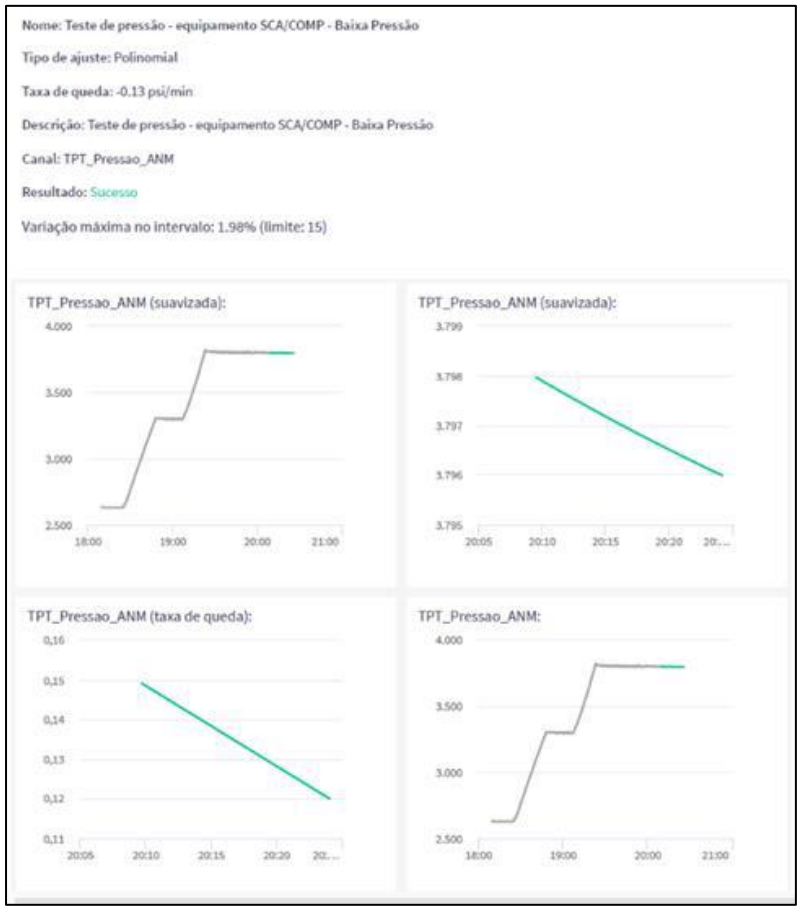


Operations

- 3.250” OD BiSN Wel-lok Tubing Seal
- First plug set at 3,482 m MD
- Pressure test not successful
- Plug potentially set at wrong depth
- Caliper logs showed irregularities (probably caused by corrosion) on the string from the packer to the screens
- Second plug set at 3,445 m MD in the middle of the Locator sealing area
- **1,100 psi positive test and 300 psi negative test successful**



Results

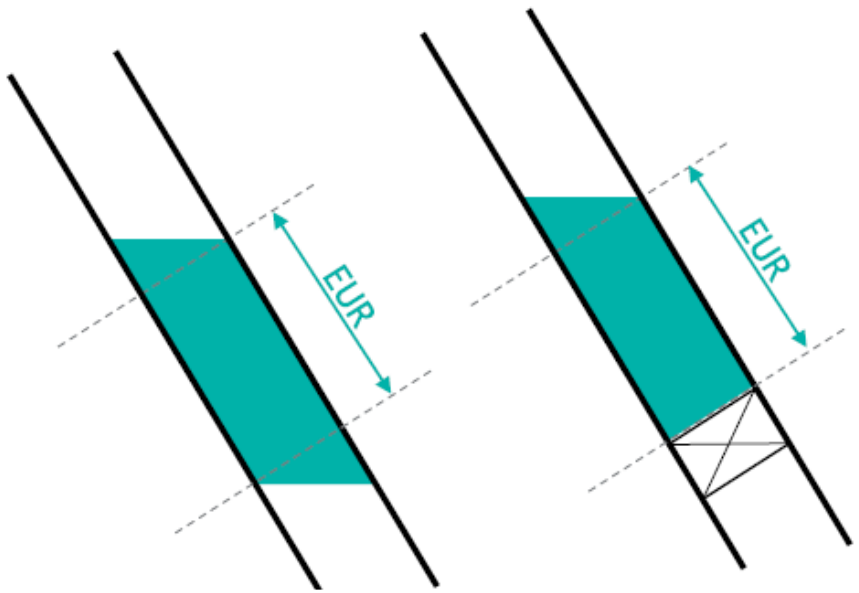


Pressure test with 1,100 psi differential at the top of the plug

Negative (bottom to top) pressure test at 300 psi

Acceptance Criteria

- Petrobras developed an acceptance criteria to validate the Bismth plug as a temporary barrier



EUR = Extensão Útil Real
(Real Useful Extension)

Characteristics	Acceptance Criteria
I. Description	Mechanical barrier resulting from the bismuth alloy solidification process.
II. Functions	Prevent the flow of fluids from the formation, between intervals of different formations inside the well and/or to the surface of the land/seabed
III. Design/Construction/Selection	...
IV. Tests/Verification	...
V. Type of Applicable Abandonment	☒ Temporary ☐ Permanent

Other Petrobras challenging operations and ongoing solutions

Building on our successful and pioneering operations, we continuously face new challenges that drive us to enhance Bismuth services to meet these demands.

High Inclination

- A robust solution is to run AOH tubing seal tool and leave the heater in the Bismuth barrier
- While Petrobras's well configurations may present challenges, they also offer opportunities for innovation and improvement

Solutions ongoing in partnership

High temperature

- Broad operating range requires wide variety of alloy types
- High Temp batteries to accomodate challenging well conditions sourced

Solved by BiSN

Scale

- Worldwide challenge even for cement or mechanical plugs
- Need to understand scale behavior during Bismuth plug solidification

Solutions ongoing in partnership

Milled restrictions

- Sharp surfaces bring difficulties when BHA is run in hole
- Some BHA elements redesigned to be more robust

Solutions ongoing in partnership

Overview on Petrobras Operations

- Service flexibility directs the application to challenging scenarios
- Increasing expertise from Petrobras' technical staff in the application
- Petrobras’ scenarios add challenges to be overcome regarding well design and operation
- Value of the service is high when installation and verification of the barrier are positive
- Future challenge in the application for generating simultaneous tubing seal + annulus A barrier