# The Ups and Downs of Introducing a Novel Technology for Rigless Well Abandonment

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Italmatch Chemicals
SPECIALTY, ENERGY/ELECTRIFICATION & OLEOCHEMICALS

# Presentation Overview



- Introduction

- Established Solutions

- Alternative Barrier Technology
  - Introduction
  - Testing
  - Field Case History
  - Product Benefits

- Lessons Learned

- Development to Application – The Disconnect?

# Introduction - Well Abandonment / P&A?

**Objective** — "Isolation of formations with flow potential"*

- Zones of flow potential:
  - "Flow potential originates from formations with permeability and a pressure differential with other formations or surface."*
  - Two key elements: Pressure and permeability

**Goal** — Ensure no unplanned escape of fluids from the well / reservoir to which it led

- UK Design and Construction regulations (DCR) do not state how this is done, only that this,
  - Must not hurt anyone
  - Must not result in "uncontrolled emissions to the environment"

**Traditional Method** — "Restore the cap rock"

- By placing a pressure retaining barrier in the wellbore across caprock

- Could we look at this differently - looking at zones of flow potential and permeability?

*Definitions as per OGUK *Well Decommissioning Guidelines, Issue 6*

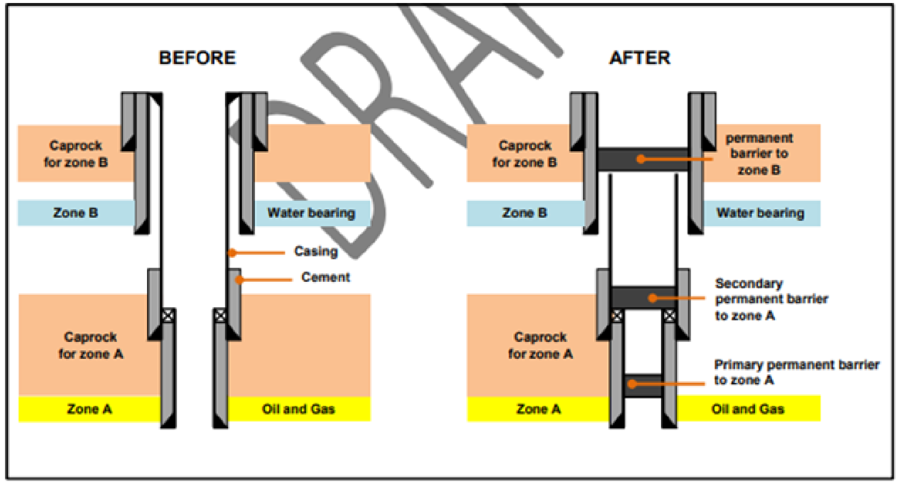
# Introduction - OEUK Decommissioning Guidelines

- Guidelines developed to identify best practice in line with UK DCR – three documents
  - Well Decommissioning
  - Use of Barrier materials in Well decommissioning
  - Well decommissioning for CO2 storage

- UK regulator uses these guidelines to assess and approve well decom programs
  - These have adopted around the world by regulators and major oil companies to assess the approve decom programs

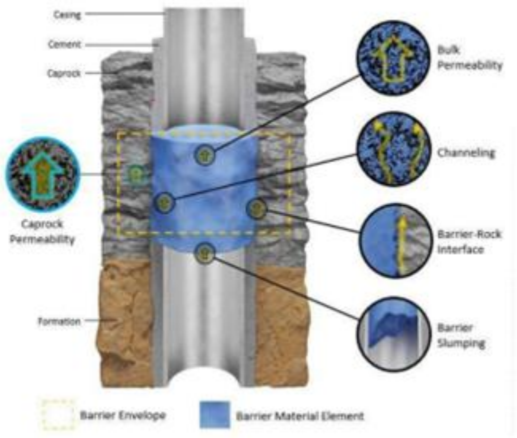
- Guideline Basics

| |
|---|
| Zones of flow potential must be controlled |
| Oil producing zones must be isolated with two permanent barriers in the well to provide control |
| The barriers must be permanent and last “forever” under well conditions |
| Most barriers are in the well set across impermeable caprock with the effect of restoring the cap rock |
| You must be able to verify the barrier once in place |

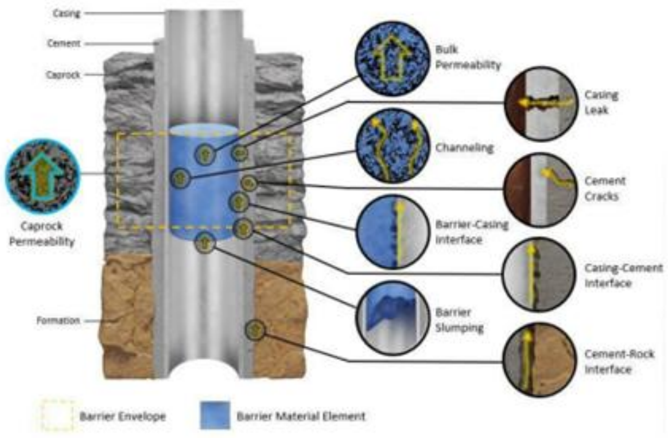


# Introduction - OEUK Decommissioning Guidelines

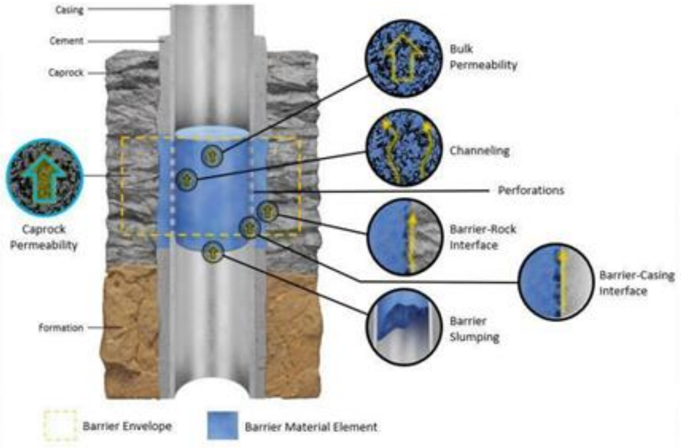
- Examples of accepted barriers and failure modes previously included in guidelines




Against caprock – casing mechanically or chemically removed



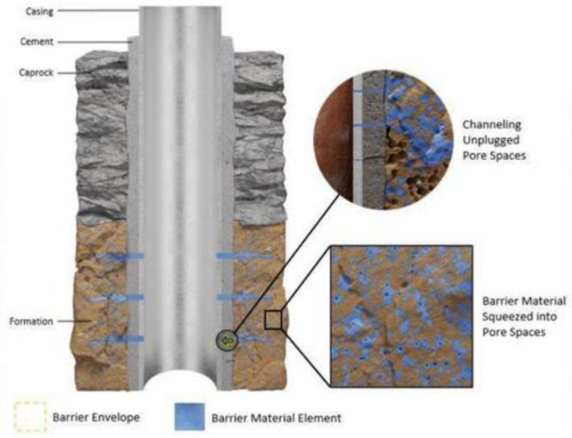

Against casing cement and caprock




Through perforations against caprock

- The guidelines have recently been revised and rewritten to encourage the take up of new technology for Decom and are less "cement centric"

- 'Through perforations against caprock' has now been extended to include barrier squeezed into pore spaces as an example of an accepted barrier
    - This is a crucial step towards Aubin® Xclude being considered as a viable barrier technology




Through perforations against caprock

# Established Solutions

- Rigless zonal isolation methods are available however, there are often challenges associated with these solutions that impact their effectiveness

## Bridge Plug or Straddle Packer

- Zonal isolation can be achieved with a mechanical plug or packer, or a packer assembly such as a straddle
- Difficulties in achieving seal in older wells with worn and corroded sections of casing
- Compromised tubulars can prevent conveyance of mechanical seal down to the relevant depth
  - Coiled tubing can be used to overcome these challenges and accurately target an area for isolation by pumping a chemical treatment or cement

## Cement

- Usually, the first seal material and remedy employed due to its popularity, availability, and cost
- Despite low cost, operations can quickly become expensive if it fails to provide a seal
  - Multiple cement plugs may be required over the course of several days to successfully establishing a seal
  - Introduction of particles that can bridge off in small cracks and pores, making it difficult to squeeze off and seal small leak paths
- Additional challenges introduced using cement involve slurry contamination
  - Cement slurry is heavy and is diluted when exposed to water
  - Cementitious particles settle and alter the design density of the slurry thereby compromising the system
  - Further contamination can occur if the cement slurry is exposed to hydrocarbons that can ultimately inhibit hydration

## Resins

- Resin technology may be able to overcome many of the challenges affiliated with these conventional solutions
- Challenges with some resins still exist include
  - Hardening before placement
  - Exothermic reaction triggered by water creating potential damage downhole or to surface equipment

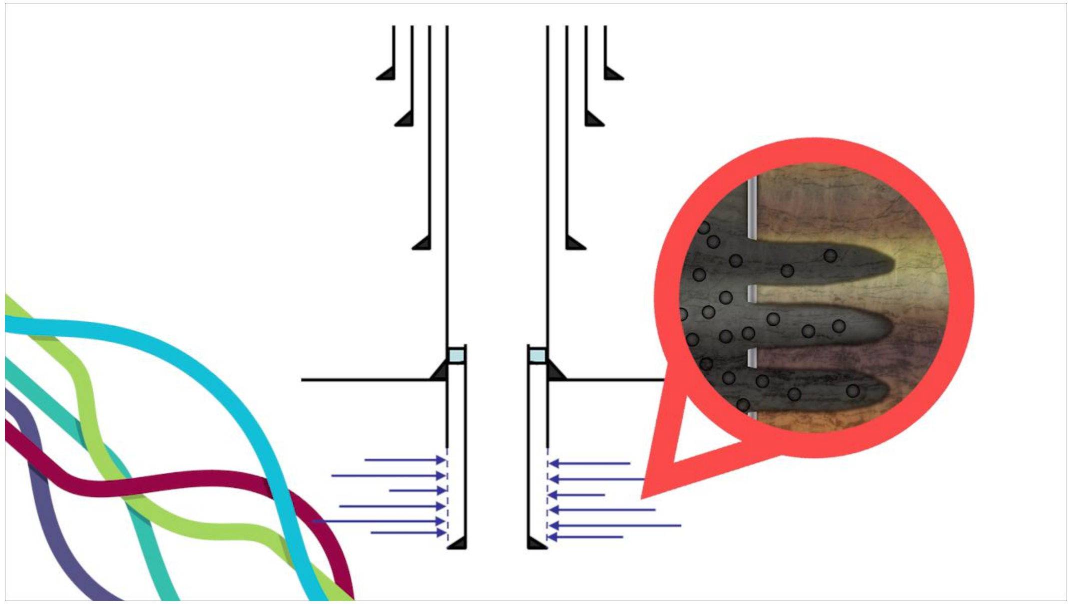
**Well integrity challenges for placement making plugs prone to leaking, need of a rig**

**Finite life meaning retreatment will be required**

- There are other technologies being considered but there is no ‘one size fits all’ solution
  - Instead, multiple technologies make up the well decommissioning toolbox

# Induced Formation Damage

- Italmatch have developed an alternative barrier technology for zonal isolation and reservoir abandonment
- Principle is inducing inorganic scale deposition in the formation, while keeping the tubing protected



## Alternative to cement or mechanical plug

- A calibrated mix of 3 fluid chemical components pumped into the zone to be isolated
  - Solids free, Low Viscosity, (CEFAS registered, low hazard or PLONOR) components
  - Once in the formation, scale precipitates, blocking pore throats and reducing permeability

## Mineral scale barrier created in formation rather than wellbore

- Reaction is controlled until fluid enters formation
- Reaction is not reversible
- Maintains wellbore internal diameter and access for future well work (e.g., geothermal operations, additional plugs, carbon capture)
- Does not require good annular cement - barrier extends beyond this

## Eliminates or reduces the need for, or period of, rig hire

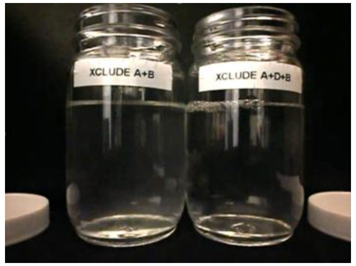
- Can be bull-headed through tubing into formation without need for expensive rig hire
- Can be deployed using coil tubing (*e.g.*, geothermal well systems)
- Significant savings over technologies requiring rig for deployment
- -68% Carbon footprint reduction vs. traditional cementing job (P&A)

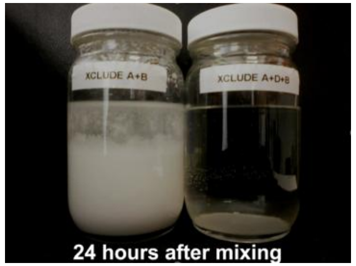
- Patents filed by Italmatch to protect this technology globally

# Testing - Proof of Performance

- Scaling components, mixing ratios, inhibitor chemistry and dose rates optimised during development

- Static jar tests
  - Comparing uninhibited system with inhibited system
    - Observations made over 24 hr period
  - Xclude D is the scale retarder component



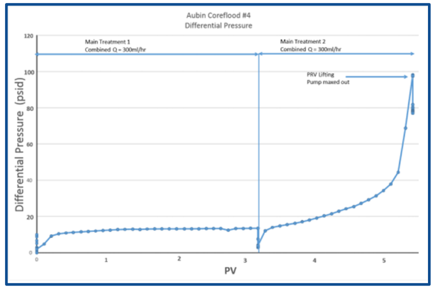

- Sand pack tests
  - Pre-flush – fluid passed easily through
  - Initial Xclude treatment - fluid passed through but increasing resistance to flow
  - Shut in fluid for 3 hours - sand pack saturated
  - Second Xclude treatment – fluid would not pass though

Before

After

Scale filling the pore throats and extending throughout the sand pack

- Core-flood tests
  - Confirmed core blockage, with 90 – 99.7% reduction of permeability achieved
    - Core: Sandstone
    - Permeability: 400 – 650 mD
    - Temperature: Ambient



# Testing - Application Specific



## Scaled Solutions Ltd, commissioned by an IOC, North Sea

### Proof-of-Concept Testing

- Modified core flood equipment - mixing inlet end platen created
- Adjustment of ‘standard’ test protocol and optimisation of fluid concentrations and flow rates
  - 500 mD Clashach Sandstone
  - 130°C
  - 30 – 240 ml/hr

### Results

- Permeability reduction of >99% achieved
- 500 psi differential successfully applied over extended period
- micro-CT scanning confirms that scale has been precipitated throughout core sample

### Next Tests

- Permeability reduction in field core
- Exposure to a range of field fluids and production/stimulation products
- Pressure testing after long term thermal ageing of scaled plug

**Image 3.3:** Left – F>W Inlet face, Right – W>F Inlet face

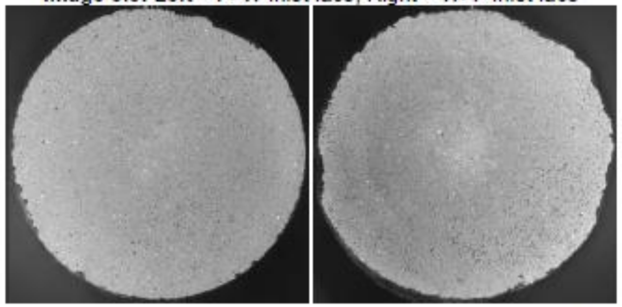
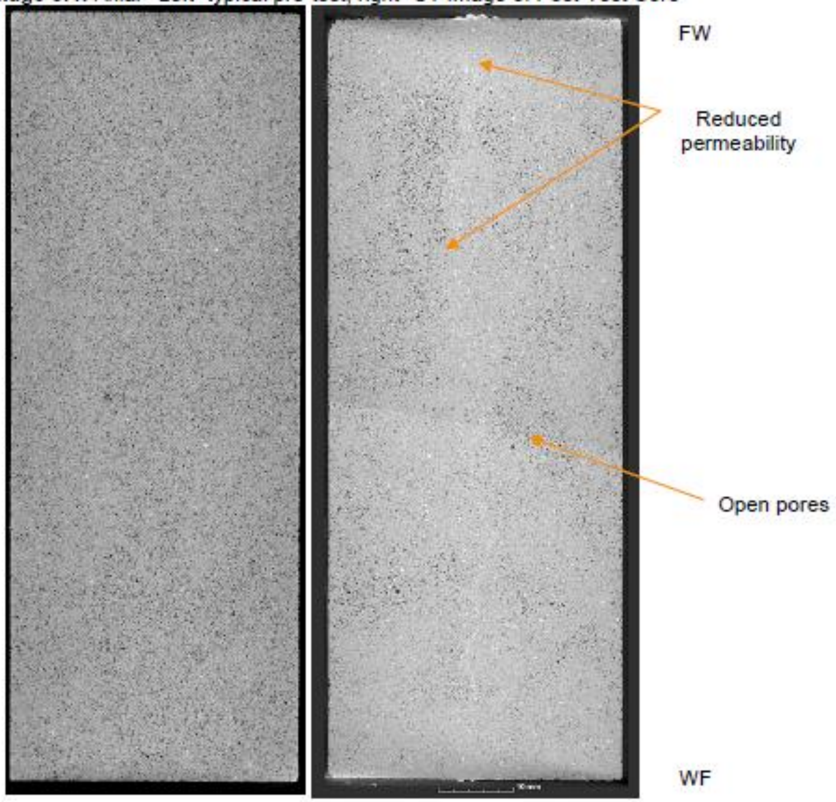


**Image 3.4:** Axial –Left- typical pre-test, right- CT Image of Post-Test Core



# Testing - Alternative Cement Barrier Remediation JIP

- JIP being run by Innotech Alberta
  - Aubin® Xclude selected as 1 of 5 most interesting technologies from >40 submissions

## Treatment Results: Italmatch

- Tests looking at a range of potential applications
- Testing based on core flooding
  - Sand pack with permeability of 7000 – 7500 mD
    - ~70% permeability reduction
  - 100 µm and 200 µm cement apertures
    - Carbonate core sliced along length to create apertures replicating micro-annuli
    - 100% permeability reduction in 100, 200 and 3175 µm apertures

| | Sandpack | | 100 µm Aperture | | 200 µm Aperture | | 3175 µm Aperture | |
|---|---|---|---|---|---|---|---|---|
| **Before Treatment** | | | | | | | | |
| **Brine Permeability** | 7366 | md | 583 | md | 7531 | md | 50000 | md |
| **Q1** | 10 | ml/min | 10 | ml/min | 11.7 | ml/min | 8.33 | ml/min |
| **P1** | 1.25 | psi | 10.815 | psi | 1.12 | psi | 0.1 | psi |
| | | | | | | | | |
| **After Treatment** | | | | | | | | |
| **Q2** | 13.33 | ml/min | 0.058 | ml/min | 0.002 | ml/min | 0.003 | ml/min |
| **P2** | 5.5 | psi | 600 | psi | 600 | psi | 1000 | psi |
| **Permeability Reduction Factor** | 3.30E+00 | | 9.51E+03 | | 2.89E+06 | | 3.33E+07 | |
| **Permeability Reduction %** | 69.697 | % | 99.989 | % | 100.000 | % | 100.000 | % |
| **Permeability After Treatment** | **2232** | **md** | **0.061** | **md** | **0.003** | **md** | **0.002** | **md** |

InnoTech ALBERTA

# Field Case History

## Challenge

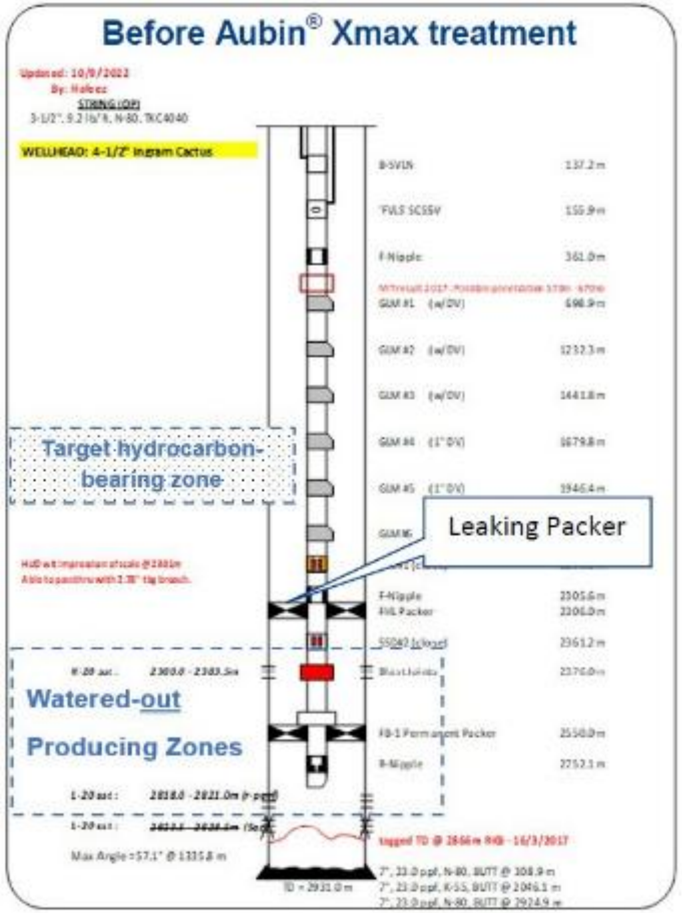
- Behind Casing Opportunity (BCO) to enhance oil production in a brown field development offshore.
- Leaking top packer required remediation prior to cement packer job to allow BCO without need for costly workover.

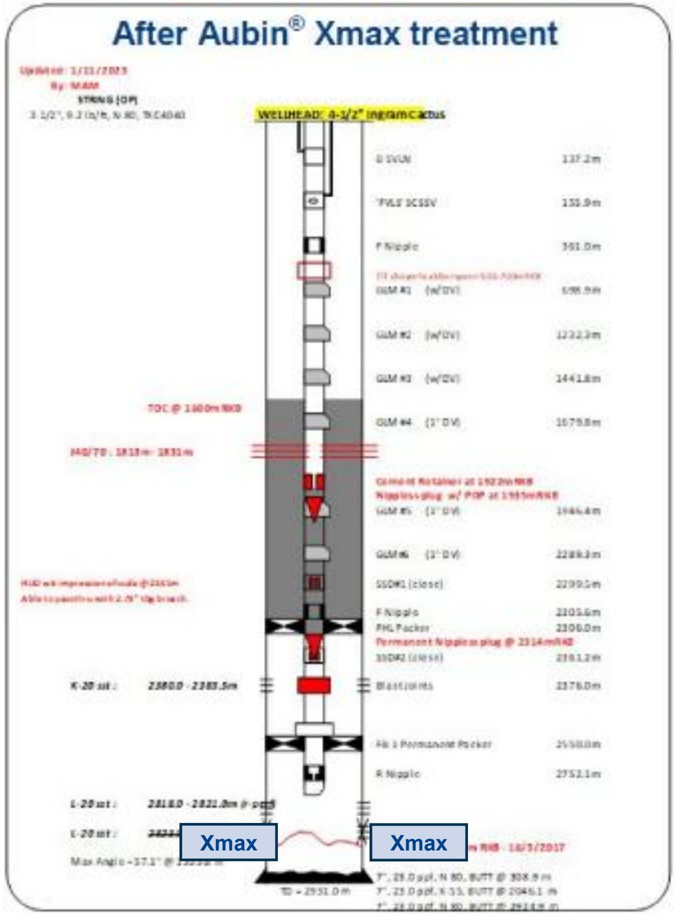
## Solution

- Treatment using Aubin® Xmax for zonal isolation of lower, watered-out production zones as a means of remediating the top packer leak.

## Outcome

- Pressure test was conducted 24 hours after treatment shut-in maintained 1,000psi over 1 hour.
- Pressure test conducted 2 months after treatment maintained 500psi over 15 mins. prior to cement packer job.
- Cement packer job completed without full workover and associated costs.
- New perforations added to access BCO.




**100% Oil**
No water from lower zones

**300 bopd**
From new perforations

**16 years**
Production life extension

**$1.9 million**
cost savings vs. workover

# Cost Challenges of Decommissioning

- Cost challenges arise from sheer number of wells and the eventual need for multiple jobs on the same well

| Onshore | Offshore |
|---|---|
| • Huge number of wells but tighter costs<br>• Data from 19,500 wells found average costs<br>  • $20,000 (plugging only)<br>  • $76,000 (plugging and surface reclamation)<br>  • In rare cases, costs exceed $1 million per well<br>  • Each +1,000 feet of well depth increases costs by 20%<br>  • Older wells are considerably more costly than newer ones | • Less wells but demand for success is high<br>• Potential for major cost savings<br>• On average, well P&A costs:<br>  • $500,000 per shallow-water well<br>  • $10 million per deepwater well |

- Well P&A accounts for 50% of total P&A costs, with requirement for rig deployment being the major cost
- The majority of established technologies require rig deployment
- Rigless abandonment technology has the potential to reduce rig time and significant cost savings may be achieved as a result
  - Offshore wells will see the largest benefit as rig hire costs are the main cost here

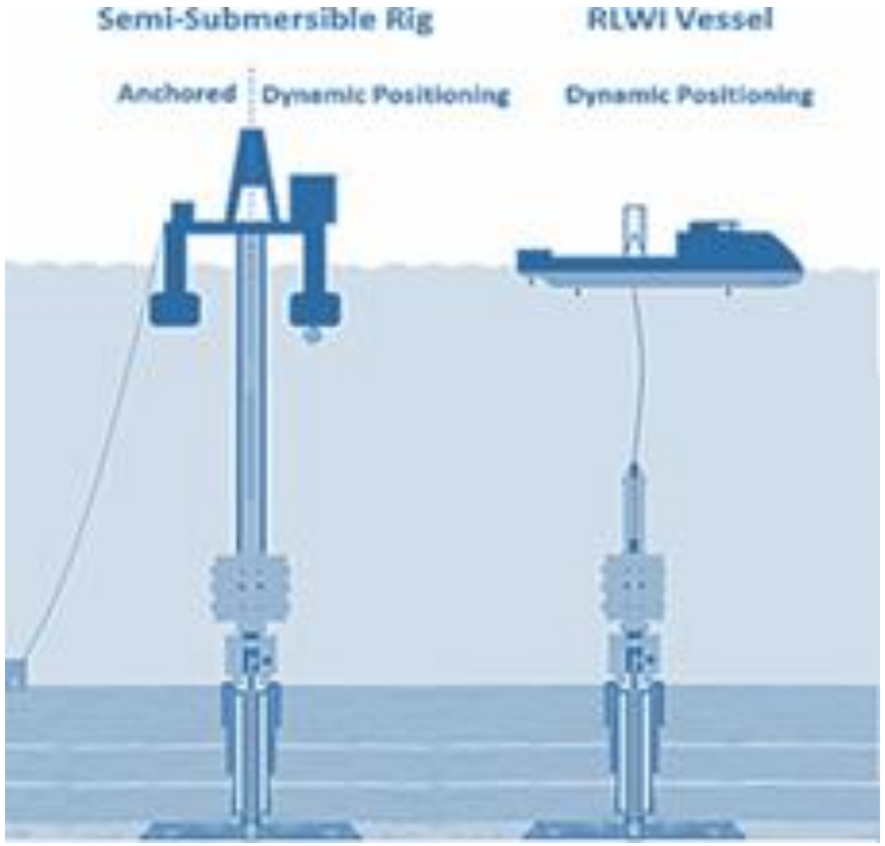
| | USA | Canada | UK | Netherland | Norway |
|---|---|---|---|---|---|
| Total Wells to be abandoned | 3.5mio | 145K | 1.6K | 470 | 250 |

# Product Benefits | Cost

- Xclude has the potential to reduce rig time or even eliminate the need for a rig (depending on decommissioning plan), and significant cost savings may be achieved!
  - Rig hire is the key cost item (above €300K/day in offshore operations)
    - Xclude buys time
  - The use of a rig immediately increases cost
    - Significant rig costs per day \$200 - \$500k/day
    - Average time to P&A offshore well (2021) **28 days**
    - 28 days @ **€350k** = **€9.8M** just for **rig costs**
  - Treatment costs are influenced by, and will vary with, well integrity / complexity

| | Aubin® Xclude | Cement |
|---|---|---|
| Service | Low | Low |
| Transport / Shipping | Low | Low |
| Manpower | Low | Medium |
| Waste (Transport and Treatment) | None | Low |
| Rig hire | None | High |

  - Cementing may require higher volumes or multiple plugs
    - Poor well integrity or higher well complexity (depth, deviation and location)
    - Multiple plugs increases ancillary costs (rig hire, manpower, logistic, waste, etc.)




- Potential saving of €4.23m per well - Assuming reduction of P&A rig time from 28 to 15 days is possible using Xclude

# Product Benefits | Other Factors



Low Hazard Components

Lower waste transport/ processing

Reduced or eliminated requirement for Mobile Drilling Unit/ Vessel

Improved Carbon Footprint

- CEFAS categorisation of Aubin® Xclude components
  - Aubin® Xclude A - Non-CHARMable
  - Aubin® Xclude B - PLONOR
  - Aubin® Xclude D - Gold with sub warning
    - Alternative Gold no sub warning inhibitors are available
    - Limited volumes of additive required

- Aubin® Xclude offers **68% reduction of $CO_2$ emissions** – or 218 $CO_2$ tonnes/well - when compared to traditional cement P&A Treatment*

| Emissions Summary Comparison | | | |
|---|---|---|---|
| Emission source | Process Using traditional cement method (Kg /$CO_2$e) | Process Using XClude (Kg /$CO_2$e) | Savings (Kg/$CO_2$e) |
| Embodied | 4,120 | 43,480 | -39,360 |
| Transport & site preparation | 149,381 | 40,250 | 109,176 |
| Application | 168,466 | 20,656 | 147,810 |
| TOTAL | 321,967 | 104,341 | 217,626 |

* - As reported in the Carbon Zero® report: Xclude Carbon Emissions Comparative Assessment – Offshore Application

# Lessons Learned

## Technology development

- Optimised scaling component ratios
  - Highest scaling tendency and maximum potential mass
- Static testing demonstrates ability of retarder to delay scaling within bulk fluids
- Core flood testing confirms ability to block a core plug
  - Modification to industry standard core test equipment and protocols required to ensure scaling confined to within the core plug
- Standard approach to treatment design
  - Volume aims to fill 3 pore volumes of target formation
  - Radial penetration to 1 - 1.5m
  - Employs 2 main treatment applications separated by shut-in

## Field case study

- Permeability impairment achieved during displacement of $1^{st}$ Aubin® Xmax treatment
  - i.e. no 2nd treatment required
- HUD in well unchanged after treatment application
  - No evidence of scale deposition in tubing during or after deployment
- Barrier longevity established with successful pressure testing completed 2 months after treatment prior to next phase of well workover activity

## From potential end users

- Reluctance to progress to field trials despite a high level of interest in new barrier technology
  - “It is not cement”
  - Perceived risk of scale deposition during application - damaging equipment, or limiting well access for use of tubing-based barrier technologies
  - “Will it last for 1,000s of years?”
- Logistics and fluids handling considerations on platform
  - Deck space limitations
  - Volumes and mixing / bunkering procedures
  - Supply vessel requirements

# Development to Application - The Disconnect?

## Challenge

- A need for alternative barrier technologies recognised within the industry
  - Issues and cost challenges with established P&A solutions
  - Well integrity impacting placement and setting of tubing-based methods
  - Methane emissions from ‘abandoned’ wells

## Solution

- An in-reservoir barrier suitable for rigless deployment has been developed
- Proof-of-concept demonstrated in a range of lab test studies, both internally, and via 3rd party labs
- Discussions held with various global and regional regulators and safety bodies
- Interest and potential applications from across multiple geographies
  - UK and Europe
  - US, Canada & LATAM
  - Malaysia
  - Australia
  - Middle East

## Status

- Limited field applications realised
- Apparent reluctance to adopt new technology / move away from Mechanical / Cement plugs

## Goal

- Verification as an effective barrier through multiple successful field applications
- Establish the technology as an accepted barrier and part of decommissioning toolbox
- Simplify Well P&A process and reduce costs for the decommissioning community

# Thank you

- My colleagues and co-authors at Italmatch Chemicals
- The conference organisers
- You, for listening