IPS 2024

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# New Technologies Optimized for Plug & Abandonment Operations

**Presented by:**
**Jarrod Pearson, Owen Oil Tools**

AUTHORS: Jarrod Pearson, Shaun Geerts, Justin Coker – Owen Oil Tools

# Technologies

## Optimized Perf Wash Perforating

- Historically high shot density big hole perforating systems that were off the shelf
- Develop system and charge to target specific completion design that is optimal for select perf wash tools

## Optimized Casing Recovery Operations

- Historically required expensive milling operations to recover casing
- Develop systems to de-bond casing from cement to pull casing or alternative abandonment/remediation operations

# Plug & Abandonment Operations

## Strategies

Typical abandonment operations have evolved over time

- Section mill casing for annular exposure
    - Long duration operations, costly rig time

- Jet wash or cup wash style tools for remediation prep allowed for traditional perforating operations to shorten total rig time
    - Traditional perforating charges to place cement
    - Historically long intervals up to 200ft

- P&A perforating systems
    - Custom designed perforating charges to eliminate perforation of outer casing
    - Allowed for less cement, better remediation, shorter intervals
    - Reduced perforating costs and rig operation time

- Full Perf Wash system design
    - Optimizing wash tool and cement placement systems
    - Designing in conjunction with new perforating system for optimal performance

# Perf Wash Optimization

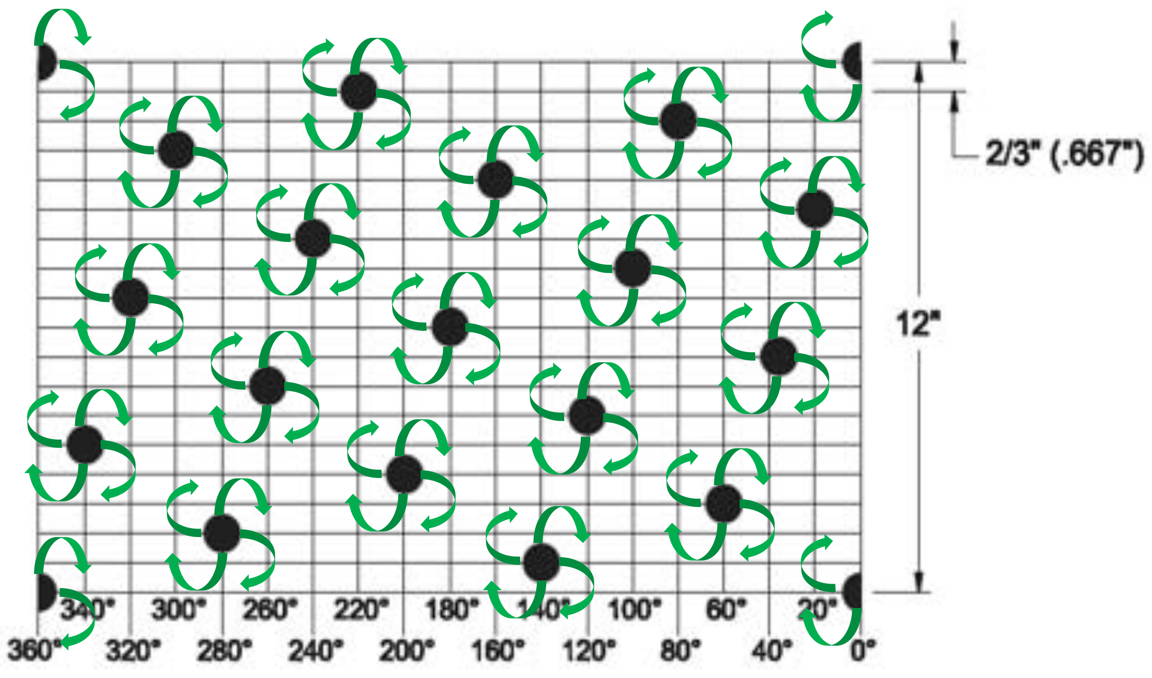
## Variables

- Historical preference was geared toward:
  - Total area open to flow or total casing removal
  - Large hole size was top priority
  - Did not evaluate phasing, shot density

- Did not account for actual flow dynamics or optimization of wash tool
  - Discovered that phasing was large factor on running speed
  - Distance between perforations impacted wash efficiency

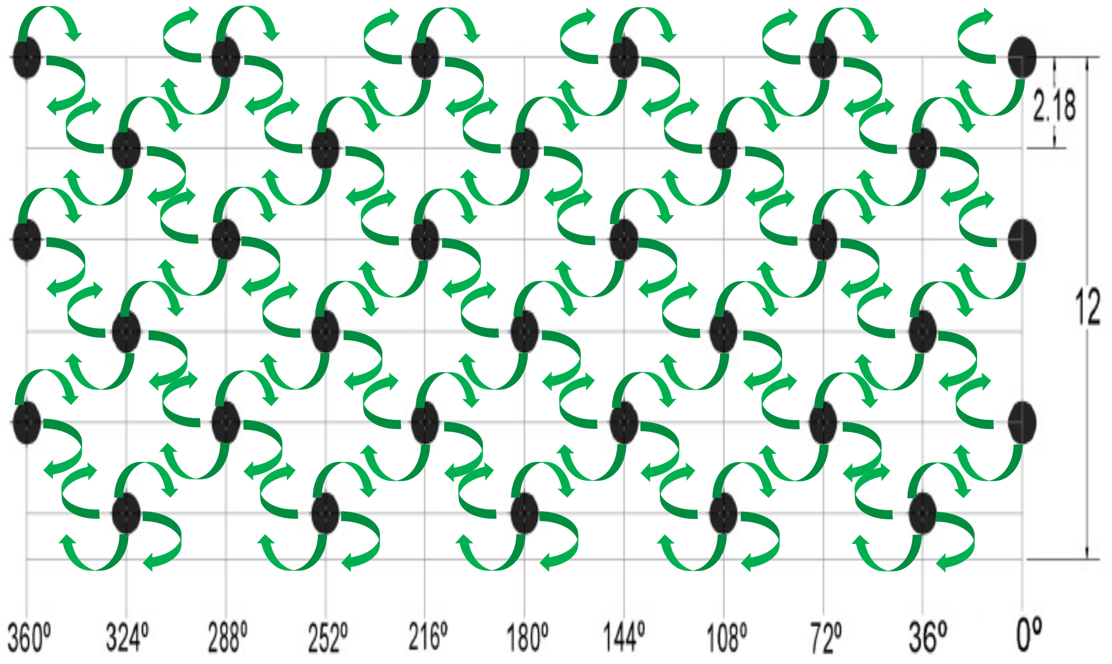
# Shot Phasing

## Optimization



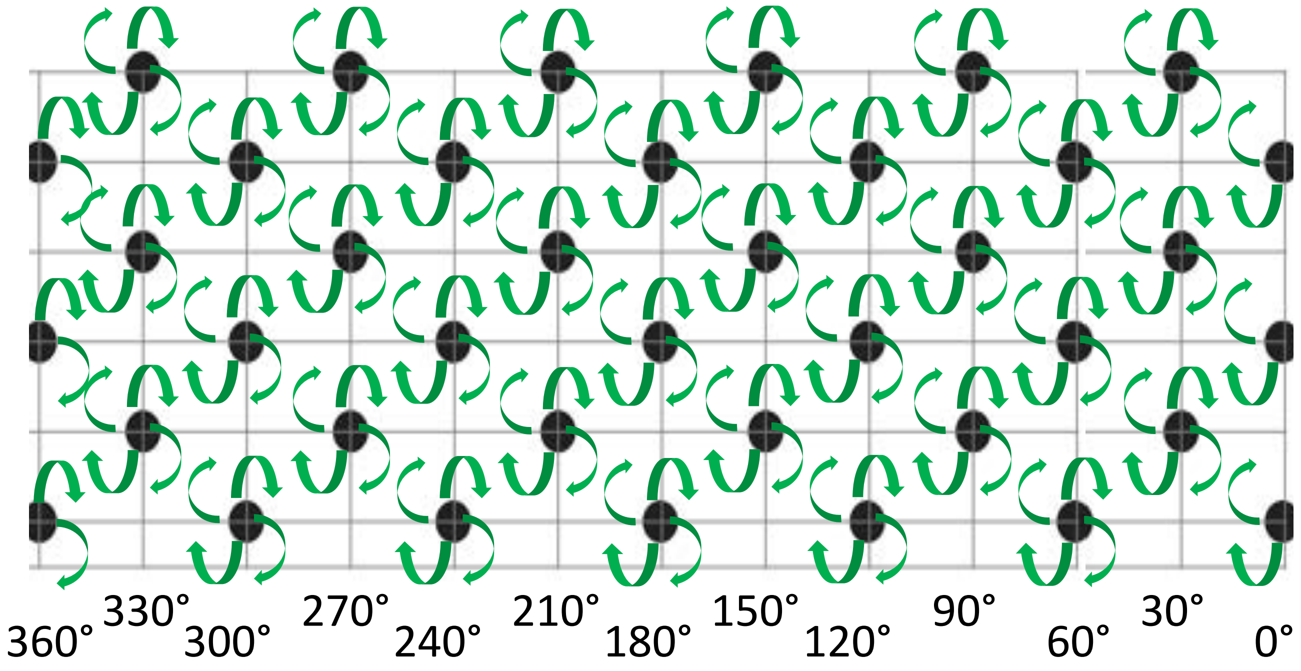

Traditional 18spf phasing

- Only washed one perforation at a time
- Large distance between perforations
- Longer wash times
- Lower efficiencies




Gen 1- 27.5spf phasing

- Washed 5 perforations at a time
- Shorter distance between perforations
- More efficient wash




Gen 2- 33spf phasing

- Wash 6 perforations at a time
- Shortest distance between perforations
- Faster wash run rate
- Highest efficiencies

# Run History

- Generation 1 @27.5spf systems have been deployed in the field for regular operations
  - Wash operations showed good efficiencies
    - Despite smaller hole size, the shot phasing improvement demonstrated that AOF was in fact not the most important variable
  - Cement Bond Logs showed good cement placement
    - Historical issues were present with resolution over 12spf. Current systems have improved to show at 27-33spf a good bond
  - Regulatory pressure testing to verify successful abandonment have been successful
  - Lower gram weight charges mitigates gun swell and operational challenges from previous systems

- Generation 2 @33spf has been preliminarily evaluated via CFD models
  - Shows promising results of increased wash efficiencies
  - Proceeding to field trials in H2 2024

# Slot Recovery Operations

## Design Considerations

- Remove the need for section milling
- Support slot recovery operations
- Recover stuck completions
- Improve perf and wash circulation and clean out
- Remedial cementing operations are better

# Theory

## Sequence of Initiation:

- Gun is ran to target depth.
- Gun is fired, limited penetration and propellant charges activated together
  - Limited penetration charges creates the path through the target casing without exiting outer casing
  - Propellant charge creates a path through the gun body and propellant sleeve.
- The pressure is then propagated through the casing exit holes causing the cement to pulverize and de-bond from casing.
- The casing is then retrieved to surface.

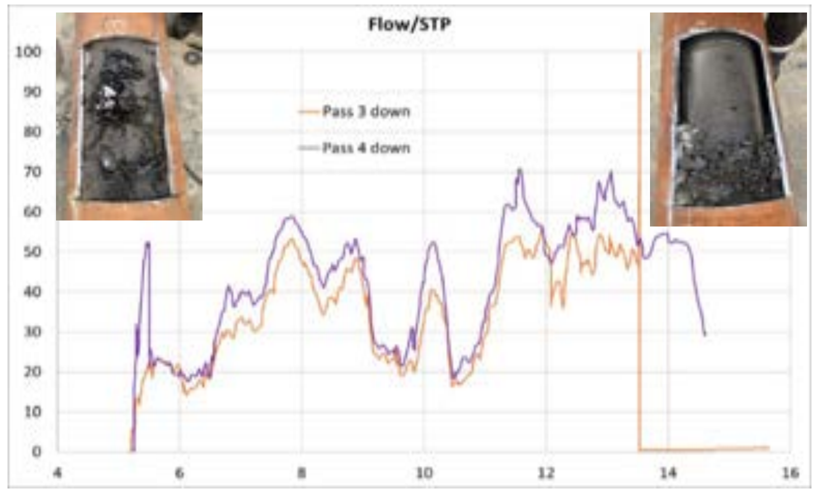
# Test Setup

- Full System testing for validation
- Needed to provide full confinement for cement annulus
- Required pressure seal for wellbore to drive pressure out into annulus
- High speed fast gauges ran on gun string to measure pressure dynamics
- Compare pressure data to computer modelling
- Various different methods for cement breakup analysis
  - Cut casing to visually inspect
  - Run bond logs to evaluate cement

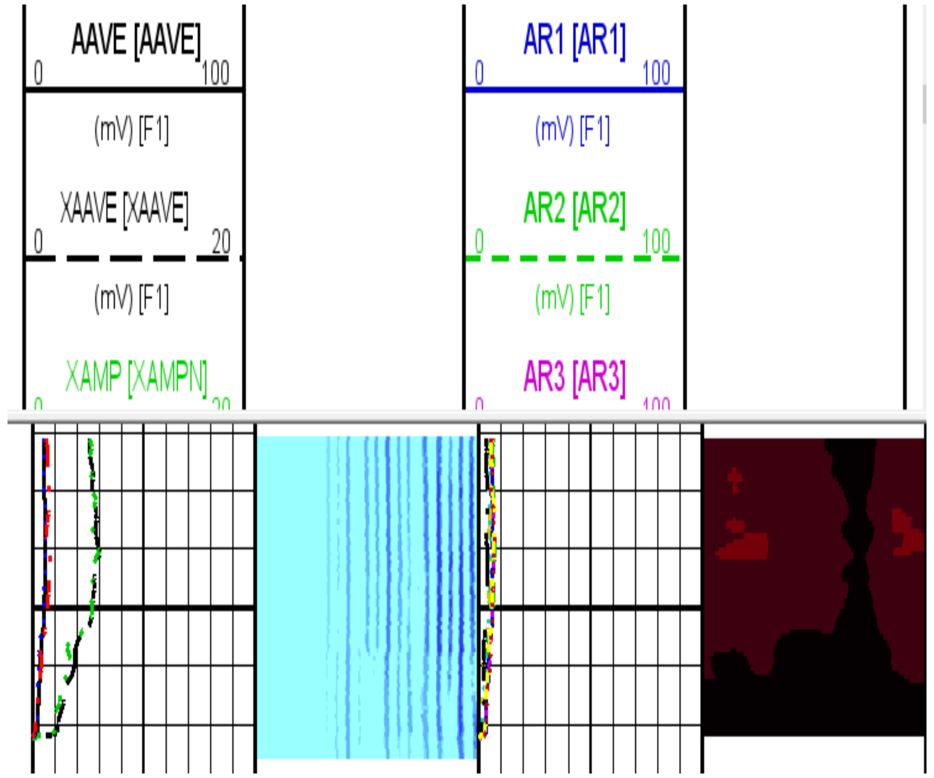
# Cement Plug Analysis

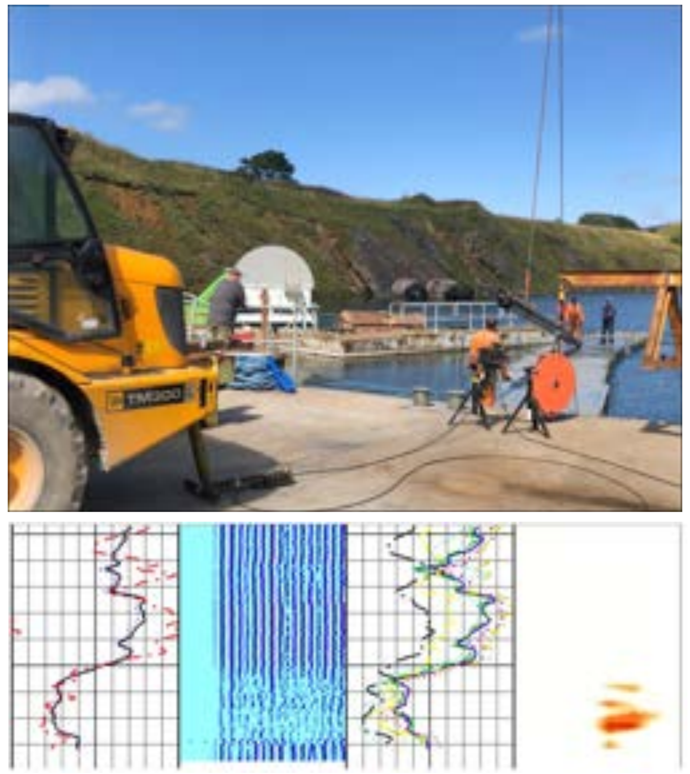
## Procedure

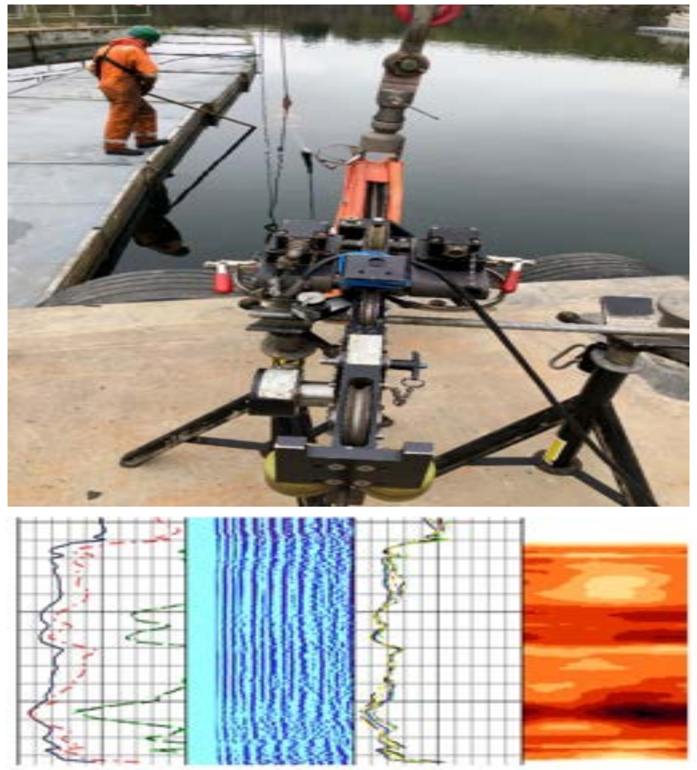
- Section of the full test vessel was taken for a cement plug to be set per typical perf wash methods
- Was setup in a dedicated rig facility after the perforating event
- Vessel was ‘washed’ utilizing a perf wash tool by same means as downhole
- Able to circulate fully across 10m interval
- Washing showed improvement with repeated cycles, indicating small cement debris was adequately broken up
- Was cemented post washing for analysis




# Cement Bond Log





Before perforating:
ca. 2 – 6 mV CBL response

Vessel cemented in controlled conditions at NORCE with standard 1.90 SG / 16 ppg G-class slurry

Definitively well bonded cement

Following perforation:
ca. 60 – 80mV in the top half, ca. 25 – 40 mV in the bottom half

Significantly debonded cement

After cementing:
ca. 10 – 20 mV over the majority of the vessel.

Substantially remediated cement!

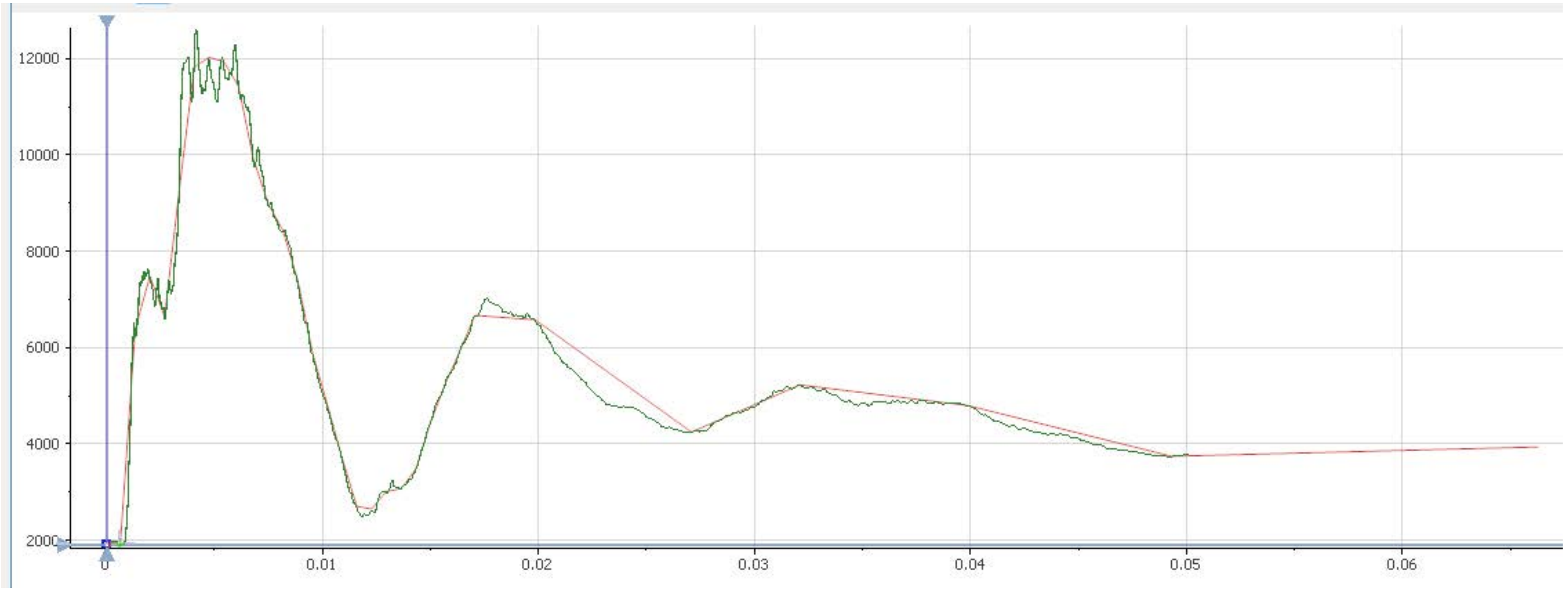
# Eutectic Plug Remediation

- Complete breakup of cement annulus was seen from testing when casing was sectioned
- Unopened portion of casing was sent to have an eutectic material pumped into the annulus
- Upon completion it was cut open and visibly solid annular plug was in place
  - When dissected further there are visible veins of eutectic material throughout the pulverized cement

# Computer Simulations

## Development

- No current propellant technologies to accurately model
- Important to be able to model because the system is not a simple, “more propellant = more breakup” design
  - Risk of overpressure causing damage to casing and BHA
- Attempted numerous different techniques and countless iterations in PulsFrac
- Relied heavily on fast gauge data from full system testing to refine propellant properties in simulations



# Conclusion

- Perforating technology was a fast step change in technology performance provided to operators
  - Able to capture increases in efficiencies relatively quickly
  - Reducing rig and operational time offset any perforating expense

- As the new perforating technologies became the new normal, operators looked back to operations
  - Dedicated focus on increased operational efficiencies have now pushed perforating into review

- Perforating tools are now back in review
  - Historical step ladder of one piece of the completion getting better at a time seems to be shifting
  - Need to continue to advance and grow all technologies in conjunction with one another

- Operators must work intimately with service providers and manufacturers on these initiatives to drive all the technologies together so that a reliable and highly efficient system is the result

# Special Appreciation

Partners in Development for systems development and test programs

Perf Wash System- TCO and ConocoPhillips

Casing Recovery System- Total, Archer, Baker Hughes, Wellstrom

# QUESTIONS?

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