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MENAPS 2022

MIDDLE EAST AND NORTH AFRICA PERFORATING SYMPOSIUM

Relevance of Single and Dual-Casing Erosion Mechanics for Re-Frac Applications

DynaEnergetics

MENAPS-18-22 AUTHORS: L.McNelis, J.Loehken, B.Fricke, D.Yosefnejad.

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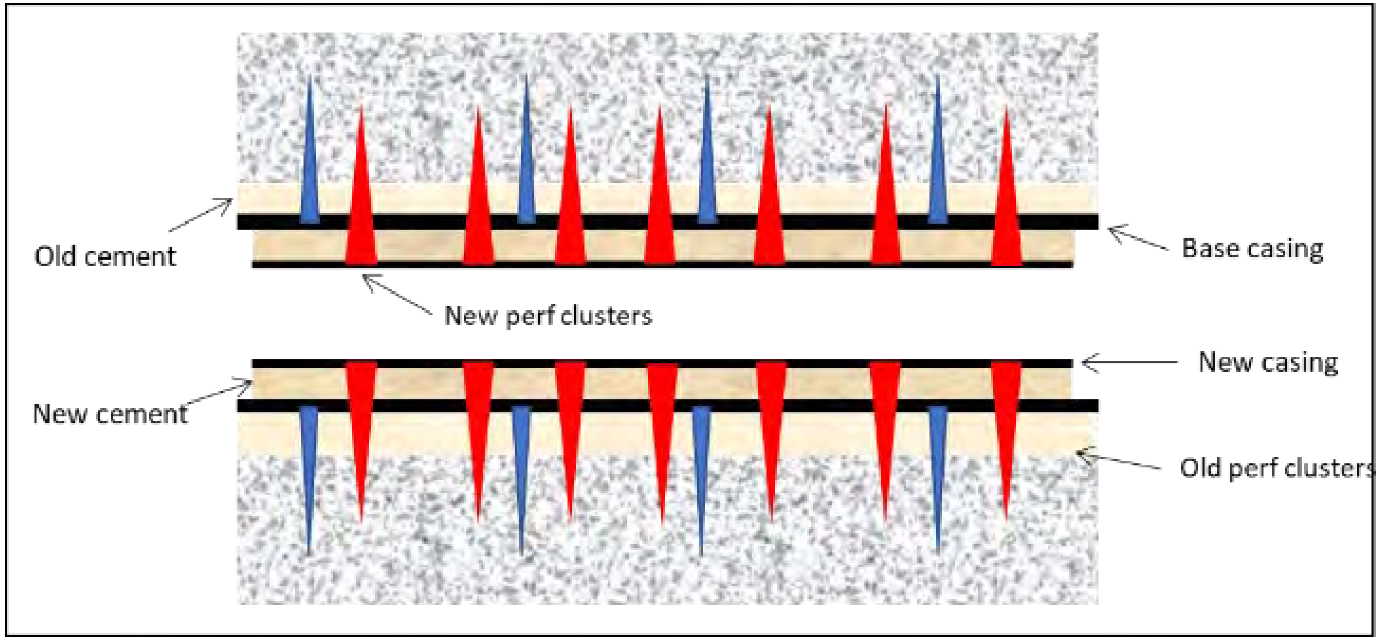
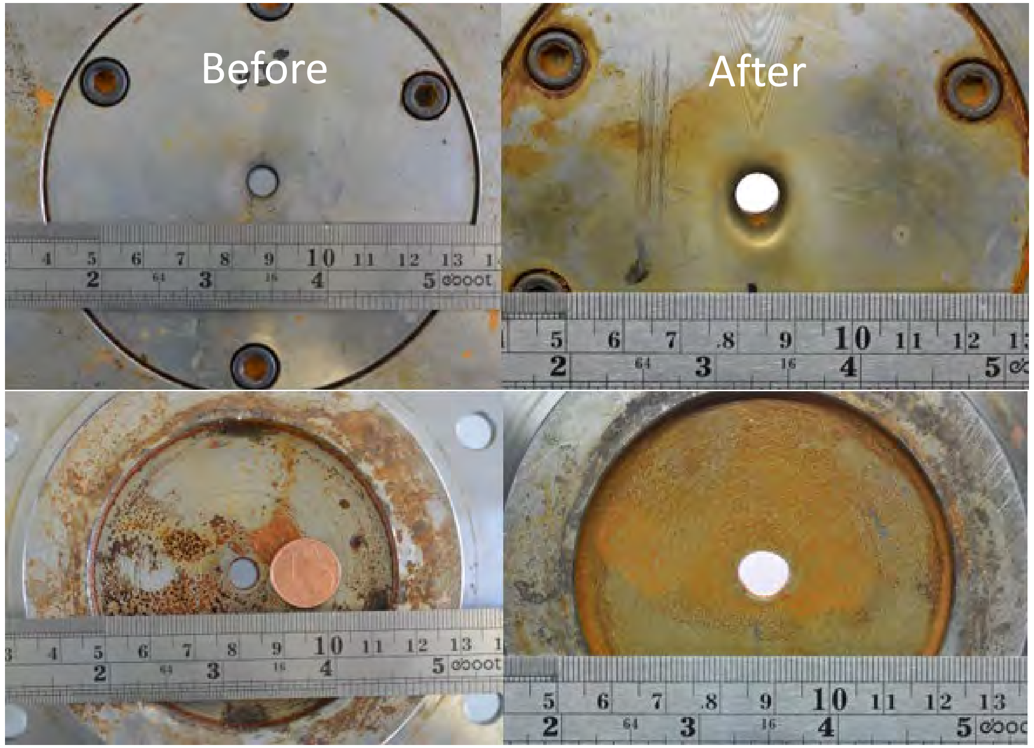


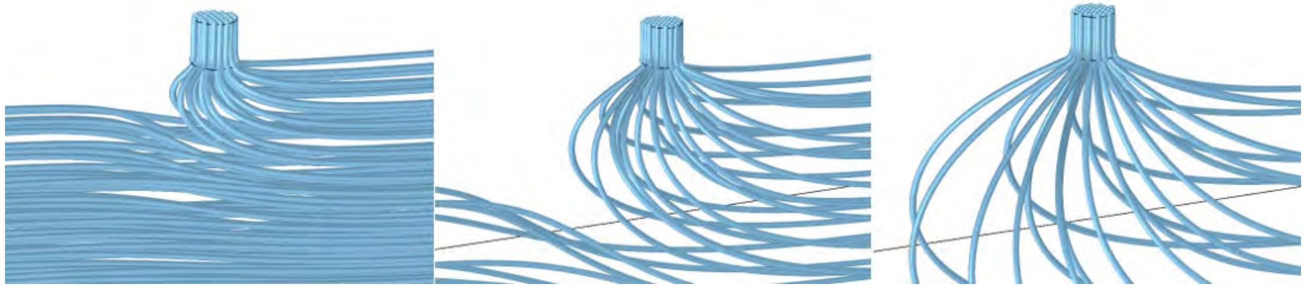
Old cement
Base casing
New perf clusters
New casing
New cement
Old perf clusters

Background

Introduction

- During frac treatment, proppant causes abrasive growth of the perforation hole
- Uncontrolled and asymmetric erosion of the holes may lead to a non-uniform frac treatment
- Testing has been done on erosion of holes in single casings, but what about dual casings?
- What is the influence of the velocity gradient around the perforation?

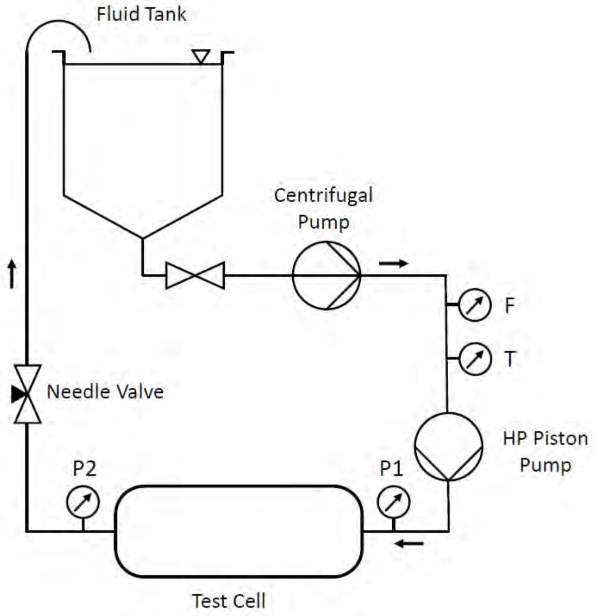




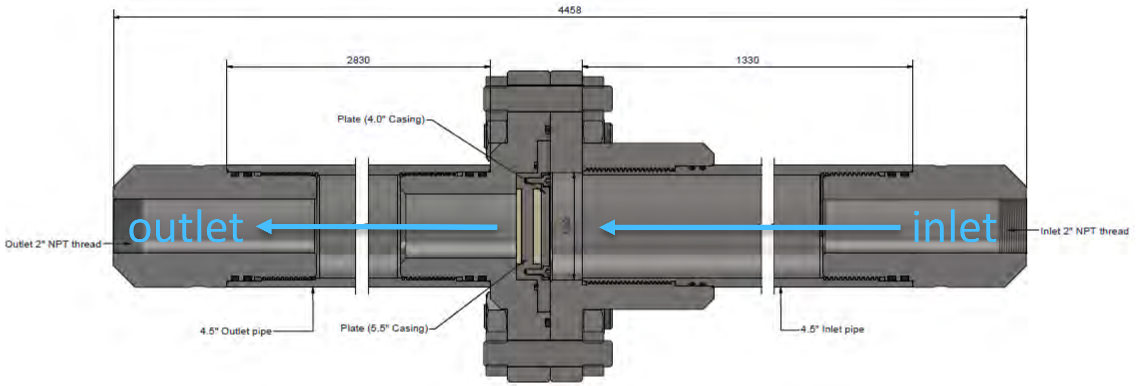
Effects of flow velocity of single shot cluster spacing

Physical Test Set-Up

Laboratory Flow Test Setup Cell A – Flow through Single & Dual Casing (CoD)



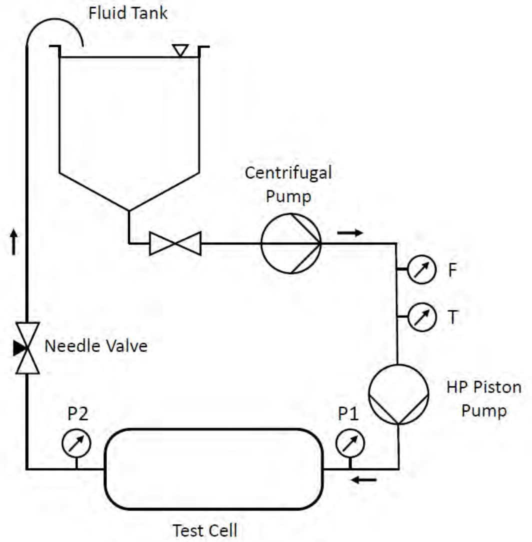
- High pressure test cell
  - flow rates of up to 3-4 bbl/min per hole
  - Pressure rating 5000 psi
- Flat casing plates from API Section 4 tests
- Effect of the cement and wellbore pressure on the hole is accounted for
- Benefits:
  - Backpressure can be applied
  - Long chamber to host sand jet (no abrasive destruction)
- Drawback:
  - flow direction is perpendicular to the plate not parallel to perforation as in a well.

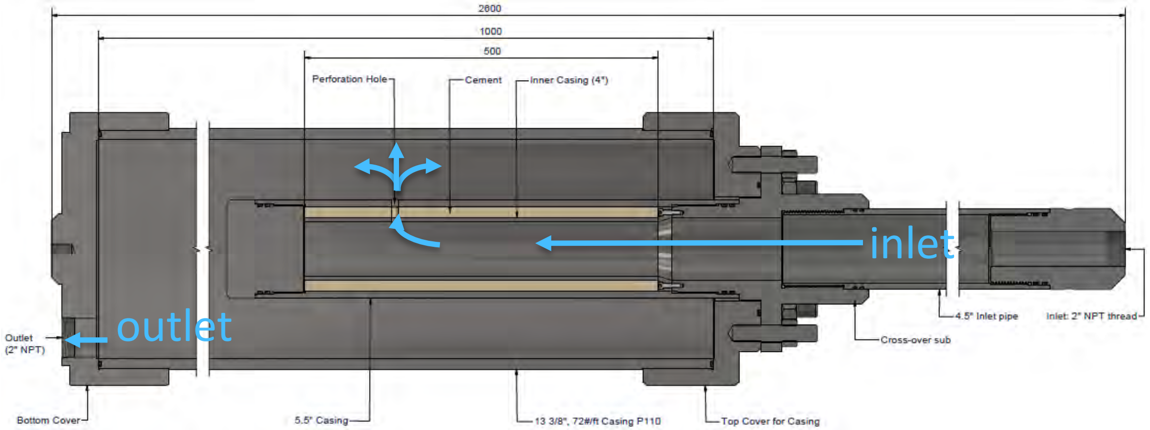


Physical Test Set-Up

Laboratory Flow Test Setup Cell B – Flow through Single & Dual Casing (CoD)

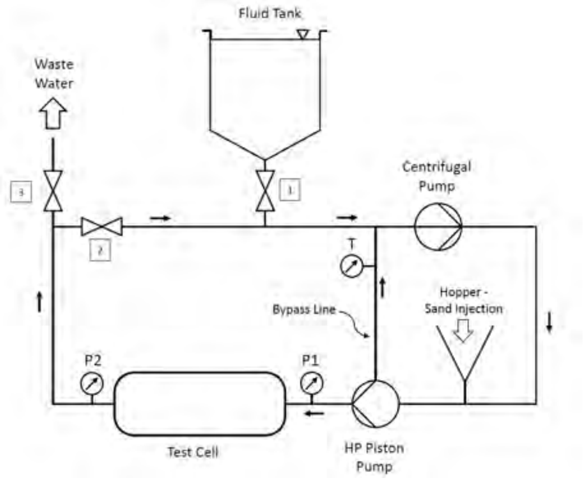
- Larger 2k psi pressure test cell for casing pipes
- Benefits:
  - Original Casing Pipe can be used
  - Flow direction mimics a real well bore
  - Multi-shot guns can be tested (opposed to single-shot plates)
- Drawbacks:
  - Perforation not shot under realistic pressure conditions
  - Lower pressure rating of the test cell (compared to Set-Up A)
  - Outer cell wall is close to the perforation:
    - Additional backpressure?
    - Sand jetting?

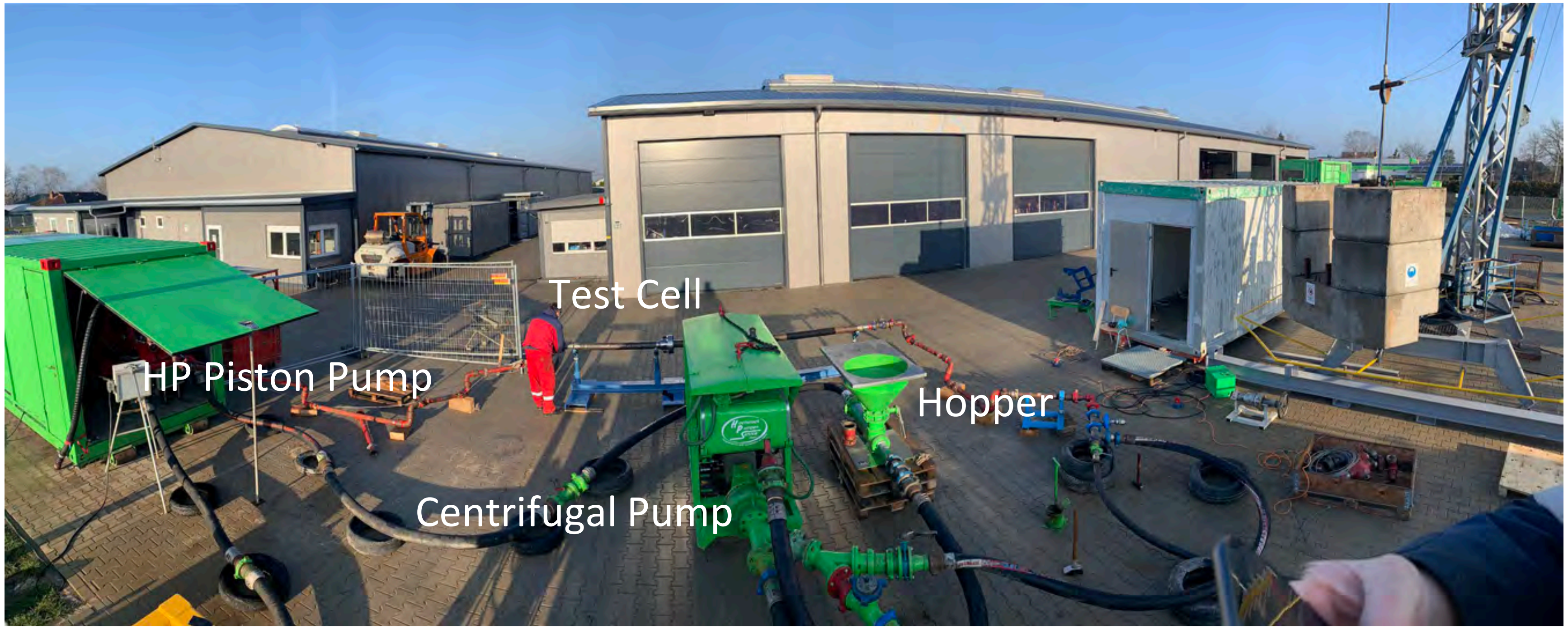




Physical Test Set-Up

Sand Erosion Test Setup – Used with both Test Cell A and Test Cell B from Flow Tests



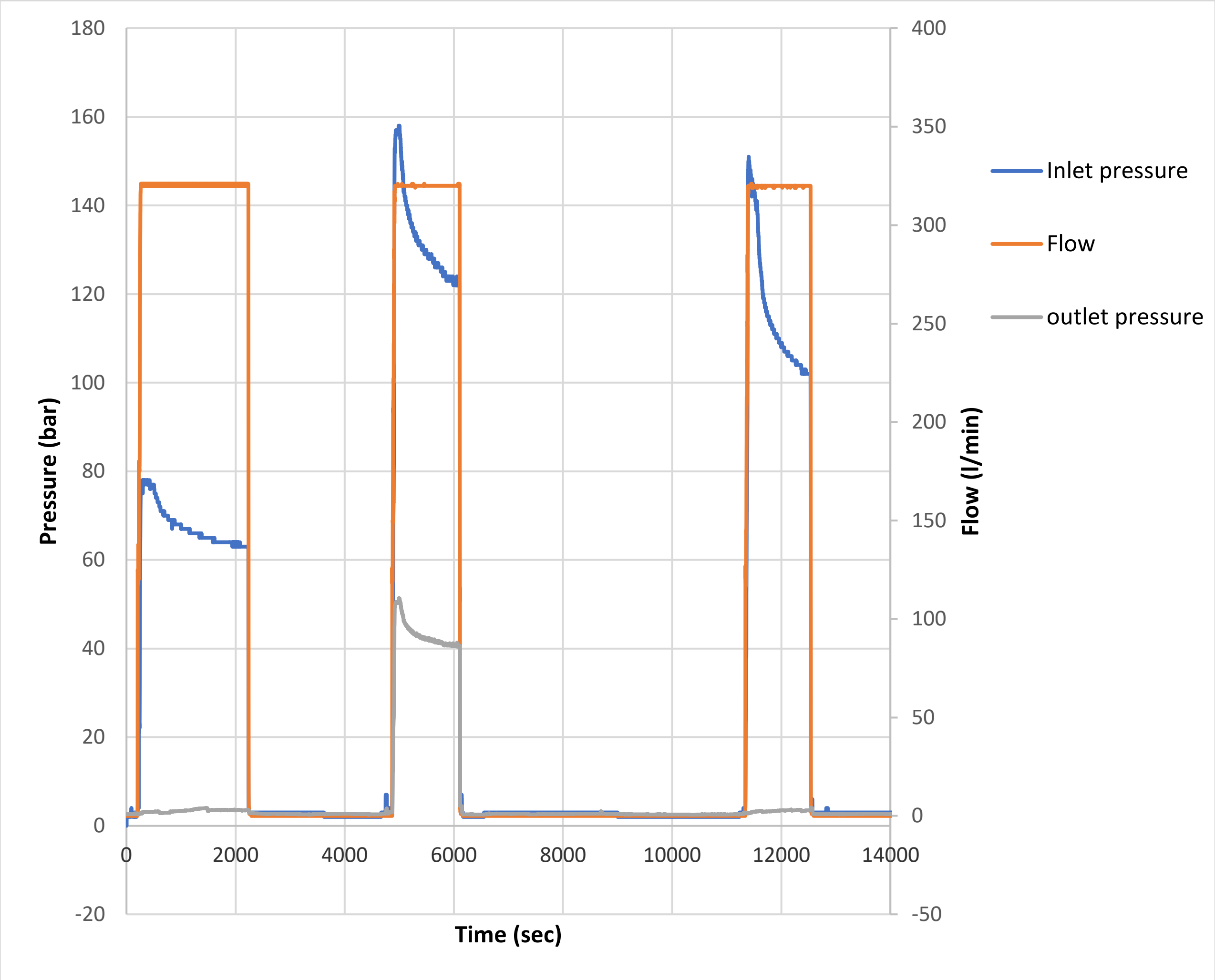


Test Set-Up

Testing Parameters

- Erosion tests with 2bbl/min and 3 bbl/min per perforation
- Flow rate was kept constant
- Inlet, outlet pressures, flow rate and fluid temperature were recorded
- Tests also performed with backpressure on machined holes for better comparability

Ideal scenario with constant flow-rate



Test Set-Up

Testing parameters (continued)

- 35/70 mesh sand was used in all erosion tests
- Sand concentration was approx. 1 ppg (120 kg/m3)
- Flow duration 10-20 min
- Total Sand 840 lbs. - 1680 lbs.
- No viscosifiers or friction reducers were used

Numerical Simulations

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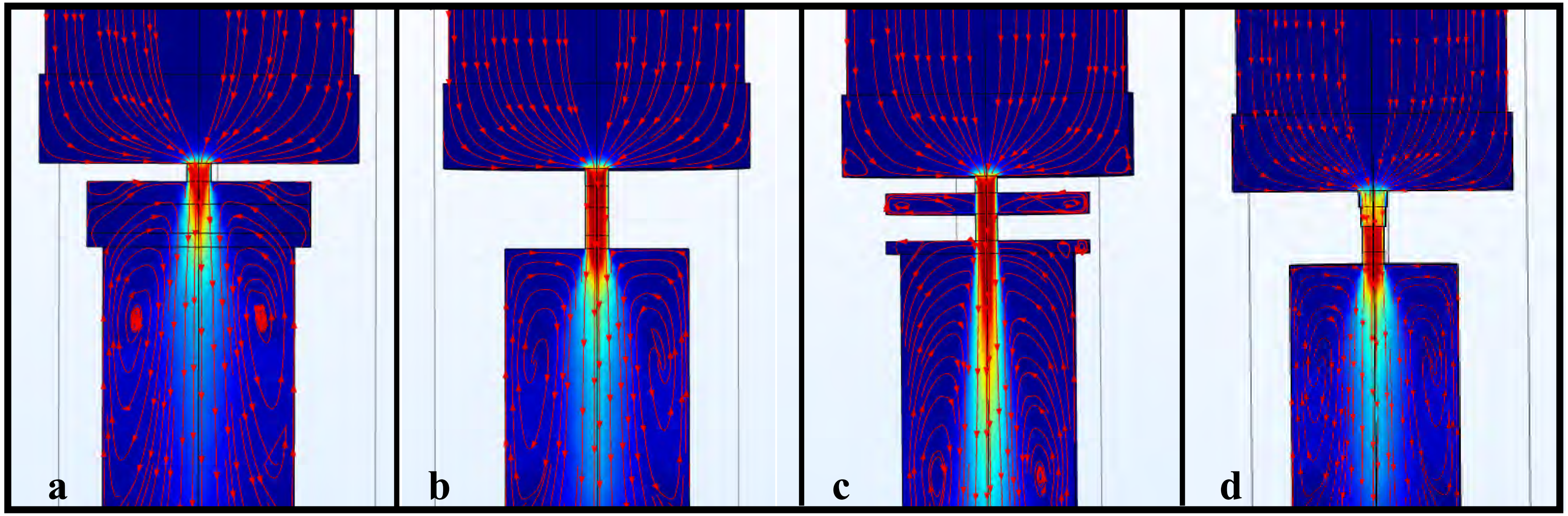
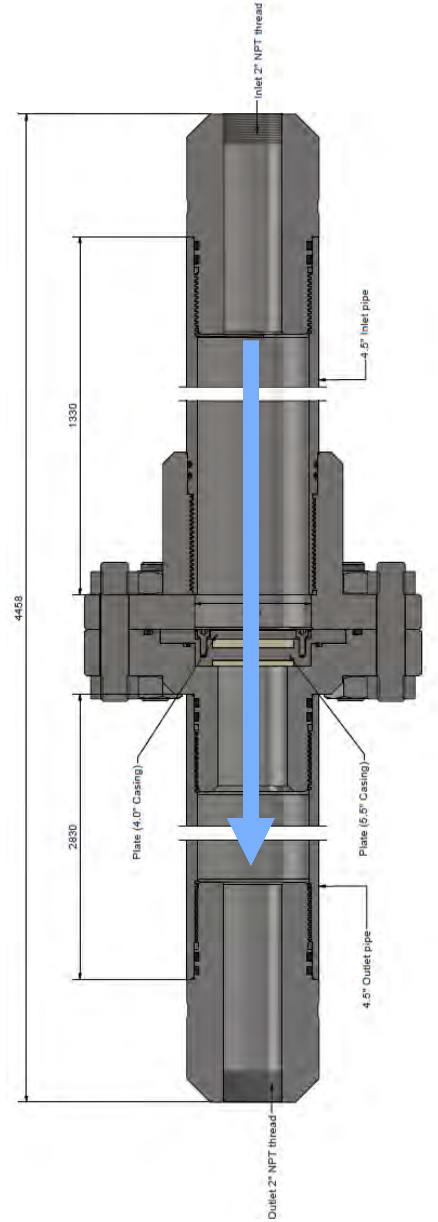
CFD Modelling:

- Accompanying numerical CFD simulations were run to limit the number of tests and to visualize flow patterns (effect of casing stand-offs: high-side, low-side
- Test Setup A was simulated and the hole sizes, casing sizes and the presence of a cement layer was varied to see the results effects
- Scenario’s with single, dual casing (with & without cement layer)

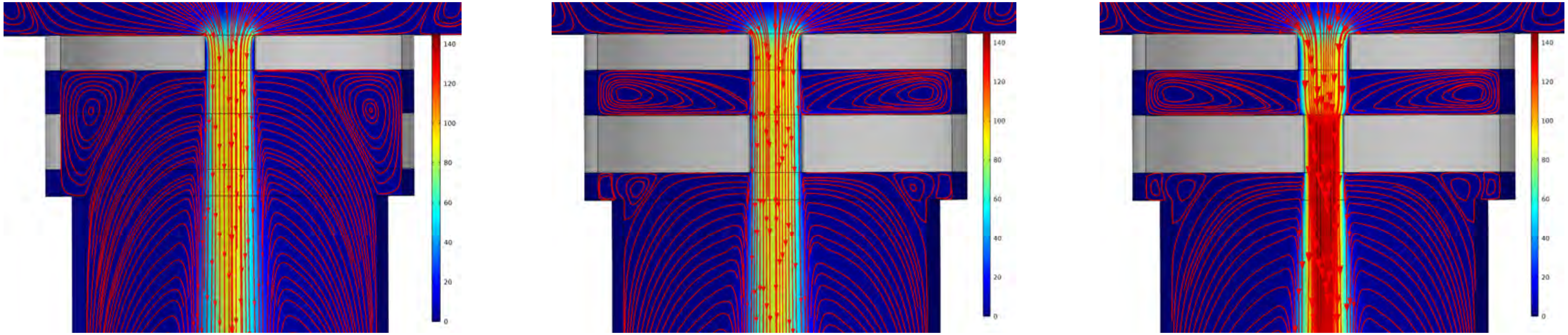




Numerical Simulations

Initial findings:

- At 2bbl/min flow rate through a single and dual casing
- Worst case scenario, no cement in area between casings
- First hole acts as nozzle and leads to an increased inflow velocity at the second hole
- Distance between the inner and the outer casing was not varied in the physical tests
- Simulations show focused flow has nearly the same speed for larger clearances (important for understanding the effects of decentralized casings)



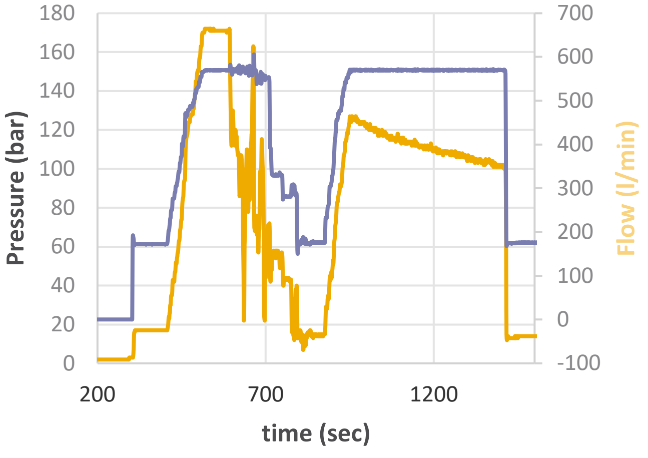
Experimental testing

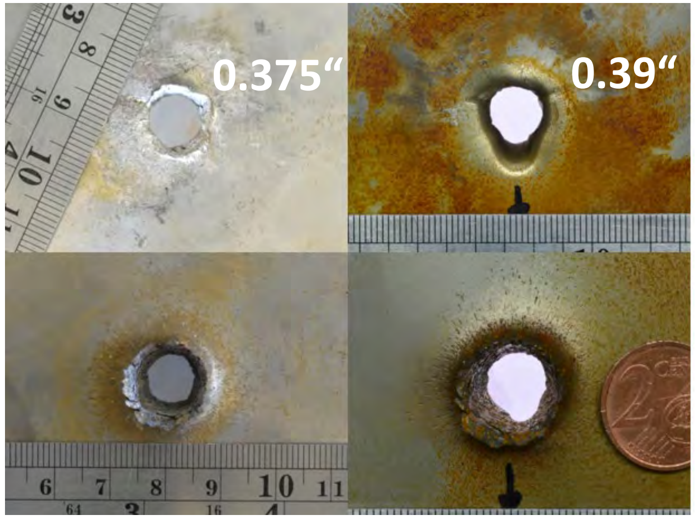
Testing Results - Erosion Measured in Setup Cell A (Flat plates)

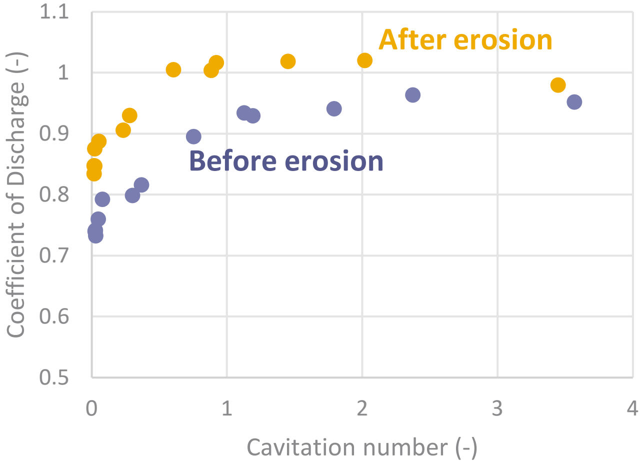
Experimental testing

Testing Results - Erosion of <u>Single</u> Casings Measured in Setup Cell A

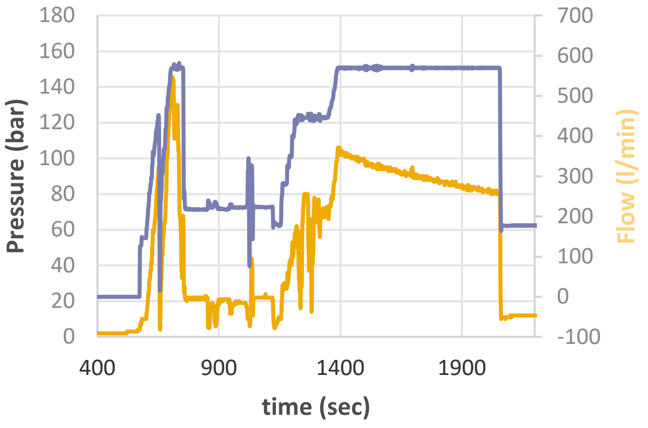
Charge C

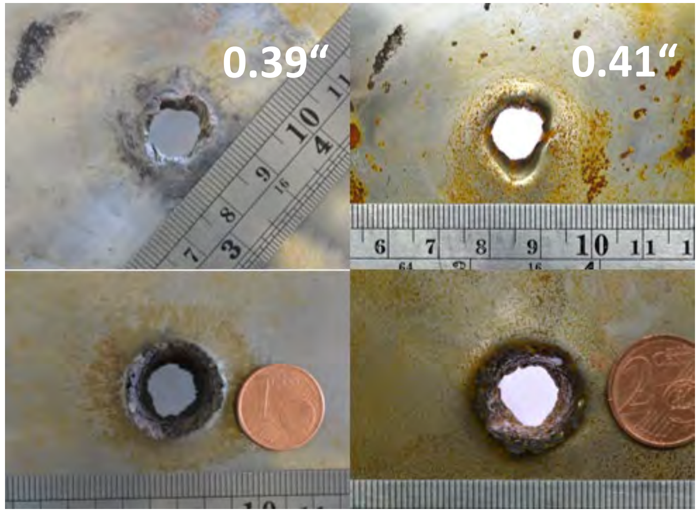


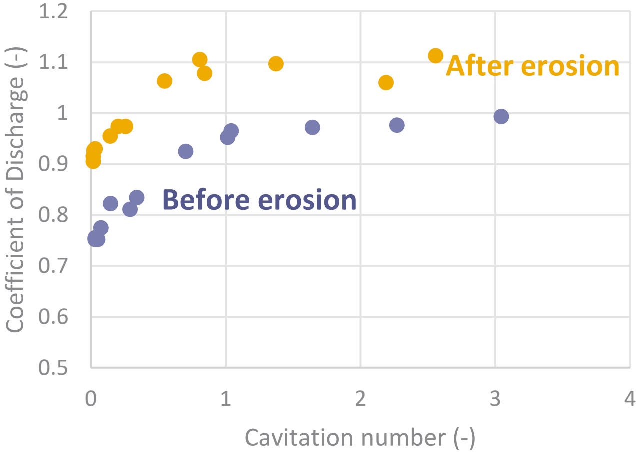




Charge D







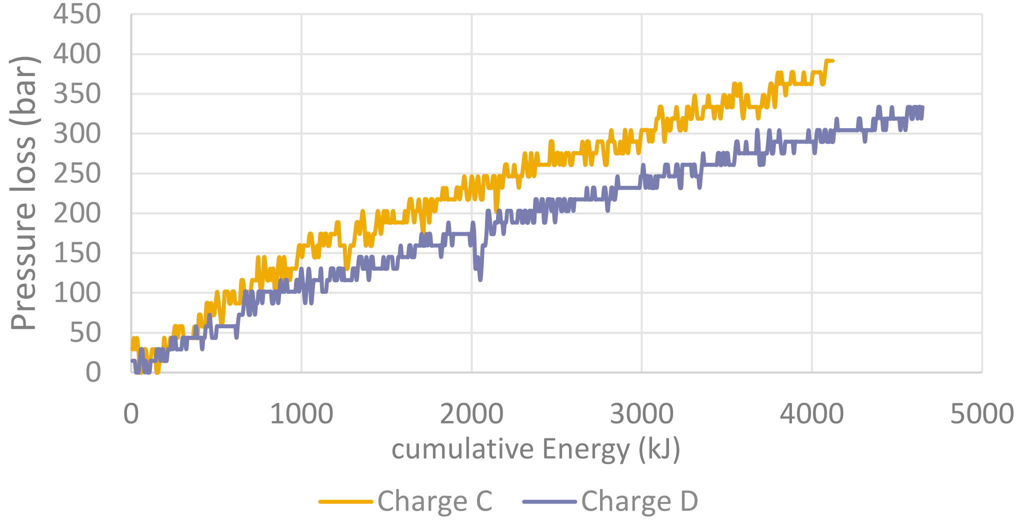
* air pockets occurred during introduction of sand at high flow rates.

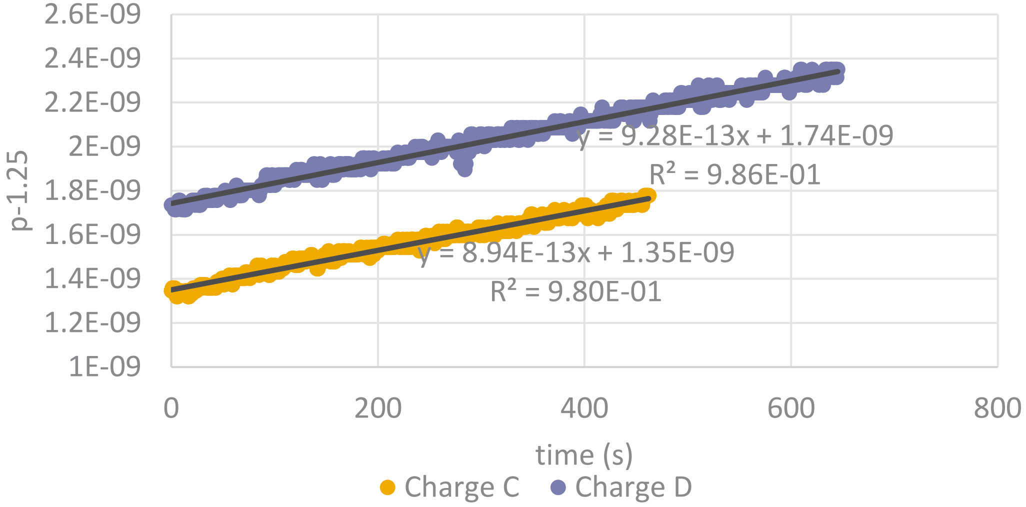
*C_d values calculated for the initial hole size

Experimental testing

Analysis of Results – Erosion of Single Casings Measured in Setup Cell A

- Pressure loss due to the erosion increases with pumped cumulative energy
- Both charges designs show a linear $p^{-1.25}$ vs t behavior (similar erosion behavior)
- Supports correlation between pumped energy and erosion rate (see Long et al., 2018)



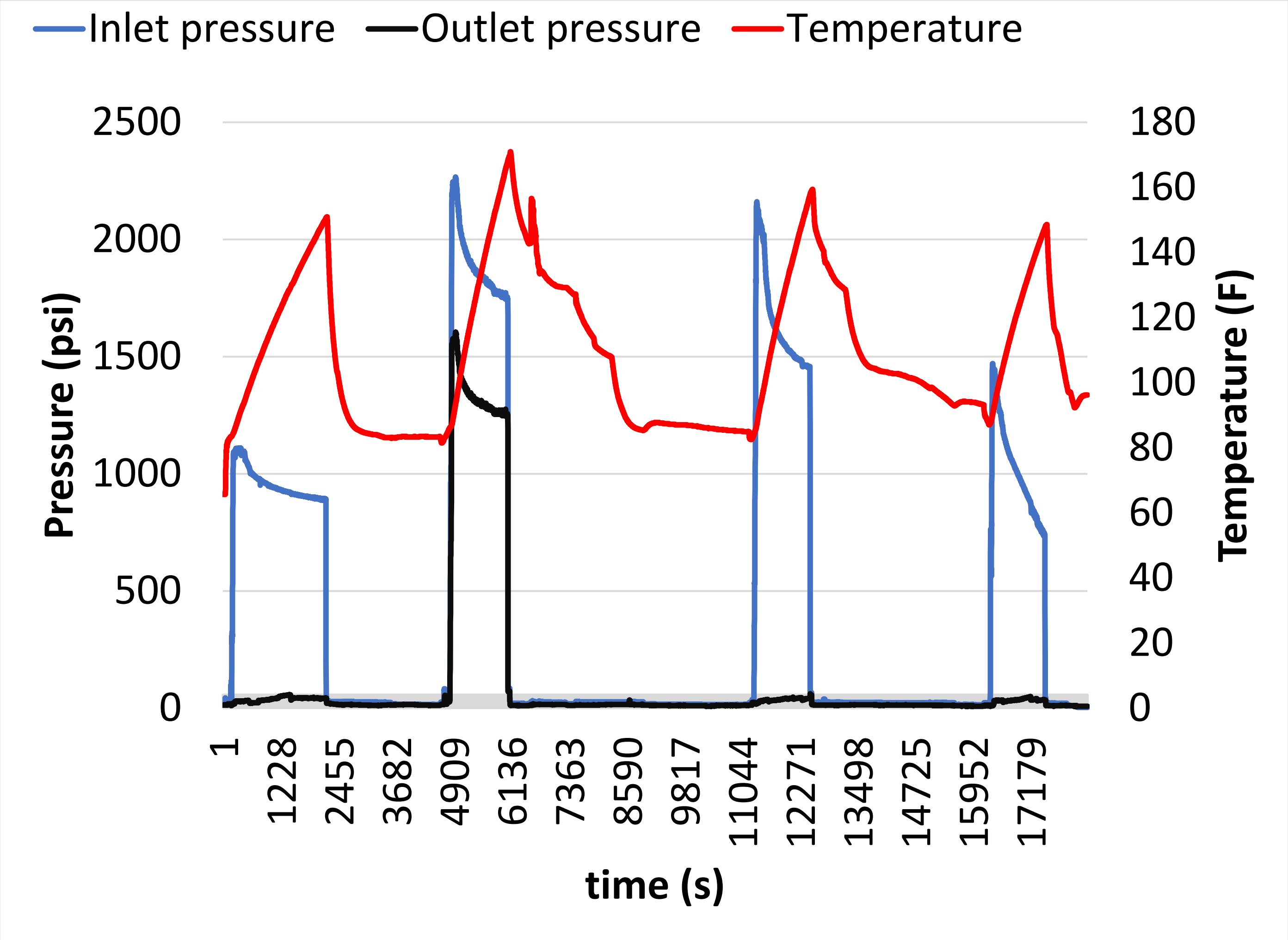


* $p^{-1.25}$ is a normalized pressure-loss unit to enable a linear plot against time

Experimental testing

Limitations of the closed loop setup – temperature effects/overheating

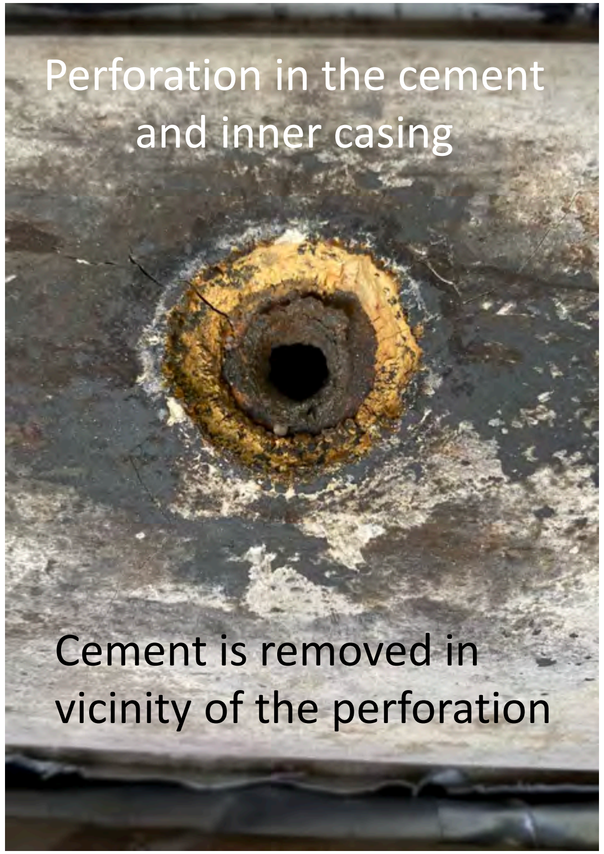
- Temperature increases due to the kinetic energy of the sand grains impacting the casing
- Temperature raises from 30 °C to 70°C within 10-15 mins
- Risk that rubber hoses burst
- Test duration limited
- Effect not observed with pure water



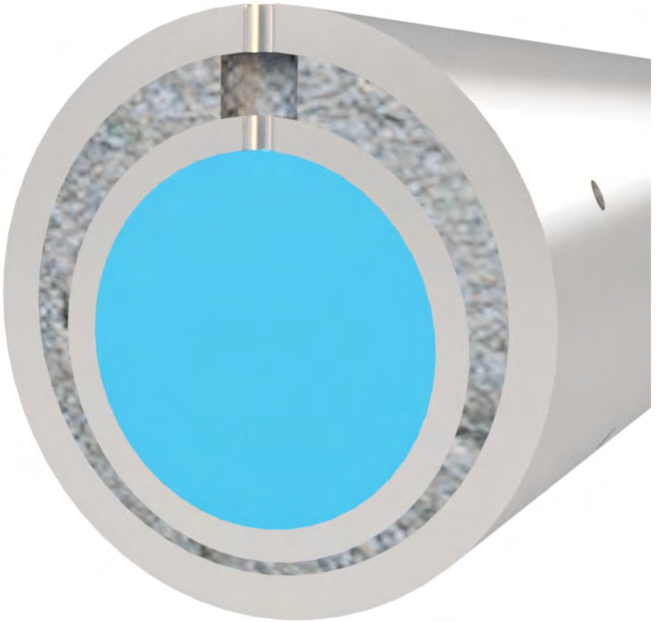
Experimental testing

Dual Casing Testing Scenario

Examples of typical effects & observations



Dual Casing with Cement annulus



Example: 4“ in 5.5“

Experimental testing

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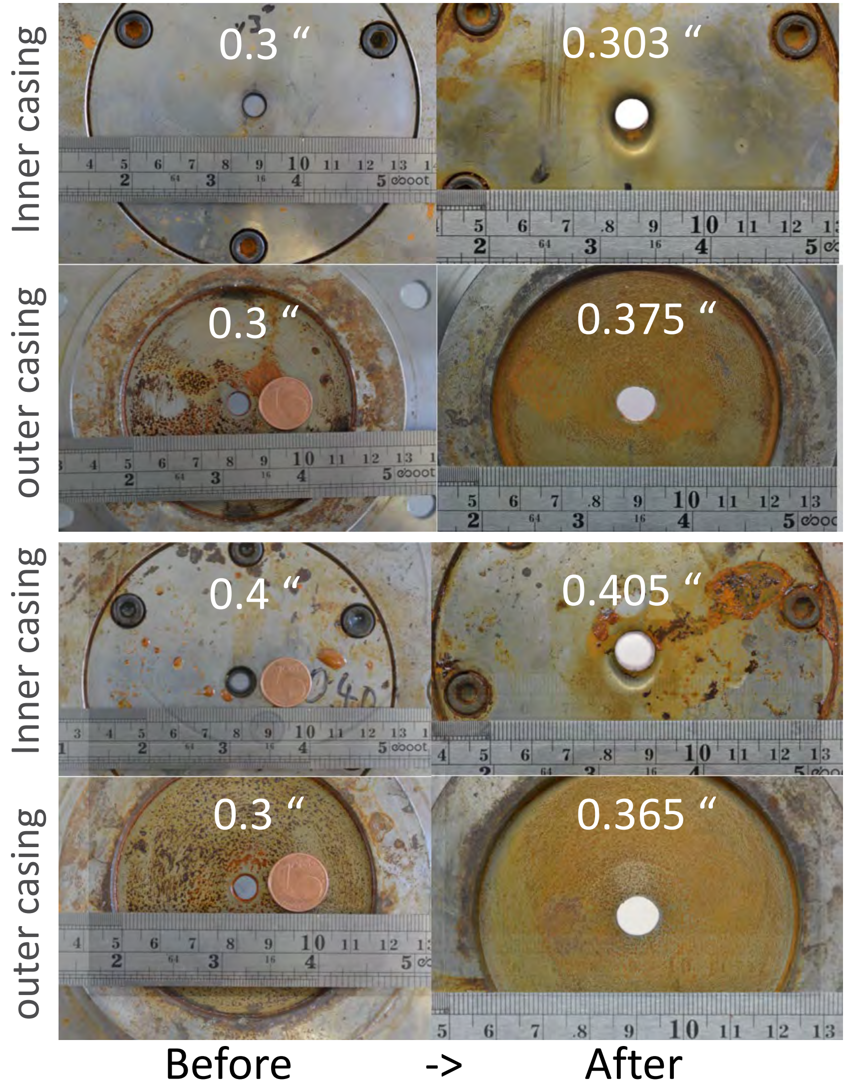
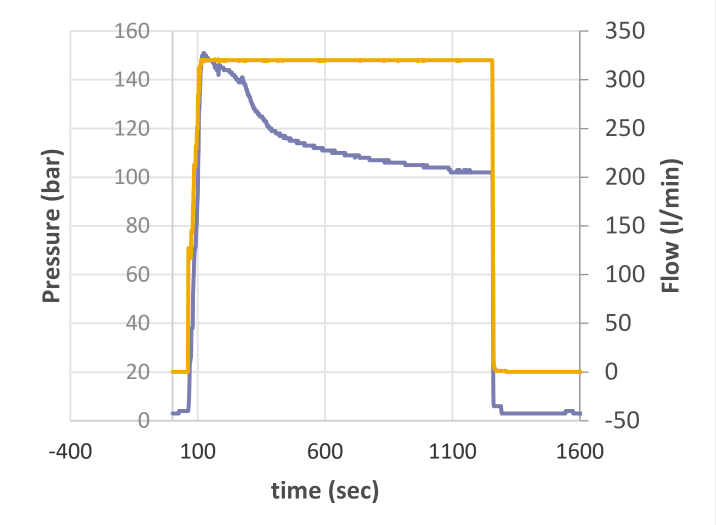
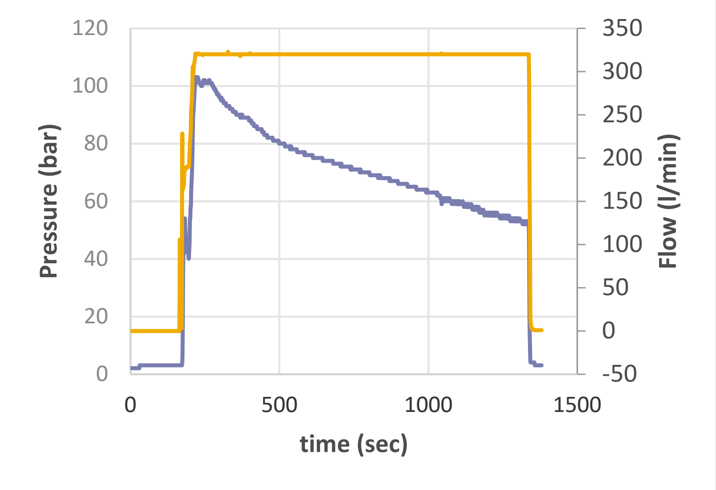
Testing Results - Erosion of Dual Casings Measured in Setup Cell A (Flat Plates)

- Machined plates were tested
  - 0.3“ EHD on the inner casing and 0.3“ EHD on the outer casing
  - 0.4“ EHD on the inner casing and 0.3“ EHD on the outer casing

- Strong erosion of second casing due to the focused flow caused by first casing hole (conforms with simulations)







Experimental testing

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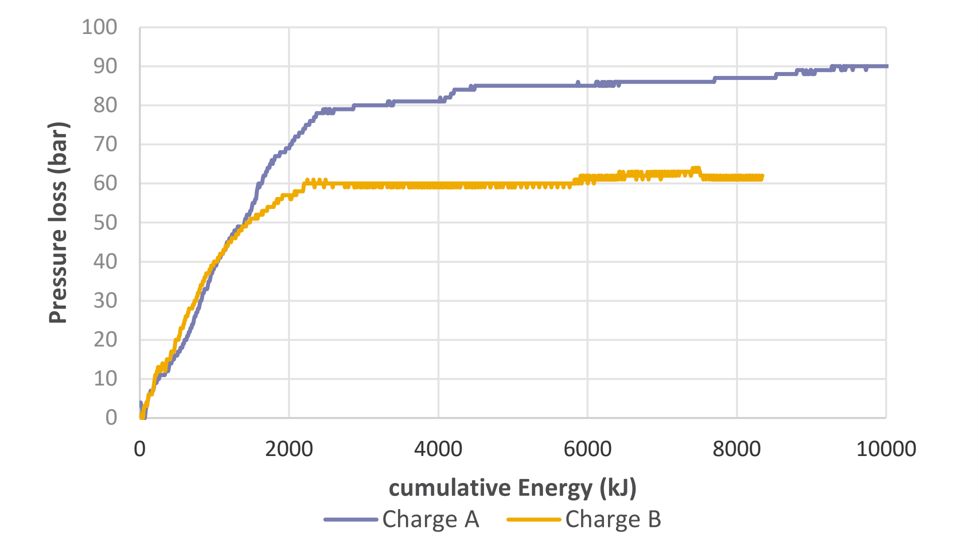
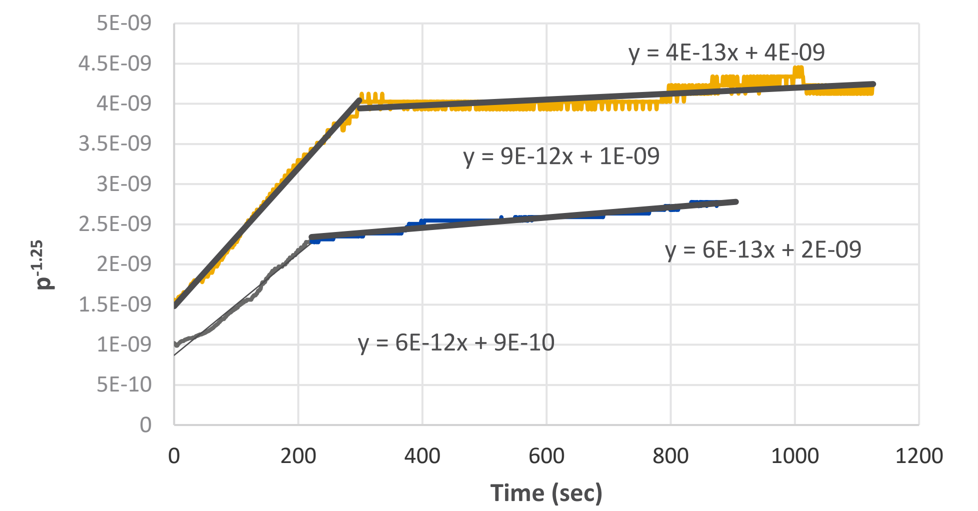
Testing Results - Erosion of Dual Casings Measured in Setup Cell A (Perforation Holes Example 1)

- Two charge designs were tested which show a similar erosion pattern and growth
- A fast first erosion phase is followed by a slower second phase
- Pressure loss identical for both charges during the first phase, where the flow is focused by the inner hole
- For dual casings, a fast increase in CoD is observed, which causes quick pressure drops
- Results indicate after a short initial phase of erosion, flow will be controlled by the hole in the inner casing

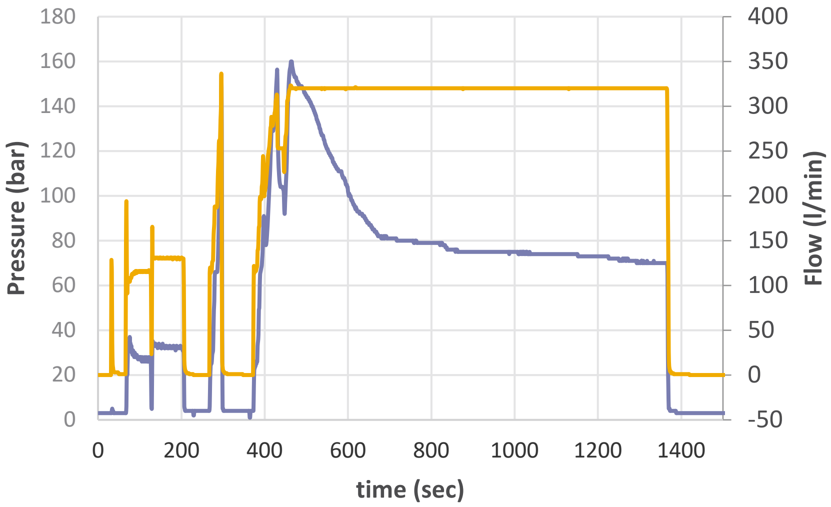


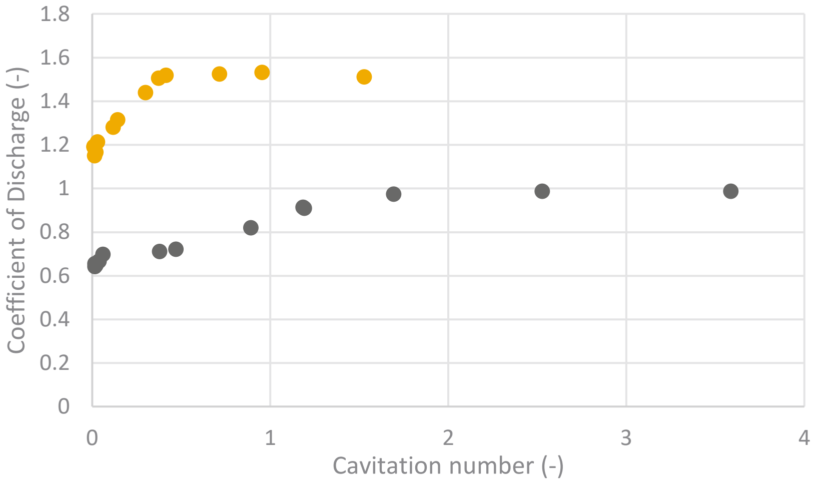


Experimental testing

Testing Results - Erosion of Dual Casings Measured in Setup Cell A (Perforation Holes Example 2)

- EEH Frac charge with 0.31“ hole on the inner casing and a 0.27“ hole on the outer casing
- EHD after erosion 0.33“ (inner) and 0.42“ (outer)
- CoD increases by 40%-50%





*CoD values calculated for the initial, smaller hole size

Experimental testing

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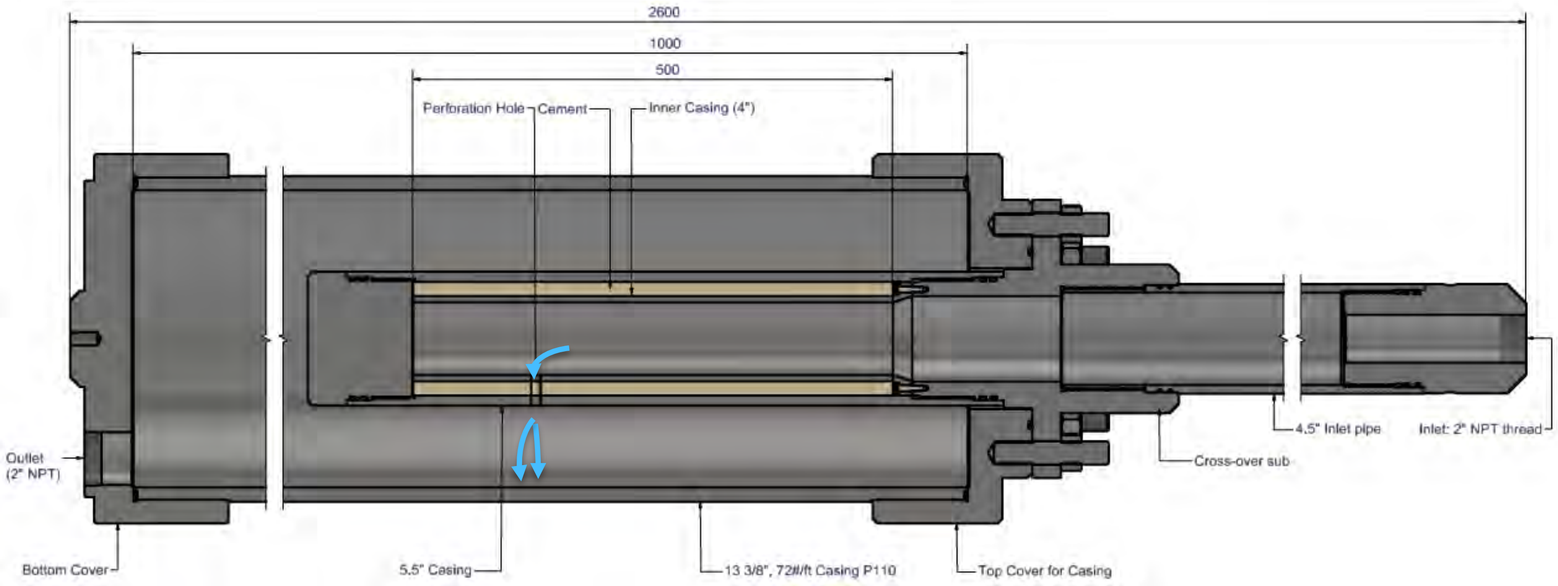
Testing Results - Erosion of Dual Casings Measured in Setup Cell B (Perforation Holes)

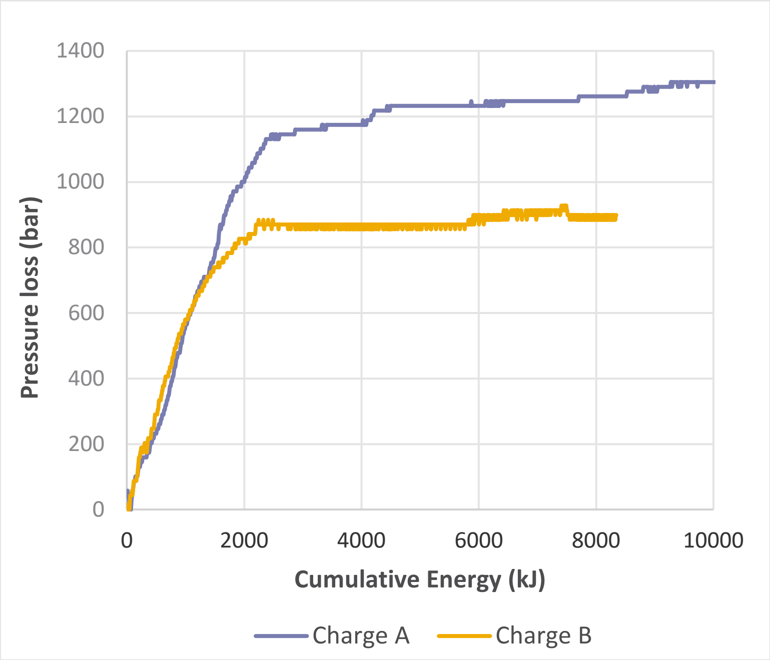
- Tests like those presented from Setup Cell A were planned to be conducted in Setup Cell B
- However, the test cell was destroyed by the sand/slurry jetting within minutes

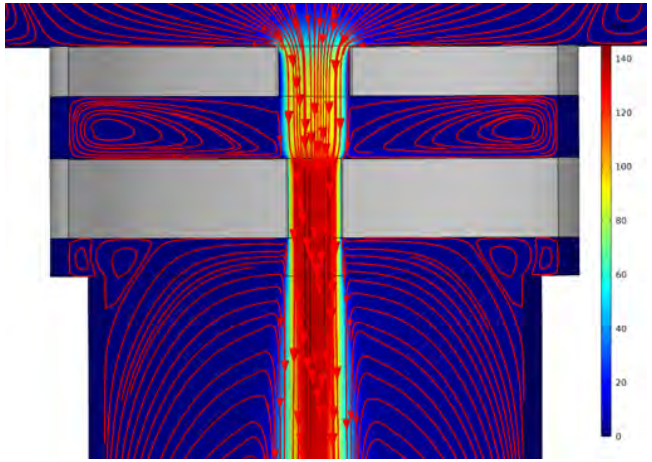


Conclusions

Based on the results observed:

- The data for single and dual casing can be described by a relationship between the growth of the hole to the kinetic energy of the pumped slurry (Long et al., 2018).
- Numerical simulations in line with experimental results
- Charge Design can influence the erosion rate.
- For Dual Casing: After an initial phase, which is governed by the erosion of the hole on the outer casing, treating pressures will be mostly controlled by the hole in the inner casing.
- Erosion on dual casings happens much quicker due to a “focusing effect” effect of the inner hole. This causes a faster initial increase in C_d and consequently a faster pressure drop compared to single casings.

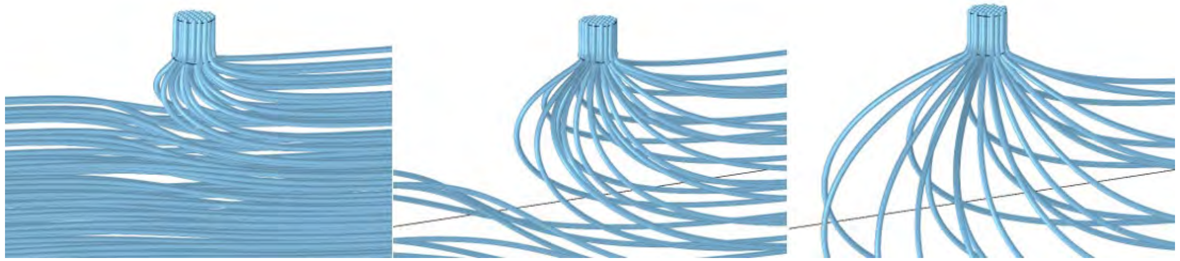




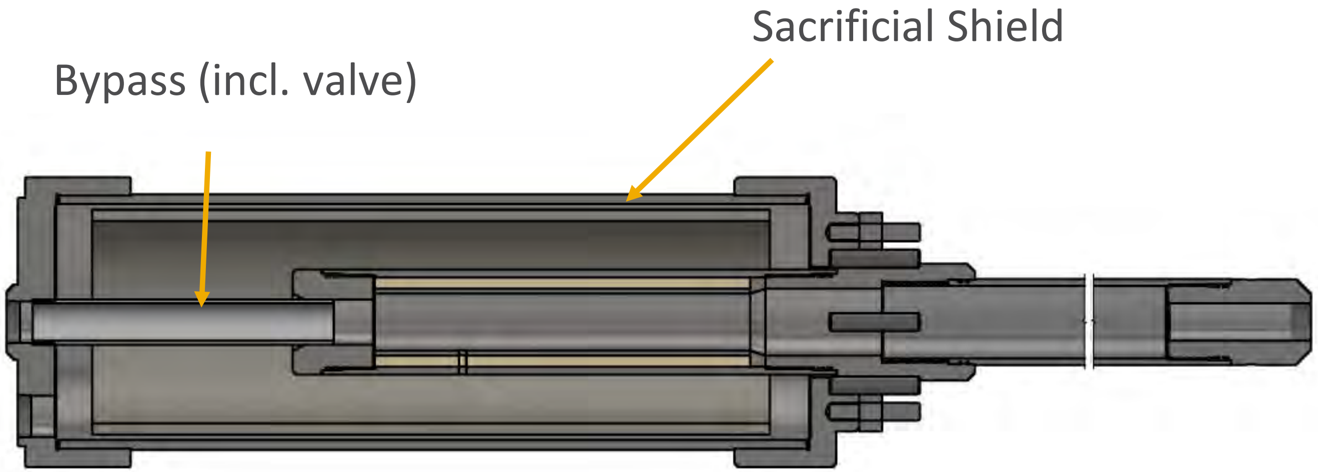
Future Testing

Conclusions & Next Steps

- Many factors influence the erosion-rate
  - Proppant size & Concentration
  - Flow velocity
  - Position of the cluster (heel vs. toe)
  - Position within the cluster (up vs. down)



- Improvements to Setup Cell B
  - Installation of sacrificial shield to allow completion of tests without destroying/eroding away test cell
  - Installation of Bypass to allow more accurate heel side and mid interval flow patterns and test results
  - Testing with larger EHD hole sizes



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Q&A