Laboratory Testing for Wellbore Strengthening Versus Lost Circulation Control

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Lost Circulation vs Wellbore Strengthening

Fracture Sealing Mechanisms

Slot Tester Equipment Overview

Block Tester Equipment Overview

Advantages and Disadvantages

Conclusion

What is Lost Circulation?

Dynamic Lost Circulation is the condition where the volume of fluid returning to the surface is less than the volume being pumped into the wellbore

Static Lost Circulation is the condition where the surface of the fluid column in the wellbore is falling away from the wellhead

The two drivers of Lost Circulation are wellbore pressure, and the formation's ability to take in fluid

Where does the fluid go?

Pressure induced fractures are created by wellbore pressure or pressure surges that exceed the formation fracture pressure

Once open, the wellbore pressure is transmitted to the fracture tip causing the fracture to lengthen

Contributors to wellbore pressure include:

- Excessive drilling mud density and/or viscosity
- Rapid pipe movement (downward surge)
- Drilling into weak or depleted formations (exceeding fracture gradient)

Pre-existing fractures are natural fractures, faults, vugs, or caverns that are already present through no result of drilling operations

- Characterized by sudden onset losses while drilling that may be severe to complete loss
- The loss rate and volume is controlled by the dimensions and interconnectivity of the void spaces
- Fluid loss will proceed until the void spaces are either filled or plugged

What can I do about it?

Since we cannot change the presence of pre-existing fractures, and the wellbore pressure is dictated by things other than the fracture gradient, Lost Circulation is sometimes seen as inevitable

Once losses are encountered, Lost Circulation Material (LCM) treatments are pumped with the goal of reducing the loss rate to a manageable level

For pressure induced fractures, the width is already at its maximum size before the seal is formed

Is there a better option?

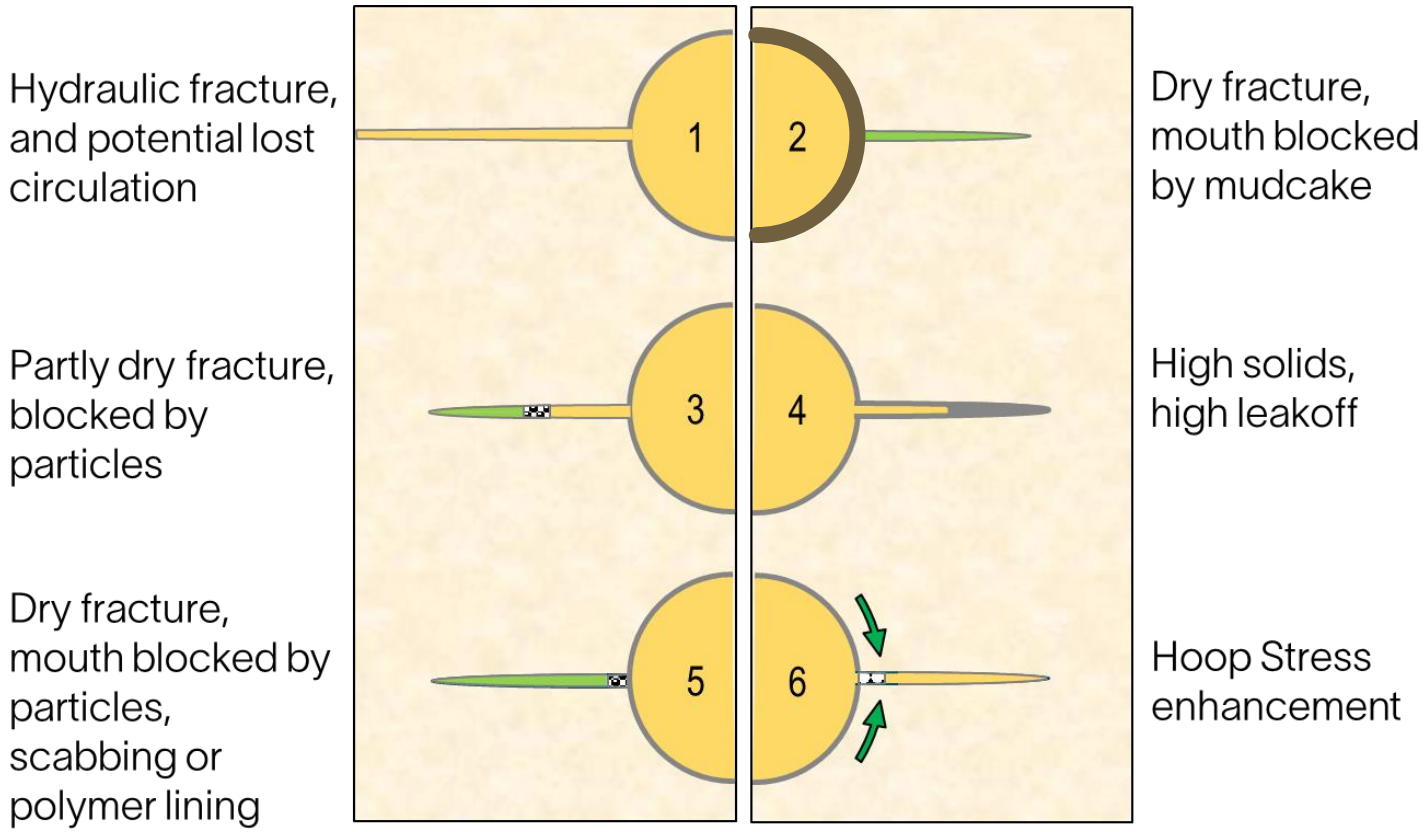
Wellbore Strengthening is a preventative treatment, with the goal of stopping Lost Circulation before it can start

This is done by changing the stress conditions of the formation, and minimizing the wellbore pressure from acting on the formation

Wellbore Strengthening Materials (WSM) are a subset of Lost Circulation Materials

There are different fracture sealing mechanisms by which wellbore pressure can be isolated

Different mechanisms require different pieces of lab equipment to be simulated



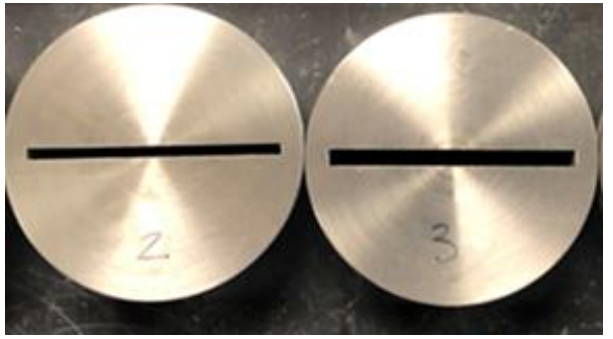
The Slot Test is the closest thing to an industry standard for evaluating fracture sealing performance

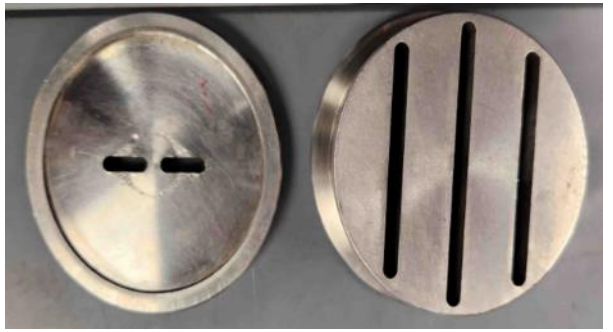
However, there are differences in equipment design, testing procedure, and interpretation of results from one lab to another







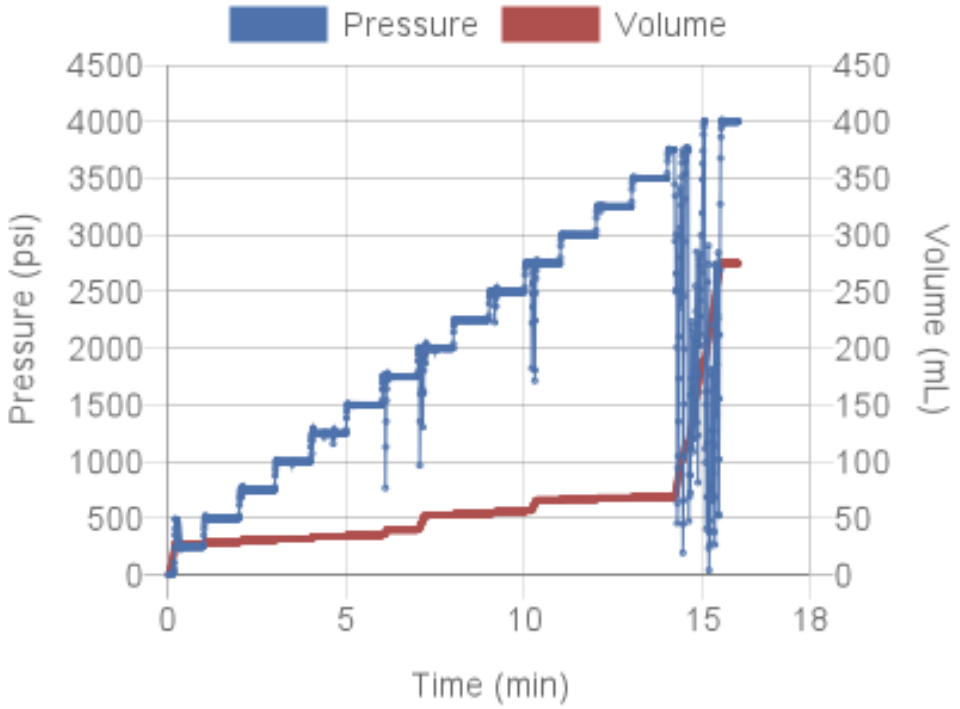




Our Slot Test device uses a computer controlled hydraulic pump to displace test fluid through a metal disk with a single slot of the desired width

Pressure is increased by 250 PSI every minute up to 4000 PSI

A data logger measures the volume of fluid lost and the pressure that the seal can hold throughout the test

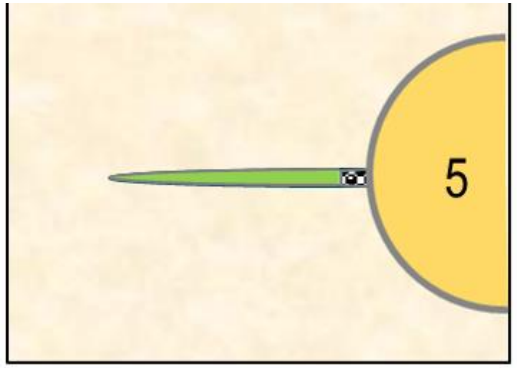


Pressure psi	IBE %	BSS %	FBE %
250	92 %	-	-
1000	-	99 %	90 %
2000	-	92 %	84 %
3000	-	88 %	80 %
4000	-	23 %	21 %

The design of the Slot Tester is ideal for simulating pre-existing fractures

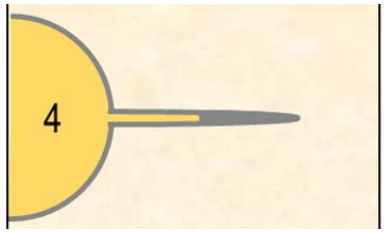
While it is often used to design treatments for pressure induced fractures, this represents a worst-case scenario where the fracture has fully opened without any initial seal forming

Dry fracture, mouth blocked by particles, scabbing or polymer lining

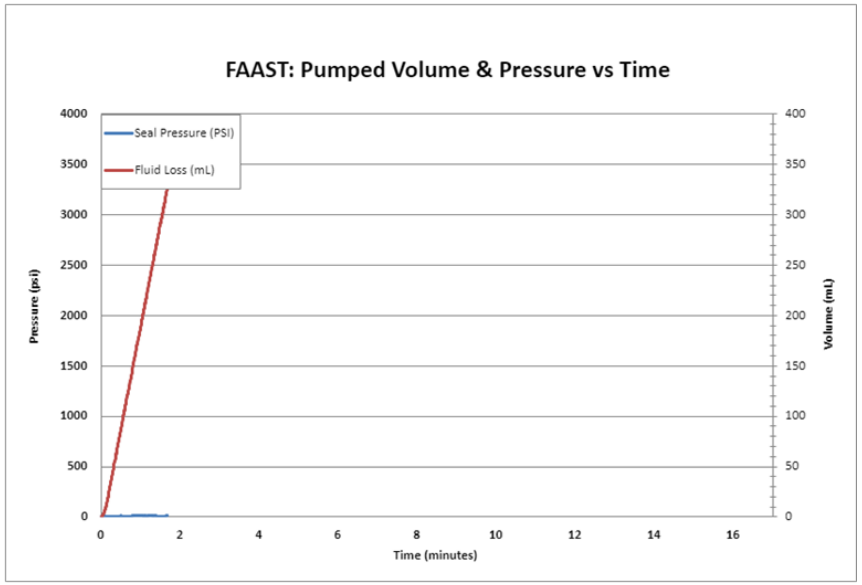


While not ideal, the Slot Test can be used to evaluate certain high leakoff or defluidization products

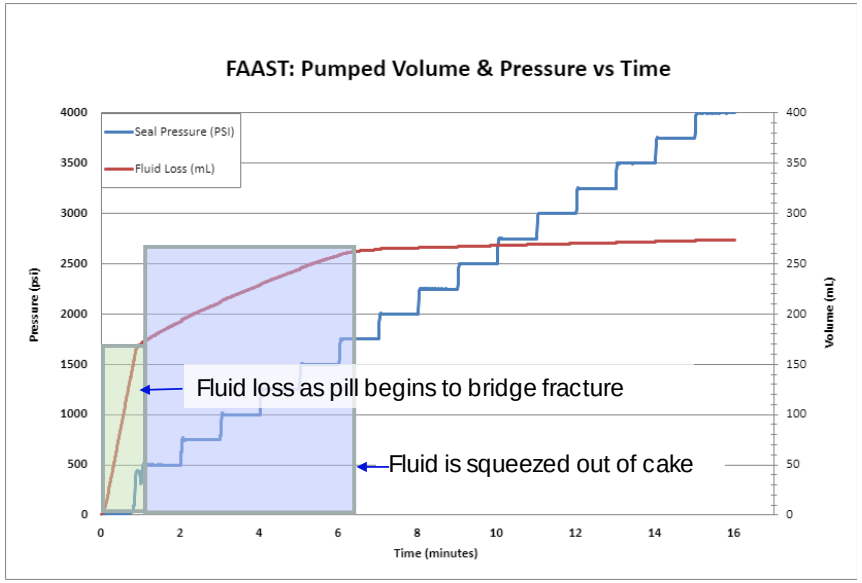
More of a pass / fail for determining if the material will form a plug



High solids, high leakoff











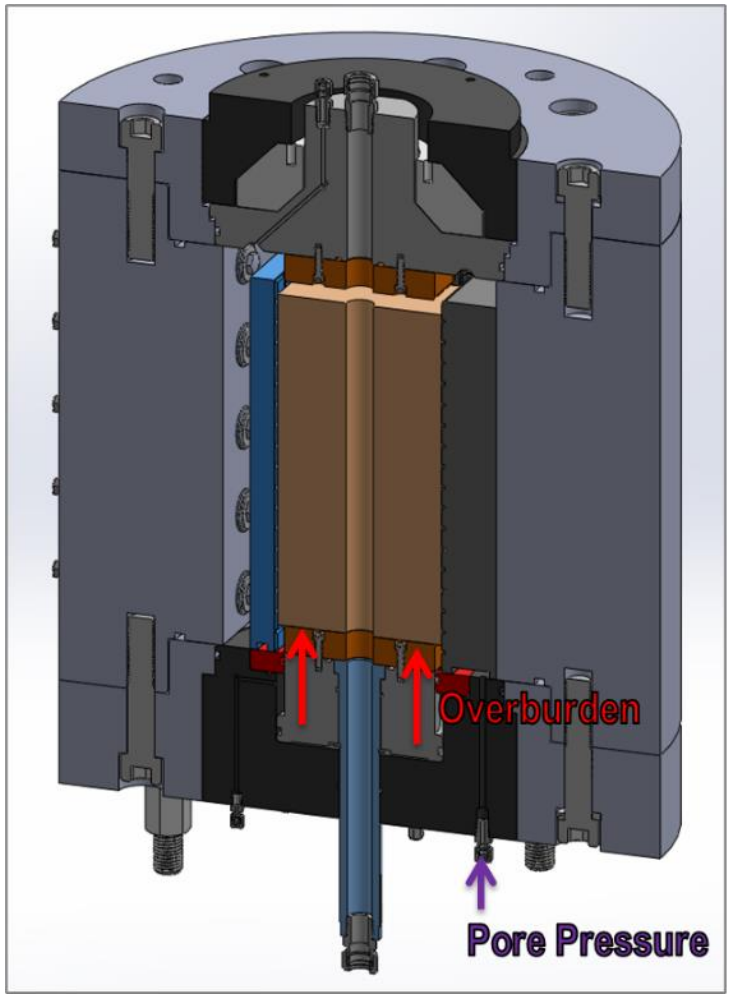
Small Block Tester

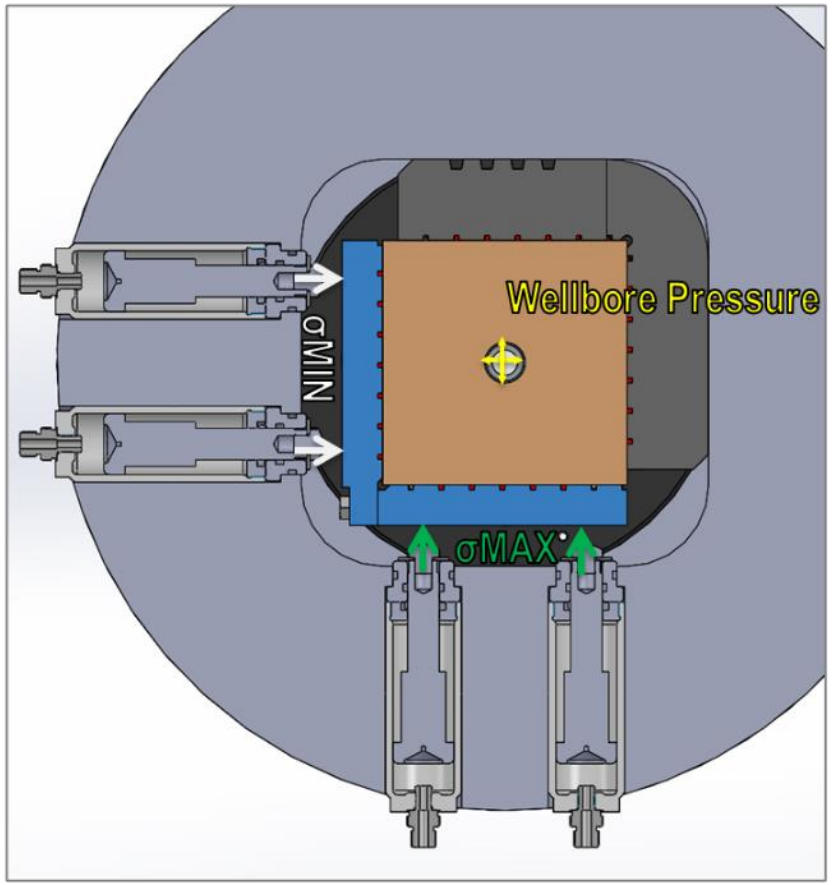
- True tri-axial stress state, plus pore pressure
- Uses either a 6” cube or 6”x6”x12” block of rock, typically sandstone
- Blocks can be intact, pre-fractured, or shimmed open



Independent control of Overburden, minimum and maximum horizontal stress, pore pressure, and wellbore pressure

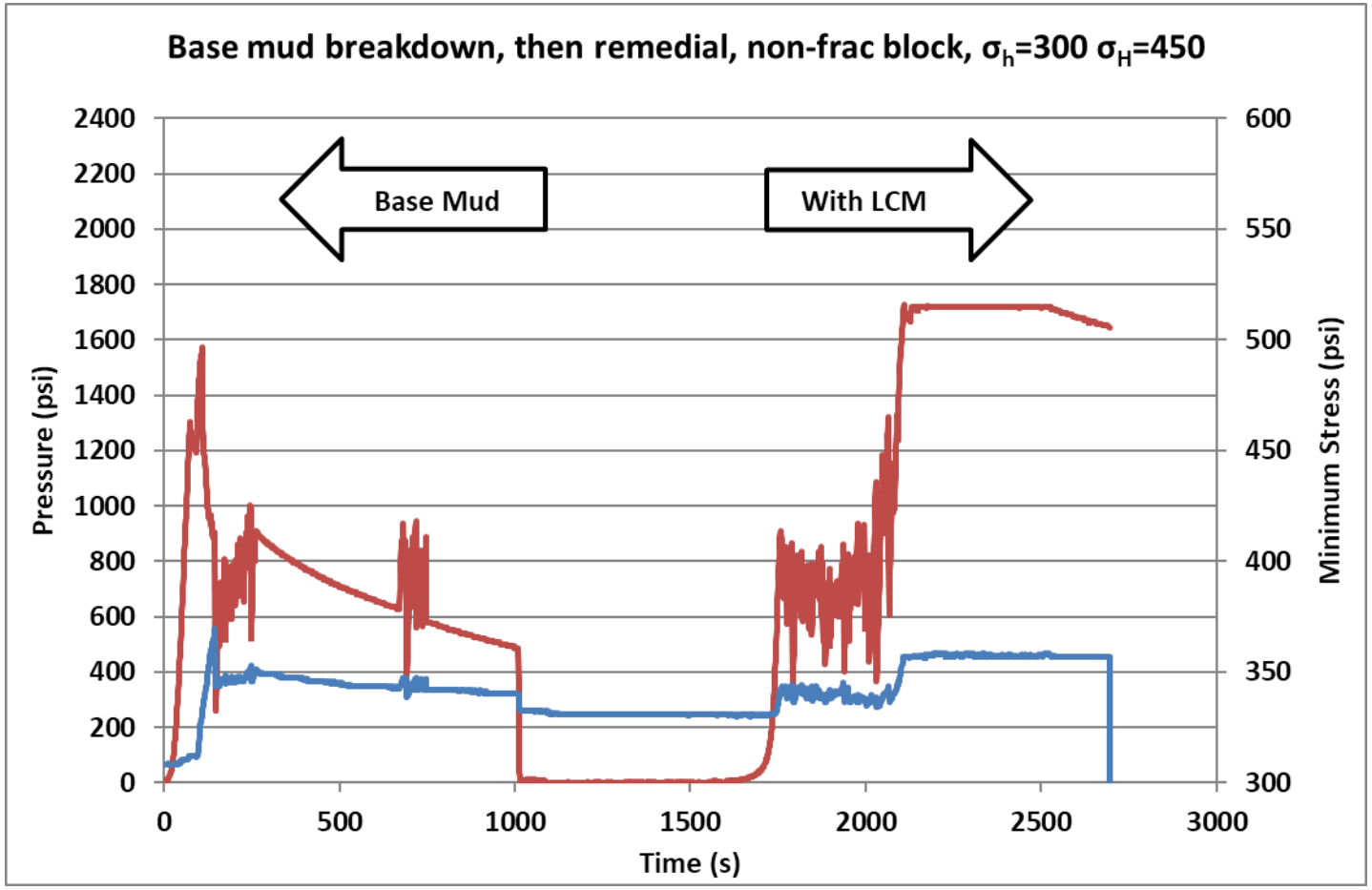
Test fluid is injected into top of test cell, wellbore pressure and minimum horizontal pressure are measured



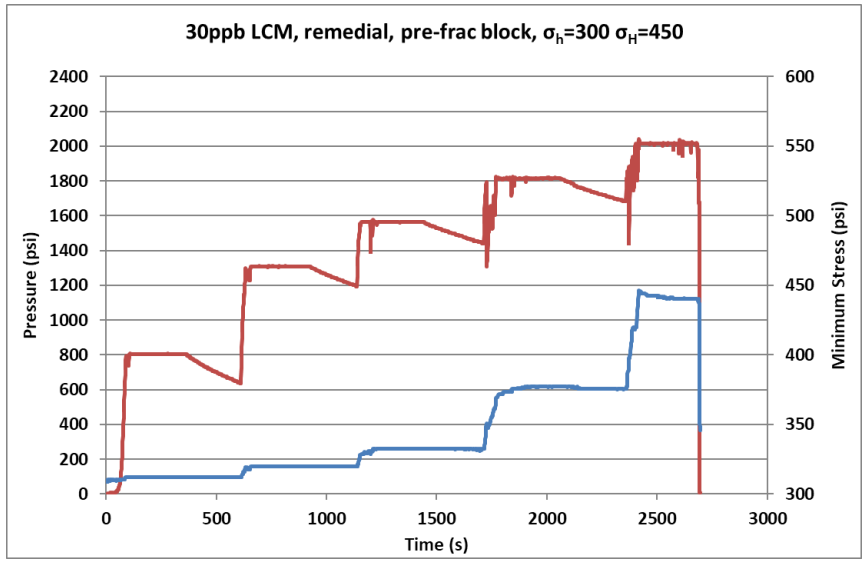


Fracture generated at 1550 psi, re-opening pressure of approximately 900 psi with base mud

When LCM added, wellbore pressure could be increased above initial fracture generation pressure

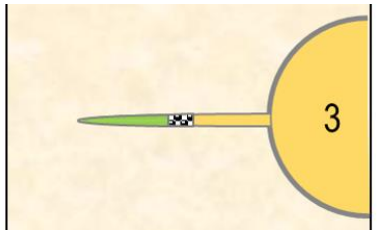


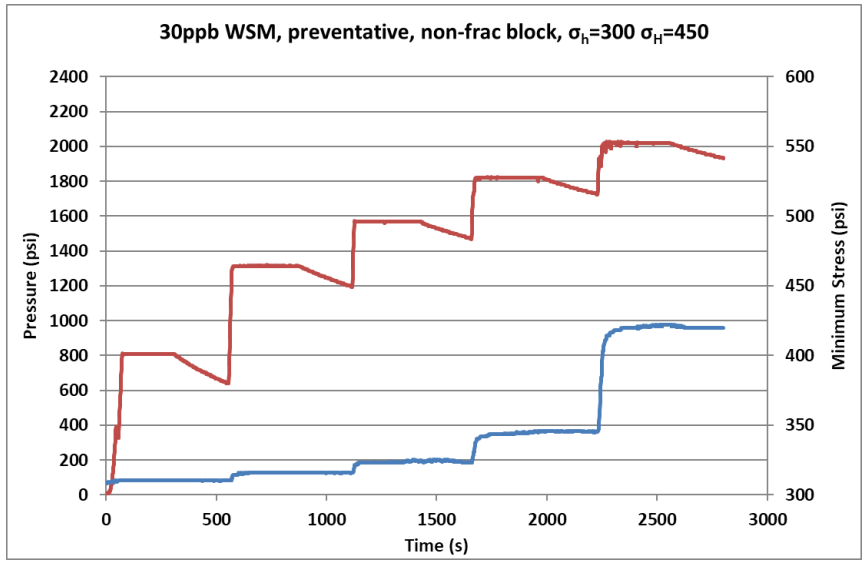
In both tests the same products and concentration were used, but the remedial treatment shows much more instability, and test fluid flowed through the fracture and out the edge of the block





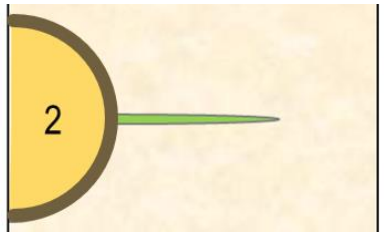
Partly dry fracture, blocked by particles



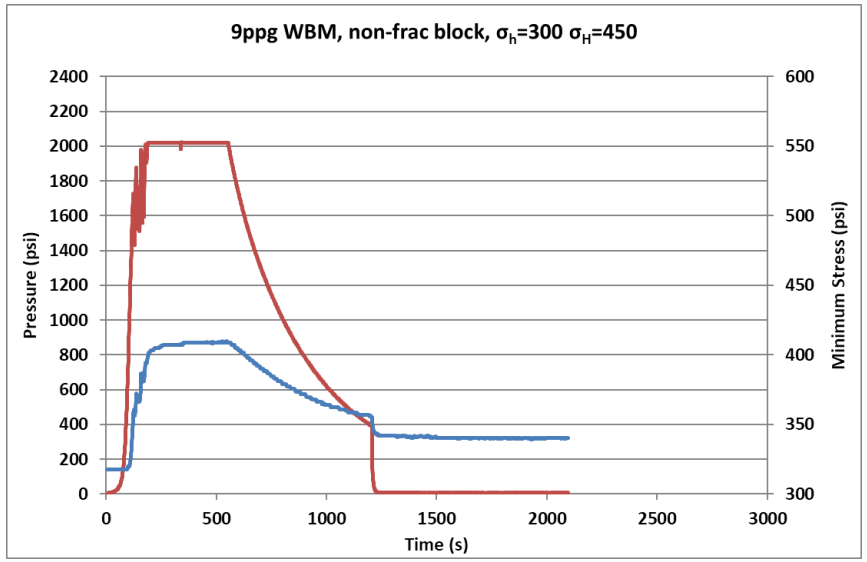


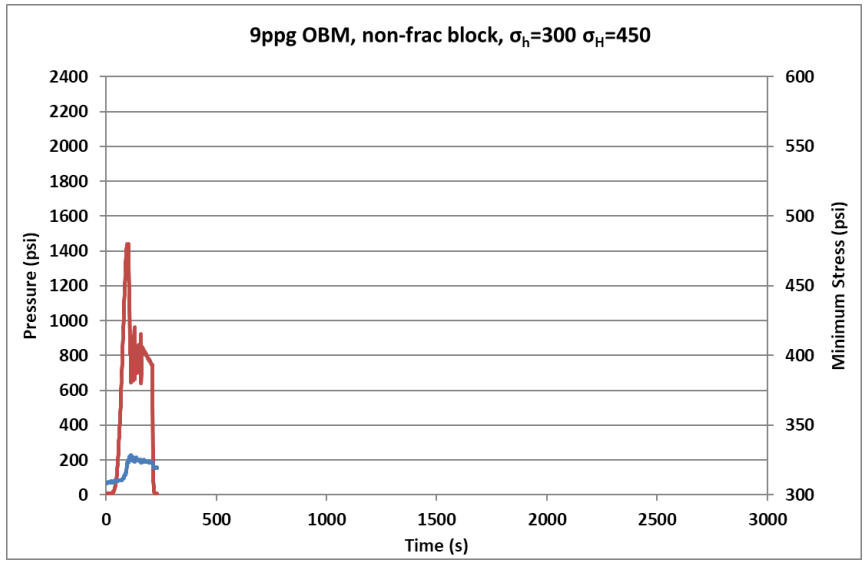


A fracture was generated in both tests, but the WBM formed a much thicker and therefore stronger filter cake that was able to keep the fluid within the wellbore



Dry fracture, mouth blocked by mudcake









Slot Tester Advantages and Disadvantages

Advantages

- Tests can be completed in 30 to 60 minutes
- Results are typically very repeatable
- Equipment is compact and (relatively) inexpensive
- Very precise control over fracture width
- Tests can be performed at temperature

Disadvantages

- Fracture width is perfectly rigid
- Fracture surface is perfectly smooth and (typically) parallel
- Not ideal for non-particulate materials
- Equipment can only simulate a pre-existing fracture

Small Block Tester Advantages and Disadvantages

Advantages

- Can be used for testing preventative treatments
- Fracture surfaces have an appropriate texture and permeability
- Fracture length is sufficient for a seal to form within the fracture
- Fracture width will grow with increasing wellbore pressure requiring the particles to accommodate

Disadvantages

- Tests are more expensive and take 4 to 6 hours to run
- There is more test-to-test variability due to rock inconsistency and possibility of stress anisotropy
- It is not possible to measure or control the width for pressure induced fractures

Conclusion

- Lost Circulation Control is a remedial treatment meant to reduce the loss rate
- Wellbore Strengthening is a preventative treatment meant to avoid lost circulation by allowing for wellbore pressure greater than the fracture gradient
- Different fracture sealing mechanisms require different lab equipment
- Slot Tests are quick and easy, but can only simulate a pre-existing fracture
- Small Block Tests can evaluate preventative treatments, but cannot control the fracture width

Thank you