Frac Charges: How Do They Really Perform Downhole? (Part II)

2022-IPS-1.2

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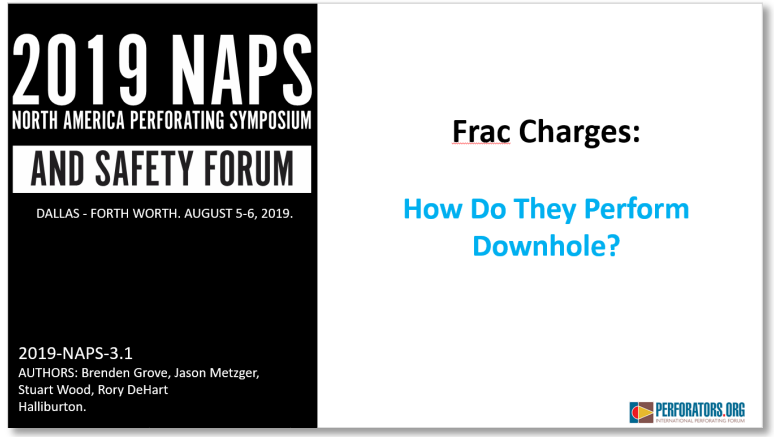
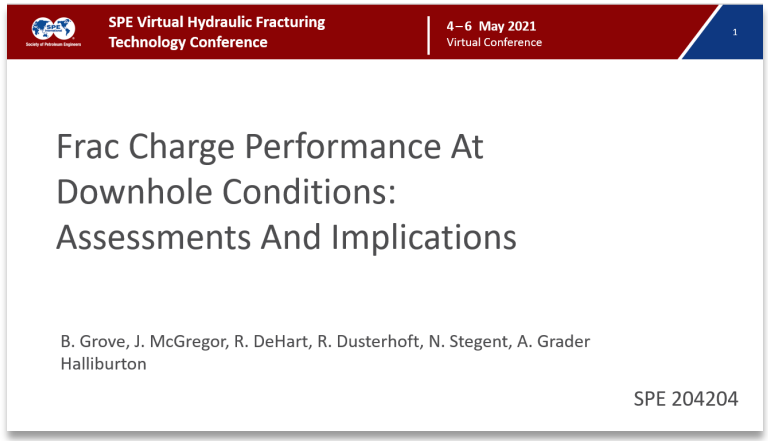
IPS 2022
INTERNATIONAL PERFORATING SYMPOSIUM

Agenda

- Background and Introduction
- Perforation characteristics of interest
- Surface testing – brief review
- Laboratory testing @ downhole conditions
- Results and implications





Background and Introduction

- Hydraulic Fracturing
  - Lower breakdown pressure
  - Minimize NWB tortuosity and treating pressure
  - Enable LE treatments
  - Enable efficient proppant placement

- Production
  - Maximize flow capacity from reservoir → WB
  - Minimize resistance to high closure stress & proppant embedment
  - Maximize resistance to fines migration and NWB plugging

Perforation Characteristics

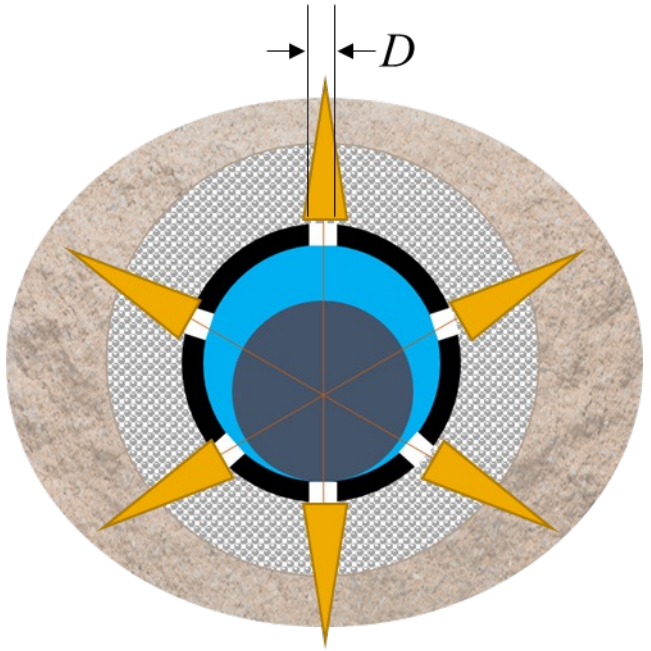
$$Q = \sqrt{\frac{\Delta P}{0.237\rho}} D^2 CN$$

$\Delta P \propto 1/D^4$

$Q \propto D^2$

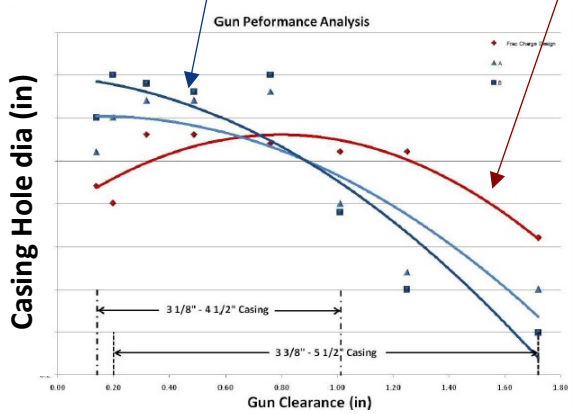
- Casing hole diameter
  - LE design
  - Orifice, controlled backpressure
  - Want all holes in stage to take equal rates

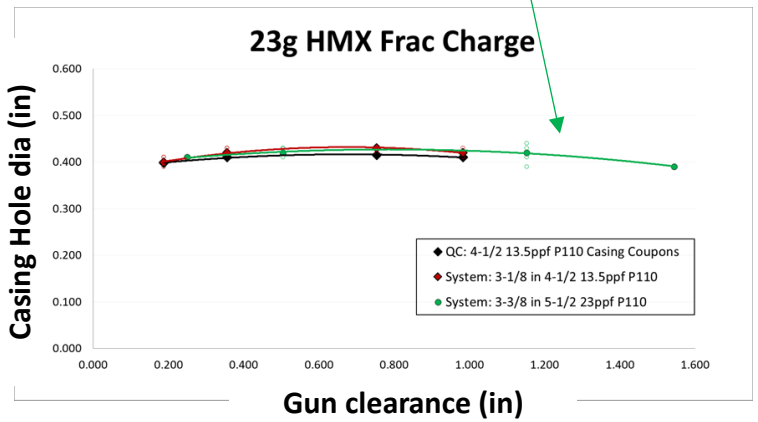
- Other characteristics
  - Shot pattern
  - Behind the pipe

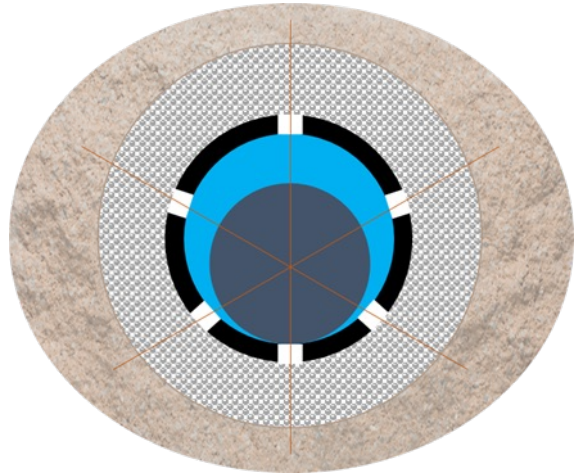


Hole Size Consistency - Evolution

Traditional DP charge → 2011 1st gen frac charge → 2020s Current gen frac charge





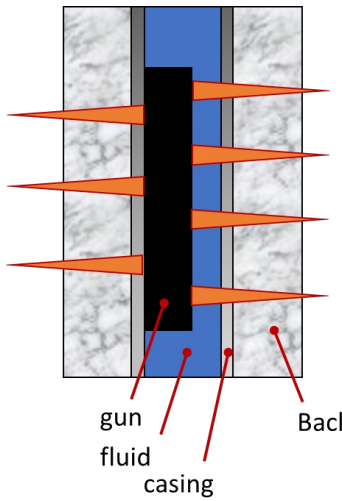


Explosive type	Explosive load (g)	Gun size (in)	Casing size, weight (all P110)	EH (in)	EHV (%)
HMX	15	2 ¾	4-1/2” 13.5ppf	0.36	2.4
RDX				0.35	2.4
HMX	23	3 1/8	4-1/2” 13.5ppf	0.42	3.0
RDX				0.41	2.3
HMX	23	3 3/8	5-1/2” 23ppf	0.40	4.3
RDX				0.40	3.5

How Do We Measure Performance?

Surface conditions

- "Barrel test"
- 18 datapoints
- Cement-backed casing

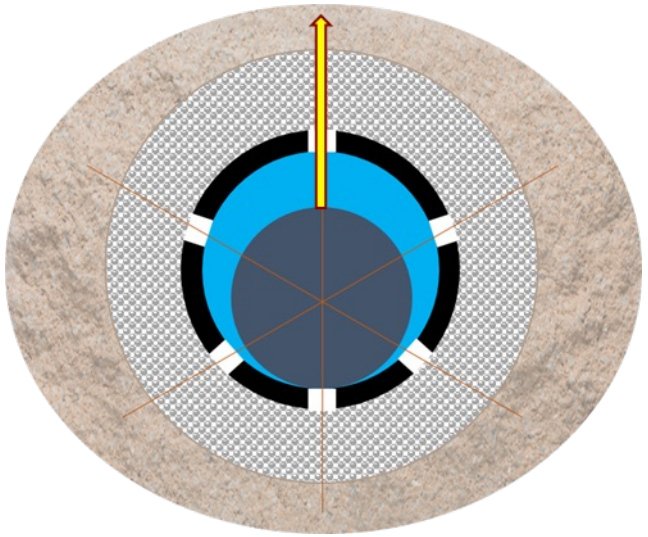


Backing material

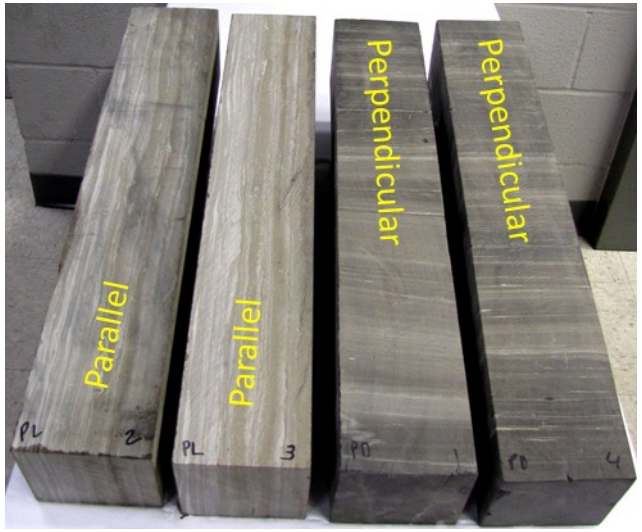
Downhole conditions

- 19B Section 2 / 4 (special)
- Perforate (+ flow) real, stressed, rock
- Downhole P and T

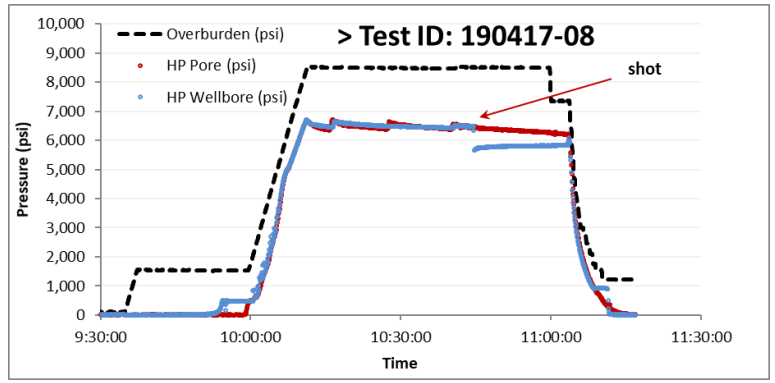
Laboratory Test Program – Downhole Environment



- 3-1/8” gun
- 5-1/2” 20ppf P110 casing
- Cemented in 8-1/2” borehole
- Fluid gap = high side of WB



- Eagle Ford shale targets
- Bedding plane orientations



- Downhole conditions
- Overburden stress = 8,500 psi
- BHP = 6,500 psi

- **8 tests total (each core shot twice)**
- **Oil vs. gas in pore space**
- **23g & 15g charges**
- **Wellbore dynamics**

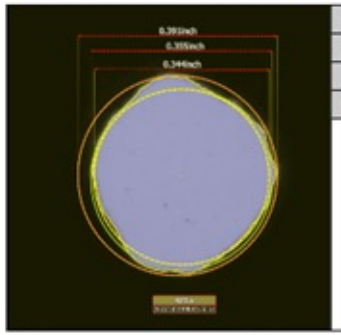
Laboratory Testing Matrix

		Dimensions (in)				Pressures (psi)			Formation Target			
Test No.	Charge	Gun size	Casing	Fluid gap	Borehole size	Overburden	Pore	Wellbore	Material	Bedding plane orientation	pore fluid	DUB (psi)
1	15g RDX	3-1/8	5-1/2 (20ppf; P110)	1.65	8-1/2	8,500	6,500	6,500	Eagle Ford Shale	parallel	OMS	5,704
2										perpendicular		5,651
3	23g RDX									parallel		5,462
4										perpendicular		5,536
5	23g RDX	3-1/8	5-1/2 (20ppf; P110)	1.65	8-1/2	8,500	6,500	6,500	Eagle Ford Shale	parallel	OMS	1,549
6										perpendicular		1,641
7										parallel	N2	1,756
8										perpendicular		1,722

Results: Casing Hole Diameter

- Same performance as surface testing (23ppf)
- This charge is insensitive to downhole conditions

HOLE DATA REPORT

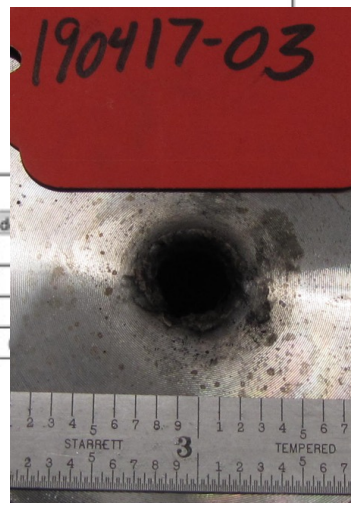


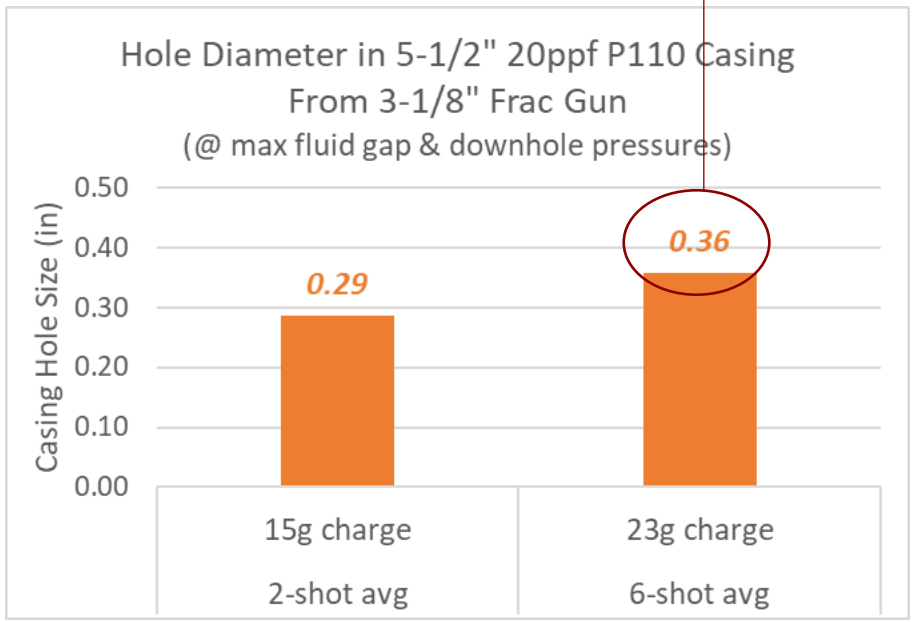
DATE & TIME	7/10/2019 10:24:49 AM
PROJECT NUMBER	190417
TEST NUMBER	03
PART DESCRIPTION	Casing

[Measurement results]

measurement item	mes. value	units
BEST FIT DIA	0.355	inch
MAX DIA	0.391	inch
MIN DIA	0.344	inch
AREA	0.099881	inch²

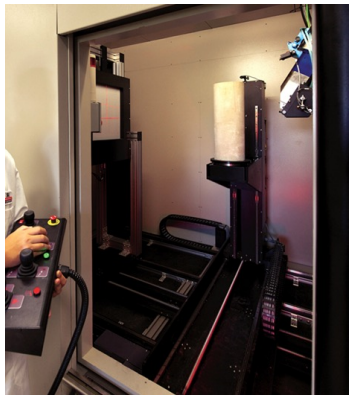
#3

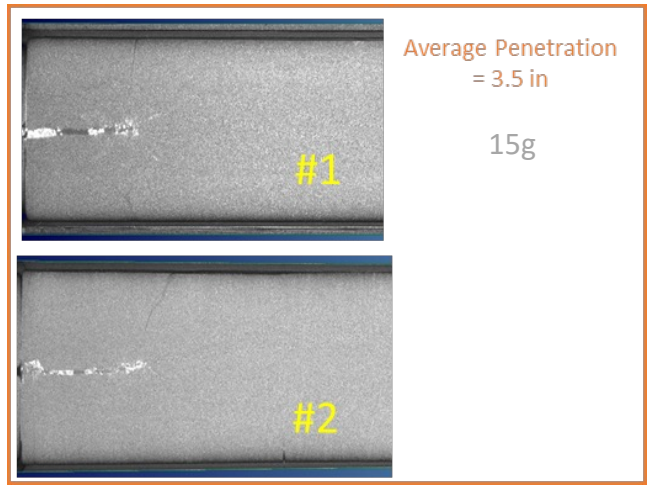


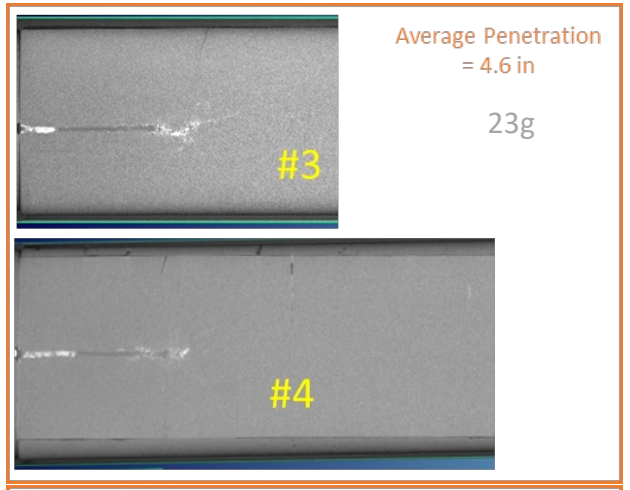


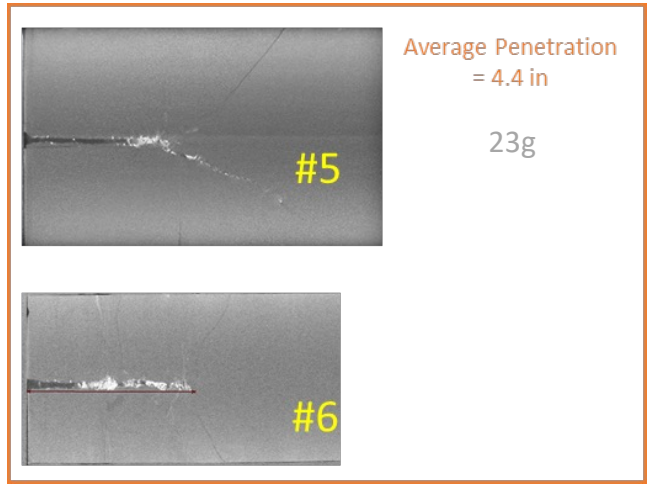
Results: Perforation Depth

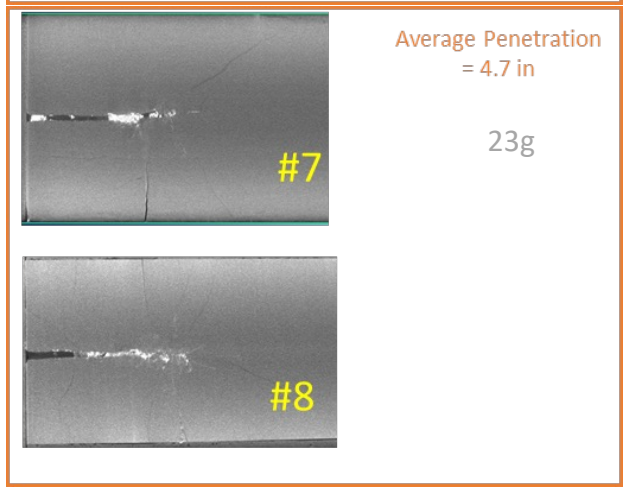
- 15g: ~3.5 in
- 23g: ~4.6 in



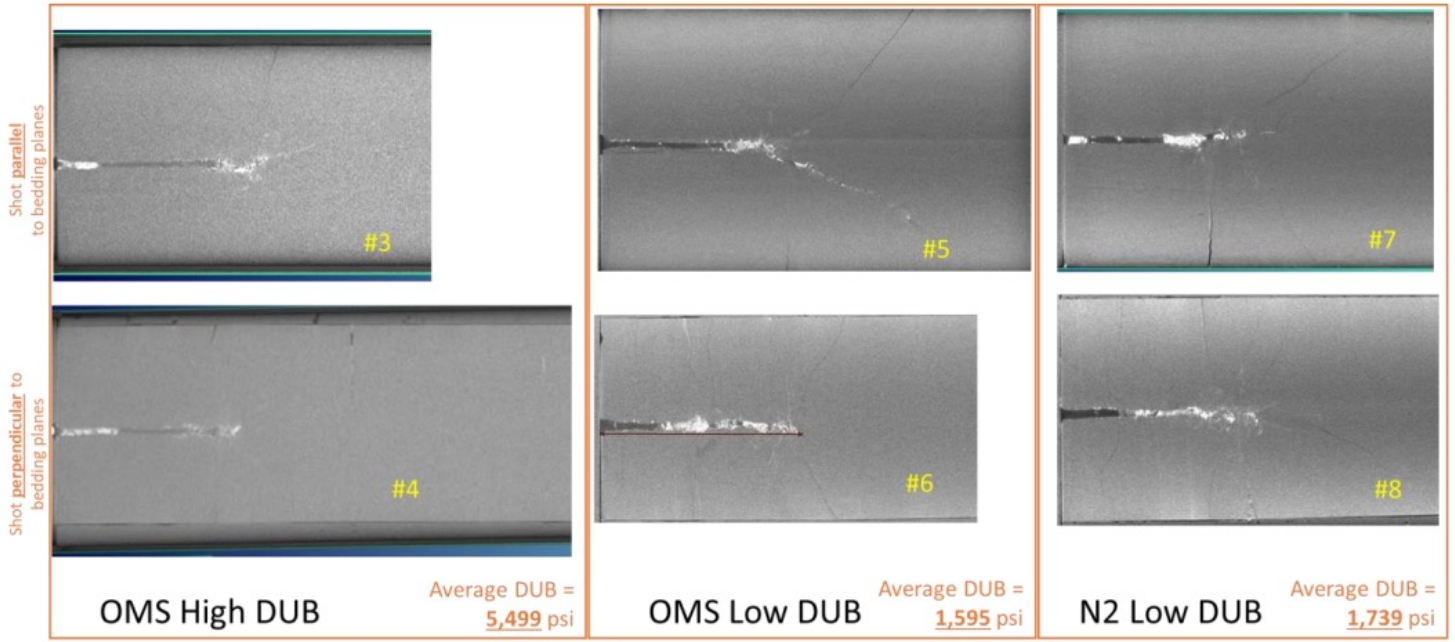




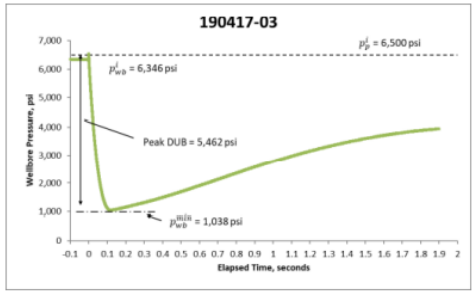




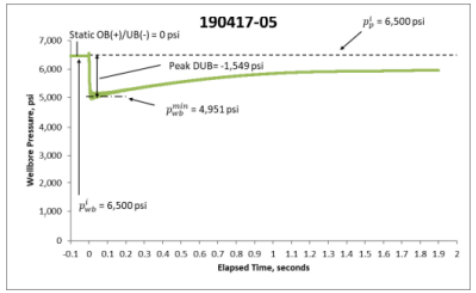
Results: Tunnel Cleanout (DUB)



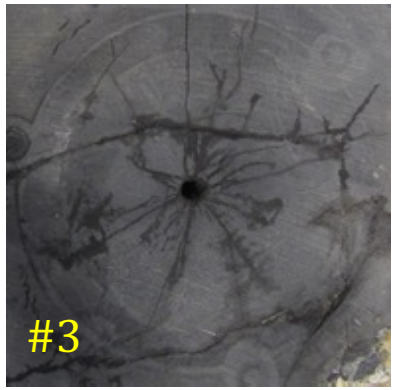
High DUB

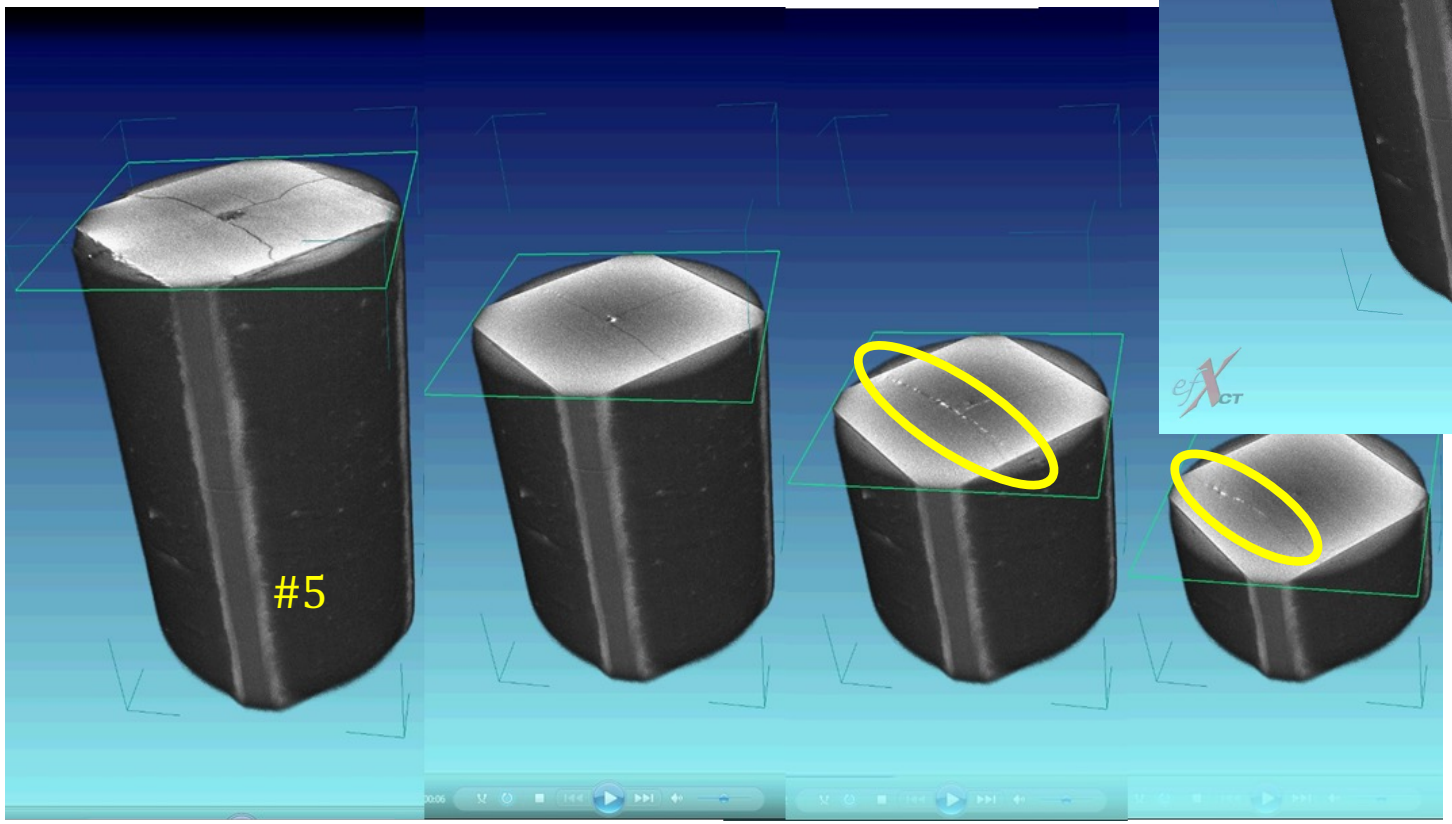


Low DUB



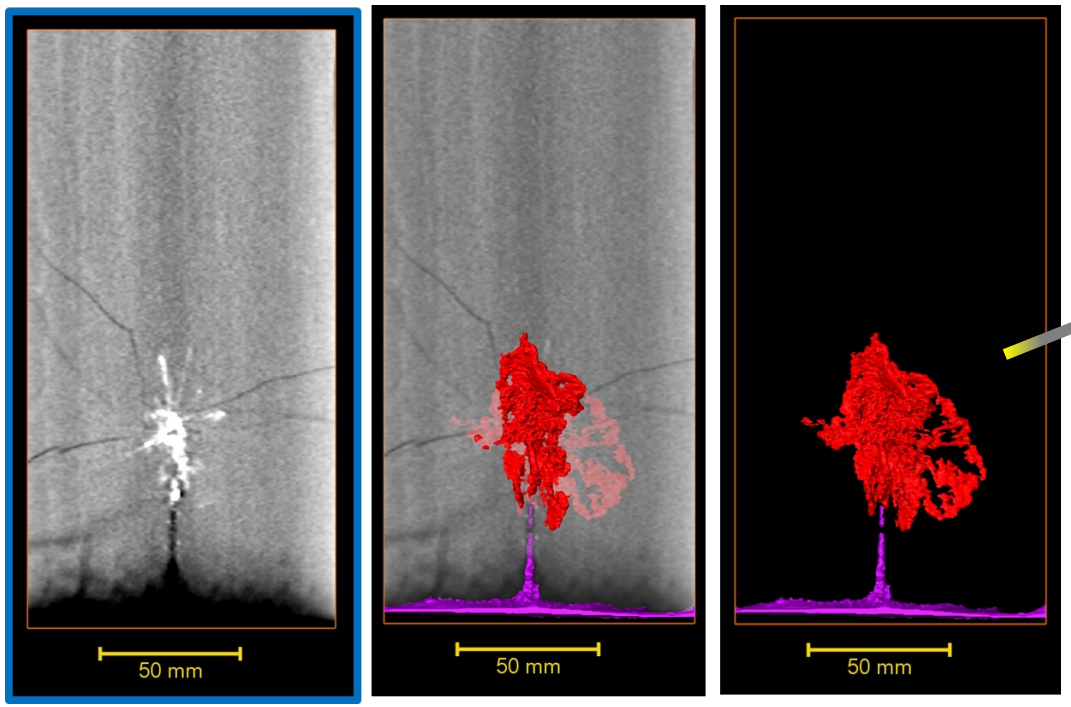
Results: Fracture Patterns

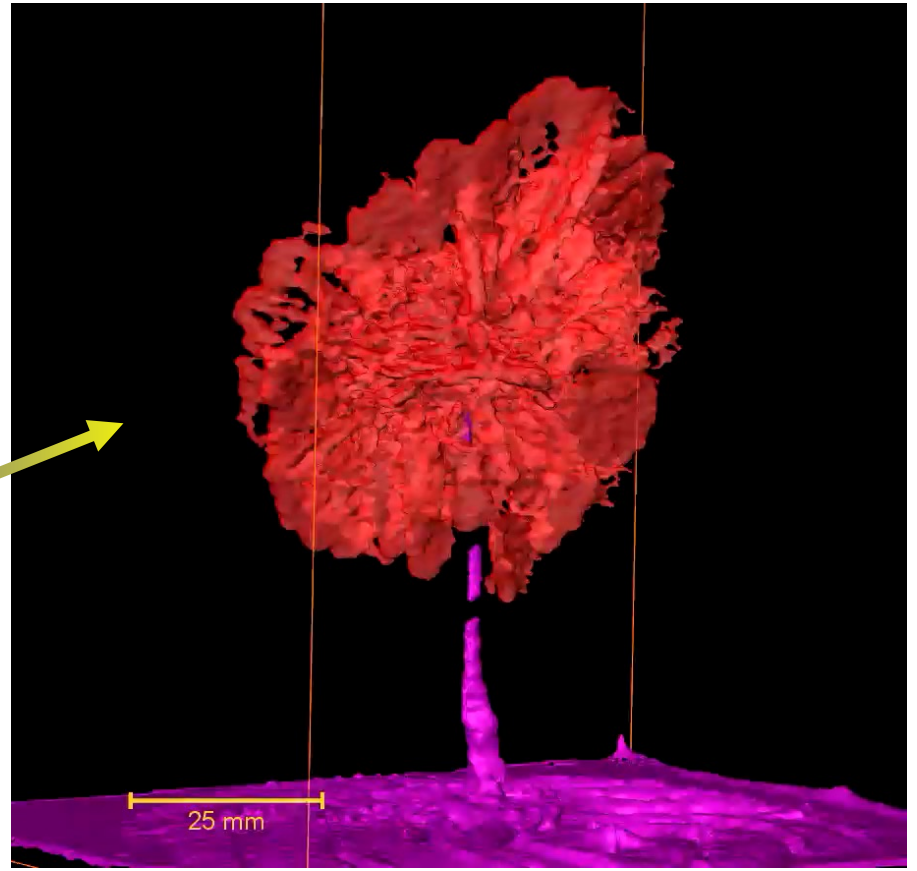




Results: Fracture Patterns

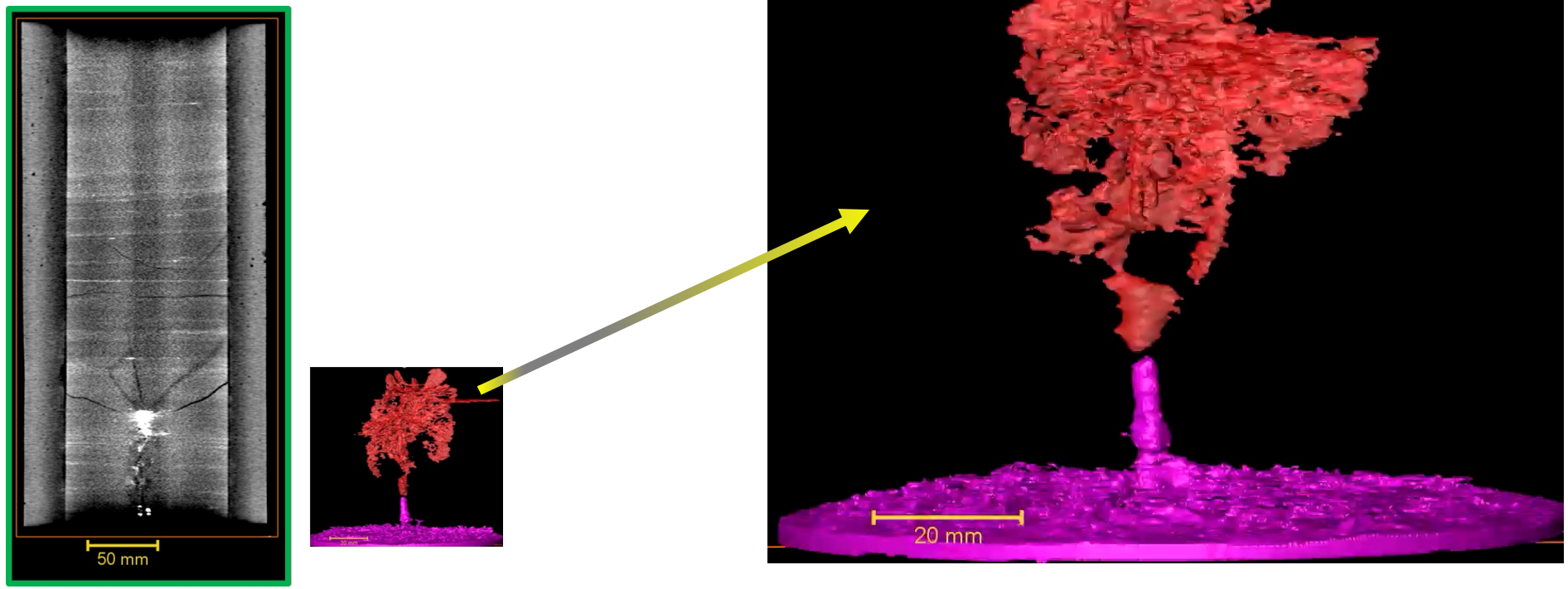
(parallel core)





Results: Fracture Patterns

(perpendicular core)



Frac Charges: How Do They Really Perform Downhole? (Part II)

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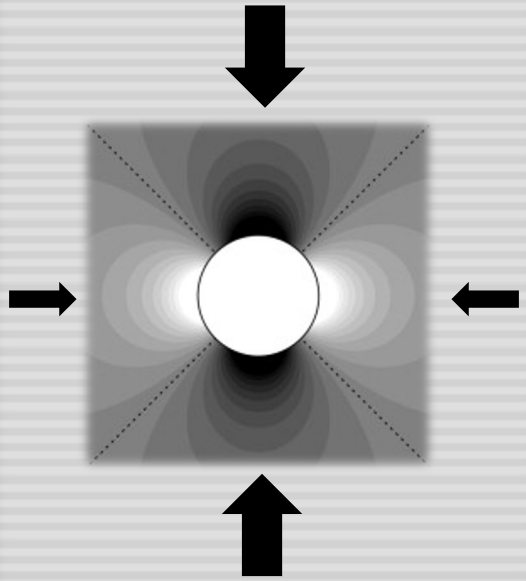
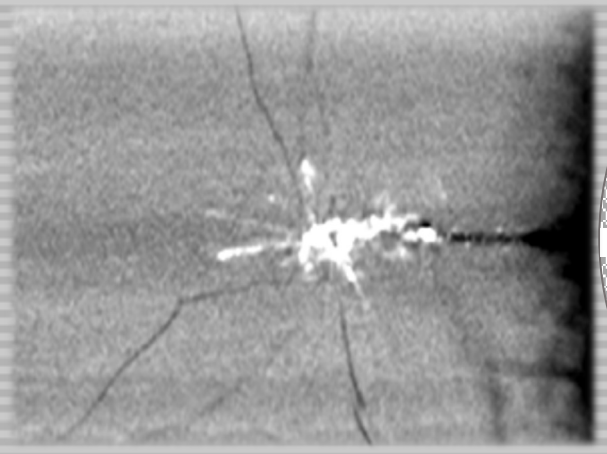
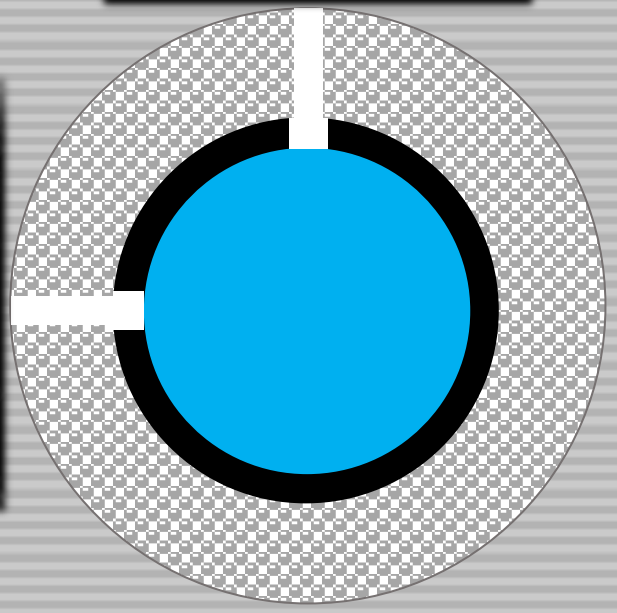
Perforations shown to scale in downhole environment







Summary and Conclusions (1)

Perforating for Fracturing

- Casing hole diameter consistency
  - Necessary for effective stimulation
  - Has improved in recent years
  - Test method matters
  - Demonstrated at DH conditions

Summary and Conclusions (2)

Perforating for Fracturing

- Perforation into stressed shale
  - Industry-first study
  - Shallow perforations
  - Heavily fractured
  - Propped fracs / residual stresses?
  - DUB may play a role?

- *What happens behind the pipe may be important*
- *Perforating is more than just "holes in the pipe"*

Q&A

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