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APPS13-025

An Evaluation of the Impact of Reactive Perforating Charges on Acid Wormholing in Carbonates

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Agenda

Background

Objectives

Experimental Procedure and Parameters

Results

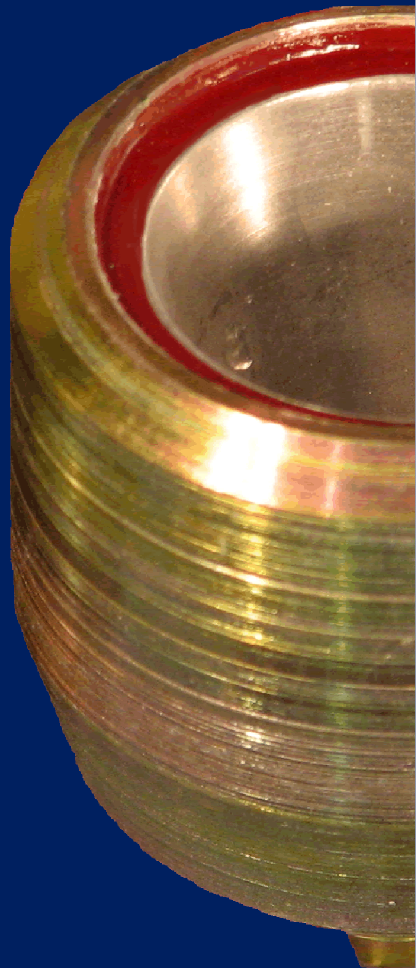
Conclusions and Recommendations

Industry Agreement – Over Prediction

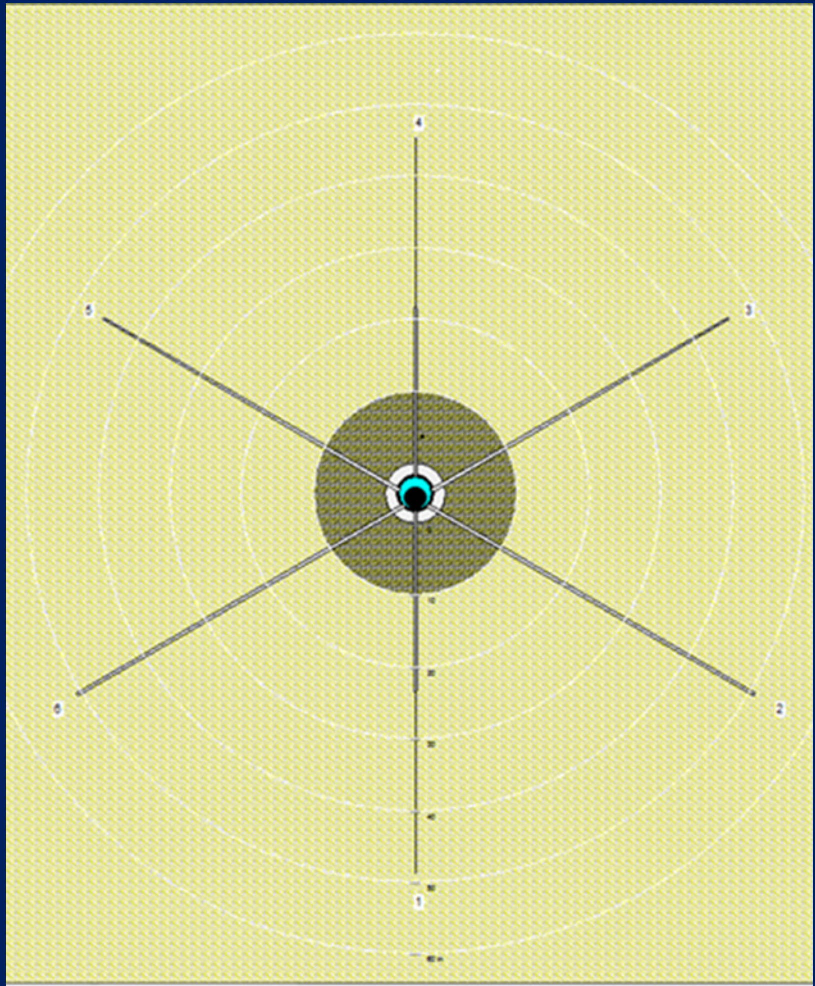
- **SPE 124783** "Predicting Depth of Penetration of Downhole Perforators", Gladkikh et al, Baker
- **SPE 125020** "A Survey of Industry Models for Perforator Performance: Suggestions for Improvement", Behrmann et al, Schlumberger
- **SPE 127920** "New Predictive Model of Penetration Depth for Oilwell-Perforating Shaped Charges", Harvey et al, Schlumberger

"The primary conclusions of this work include: (1) historical penetration models tend to over predict penetration at downhole penetrations … partly due to the industry's continued reliance on performance into surface targets."

---SPE125020



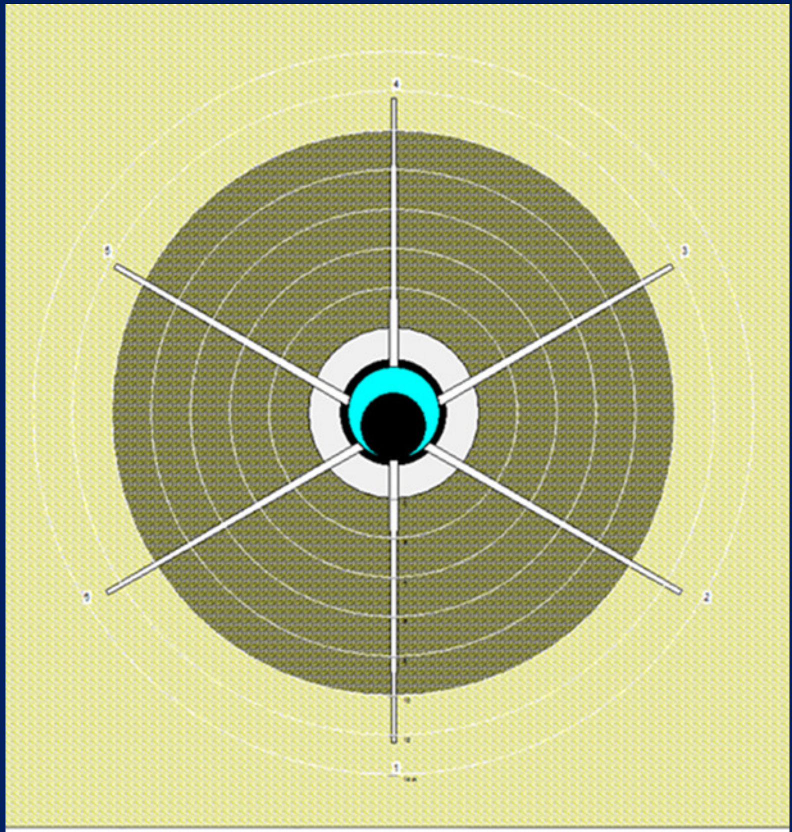
Perforation Performance Evaluation



- 22.7 g Charge
- API Cement 39.02”
- 8” Borehole
- 10” Damage Radius

- Perforations Far Field
- Commodity Selection
- Assumed Open
- Doesn’t Match Reality

Perforation Performance Evaluation

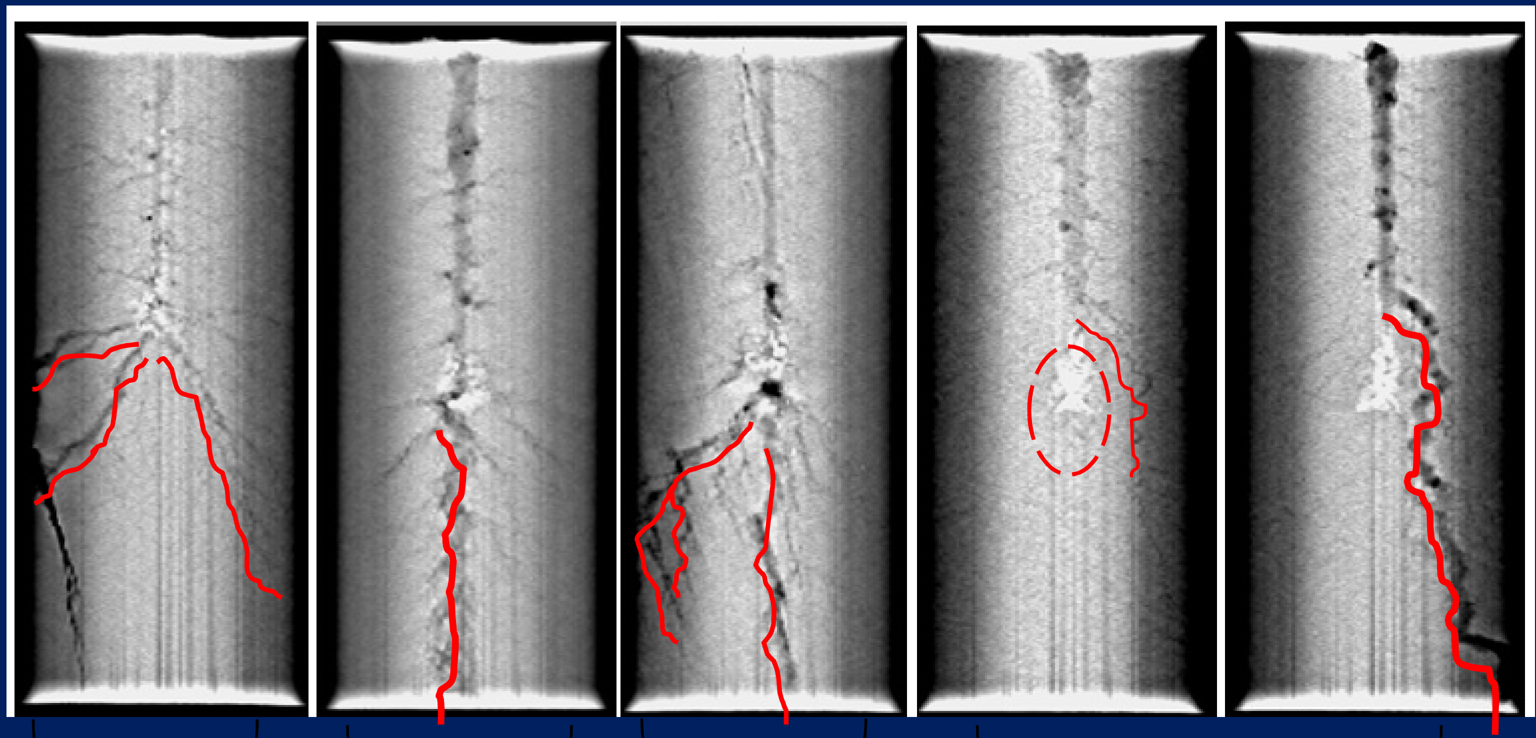


- 22.7 g Charge
- Cement Pen
- 8” Borehole
- 10” Damage Radius

- Perforations Near WB
- Performance Valuable
- Geometry Important
- Testing Useful

Background

CT Scan images of acidized cores (Bartko et al. 2007. SPE 105022)



Static Underbalanced Pinj=3600 psi

Dynamic Underbalanced Pinj=2700 psi

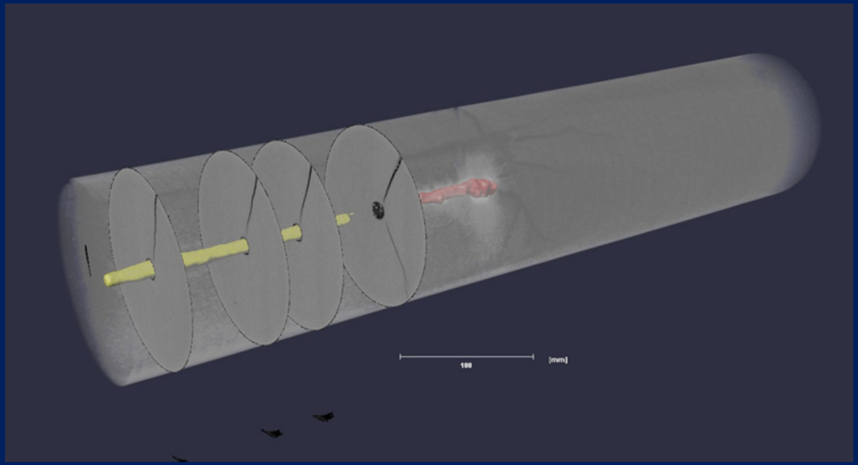
Gas-filled Wellbore Balanced Pinj=2500 psi

Acid-filled Wellbore Dynamic Underbalanced Pinj=90 psi

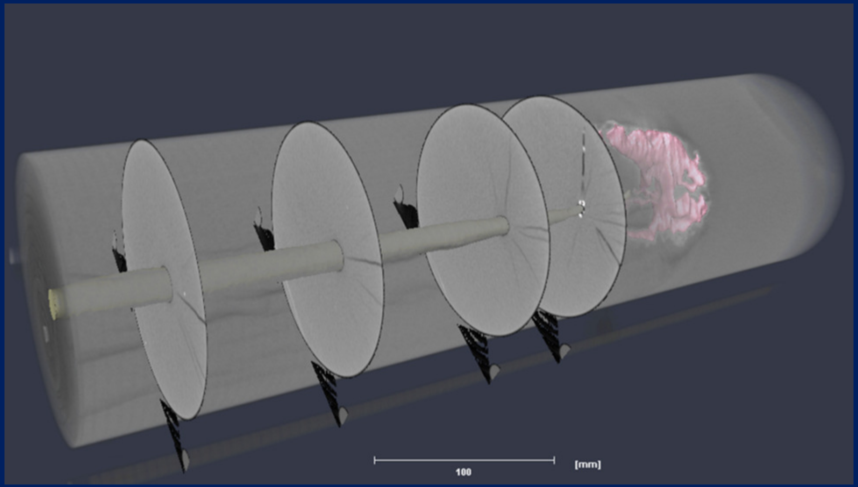
Perforation Geometry

Background

Conventional 25g



Reactive 25g



Background

Advantages:

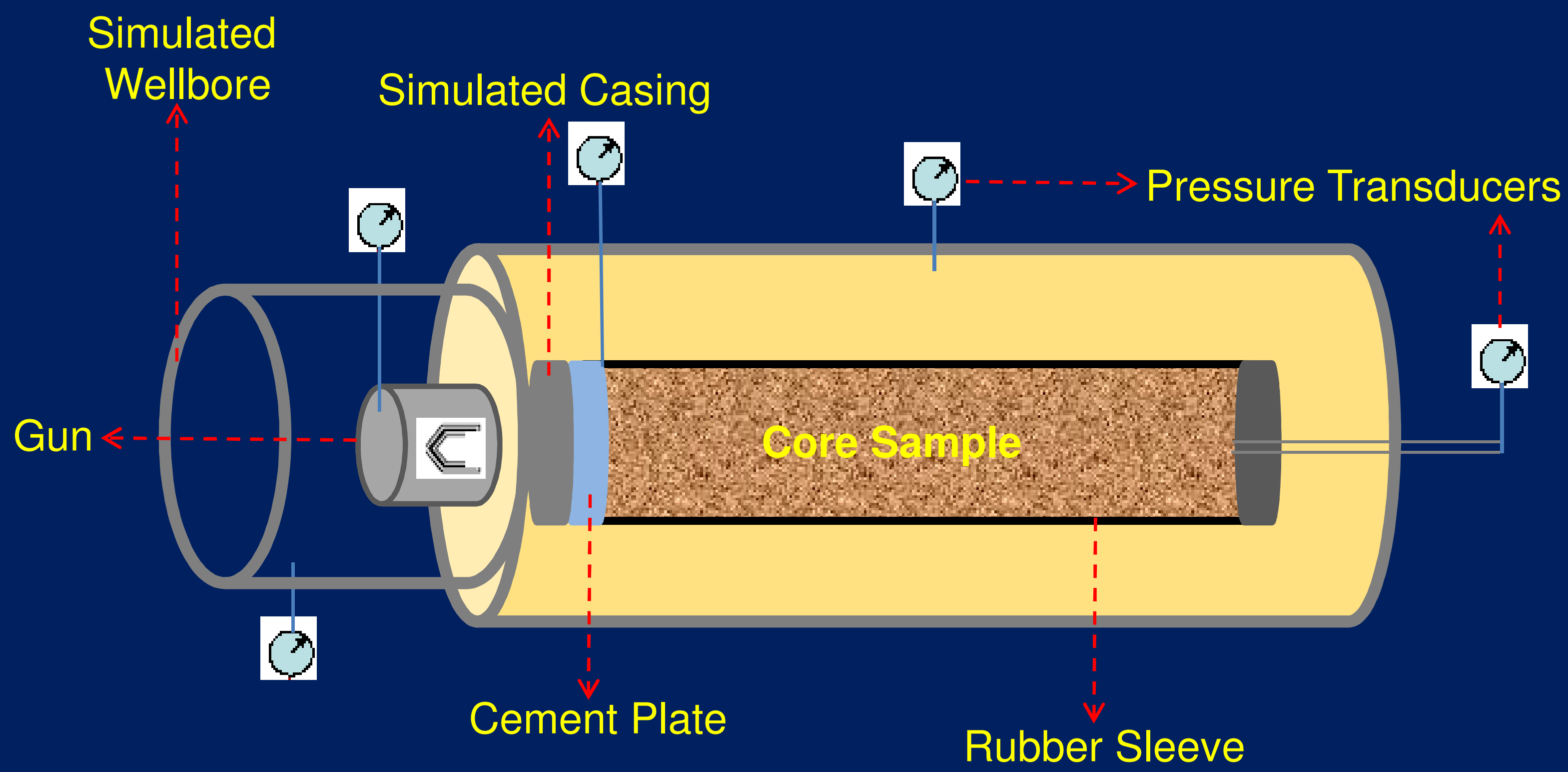
- Improve injectivity and flow performance.
- Enhance stimulation job's efficiency .
- Increase productivity to a point that would offset cost.

SPE116226, SPE122174,
SPE125901, SPE144167, SPE149453

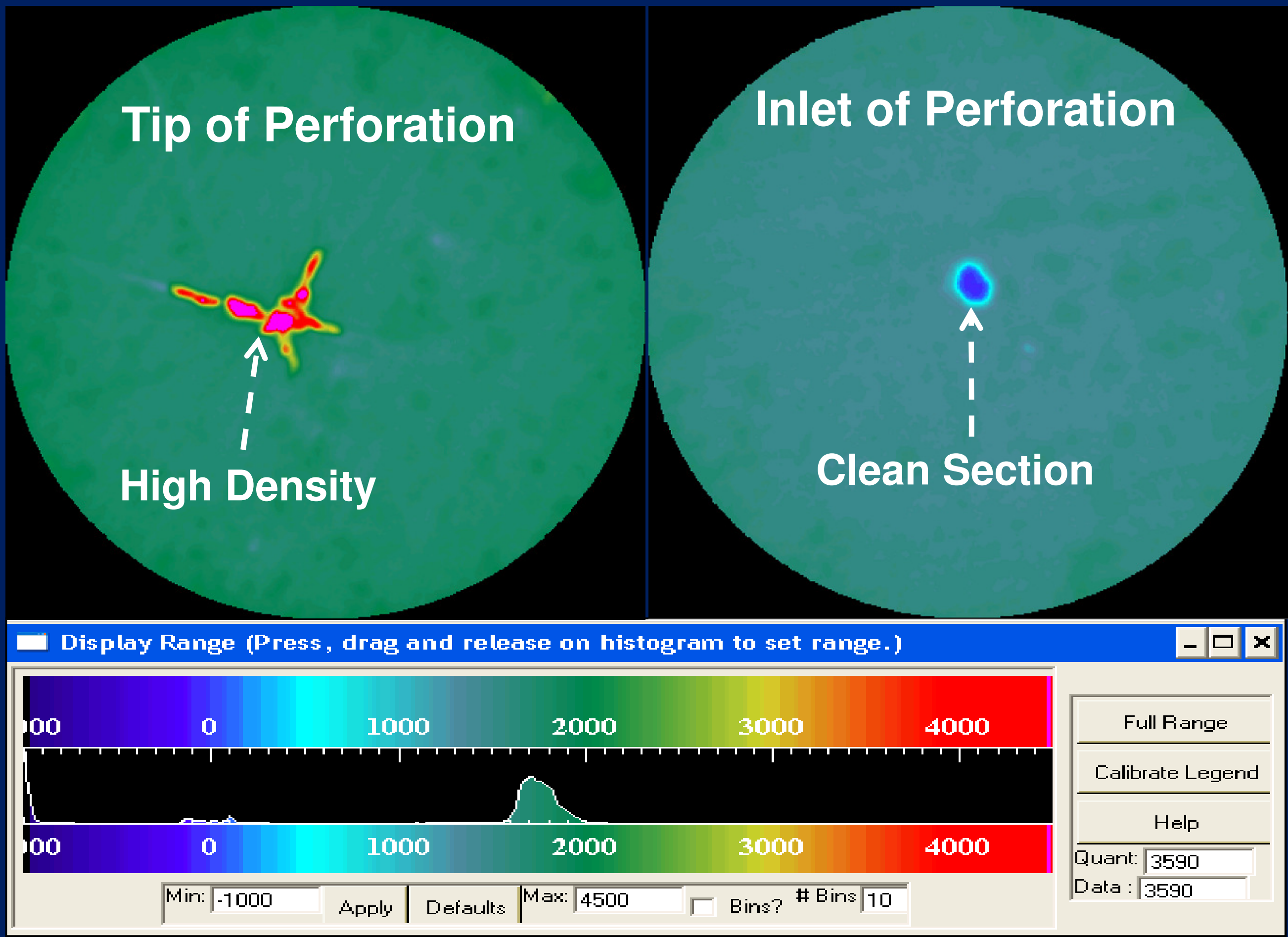
Objectives

- Perforate a set of carbonate cores using conventional and reactive charges.
- Evaluate the geometry of reactive charges in carbonate rocks.
- Evaluate the effect of reactive charges on acid wormholing.

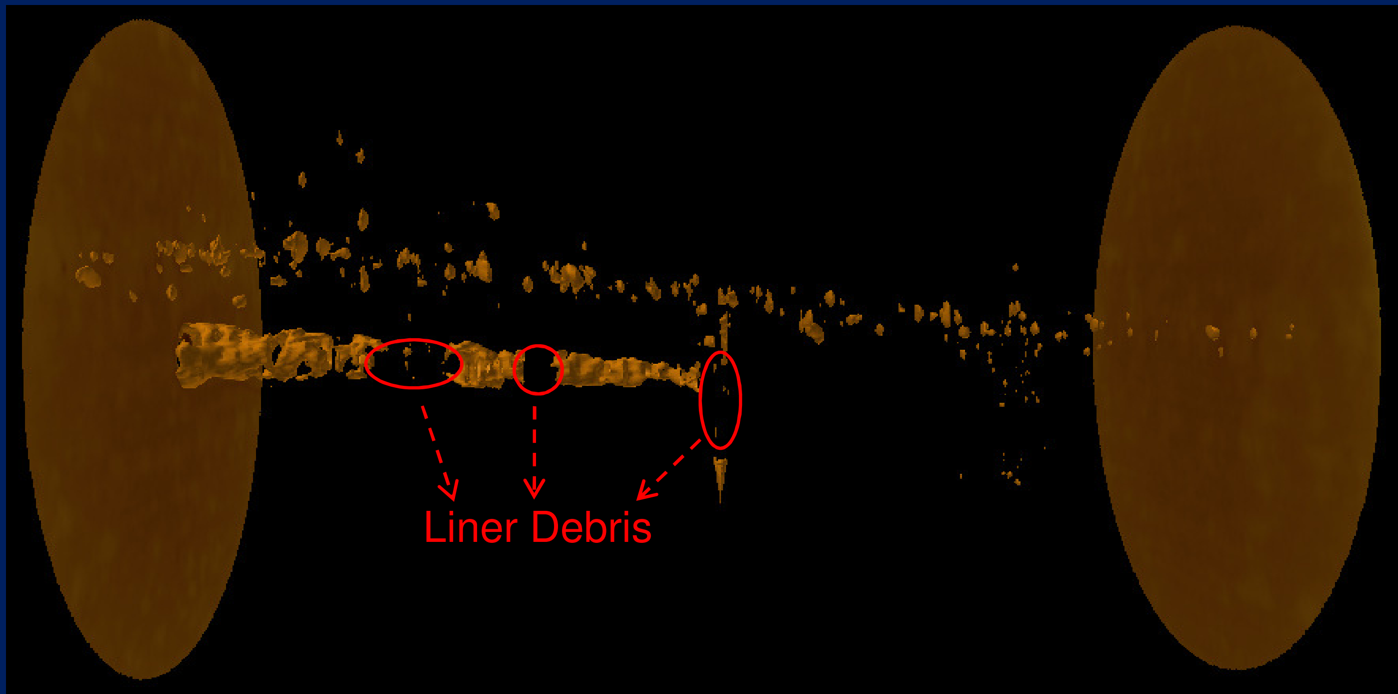
Experimental Procedure and Parameters



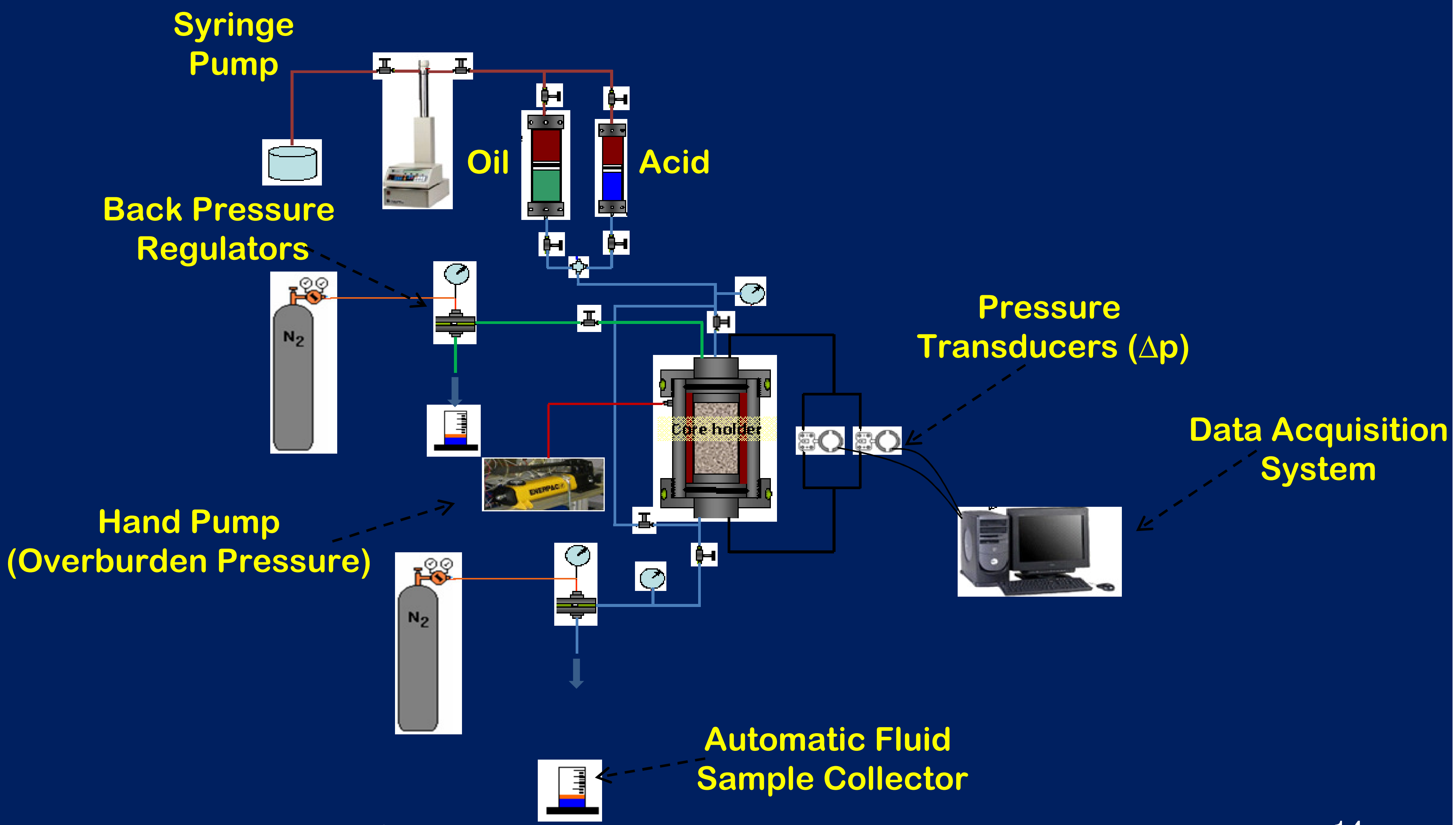
Experimental Procedure and Parameters



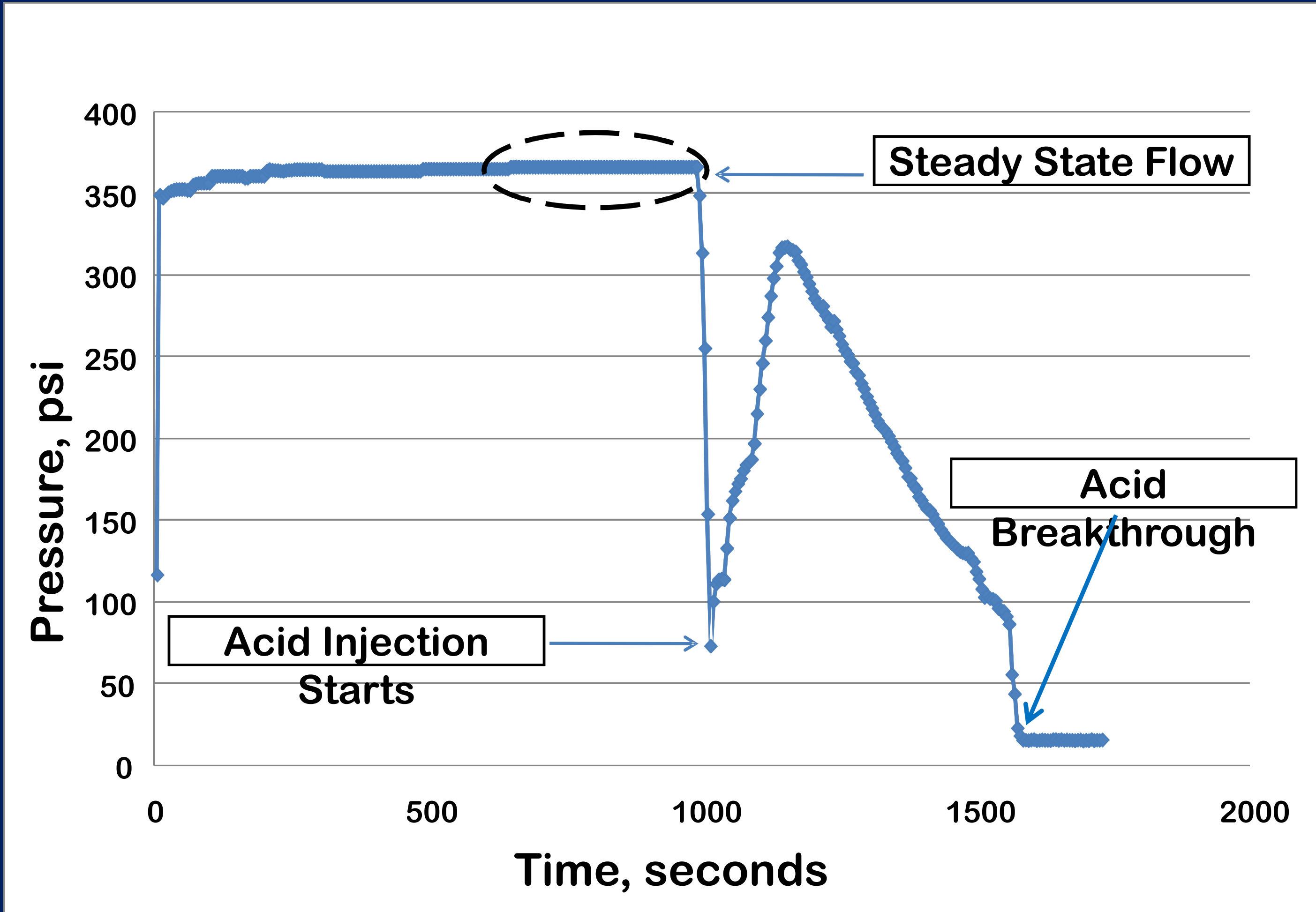
Experimental Procedure and Parameters



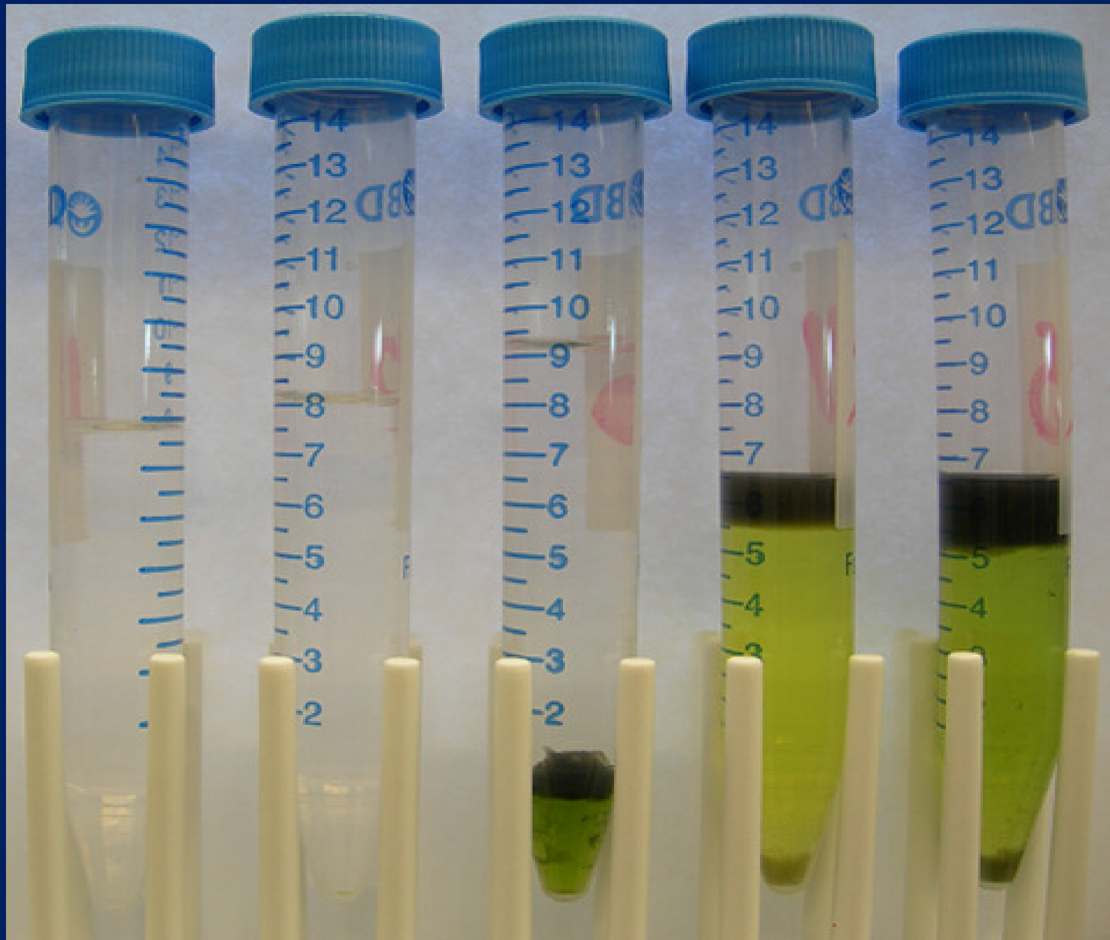
Experimental Procedure and Parameters



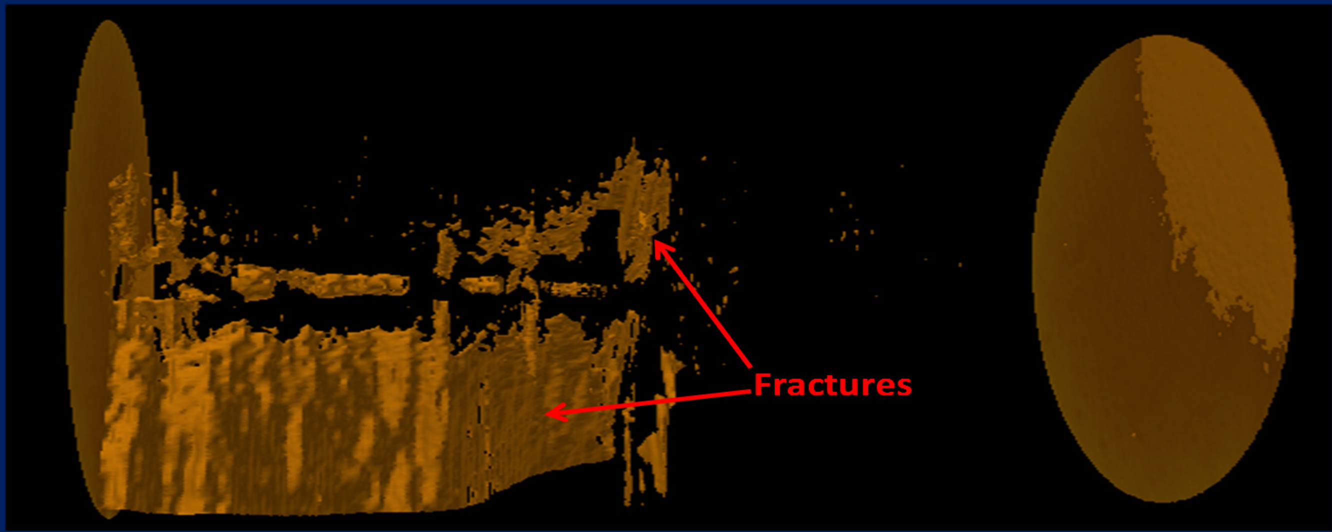
Experimental Procedure and Parameters

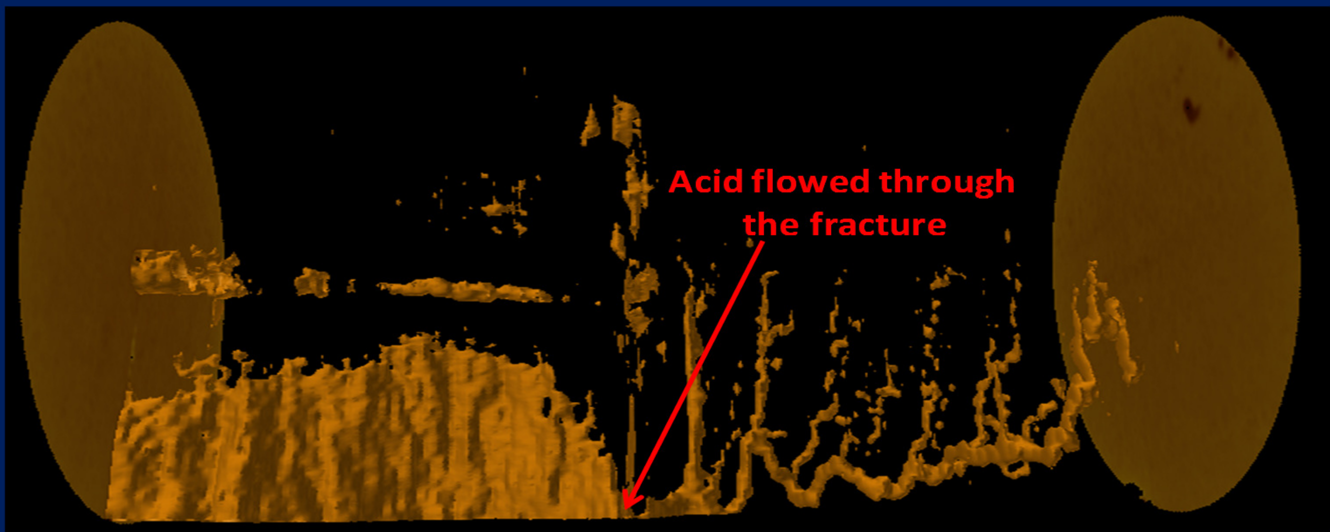


Experimental Procedure and Parameters



Initial Experiments





Initial Experiments Results

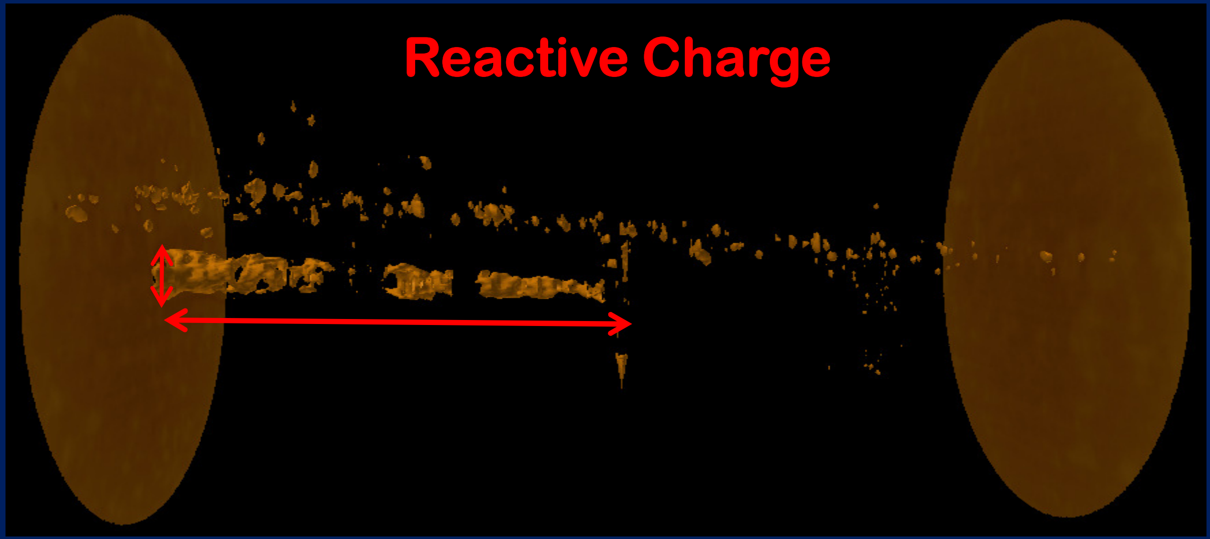
15 gram Charges

Shot Type	Injection ΔP, psi	Acid to Break through, ml
Conventional	274.00	66.67
Reactive	327.00	58.23
Conventional	321.50	41.67
Reactive	660.00	101.67
Conventional	206.00	62.5

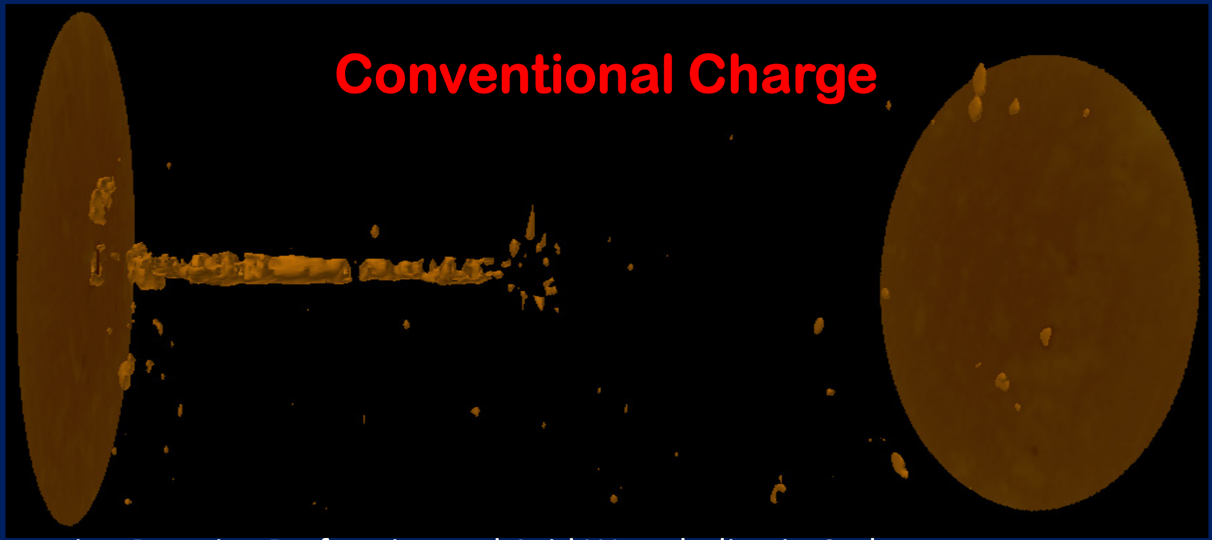
7 gram Charges

Shot Type	Injection ΔP, psi	Acid to Break through, ml
Conventional	406.00	65
Reactive	371.00	60
Conventional	421.00	64.17
Reactive	386.00	73.33
Conventional	953.00	77.5
Reactive	335.00	60.42

Conventional Vs Reactive Charges

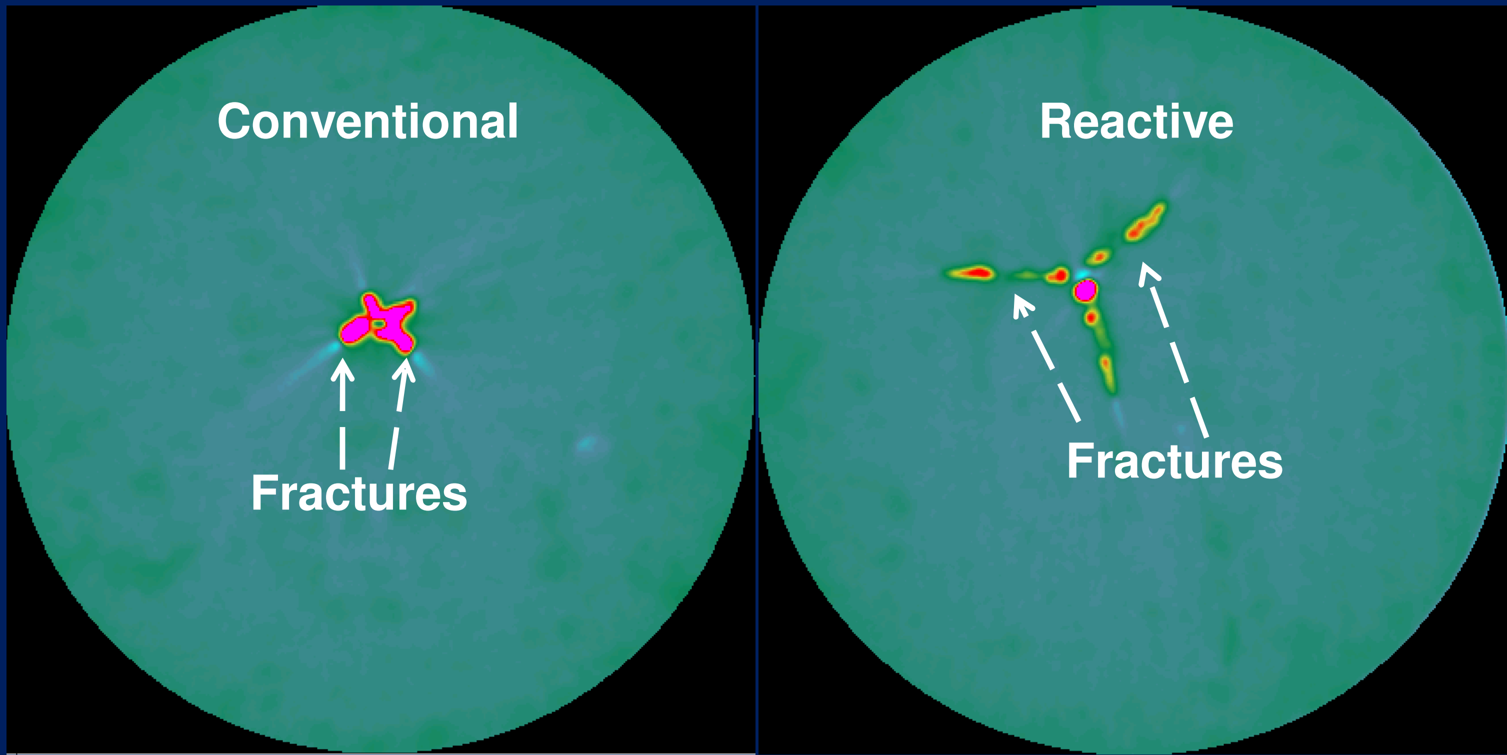


Perf. L = 10.39 in
Perf. D = 0.26 in
K = 3.5 md
ΔPinj = 335 psi



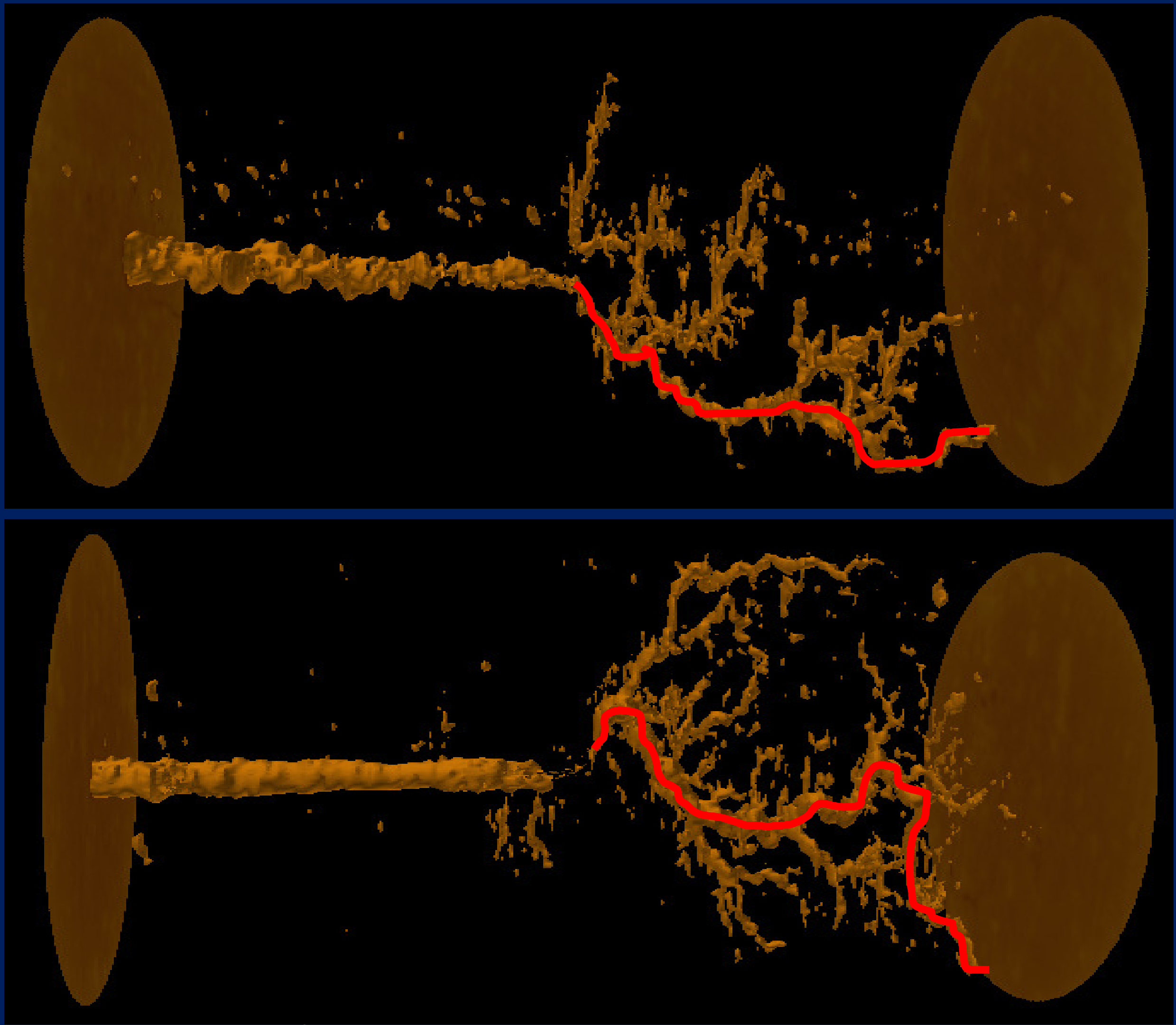
Perf. L = 10.27 in
Perf. D = 0.21 in
K = 5.3 md
ΔPinj = 351 psi

Conventional Vs Reactive Charges



CT images taken at the tip of the perforations before acidizing

Conventional Vs Reactive Charges



Reactive Charge

V_{acid} = 91 ml

Conventional Charge

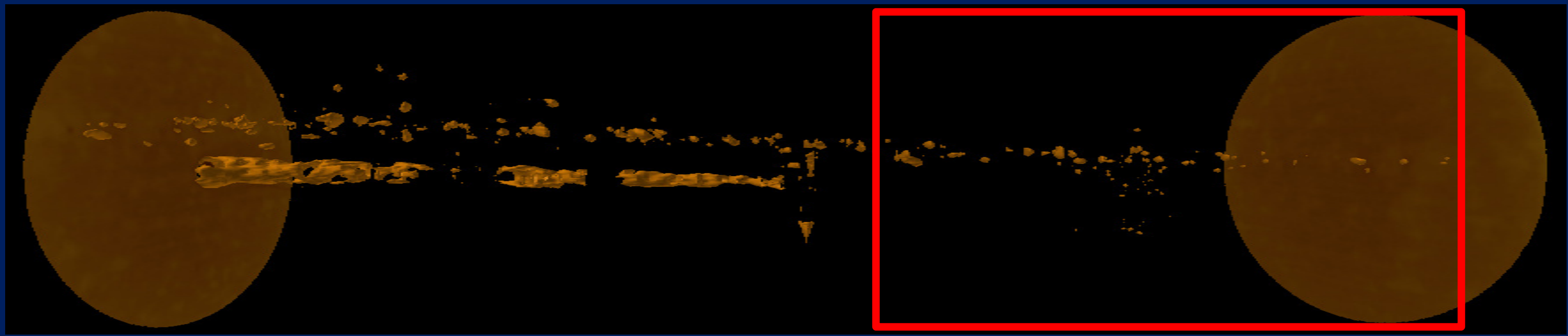
V_{acid} = 95 ml

Perforating Results: Tunnel Dimensions

Charge Wt, Grams	Type of Shaped Charge	Perforating Pressure Condition	Inlet Perforation Diameter, inches	Perforation Length, inches	Volume of Perforation, cubic inches
7	Conventional	Balanced	0.206	10.27	0.33
7	Reactive	Balanced	0.257	10.39	0.49
7	Conventional	Overbalanced	0.229	10.27	0.32
7	Reactive	Overbalanced	0.263	10.51	0.50
12	Conventional	Balanced	0.320	17.72	1.09
12	Reactive	Balanced	0.390	15.42	1.05

Acidizing Results: Injectivity and Acid to Breakthrough

Type of Shaped Charge	Porosity, fraction	Original Rock Permeability, md	Injection ΔP, psi	Acid to Break through, ml	Acid to Break through, PV
Conventional	0.257	5.29	375	95	0.1851
Reactive	0.256	3.48	351	91	0.1802
Conventional	0.254	2.67	365	87	0.1712
Reactive	0.256	2.89	298	85	0.1706
Conventional	0.259	3.95	224	56	0.4605
Reactive	0.258	2.58	288	63	0.2589



Conclusions

- CT scan images and effluent fluid samples confirmed the presence of debris.
- Reactive charges tested in this project provide perforation tunnels with higher injectivity.
  - Tunnels with larger diameter.
  - Long fractures at the tip of the tunnels.
- Tunnels created with reactive charges help to generate dominant wormholes.

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Complete work can be found in SPE 149453

Path Forward

- Future experiments are planned using larger cores and shaped charges to better simulate field conditions.
- Other Acid / Acid Conditions

15 KPSI Heated Treatment Cell

Acid and Fluid Injection System

SPE-165141

Impact of Charge Type Used in Perforation on the Outcome of Matrix Acid Treatments in Carbonate Formations: A Comparative Study

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5-7 June, 2013

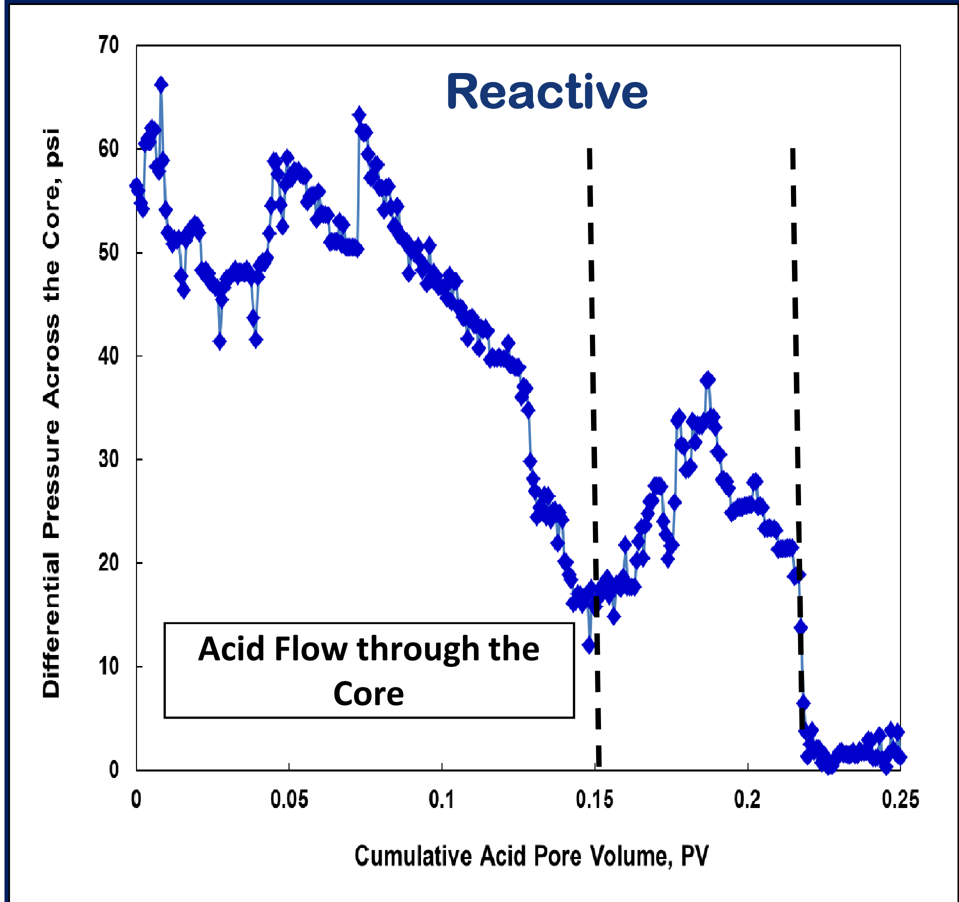
Results & Discussion

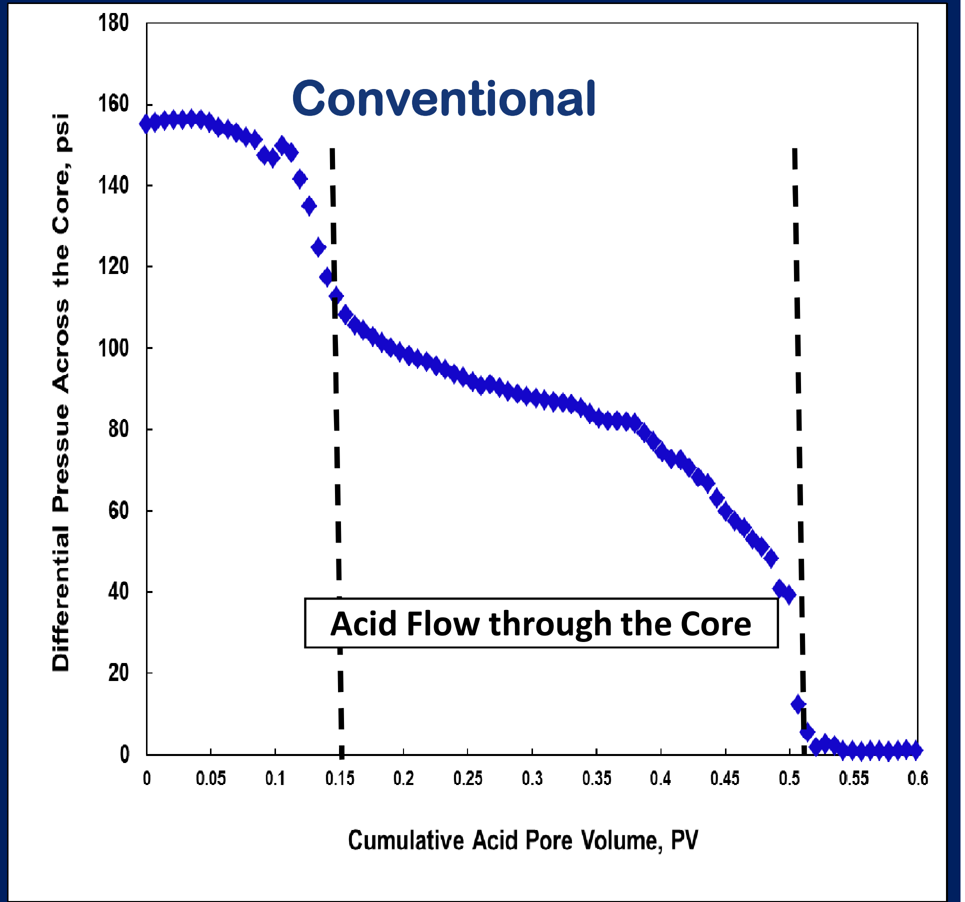
Summary of the Results

Type of Charge	Charge Weight, gm	Length of Perforation Tunnel, in.	Cumulative Acid Pore Volume, PV_{tb}
Reactive	23	17.6	0.07
Conventional	23	17.1	0.37

Results & Discussion

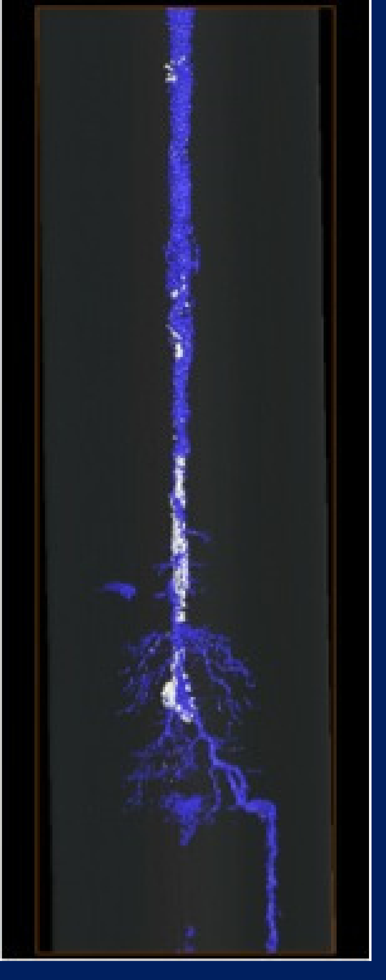
Group #2: Deep-Penetration-23 gm Load



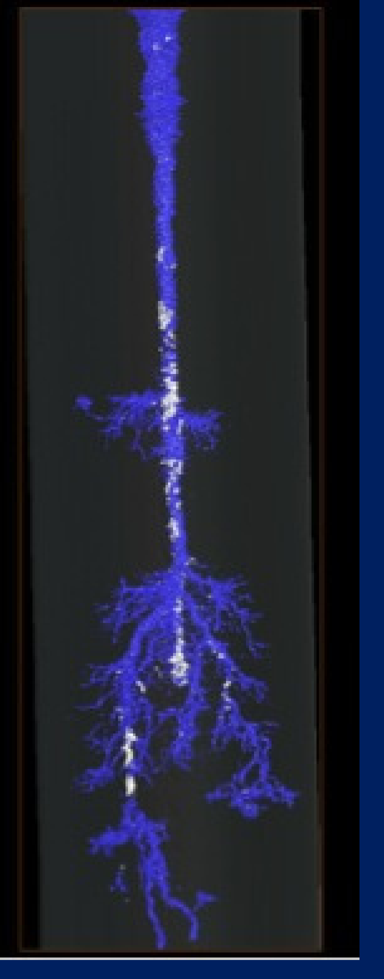


Acidized 23g Tunnels

Reactive



Conventional



New Conclusions

- Perforation of carbonate formations with properly designed reactive liner shaped charges rather than conventional shaped charges should result in more effective matrix acid stimulation as dominant wormholes will be created from the tip of each perforation tunnel, resulting in greater effective wellbore radius for a given volume of acid stimulation.

References

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- **Williams, Bert B., Gidley, John L., and Schechter, Robert S**., "Acidizing Fundamentals ", Jun 1979.
- **Economides, Michael J., Hill, Daniel A., and Economides, Christine E**., "Petroleum Production Systems", December 1993.

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