GEODynamics®

Engineered Perforating Solutions

IPS 14-14-11
More than just Penetration: Perforation Design for Naturally Completed and Stimulated Wells

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More than Just Penetration: Perforating for Better Wells

Discussion Topics

- Introduction – A little bit about GEODynamics
- Perforation Performance Evaluation – Tools for Development
- Perforation Design for Natural Completion
  - New Wells
  - Re-perforation
  - Injection
- Perforation Design for Sand Control
  - Area Open to Flow: Gravel Pack Application
  - Overbalanced Sand Control: Systems for Stable Tunnels
- Perforation Design for Fracture
  - Tunnels that take Acid
  - Improvements in Well Decline

API RP19B Section I Test: Unstressed Concrete

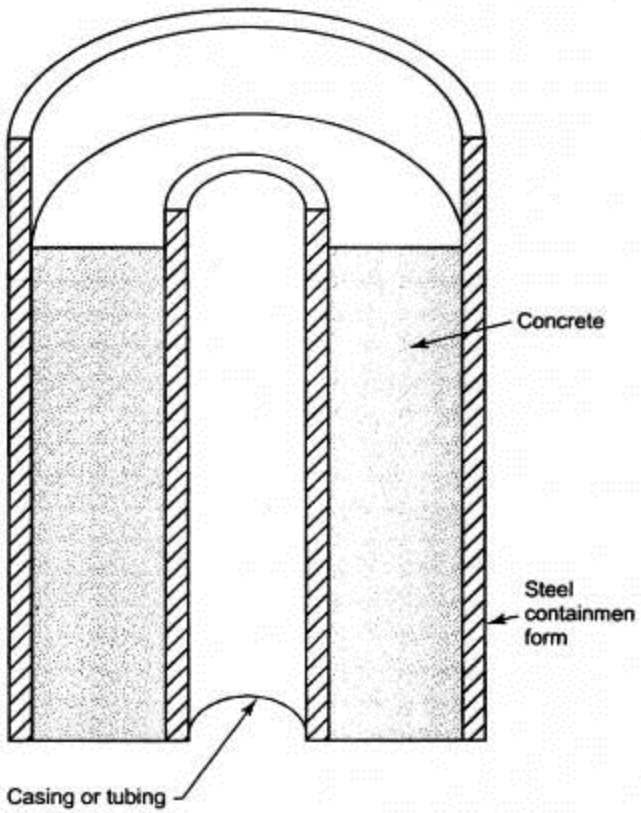


Figure 1—Example Concrete Target

- The API Section I Test is conducted by firing a representative gun section from the center of a poured cement target.
- This test can be registered with the API
- The targets and charges are aged 28 days prior to performing the test for registered data.

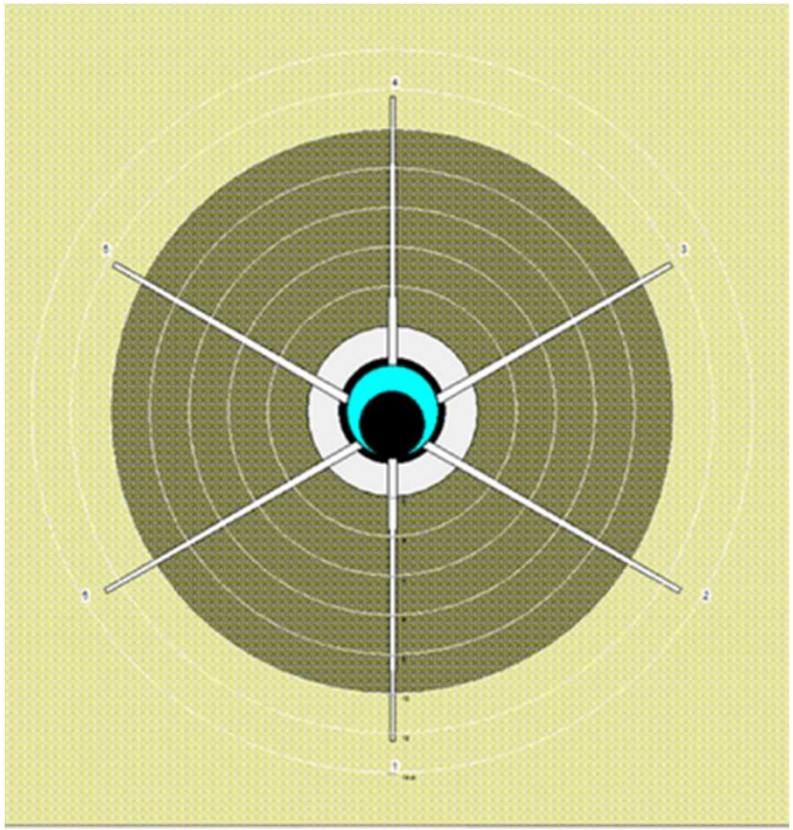
API Section I Test

- The target must meet minimum specifications of construction, composition, and compressive strength.
- After the shot, the targets are split, and data collected on:
  - Hole Size
  - Penetration Depth
  - Debris
  - Burr Height of Casing

New Industry Tools for New Products

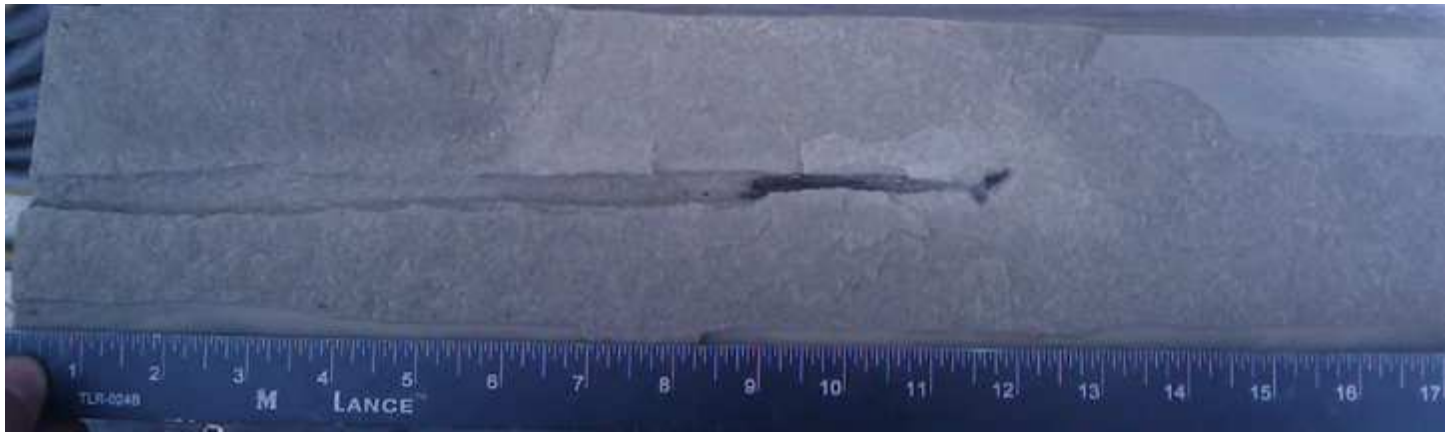
- API RP 19B Section 1: Evaluated
  - Does not correlate to downhole performance
  - QC may not correlate for every charge either!
- API RP 19B Section 4: Released
  - Highlights sources of Experimental Error
  - Adds new ways to analyze results
  - Enables more uniform testing between companies
- API RP 19B Section 2: Under Revision
  - Wide Involvement by Service and Product Providers
  - Draft Standard: New Performance Metric
  - New Registered and Witnessed Test
  - Still Concentrating on Penetration Only – No Analysis
  - Currently Evaluating Equipment and Processes

Perforation and Well Geometry

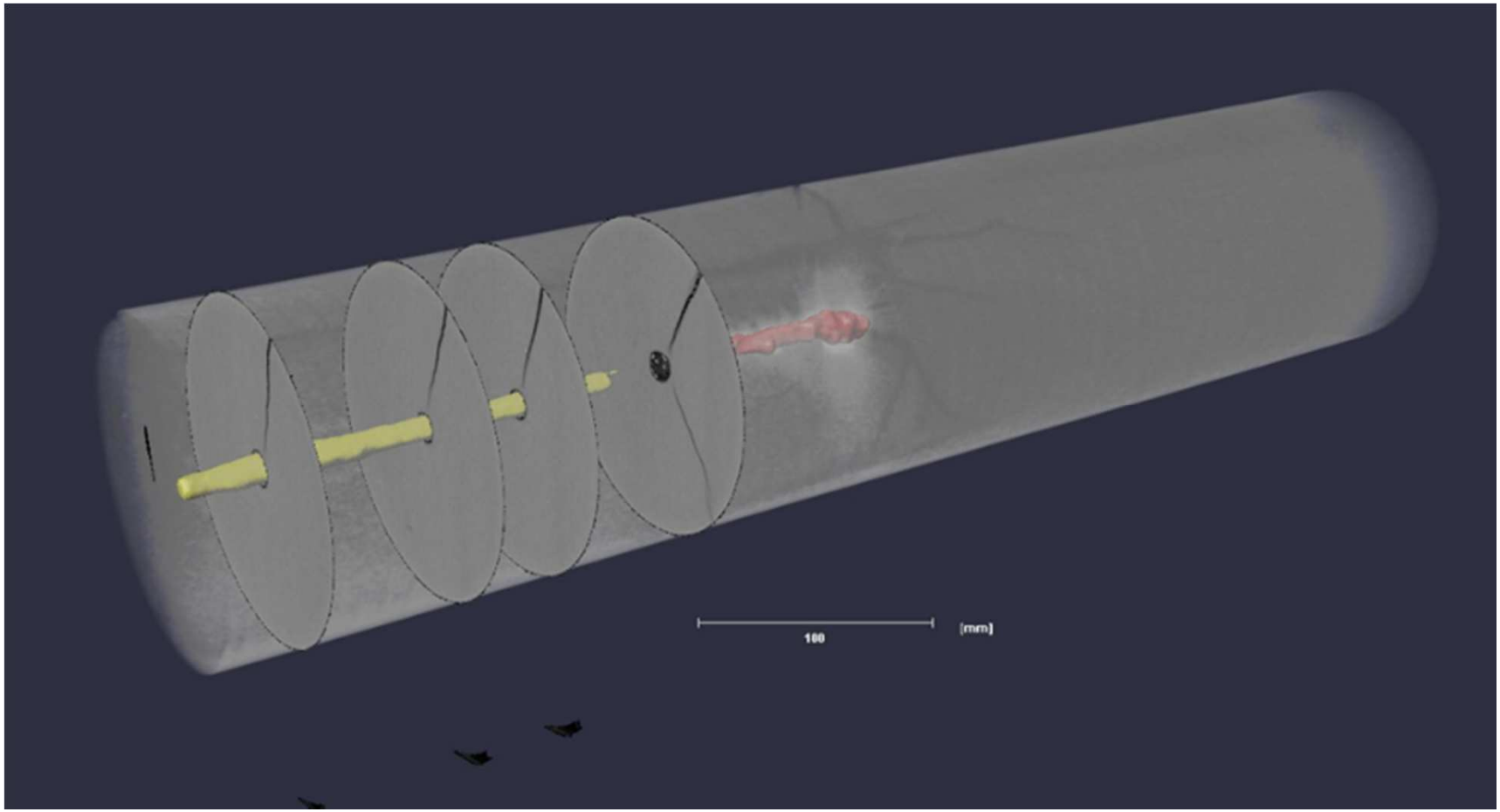


- Perforations Near WB
- Interaction of perforation geometry with near wellbore geometry
- Improved perforation may not improve some wells
  - (too much or too little damage)
- Critical for others

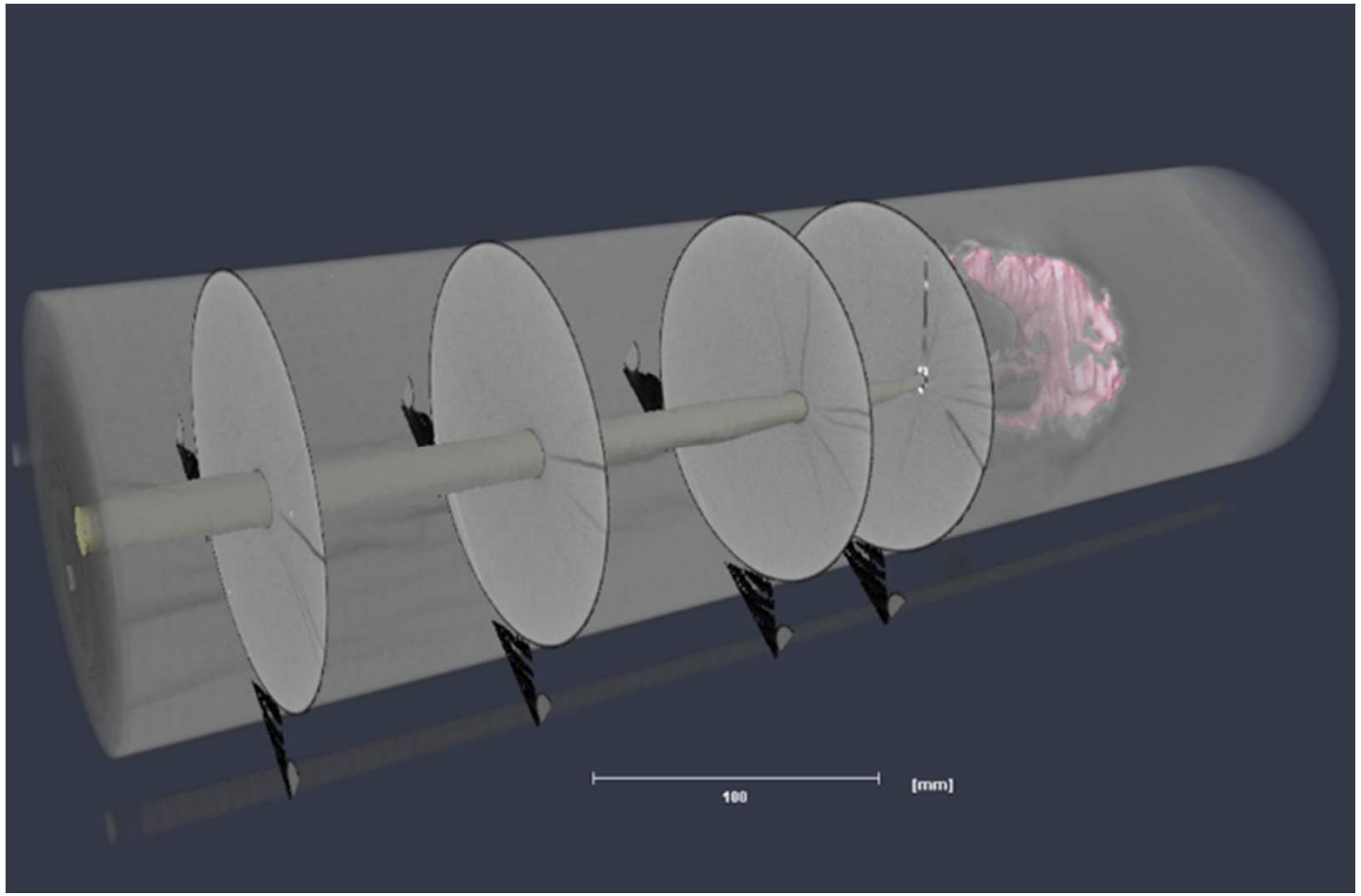
Perforation Geometry Design Variation



Permeability Map, Conventional Tunnel



Permeability Map, Improved Tunnel



Perforation Design for Natural Completions

- New Design Considerations!
  - Dual String – Plugging in second string
  - Gun plugging which alters dynamic surge
  - Real World Formation: Plugging in the hard layers
  - Injection Wells: Design for injection damage
- Other Lithology
  - Weak sandstone: Can we reduce the need for sand control with shaped charge systems?
  - Carbonate: Shorter tunnels. Narrower Tunnels. More Opportunity for plugging.
  - Shale: In some cases much shorter than expected. Open tunnel a primary function of charge design, and not of perforating balance.

Field Applications • Re-Perforation

- Generally a tough task for perforators
  - Effective stress increases as reservoir pressure drops
  - Hard to apply underbalance with open perforations etc.
  - Depleted reservoirs have no pressure for DUB techniques.
- Success = increased productivity
- Examples:
  - UK • 30x productivity after re-perforation (best in field)
  - USA • 10x productivity … more than 2x the increase seen re-perforating offset wells with conventional systems
  - USA • 10x increase in gas well production after re-perforation … already shot twice with premium DP system

Perforation Design for Sand Control

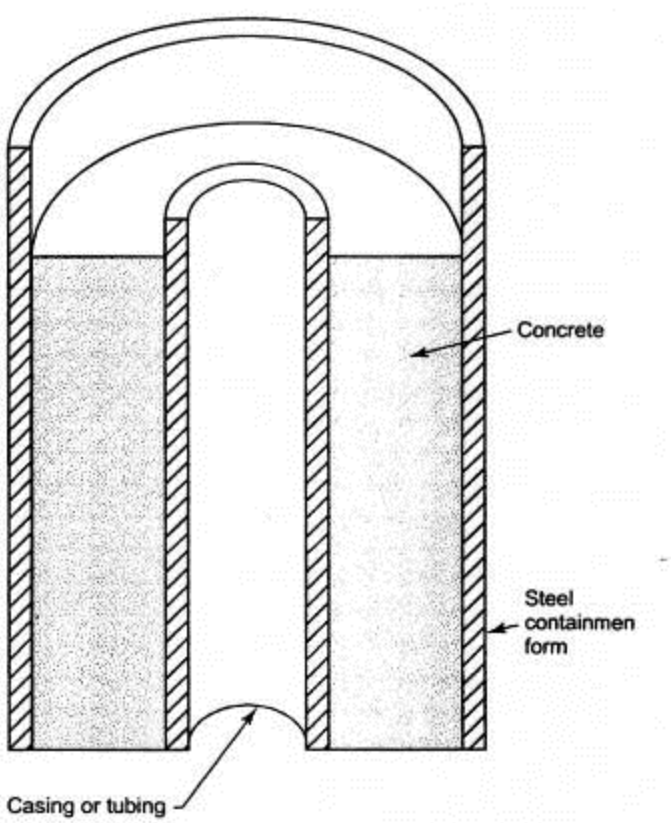
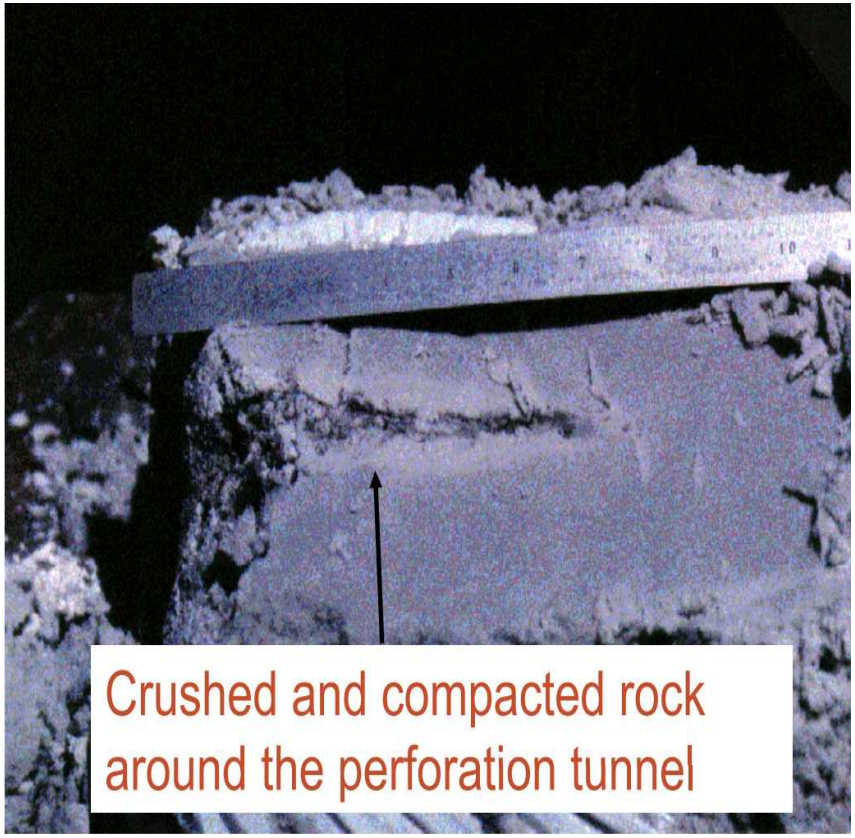


Figure 1—Example Concrete Target

- API RP 19B Section 1 Test
- Maximize Area Open to Flow (Square Inches/Foot) in Standard Casing Only
- Standard Casing is L-80 Grade, and thinner than most modern applications
- Extrapolation is used by software to predict down hole performance.
- This translation is charge design dependent.

API RP19B Section 1 Test

Perforation Geometry for "Big Hole" Sand Control Charges



- Affected area much larger in diameter than hole size
- Crushed sand can form an effective injection plug
- In lab, plug can be broken down, fluidized without fracture

Perforator Performance: Gravel Pack

- Translation to Heavy Wall Casing is Design Dependent
  - In one instance heavy wall performance exceeds that in thin wall casing
- Design For Heavy Wall Casing
  - Publish performance in both standard casing and heavy wall casing
  - Two data point design allows for better prediction
  - Superior charges translate across all applications

Next Generation SBH Performance:

Dominant in Standard Casing

API RP 19B Section 1 Registered & Witnessed Standard Test				
Gun Size	**Casing Info**	**Entry Hole**	**Penetration**	**Area Open To Flow**
4-5/8" 16 SPF	7" 32# L-80	0.90	5.5	10.18
5-1/8" 16 SPF	7-5/8" 33.7# L80	1.07	6.7	14.39
7" 15 SPF	9-5/8" 47.0# L80	1.39	6.5	22.76

Next Generation SBH Performance:

Unmatched in Heavy Casing

API RP 19B Section 1 Registered & Witnessed Special Test				
Gun Size	**Casing Info**	**Entry Hole**	**Penetration**	**Area Open To Flow**
4-5/8" 16 SPF	7-3/4" 46.1# C-110	0.96	5.4	11.58
5-1/8" 16 SPF	7-5/8" 47.1# Q-125	1.04	6.7	13.59
7" 15 SPF	10-1/8" 79.75# SM-125S	1.12	6.6	14.78

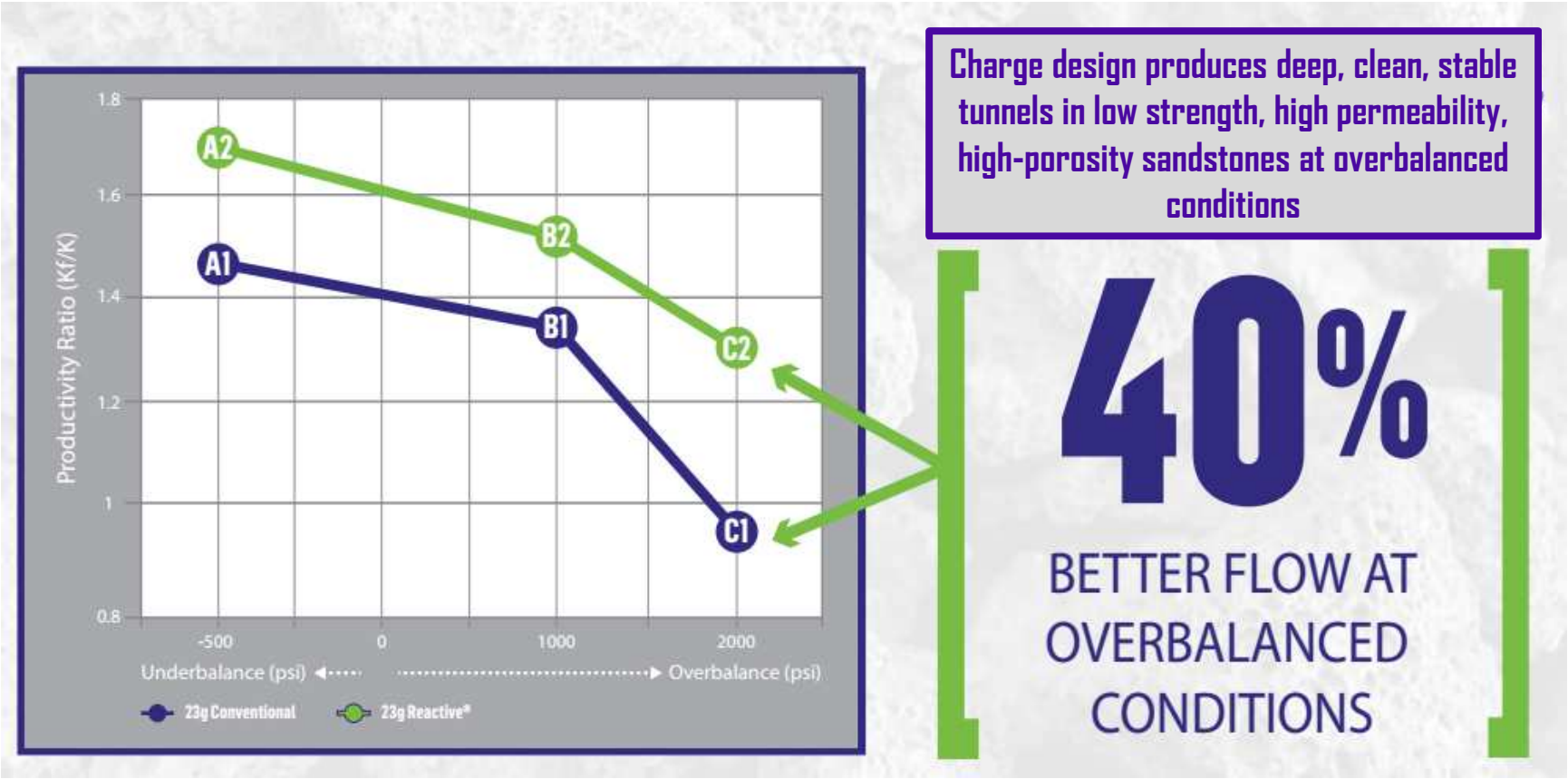
Benefits

- Exceptional Area Open to Flow
- New Standard for Performance
- 2 Point Published Performance for Accurate Estimation of Hole Size in Casing
- Reliable, More Effective Stimulation
  - Reduced Pressure at Sand Face
  - Maximized Area Open to Flow for Gravel Pack

Opportunities

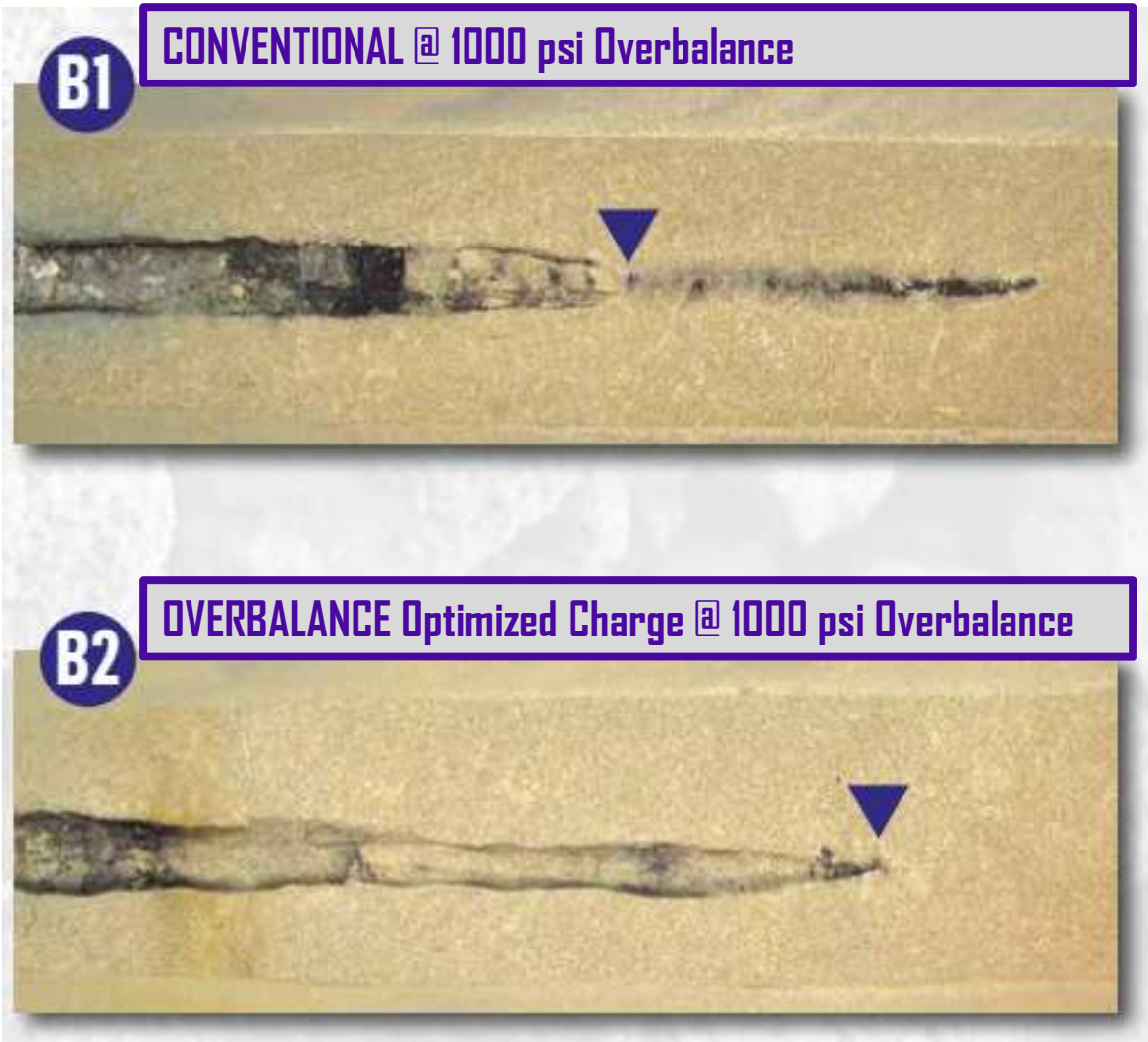
- GOM Platforms
- Drop-in Substitute for Conventional Charge
  - Deploys in identical hardware
  - No change in handling or running procedures
  - No change in HSE risk

Stable Clean Tunnels at 2000 psi OB

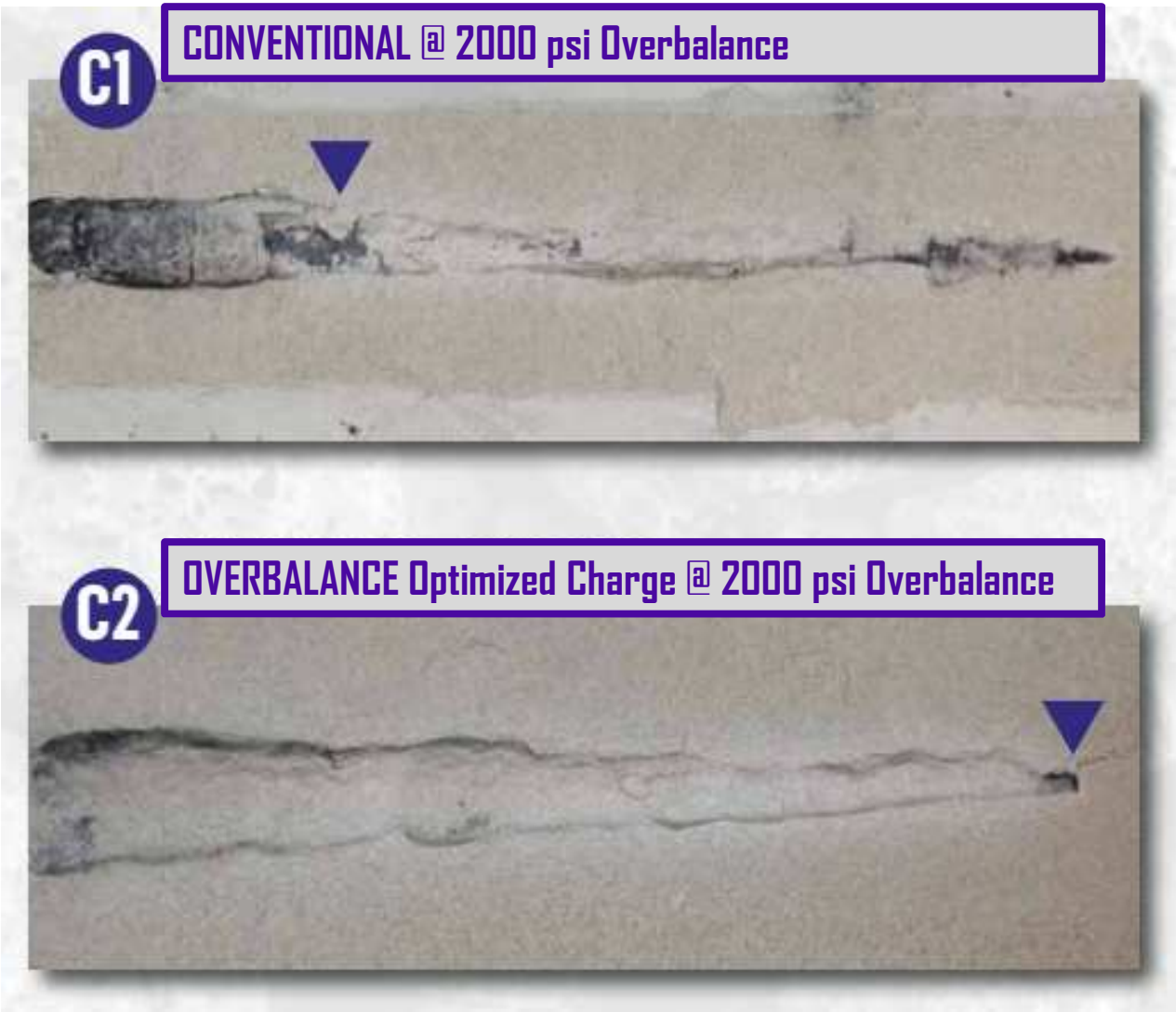


500 PSI Underbalance Condition

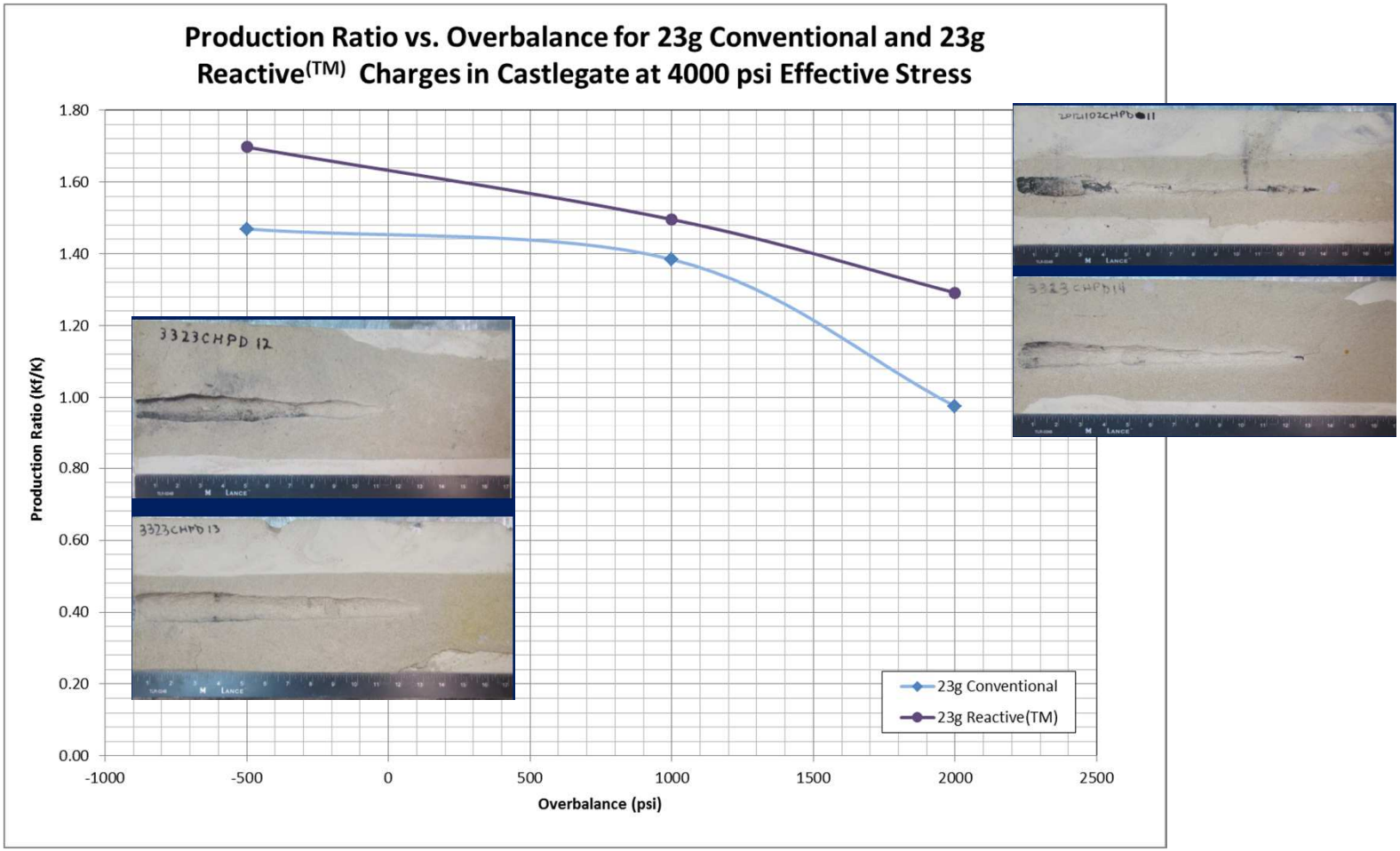
1000 PSI Overbalance Condition



2000 PSI Overbalance Condition



Clear Tunnel at Overbalance: Flow



Performance

- Innovative Systems deliver good AOF
- Stable Tunnels at Overbalance Condition
- Flow Performance is 6% to 59% superior to the conventional charge at every balance condition.
- Optimized Overbalance Charge provided a PR of 0.92 at overbalance condition.
- Conventional charge produced deeper tunnels, however reactive design produces cleaner perforations, with better side wall condition.

Shaped Charge Systems for Fracture

- Many complex considerations!
- Acidizing plays a crucial role in many completions
- Improved Hole Size Distribution
- Interaction of the fracture with the near wellbore region – In some wells fractured tips and open tunnels improve near wellbore region

- Current Systems may not demonstrate a repeatable downhole performance
  - Therefore completion, stimulation, and fracture treatment design evolves to compensate

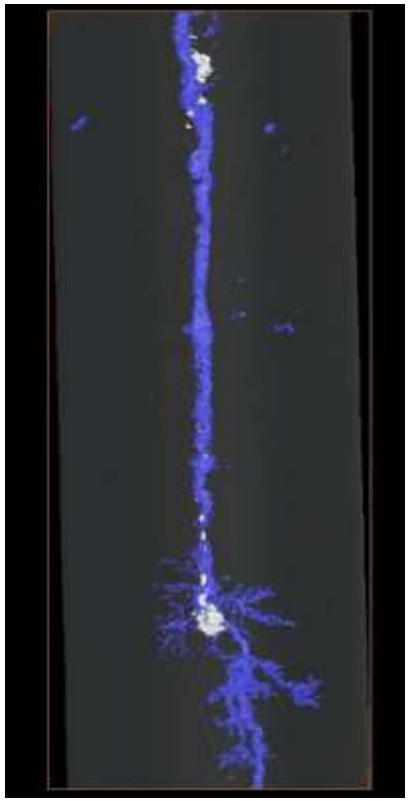
Matrix Acidizing:
Conventional Good Hole Geometry

Before Acidizing

After Acidizing

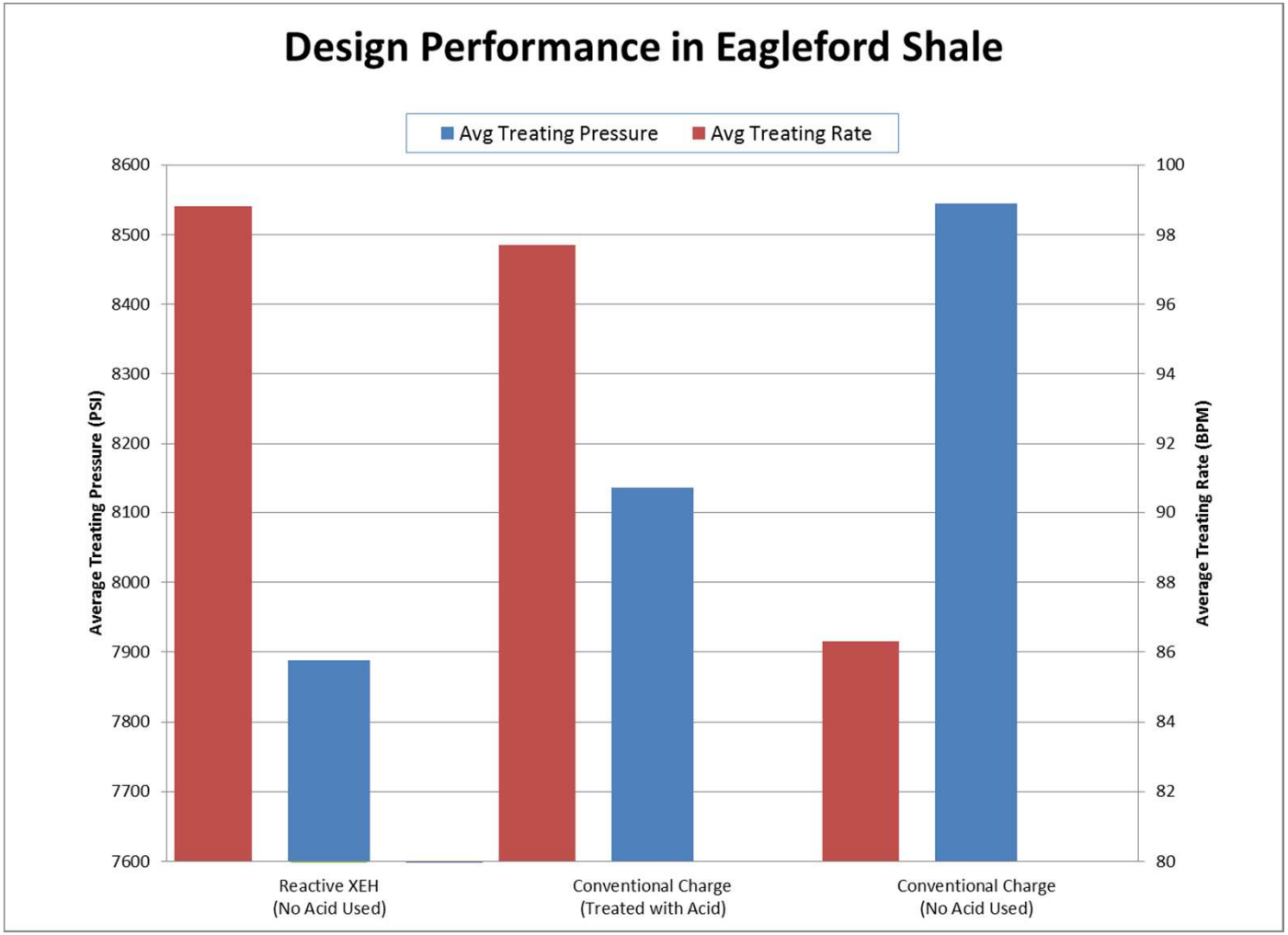
Tunnels Designed to Take Acid:
Needs 1/6 of Acid to break through

Conventional

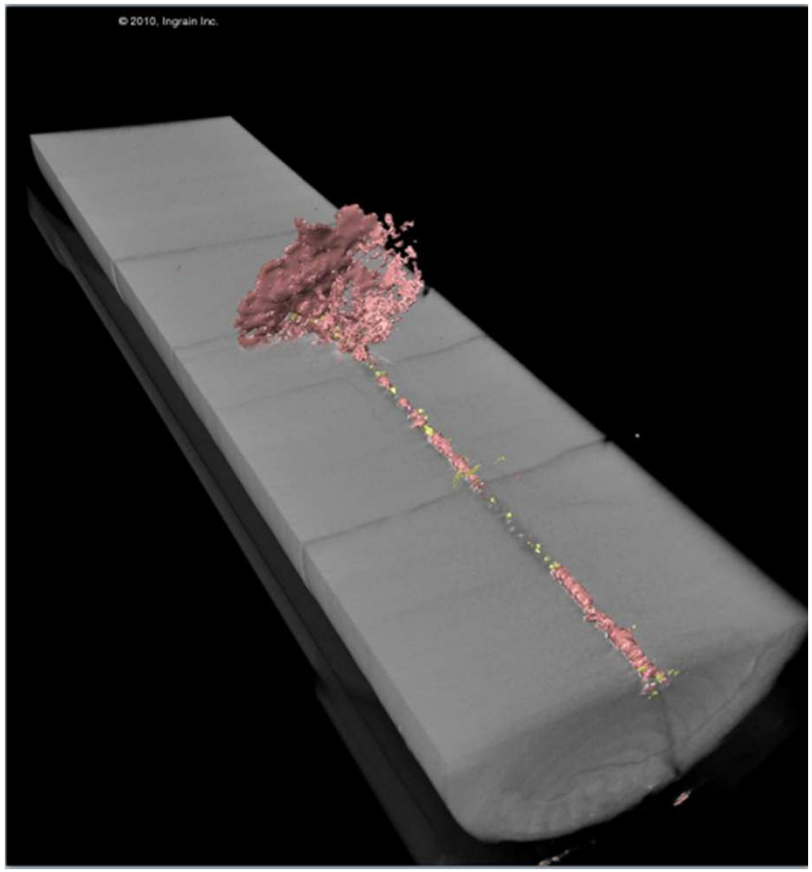


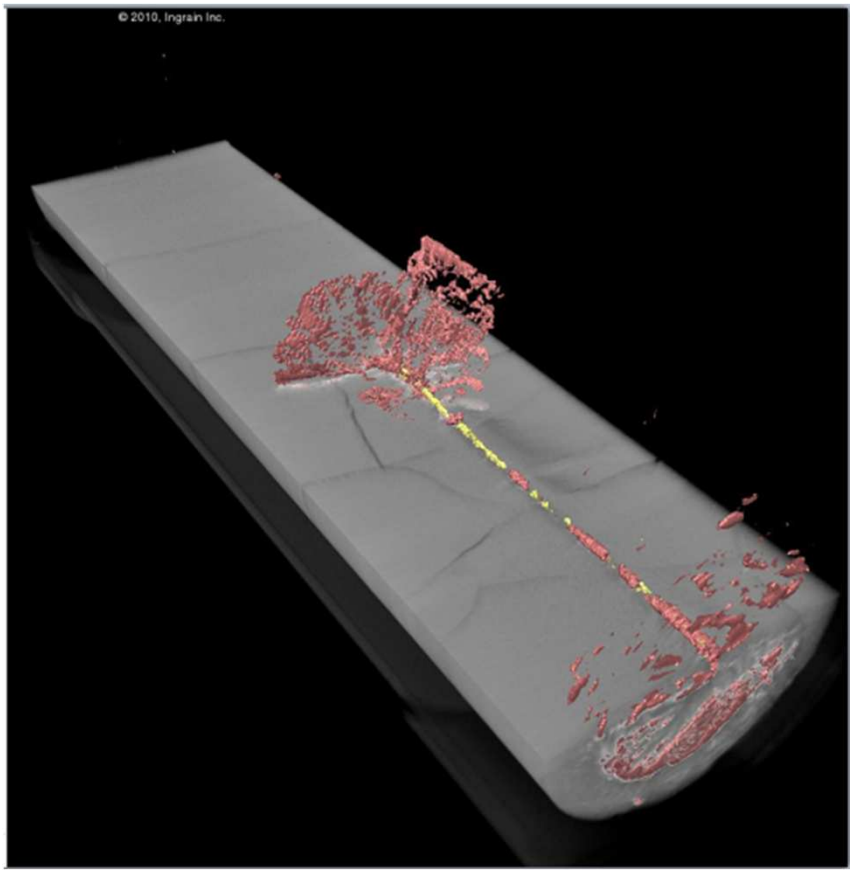
Fracture Charge

Field Result: Acid Elimination

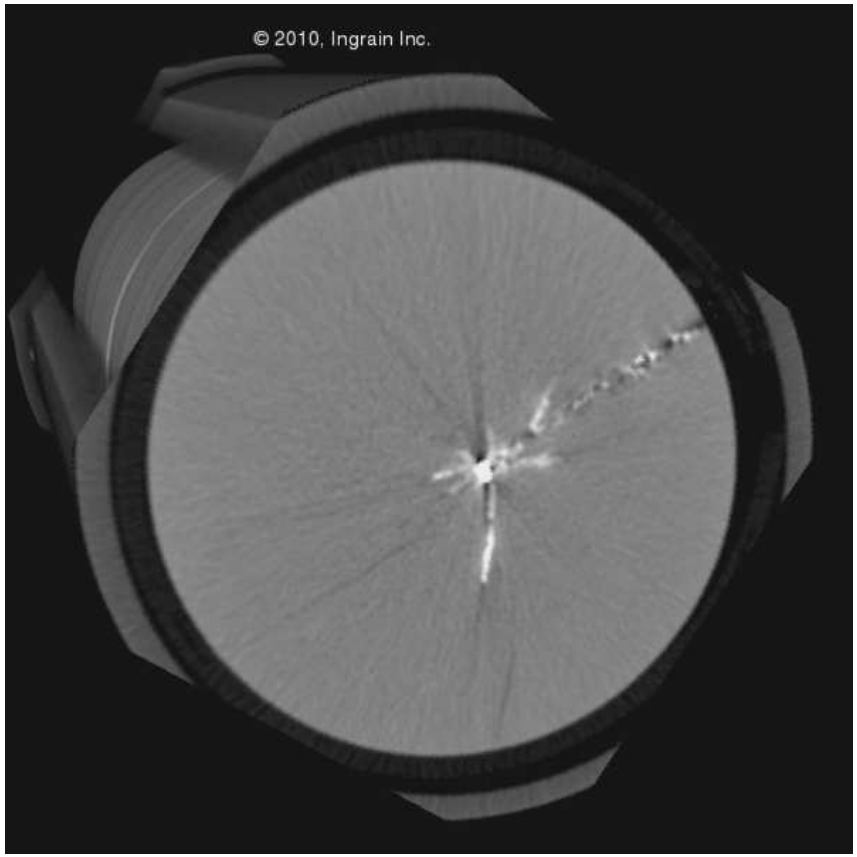


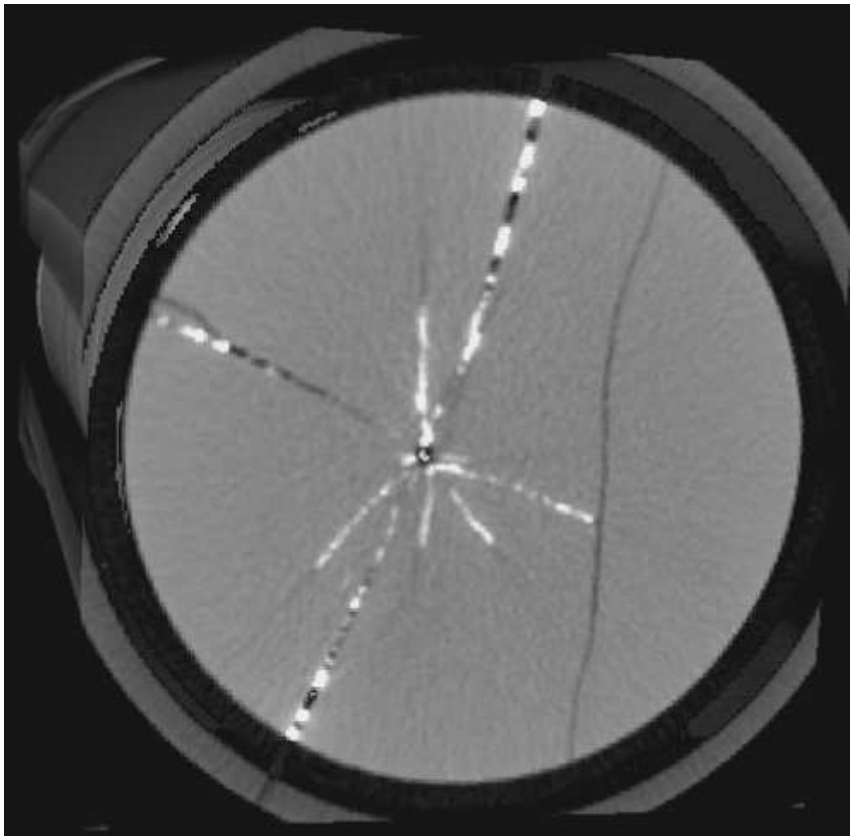
CT Scans, Mancos Shale, Frac Charges





CT Scans, Mancos Shale, Frac Charges





Field Results – Breakdown Pressure Red

Field Results – Treating Pressure Reduction

Field Results – Productivity Improvements

Field Results: 10 Well Pairs

- 10 Well Pairs – Frac Charge vs. Conventional
- Treating Pressures show no correlation
- 7 of 10 pairs showed higher MCFD/Stage with Frac optimized charges
- 7 of 10 pairs show higher total MCFD with Frac optimized charges

Field Result: Decline Curve Improvement

Thank you!

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