A New Concept For Perforating That Integrates Propellant and Shaped Charges

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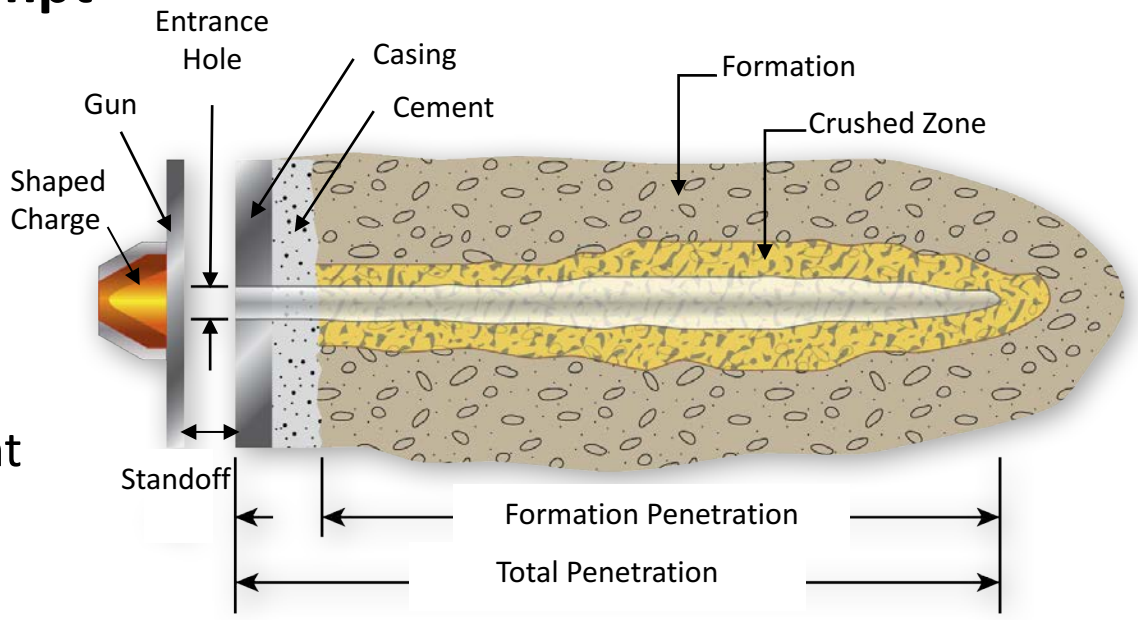
Perforating – The Problem Compaction and Reduced Permeability

The industry has been working to solve tunnel compaction and improve perforation permeability for decades.

Several Solutions have been developed to attempt to solve the problem. These include:

- Underbalanced Perforating
- Overbalanced Perforating
- Dynamic Underbalanced Perforating
- Solid Propellant (**sticks** of propellant post-perforating)
- Composite Perforating (combination of solid propellant and perforating)
  - Over Gun Body Solid Propellant **Sleeves**
  - Internal Gun Body Solid Propellant **Discs**



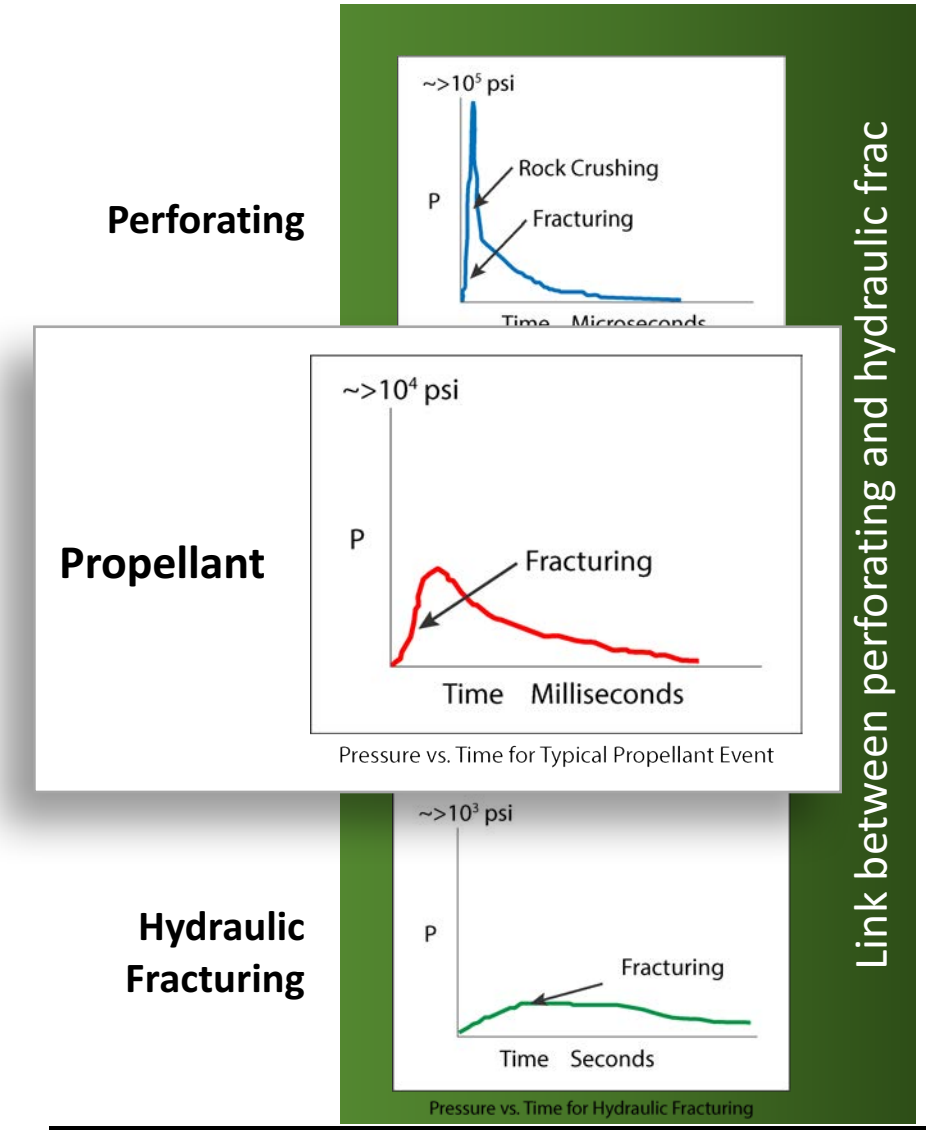
These solutions were designed primarily for vertical wells, not for horizontal plug and perforating.

Perforating – Solid Propellant Works

Solid propellant has proven to be an effective method to break-up tunnel compaction and improve reservoir permeability.

Pressure build up is the key:

- Perforating with high energy explosives releases energy very quickly (microseconds) crushing the formation
- Solid propellant releases energy 1,000 times slower (milliseconds), the pressure pulse fractures compacted zone and formation
- Hydraulic fracturing releases energy over seconds / minutes creating fractures in the formation



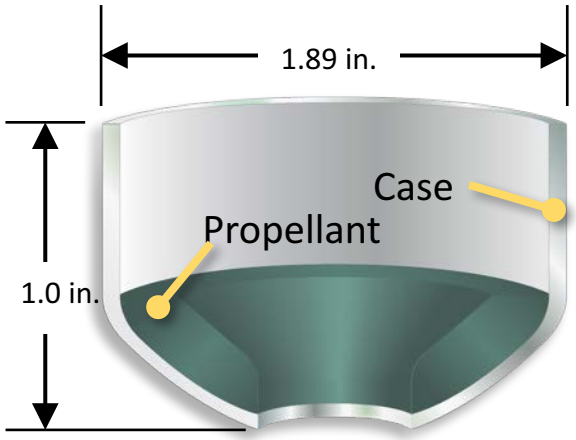
Perforating – Horizontal is the New Normal

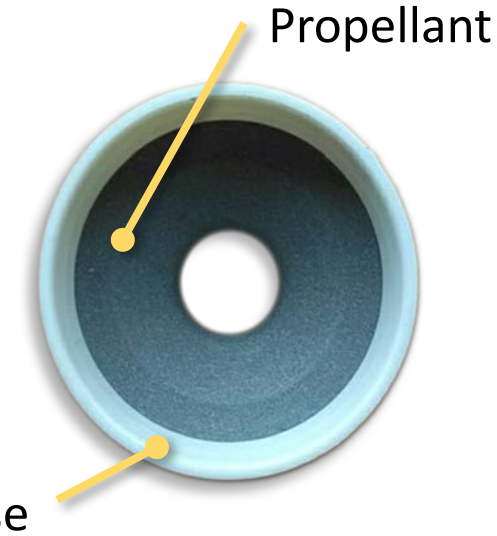
Why do we need a new solution for Unconventional Horizontal Completions? The list is long.

A new product was needed to allow solid propellant to deploy to the perforation tunnel before deflagration; therefore, delivering maximum energy to remove compaction and improve reservoir permeability.

Perforating – Composite Charge is the Key

A composite solid propellant cap for the perforating shaped charge is the key to deflagration in the perforation tunnel.





The Composite perforating charge consists of...

Composite Charge

Loaded Charge Holder Tube

Perforating – Composite Charge is the Key

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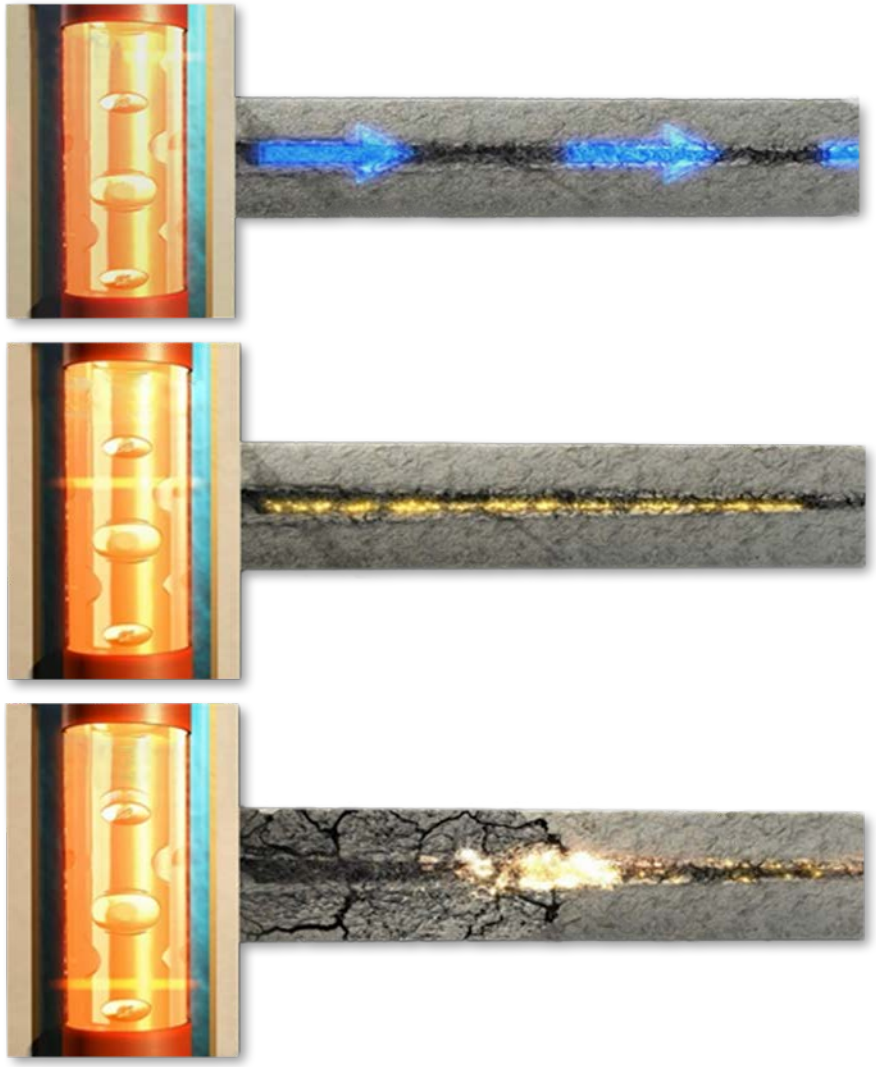


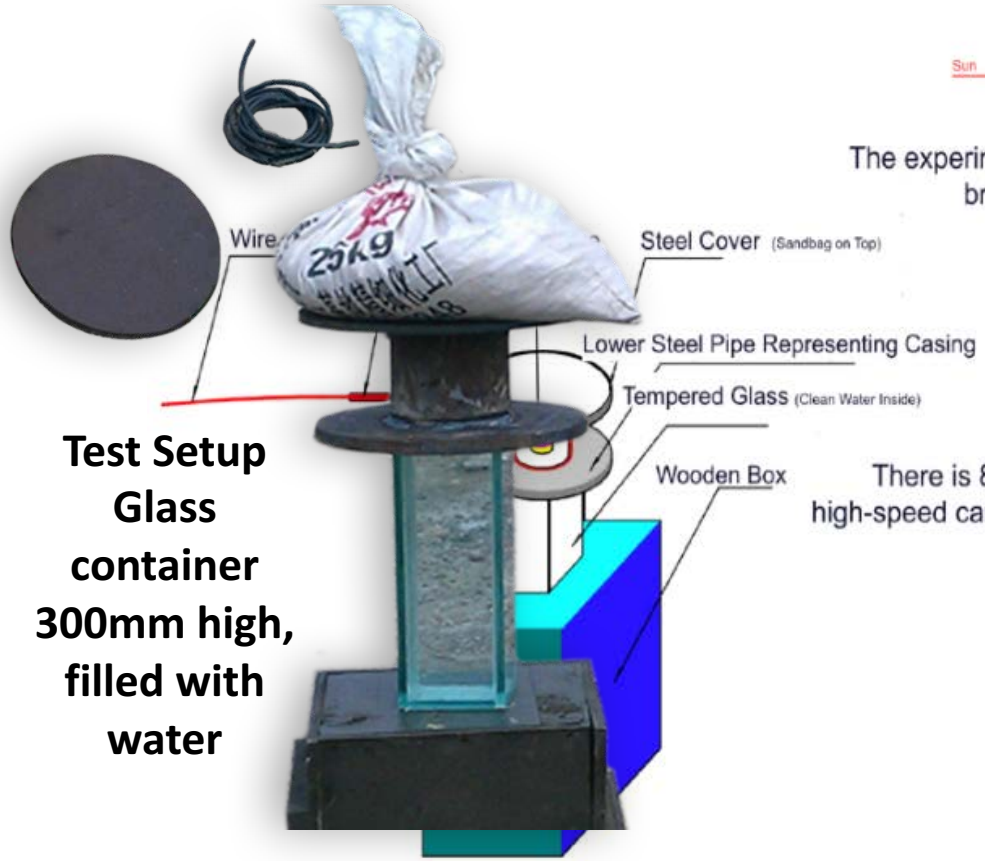
- The shaped charge detonates and initiates the perforation.
- As the perforation jet is formed, super high pressure (more than 145,000 psi) is produced within the gun body.
- Under this super high pressure, propellant won't explode.
- As the jet is formed, pressure in the perforation tunnel is low compared to pressure inside the gun body.
- The propellant material in the case on the shaped charge face is pushed into the perforation tunnel following the jet.
- The propellant deflagrates within the formation as the jet energy extends the tunnel.
- The deflagration of the propellant releases energy directly to the formation, generating multiple fractures and breaking through the tunnel compacted zone.

Perforating – Propellant Deflagrates in Perforation Tunnel

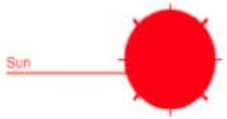
A key objective for the composite charge was the deflagration of the propellant inside the perforation tunnel. To prove this concept a test was setup with a high speed camera to capture the deflagration process.

Water Filled Glass Container

Composite Charge in Gun/Casing Test Jig

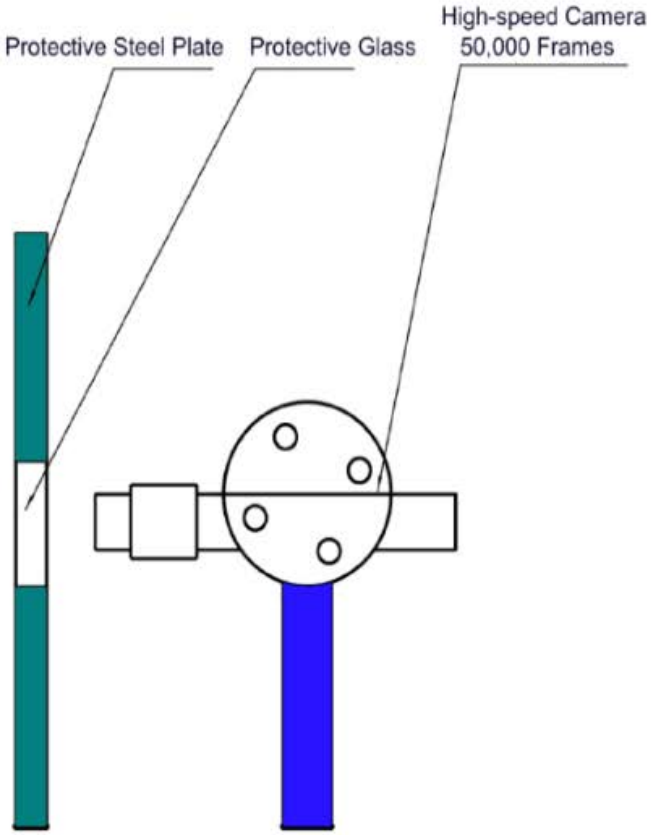


Test Setup Glass container 300mm high, filled with water



The experiment was conducted on a bright, sunny day.

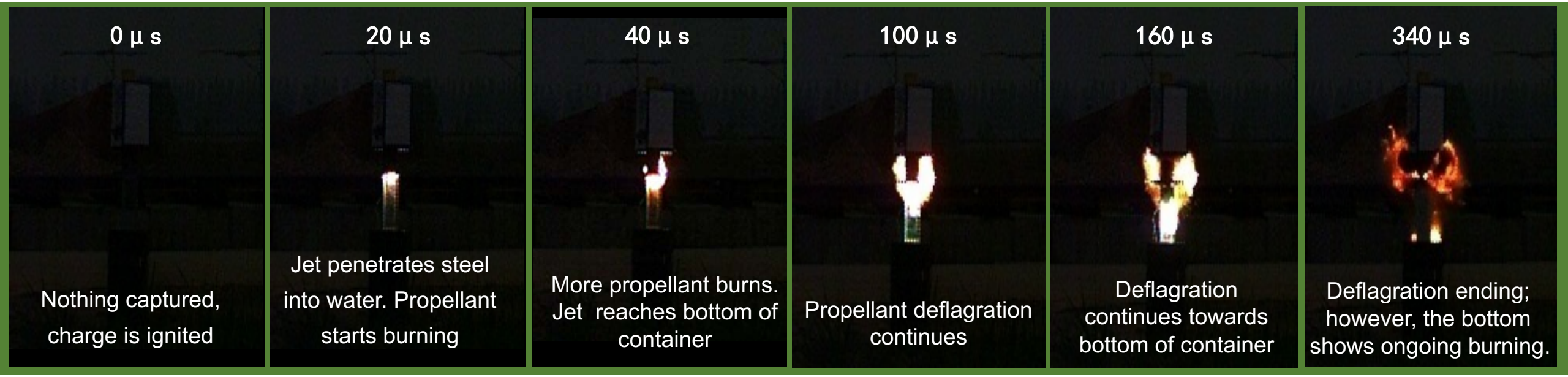
There is 8 meters between the high-speed camera and the ReCo Charge



Perforating – Propellant Deflagrates in Perforation Tunnel

A high speed camera (50,000 frames per second) was used to capture the deflagration process in a test jig.

Captured by High Speed Camera



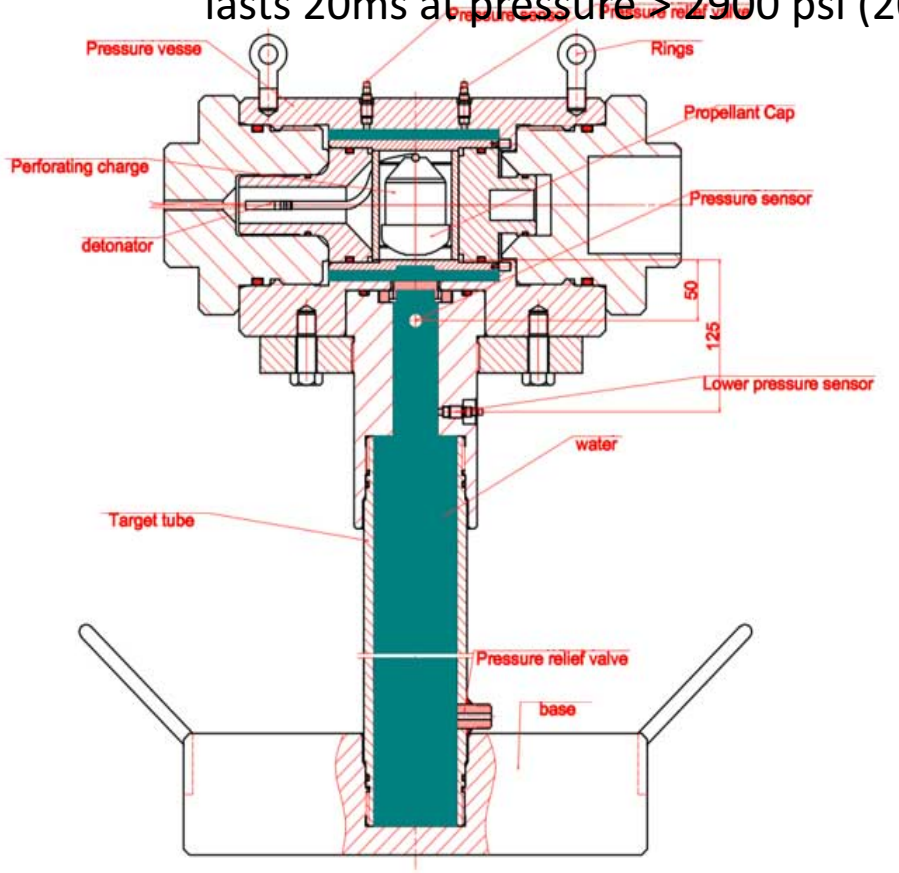
Observations

- High-speed camera captured images of perforation and propellant deflagration in 3 milliseconds real time.
- High-speed photos indicate the propellant deflagrated inside target and within tunnel.

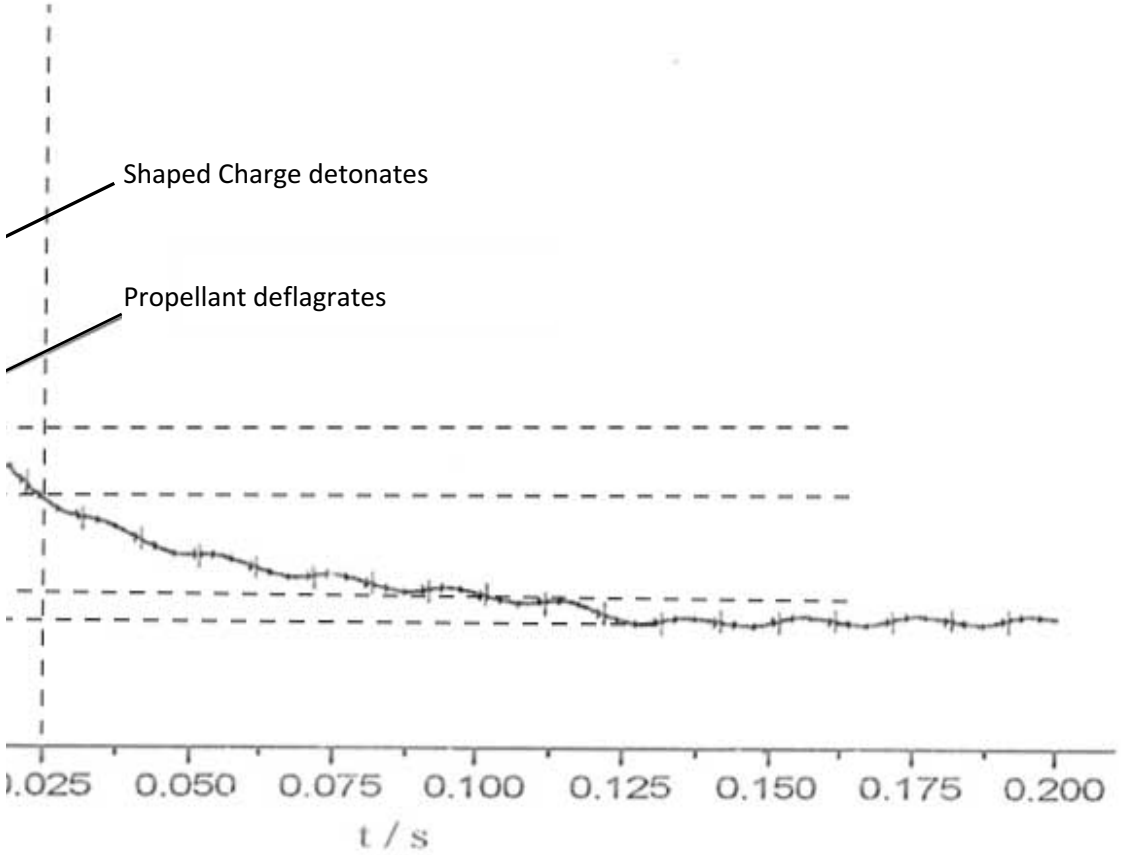
Perforating – Perforation Tunnel Pressure Test

A test chamber was setup to measure the perforation tunnel pressures during the perforating event. The pressure parameters were observed on the p-t curve for the Composite Charge.

After a shockwave pressure formed by shaped charge main explosive, the secondary pressure peak produced by propellant deflagration is 5500 psi (38 Mpa); the propellant pressure peak lasts 20ms at pressure > 2900 psi (20 Mpa).

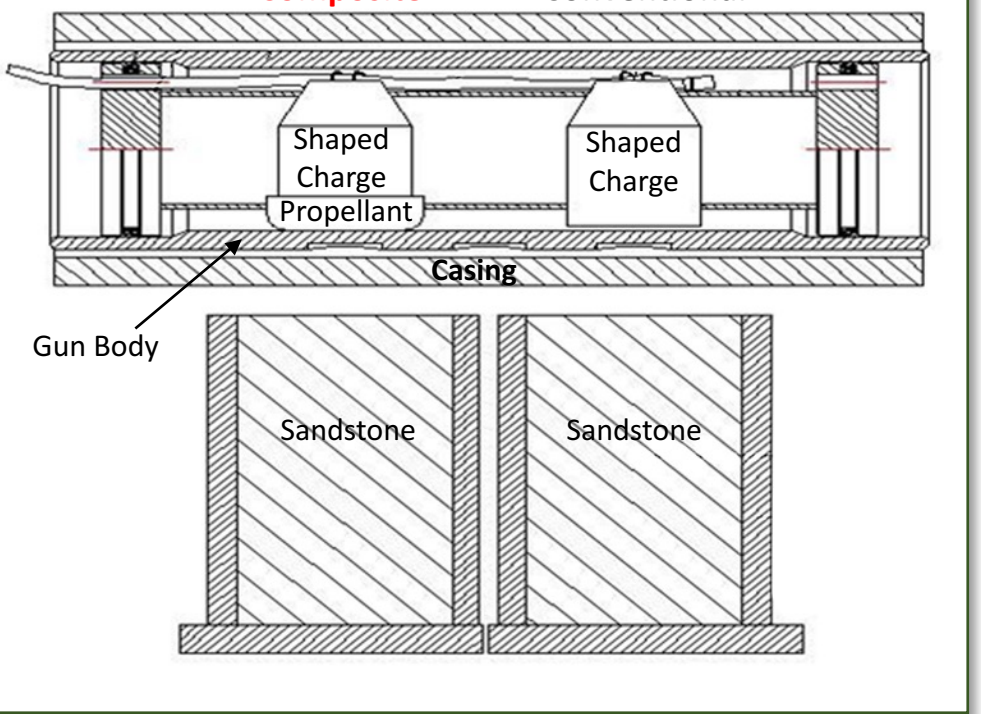


Pressure Test Chamber



Perforating – Surface Testing of Composite Charge

A test was conducted to compare a conventional shaped charge and the composite charge in different material targets.



Design of experimental device

- **Experiment objective**: Compare perforation hole size and target fracturing for composite charge and conventional perforator in a simulated, confined (stressed) space in steel and sandstone targets
- Shaped charge same for both tests
- Environmental Conditions: Room temperature, standard atmospheric pressure

Sandstone Targets

Perforating – Surface Testing of Composite Charge

Test results show composite charge enlarged the perforation tunnel and fractured the sandstone target.

Conventional Shaped Charge

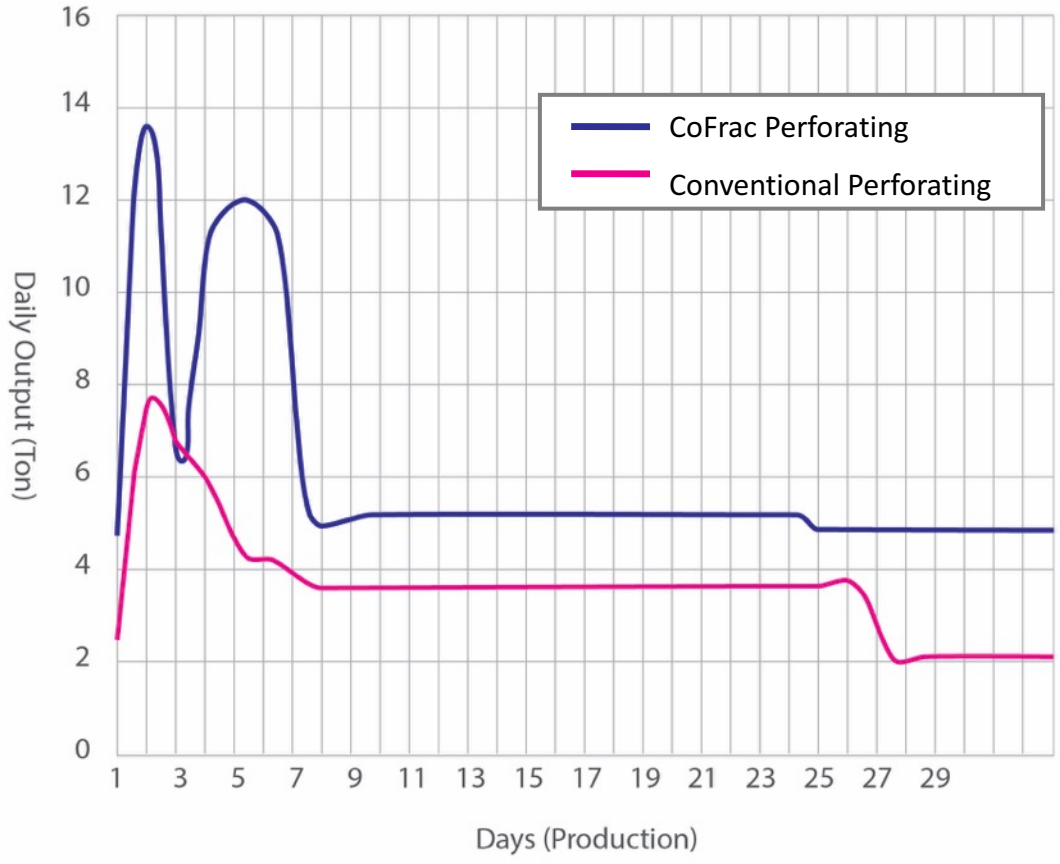
Aluminum molds of perforations

Conventional ***CoFrac***

Composite Perforating System

Perforating – Proven Field Results

The new composite perforating system has been deployed in over 5,000 wells in China. These Chinese reservoirs have very low natural permeability, similar to USA unconventional reservoirs.



7 New Wells Performance Evaluation

4 wells – Composite Perforating System

3 wells – Conventional Perforating

**** Fracturing equipment and procedures same for both groups.***

Results:

Composite perforation system had higher initial production. Avg. 65.7 bbls/day for first 7 days. Conventional 35 bbls/day avg. over 7 days.

Composite 30.7bbls/day higher, 88% increase

Composite perforating system had slower decline rate. Day 8 to 25 avg. 36.4 bbls/day. Conventional only 25.7 bbls/day.

Composite 10.7 bbls/day higher, 42% increase

After day 25, avg. Composite 35/day; Conventional 15 bbls/day.

Composite 20 bbls/day higher, 133% increase

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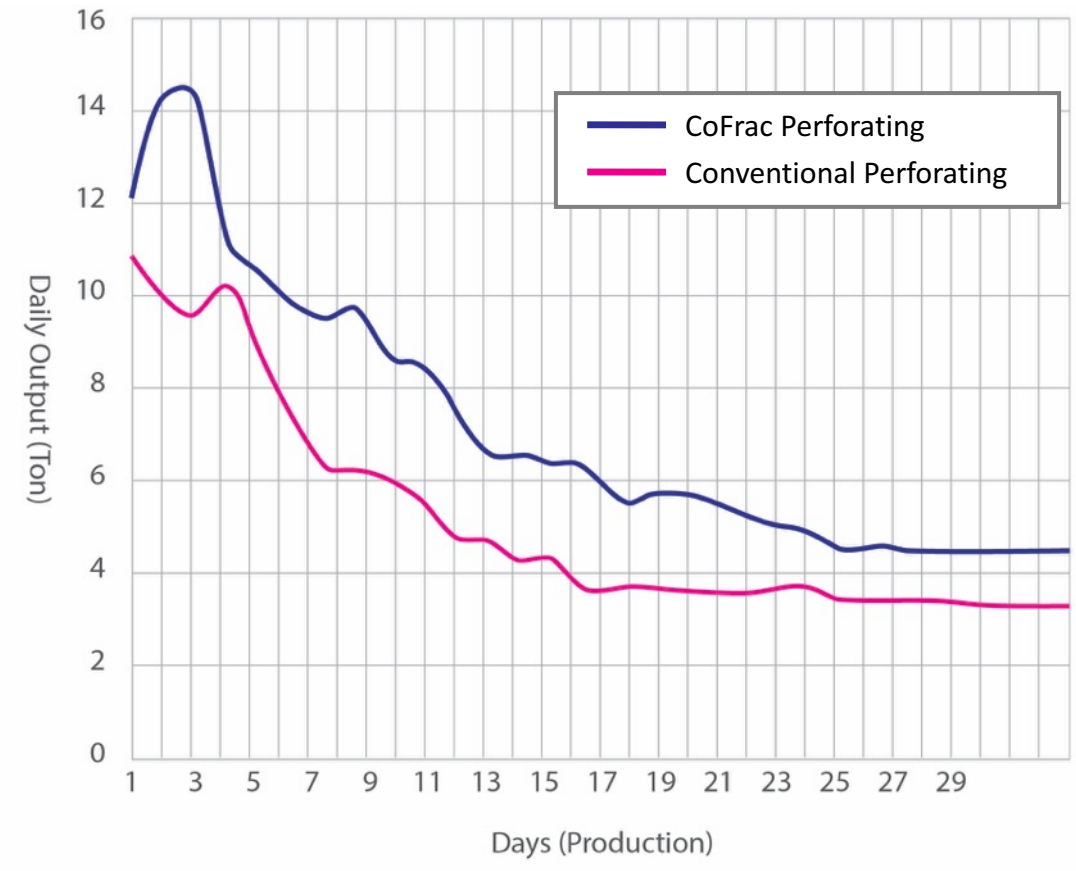


12 Well Refrac Performance Evaluation:

7 wells – Composite Perforating System

5 wells - Conventional Perforating

**** Fracturing equipment and procedures same for both groups.***

Results:

Composite perforating system had higher initial production. Avg. 23 bbls/day for first 7 days. Conventional avg. 16.8 bbls/day over 7 days.

Composite 6.2 bbls/day higher, 37% increase

Composite perforating system had slower decline rate. Day 8 to 25 avg. 9.6 bbls/day. Conventional 7.5 bbls/day.

Composite 2.1 bbls/day higher, 28% increase

After day 25, avg. Composite 8.9 bbls/day, Conventional 6.1 bbls/day.

Composite 2.8 bbls/day higher, > 46% increase

Perforating – Proven Field Results

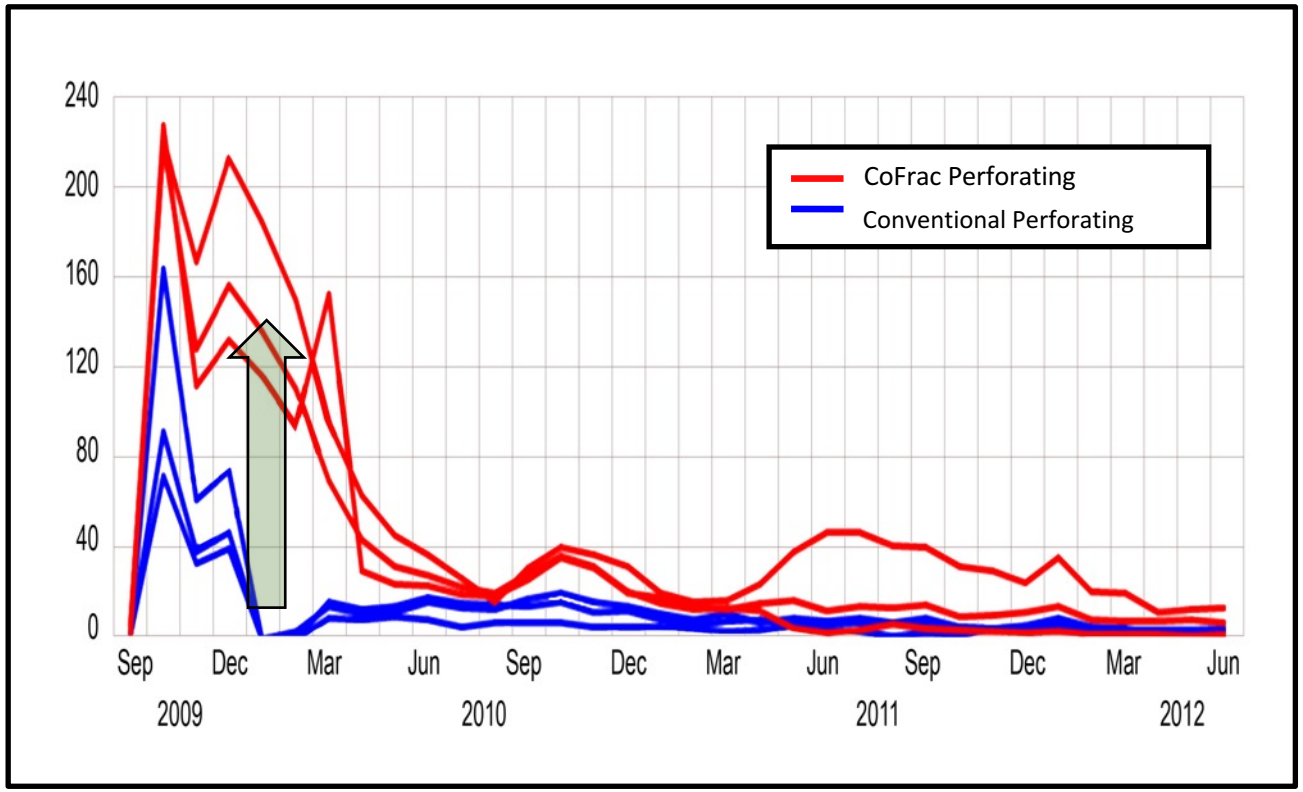
The new composite perforating system has been deployed in over 5,000 wells in China. These Chinese reservoirs have very low natural permeability, similar to USA unconventional reservoirs.

Extended Test over 34 months

From 2009 to 2012, Ganguyi Oilfield selected 6 wells in same formation and area and conducted a comparison test.

Under same well conditions, oil production was monitored for 34 months for 3 wells completed with Composite perforator and 3 wells with Conventional perforator.

Composite perforating system wells had higher initial oil production and slower decline rates. For 34 months period total production was 31,191 bbls for Composite wells, and 9,424 bbls for Conventional wells, an increase of 21,767 bbls (+231%).



THANK YOU
QUESTIONS?

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