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INTERNATIONAL PERFORATING FORUM

ALLIED HORIZONTAL WIRELINE SERVICES

2016 LATIN AMERICA PERFORATING SYMPOSIUM, BUENOS AIRES

SLAP 2016
SIMPOSIO LATINOAMERICANO DE PERFORATING

IMPROVED FRAC EFFICIENCY USING CONVERGING PERFORATING

SLAP-16-6

OCTOBER 18, 2016

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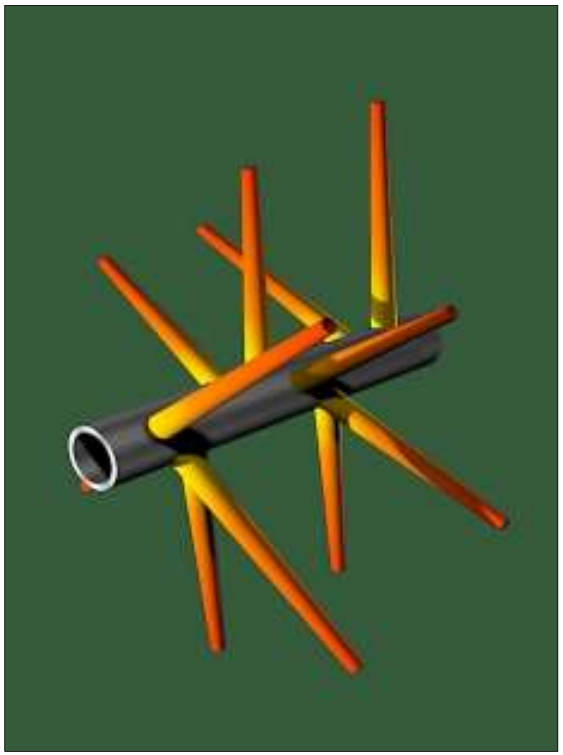
Conventional Perforating



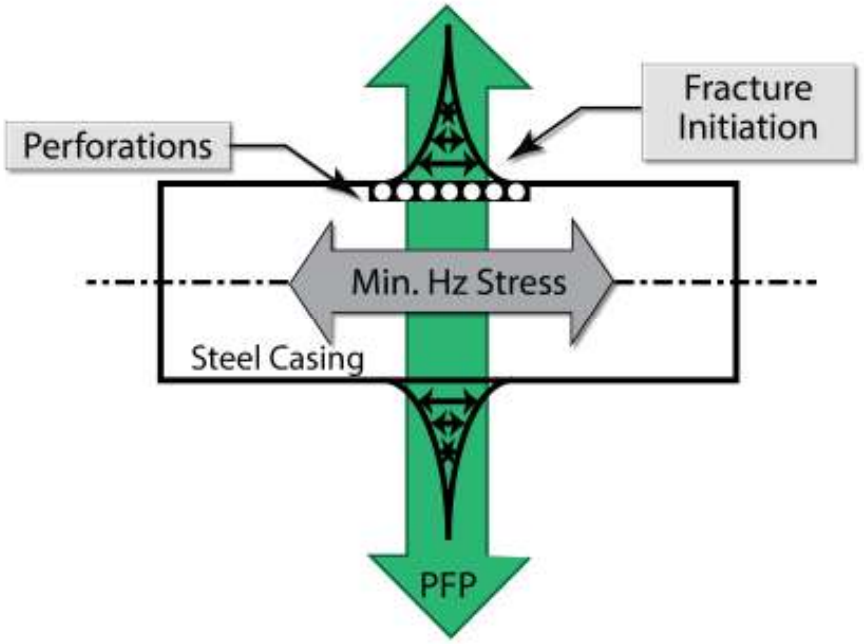
- Perforating tunnels perpendicular to gun body and casing
- Design improvements to change this 90°angle
- Ultimate goal reducing friction and frac HP, or improve well flow and production

Converging (Focused) Perforating

- True Limited Entry – Balanced Configuration
- Significant energy to single / double point or centralized ring
- 0 degree, 0 – 180, or 60 degree rotational phasing

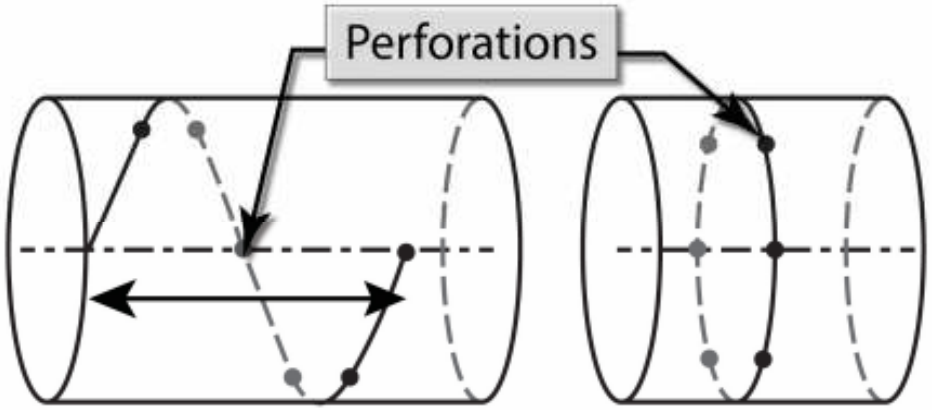
Ideal Perforations

- Sufficient friction/pressure drop to distribute fluid to all perforations/clusters
- Reduce fracture path tortuosity
- Allow early initiation of a single transverse fracture at the Preferred Fracture Plane
- Reduce multiple or longitudinal fractures



Ideal Perforations

- It has been proposed that perforations would be more effective if they could align on a single plane
- Perforating charges cannot be aligned on a single plane within gun body (space and shaped charge interference)
- Alternative: change the shaped charge angles to converge the perforating tunnels at the center of the gun/cluster



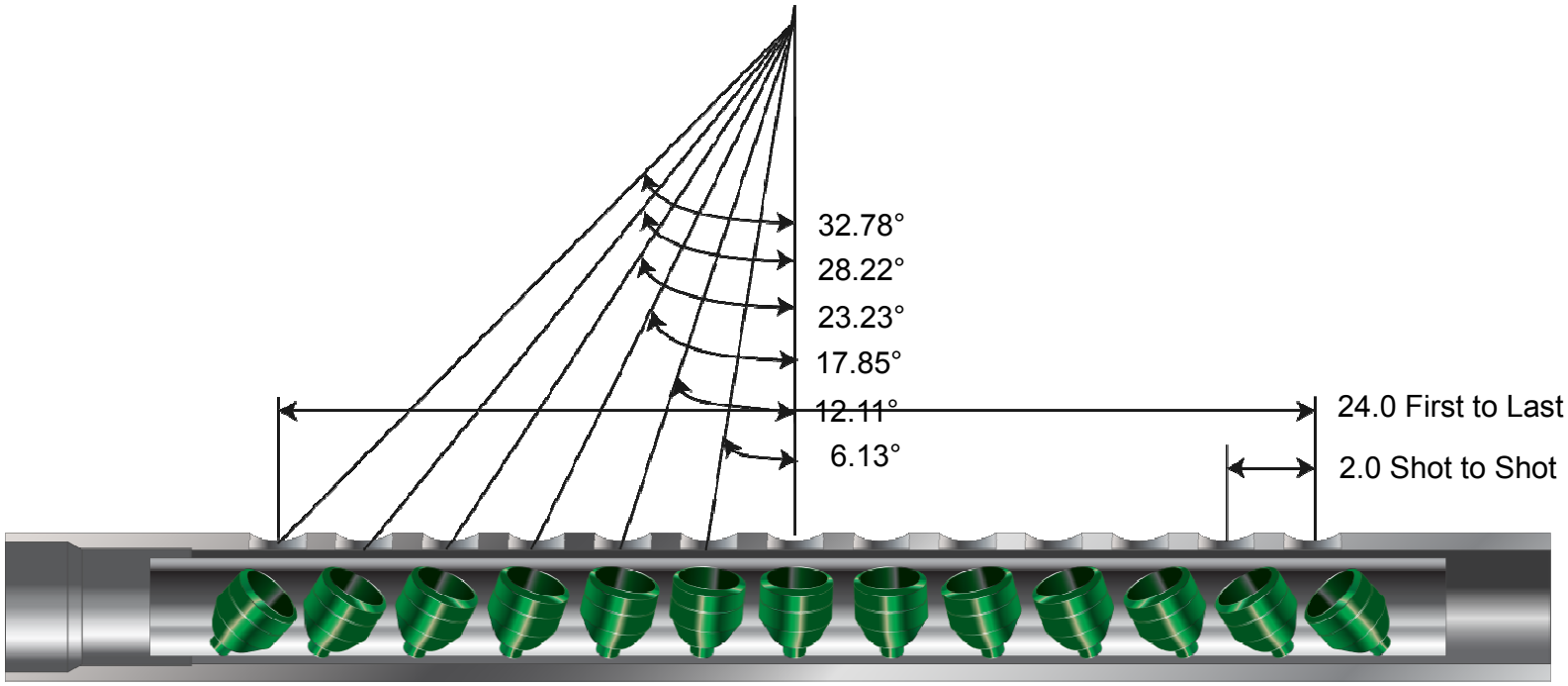
Typical 60° Phasing Pattern

Converged to Single Plane

Why Converging Perforating?

- Aligns perforation tunnels on single plane at center of gun/cluster
- Reduce fracture path tortuosity that can block fluid flow
- Remove fluid flow restrictions that can lead to proppant accumulation and potential screen-outs
- Prevent high friction pressure losses near well-bore which can cause higher treatment pressures

The Converging Gun Configuration



Technology Overview

- Product goal
  - Improve production
  - Reduce treatment pressures
  - Limit chemical usage
  - Quicker Frac times
- Proprietary technology (US Pat. 9145763)
- 350+ stages completed
  - Marcellus, Utica, Woodford, Hunton, Eagle Ford
  - Zero pressure outs
  - Zero screen outs
  - All stages have pumped according to frac design

Test Shot Comparison

Converging

Conventional

Down Shot

Ballistic Testing Summary

- Perforating with shaped charge orientation angles (25°, 30°, 45°) did not make an appreciable difference in depth of penetration.
- No evidence of shaped charge interference. All perforation tunnels and entrance holes were complete (round / oval).
- Forces can / must be balanced within a perforation gun so that there is negligible upward or downward force on the entire gun carrier (gun with all 45° down shots had sufficient energy to shoot the entire carrier out of the test tube).
- The shaped charge orientation were maintained when perforation tunnels entered the formation (i.e. 30° oriented charge remained at that angle in the test target).
- Converging Perforating provided a significant amount of focused energy compared to conventional perforating (target turned to rubble by converging energy).

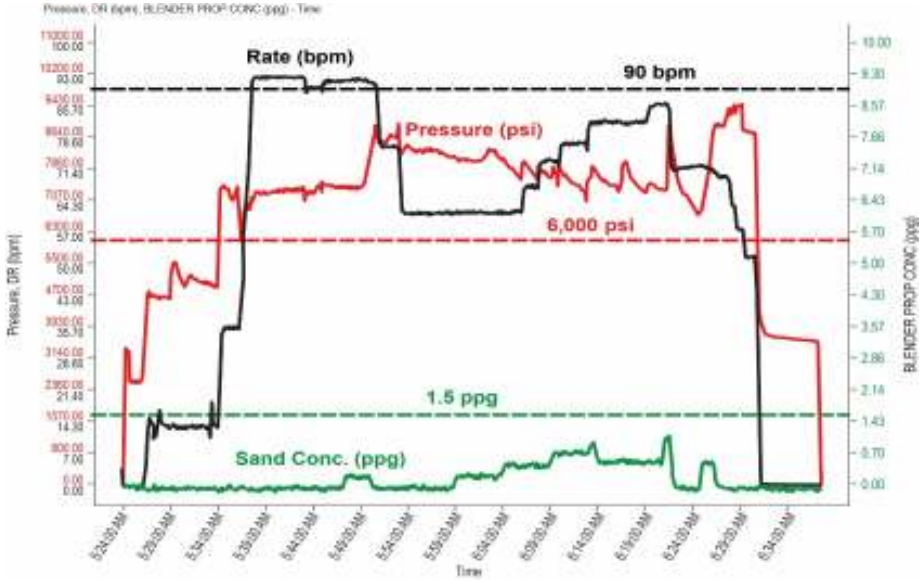
Case Study: Marcellus Shale

- 2 well pad
  - Two 1,250 m laterals, 1560 m TVD, 225 m spaced, drilled same direction
  - Frac design consistent well to well

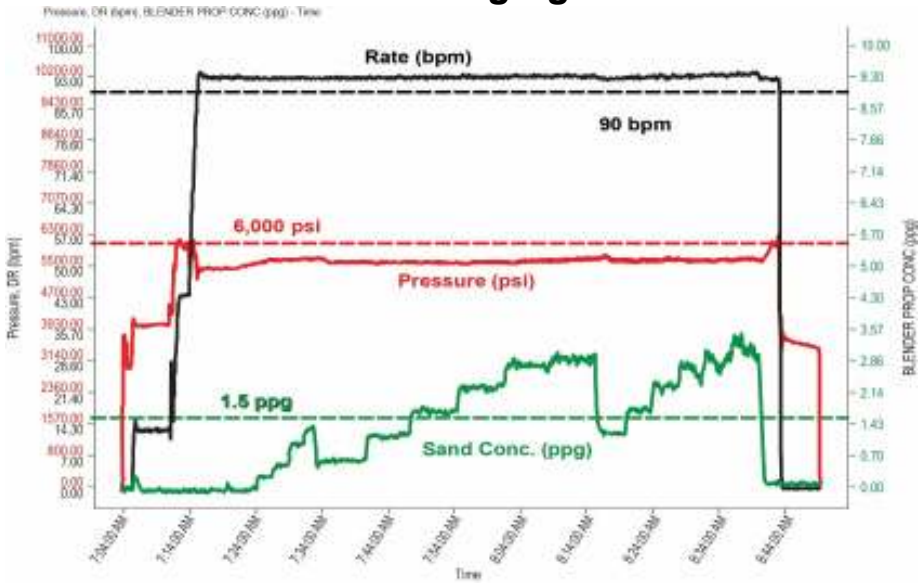
- Gun design – Five 3-1/8” 6 spf 60° 2’ load guns, 12 shots
  - Conventional guns for all stages in well one
  - Converging guns for all stages in well two

Case Study: Marcellus Shale

Conventional

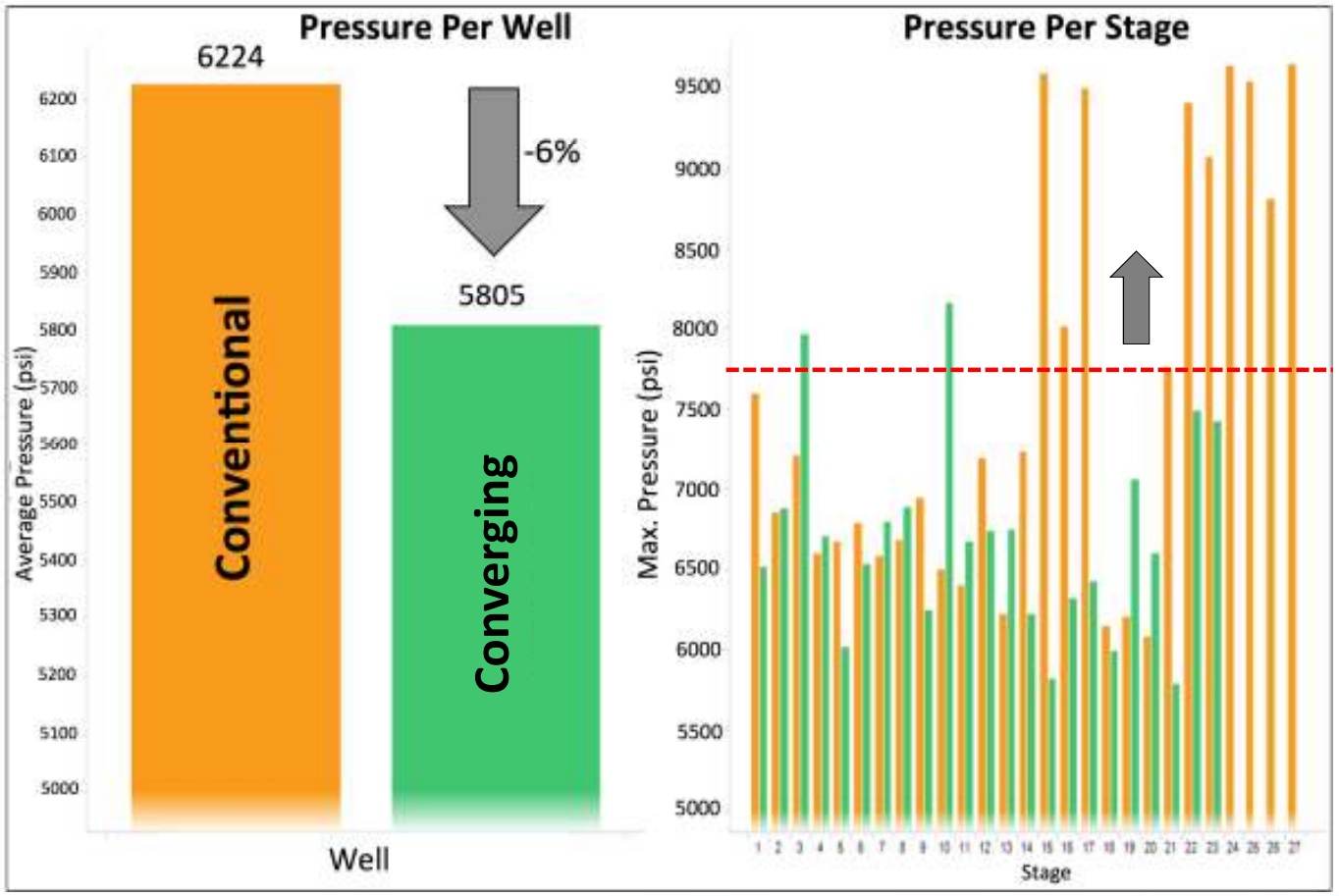


Converging



Case Study: Marcellus Shale

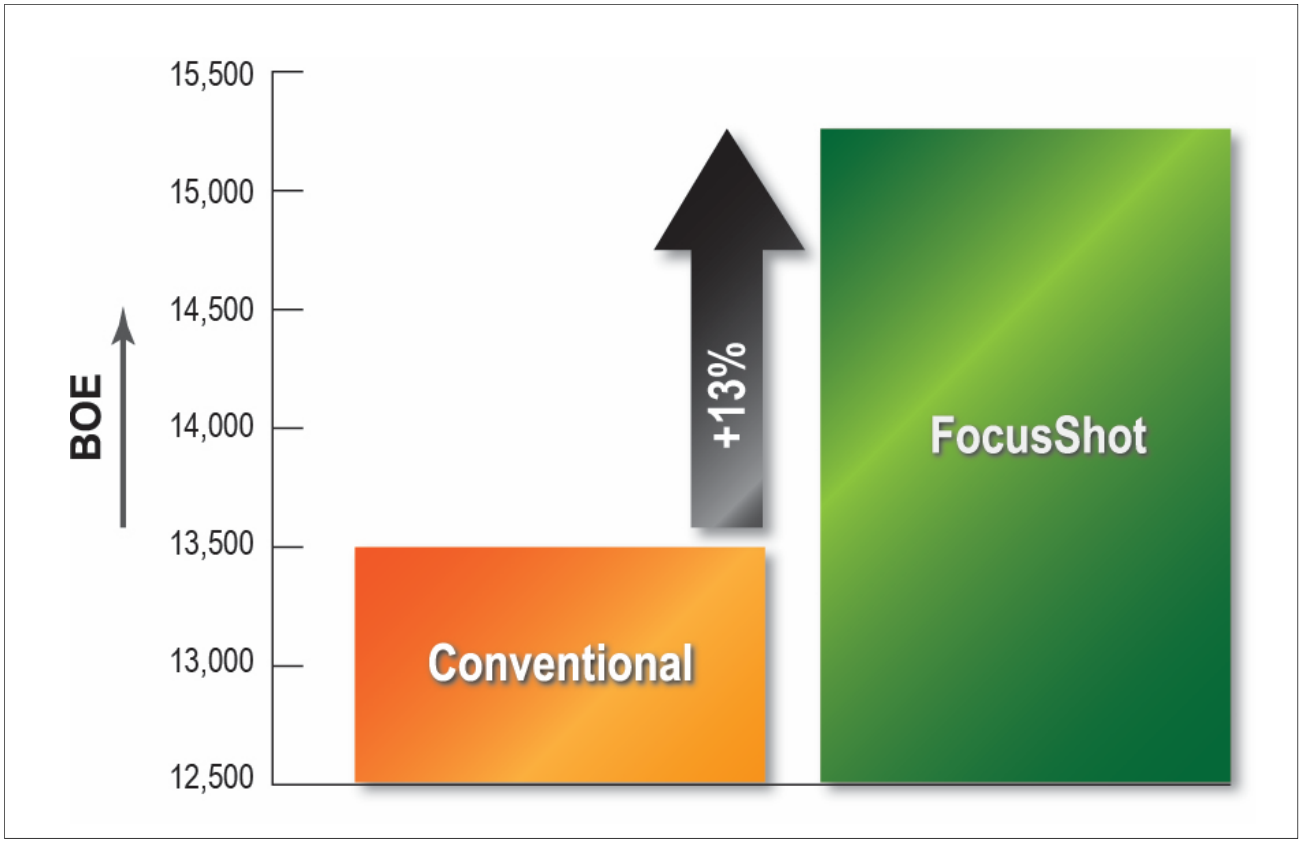
Treating Pressures



Higher Cost to Pump

Case Study: Marcellus Shale

Production Comparison



Conclusion

- What impact will converging perforating have on the frac?
- What impact will converging perforating have on production?
- What operational impacts are associated with running converging perforating ?
- What approvals would be needed to run a test?

Product Goal: <u>Increase Production and/or Reduce Frac hp</u>

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QUESTIONS? THANK YOU!

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