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2016 LATIN AMERICA PERFORATING SYMPOSIUM, BUENOS AIRES

SLAP 2016
SIMPOSIO LATINOAMERICANO DE PERFORATING

Perforation Design for Increased FRAC Efficiencies in Shale Formations

OCT 18TH, 2016

AUTHORS: Obbie Loving, Shaun Geerts
Owen Oil Tools

Core Lab

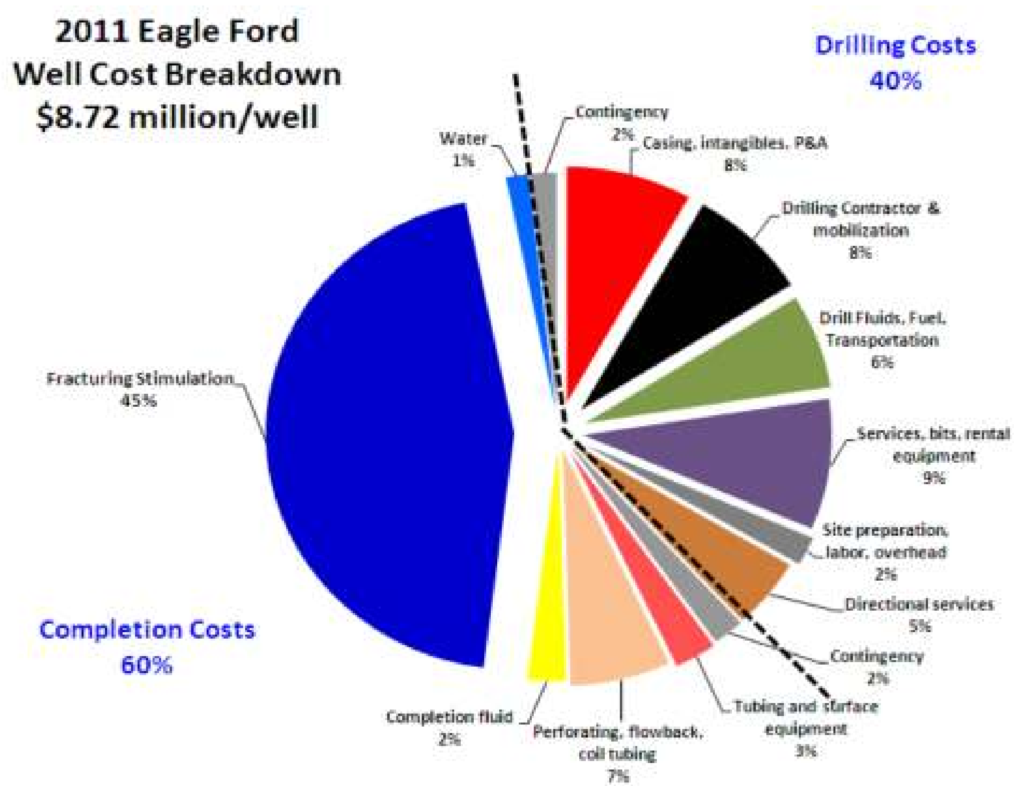
AGENDA/INTRODUCTION

- Why demand an optimized system
- What are the benefits
- How to develop a perforating system
- Certification testing
- Results
- Case study
- Conclusion

Where can Efficiencies Grow?

Smarter Perforating leads to better Fracturing

- Based on a typical well breakdown a bulk majority of cost is in the hydraulic fracturing operation
- Perforating by itself comprises 2-3% of costs to complete a well
- The perforating event is directly responsible for the efficiency of the hydraulic fracturing at 45% of well costs
- Imagine being able to lower the 45% of well costs by being more selective about the 2-3% of perforating costs



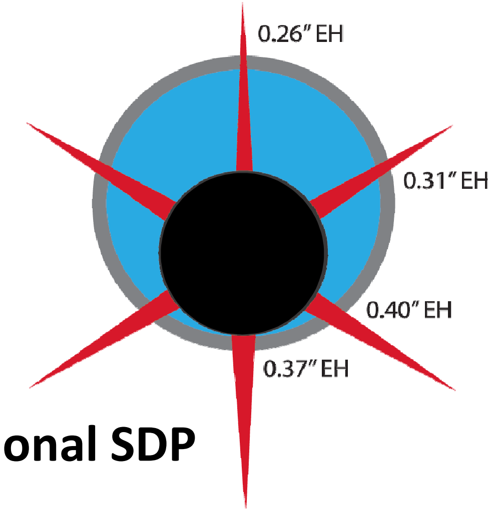
Graphic source: Weatherford, Shale Gas & Tight Oil Presentation, 2012

Why Perforation Design is Important

System Performance

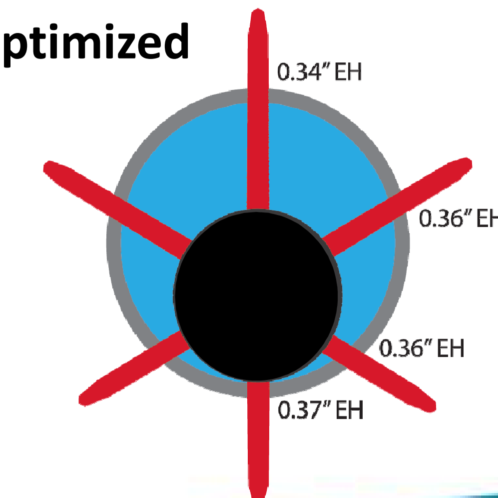
- Perforating systems offer unique opportunities due to interchangeability of components
- A perforating charge is designed and optimized for specific systems and well scenarios
- A conventional perforating charge may provide insufficient performance for hydraulic fracturing operations

- By selecting a FRAC optimized perforating charge the results can be far more productive for the hydraulic fracturing operation
- These FRAC optimized perforators are designed to give a consistent through hole in the casing, at all phasings, regardless of gun orientation



Conventional SDP

FRAC Optimized



Performance Criteria

Ideal Performance Demands from Operating Companies

- Customer have a desire to select from a variety of charges and gun systems

- Require consistent entry hole around circumference of casing
  - Consistent entry hole equalizes perforation friction (ΔP_{perf})
  - By reducing variability in hole size the FRAC should breakdown 100% of perforations versus conventional where 30-60% of perforations don’t accept the hydraulic fracturing

- Achieve **consistent penetration and consistent hole size**

- Be able to give superior performance regardless of centralization and/or orientation

Testing and Certification

Extensive Development for Consistency

- Testing unique and specialized perforating systems requires more than the standard API tests

- Important to test numerous gun systems to develop a true average of performance
  - 21 gram charge tested in 3.125” and 3.375” perforating guns
  - 3.125” and 3.375” guns tested in 4.5”- 5.5” casing as well as L80-P110
  - 2.75” system tested in 4.5”- 5.5” casing as well as L80-P110

- Numerous test series to verify consistent hole size and penetration performance in the varying gun systems, casing sizes, and target mediums

Testing and Certification

- Testing full systems under hydrostatic pressure to verify wellbore pressure will not negatively effect performance
  - Full system gun test with wellbore pressure of ~5500psi
  - Gun system decentralized in wellbore casing
  - Concrete confinement around exterior of casing to simulate cement sheath

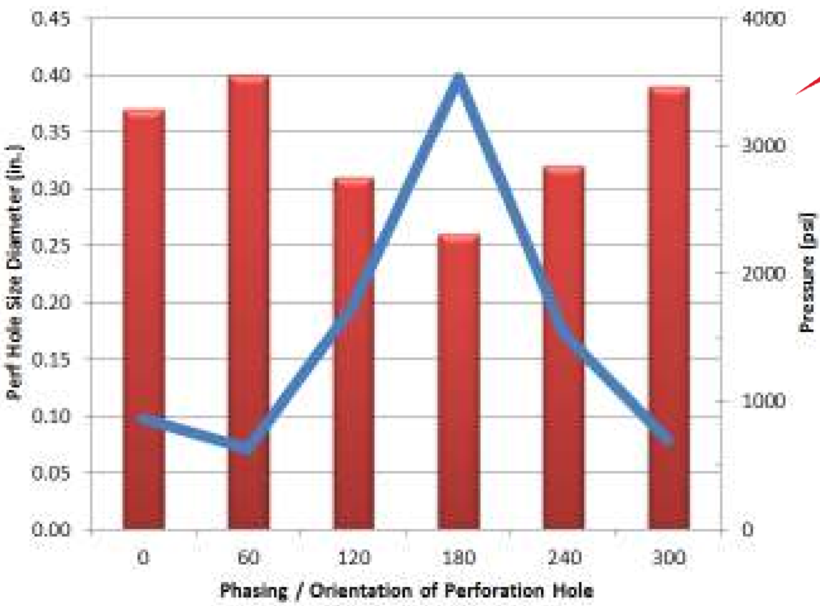
- Test performance in stressed rock conditions to verify consistency in design and performance

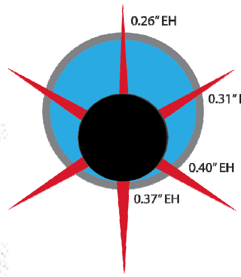
- API RP-19B Section 2
  - Berea Sandstone Penetration
    - 2.75” charge – 10.4”
    - 3.125” charge – 9.63”
  - Eagleford Shale

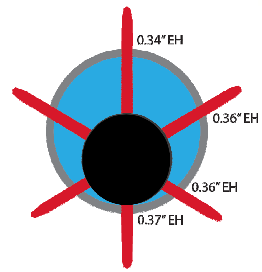
Deliverable Results

Equalized ΔP_{perf}

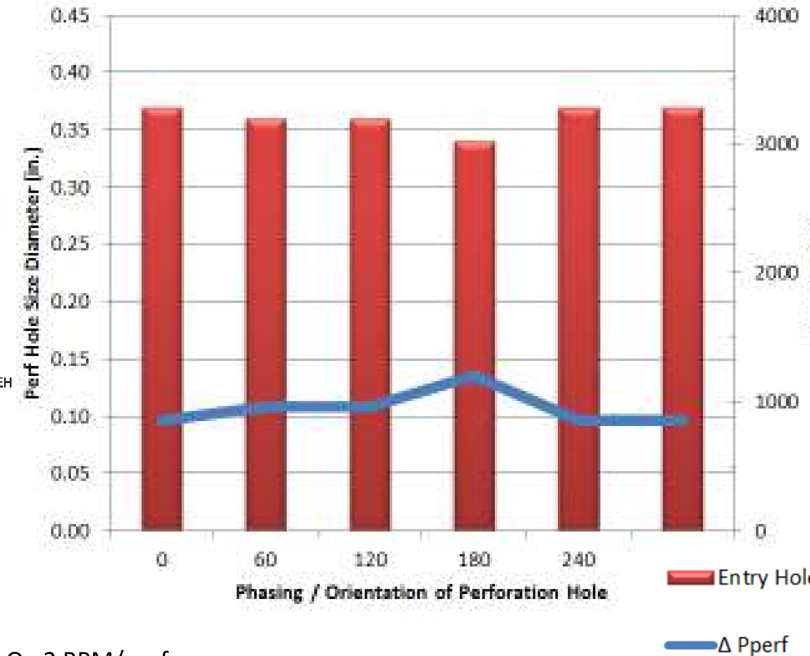
Conventional SDP







FRAC Optimized



$$\Delta P_{perf} = \frac{.237 \rho Q^2}{D^4 C^2}$$

Where: Q= 2 BPM/perf
C = 0.7
ρ = 8.33 ppg

Case Study

WolfCamp Play

	Effective Lateral Length, ft	# of Stages	Total Proppant per foot	Average Break Down Pressure, psi	Max Treatment Pressure, psi	Average Pump Rate, bbl/min	Average Treatment Pressure, psi
Competitor 'A'	7477	41	1804.5	4044	6916	87	5886
Competitor 'B'	7155	48	2033	3821	7084.5	88	5932
% Improvement		15.7%	11.9%	-5.7%			

- Competitor 'B' was able to complete almost 16% more stages than Competitor 'A'
- Competitor 'B' was able to place 12% more proppant per foot, ~230 lbs per foot
- Competitor 'B' was able to maintain pump rates and treatment pressures while reducing the breakdown pressure by nearly 6%

Case Study

Wolfcamp Play

- Well Productivity showed:
  - 15% higher I.P.'s
  - 5-15% higher estimated E.U.R.
  - Notably higher near wellbore permeability
  - Notably lower skin factor
  - No Screen Outs

Conclusion

- Based on all the testing and data presented so far
  - The perforating system selected and use of perforating charges designed specifically for better hydraulic fracturing operations has resulted in better efficiencies for Shale formations

- Performance of perforating system depends on:
  - Consistency of the charge performance
    - Both consistent entry hole and penetration
  - Clean perforation tunnels that are free from debris

- Technology has been designed into the perforating charge
  - Does not require special running hardware
    - Such as centralizers or orientating devices
  - Allows interchangeability within multiple size perforating systems

QUESTIONS? THANK YOU!