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Advancing Consistent Hole Charge Technology to Improve Well Productivity

IPS 16-10

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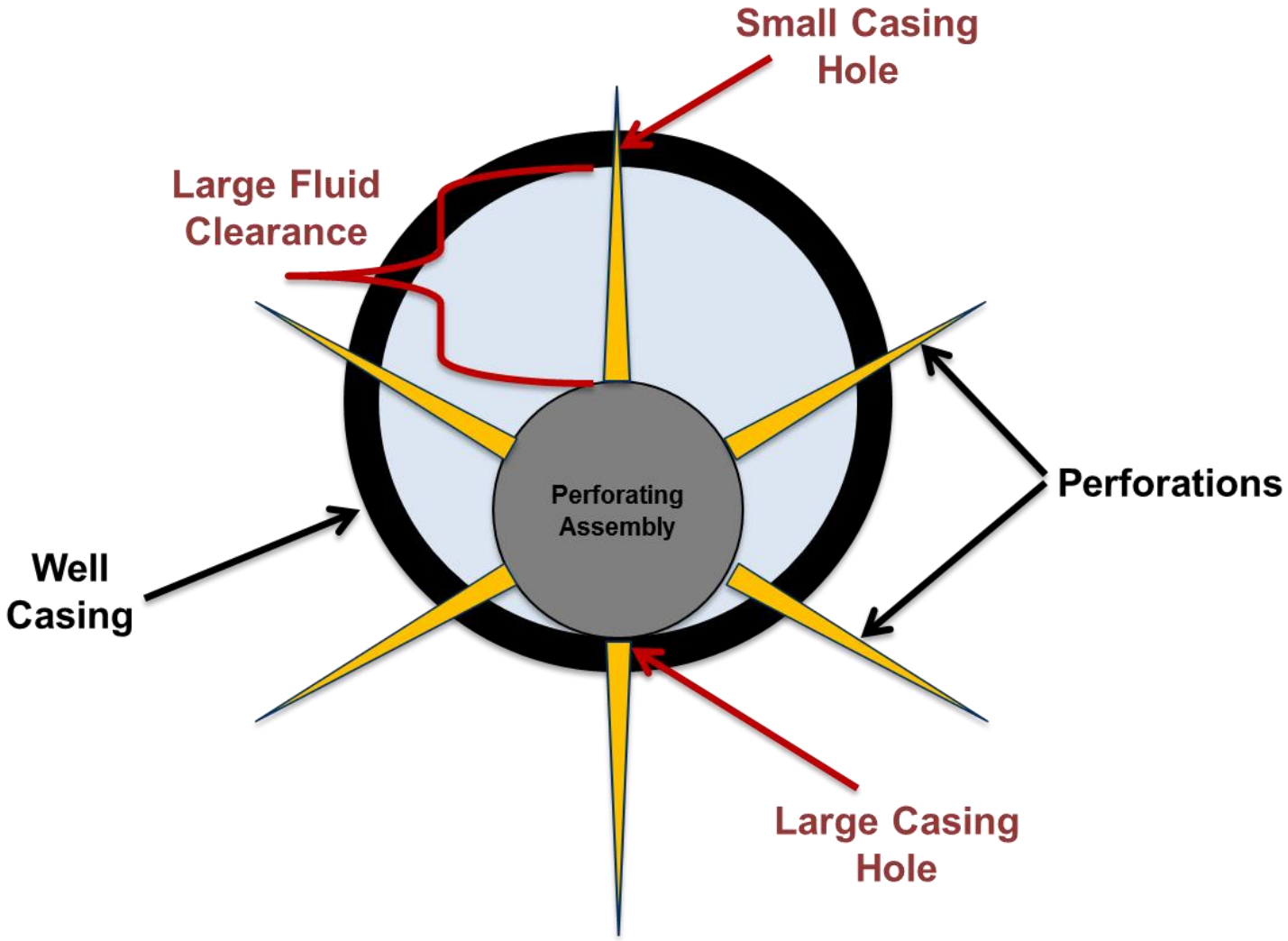
AUTHORS: Chris Sokolove & James Cole
Hunting

AGENDA/INTRODUCTION

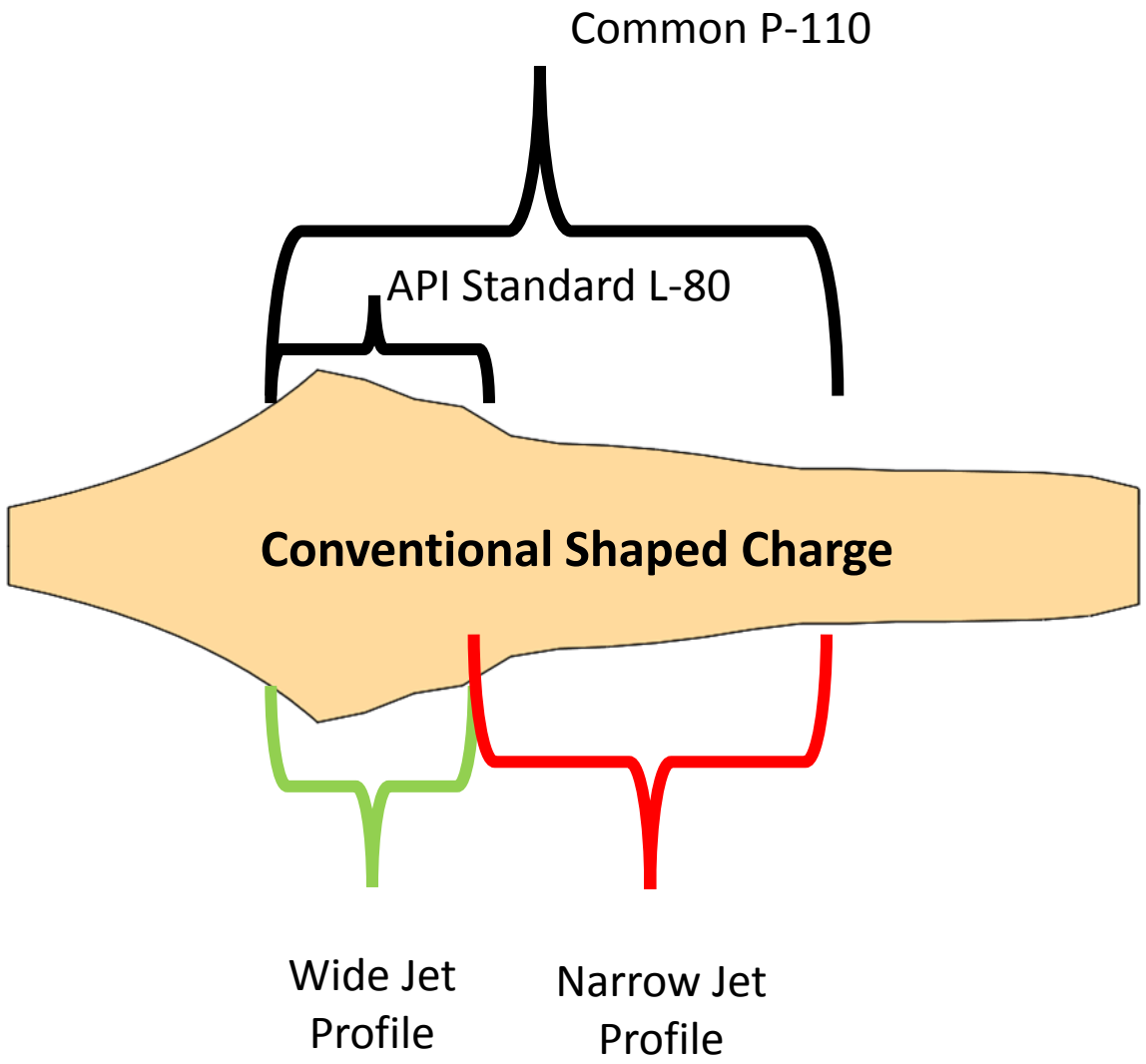
- Consistent Hole (CH) Technology
- Growth in a Down Market
- Opportunities for Advancement
- Review of Published Data
- Comparison of Charges in Common Well Configurations
- Guidelines for Selection, Evaluation, Comparison and Feedback
- Recommendations for Improvement to API RP19B

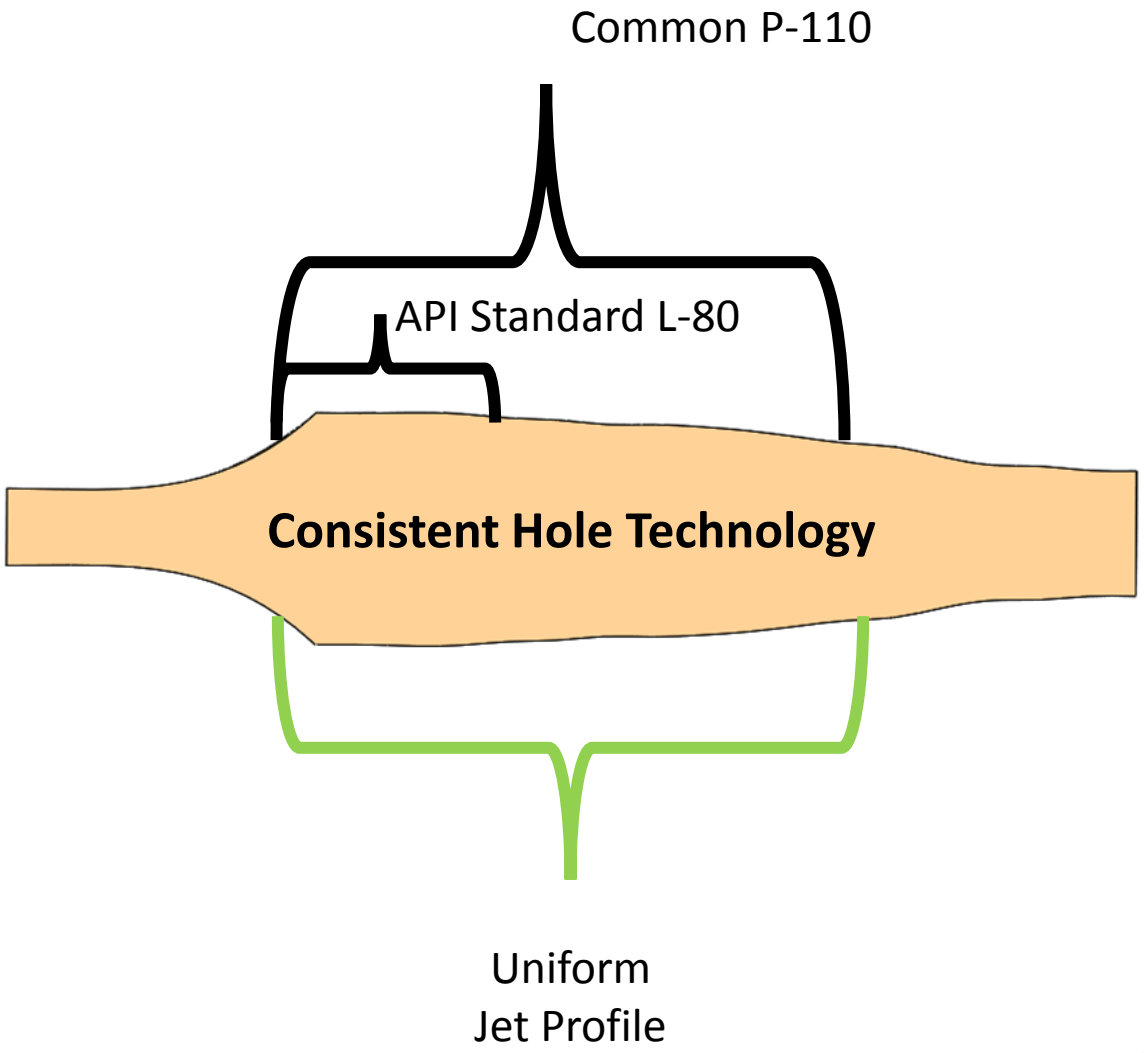
Conventional DP and GH Shaped Charges

- Non-uniform distribution of treating fluids
- Erosion and slotting of small perforations
- Under-utilization of all perforations
- Less efficient well stimulation
- Slow ramp-up to higher treating pressures



Shaped Charge Jet Profiles

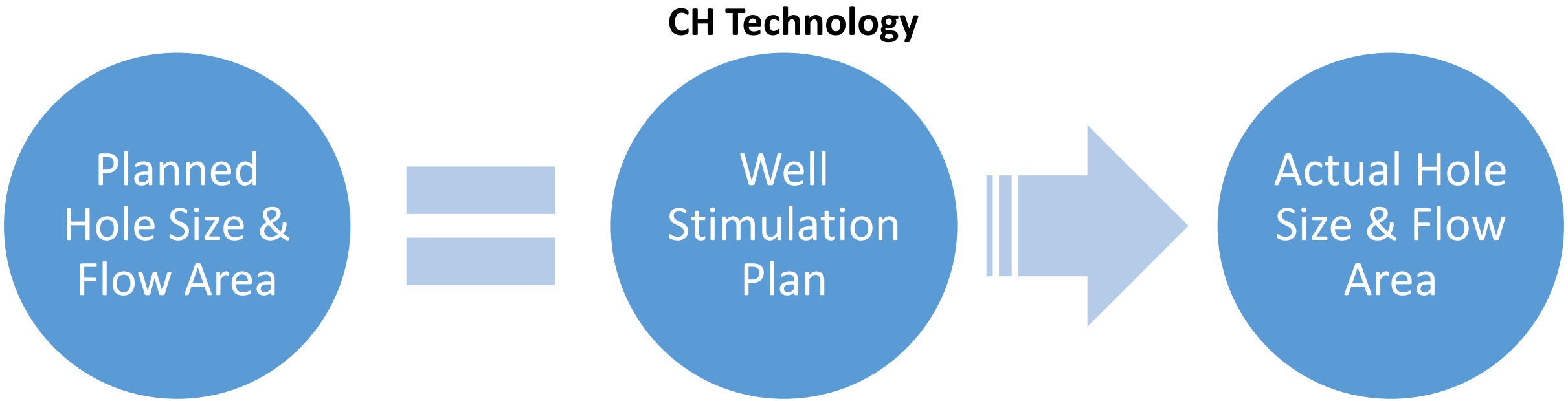




Importance of CH Technology

- API 19B Section 1 Data
- Predictive models
- $\Delta p_{perf} = \frac{0.2369\rho}{d^4 C_d^2} \left(\frac{q}{N}\right)^2$

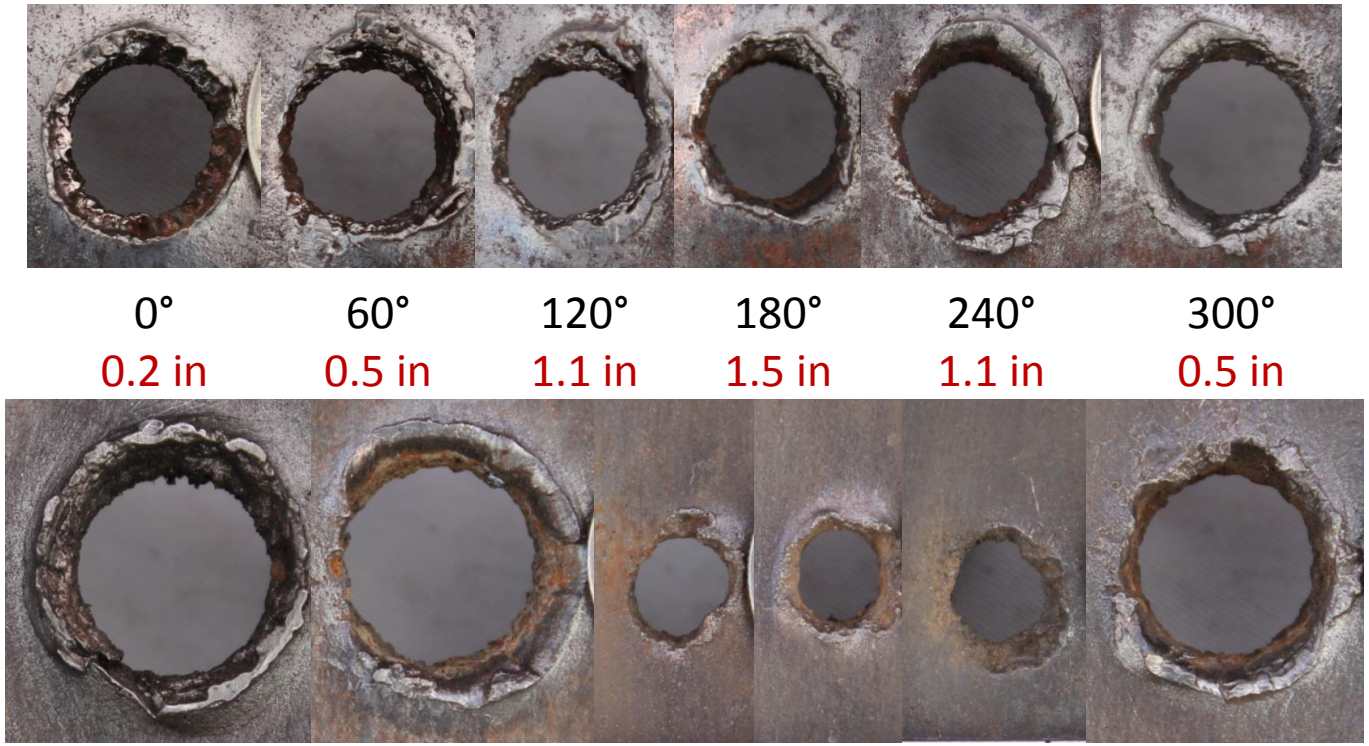
Importance of Consistent Hole Technology



Consistent Hole Technology enables opportunity for optimal well stimulation

Consistent Hole Shaped Charges

CH Technology

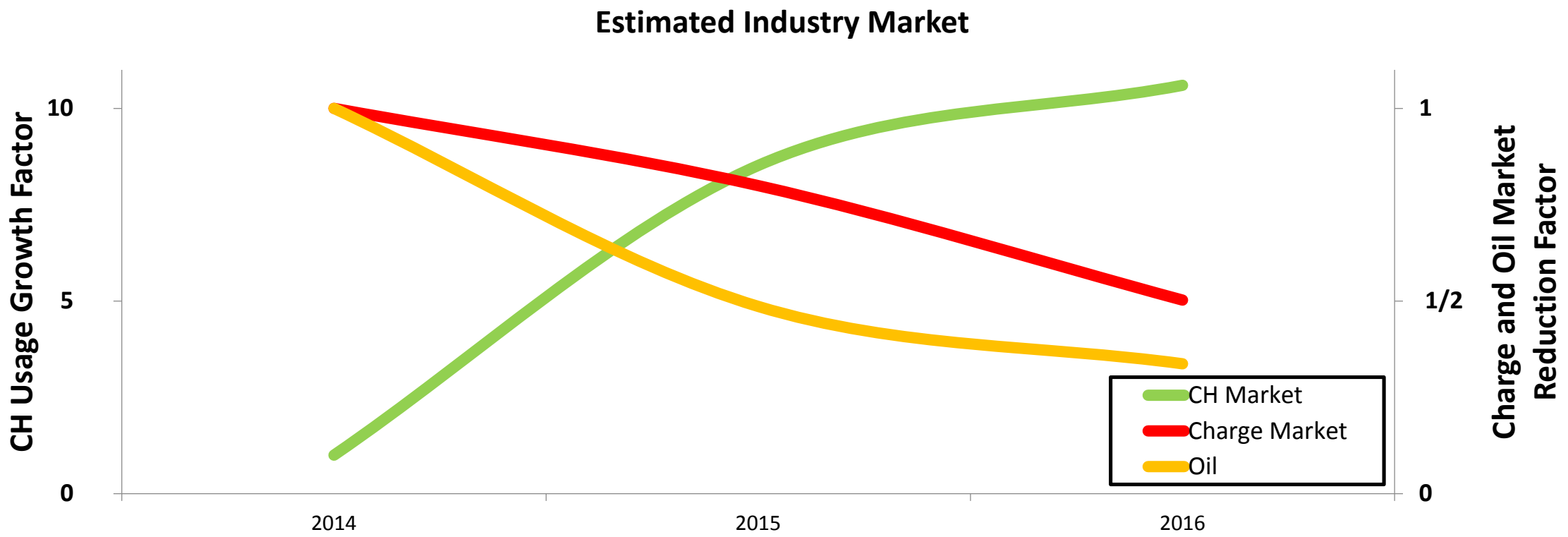


Conventional Charge

- New category of shaped charges
- Designed for decentralized perforating
- Improves efficiency of well stimulation
- Achieves consistent hole size regardless of fluid clearance
- Advertised with Average Hole Size **AND** Variation in Hole Size

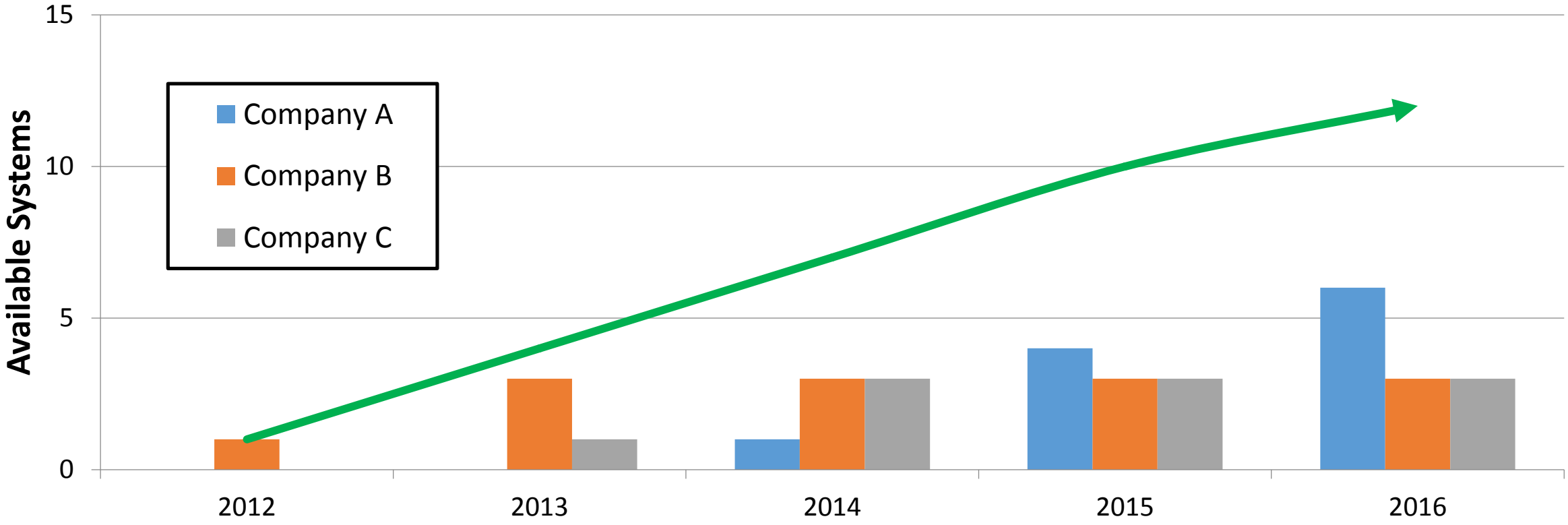
Consistent Hole Market Trend

Growth in a Down Market



CH Technology has seen significant growth despite a 50% reduction in the overall charge market

Consistent Hole System Growth



- Exponential growth in availability of CH perforating systems
- Growth driven by market demand for efficient technology

Why Growth in Consistent Hole Technology?

- …operator ***Increased Injectivity*** by 20%
- …evaluated 15 frac stages to show ***Lower Treating Pressures*** at the same pump rate or 8-10% higher pump rate
- …two well studies show 10% ***Reduction in Breakdown Pressure***, 2% ***Reduction in Treating Pressure***, and 3% ***Increase in Proppant Placement***
- …**Reduced Injection Pressure** by 15%
- …achieved and maintained **Faster Pump Rate** with ***Reduced Stimulation Pump Pressure***
- …***More Consistent Treating Rate*** with ***Increased Sand Concentration*** at ***Lower Pressure***
- …***Decentralized*** CH charge resulted in 10% ***Higher Treating Rate*** than a ***Centralized*** DP charge

Case study information compiled from multiple CH technology providers

Advancing Consistent Hole Technology

Existing case studies highlight benefits of CH Technology utilizing the same well simulation method

Good News!!

These studies have established a foundation for CH Technology

Are current well simulation methods and designs best?

Advancing Consistent Hole Technology

Conventional Shaped Charges

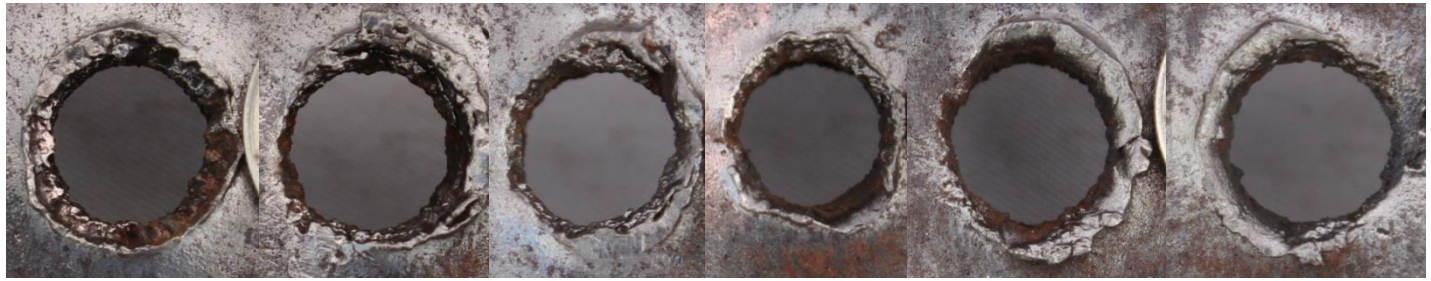
- Variation in hole size (a key design input) yields unpredictable stimulation result
- Accept that actual results differ from design – often without explanation

Consistent Hole Technology

- Consistent hole size increases control and predictability of stimulation → More strategic placement of perforations
- Removing hole size variability provides opportunity to investigate difference between design and actual results → Increased understand of effective stimulation

Advancing Consistent Hole Technology

CH Technology



0°	60°	120°	180°	240°	300°
0.2 in	0.5 in	1.1 in	1.5 in	1.1 in	0.5 in

Conventional Charge

Unlikely that the same stimulation design is optimal for both perforation profiles

Advancing Consistent Hole Technology

1. Select the optimal CH Technology – use CH Technology with distinctly different performance from conventional charges

2. Evaluate down hole performance – comparable baseline, ideally different stages in the same well

3. Provide feedback – what worked? Where is the opportunity for improvement?

Selecting Advanced Consistent Hole Technology

	Company A
Number of Systems:	6
Size Range:	2-1/2” – 4-1/2”
Casing:	Common size, grade, weight

	Company B
Number of Systems:	3
Size Range:	2-3/4” – 3-3/8”
Casing:	Unknown grade, weight

	Company C
Number of Systems:	3
Size Range:	3-1/8” – 3-3/8”
Casing:	Low grade and small dia. or low weight

- Several perforating systems currently available
- Anticipate increase in options:
  - Broad range of systems optimized for different casing sizes, weights, and strength
  - Broad range of hole size options tailored for various well stimulation techniques
- **CAUTION!** Variation from tests in low grade, small diameter or low weight casing does not reflect performance in common casing.

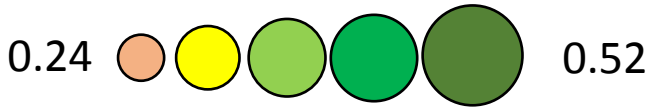
Selecting Advanced Consistent Hole Technology

	Gun Size	Casing	Hole Size	Variation	Test
Company A	2-1/2"	4-1/2" 13.5# P-110	0.29	7.3%	Gun
	2-3/4"	4-1/2" 13.5# P-110	0.38	6.8%	19B
	2-3/4"	5-1/2" 23# P-110	0.33	5.9%	Gun
	3-1/8"	4-1/2" 13.5# P-110	0.40	2.5%	19B
	3-3/8"	5-1/2" 23# P-110	0.38	4.9%	19B
	3-3/8"	5-1/2" 23# P-110	0.44	5.9%	Gun
Company B	2-3/4"	4-1/2"	0.41	22.0%	Unk.
	3-1/8"	4-1/2"	0.46	10.9%	Unk.
	3-3/8"	5-1/2"	0.43	25.6%	Unk.
Company C	3-1/8"	4-1/2" 11.6# L-80	0.48	7.1%	19B
	3-3/8"	4-1/2" 11.6# L-80	0.50	6.6%	19B
	3-3/8"	5-1/2" 17# L-80	0.45	13.4%	19B

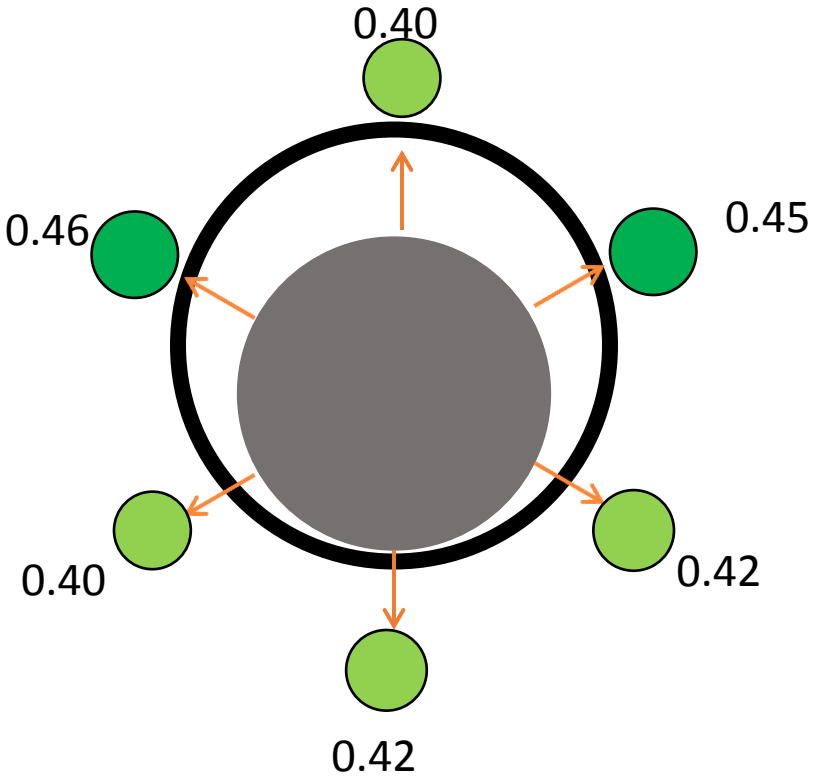
Low variation in high strength casing

Moderate to high variation in unknown casing strength

Low to moderate variation in low strength casing



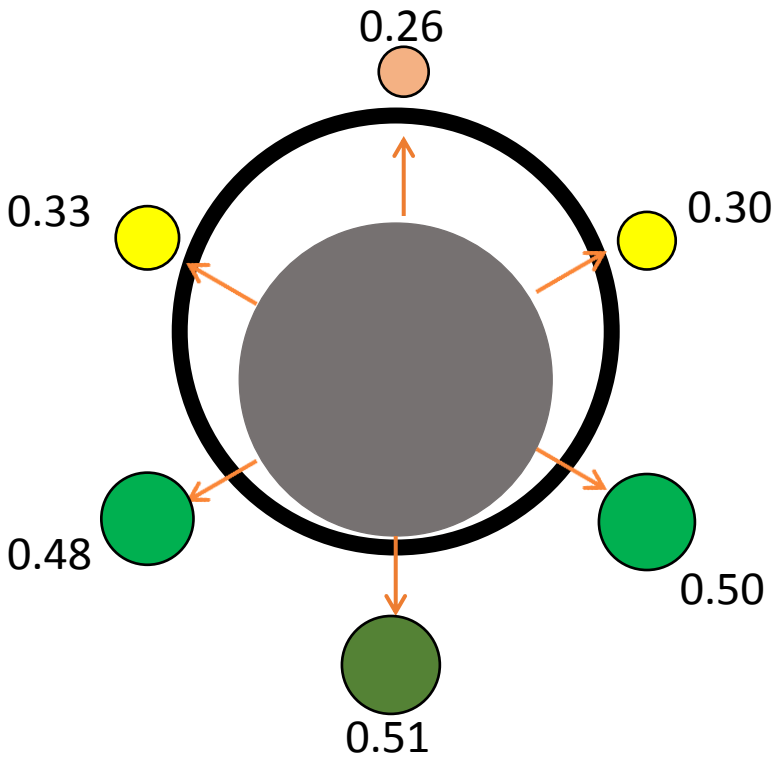
3-3/8” 6 SPF 60 deg. Gun
5-1/2” 23# P-110



Company A

Average:	0.43 in.
Min:	0.40 in.
Max:	0.46 in.
Variation:	5.9%

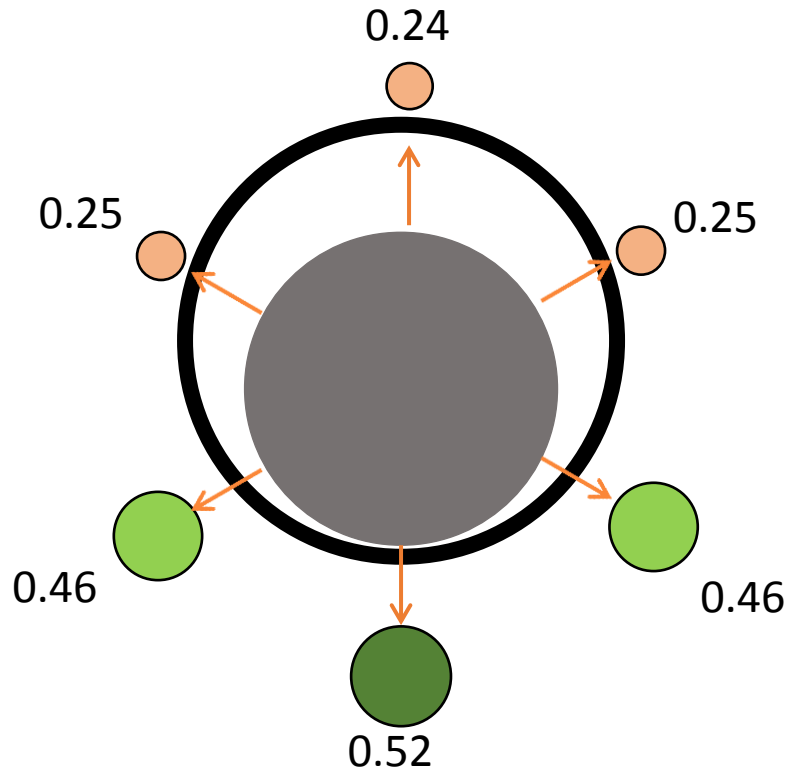
API Test: 5-1/2” 23# P-110



Company C

Average:	0.39 in.
Min:	0.26 in.
Max:	0.51 in.
Variation:	32.6%

API Test: 5-1/2” 17# L-80



Conventional GH

Average:	0.36in.
Min:	0.24 in.
Max:	0.52 in.
Variation:	35.7%

Calculation of Variation

Range: $\frac{Max - Min}{Avg} X\ 100$

Coefficient of Variation: $\left(\frac{St.Dev}{Avg}\right) X100$

System	Min	Max	Range	% Range	CV
Comp. A 3-3/8” (5-1/2” P-110)	0.39	0.47	0.08	18.3%	5.9%
Comp. C 3-3/8” (5-1/2” L-80)	0.35	0.53	0.18	40.1%	13.4%

Important

Statistically Important

Selection Principles

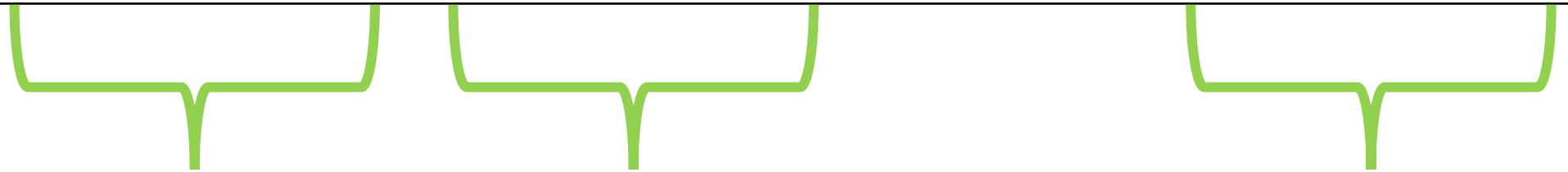
- Only compare performance data for charges tested:
  - Casing of equivalent or higher strength/weight
  - Fluid clearance of equivalent or greater distance
- Ensure the same calculation method is used when comparing variation
- Verify suitable Quality Control for CH Technology

Recommendations for API Standardized Testing

- Decentralize perforating gun
- Align perforating gun with one bank of shots at the minimum and maximum fluid clearances
- Common casing strength (i.e. P-110 casing)
- Common casing size (i.e. 5-1/2” casing for 3-3/8” gun)
- Minimum of two shots at each fluid clearance

Recommendation for Data Publishing

Gun Size	Casing	Min	Max	Avg.	Range	CV
3-3/8”	5-1/2” 23# P-110	0.39	0.47	0.44	0.08	5.9%



OD, Weight, Grade

Specific Hole Size Range

Comparison Values

Conclusion

- Consistent Hole Technology market presence is expected to increase
- Consistent Hole Technology has proven to reduce stimulation costs
- There is need for standardized testing and data publication

Next Phase:
Optimizing stimulation design with Consistent Hole Technology to increase well productivity

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QUESTIONS? THANK YOU!

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