



Completion Solutions for Multi-Stage Stimulation of Unconventional Resources

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Agenda



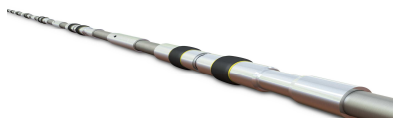
- Why is there a need for multiple completion solutions?
- What completion options are available?
- Summary and conclusions



Why There is No “One” Optimal Solution



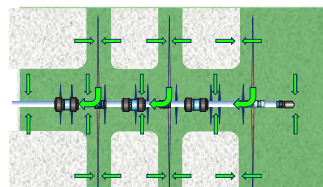
Reservoir Fluids - HPHT



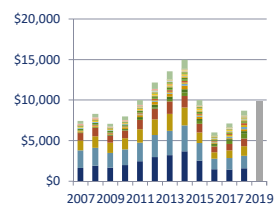
Compliance – Testable Toe



Natural Fractures - OH



Economics – Flexibility



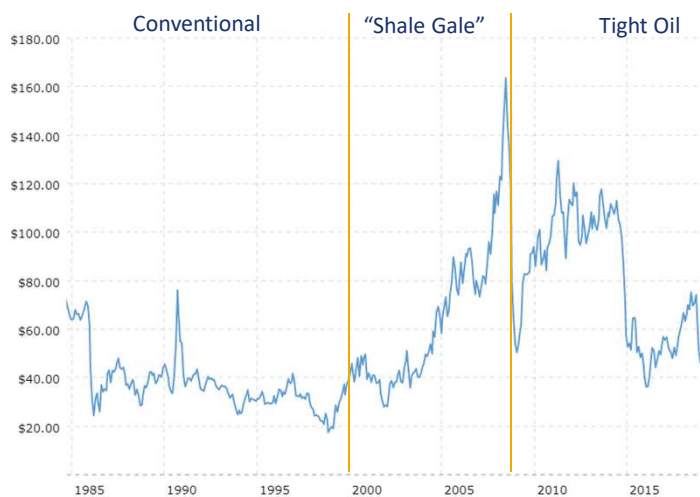
Poll Question



What is Your Top Influence for Completion Design Choice?



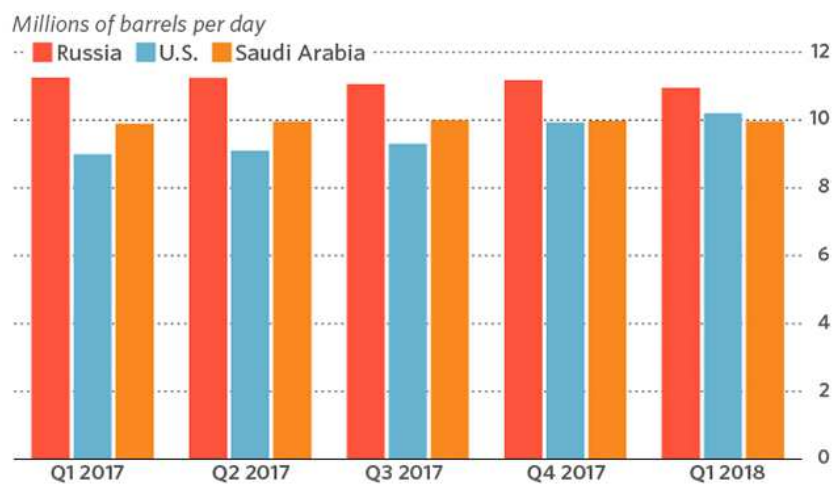
Unconventional Development History vs. Price



Source: macrotrends.net



U.S. Production Growth

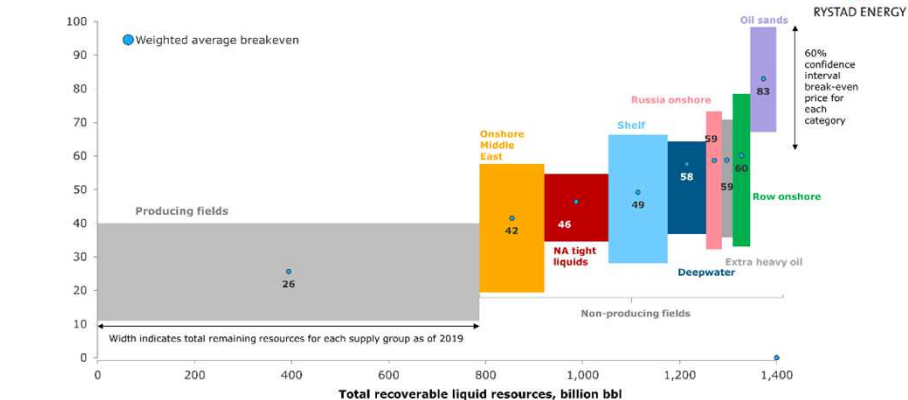


Source: MarketWatch

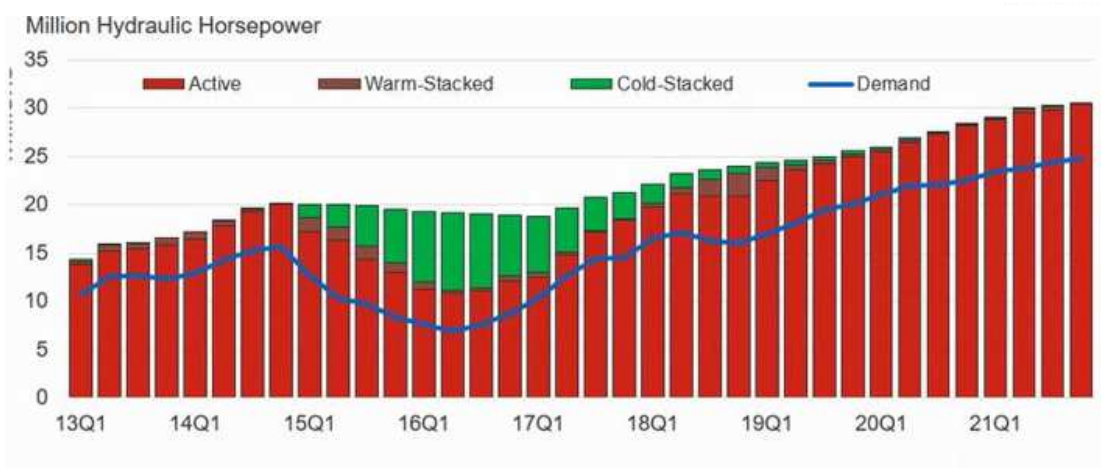


Global Breakeven Averages

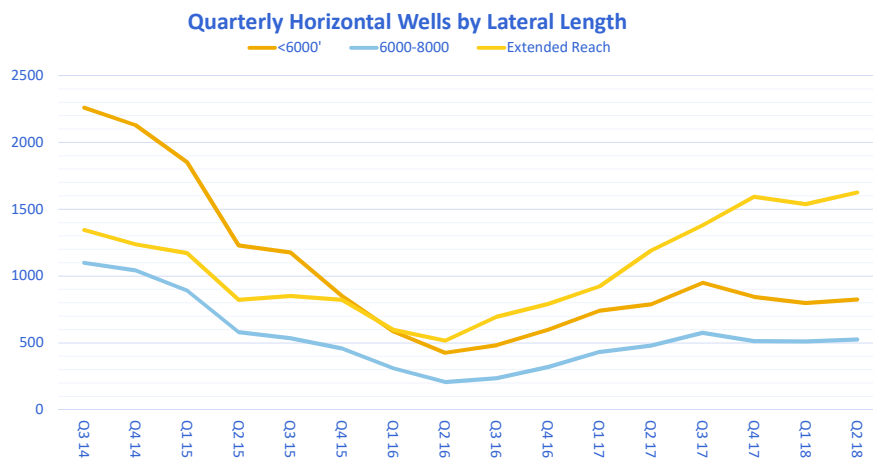
Global liquid supply curve
Real Brent Break-even price, USD/bbl



North America Frac Equipment Supply and Demand



Lateral Length Trends



Source: Spears & Associates



Ideal Frac Distribution



Even fracture distribution and uniform length ensures efficient drainage of resources with no interference between wells



Getting Started



Testable Toe Sleeve



Wet Shoe Tool



Rupture Disc Sub



Glass Barrier Sub



Poll Question



How Many Toe Subs Do You Typically Run in a Well?



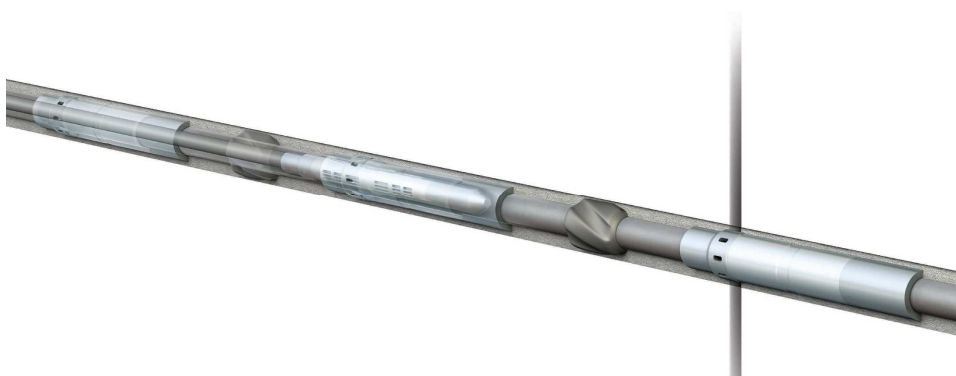
Toe Sub Value Creation Through Reliability



- Testable Toe Sleeve installed as first stage of hybrid plug-and-perf well
- Well stimulated nearly 8 months after installation
- Casing integrity tested at 8,900 psi for 15 minutes at 2 bpm prior to tool activation



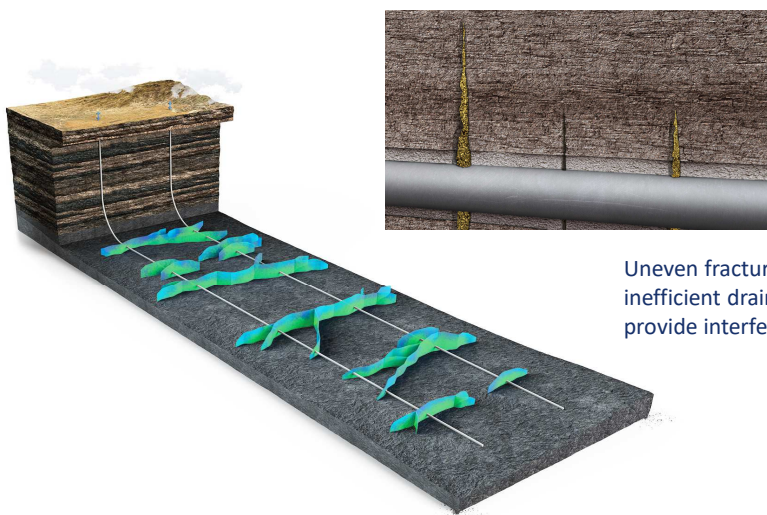
Single Point Entry: Coil-Activated Sleeves



Single Point Entry: Collet-Activated Completion Systems



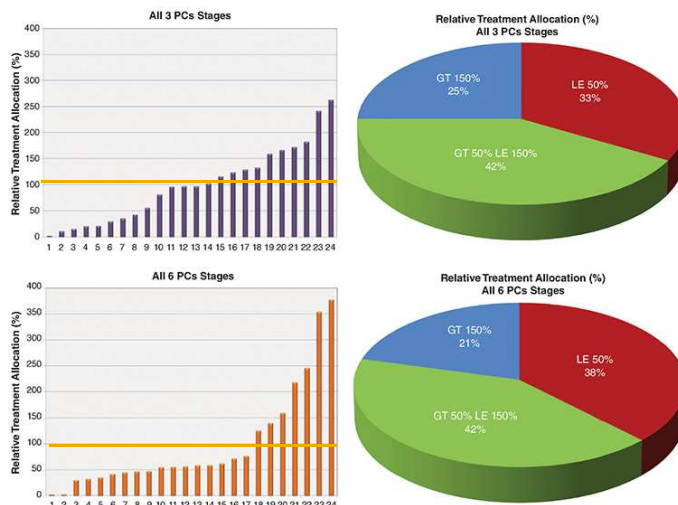
Multi-Point Entry: Plug-and-Perf Performance Issues



Uneven fracture distribution leads to inefficient drainage of resources and long fractures provide interference between wells



Inefficient Treatment of Perforation Clusters



SPE 179124 – Perforation Cluster Efficiency of Cemented Plug and Perf Limited Entry Completions; Insights from Fiber Optics Diagnostics

Frac Hit Consequences



- In some parts of the Permian, the [frac hit] effect has caused child wells to deliver a 30% lower recovery rate than their parents (when factors such as well lengths are normalized). When such production shortfalls are felt fieldwide, the losses are measured in millions of dollars per day.

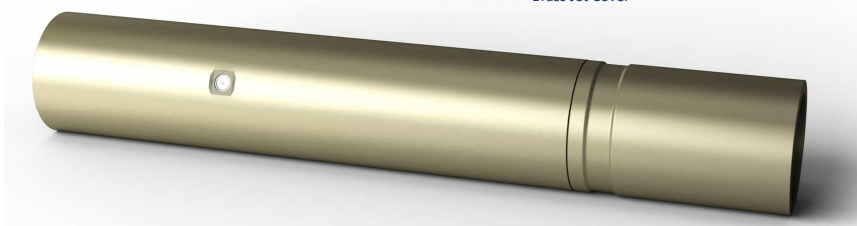
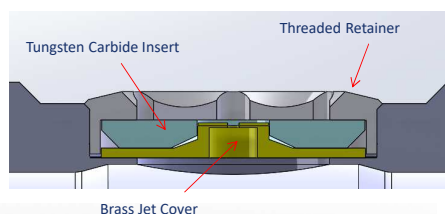
JPT August 2018



Limited Entry Sliding Sleeve



- Tungsten carbide insert eliminates erosion
- Brass insert custom sized for optimal completion program



Well Design Based on Operator Requirements

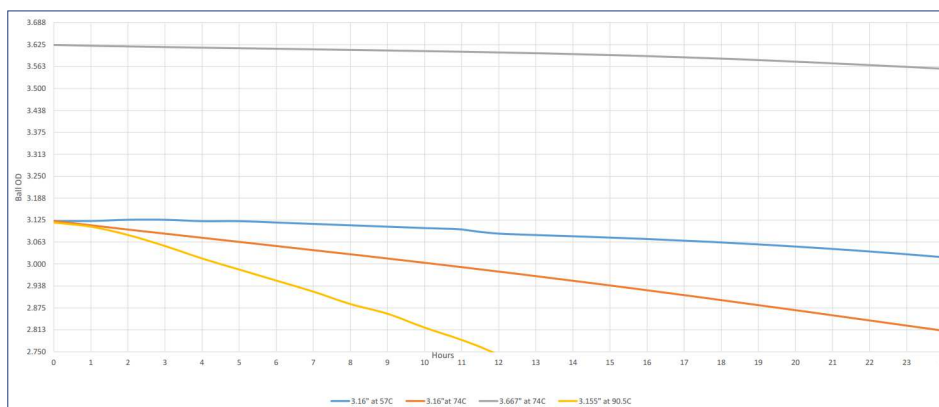


Seat Size	Number of Subs in Use	Jet/Insert Size (inches)	Pressure Drop Through Nozzles (psi)	Flow Rate (bbl/min)	Surface Pumping Pressure (psi)
3.063	3	0.750	545	80	7567
3.125	3	0.750	601	84	7801
3.188	3	0.750	616	85	7622
3.250	3	0.750	630	86	7446
3.313	3	0.750	690	90	7614
3.375	4	0.688	550	90	7155
3.438	4	0.688	550	90	6841
3.500	4	0.688	550	90	6542



Reduce Operational Risk

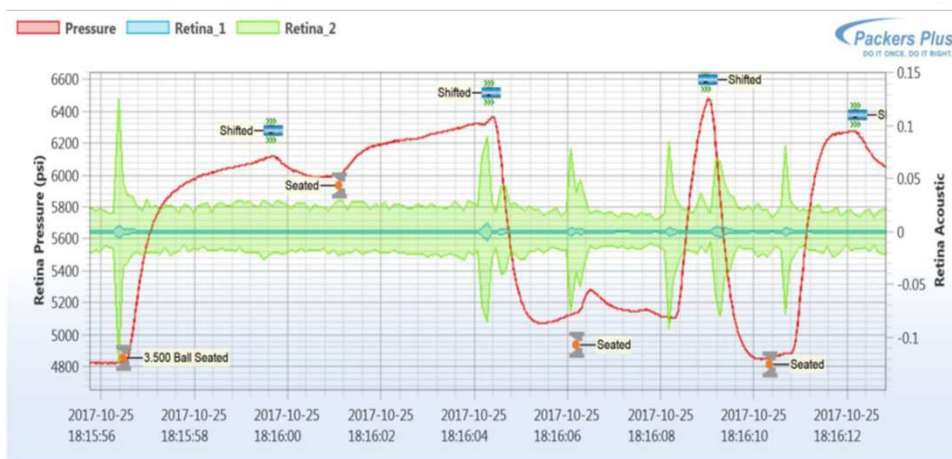
Predictable ball degradation



Get Immediate Feedback



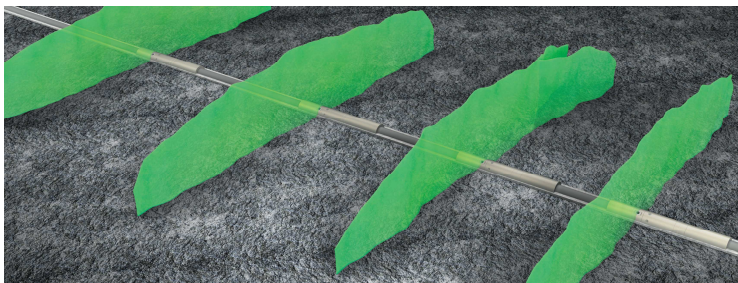
Understanding What's Going on Downhole



Argentina High Stage Counts



- Systems with 114 and 78 entry points using limited entry sliding sleeves

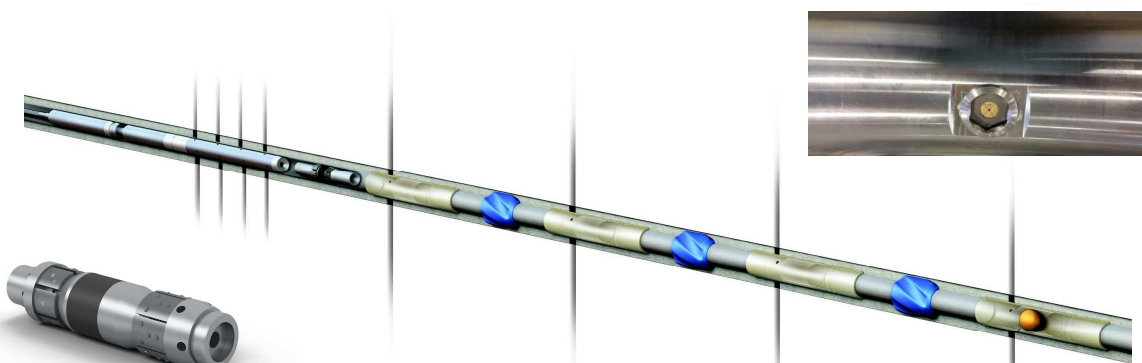


Poll Question

My Company has Considered Combining Different Completion Methods in a Well?



Hybrid Completion Systems for Extended Reach Laterals



Permian Basin Case Study

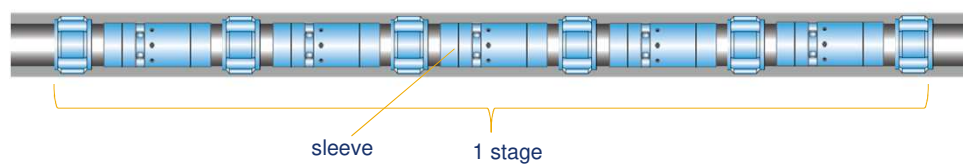


Challenge:

- Mitigating risk associated with wireline in extended reach laterals

Solution:

- 5-stage limited entry ball-drop at toe of the well
- 4 clusters per stage
- Acoustic monitoring system used to verify sleeves opening



Composite and Degradable Plugs



Composite Plug



Degradable Plug



Reduced Millout Time



- Composite plug length of 13.5-in.
- Well in Texas had 18 plugs and 60 perfs per stage
- Following stimulation (~100,000 bbl of fluid and 4 million pounds of proppant), all plugs milled out in an average of 13 minutes per plug



Degradable Plug Dissolution Rates



Full Dissolution (in days)

TEMP		FLUID					
°C	°F	Fresh	.1% KCl	1% KCl	3% KCl	8% KCl	15% KCl
20	68	-	-	-	-	-	532
45	113	-	224	69.0	28.3	11.6	9.8
60	140	-	98.1	14.8	7.0	4.8	4.4
75	167	-	19.5	7.8	5.0	3.7	2.9
90	194	-	17.8	4.6	3.5	2.2	2.0



Conclusions



- Growing onshore oil production is pushing the U.S. towards becoming the world's top producing nation
- Onshore unconventional plays lead the growth with longer laterals, higher stage counts and higher proppant loading
- Commodity prices remain suppressed but technology advances continue to reduce breakeven prices
- Partnering with service companies that can provide a variety of completion solutions to eliminate mill-out, minimize non-productive time, and reduce operational risk offers a pathway for retaining profitability in a challenging business environment



Thank You

Questions?