An Overview of Multistage Completion Systems for Hydraulic Fracturing

SPE Webinar
11-03-16

W. Aaron Burton
Unconventional Oil and Gas Training
waaronburton@uogtraining.com
www.linkedin.com/in/waaronburton
www.uogtraining.com

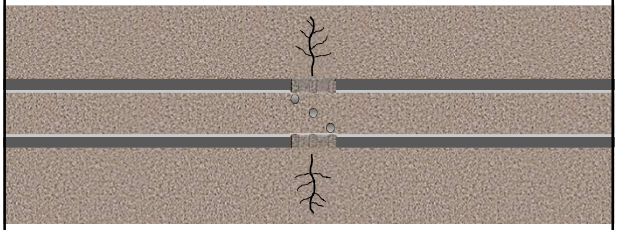
Check out my video blog on multistage completion systems:
www.uogtraining.com/blog

What is "Shale"

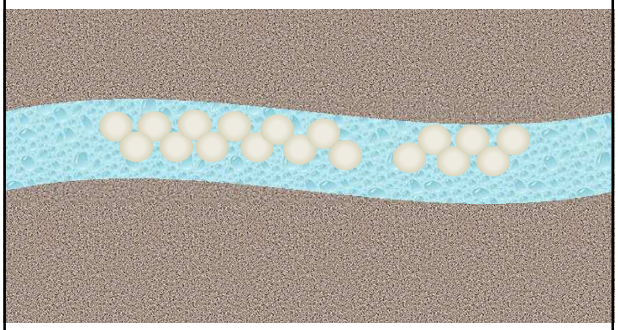
- Low-permeability formation (typically <5 mD)
- Consolidated formation
- Can be shales, but may be sandstones or carbonates

A reservoir that requires multistage hydraulic fracturing to produce at economical rates

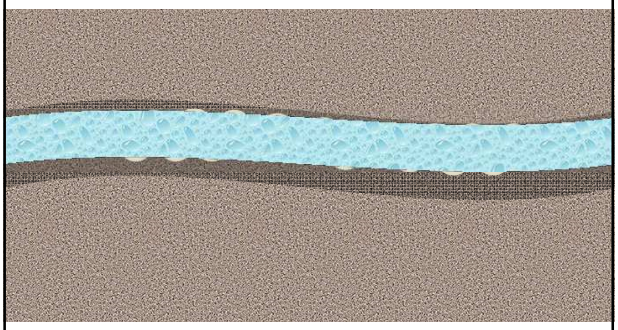
Fracture Treatment Objectives



Creating Artificial Permeability

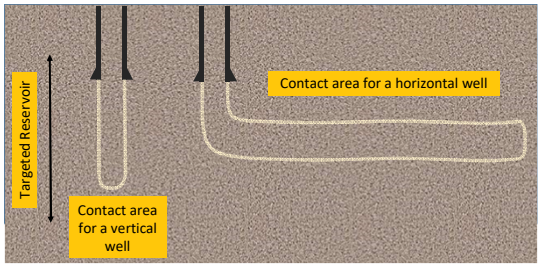


Creating Artificial Permeability



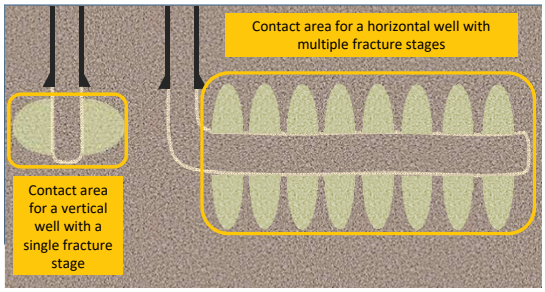
Increasing Reservoir Contact

Horizontal Wells



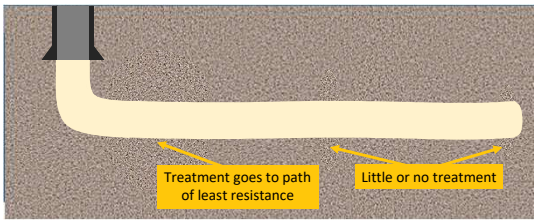
Increasing Reservoir Contact

Multistage Hydraulic Fracturing

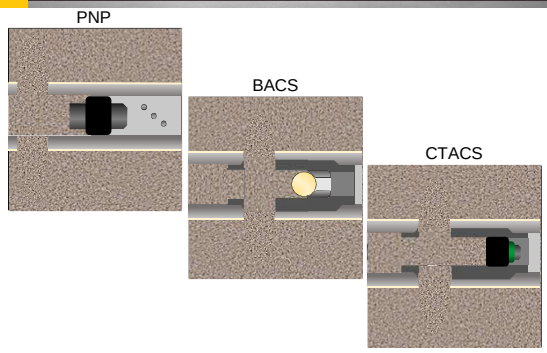


Why are Multistage Completions Required

- Fractures will grow to the path of least resistance
  - Drilling stresses
  - Drilling damage
  - Friction losses
  - Formation weakness

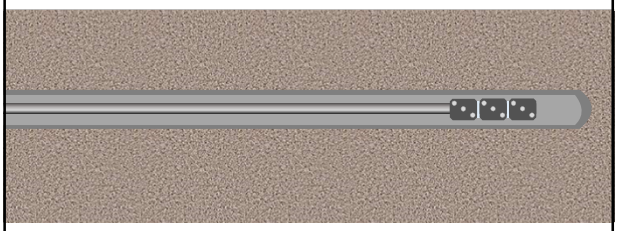


Completions Overview

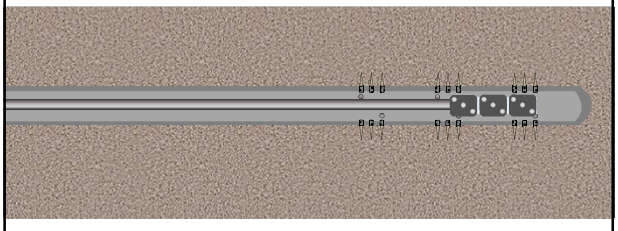


Plug-and-Perf (PNP)

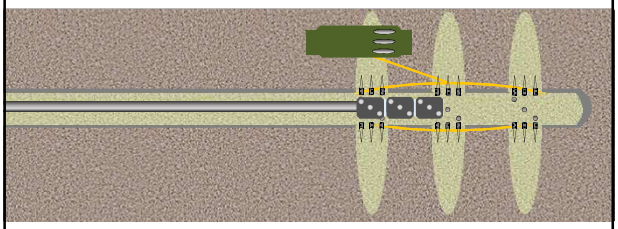
Plug-and-Perf (PNP)



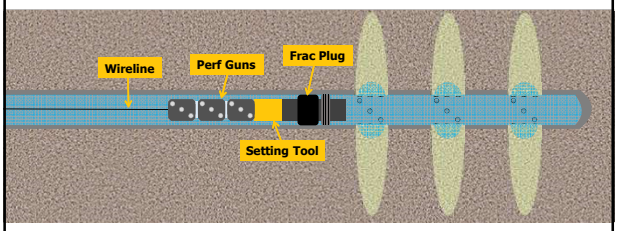
Plug-and-Perf (PNP)



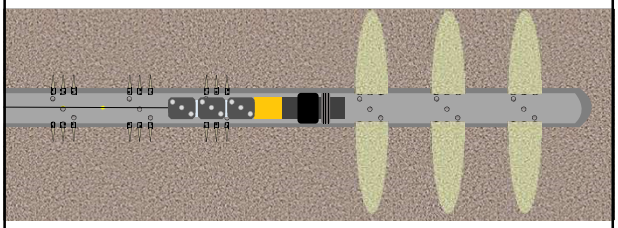
Plug-and-Perf (PNP)



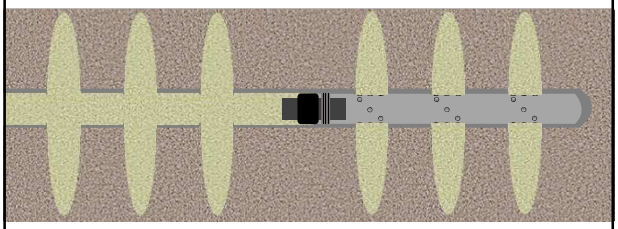
Plug-and-Perf (PNP)



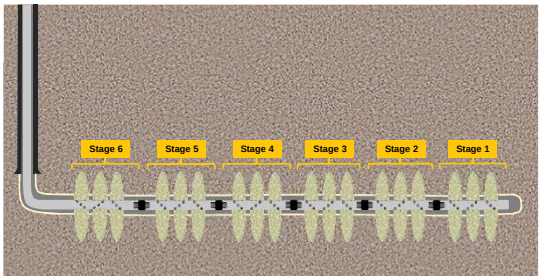
Plug-and-Perf (PNP)



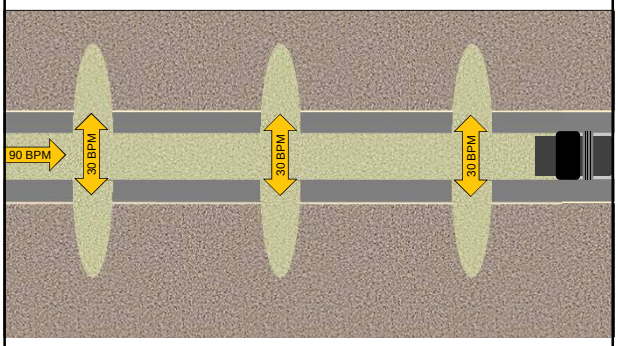
Plug-and-Perf (PNP)



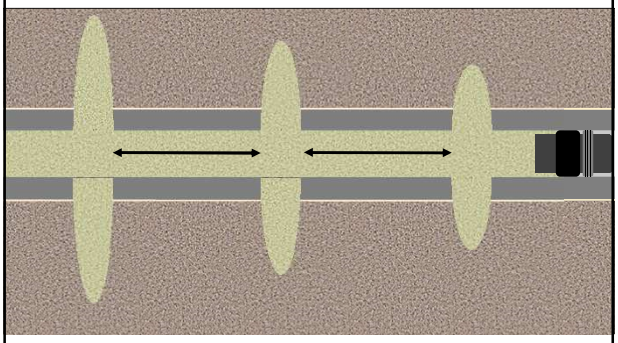
Plug-and-Perf (PNP)



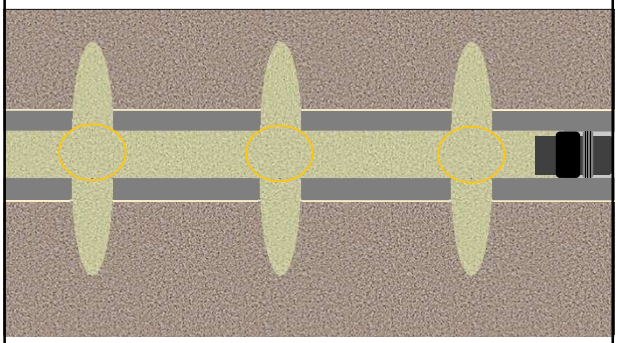
Fluid Distribution Through Clusters



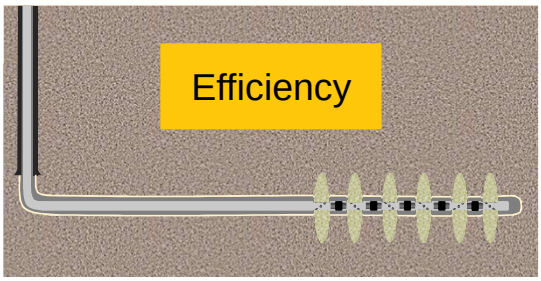
Fluid Distribution Due to Friction Losses



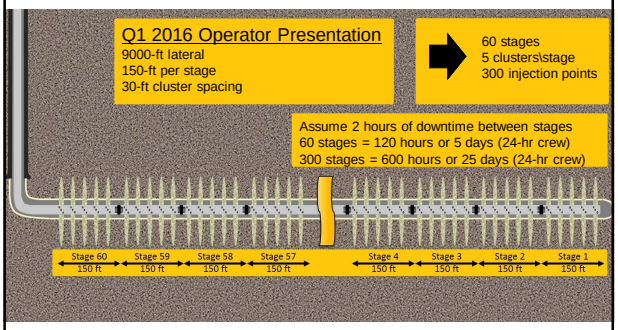
Limited-Entry Perforating



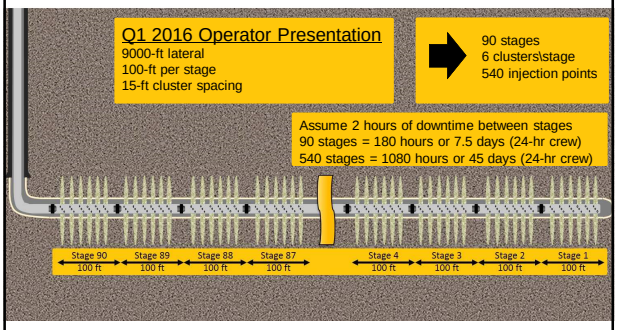
Why Use Cluster Perforations



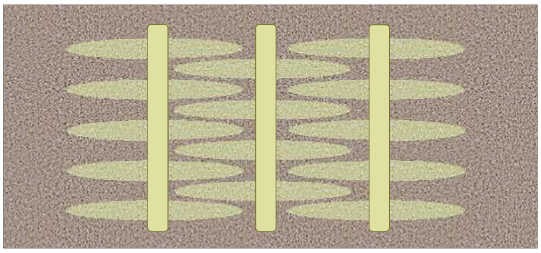
Completion Optimization



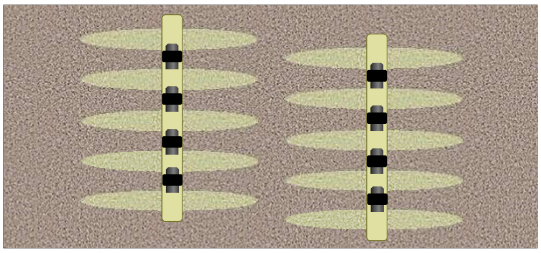
Completion Optimization



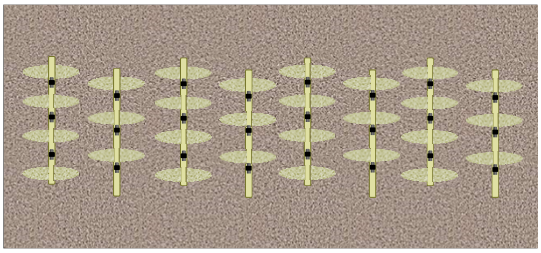
Zipper Fracs



Simultaneous Fracturing Operations



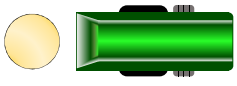
Large Scale Simultaneous Fracturing



Large Bore Permanent Frac Plug

Permanent frac plug with a large bore diameter designed to leave in the well and produce through

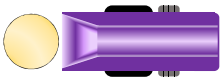
- Eliminates the mill out of the frac plugs after the well has been fractured
- Disintegrating frac balls used to make the entire system interventionless
- Large diameter makes wellbore intervention below the plug possible
- Possible to remove, but difficult and time consuming



Disintegrating Frac Plug

Frac plug made of disintegrating material that removes itself from the wellbore given the right fluids, temperatures, and time.

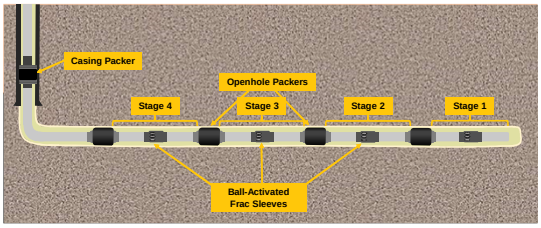
- Eliminates the mill out of the frac plugs after the well has been fractured
- Disintegrating frac balls used to make the entire system interventionless
- After the plug disintegrates, there is a full production diameter



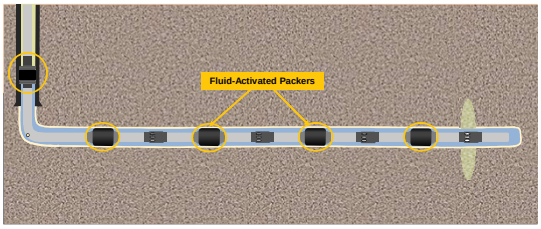
Questions

???

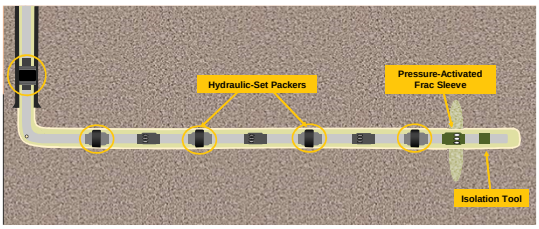
BACS Wellbore Overview



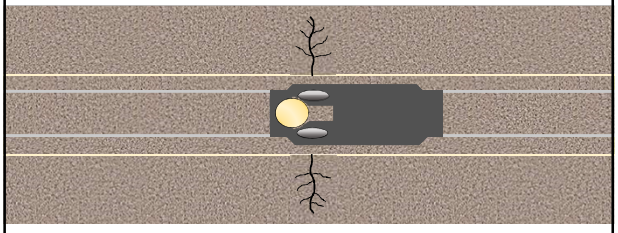
BACS Using Fluid-Activated Packers



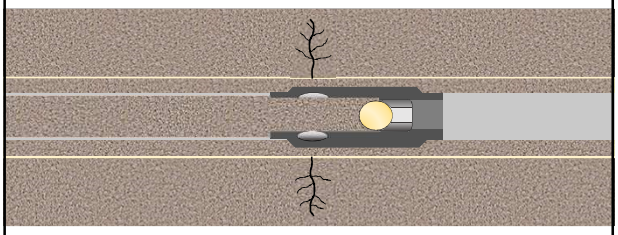
BACS Using Hydraulic-Set Packers



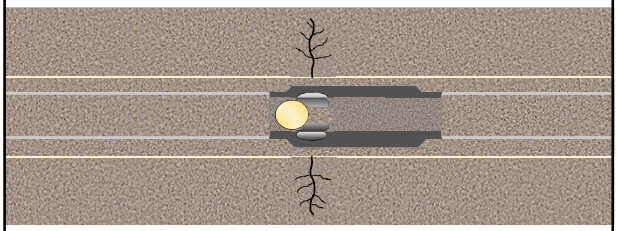
Ball-Activated Frac Sleeves



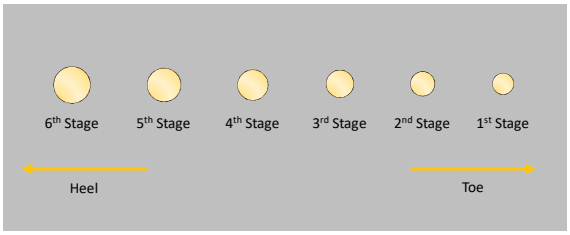
Ball-Activated Frac Sleeves



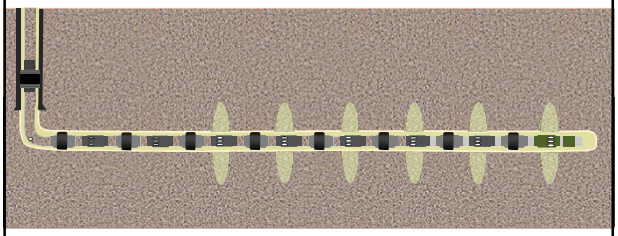
Ball-Activated Frac Sleeves



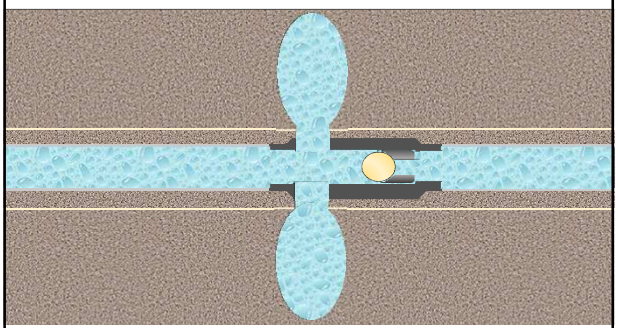
Frac Balls



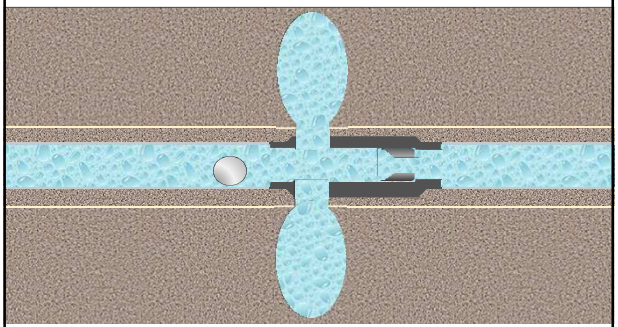
Fracturing Procedure



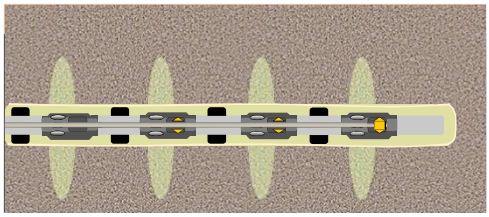
Post-Frac Operations with BACS



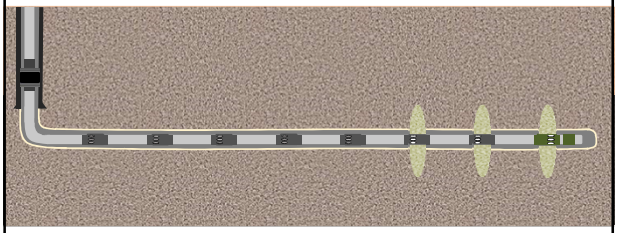
Post-Frac Operations with BACS



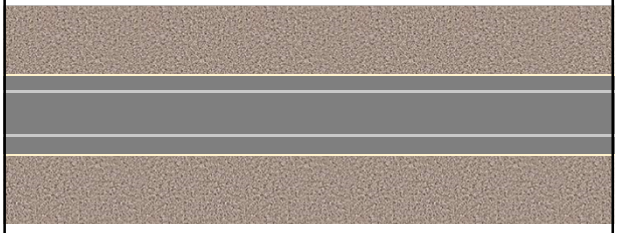
Reclosable Frac Sleeves



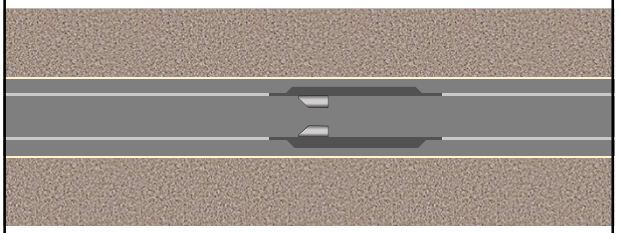
Cemented Ball-Activated Frac Sleeves



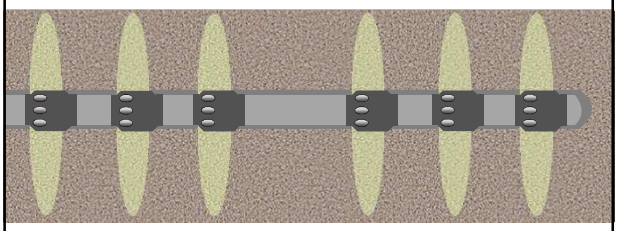
Cement Wiper Plug



Cementing Ball-Activated Frac Sleeves



Cemented Sleeves w/ Multiple Entry Points

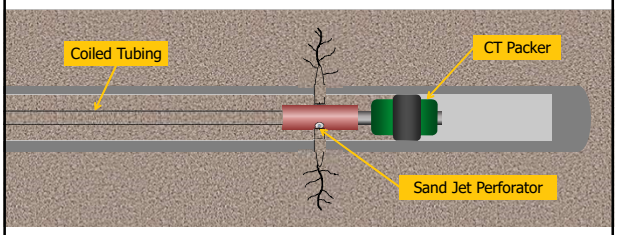


Questions

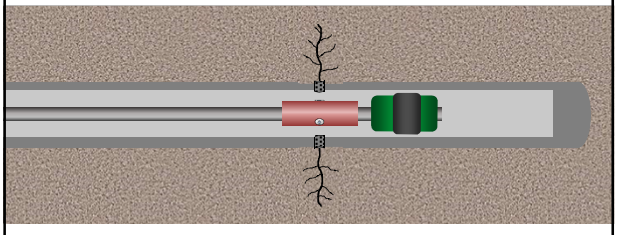
???

CTACS with Sand Jet Perforating

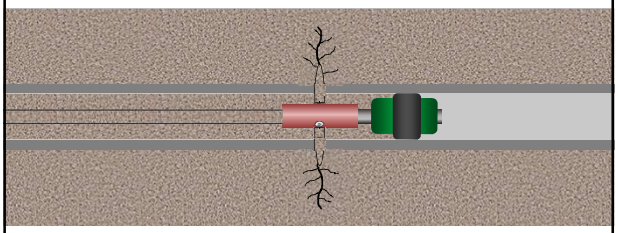
CTACS with Sand Jet Perforating



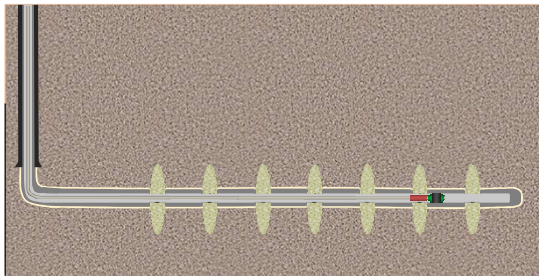
CTACS with Sand Jet Perforating



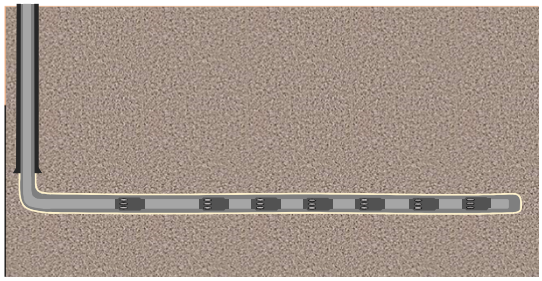
CTACS with Sand Jet Perforating



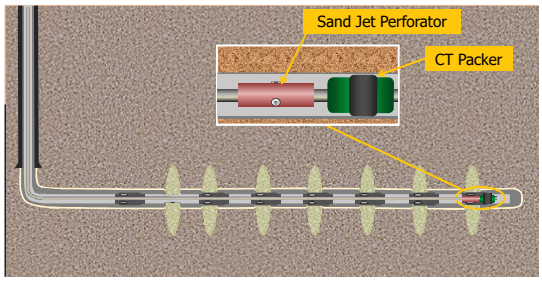
CTACS with Sand Jet Perforating



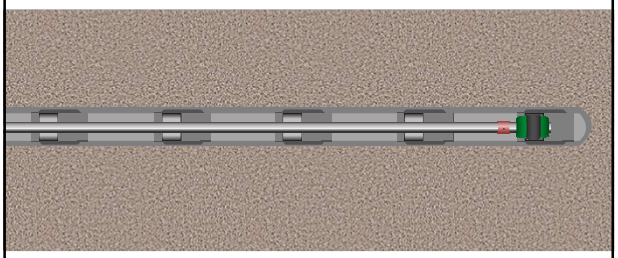
CTACS with Frac Sleeves



CTACS with Frac Sleeves

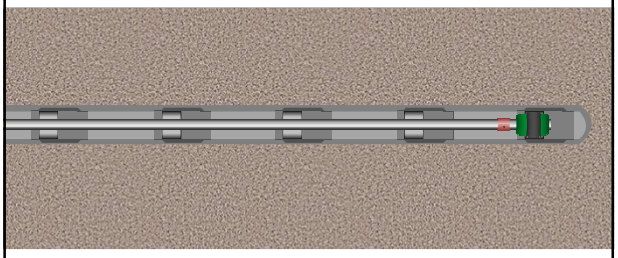


Reclosable Coiled-Tubing-Activated Sleeves



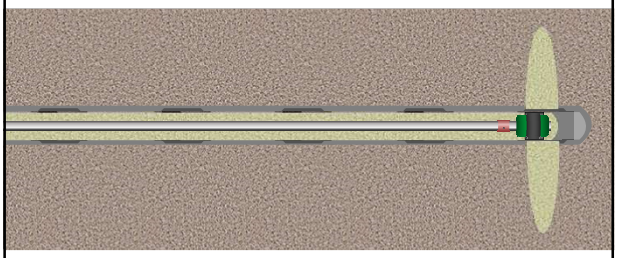
Reclosable Sleeves for the Primary Frac

Traditional Toe-to-Heel Fracturing



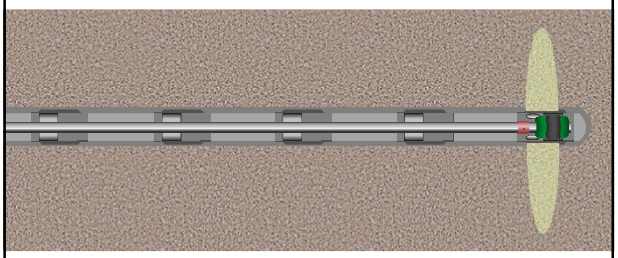
Reclosable Sleeves for the Primary Frac

Traditional Toe-to-Heel Fracturing



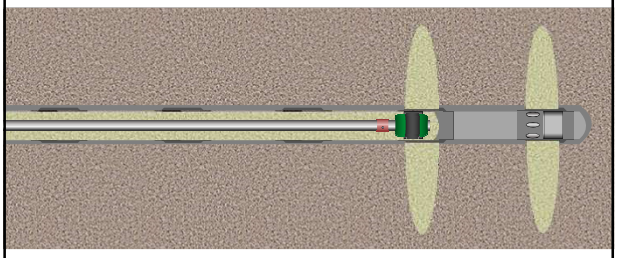
Reclosable Sleeves for the Primary Frac

Traditional Toe-to-Heel Fracturing



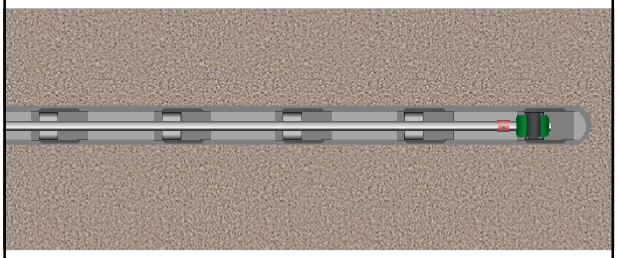
Reclosable Sleeves for the Primary Frac

Traditional Toe-to-Heel Fracturing



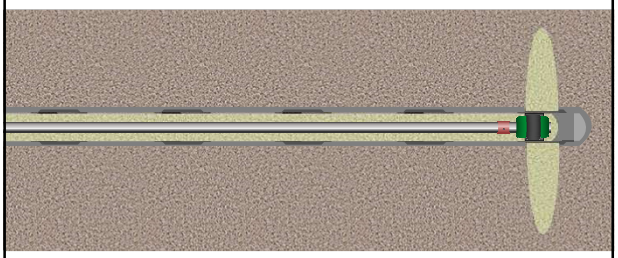
Reclosable Sleeves for the Primary Frac

Out-of-Order Fracturing



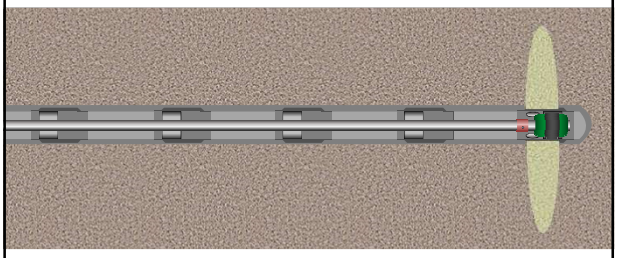
Reclosable Sleeves for the Primary Frac

Out-of-Order Fracturing



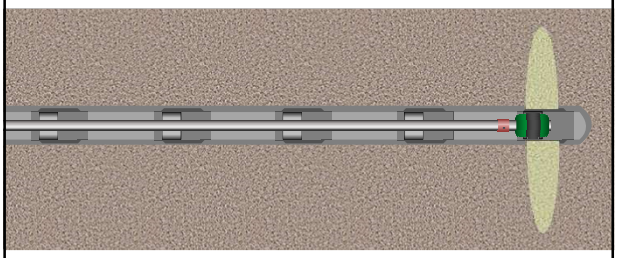
Reclosable Sleeves for the Primary Frac

Out-of-Order Fracturing



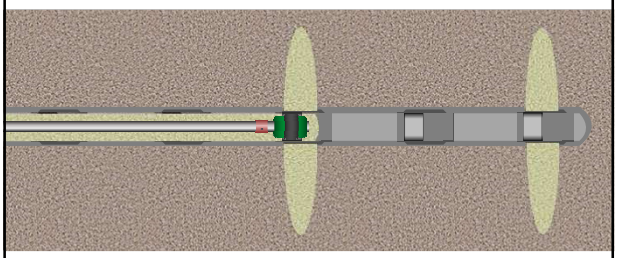
Reclosable Sleeves for the Primary Frac

Out-of-Order Fracturing



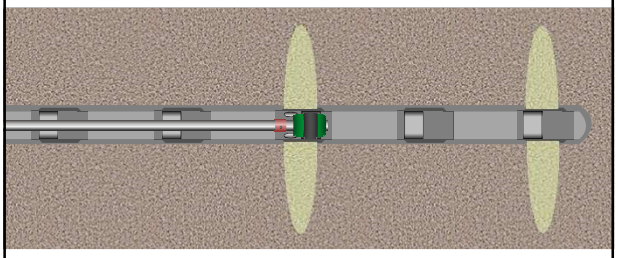
Reclosable Sleeves for the Primary Frac

Out-of-Order Fracturing



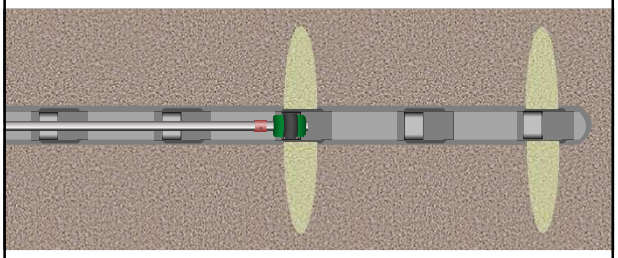
Reclosable Sleeves for the Primary Frac

Out-of-Order Fracturing



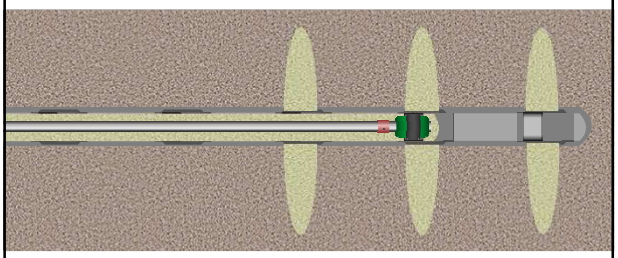
Reclosable Sleeves for the Primary Frac

Out-of-Order Fracturing



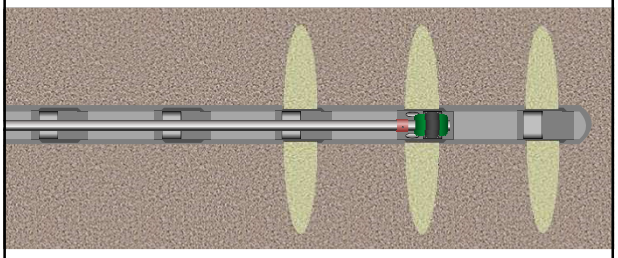
Reclosable Sleeves for the Primary Frac

Out-of-Order Fracturing

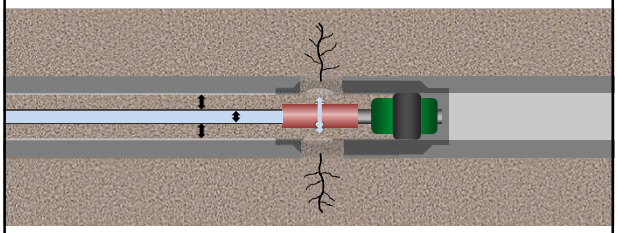


Reclosable Sleeves for the Primary Frac

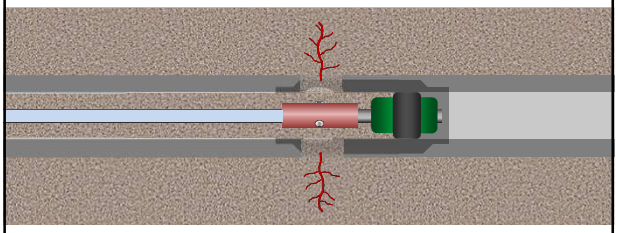
Out-of-Order Fracturing



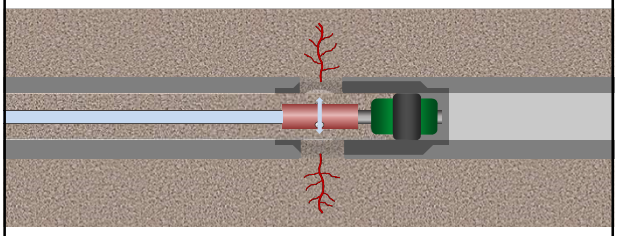
CTACS Fracturing Operations



CTACS Contingency Options



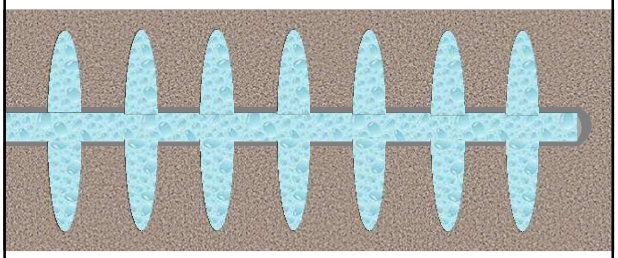
CTACS Contingency Options



Questions

???

Refracturing

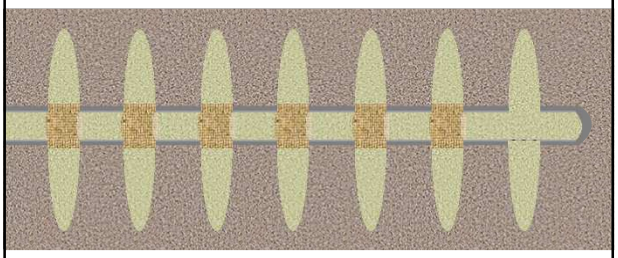


Refracturing – Well Selection

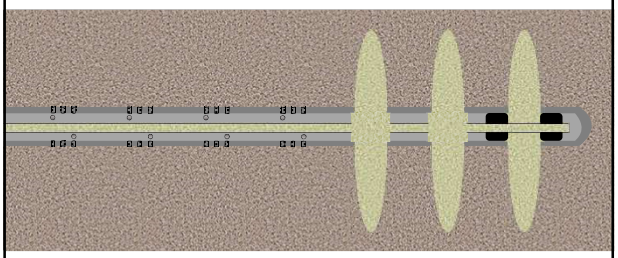
Identifying good candidates

- Wells that had large stage spacing
- Wells that used the wrong stimulation treatment for that area
- Known cause of production decline
  - Proppant crushing
  - Proppant embedment
  - Proppant rearrangement
  - Loss of near wellbore proppant
  - Proppant scaling
  - Improper breakdown or removal of fluids and gels

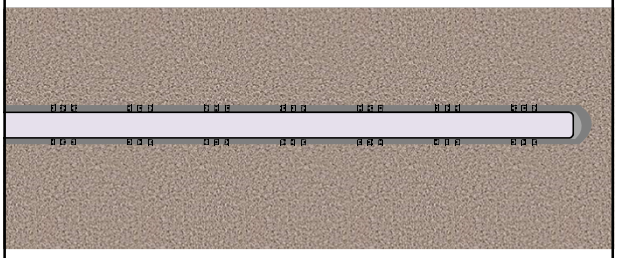
Diverters



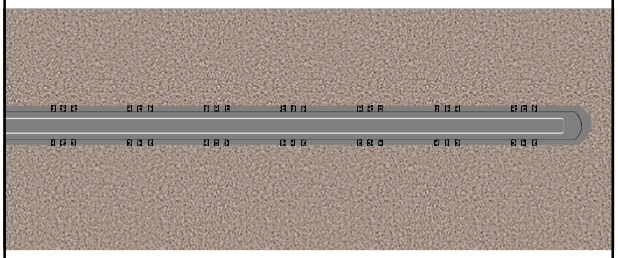
Straddle Isolation



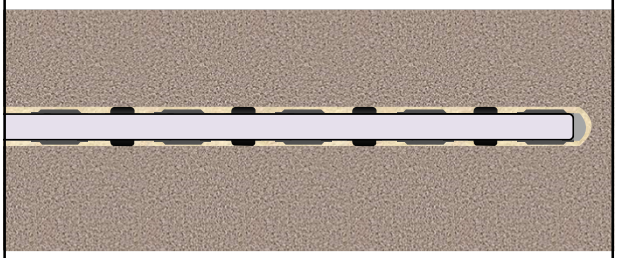
Expandable Liners



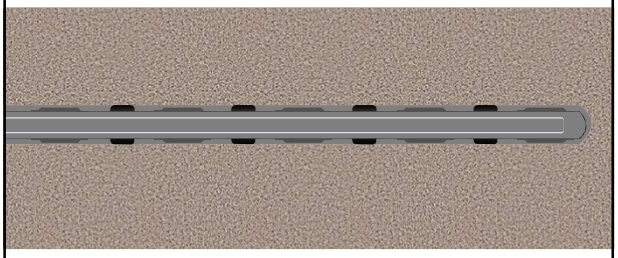
Additional Tubing String



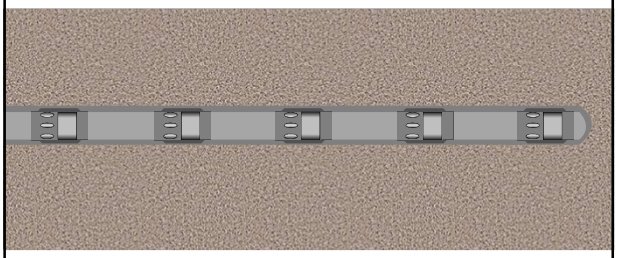
Openhole Refracturing Considerations



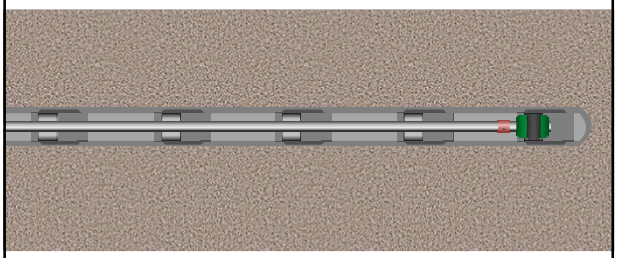
Openhole Refracturing –Tubing String



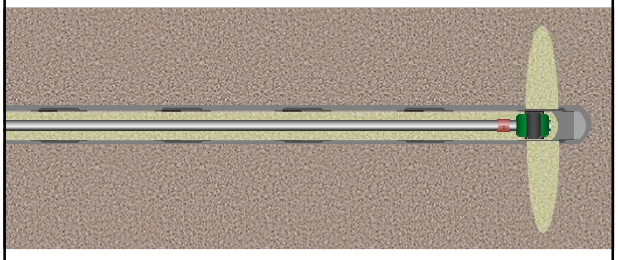
Reclosable Sleeves for Refracturing



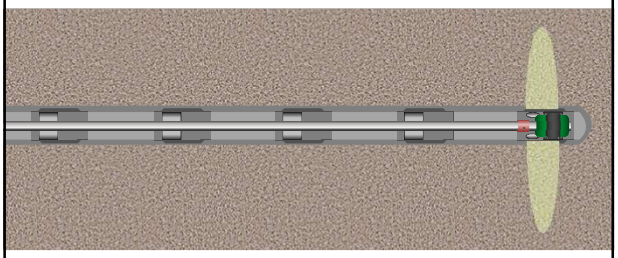
Reclosable Sleeves for Refracturing



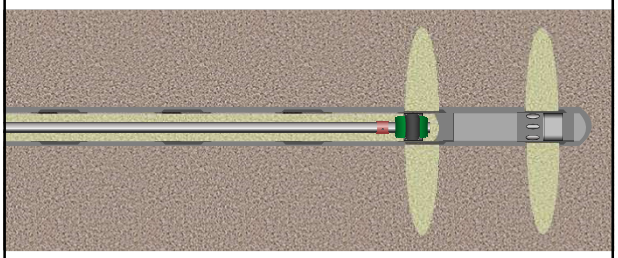
Reclosable Sleeves for Refracturing



Reclosable Sleeves for Refracturing



Reclosable Sleeves for Refracturing



Questions

???

Completion Comparison

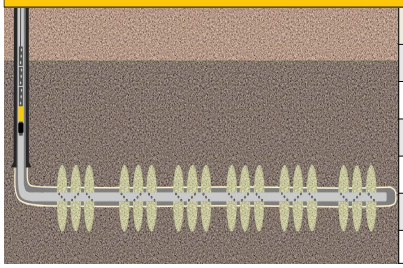
Each Completion System

- Provides effective multistage isolation
- Requires different services
- Isolates with either a cemented liner or openhole completion
- Diverts with multiple or single entry points

How do we choose the right completion system?

Plug-and-Perf Completions

Benefits and Considerations

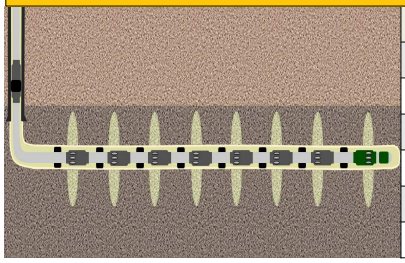


- Virtually unlimited number of stages
- Flexible stage placement
- Contingency options due to full diameter
- Requires PP, WL and/or CT
- Lack of frac operation efficiency
- Requires plug mill-out, full production diameter
- Limited refrac options

Modified from **SPE166431** • Unconventional Completions: Which is the Right one for Your Application

Ball-Activated Completion Systems

Benefits and Considerations



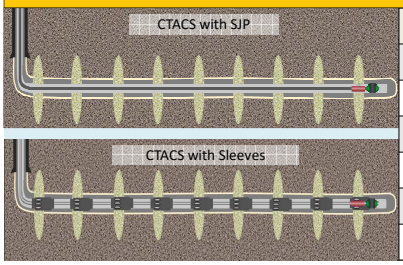
- Limited number of stages
- Stage placement is fixed once completed
- Limited contingencies, diameter restrictions
- Requires PP units to perform fracturing
- Nonstop fracturing operations
- No millout required, reduced diameter
- Reclosable sleeves

Modified from **SPE166431** • Unconventional Completions: Which is the Right one for Your Application

SPE166431 • Unconventional Completions: Which is the Right one for Your Application

Coiled Tubing-Activated Completion Systems

Benefits and Considerations



Virtually unlimited number of stages
Fixed with sleeves, Flexible with SJP
Contingency options with full ID and CT
Requires PP and CT units for fracturing
Frac shuts down to move CT
No millout required, full production diameter
Limited refrac options or reclosable sleeves

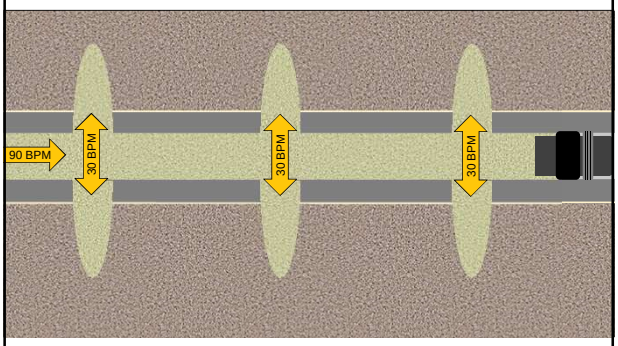
Modified from **SPE166431** • Unconventional Completions: Which is the Right one for Your Application

Completion Comparison

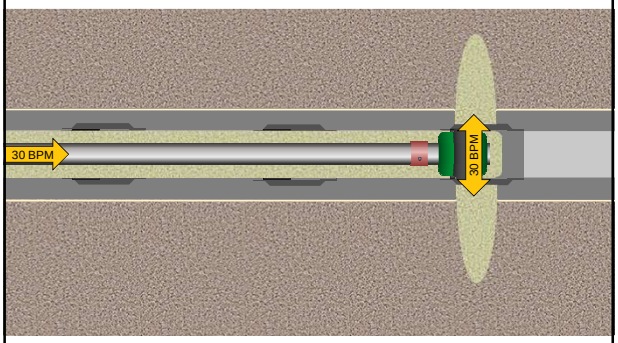
	PNP	BACS	CTACS
Number of Stages	Virtually unlimited	Limited	Virtually Unlimited
Frac Placement	Flexible	Fixed	Fixed with sleeves, Flexible with SJP
Contingency	Full diameter	Limited	Full diameter
Frac Logistics	PP, WL, CT	PP	PP, CT
Frac Operations	RU/RD between stages	Nonstop	Frac shuts down to move CT
Post Frac	Mill out plugs, Full Diameter	No mill out, Restricted ID	No mill out, Full Diameter
Refrac Options	Limited	Reclosable sleeves	Limited with SJP Reclosable sleeves

Modified from **SPE166431** • Unconventional Completions: Which is the Right one for Your Application

Multiple-Entry Fluid Distribution



Single-Entry Fluid Distribution



Multiple Entry vs. Selective Entry

Granite Wash Case History

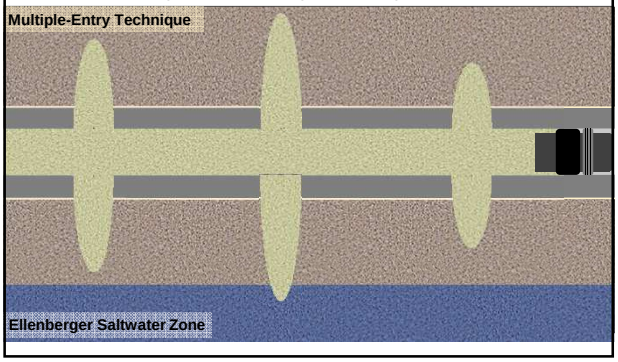
Table 1. Stimulation job results – Comparative Summary Table

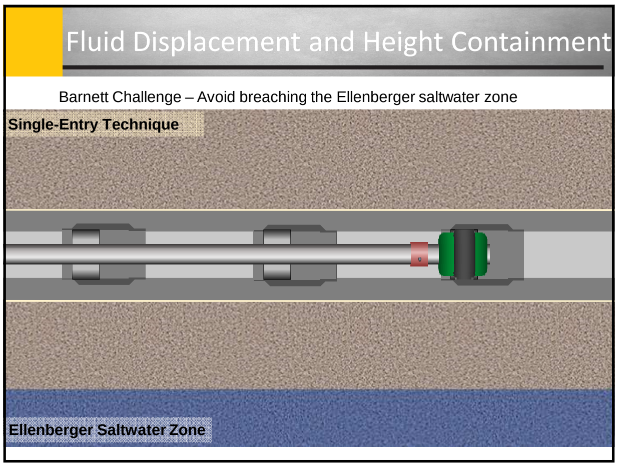
Parameter / Well:	A (Plug and Perf)	B (Targeted)	Variance
Number of Frac Stages:	10 (with 3 clusters per stage)	30	None
Frac Spacing (ft):	165	164	None
Fluids Type:	HCl Spearhead, Slickwater fluid	HCl Spearhead, Slickwater fluid	None
Proppant Type:	100 mesh sand, 40/70 Ottawa white and Resin Coated with 2% resin coating	100 mesh sand, 40/70 Ottawa white and Resin Coated with 2% resin coating	None
Total Clean Fluid Pumped (gal):	9,344,170	9,568,993	+2.4%
Total Proppant Placed (lbs):	3,675,280	3,772,380	+2.6%
Average Frac rate (bpm)	66	80	+20%
Average Treating Pressure range (psig)	5,852 to 6,801	4,125 to 6,935	-30% to +2%
Average HHP range:	13,889 to 16,387	3,004 to 5,517	-78% to -66%
Maximum HHP required:	20,030	6,993	-65%

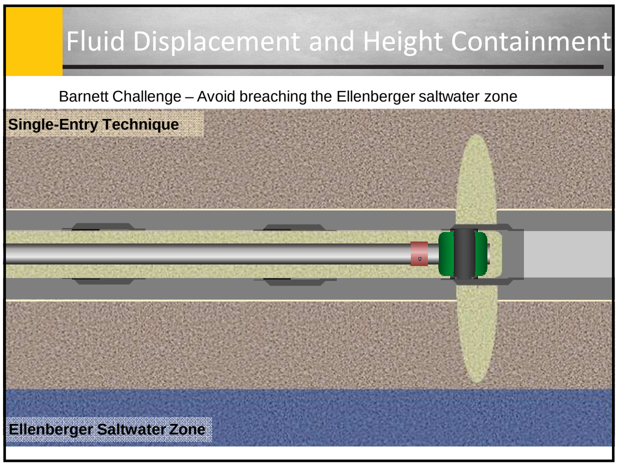
SPE 163820 • A Comparison of Proppant Placement, Well Performance, and Estimated Ultimate Recovery Between Horizontal Wells completed With Multi-Cluster Plug & Perf and Hydraulically Activated Frac Ports in a Tight Gas Reservoir

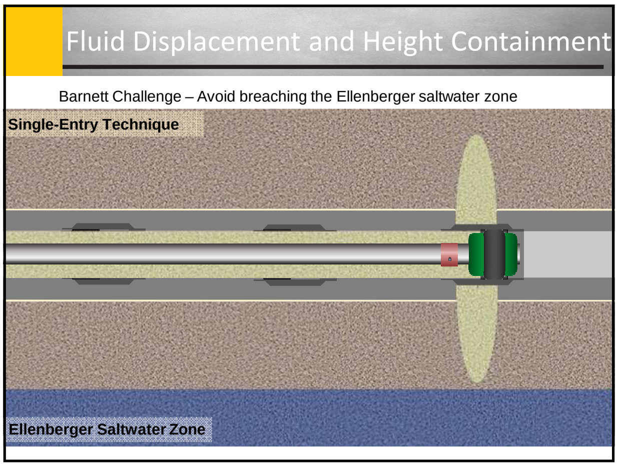
Fluid Displacement and Height Containment

Barnett Challenge – Avoid breaching the Ellenberger saltwater zone



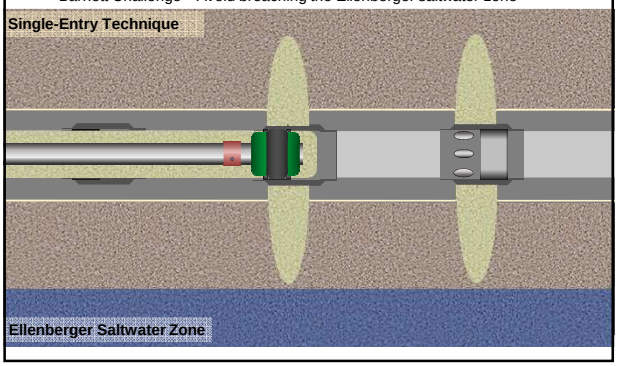

Fluid Displacement and Height Containment
Barnett Challenge – Avoid breaching the Ellenberger saltwater zone
Single-Entry Technique
Ellenberger Saltwater Zone


Fluid Displacement and Height Containment
Barnett Challenge – Avoid breaching the Ellenberger saltwater zone
Single-Entry Technique
Ellenberger Saltwater Zone


Fluid Displacement and Height Containment
Barnett Challenge – Avoid breaching the Ellenberger saltwater zone
Single-Entry Technique
Ellenberger Saltwater Zone

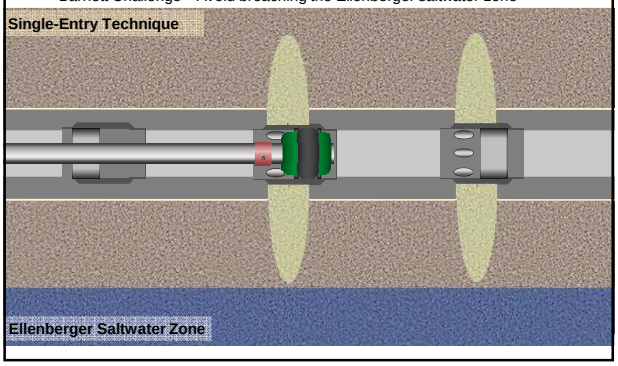
Fluid Displacement and Height Containment

Barnett Challenge – Avoid breaching the Ellenberger saltwater zone



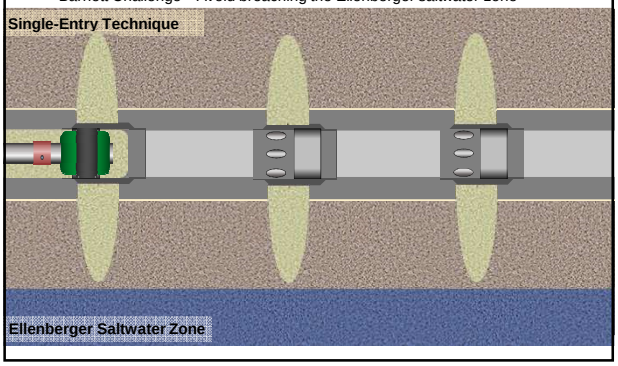
Fluid Displacement and Height Containment

Barnett Challenge – Avoid breaching the Ellenberger saltwater zone



Fluid Displacement and Height Containment

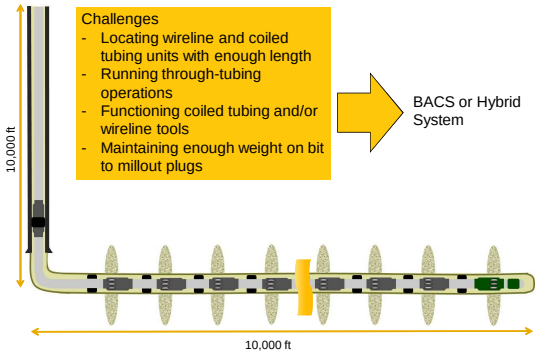
Barnett Challenge – Avoid breaching the Ellenberger saltwater zone



Wells with Longer Laterals

Challenges
- Locating wireline and coiled tubing units with enough length
- Running through-tubing operations
- Functioning coiled tubing and/or wireline tools
- Maintaining enough weight on bit to millout plugs

BACS or Hybrid System



Extended Number of Stages

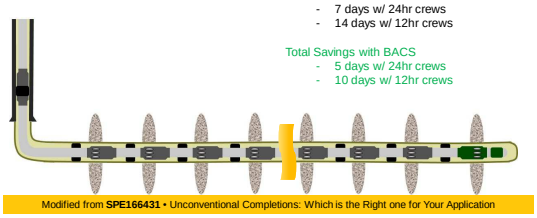
Assumptions:
- 40 stage frac job
- 1 hour/stage in frac plan
- No operational issues

- 3 hours RU/RD time between stages with PNP

BACS
40 hours total to stimulate
- 2 days w/ 24hr crews
- 4 days w/ 12hr crews

PNP
160 hours total to stimulate
- 7 days w/ 24hr crews
- 14 days w/ 12hr crews

Total Savings with BACS
- 5 days w/ 24hr crews
- 10 days w/ 12hr crews



Modified from **SPE166431** • Unconventional Completions: Which is the Right one for Your Application

Low Number of Stages

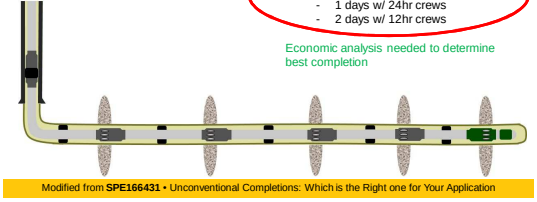
Assumptions:
- 5 stage frac job
- 1 hour/stage in frac plan
- No operational issues

- 3 hours RU/RD time between stages with PNP

BACS
5 hours total to stimulate
- 1 days w/ 24hr crews
- 1 days w/ 12hr crews

PNP
20 hours total to stimulate
- 1 days w/ 24hr crews
- 2 days w/ 12hr crews

Economic analysis needed to determine best completion



Modified from **SPE166431** • Unconventional Completions: Which is the Right one for Your Application

Appraisal Phase

- Objectives
  - Data gathering
  - Learn the formation/field
- Risks
  - Uncertain of stage placement during completion
  - Poorly drilled wells
  - Screen outs
- Completion Requirements
  - Stage placement on the fly
  - No OD increase of completion
  - Full diameter inside completion

Plug-and-Perf
CTACS with SJP

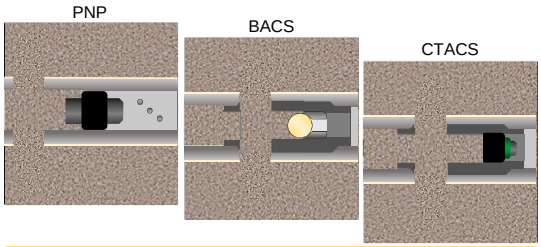
Development Phase

- Objectives
  - Cost savings
  - Efficient operations
  - Maximize Production
- Completion Options
  - BACS
    - Nonstop fracturing, improved logistics, overall efficiency
  - CTACS
    - Recovery from screen out, height containment, shortage of space
  - PNP
    - Simultaneous operations, shortage of slurry components

Fracturing Considerations

- Fracturing logistics
  - Besides pressure pumping, what other services are required for the frac job
  - What are the costs of the other services
  - Do nonstop fracturing operations have any benefit
- Fluid displacement
  - How accurate the fluid is placed is dependent on the completion
- Effect of the completion
  - The type of completion directly effects the frac job
  - Completion equipment can limit pump rates, slurry concentrations, pressure ratings, and other parameters

Conclusion



Thank You

Contact Info

W. Aaron Burton
Unconventional Oil and Gas Training
waaronburton@uogtraining.com
www.linkedin.com/in/waaronburton
http://www.unconventionaloilandgastraining.com

https://www.linkedin.com/company/unconventional-oil-and-gas-training
https://www.facebook.com/unconventionaloilandgastraining

Check out my video blog on multistage completions for hydraulic fracturing:
http://www.unconventionaloilandgastraining.com/blog

Unconventional Oil and Gas Training