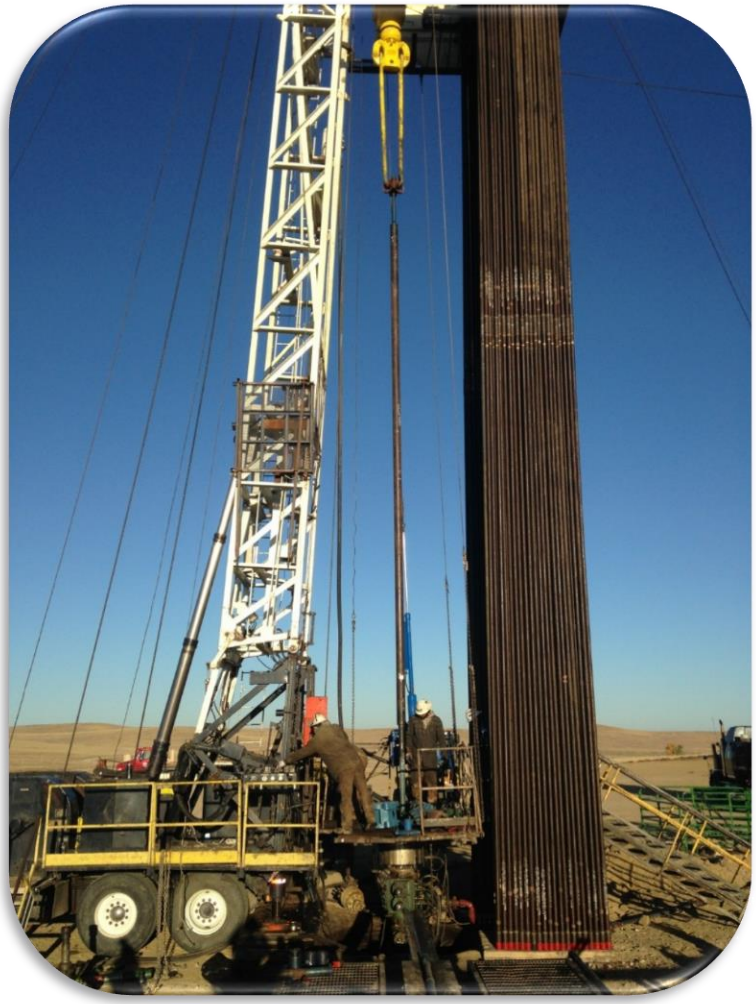
Expandable Liners

Well Recompletions and ReFracs

Topics Covered

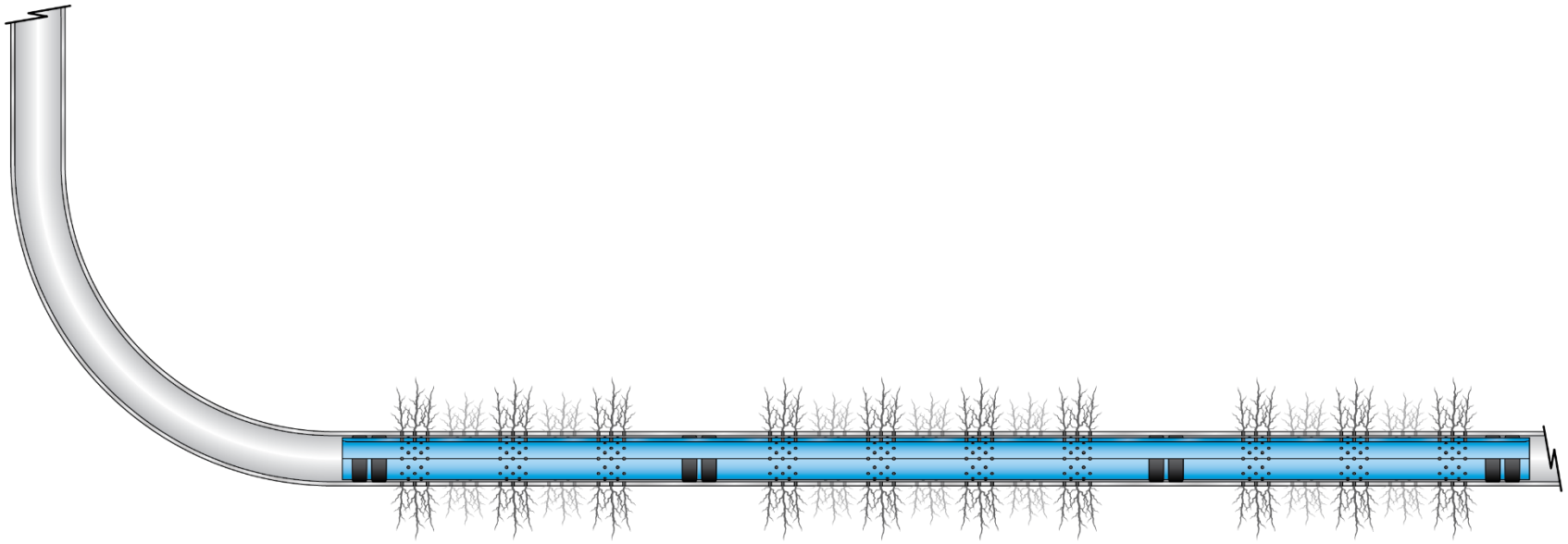
- The Problem & Solution
- Expandable Tubular Components
- Mechanics of Expansion
- Prepping to Run Expandables
- Delaware Basin Case Study
- DJ Basin Case Study



Problem – Isolating Existing Completion Designs

- Mechanically isolating existing wellbores with multiple flow paths and being able to frac at high rates/pressures

-Perforated zones as well as open & cemented frac sleeves



Solution-Expandable Tubulars

Expansion Video (short clip)

Expandable Liner Components

- Expandable Liner
  - –Low yield material desired-Mohawk preferred
  - –Low carbon content
  - –High Fracture toughness
  - –Adequate wall thickness
  - –Carbon Steel and Exotics – H2S/CO2

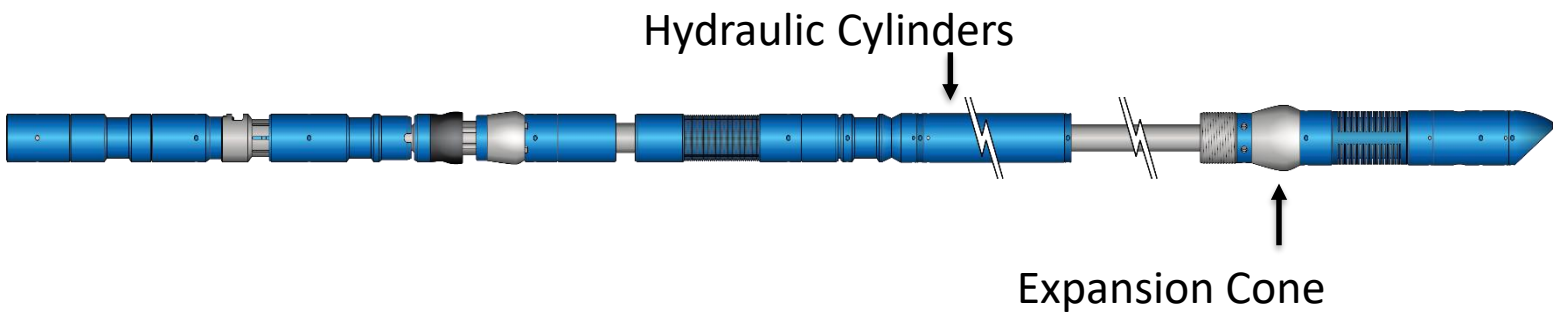
- Connections enable patch to be deployed over long lengths
  - –Connections must have pressure integrity after expansion
  - –Expandable Systems have been qualified in high Dog legs up to 45 degree/100 ft

- Mechanical Isolation (Seals)
  - –Must be able to withstand high loads typical of modern frac designs
  - –Not all seals are created equal

Mechanics of Expansion

- **Mechanical expansion is desired – quicker operation (1,000 ft per hour or faster)**
  - Straight over pull on the work string drives the expansion cone through the expandable liner

- **Hydraulic expansion is reserved for high load situations & seals – slower operation (100 ft per hour)**
  - Hydraulic cylinders in the running tool convert differential pressure to a mechanical force at the expansion cone (no over pull on work string required)
  - Running tool capable of exerting 200 kips of force at the expansion cone (4 times force needed for normal expansion)



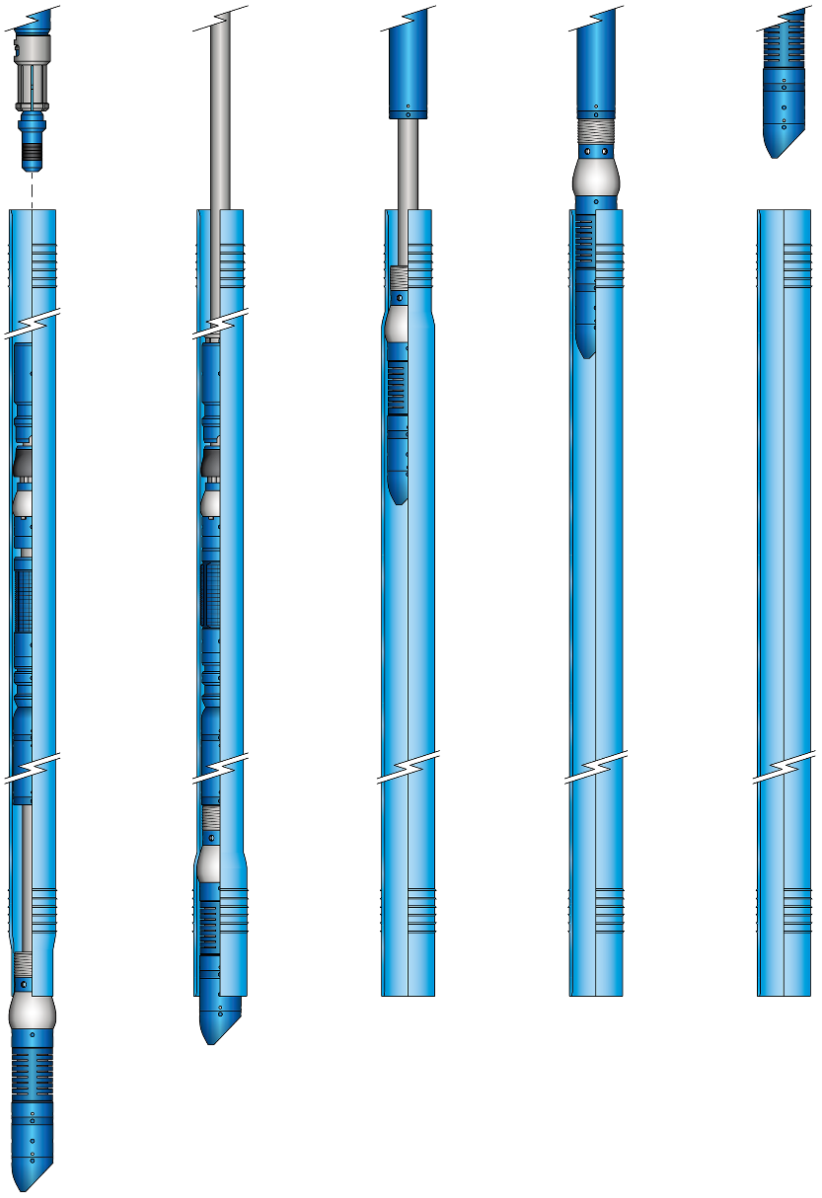
Liner Expansion

1. Make up tool,Liner, workstring ,then RIH

2. Circulate to close valve for hydraulic expansion

3. Expand by pulling through the plain pipe. Upper seal may be hydraulically expanded

4. Pull out top of liner POOH and rig down



Prepping for Running Expandables

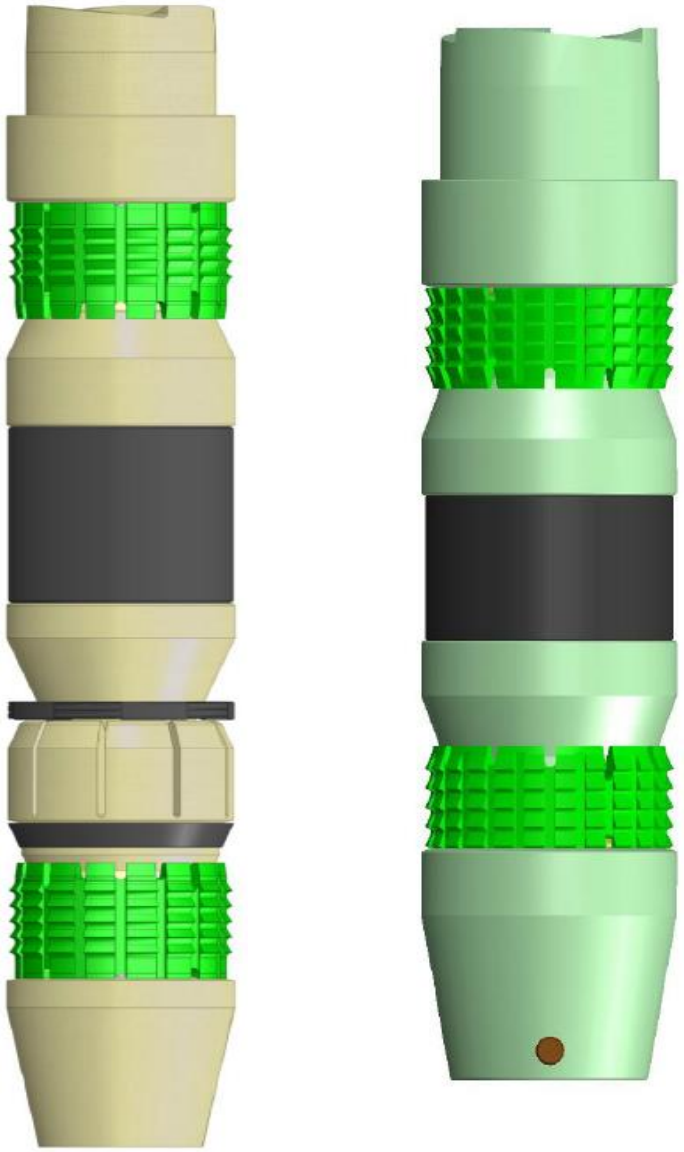
- Pre-Job Planning
  - Torque and drag modeling
  - Workstring selection
  - Rig selection
  - Anticipated hook loads for expansion
  - Bottom hole temperatures
  - Desired frac pressures
  - Frac plugs needed

- Wellbore Cleanout
  - How clean is the wellbore (lateral)
  - Should an expandable liner be installed in this well???
  - Does well hold full column of fluid-not a go/no-go

Frac Plug Options

- 4-1/2” Applications
  - ID range 3.259”- 3.416”
  - Qualified specifically for patch ID
- 5-1/2” Applications
  - ID range: 3.956”- 4.387”
  - Standard 5” plugs work in this range

- Beveled nose critical for smooth entry into expandable liner
- Pump down accessories available for certain scenarios
- Service Companies should have best practices for running plugs through patch



Refrac – DJ Basin

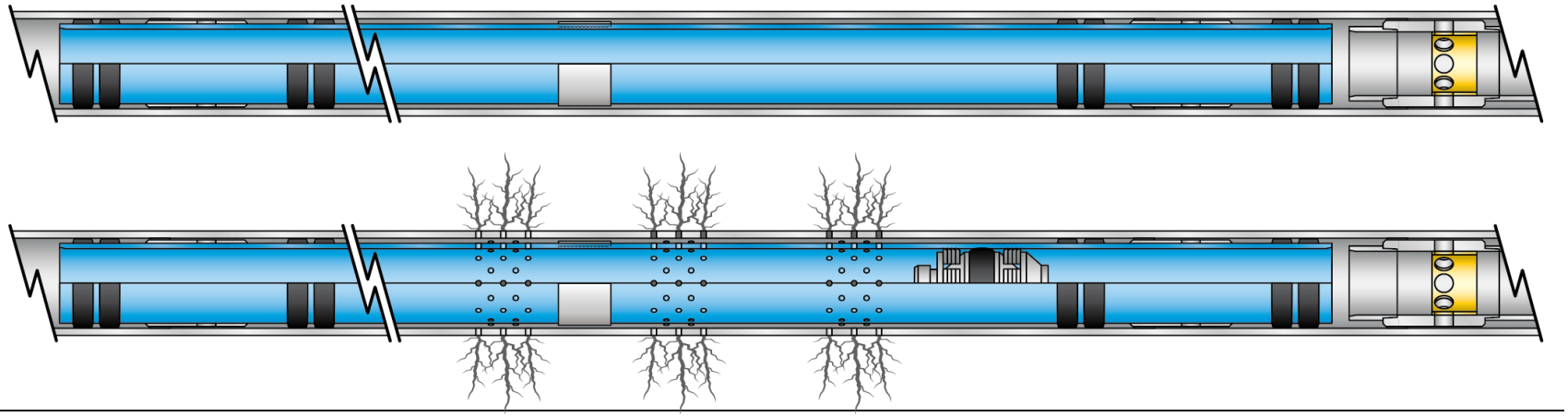
- Niobrara well originally completed and frac'ed in 2012 (26 stages/6.1 MM pounds of proppant)
- 4-1/2" 13.5# Casing
- 7,253 ft liner expanded in the lateral
- 3.321" Expanded Liner ID
- 46 Stages pumped
- 7.8 MM pounds of proppant pumped
- Oil production increased from 22 BPD to 293 BPD
- Gas production increased from 10,000 BTU to 26,000 BTU

Summary of Operations

- Drift run (debris recovered) – 42 hours
  - Had to work thru a few tight spots
  - Spotted lube across the lateral
  - Sheared drain sub and flexed tubing 10 times
- 2nd Mohawk Drift run – 31 hours
- 3rd Mohawk Drift run (no debris) – 33 hours
- Expandable liner make up - 8 hours
- Running inner string – 5 hours
- TIH – 12 hours
- Liner expansion **(7253 ft of liner expanded)** – 11.5 hours
- POOH – 5 hours
- 6 Days total

ReFrac – Delaware Basin

- 1st Bone Spring well originally completed and frac'd in 2012 (4 stages 8,600 – 11,200)
- 5-1/2" 17# Casing
- 3,246 ft liner expanded in the horizontal
- 4.218" Expanded Liner ID
- 22 Staged pumped 5.1+ MM pounds of proppant placed
- IP doubled from original frac and forecasted EUR tripled



Summary of Operations

- Drift run (debris recovered) – 48 hours
  - Rotating mills with swivel over lateral section
  - Slow progress due to low fluid levels
  - Had to work thru a few tight spots
  - Spotted lube across the lateral
  - Sheared drain sub and flexed tubing 10 times
- 2nd Mohawk Drift run (no debris) – 33 hours
- Expandable liner make up - 7 hours
- Running inner string – 3.25 hours
- TIH – 7 hours
- Liner expansion **(3246 ft of liner expanded)** – 8 hours
- Pressure testing and POOH – 6 hours
- 4.5 Days total

Society of Petroleum Engineers

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Refracturing Technology Restores Profitability of Older Unconventional Wells in Southeast New Mexico

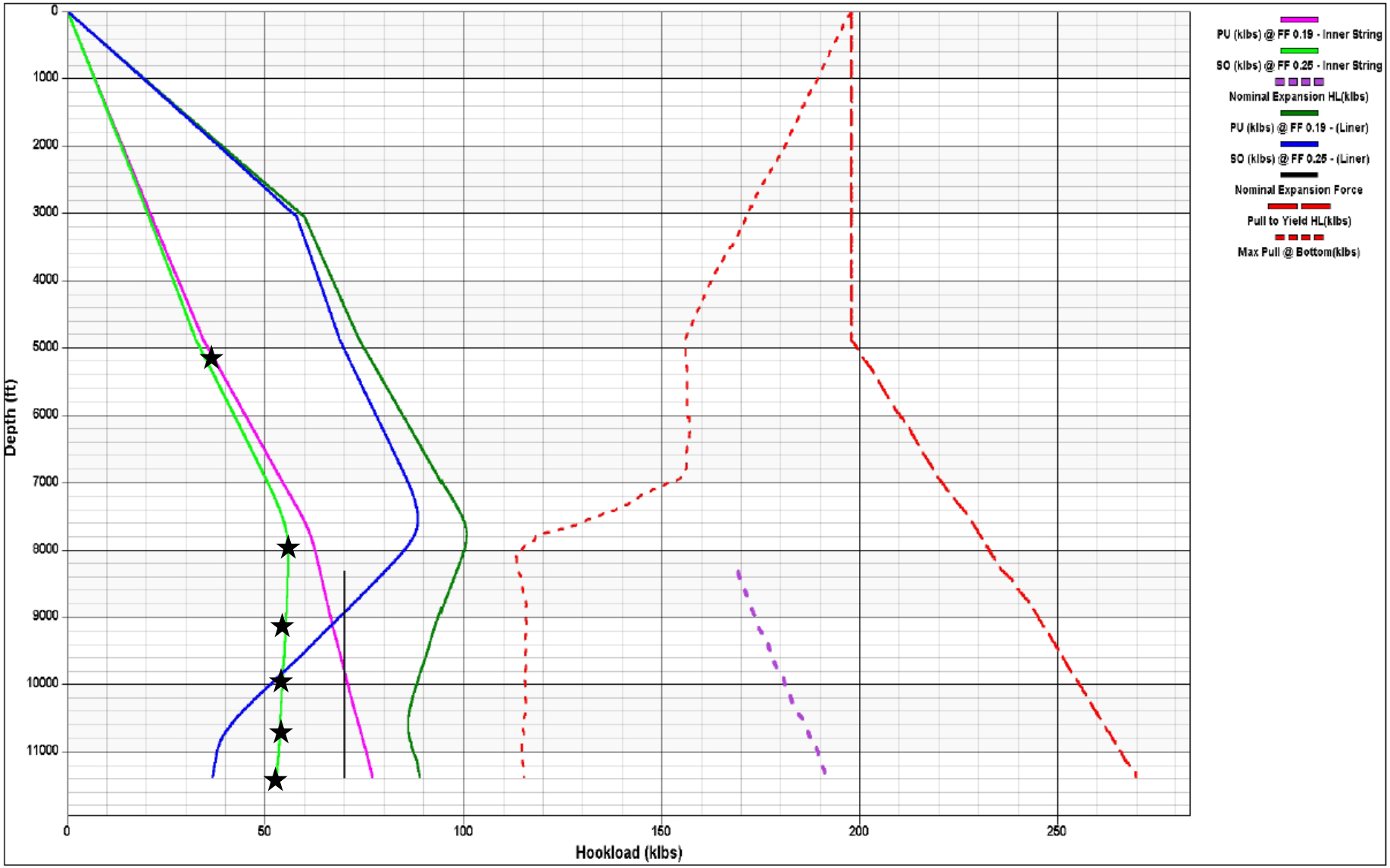
4 Candidate wells compared (1 cemented liner and 3 expandable liners)

Conclusions:

- Mechanical isolation with expandables is a more reliable and effective method than cementing casing
- Expandable technology showed the potential for consistent repeatability in terms of mechanical isolation and operational costs
- Well preparation and lateral cleanouts are the most critical components for success
- Pre-job prep and technical support by service provider is key to success
- Significant production increases can be achieved by pumping tighter cluster spacing

Predicted Torque and Drag

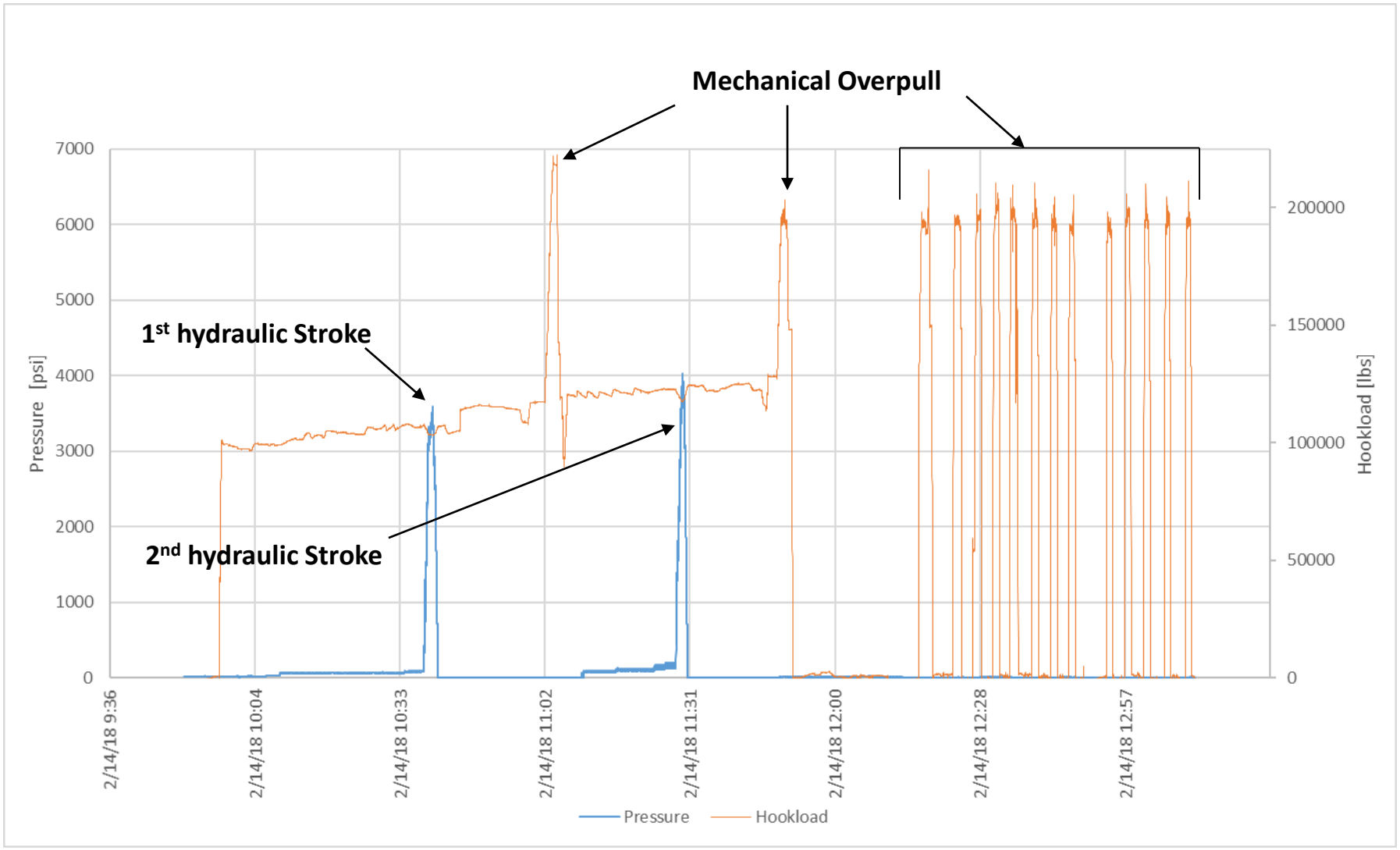
Mohawk Energy
expanding the limits



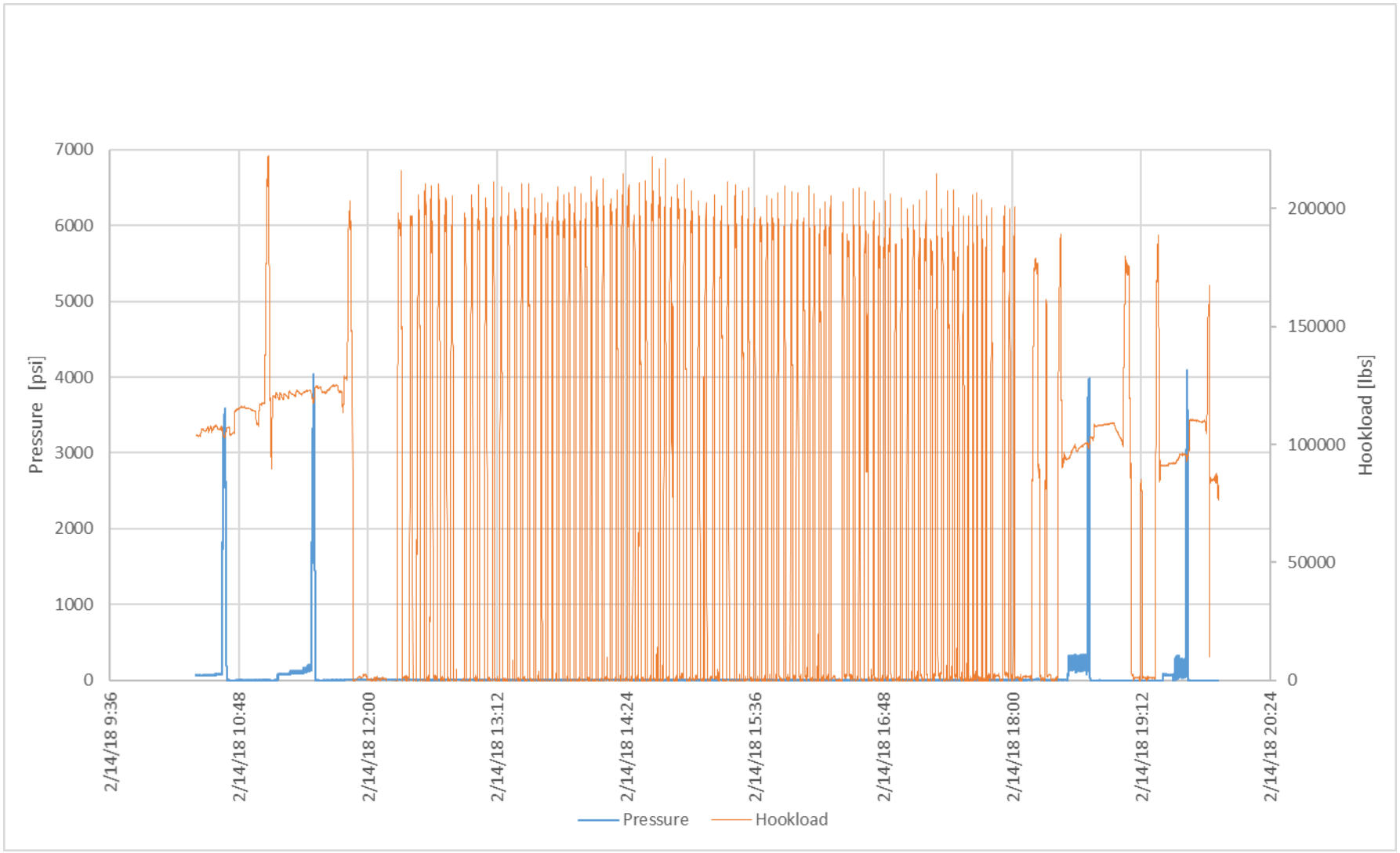
Data Acquisition

- Measuring hook load and pump pressure.
- Allows diagnosis and qualification of equipment operation downhole

Start of Job


Mechanical Overpull
1st hydraulic Stroke
2nd hydraulic Stroke
Pressure [psi]
Hookload [lbs]
7000
6000
5000
4000
3000
2000
1000
0
200000
150000
100000
50000
0
2/14/18 9:36
2/14/18 10:04
2/14/18 10:33
2/14/18 11:02
2/14/18 11:31
2/14/18 12:00
2/14/18 12:28
2/14/18 12:57
Pressure
Hookload

Data for Entire Job (4 Strokes)



Questions?