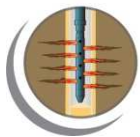


Best Practices for Plug and Perf in Acid Fractured Stimulation Wells, Completed in Tight Gas Carbonate Reservoir

Abdallah Mulhim, Jon Hansen, Saudi Aramco
Zouhir Zaouali, Alan Salsman, Schlumberger

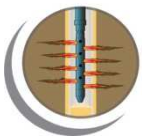
IPS 2014



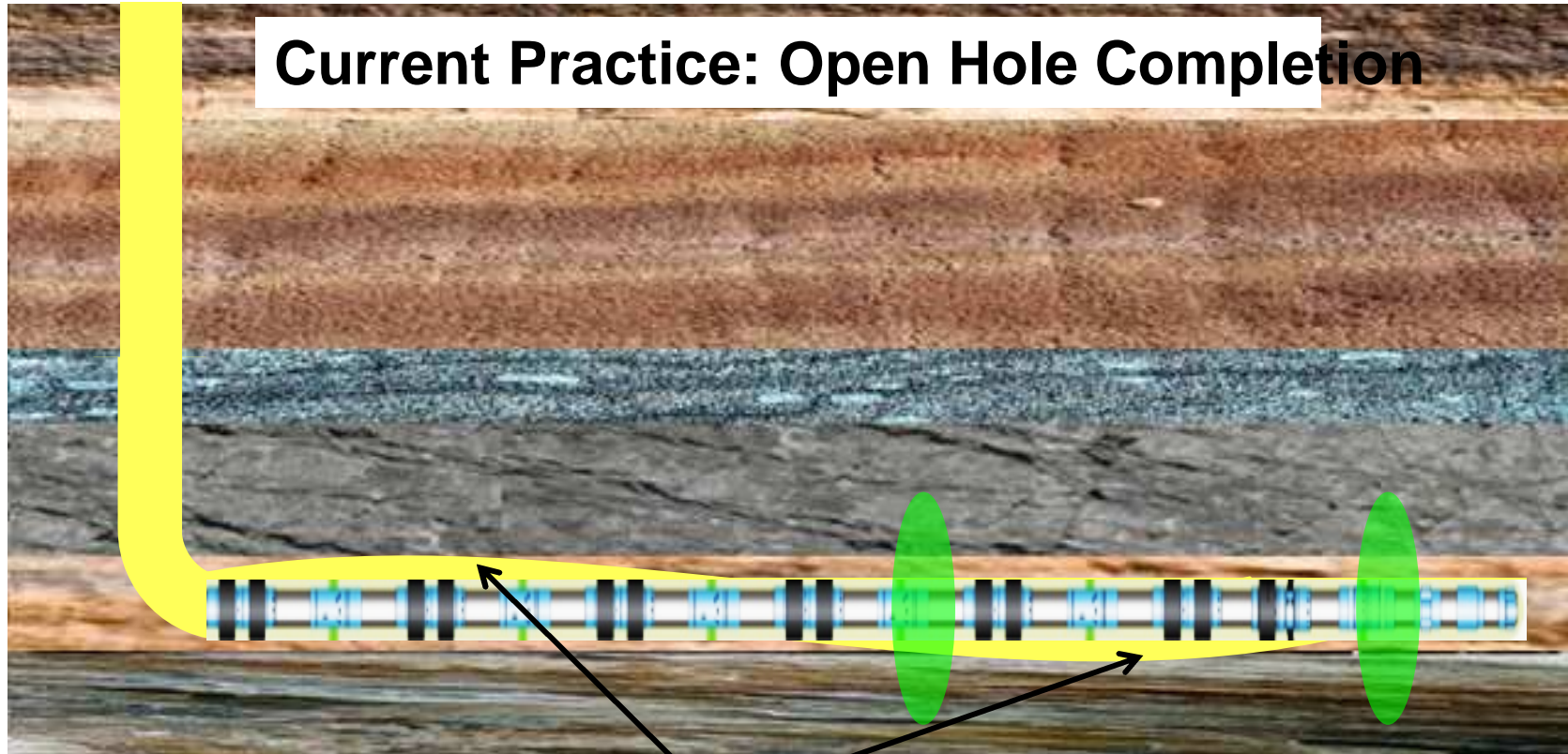
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Agenda

- Why Cemented Liner Plug & Perf in Tight Carbonate Gas
- Plug & Perf Workflow in Tight Gas Carbonate
- Case Study
- Results and Recommendations

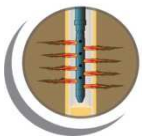


Why Cemented Liner Plug & Perf?

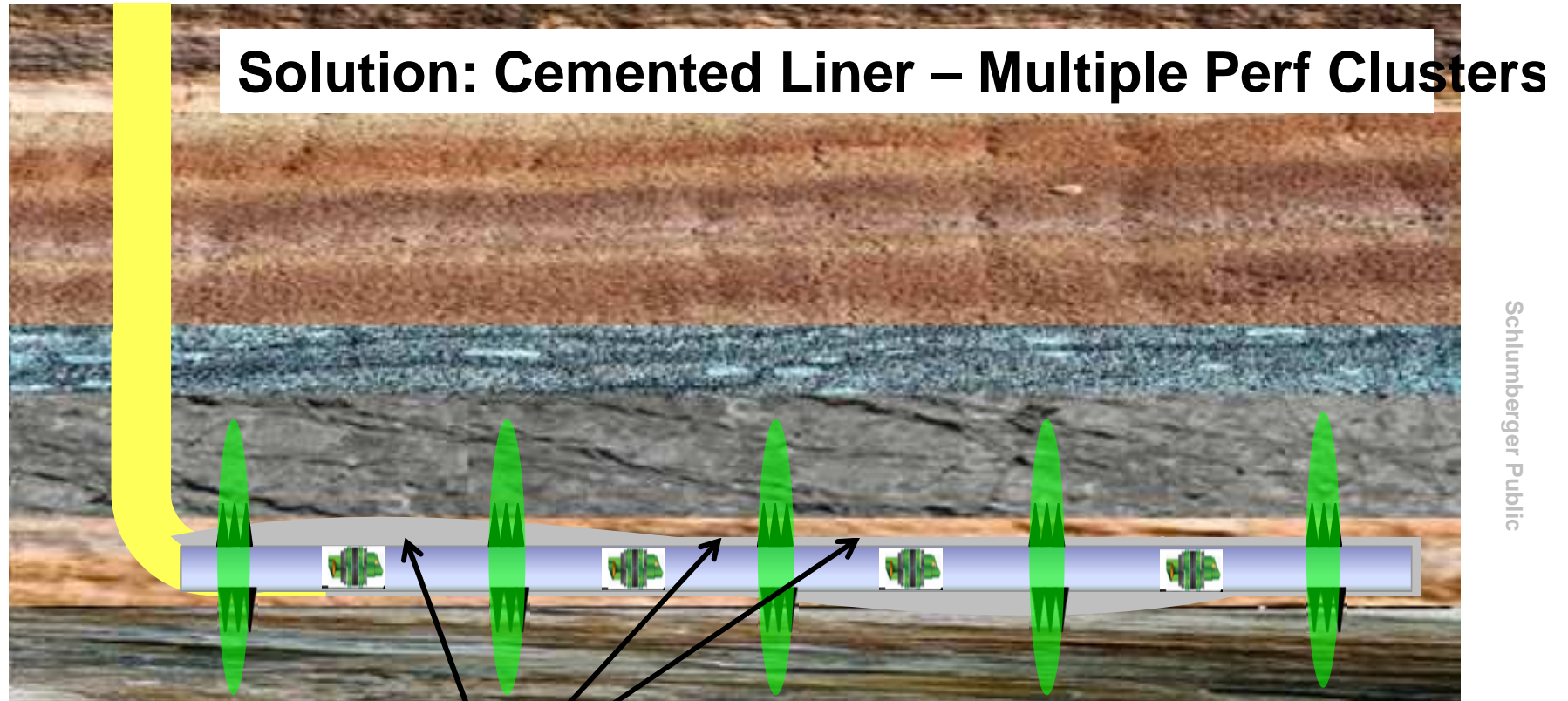


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- **Loss of Isolation - Acid Dissolving Rock Behind Packer**
- **Short Isolation length (<20 ft)**
- **Limited number of Fracs**

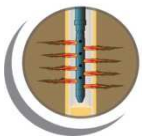


Why Cemented Liner Plug & Perf?



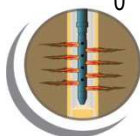
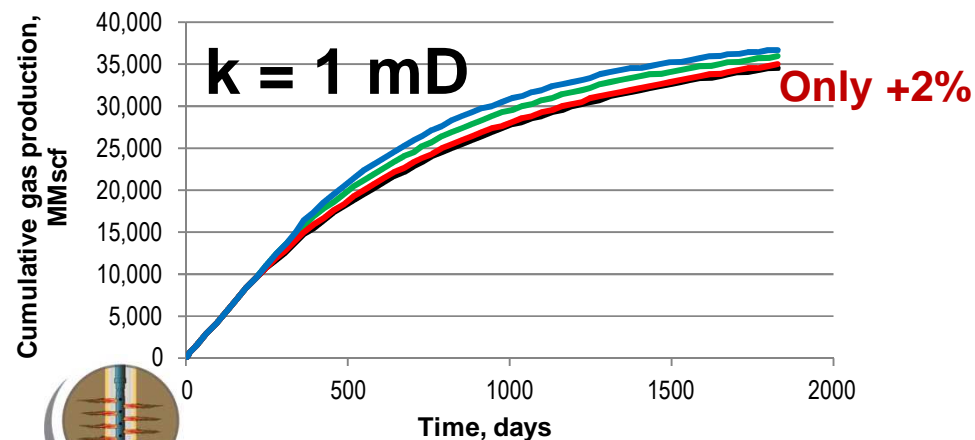
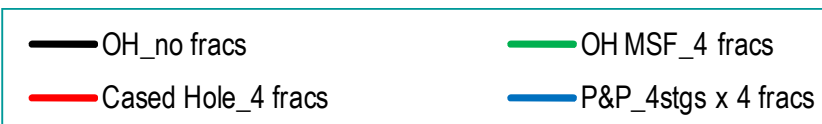
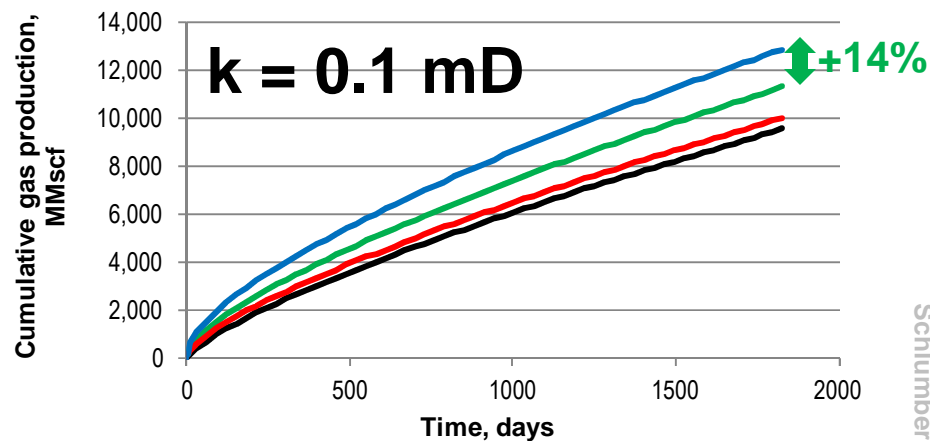
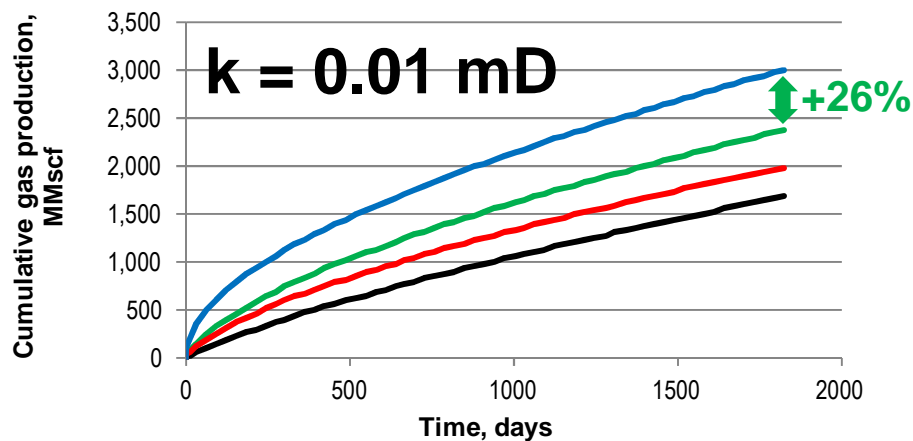
Schlumberger Public

- **Cement Ensuring Zonal Isolation**
- **Long isolation length (> 80 ft between stages)**
- **Fracturing all stages**



Why Cemented Liner Plug & Perf?

Production Simulation

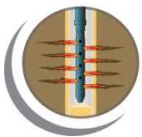
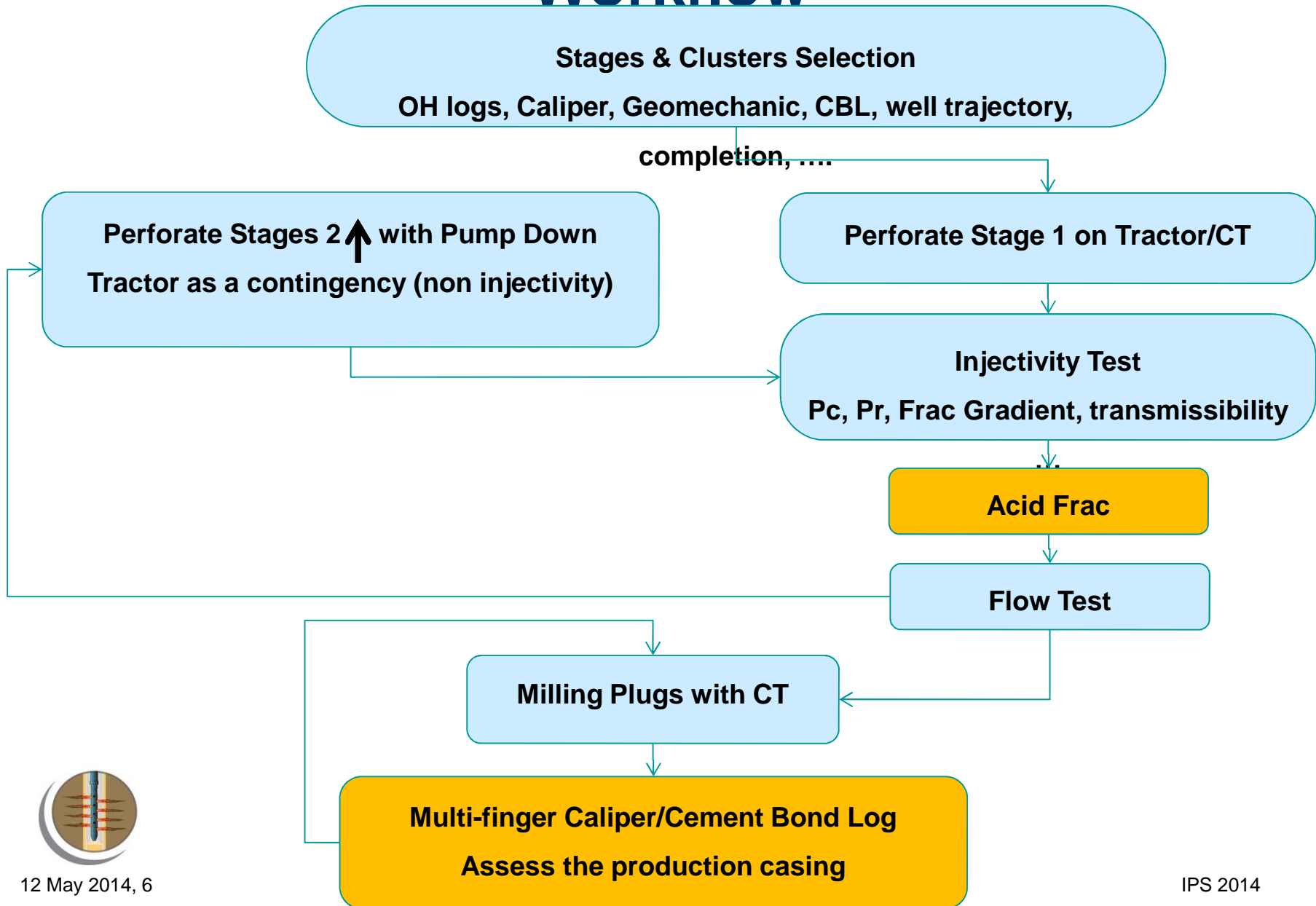


For all permeabilities cumulative production is decreasing in the following order:

1. Cased Hole, Plug & Perf, 16 fractures
2. Open Hole, MSF completion, 4 fractures
3. Cased Hole, Plug & Perf, 4 fractures
4. Open Hole, No stimulation

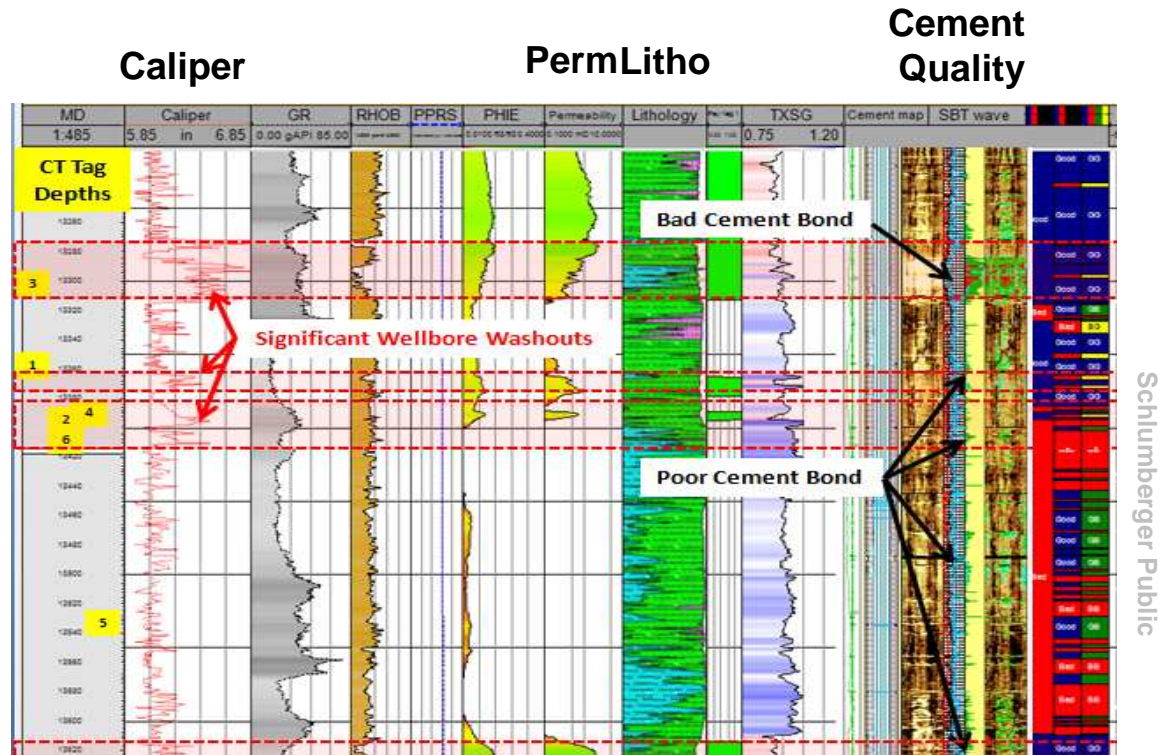
But the difference between them is decreasing with increasing of permeability

Cemented Liner Plug & Perf Completion Workflow

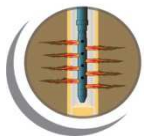
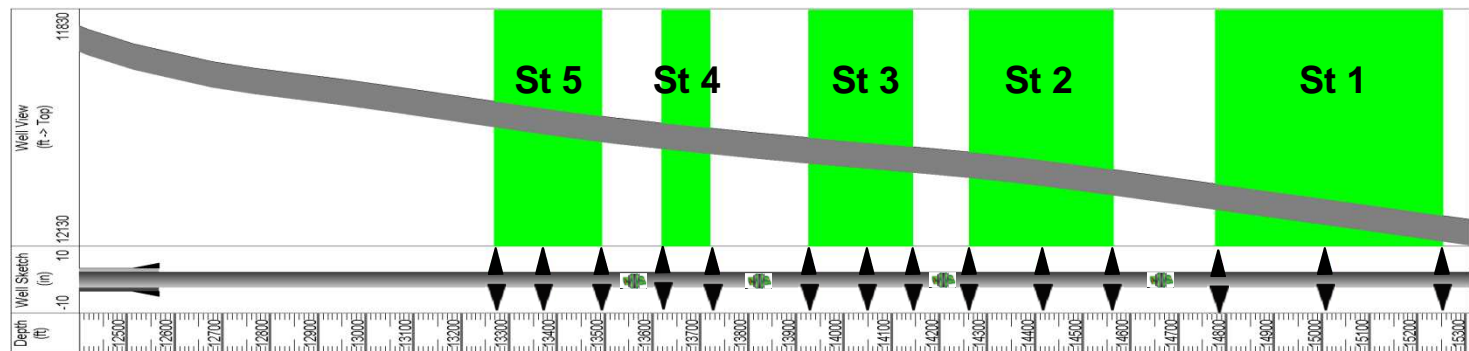


Well A: Clusters/Stages Selection

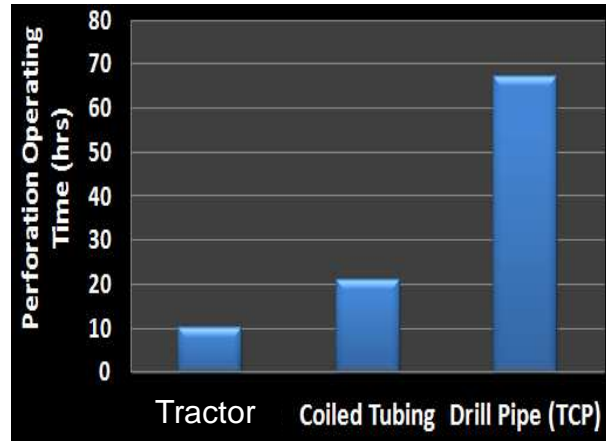
- Target high perm zones
- Avoid tight dolomite strikes
- Sonic & Geomechanic data have to be considered.
- Washout may cause poor cement quality (Caliper)
- Keep at least 2 collars between 2 stages



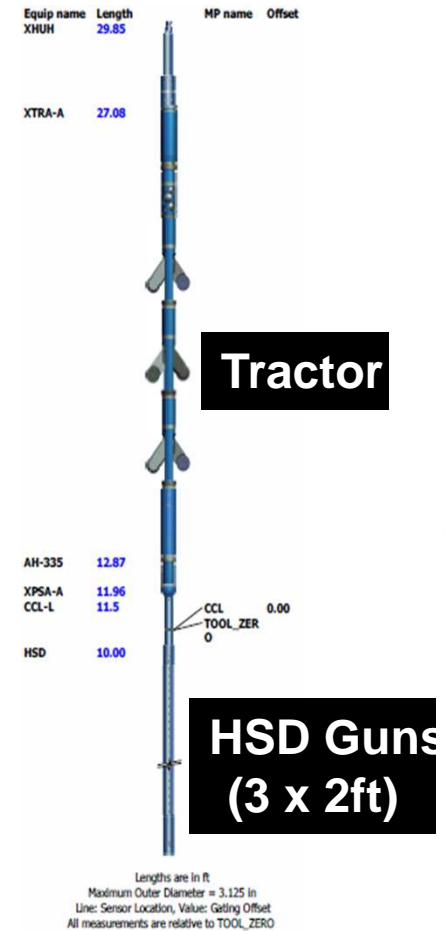
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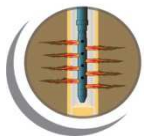
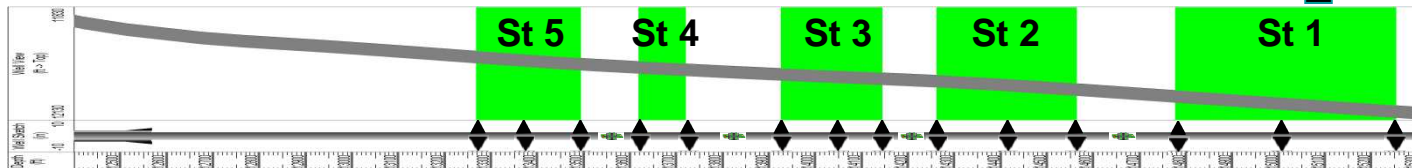
Well A: Perforation System & Conveyance



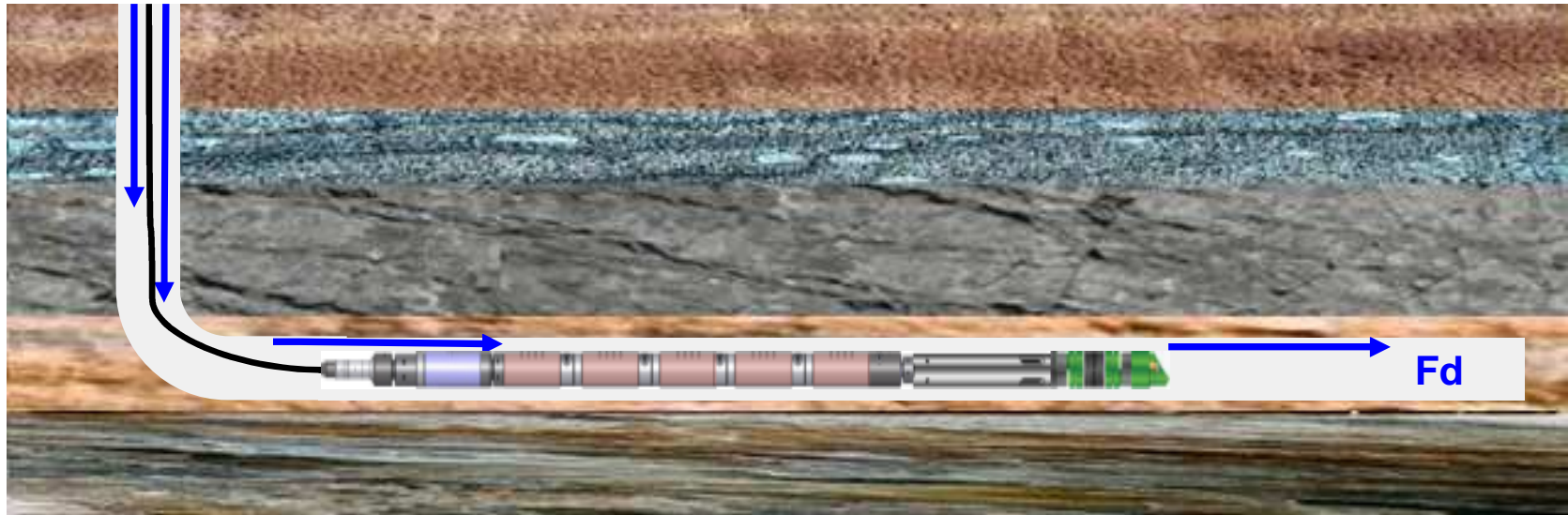
- Reduced Operating Time compared to CT.
- Accurate and more efficient depth correlation
- Better reach than CT:
 - Bidirectional and high speed Tractor.
 - Large pull and push forces.



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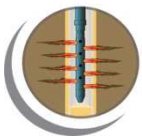
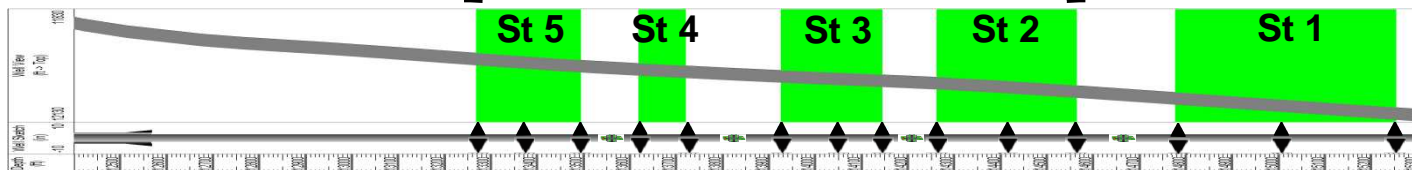


Well A: Perforation System & Conveyance

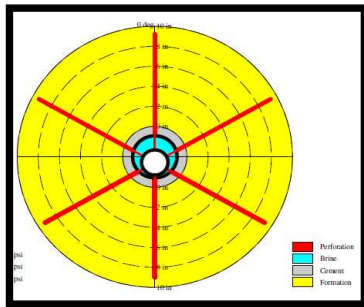


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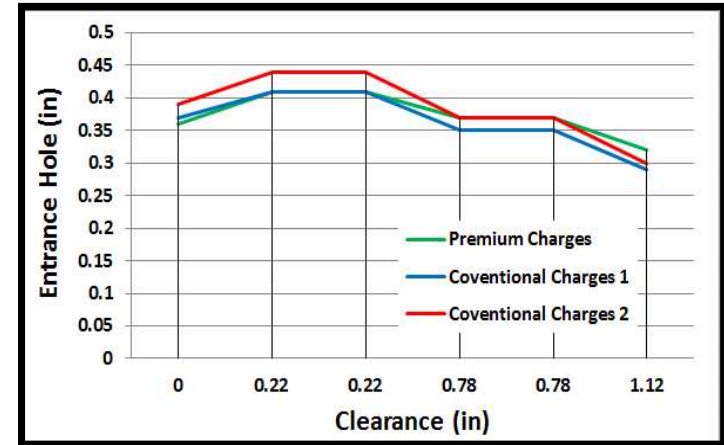
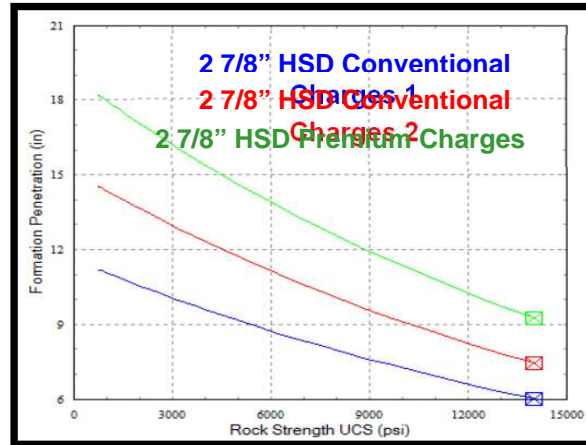
- 3-4 times faster
- Cost Effective (no need for CT/Tractor)
- Minimal complexity
- Flexibility to adjust perforation cluster compared to CT



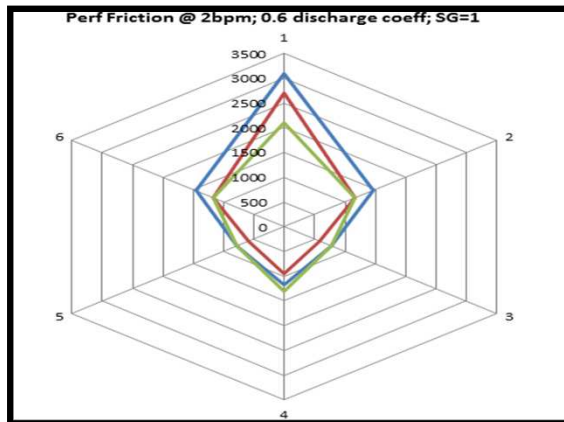
Well A: Perforation System & Conveyance



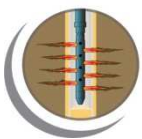
SPAN Rock



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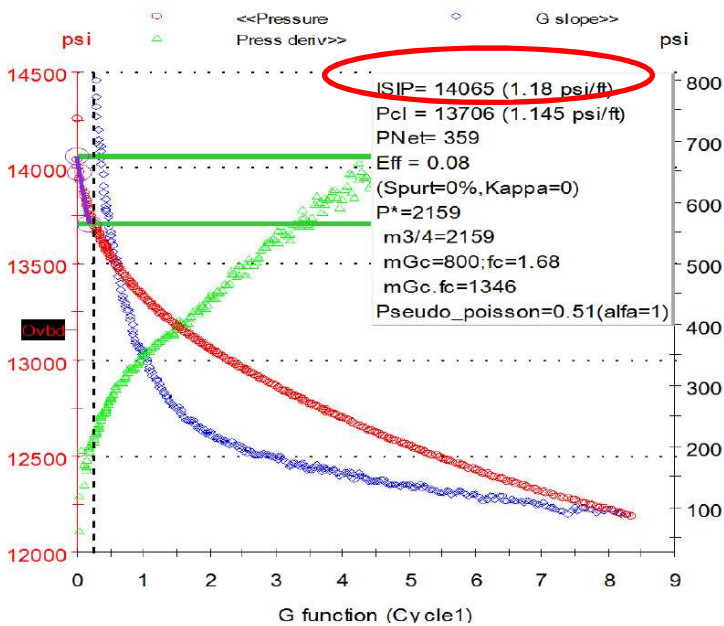


- Depth Of Penetration is important to get beyond the damaged zone.
- Perf friction is proportional to EH Diameter ⁴.
- 48% difference in EH (Conv ch1) becomes 369% difference in perf friction compared to 169% for Premium charges, where EH differ only by 28%.



Deepest Penetration and optimum EH makes frac jobs more effective by lowering the breakdown pressures, lowering treatment pressures and improving treatment rates

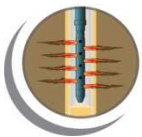
Well A: Injection Test & Acid Fracturing Job



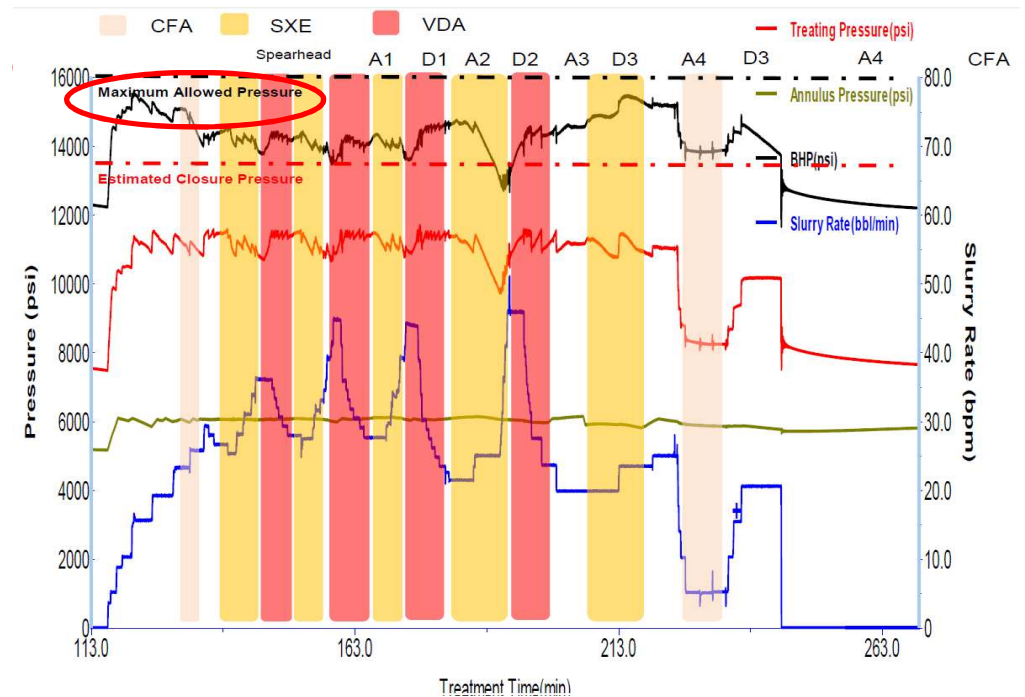
MFO pressure decline plot / Pos Closure Plot

Injection test

- Extremely high frac gradient
- 5 acid frac stages successfully pumped in 5 operating days



12 May 2014, 11

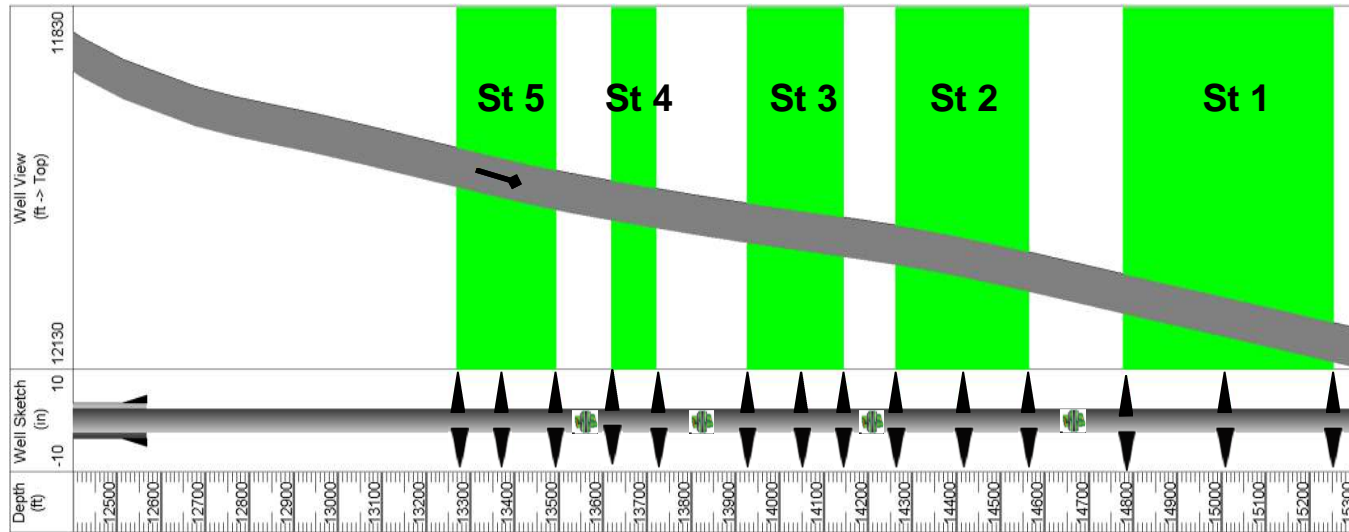


Main Job

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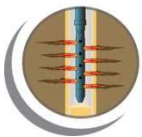
Well A: Milling Attempts

- ① 3-5/8" D2 Mill
- ② 3-1/2" Step Mill
- ③ 3-5/8" Venturi Junk Basket
- ④ 3-1/2" Tapered Mill + String Mill
- ⑤ 3-1/4" LIB
- ⑥ 3-1/2" LIB



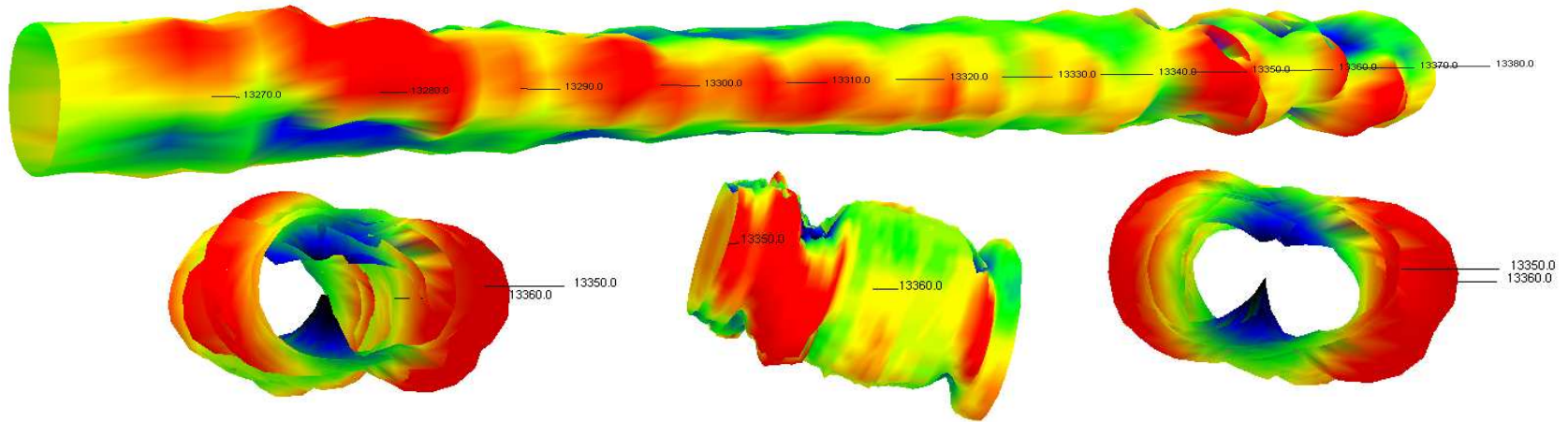
Deep, off-center irregular marks on 3 1/4 LIB

- Top plug not accessible for recommended 3 1/2" mill



Well A: Multi-Finger Caliper

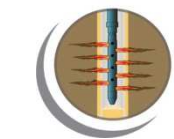
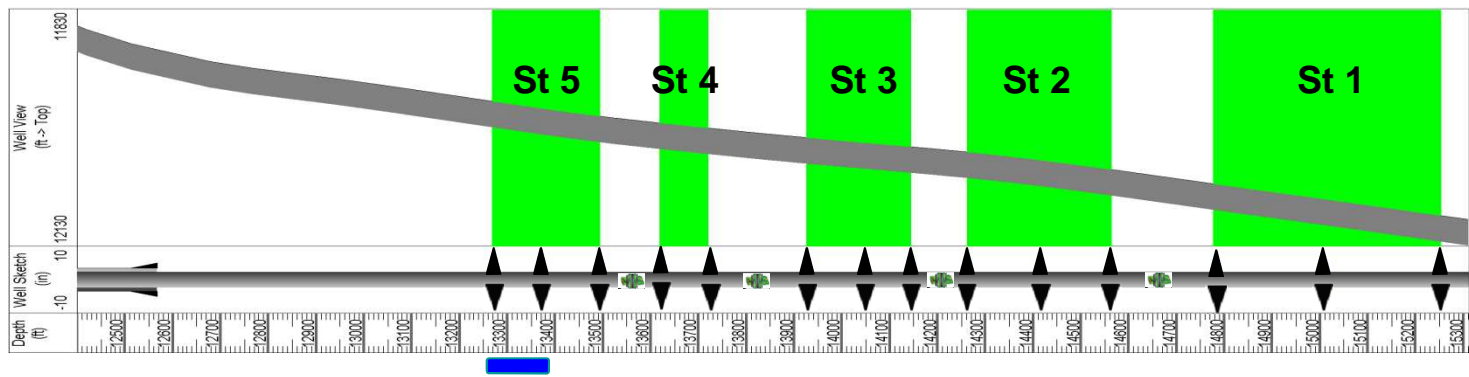
13262-13382ft



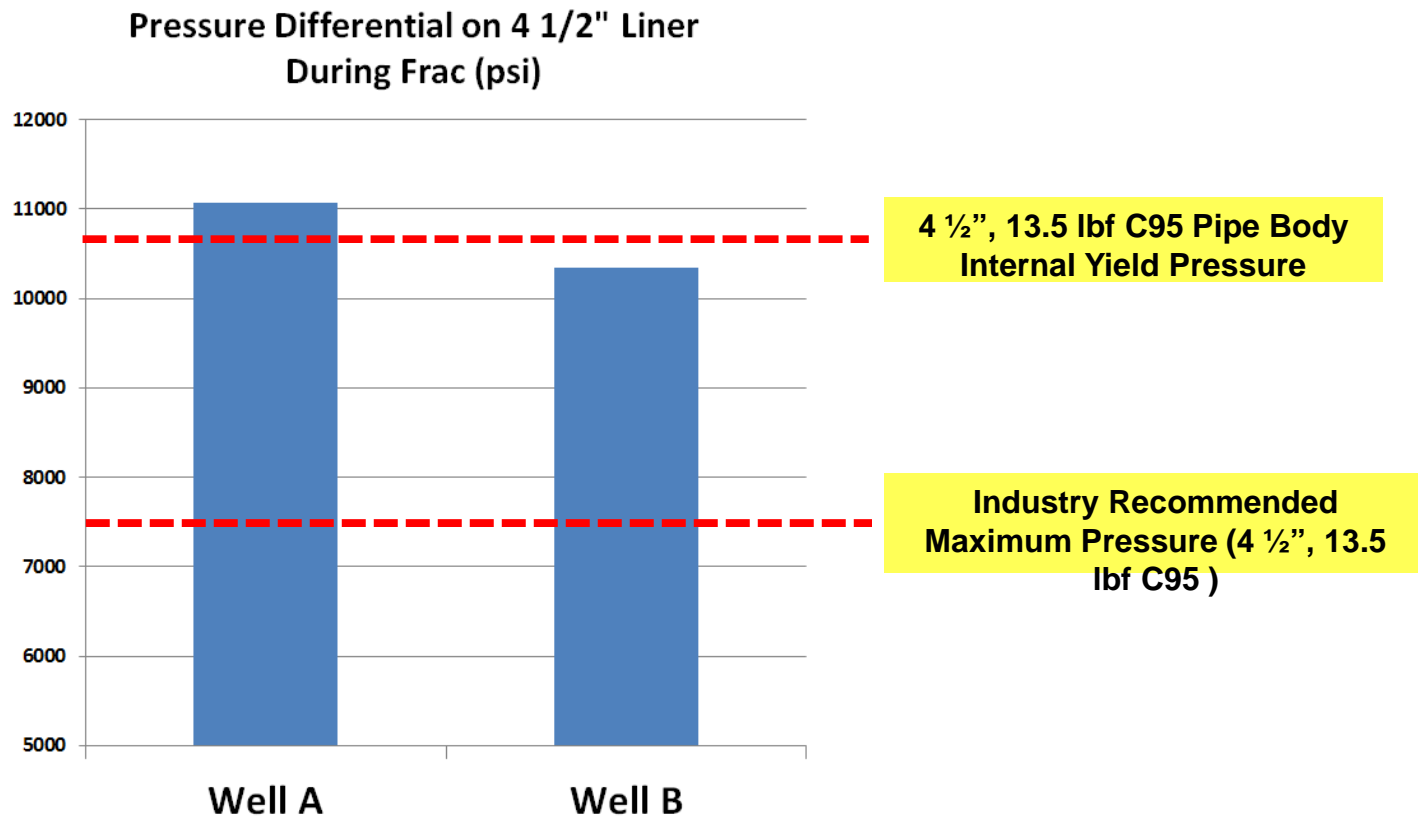
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OD	Weight	Grade	ID	Collapse Resist.	Pipe Body Yield	Pipe Body Internal Yield
in	lbm/ft		in	psi	lbm	psi
4.500	13.50	C-95	3.920	9660	364000	10710
4.500	15.10	P-110	3.826	14340	485000	14420
4.500	15.10	Q-125	3.826	15830	551000	16380

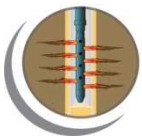
- Liner Burst/Oval - rating not suitable for frac pressures experienced



Wells A & B: Completion Suitability for High FG/ Low P res Environment

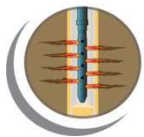


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Results

- All stages (5) were completed successfully
- Initial Production was 30 MMSCPD and declined with increasing the choke to 5 MMSCFPD (Fracture close due to High drawdown or short frac length?).
- The initial production is higher compared to OH MSF techniques. But this is too early to conclude, due to high reservoir heterogeneity.



Recommendations for Future Jobs

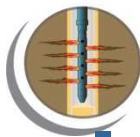
Perforating and Formation Breakdown

- Use the new engineered Frac Gun (homogeneous EH holes/high penetration → low perf friction)
- If formation doesn't break down and to preserve a planned stage, add more clusters/perforations.
- Acid spearhead after perforating stage 1 to lower formation breakdown pressures
- If difficulties rise while pumping the guns (limitation on WHP), bleed of for few hours and add heavier Tungsten weight bars to the gun string.

Completion

- Production Liner upgrade to 4.5", 15.1 lbf, Q125 (higher collapse resist.)
- Maintain minimum net pressure (1000-1,500 psi) just above the fracture closure pressure and Limit BHP to safe liner operating envelope.

- Use flow-through frac plugs instead of full-bore ones



Recommendations for Future Jobs

Reservoir Evaluation & Geomechanic

- Better understand lateral wellbore heterogeneity to optimize the number of Clusters/Frac stages by Acquiring:
 - Reservoir pore pressure (StethoScope, MDT)
 - Natural fractures occurrence (FMI)
 - Mineralogy profile (Stingray-ECS)

- Determine optimum well placement (Stresses from Sonic Data)
- Perform cement evaluation with rig

