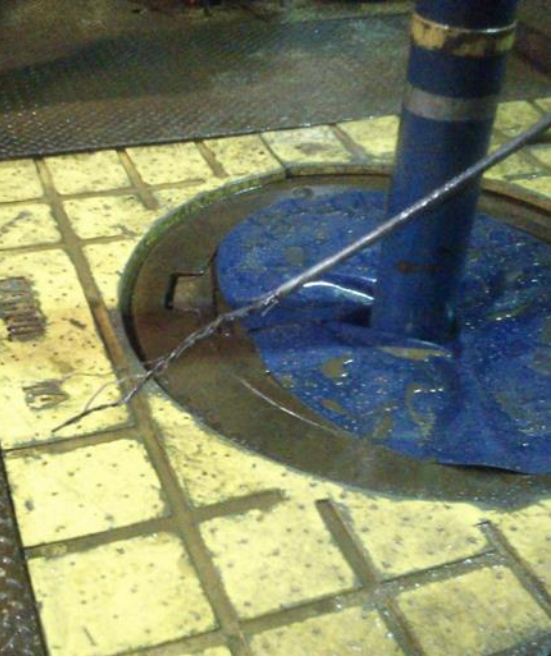


IPF 17-07

Do not Drop Live Guns

Prevent Shock Induced UPOs

Carlos Baumann – Schlumberger

May 4th 2017

Outline

- Main sources of Perforating Shock Loads:

  A. *Initial detonation / Metallic shock*: large vibration/acceleration of guns and attached tools, can damage electronics and break weak/fragile tools. WL perforating Examples.

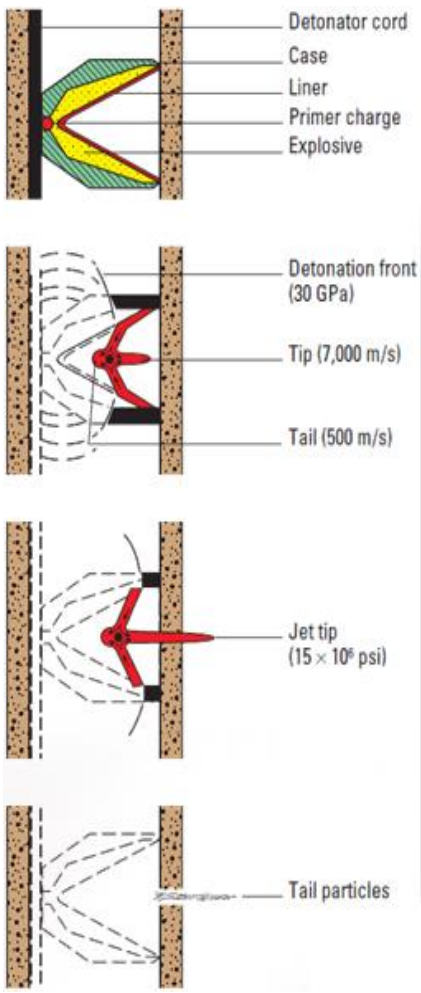
  B. *Transient wellbore pressure waves*: broken weak points, gun jumping / cable damage, corkscrewed tubing, broken packer seals, unset packers, etc. WL perforating examples. UPO from wellbore pressure waves - Can shock absorbers help?

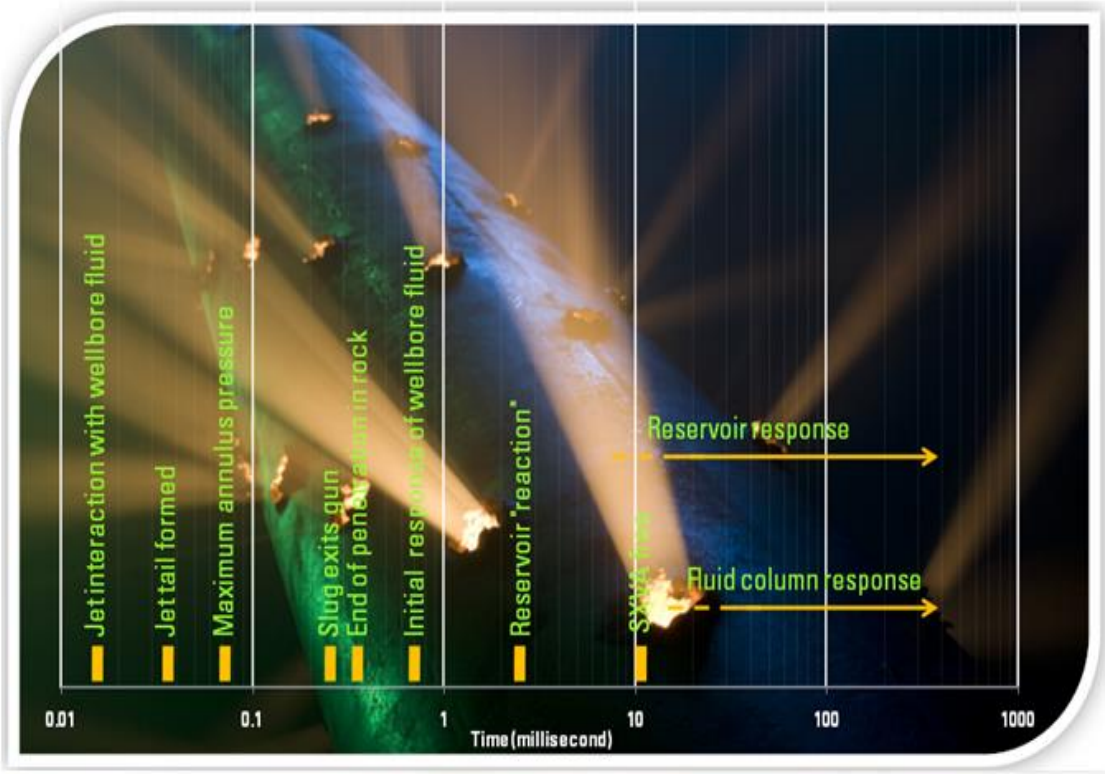
- Final Conclusions

Perforation tunnels are created in << 1 millisecond

Initial Detonation / Metallic Shock: loads generated while guns detonate ~ 1 ms / 20-ft gun

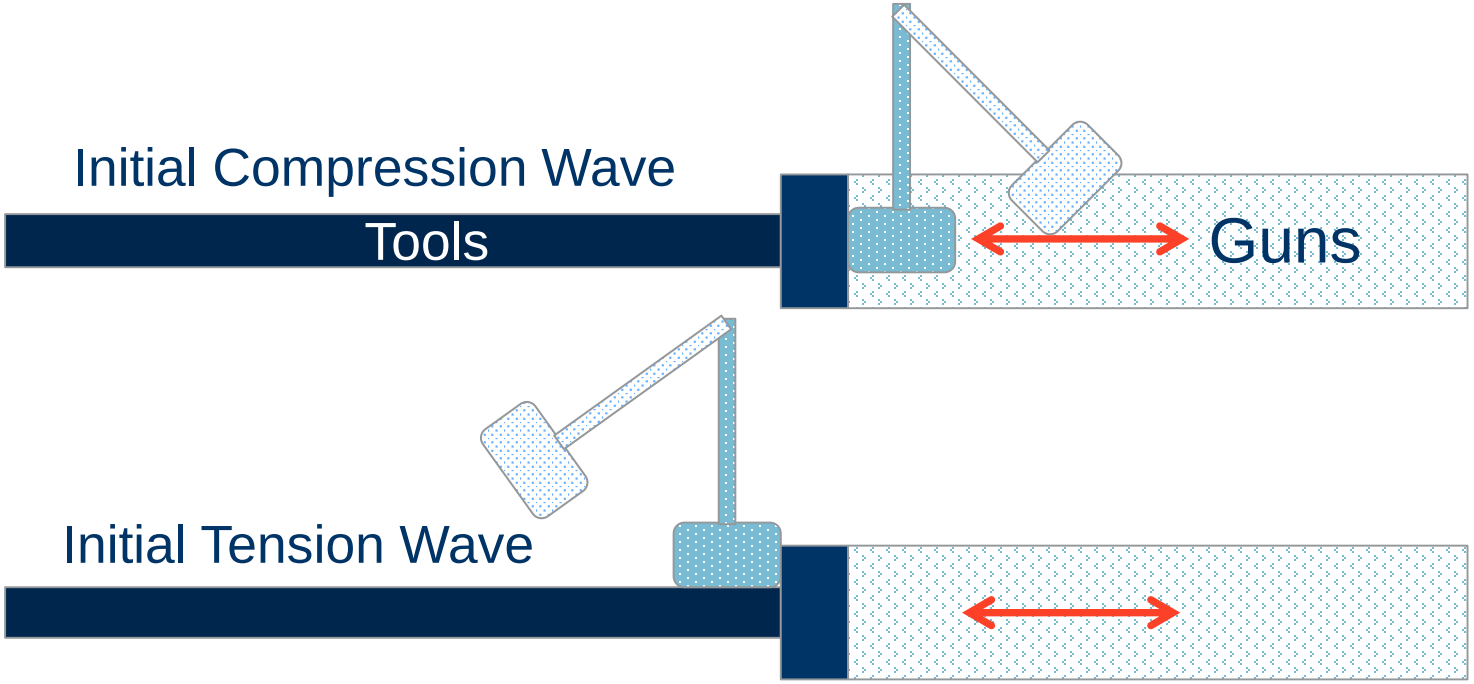
Transient Wellbore Pressure Waves Shock: loads generated 10-100s ms after detonation





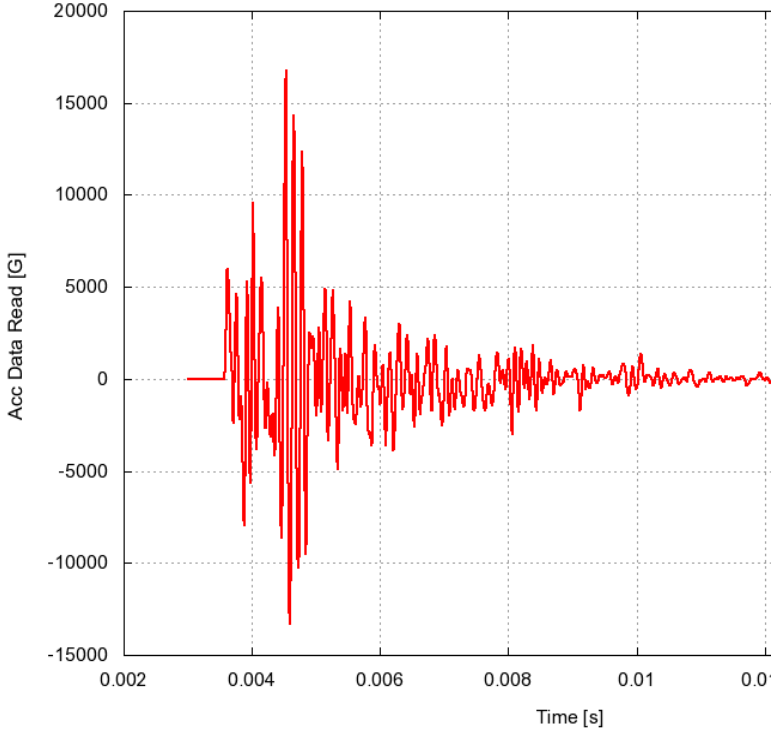
Initial Gun Detonation Shock - Metallic Gunshock

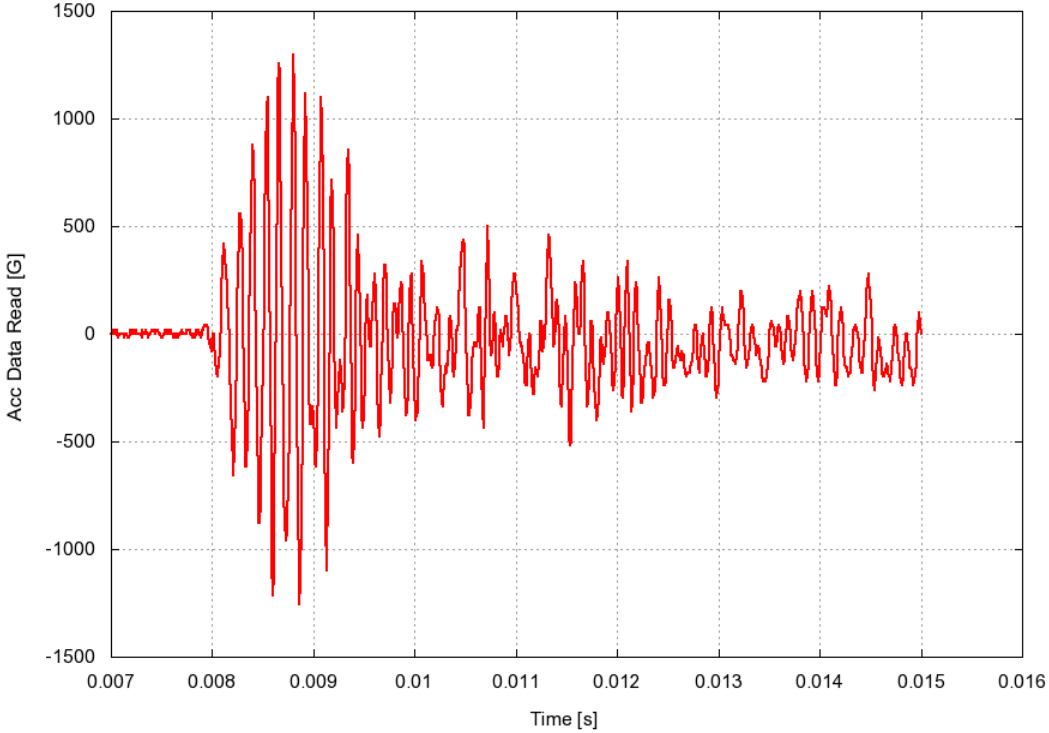
- When the guns fire, the initial vibration / acceleration of the guns produce compression / tension stress waves on the attached tools (also shear waves)
- Analog: hitting the end of a steel bar with a hammer in both directions.
- A compression wave becomes a tension wave after reflection, and vice versa.



Metallic / Initial Detonation Shock: 80-ft of 4.5-in guns 39g charges 5-spf

Acceleration below (left plot) and above (right plot) one Shock Absorber

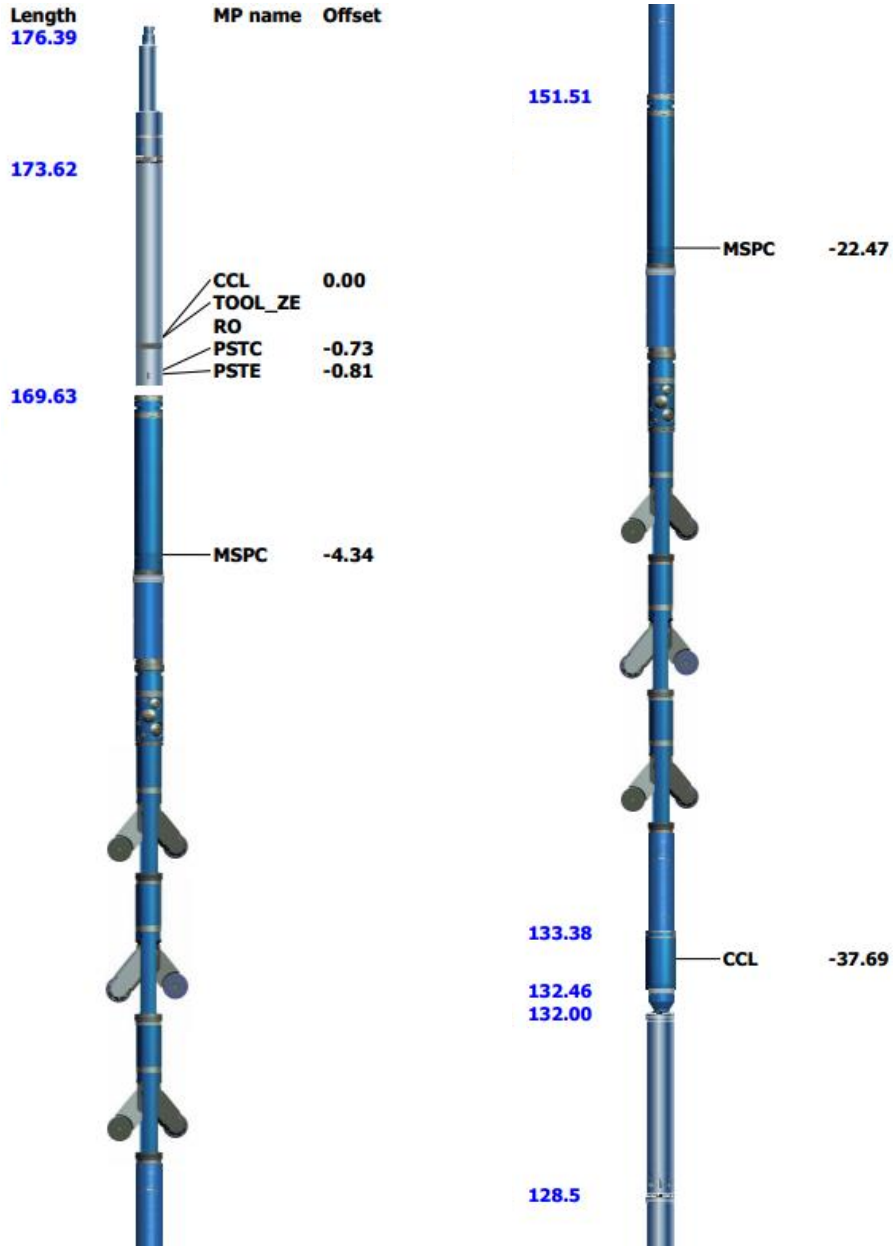




One Shock Absorber : <u>10x</u> reduction in acceleration amplitude

- A tool's shock rating of X,000 G mimics the metallic shock of a Y-ft long Z-in OD gun
- <u>*No correlation*</u> between a tool's G shock rating and the peak axial load on the tool when guns fire
- Peak axial load depends on <u>*all the attached tools and guns*</u>.

Perf Job with 6 x 20-ft 2-7/8” guns - With Tractors - 3+3 drives
Metallic Shock - Axial Load on the Tools – With and Without WPSAs



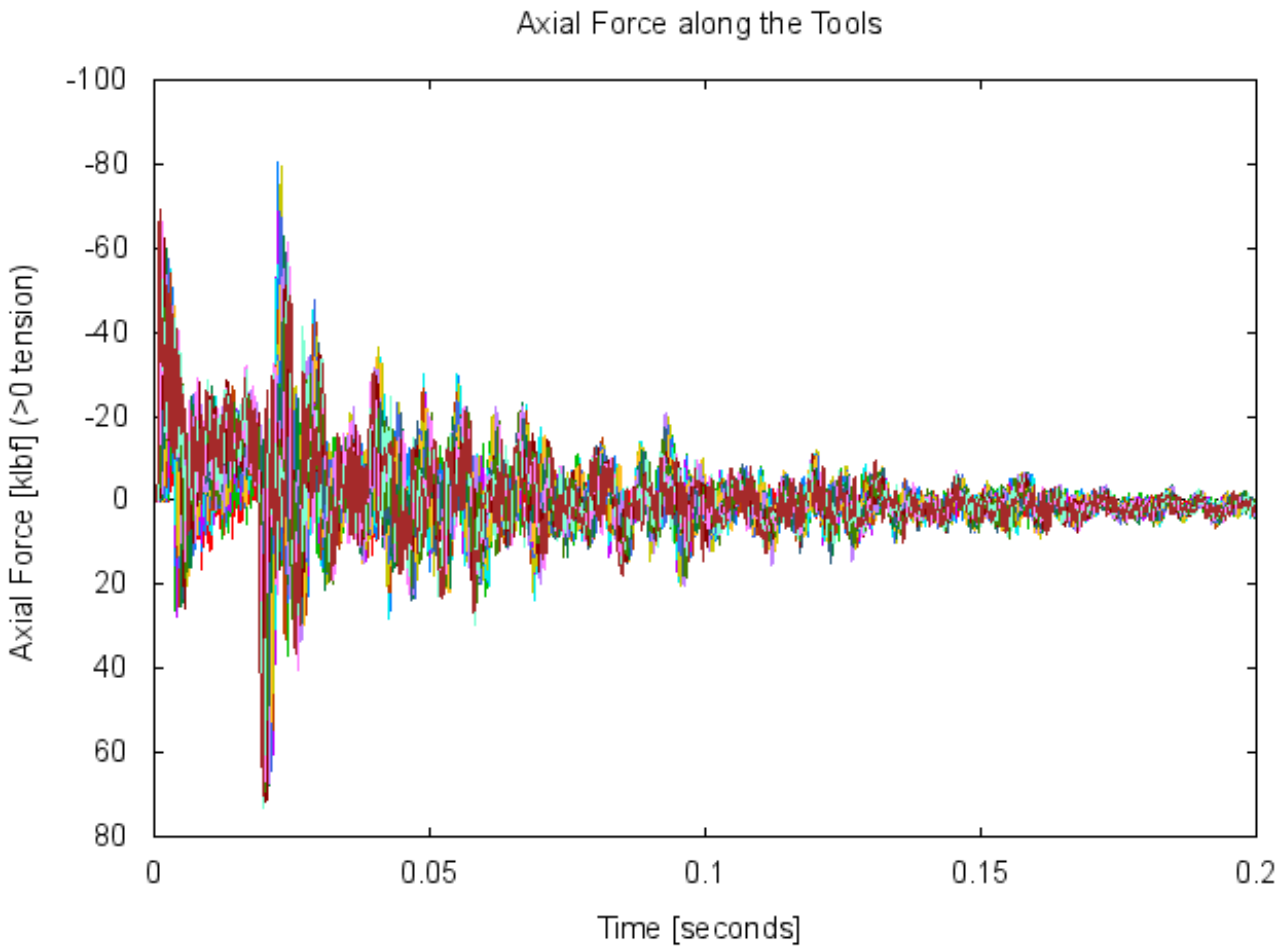
Lengths are in ft
Maximum Outer Diameter = 3.125 in
Line: Sensor Location, Value: Gating Offset
All measurements are relative to TOOL_ZERO

Tools weight with 3+3 drives (excluding guns): 1000 lbs
Tools length: 50 ft

WPSA: Wireline Perforating Shock Absorber

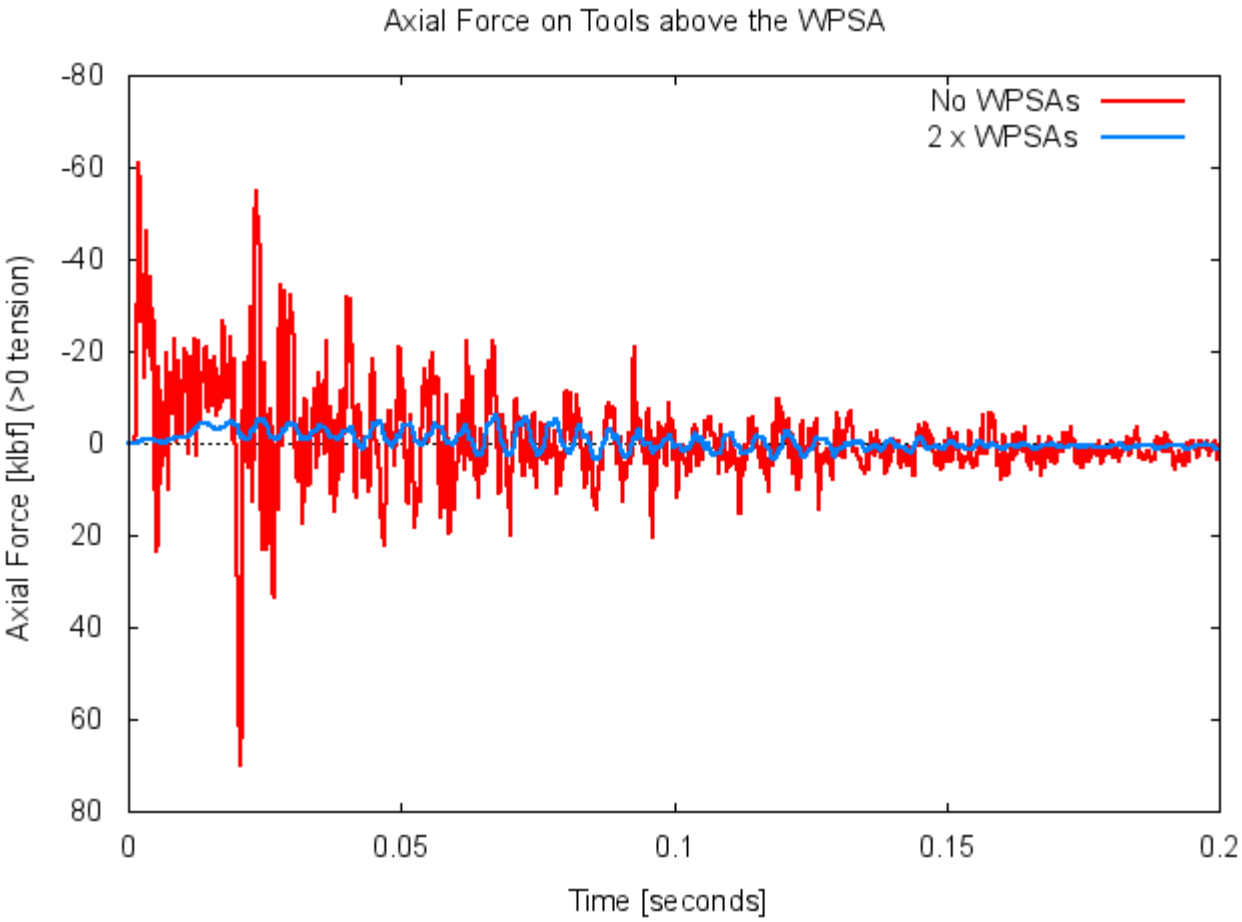
Transient Axial Load along the Tools without WPSAs

(WPSA: Wireline Perforating Shock Absorber)



Transient Axial Load at the middle of the Tools – with and without WPSAs

(WPSA: Wireline Perforating Shock Absorber)



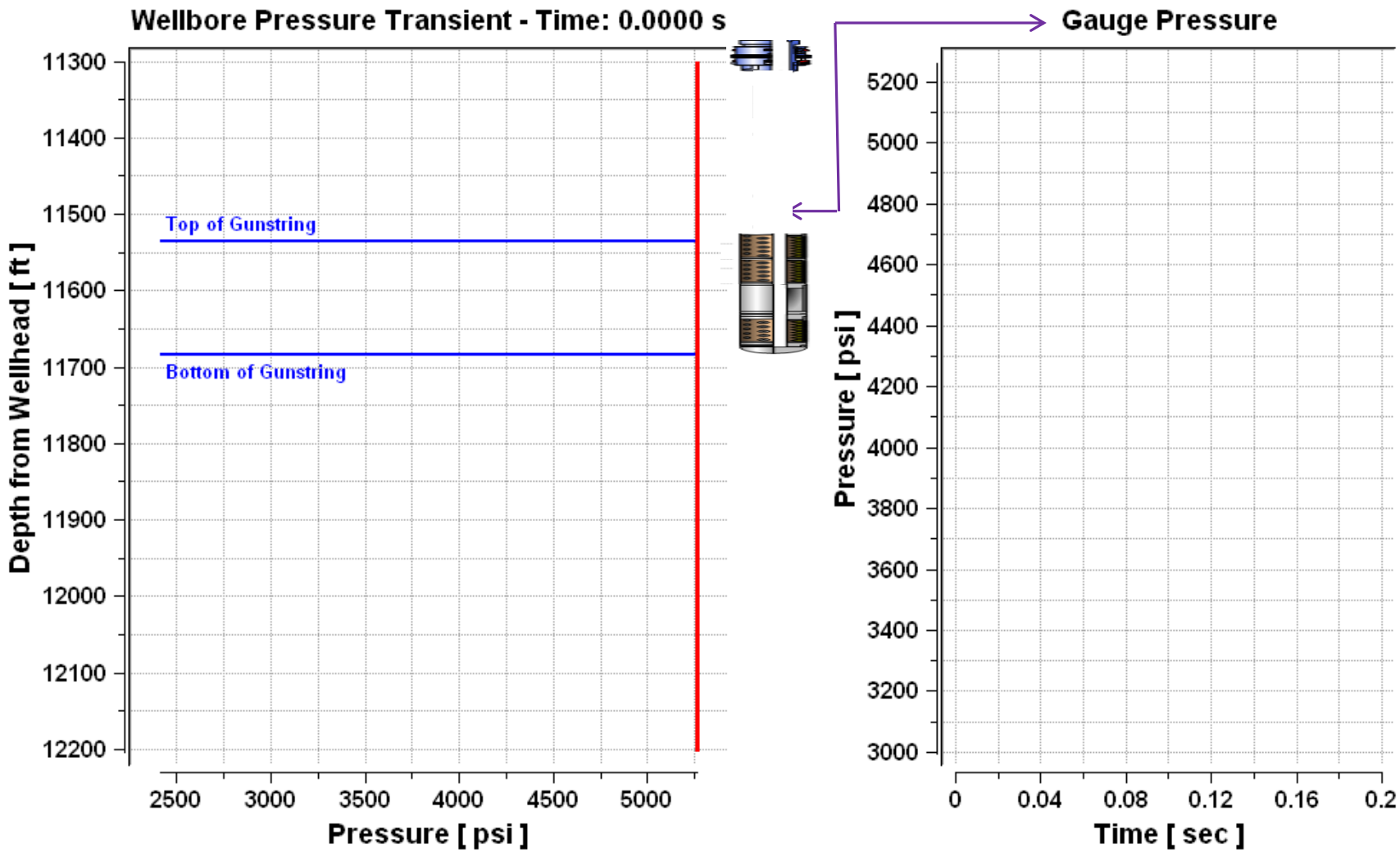
Job with Tractors - Metallic Shock - Axial Load on the Tools - Conclusions

- With 2 x WPSAs, peak tension ~ 4 klbf.
- Without WPSAs, peak tension ~ 70 klbf !
- To minimize metallic shock risk => 2 x WPSAs
- WPSAs isolate/decouple the guns from the tools, reduce the metallic shock on the tools
- Larger mass and stiffness of the conveyance => Larger loads on the tools

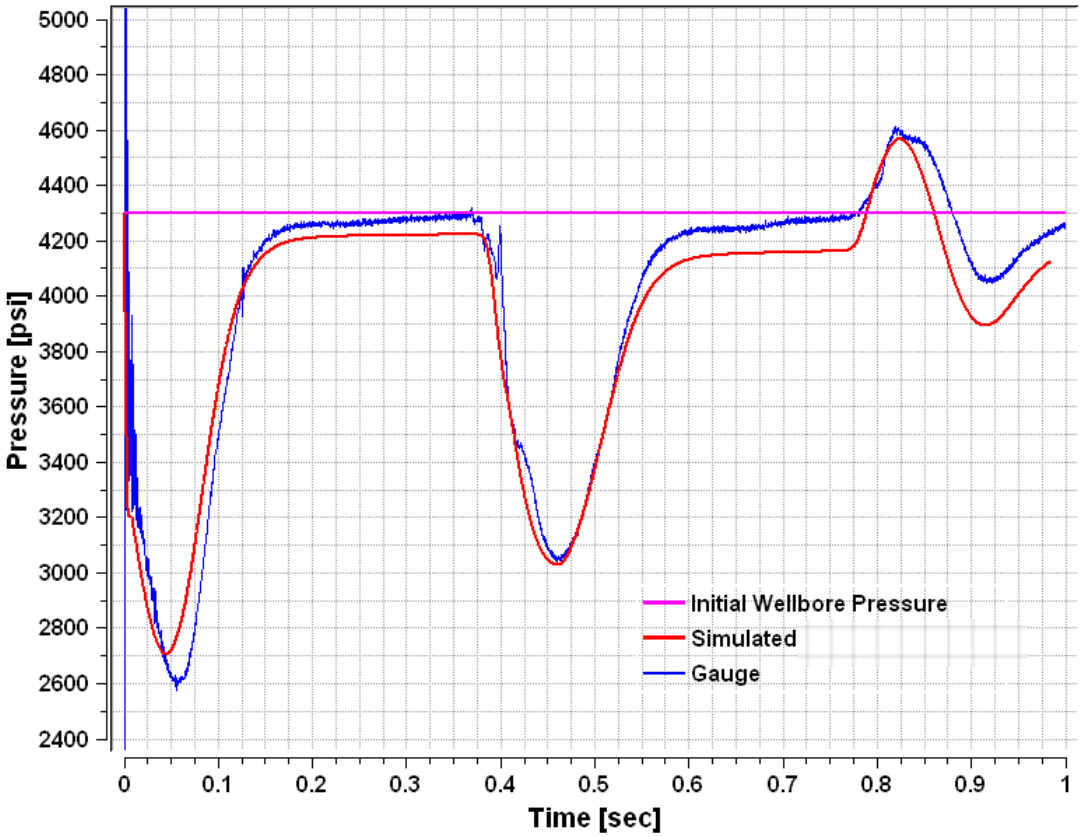
All Conveyance: WL,TCP - Transient Wellbore Pressure Waves: Origin?

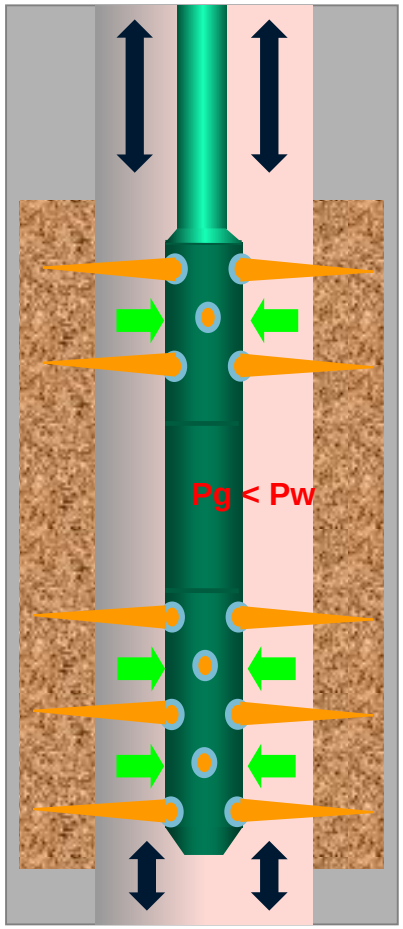
After guns fire: gas pressure in gun (Pg), wellbore fluid pressure (Pw), and reservoir pressure (Pr)

In this example: Pg << Pw ~ Pr

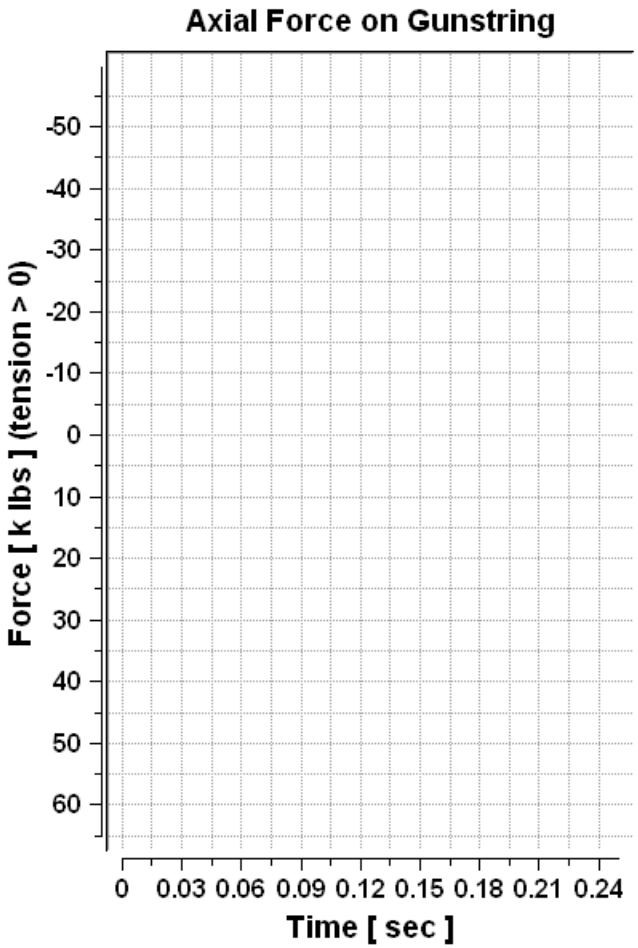


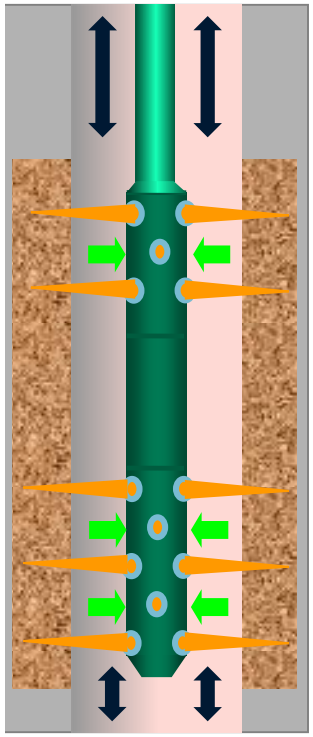
Example **Dynamic Underbalance**: Gun Pressure (Pg) < Wellbore Pressure (Pw), guns become a pressure sink Pg < Pw, lowering the wellbore pressure around the guns, and then pressure waves propagate along the wellbore.





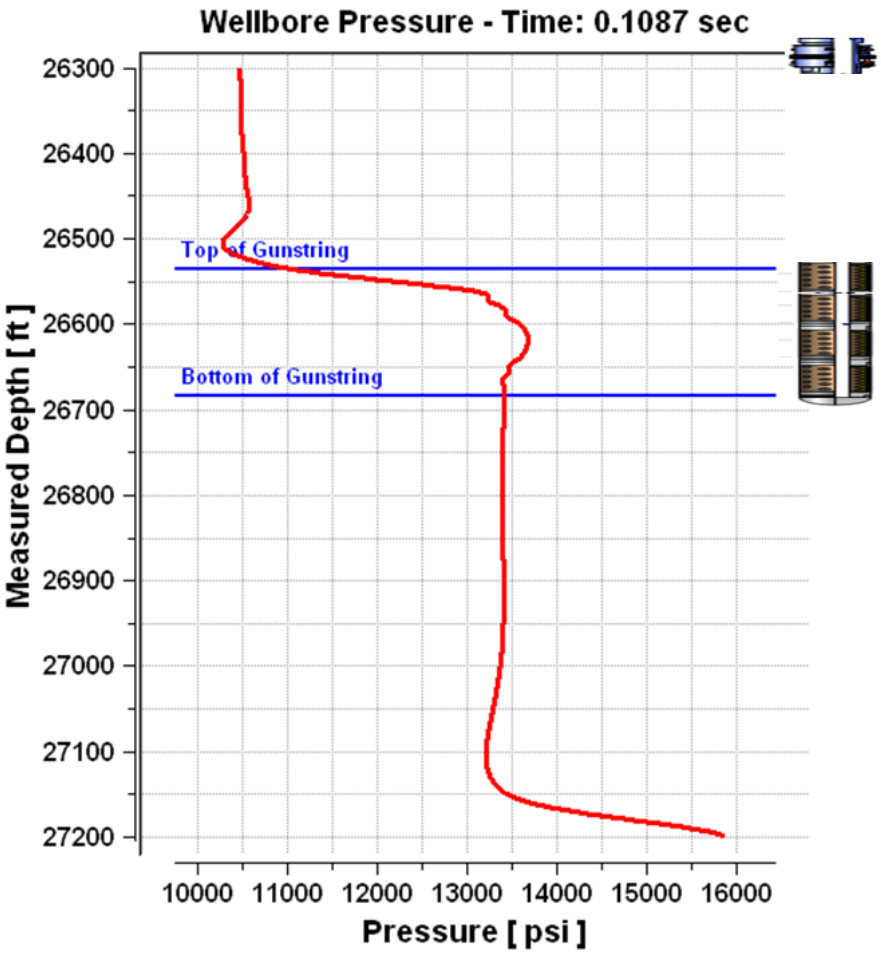
All Conveyance: WL,TCP - Transient Pressure Waves - Axial Force on the Guns

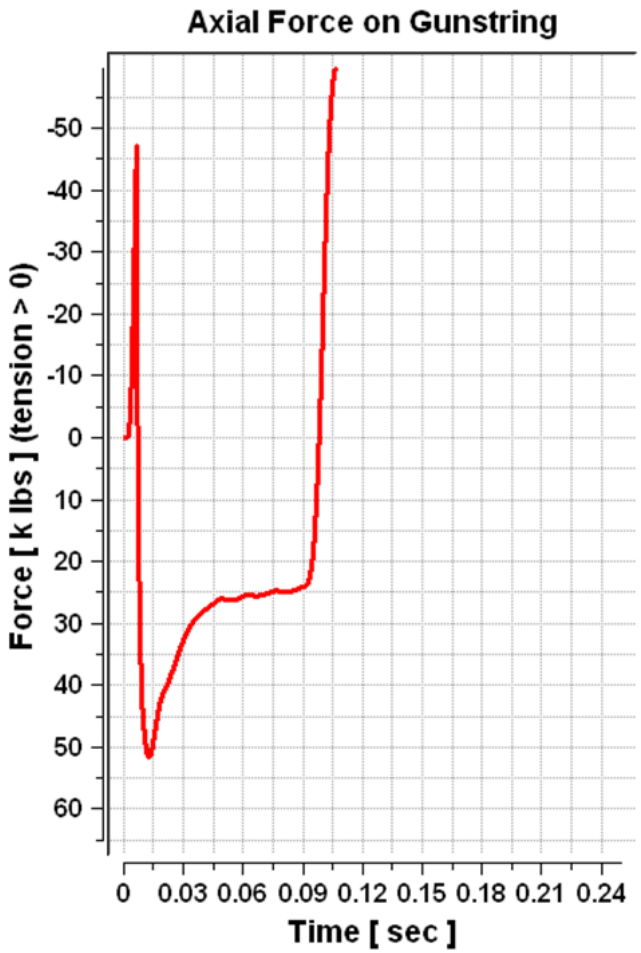


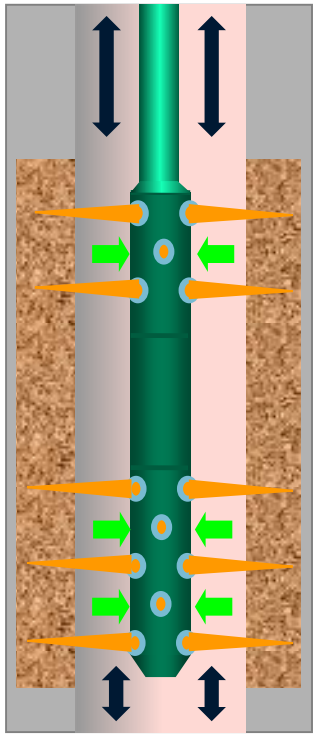


All Conveyance: WL,TCP – Instant of Max Uphole Force on the Gunstring

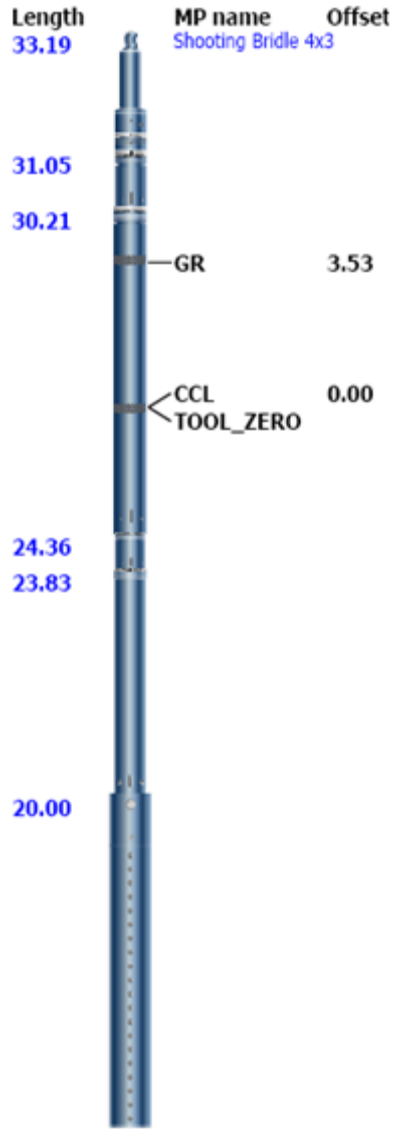
Pw at gunstring top << Pw at gunstring bottom







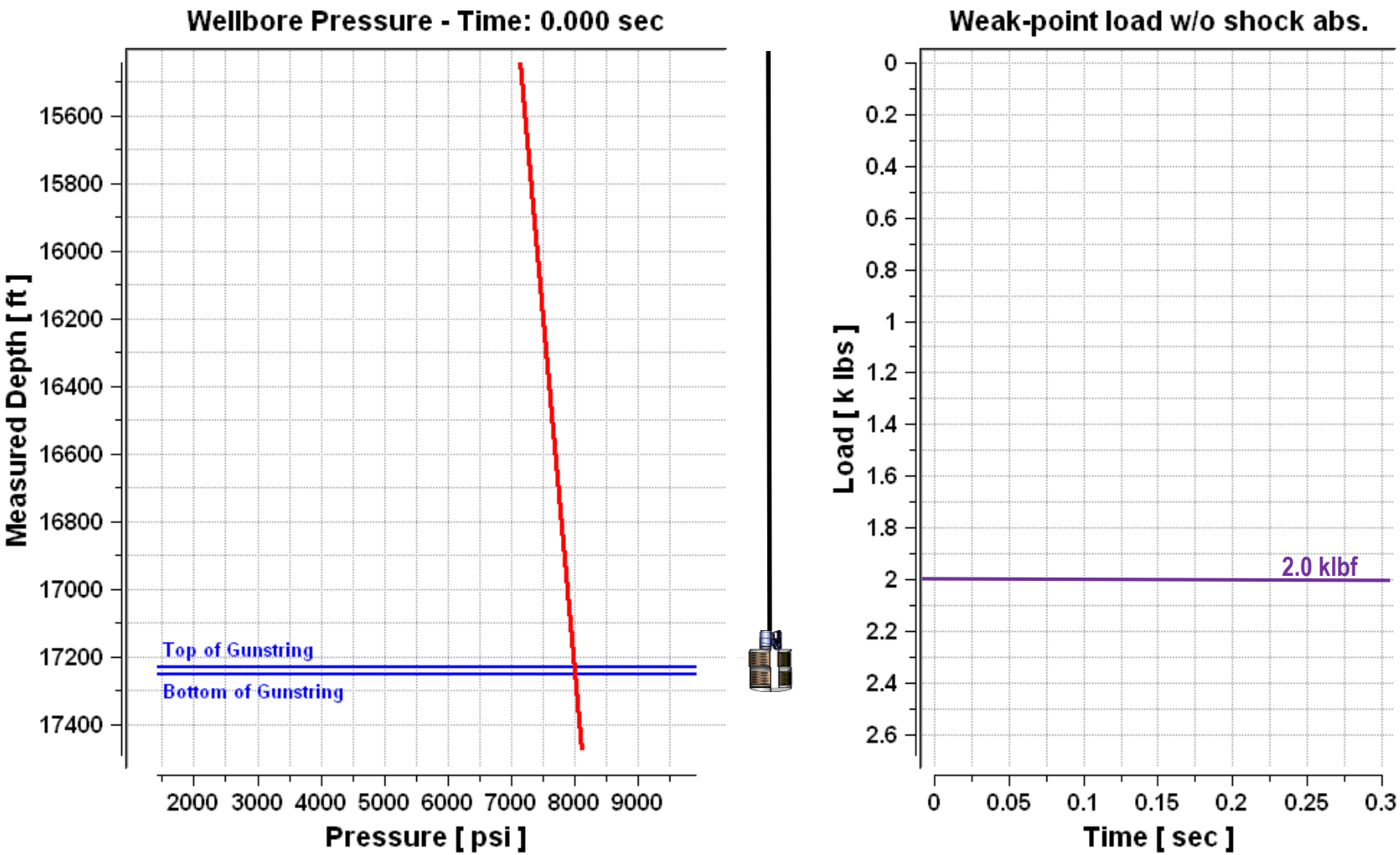
WL Perforating – Transient wellbore pressure waves => UPO



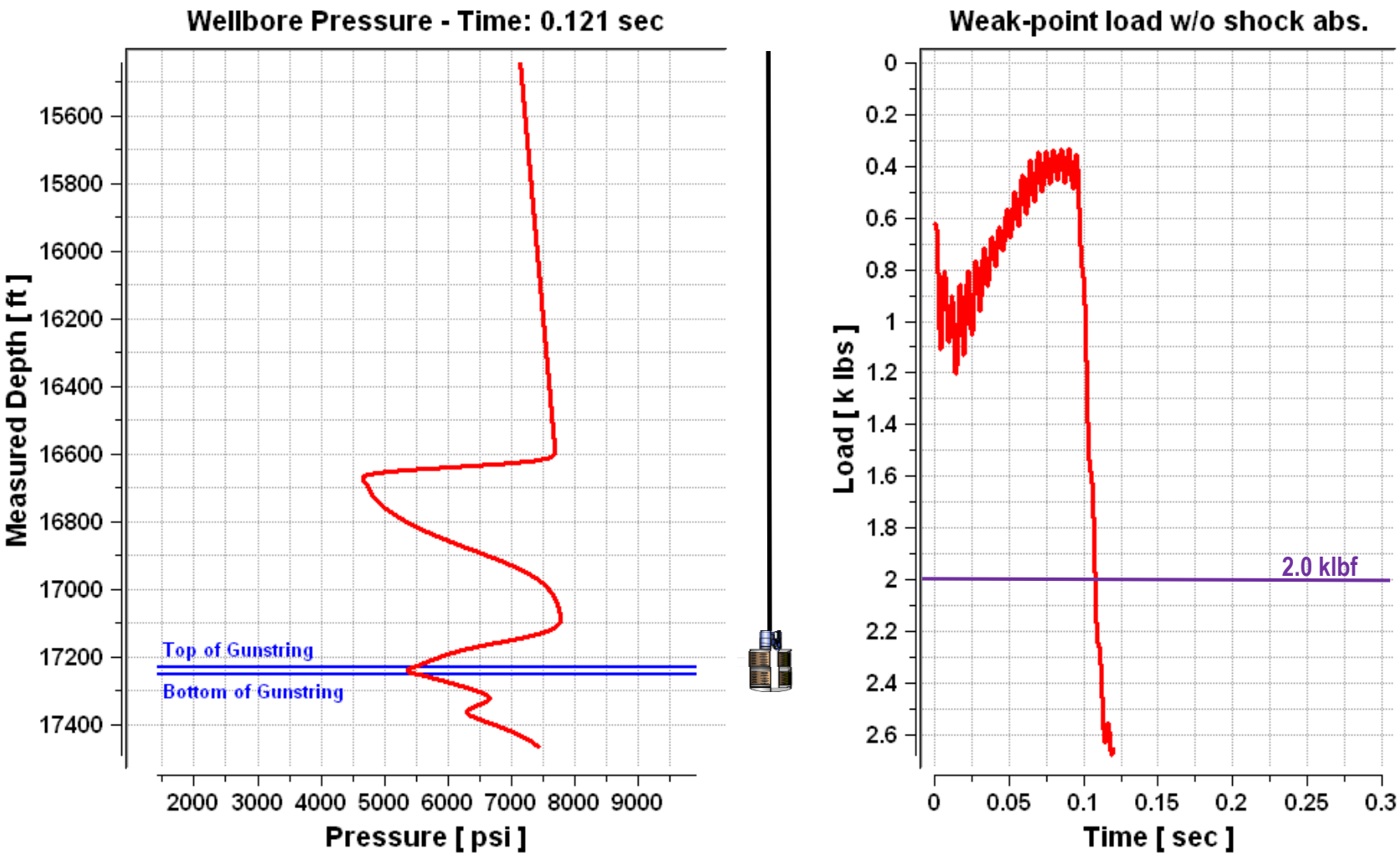
Lengths are in ft
Maximum Outer Diameter = 4.500 in
Line: Sensor Location, Value: Gating Offset
All measurements are relative to TOOL_ZERO

- Perforated net 12-ft, 2x10-ft 4.5-in (5/72)
- 7-in, 32 lb/ft casing
- Initial wellbore pressure at top shot: 8000-psi
- Estimated oil reservoir pore pressure: 7900-psi
- Weak point rating: 2715 +/- 680 lb

Wellbore pressure wave reflection on the bottom => Peak load on the weak point



Peak load at the weak point 2700 lbf > Min weak point rating: 2715 – 680 = 2035 lbf

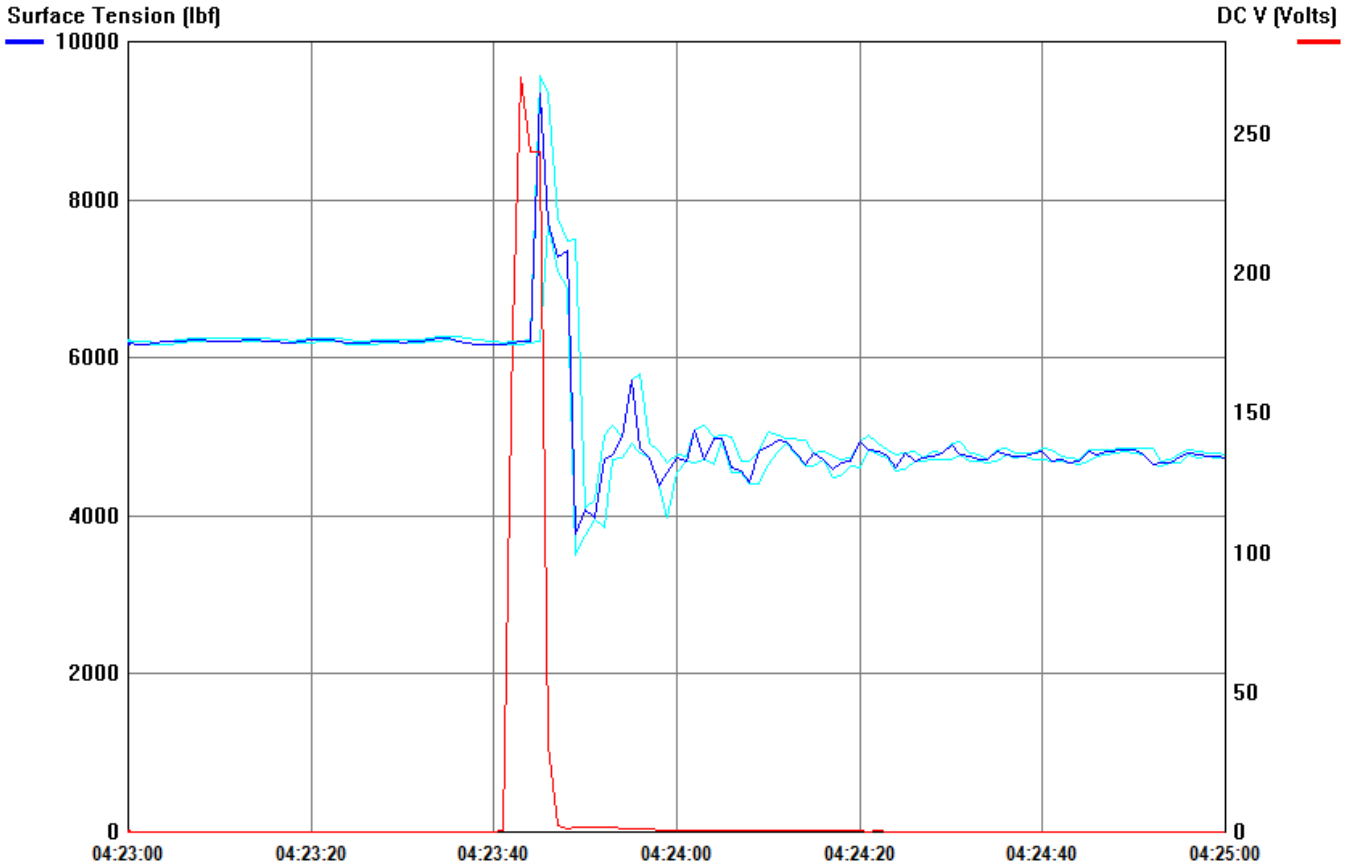


WL Perforating - Broken Weak Point

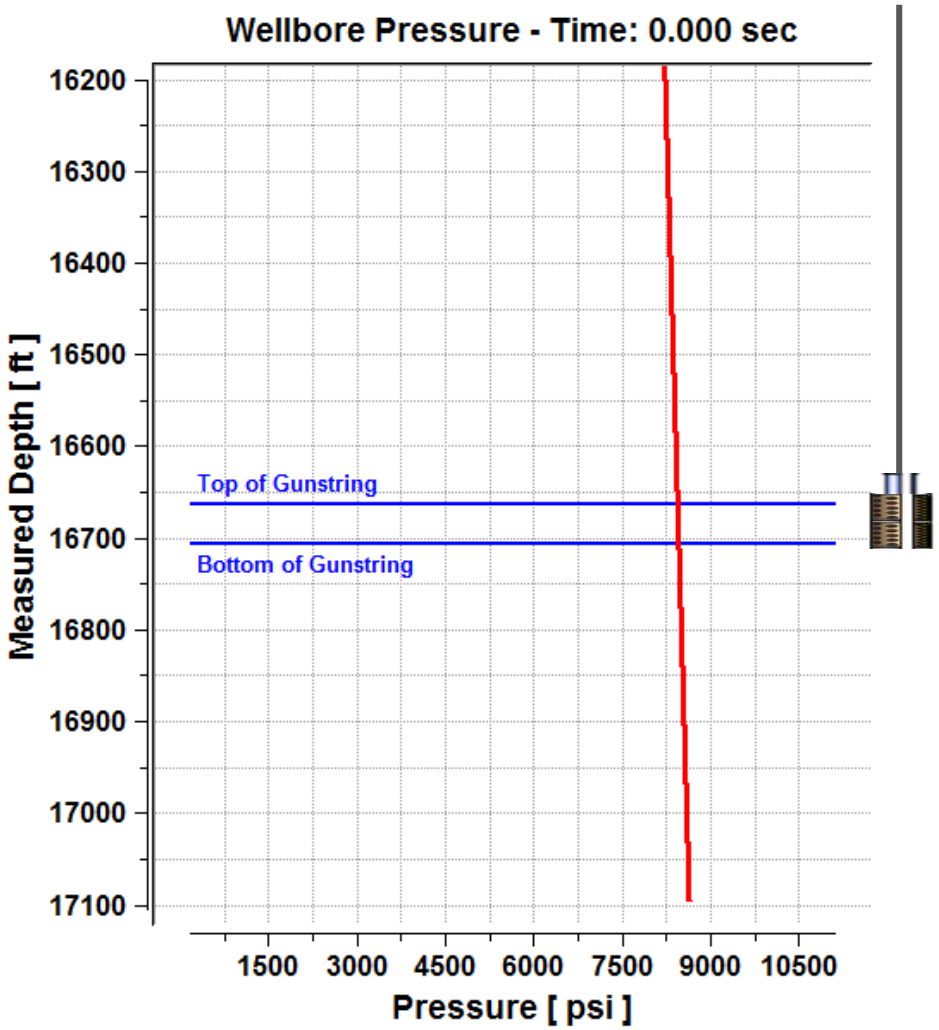
Can WPSAs help mitigate the effects of “Transient wellbore pressure waves” ?

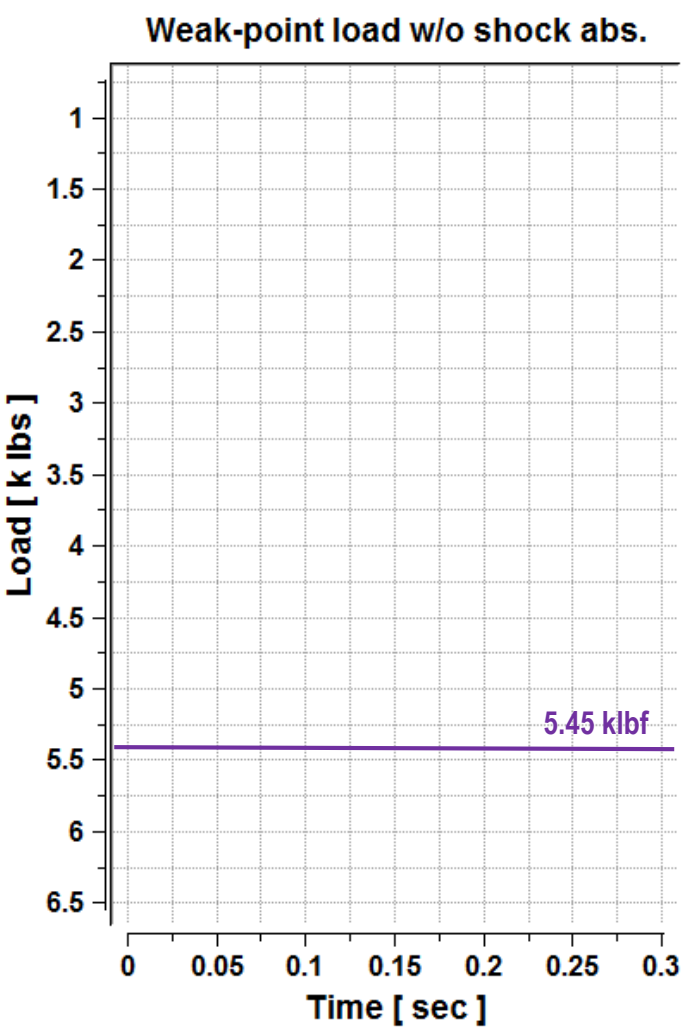
WP rating 5450-6900 lbf,

2 x 20-ft 7.0-in guns, net 33-ft, 39g charges at 12 spf



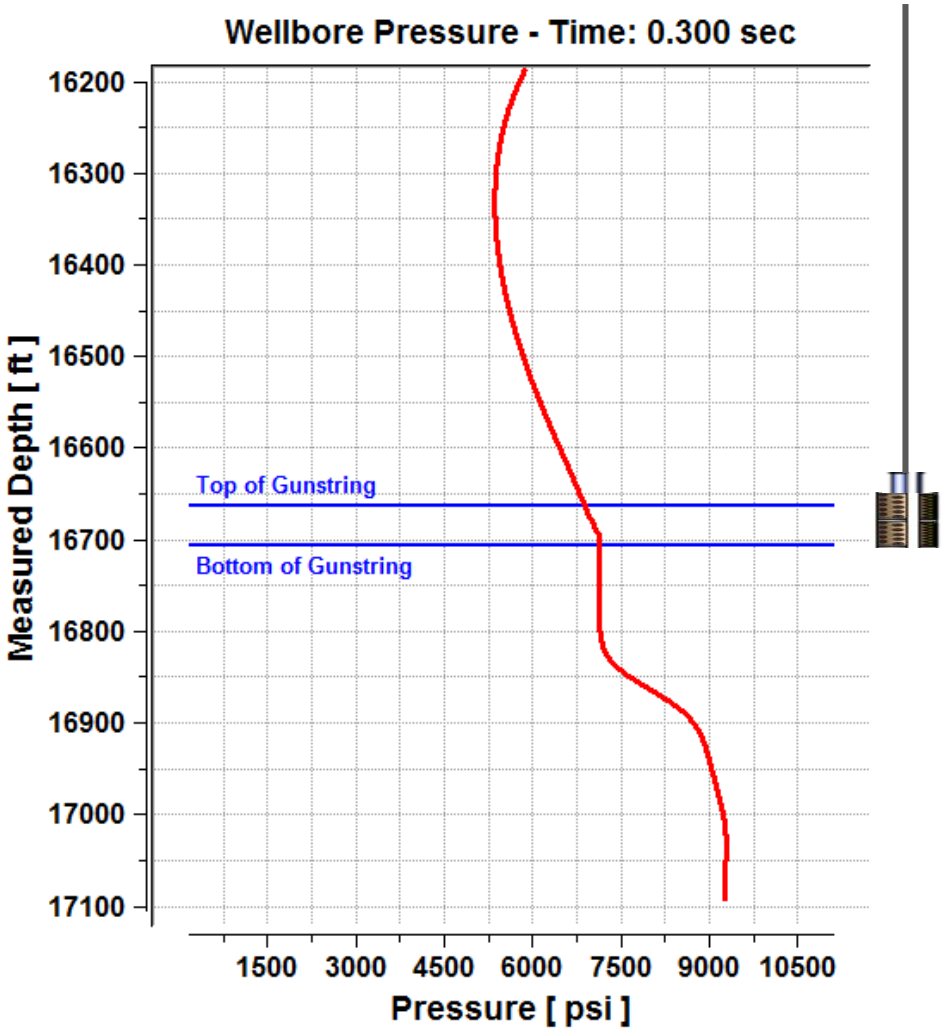
Why the Weak Point broke ?

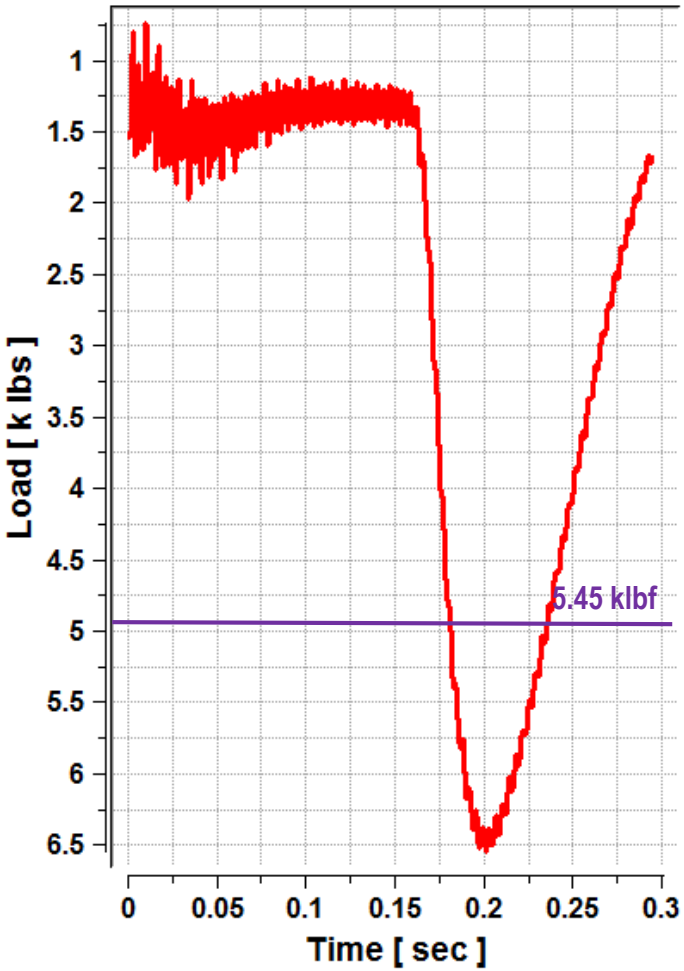




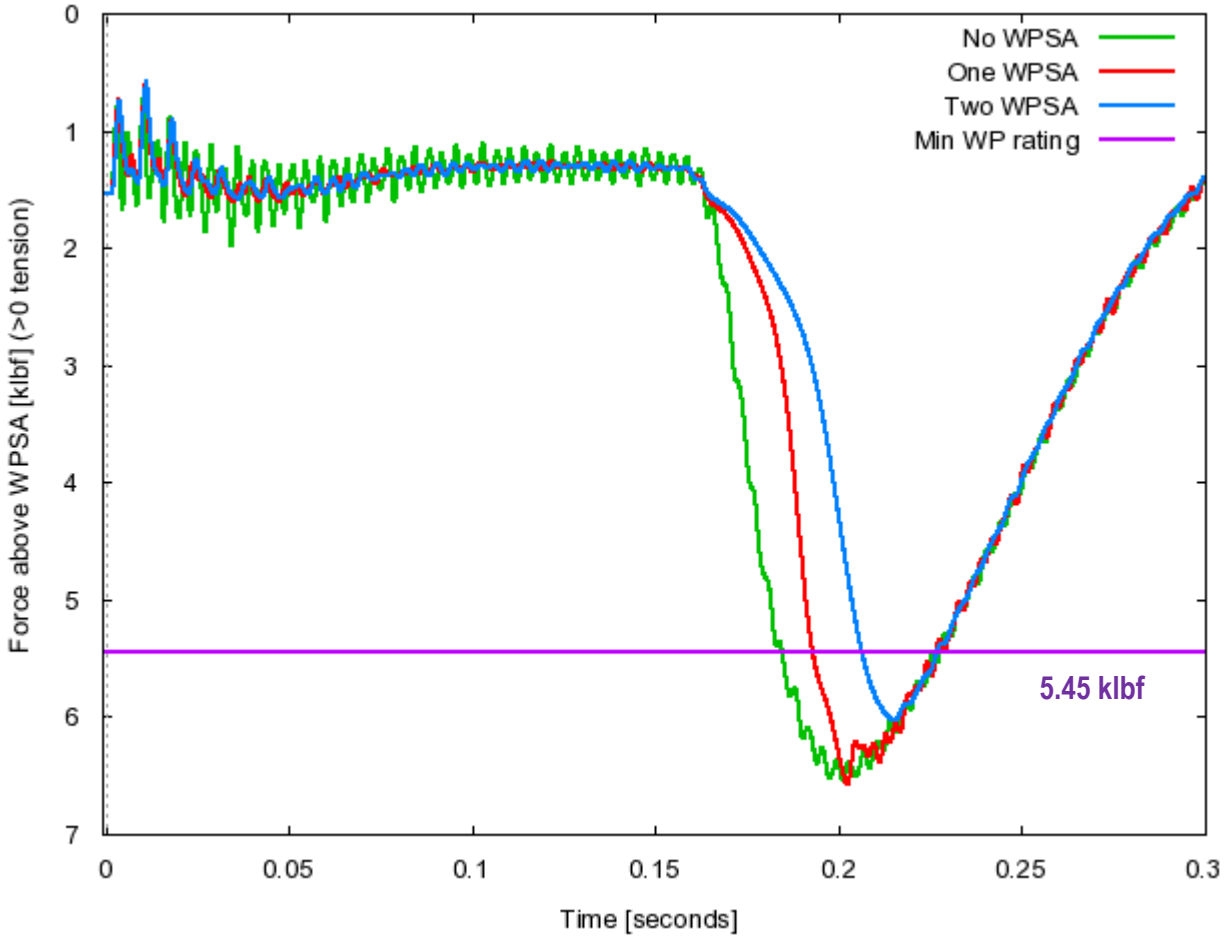
Why the Weak Point broke ?

Peak Tension 6,500 lbf > 5,450 lbf



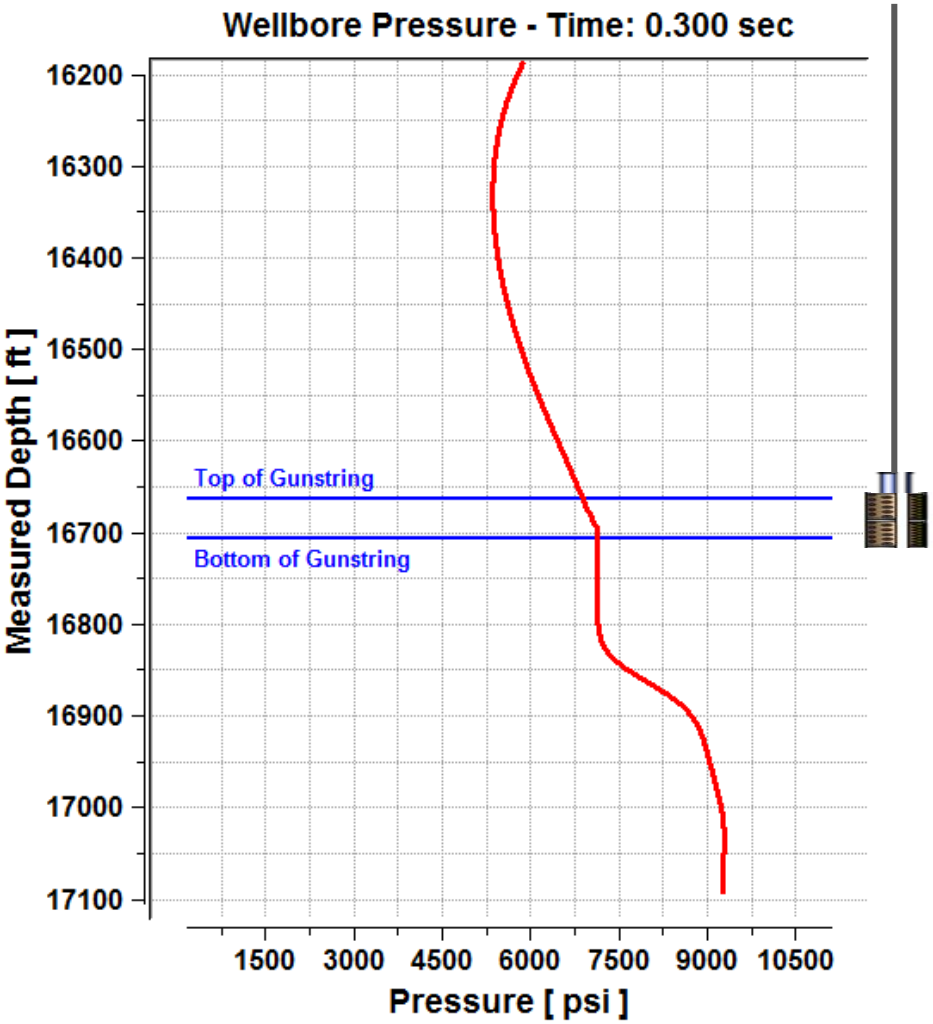


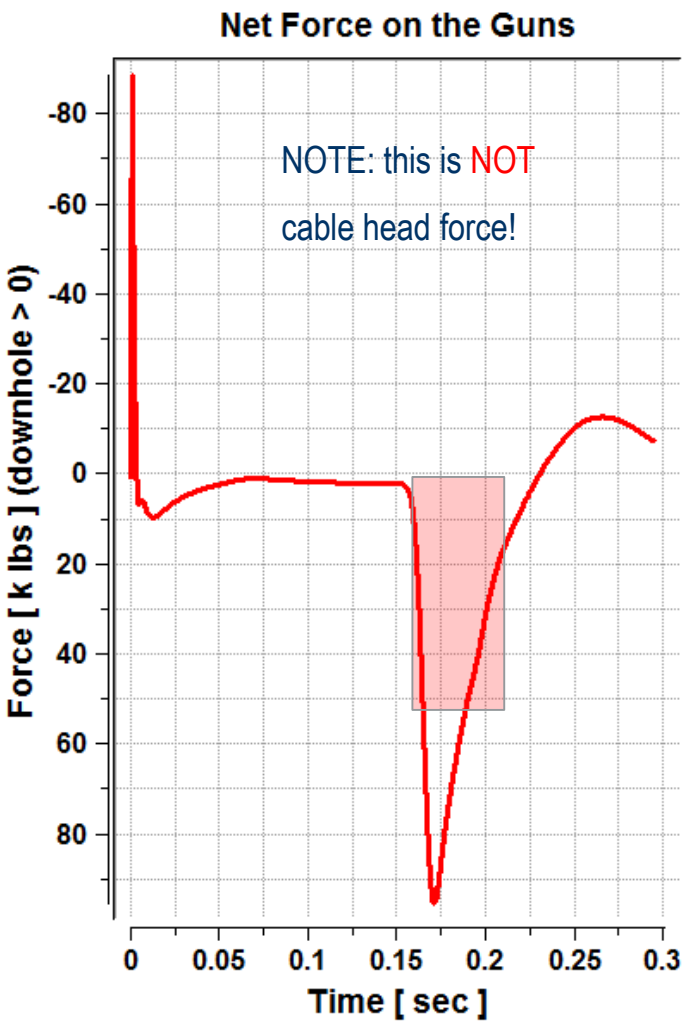
Could WPSAs have prevented the broken WP ?



Why WPSAs may not reduce the peak cable tension enough to prevent an UPO?

- Average downhole force acting on the guns: 50klbf for 50 ms
- Wellbore transient pressure => long acting loads in one direction, not high-frequency and near-zero average force as with Metallic shock.



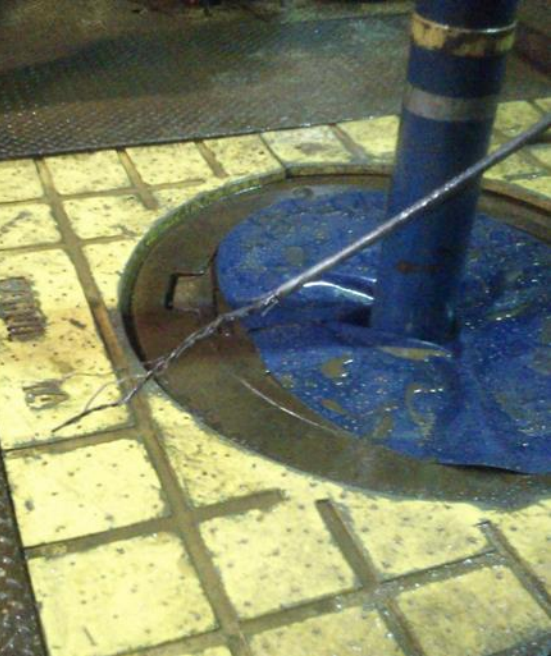


Metallic Shock Mitigation – Final Summary

- Use tools rated for perforating.
- Place tools with electronics away from guns, use a blank gun / spacer if needed.
- Use shock absorbers to reduce the G levels on shock sensitive electronics.
- Tractors and other heavy tools can lead to large loads on low strength tools, use WPSAs right above the guns. The WPSAs “decouple” the guns initial detonation vibration from the tools.

Wellbore Dynamics / Transient Pressure Waves Shock – Final Summary

- Simulation software helps to evaluate the peak load on the WP and tools, prevent UPOs.
- Need reservoir pore pressure and properties, consider worse case scenario:
  - For pressure waves from perforating guns, <u>under-estimate</u> the reservoir response.
  - For guns blown uphole in gas wells, <u>over-estimate</u> the reservoir response.
- To lower the amplitude of transient pressure waves: minimize the difference between gun detonation pressure and initial wellbore pressure.
- Contrary to common belief, for Pg<Pw shooting close to TD is less dangerous than at ~10+ gun lengths.
- Always simulate/verify last minute changes.



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Thank You !!!

Carlos Baumann – Schlumberger

May 4th 2017