SLAP-41 - SPE-163549

Perforating Gunshock Loads Prediction and Mitigation

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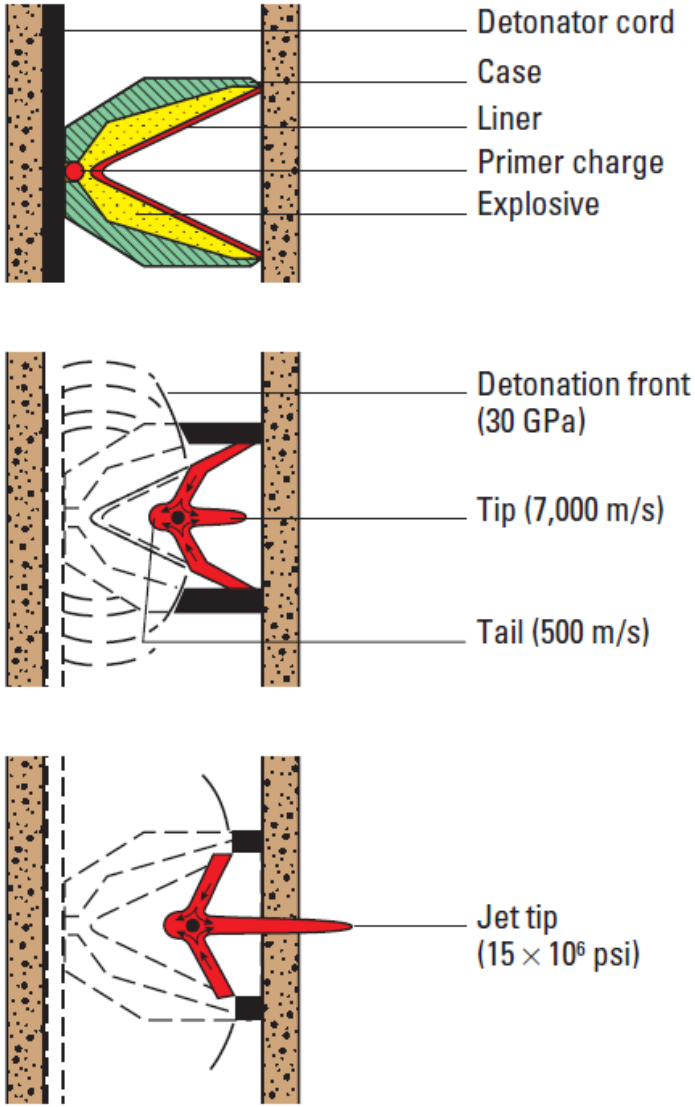
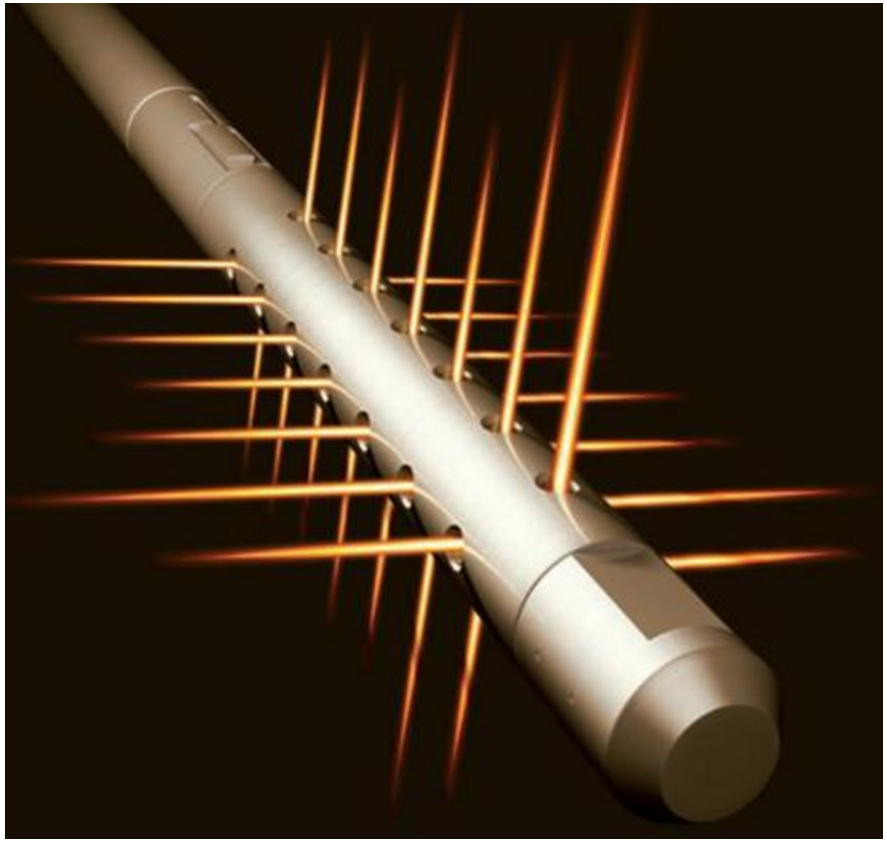
Outline

- Wellbore hydrodynamics - Pressure wave propagation animation
- Wellbore hydrodynamics and structural dynamics / gunshock animation
- Corkscrewed tubing joints analysis - TCP job with 7-in guns and 2-7/8-in tubing
  - Analysis of transient wellbore dynamics and gunshock loads
- Reduction of Dynamic Loads - TCP job with Automatic Gun Release System
  - Initial vs. Optimal gun-loading to minimize gunshock loads
- Wireline perforating - Prediction and verification of wellbore pressure and dynamic loads on the weak point
- Conclusions

Wellbore Hydrodynamics – After Creation of Perforation Tunnels

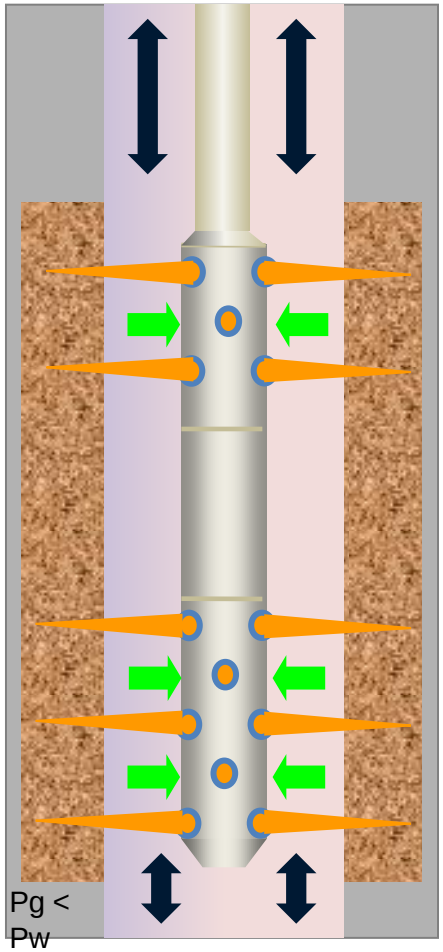




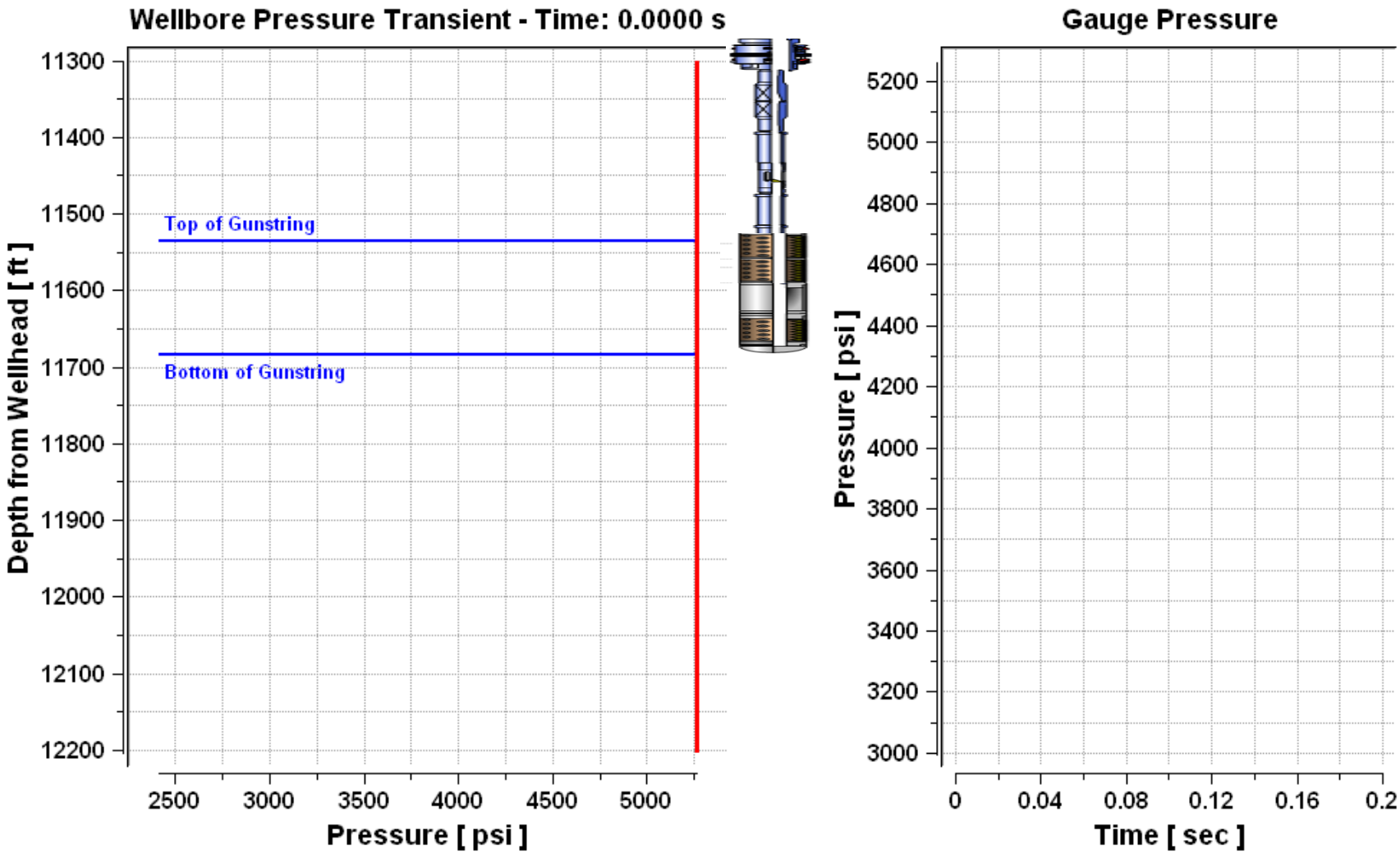
Wellbore Dynamics - Fundamentals

- Dynamic Underbalance: Deto Pressure < Wellbore Pressure immediately after firing guns become a pressure sink

- Dynamic Overbalance: Deto Pressure > Wellbore Pressure immediately after firing guns become a pressure source

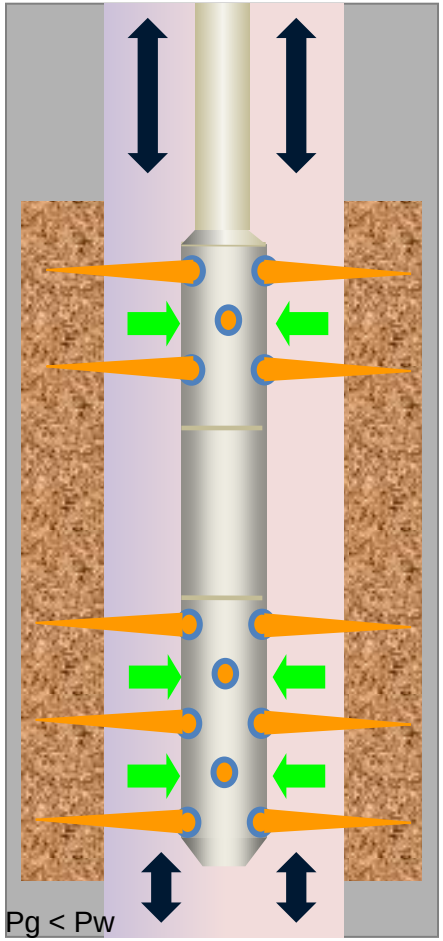


Wellbore Dynamics – Gauge Pressure above Top-Shot - Animation

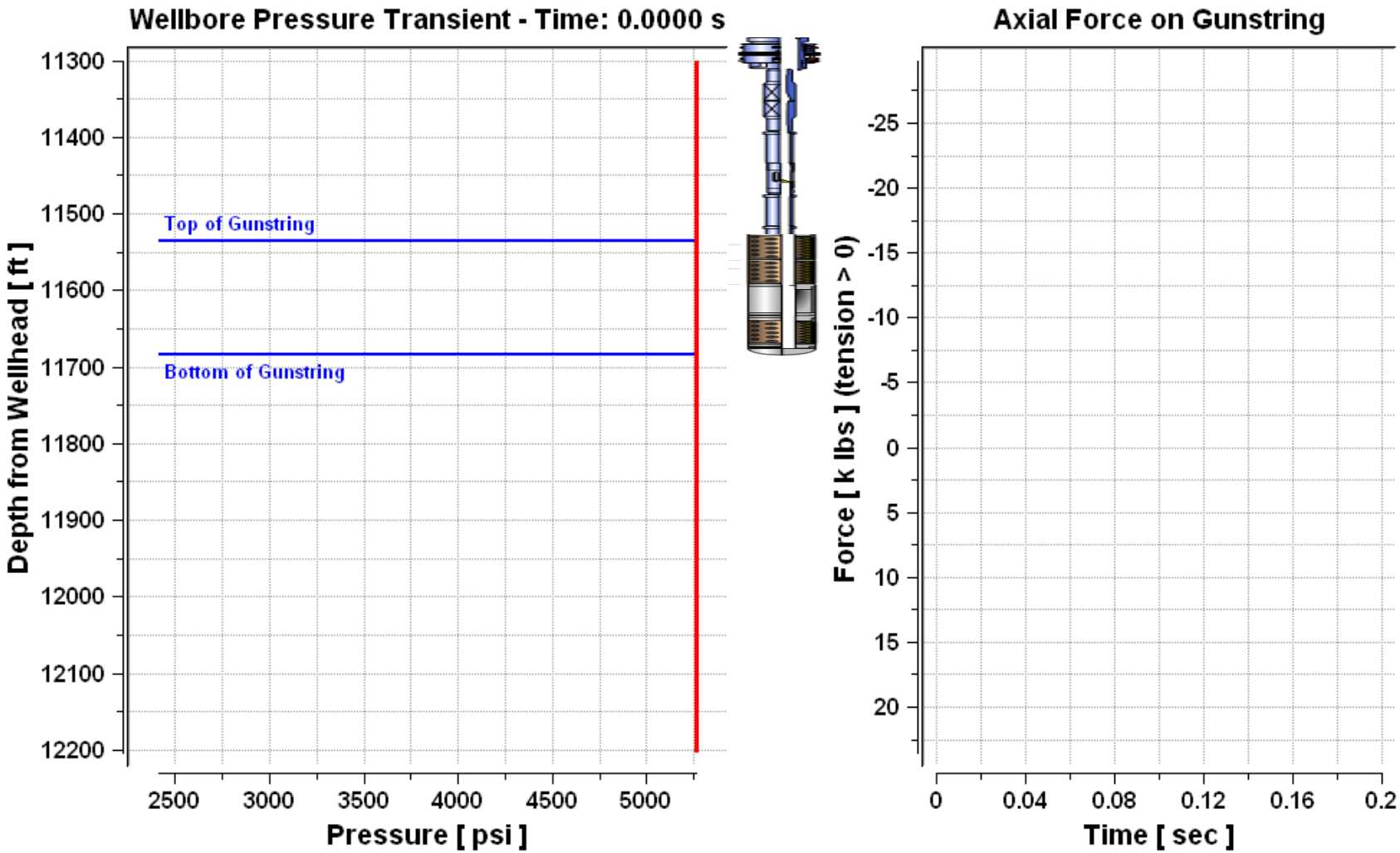


Wellbore Hydrodynamics and Structural Dynamics - Fundamentals

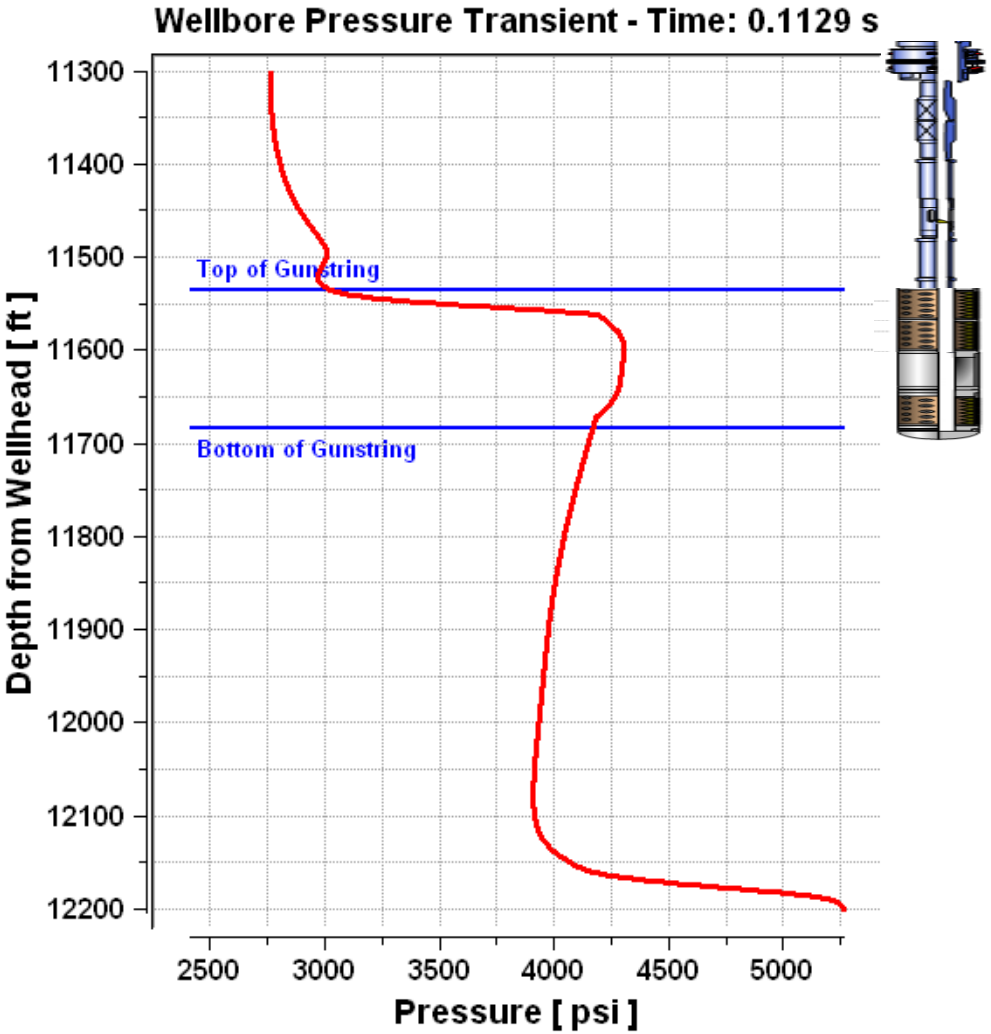
- Pressure waves propagate / reflect inside the wellbore
- Gunstring / Tools cross sectional area changes produce gunshock loads

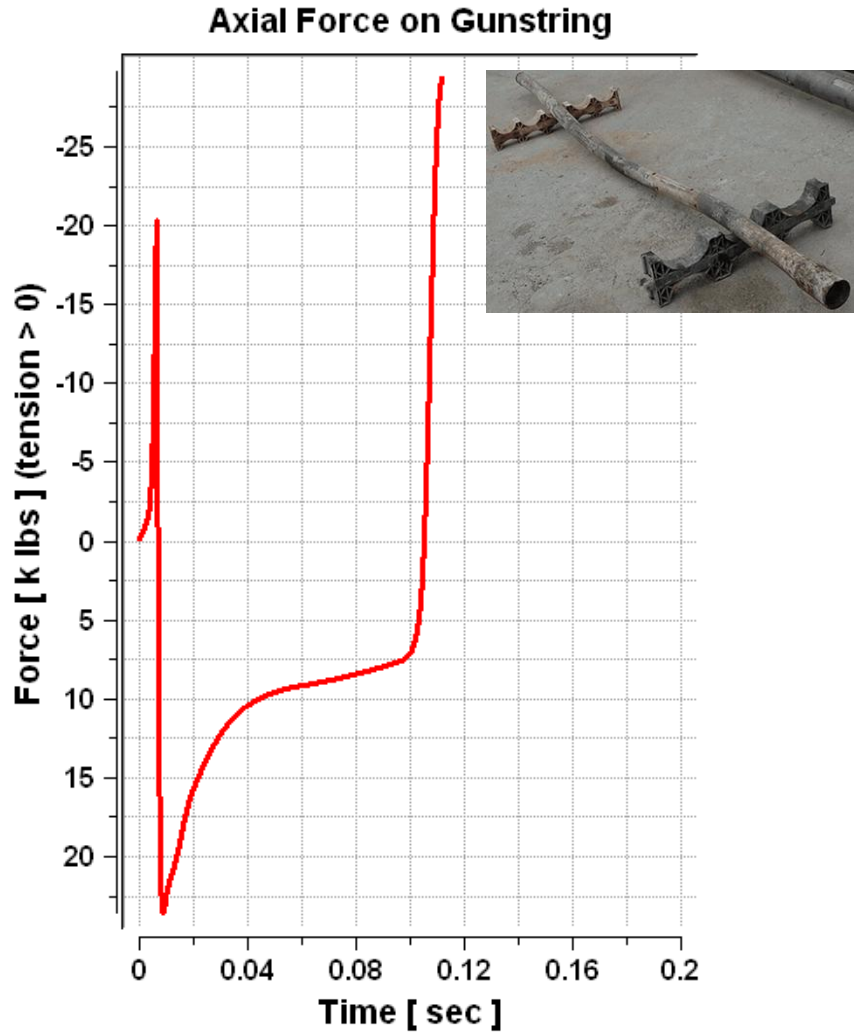


Wellbore Dynamics – Axial Force applied on Gunstring - Animation



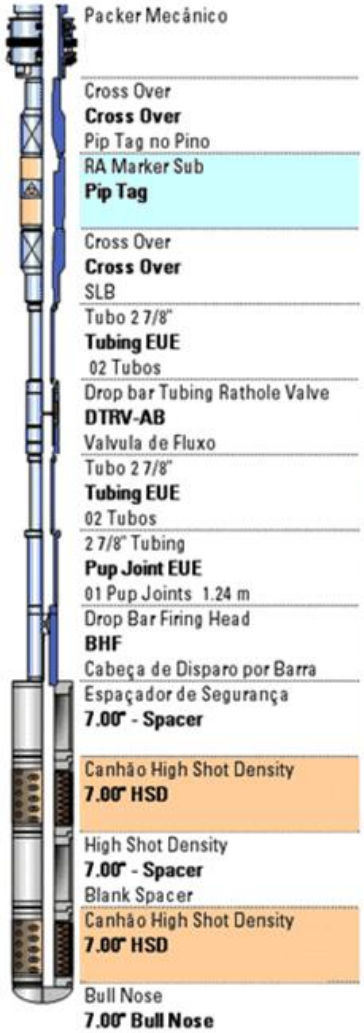
Instant when the Maximum Uphole Force on the Gunstring Occurs



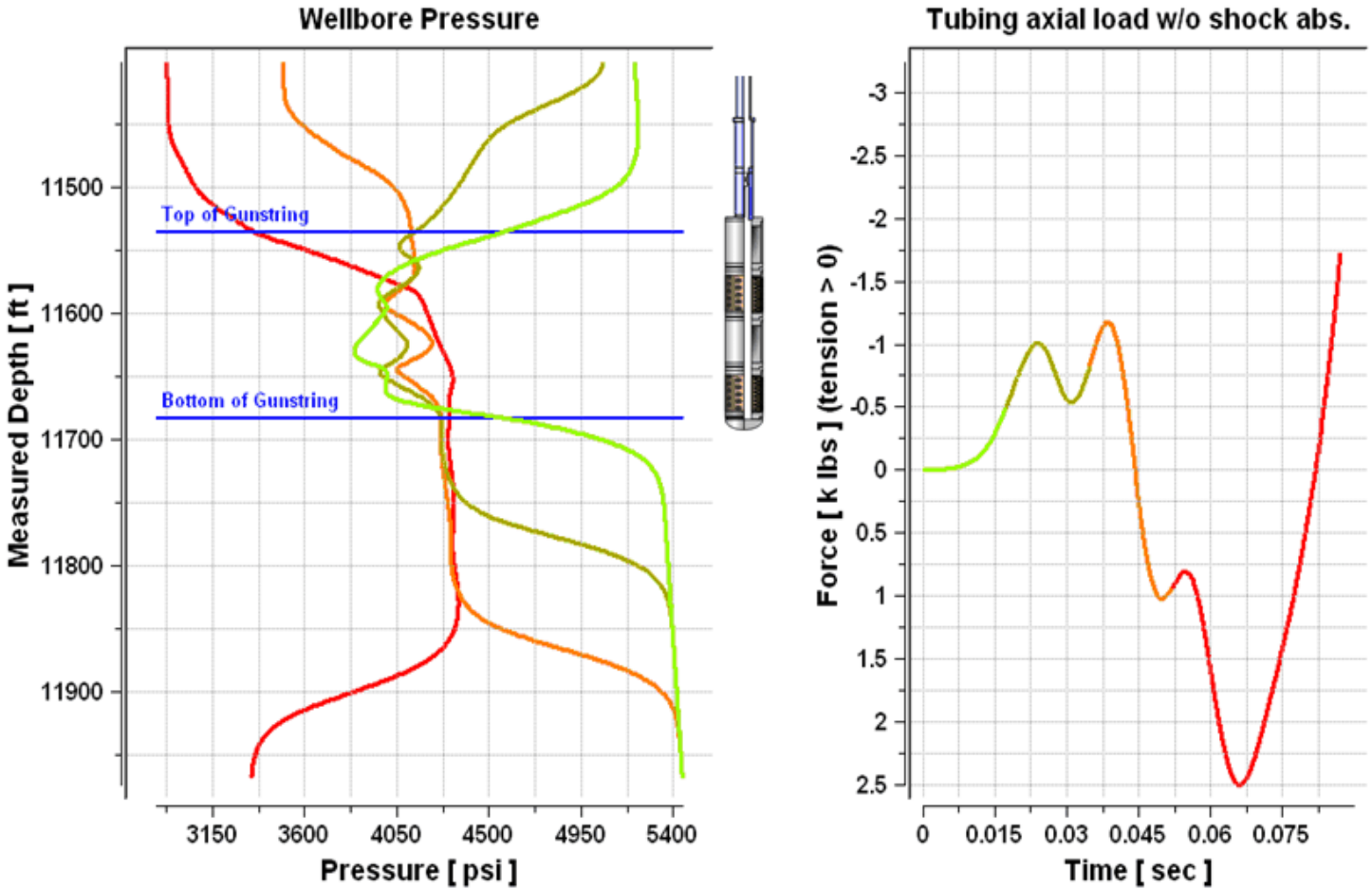


Software - Capabilities

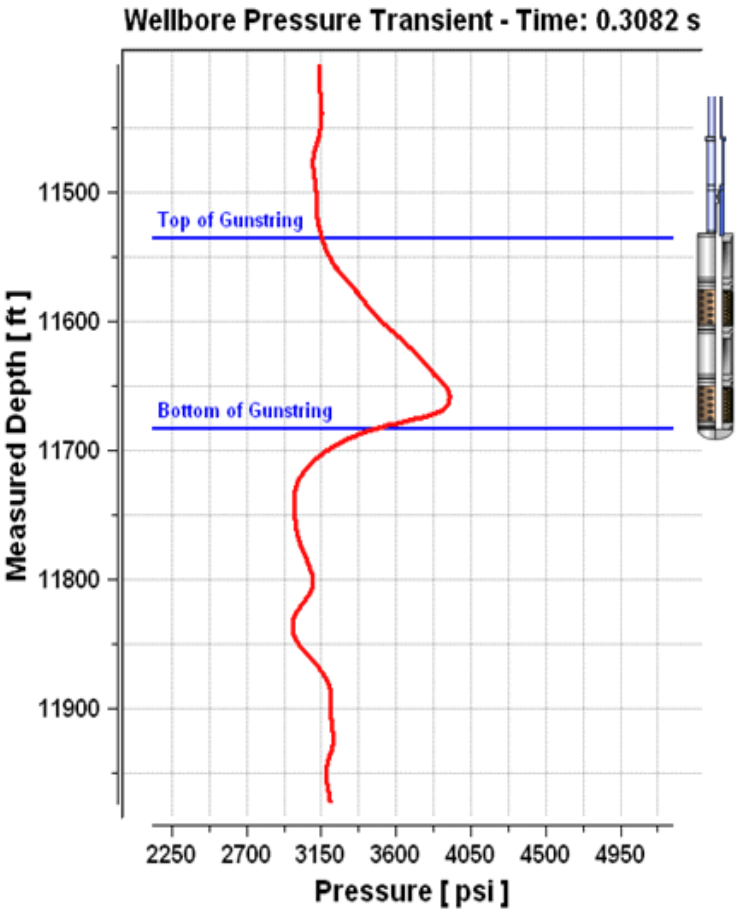
- Coupled wellbore dynamics (fluids) & structural dynamics simulation
- Prediction of transient pressure around the guns / ***sand-face***
- Gun Shock is typically a problem with large guns
- Prediction of guns movement, velocity, acceleration, tubing and packer loads, cable tension, peak load on the weak point
- Software verified with a large database of perforating jobs (thousands)

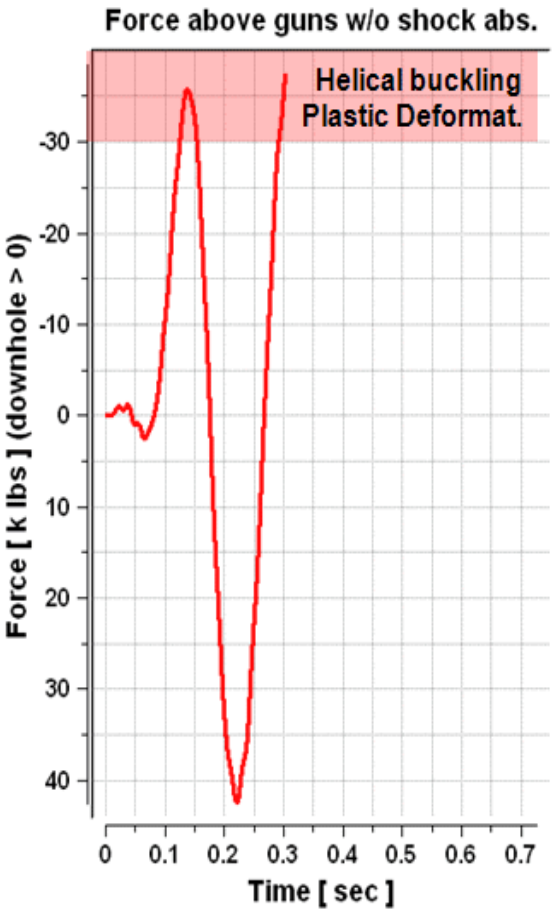

Packer Mecânico
Cross Over
Cross Over
Pip Tag no Pino
RA Marker Sub
Pip Tag
Cross Over
Cross Over
SLB
Tubo 2 7/8"
Tubing EUE
02 Tubos
Drop bar Tubing Rathole Valve
DTRV-AB
Valvula de Fluxo
Tubo 2 7/8"
Tubing EUE
02 Tubos
2 7/8" Tubing
Pup Joint EUE
01 Pup Joints 1.24 m
Drop Bar Firing Head
BHF
Cabeça de Disparo por Barra
Espaçador de Segurança
7.00" - Spacer
Canhão High Shot Density
7.00" HSD
High Shot Density
7.00" - Spacer
Blank Spacer
Canhão High Shot Density
7.00" HSD
Bull Nose
7.00" Bull Nose

Wellbore Pressure and Dynamic Tubing Load – Up to 80 ms

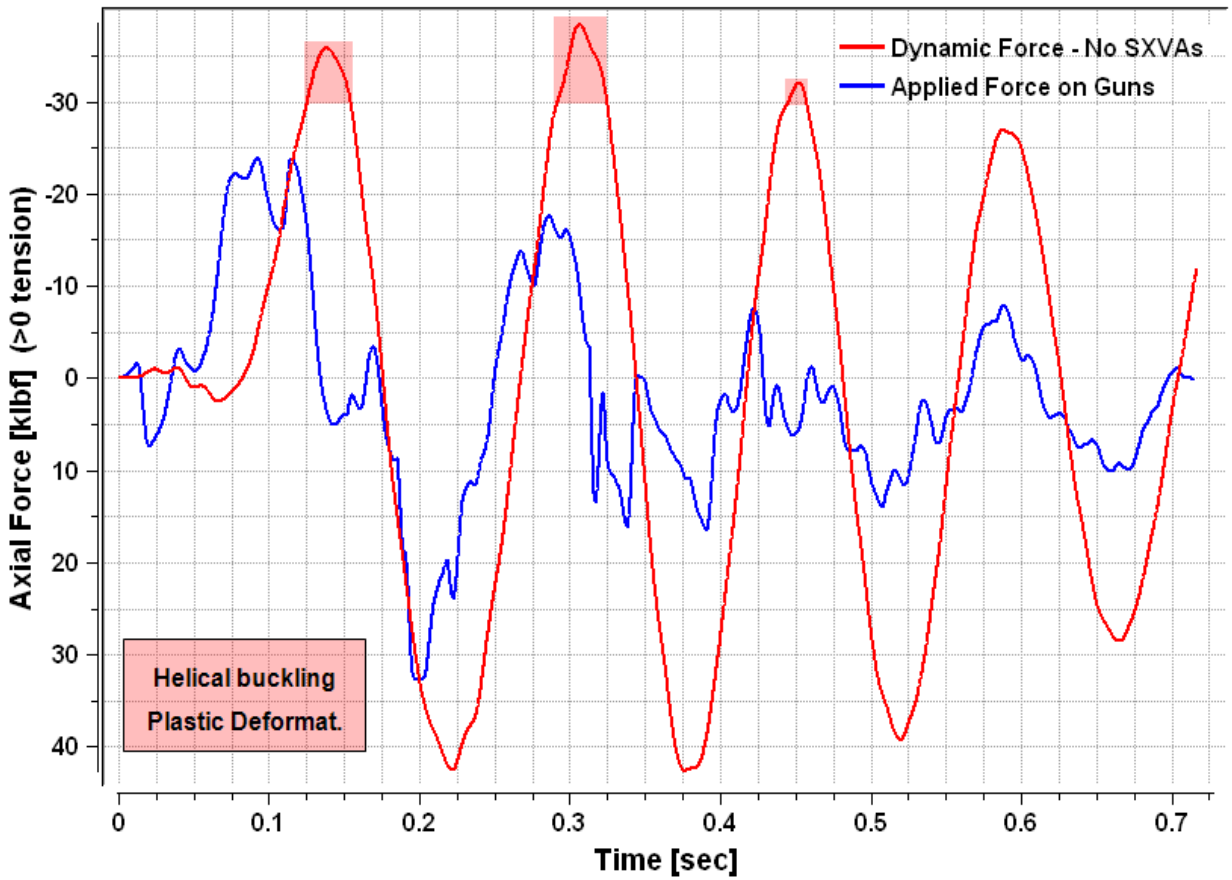


Wellbore Pressure and Dynamic Tubing Load – 308 ms



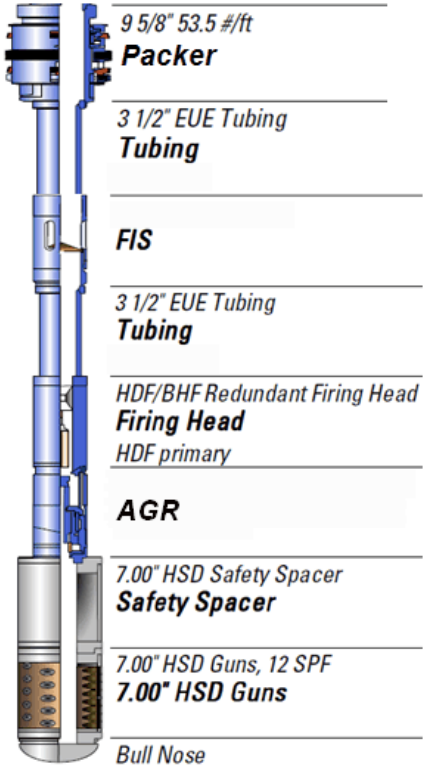


Applied Force on Guns and Dynamic Tubing Load – Up to 720 ms



Reduction of Dynamic Loads

TCP job with 7.0-in guns and Automatic Gun Release SXAR



Net perforation interval 50m.

39-gram HMX DP charges 12 spf

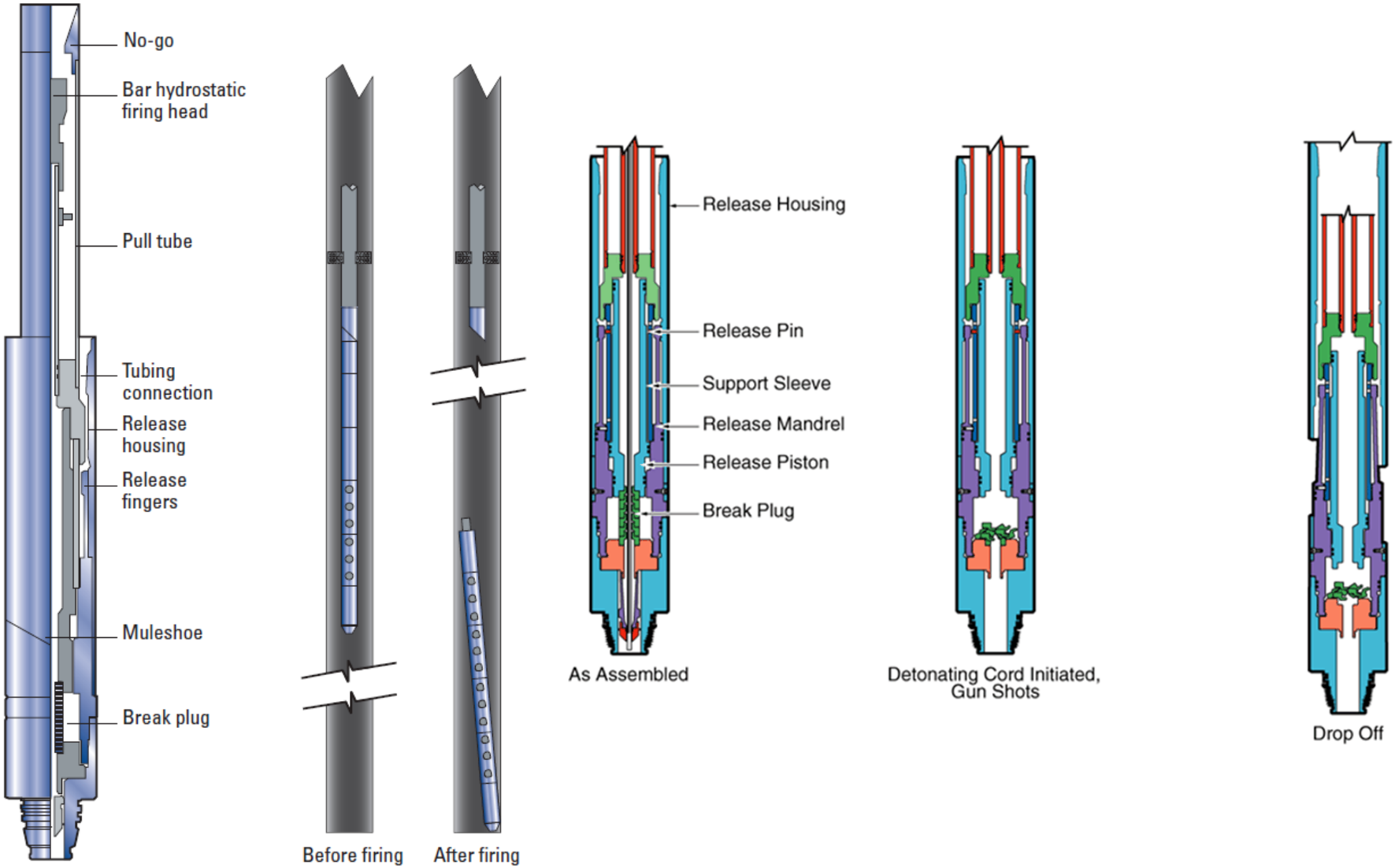
Top of safety spacer to packer 115 ft.

Bull-nose to PBTD 596 ft.

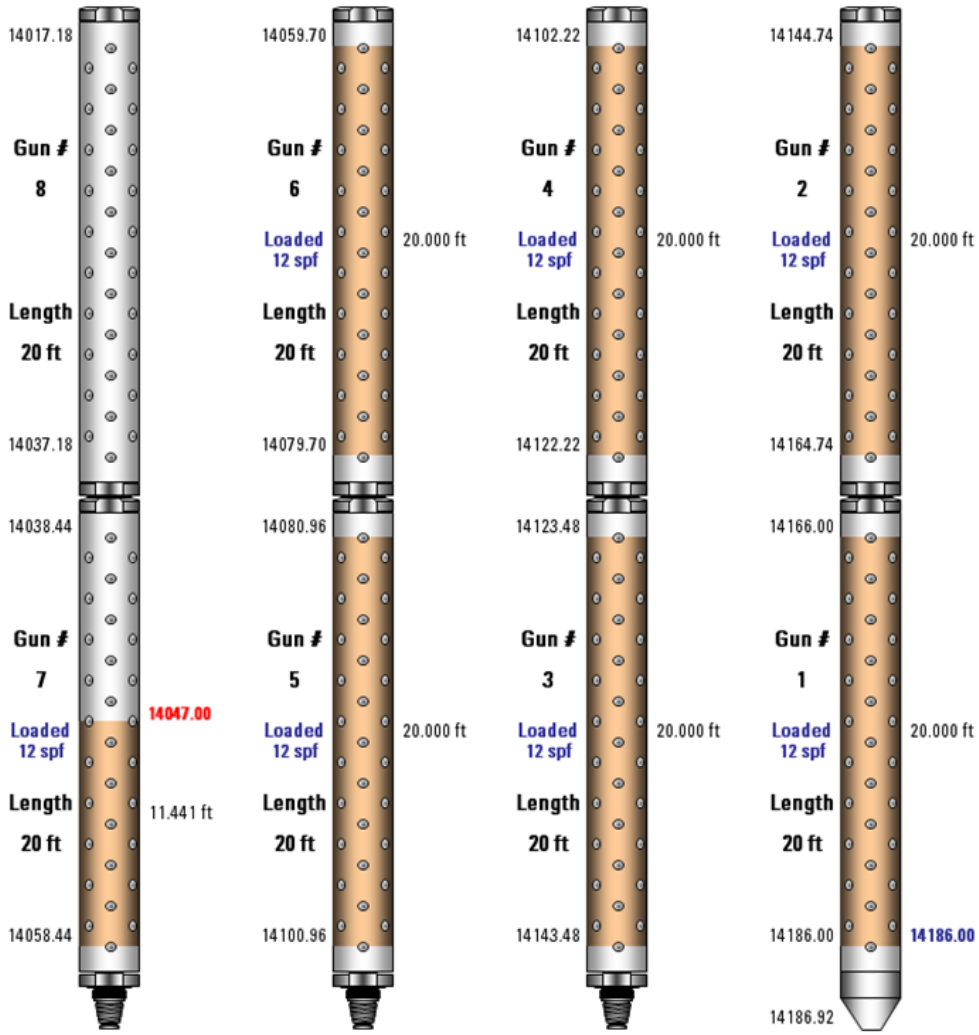
Wellbore pressure at depth 5,500 psi, 9.2 ppg

Reservoir pressure at depth 6,500 psi.

Automatic Gun Release SXAR



Initial Gun-Loading

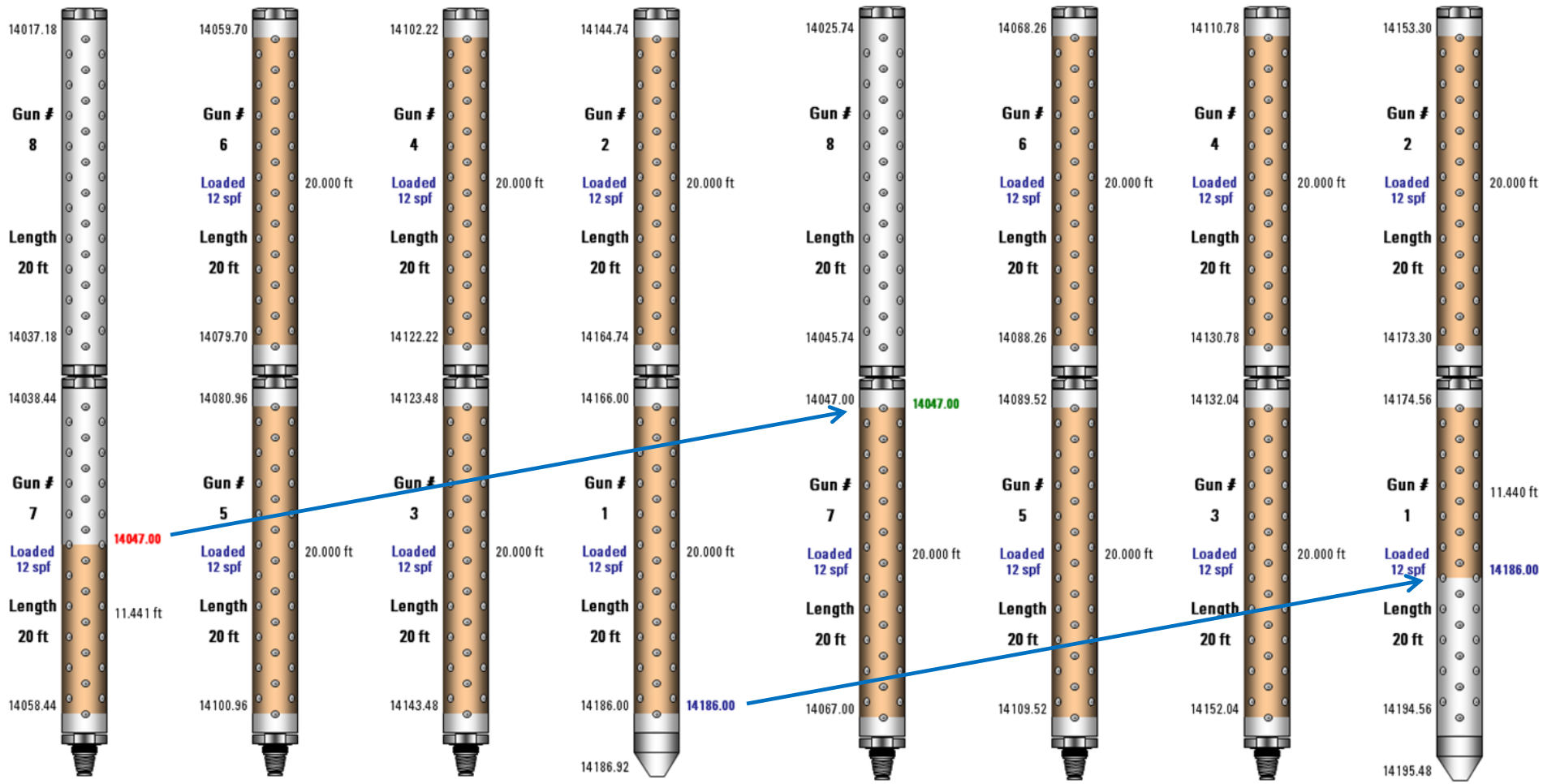


Initial Gun-Loading

Movement and Tubing Axial Load at AGR up to 0.1 sec

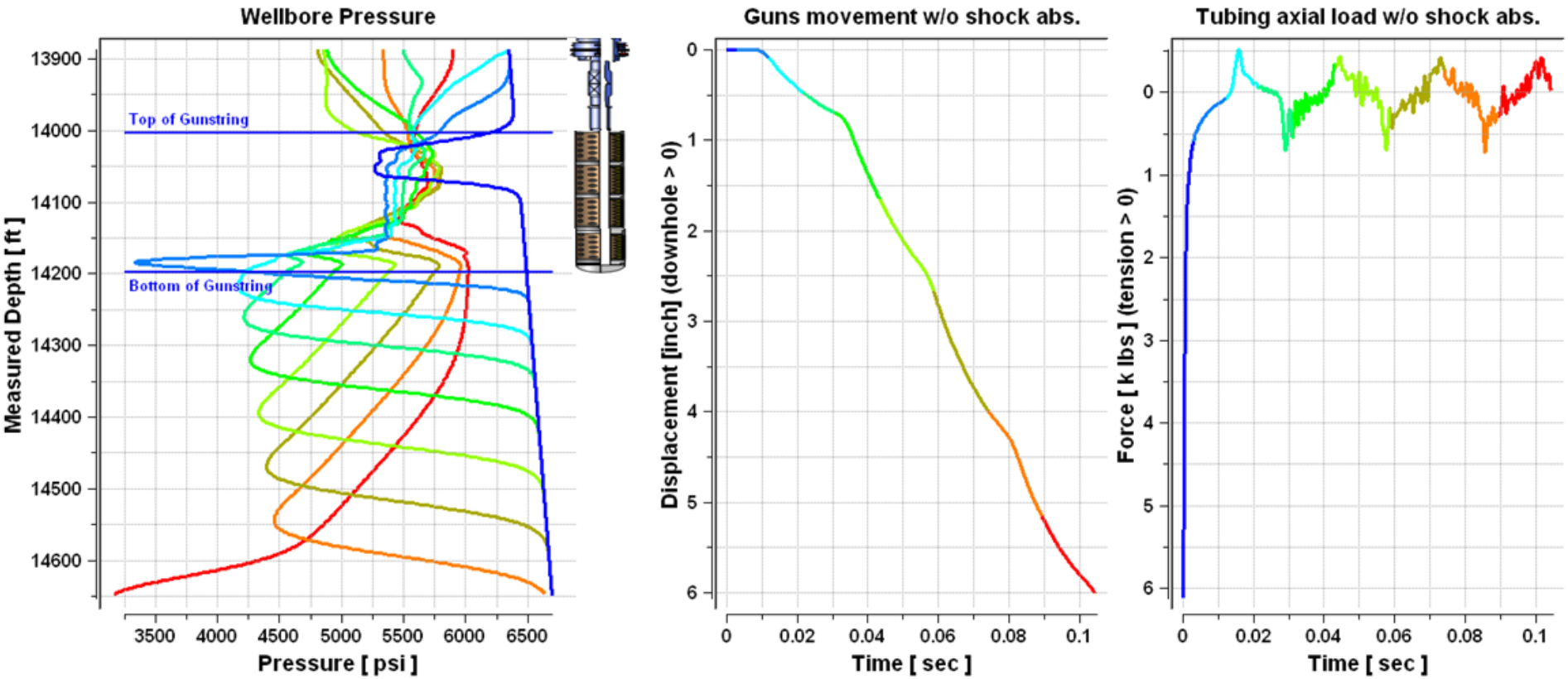
Initial Gun-Loading

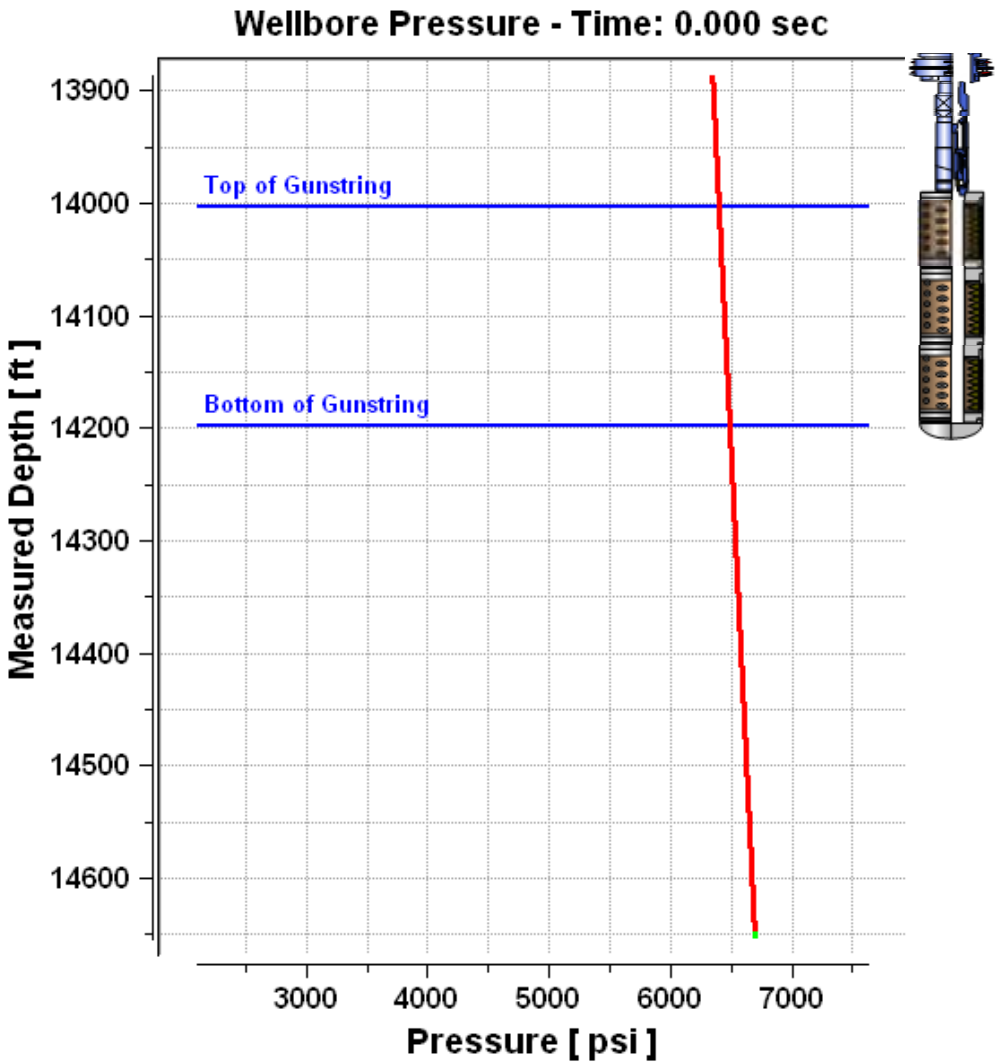
Optimized Gun-Loading to Minimize Gunshock Load

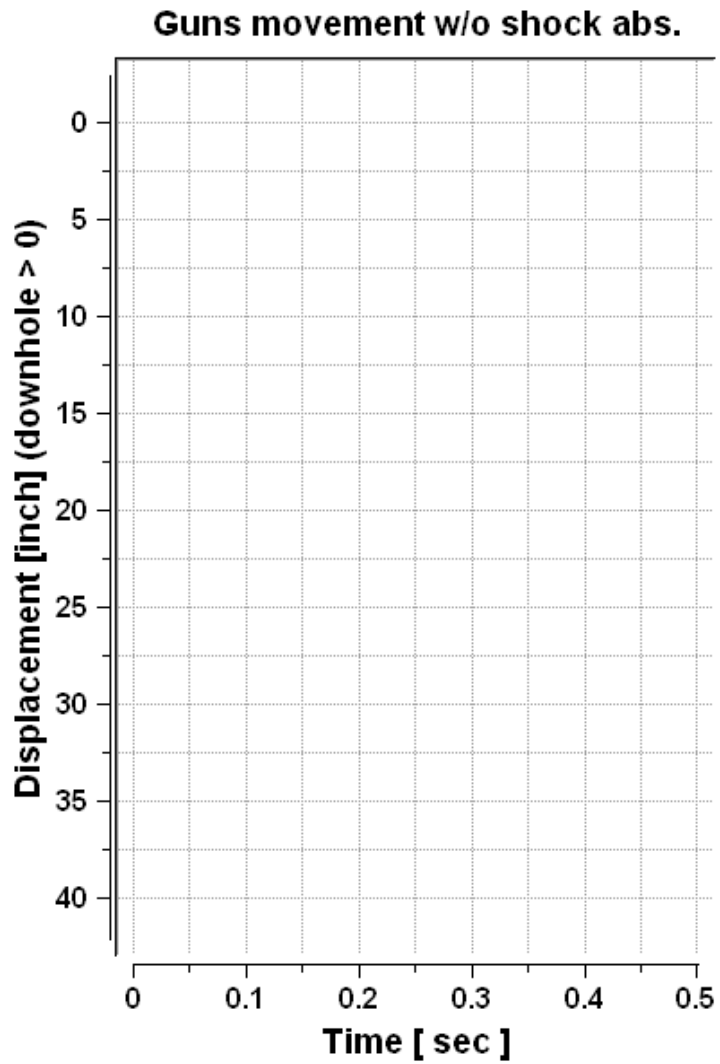


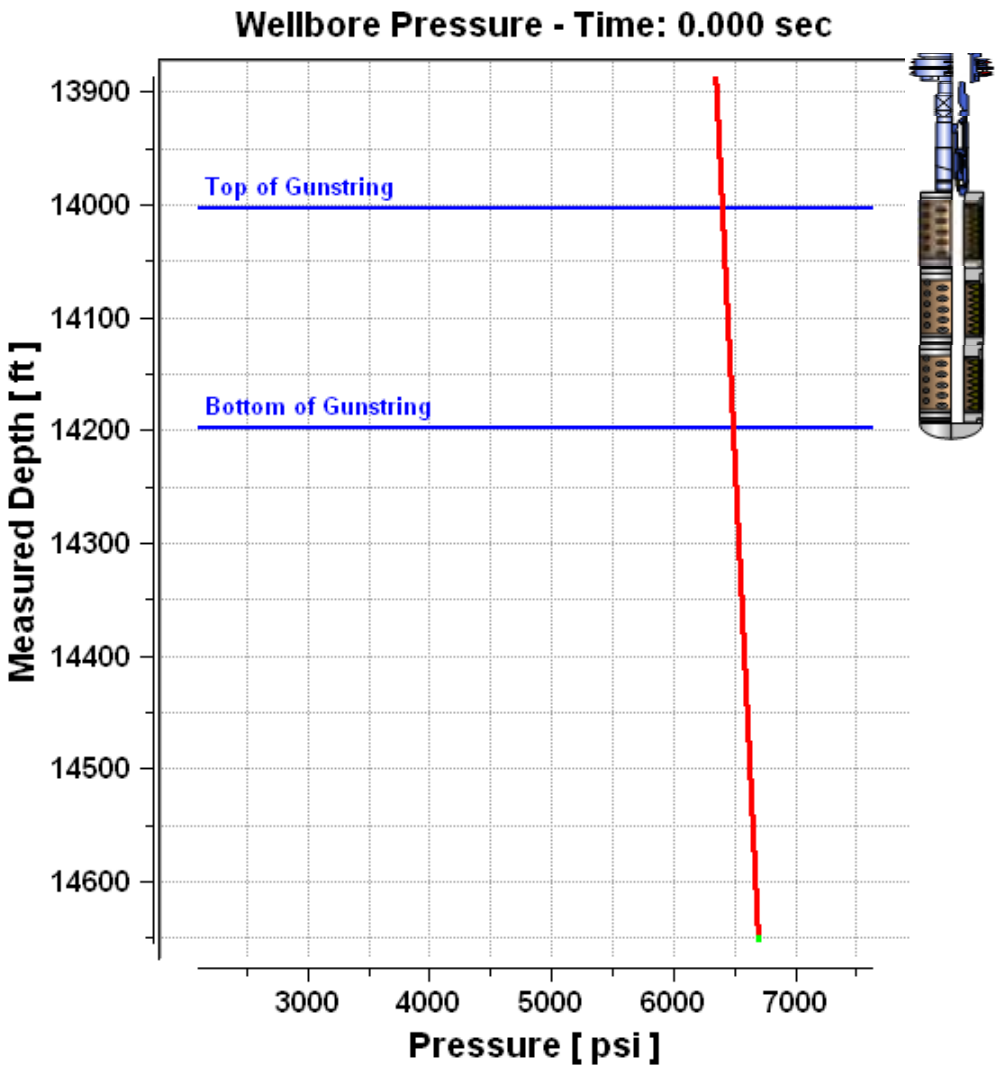
Optimized gun-loading to minimize gunshock load

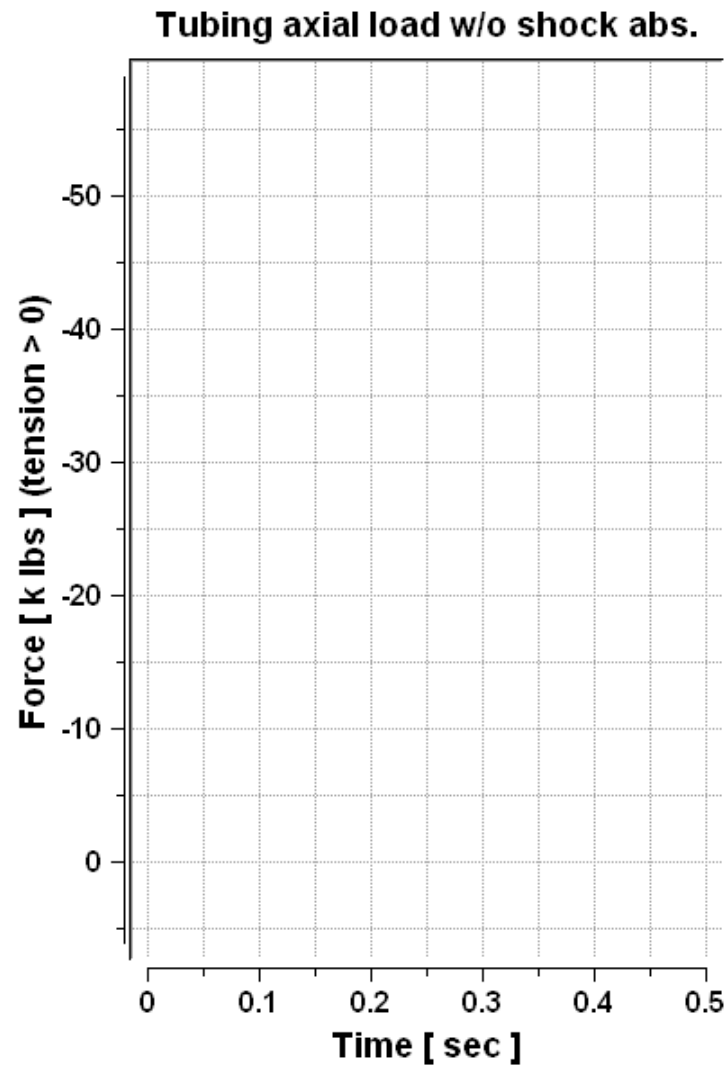
Movement and Tubing Axial Load / AGR up to 0.1 sec

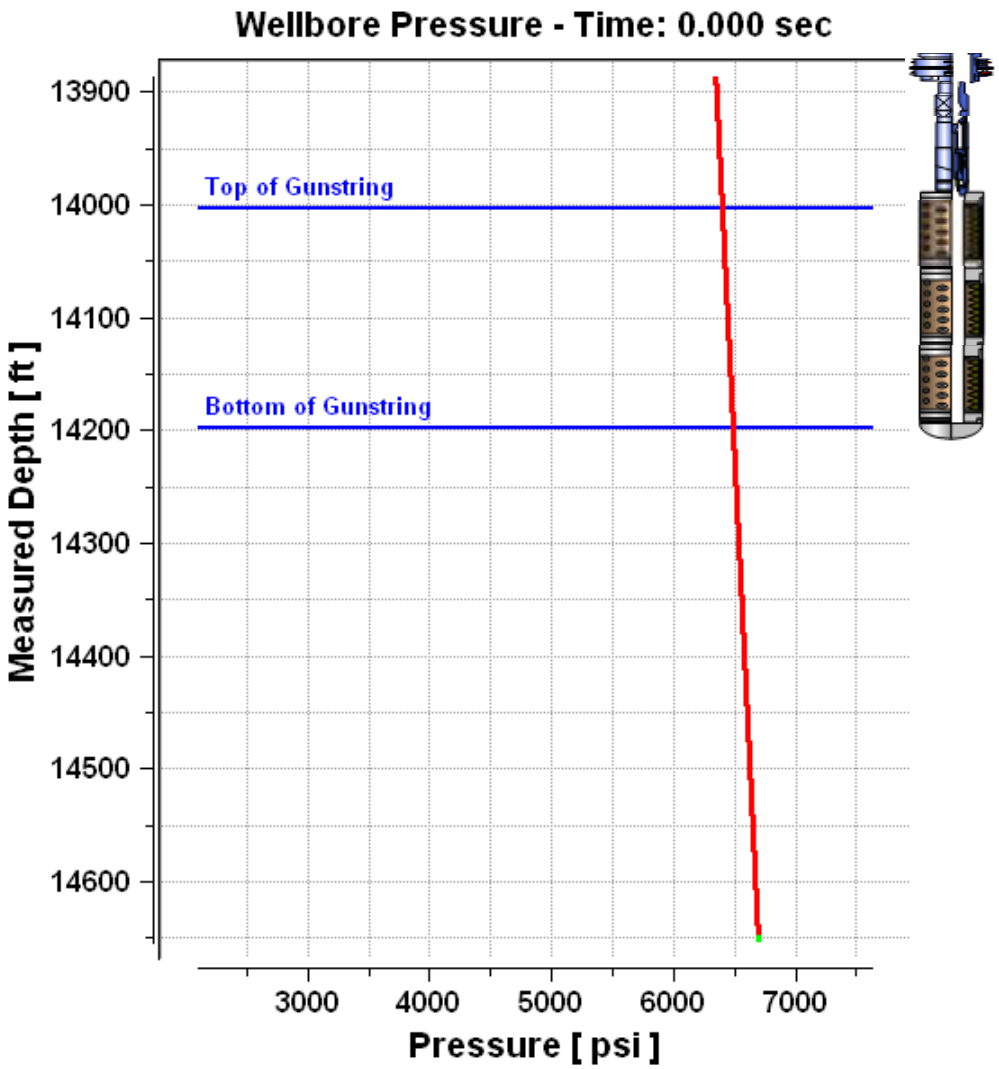


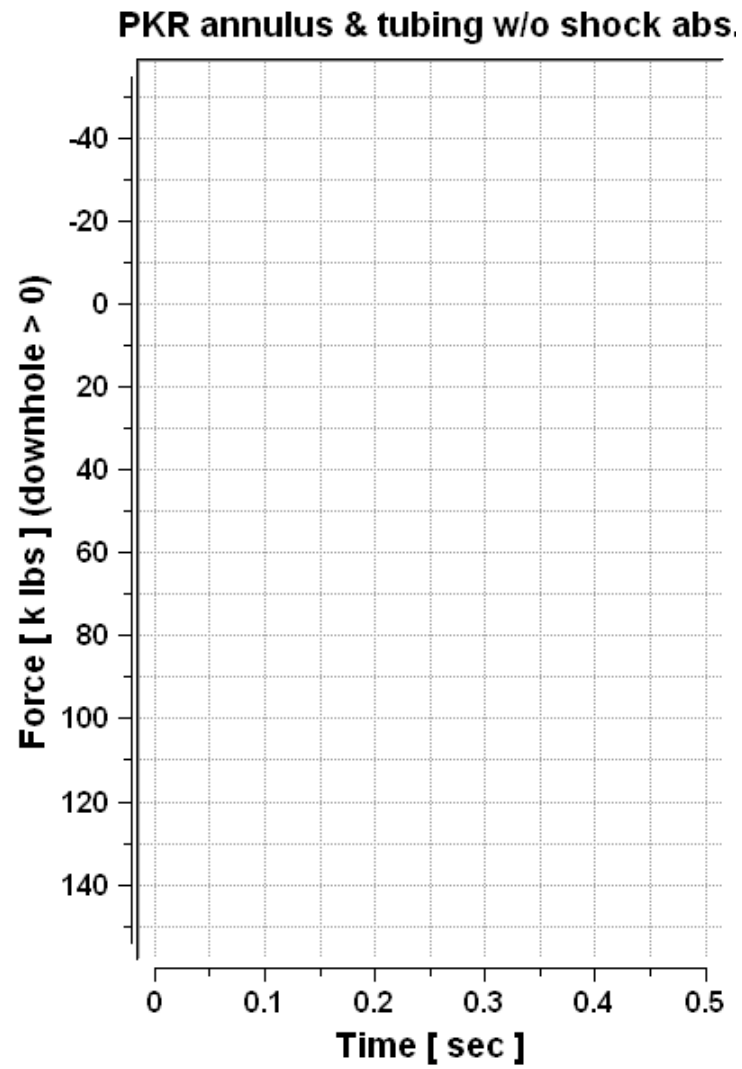

Wellbore Pressure - Time: 0.000 sec
Top of Gunstring
Bottom of Gunstring
Measured Depth [ft]
13900
14000
14100
14200
14300
14400
14500
14600
3000
4000
5000
6000
7000
Pressure [psi]


Guns movement w/o shock abs.
Displacement [inch] (downhole > 0)
0
5
10
15
20
25
30
35
40
0
0.1
0.2
0.3
0.4
0.5
Time [sec]


Wellbore Pressure - Time: 0.000 sec
Top of Gunstring
Bottom of Gunstring
Measured Depth [ft]
13900
14000
14100
14200
14300
14400
14500
14600
3000
4000
5000
6000
7000
Pressure [psi]


Tubing axial load w/o shock abs.
Force [k lbs] (tension > 0)
-50
-40
-30
-20
-10
0
0
0.1
0.2
0.3
0.4
0.5
Time [sec]

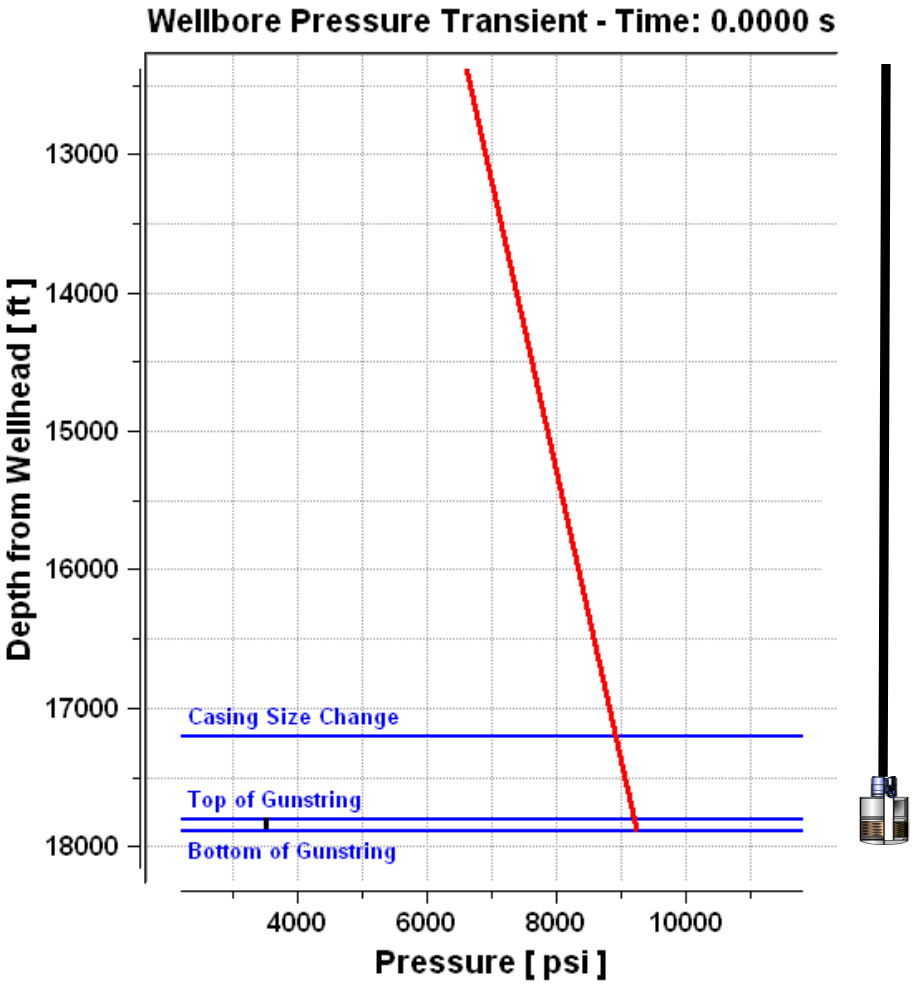

Wellbore Pressure - Time: 0.000 sec
Top of Gunstring
Bottom of Gunstring
Measured Depth [ft]
13900
14000
14100
14200
14300
14400
14500
14600
3000
4000
5000
6000
7000
Pressure [psi]

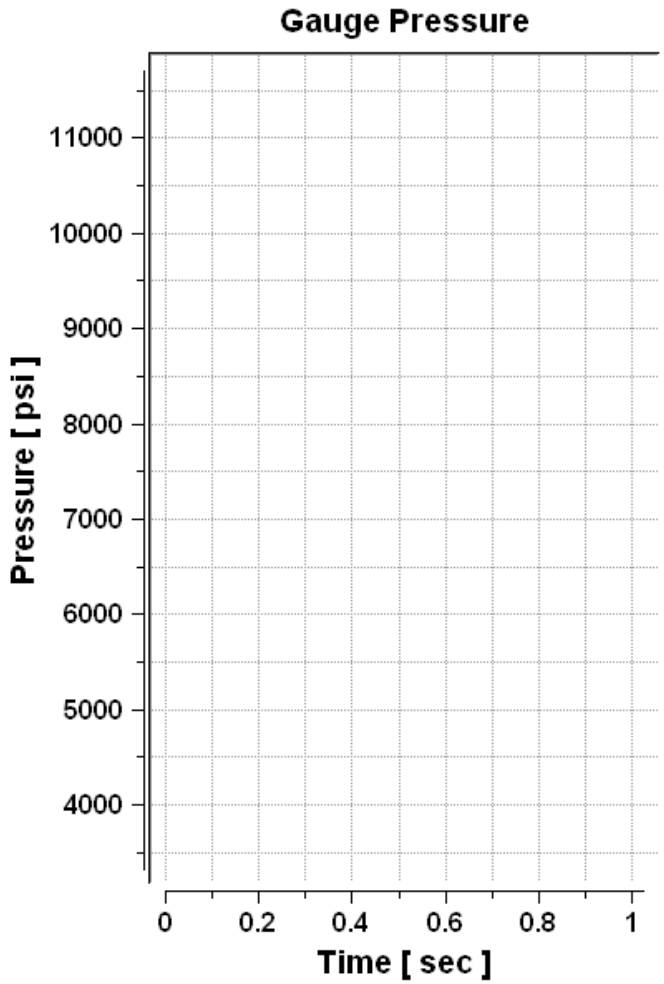

PKR annulus & tubing w/o shock abs.
Force [k lbs] (downhole > 0)
-40
-20
0
20
40
60
80
100
120
140
0
0.1
0.2
0.3
0.4
0.5
Time [sec]

Initial vs. Optimized Gun-Loading to Minimize Gunshock Loads

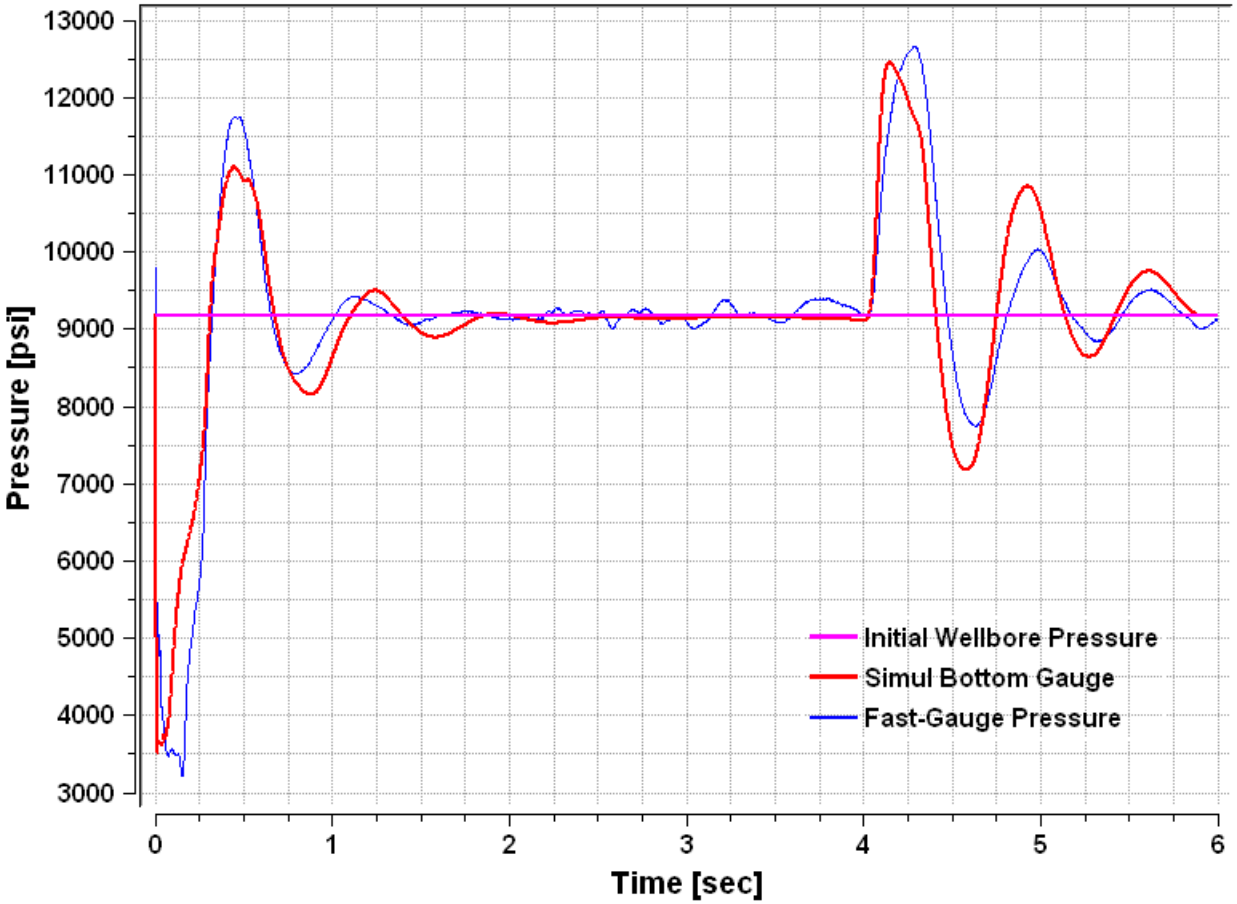
- Peak load on the Auto. Gun Release system: -58 klbf vs. -1 klbf
- Peak up-hole force on the packer: -47 klbf vs. -3 klbf
- Peak down-hole force on the packer: 155 klbf vs. 75 klbf
- Conclusion: Software optimization is crucial to prevent gunshock damage and non-productive time / $ loss

Perforating on Wireline – Four 4-1/2-in DUB guns – DP 4512 charges

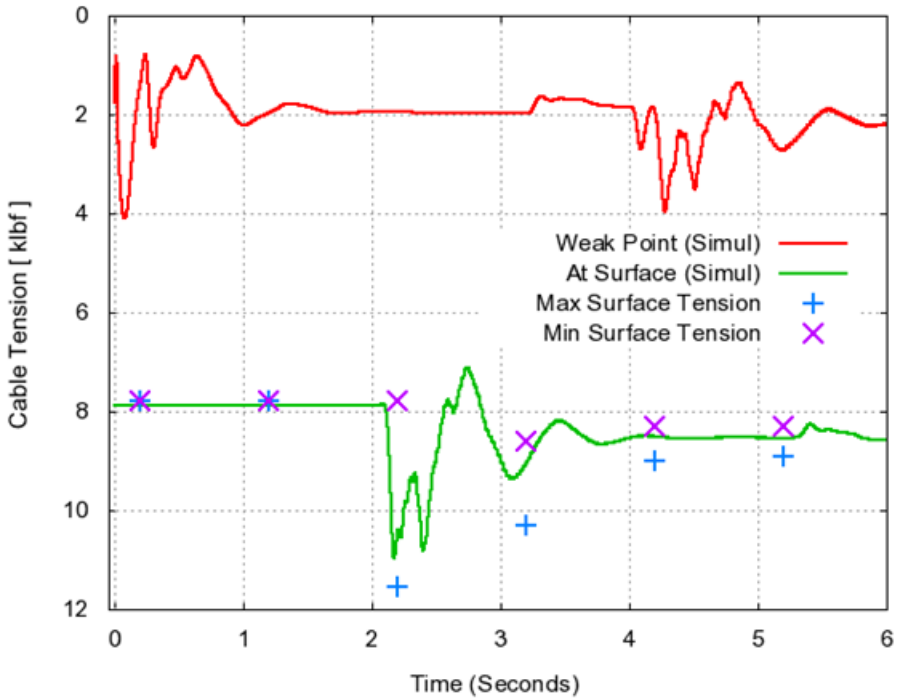


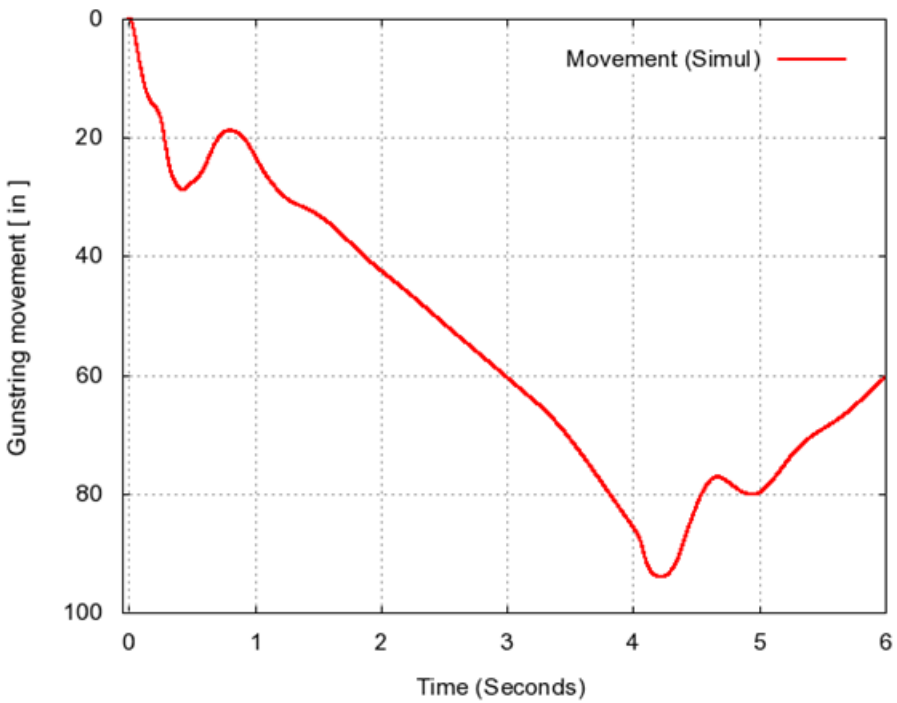


Wireline Perforating – Predicted vs. Fast Gauge Data

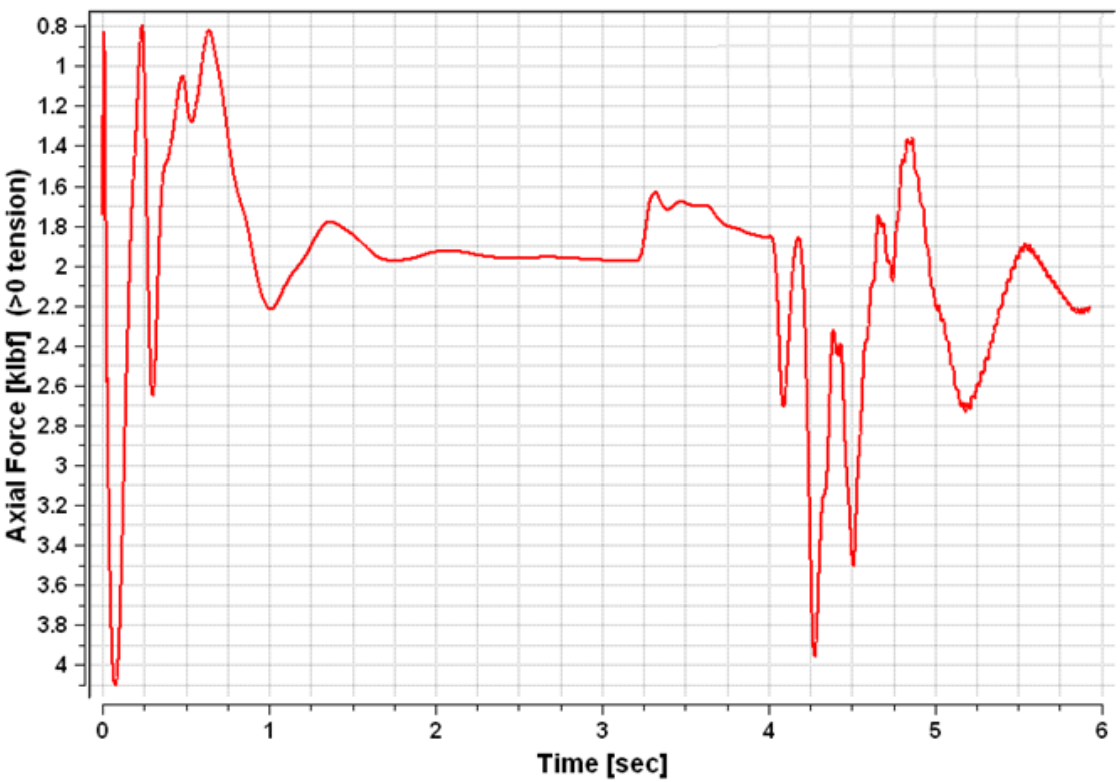


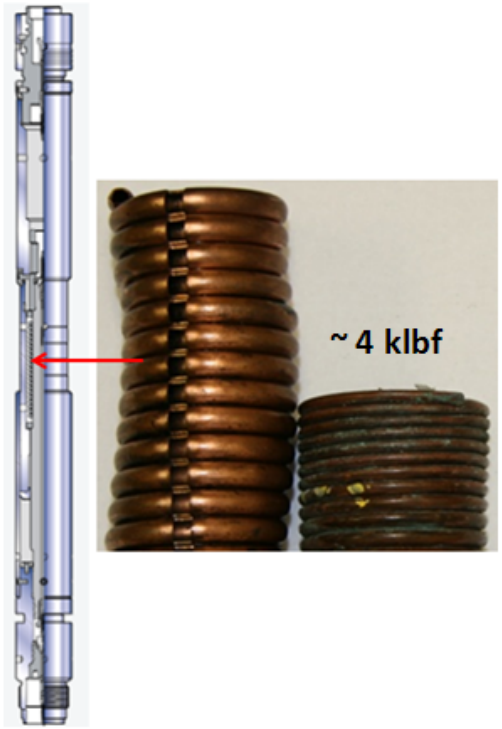
Cable – Surface Tension – Predicted vs. Measured





Cable – Weak Point Peak Tension – Predicted vs. Measured





Reliable prediction gunshock loads -TCP and WL

Effect of all components / variables can be analyzed:

- Position of packers
- Size and length of conveyance
- Type and number of shock absorbers
- Types and sizes of guns and shaped charges
- Guns loading strategies
- Reservoir pressure and properties

Perforating Gunshock Loads - Prediction and Mitigation

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- Reliable software predicts wellbore hydrodynamics and structural dynamics
- Prediction of transient wellbore pressure is crucial for
  - Cleanup – Productivity $+
  - Gunshock loads (whenever important) prevent $-
- Good prediction of gunshock loads allows risk evaluation & mitigation
- Crucial to prevent / minimize non-productive time / losses

THANK YOU ! – Questions ?