# IES Gauge Data

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# “DROP BAR” Applications

- Use the gauge to fire the StimGun™ Assembly or ***other propellant and perforating tools***
- Collect the Pressure / Temperature / Low and High G Acceleration profiles
- Leave the gauge in place to record pressure/ temperature changes ***AFTER*** the gun fires
- Determine if the tool fired correctly (if at all)

# IES Drop Bar Gauge

IES Drop Bar Gauge

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Dropping the gauge

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Recovering the gauge

IES Drop Bar Gauge Recovered

Drop Bar Gauge Test
1000 ft air, 500 ft fluid, 12 ft restriction, firing head.

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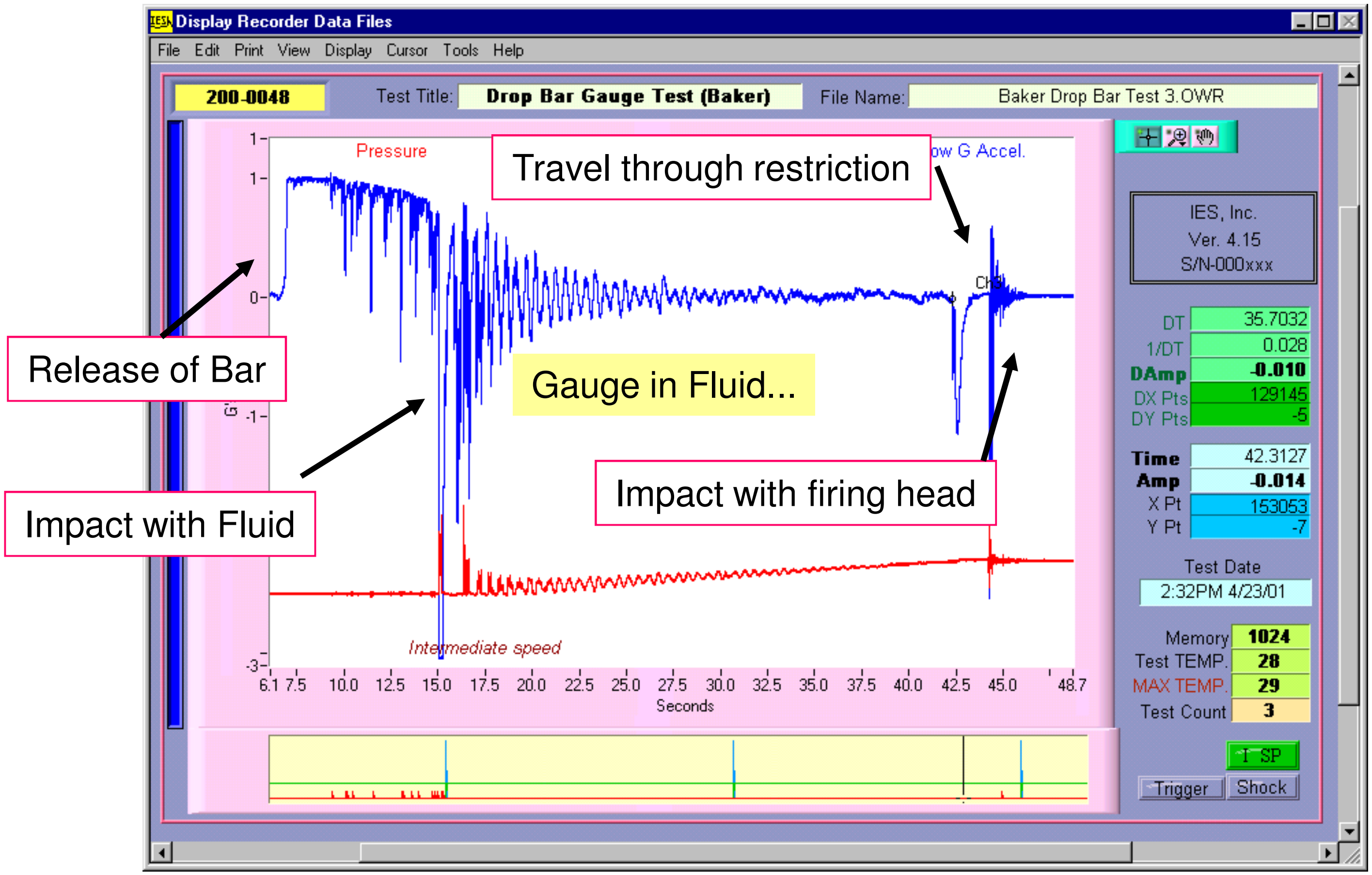
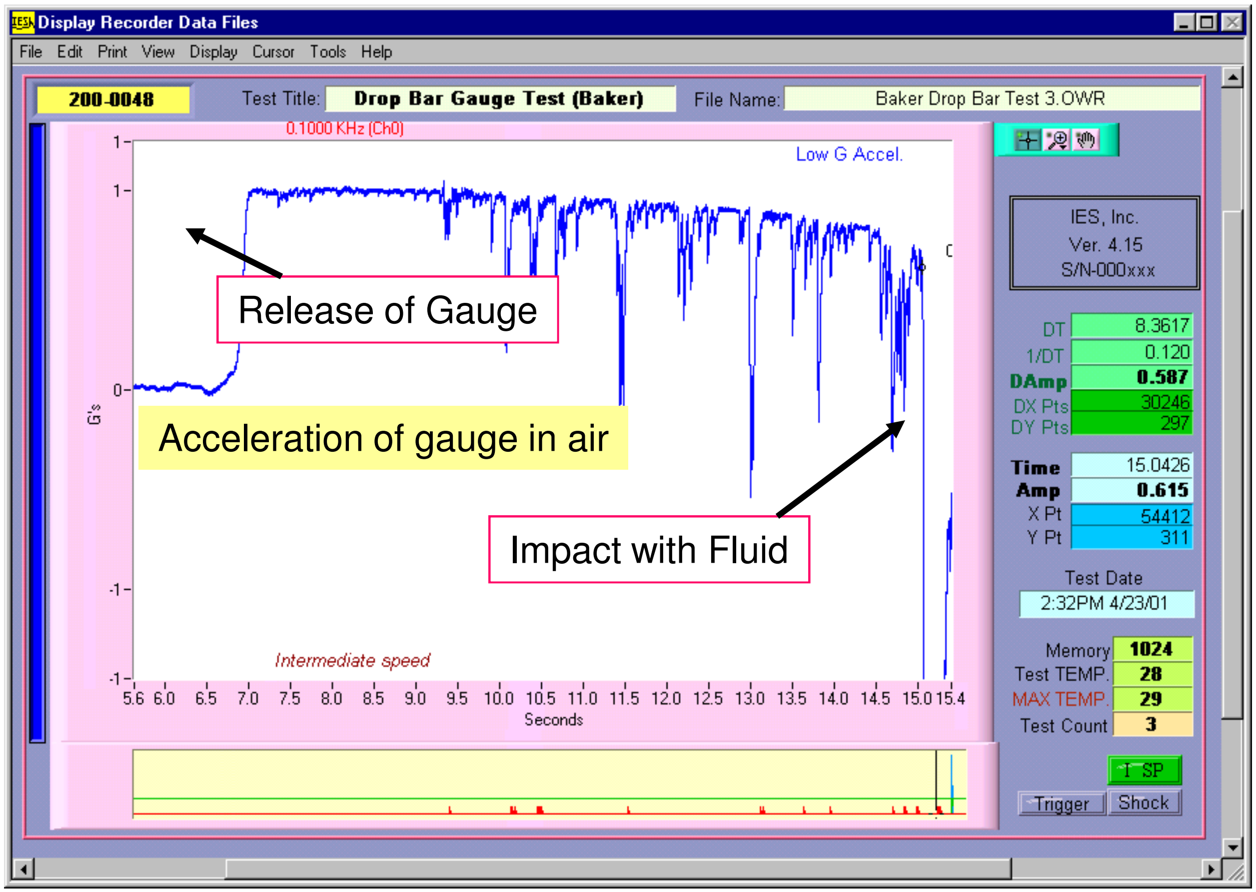
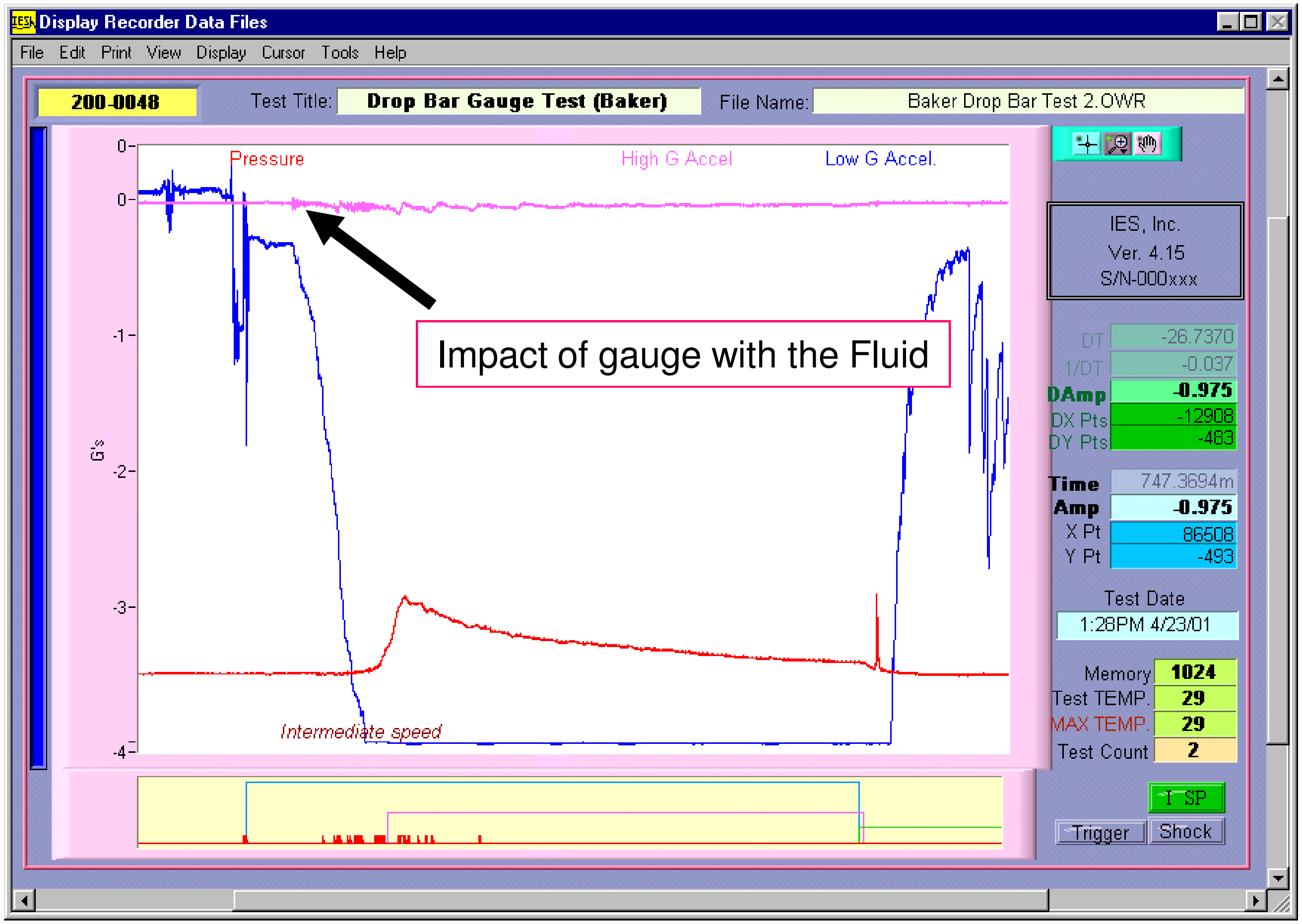
1000 ft air, 500 ft fluid, 12 ft restriction, firing head.



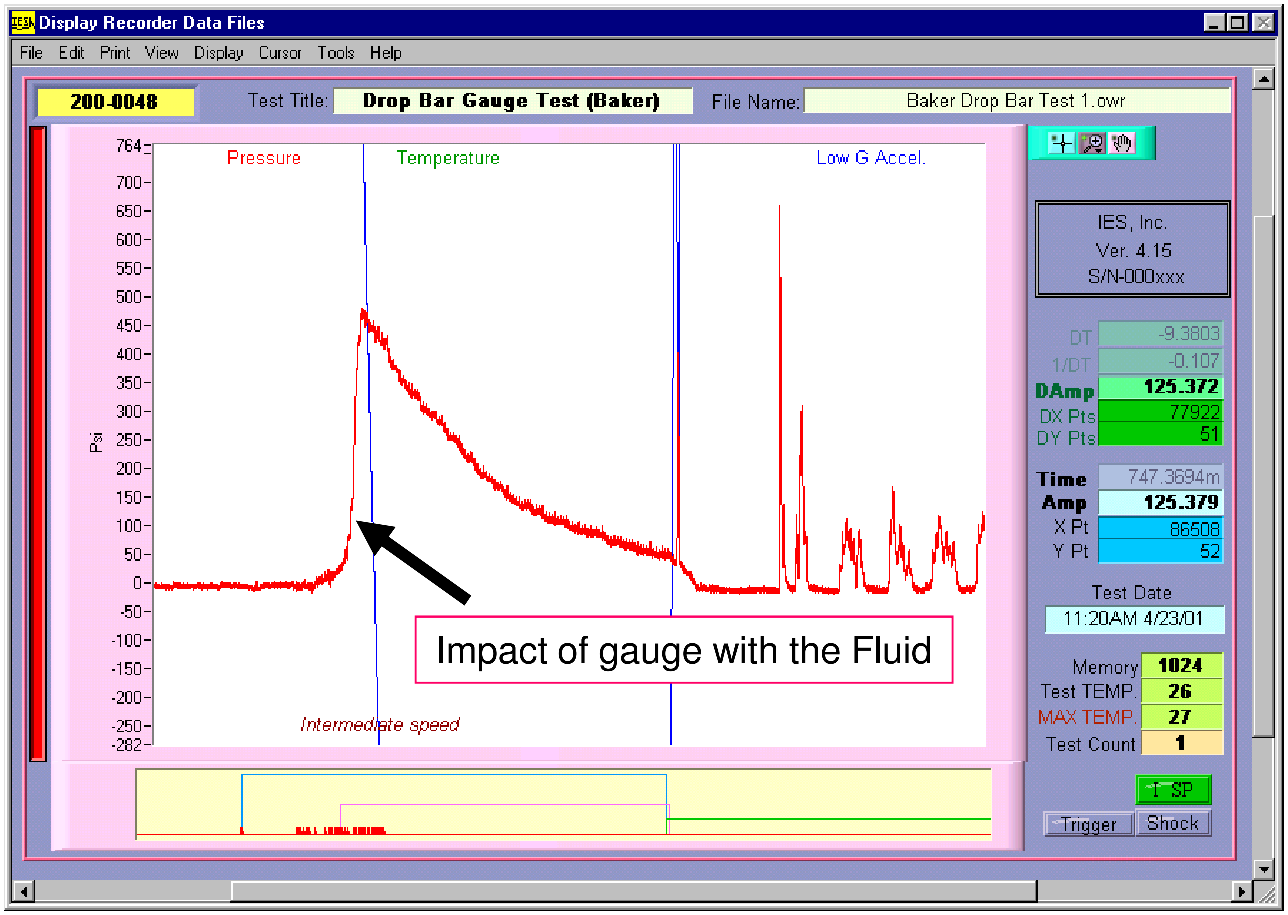
Drop Bar Gauge Test
1000 ft air, 500 ft fluid, 12 ft restriction, firing head.



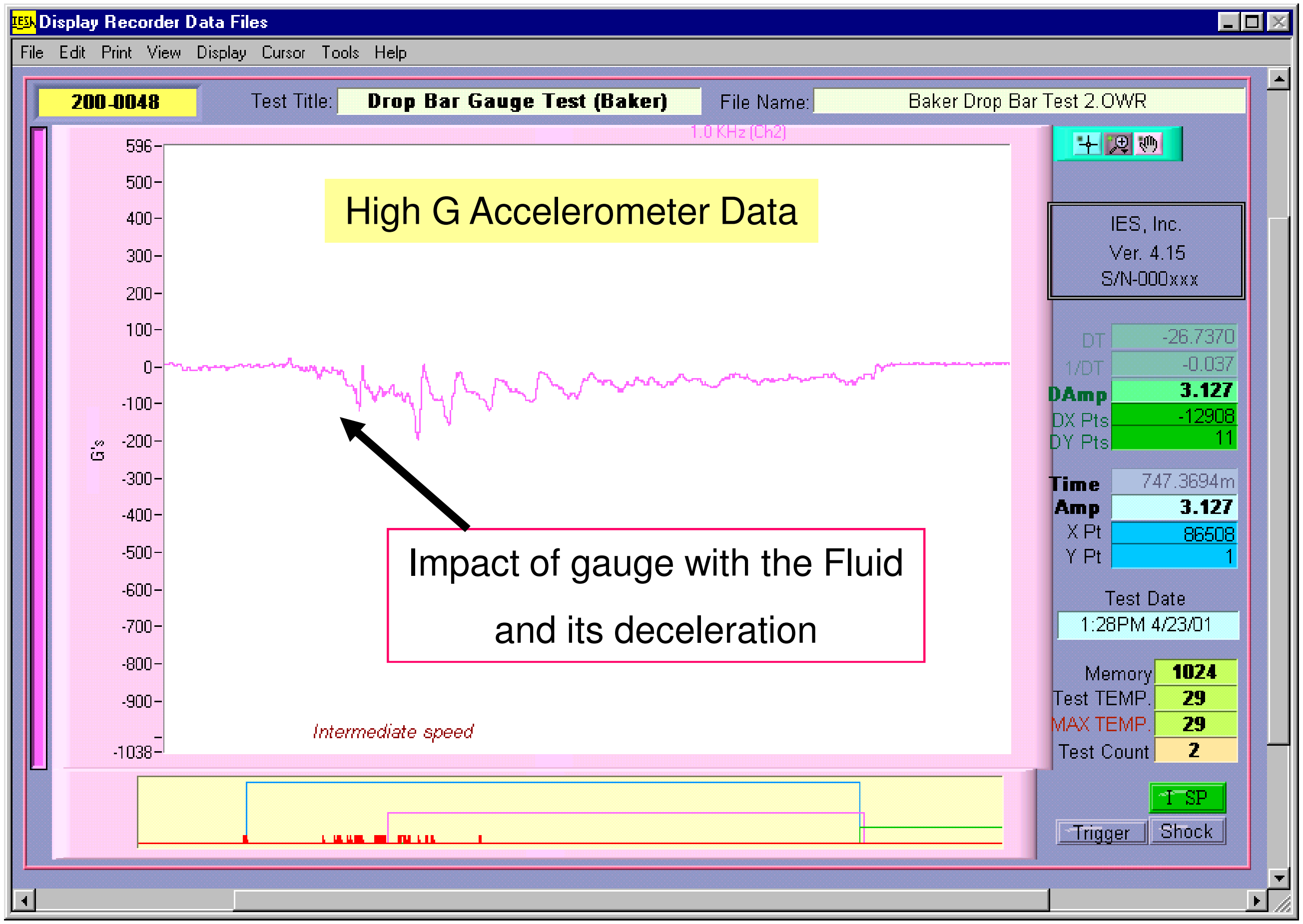
Drop Bar Gauge Test
1000 ft air, 500 ft fluid, 12 ft restriction, firing head.



Drop Bar Gauge Test
1000 ft air, 500 ft fluid, 12 ft restriction, firing head.



Drop Bar Gauge Test
1000 ft air, 500 ft fluid, 12 ft restriction, firing head.



Drop Bar Gauge Test
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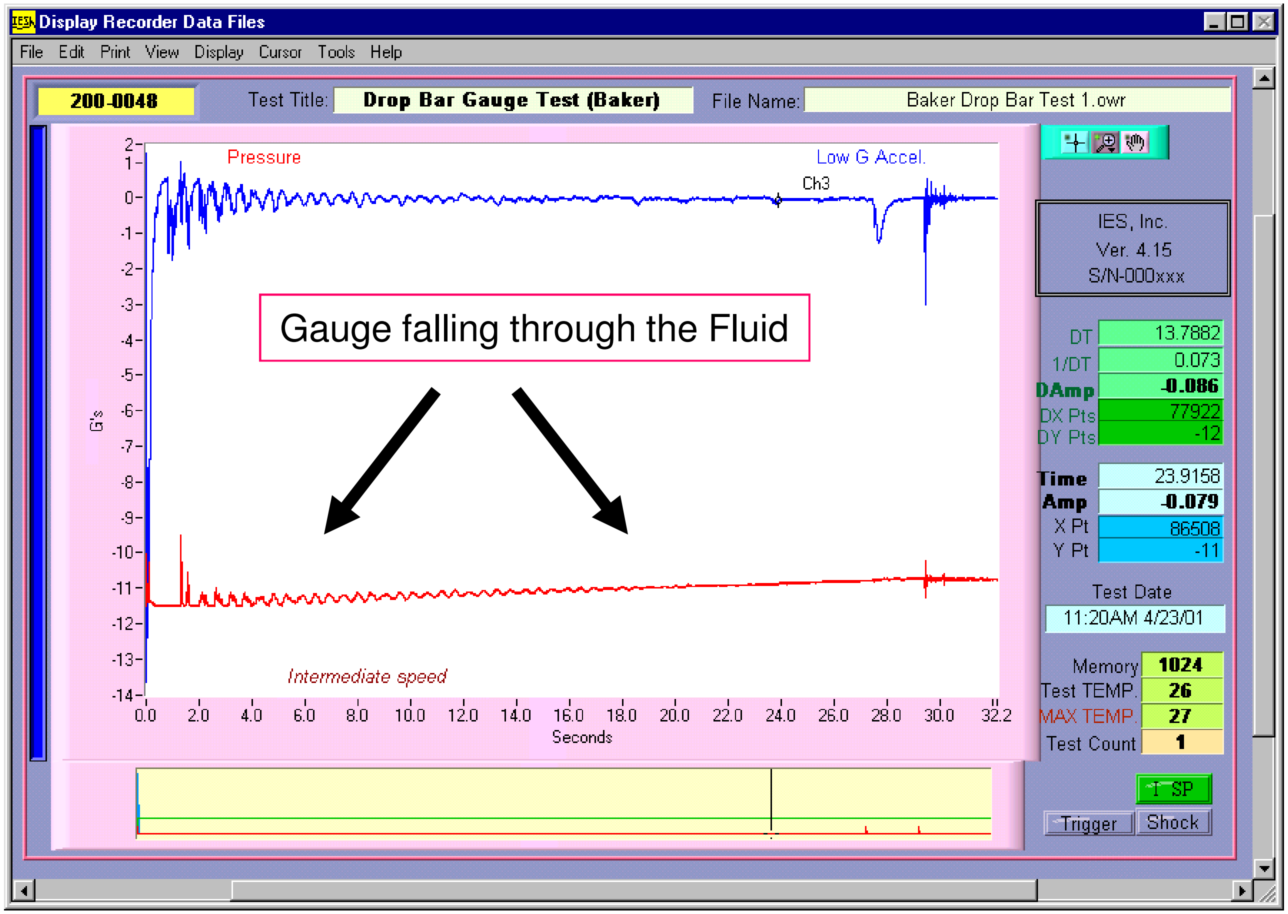

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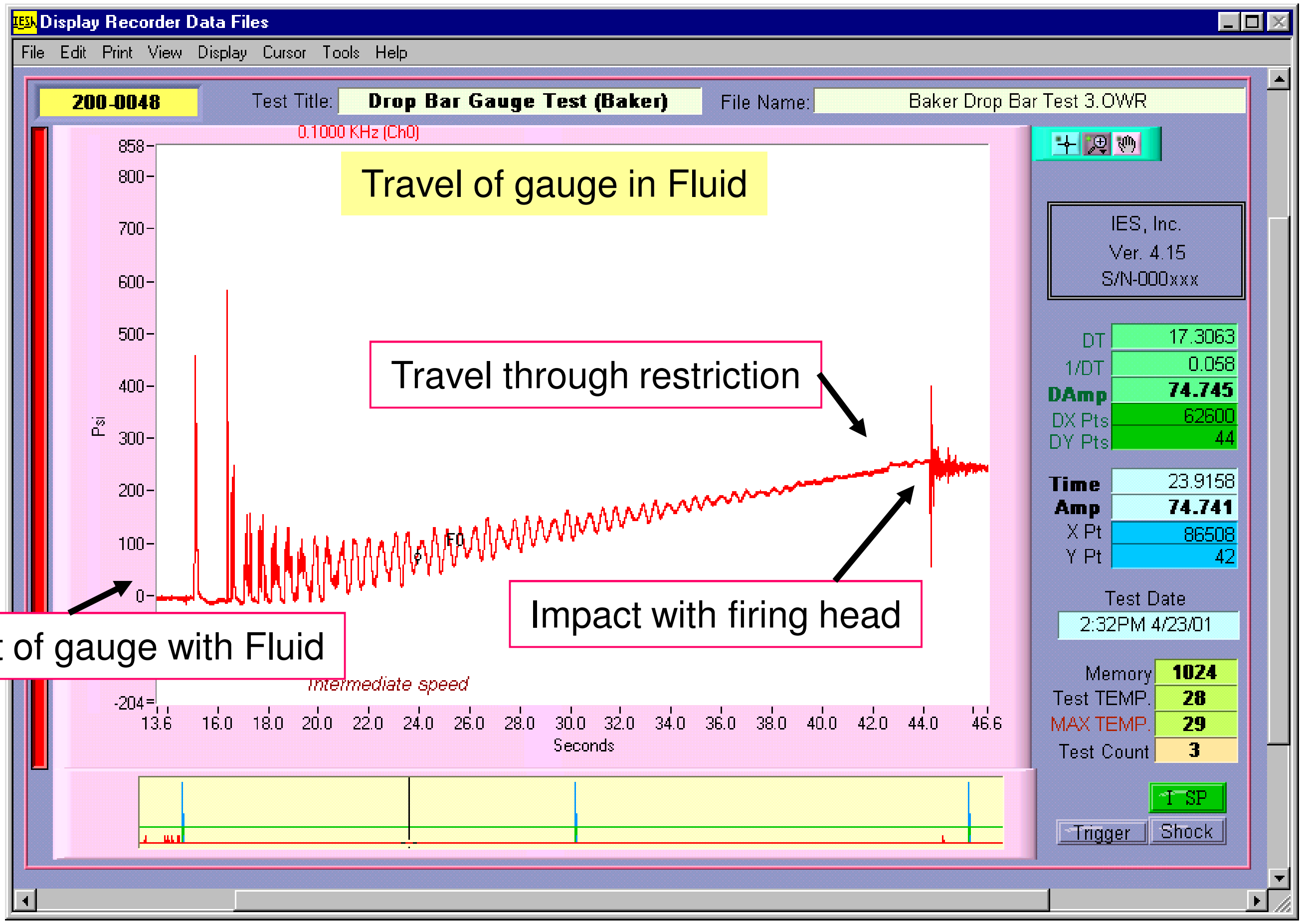
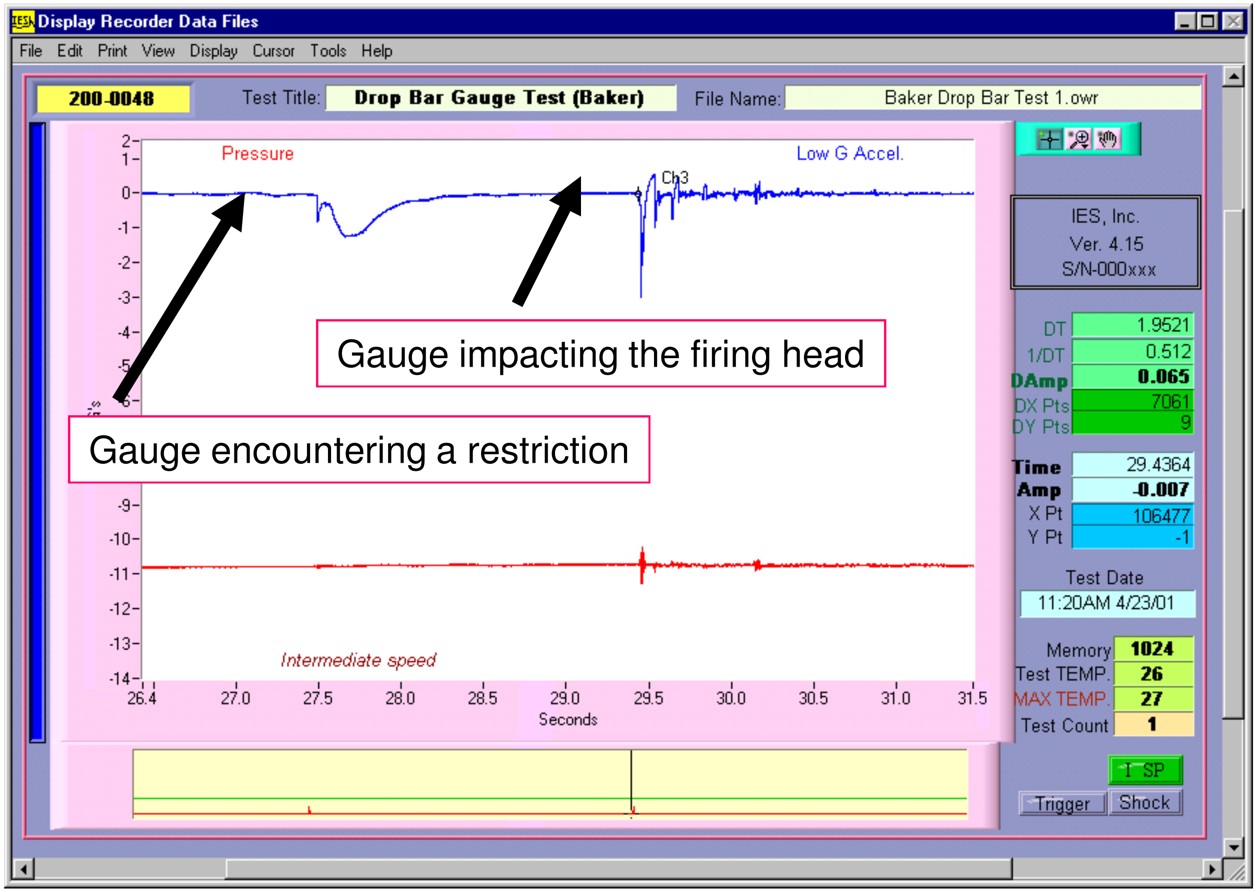
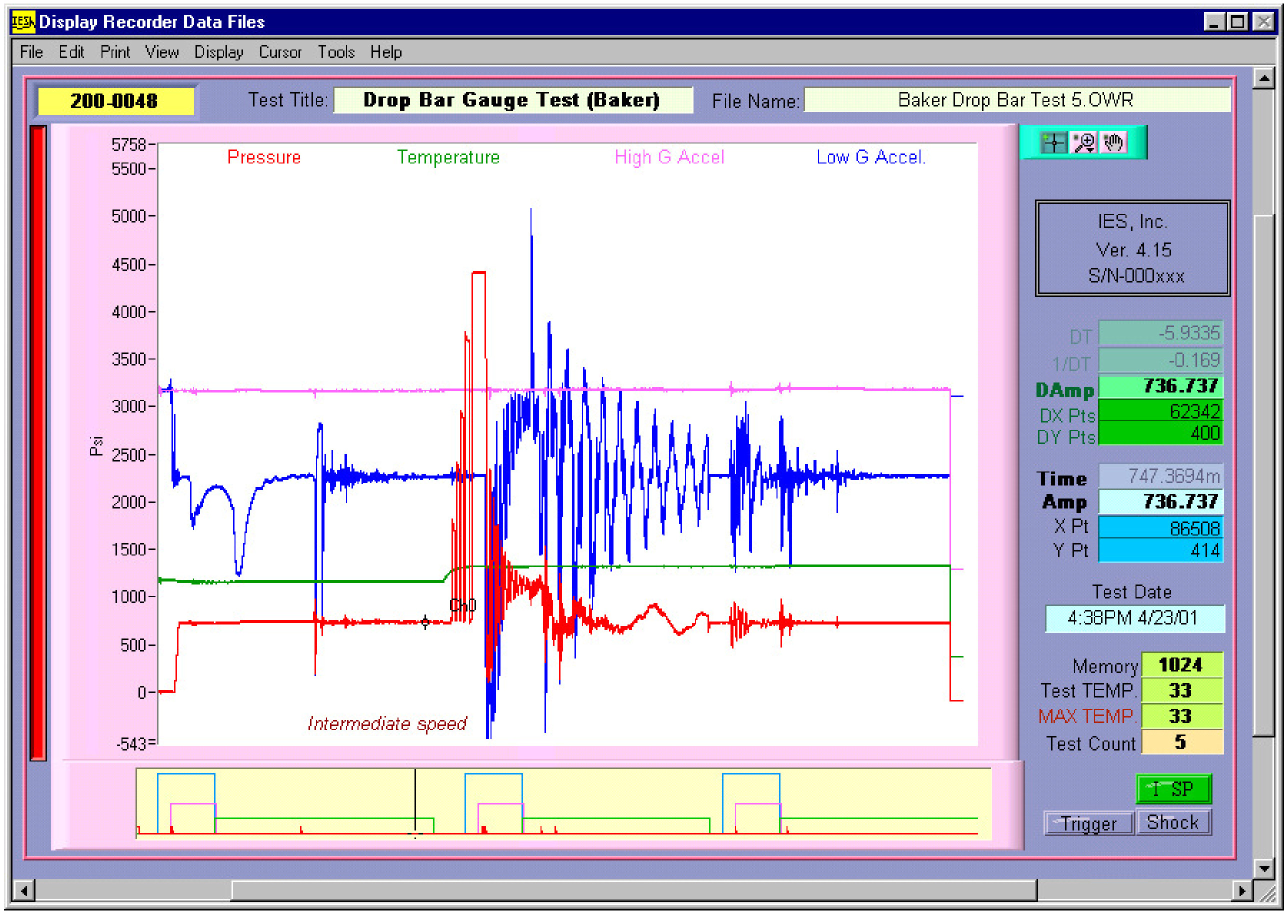


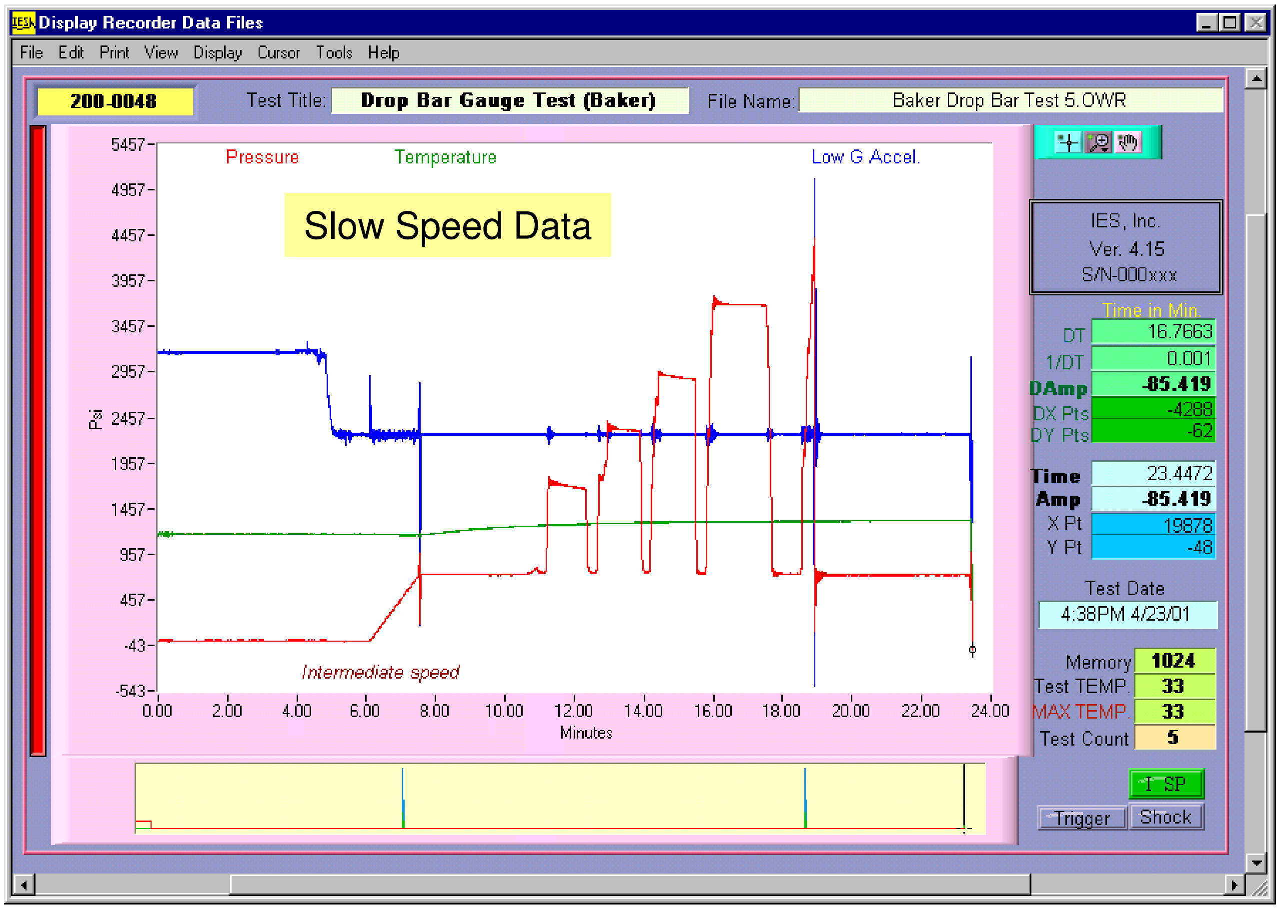
Drop Bar Gauge Test
1000 ft air, 500 ft fluid, 12 ft restriction, firing head.



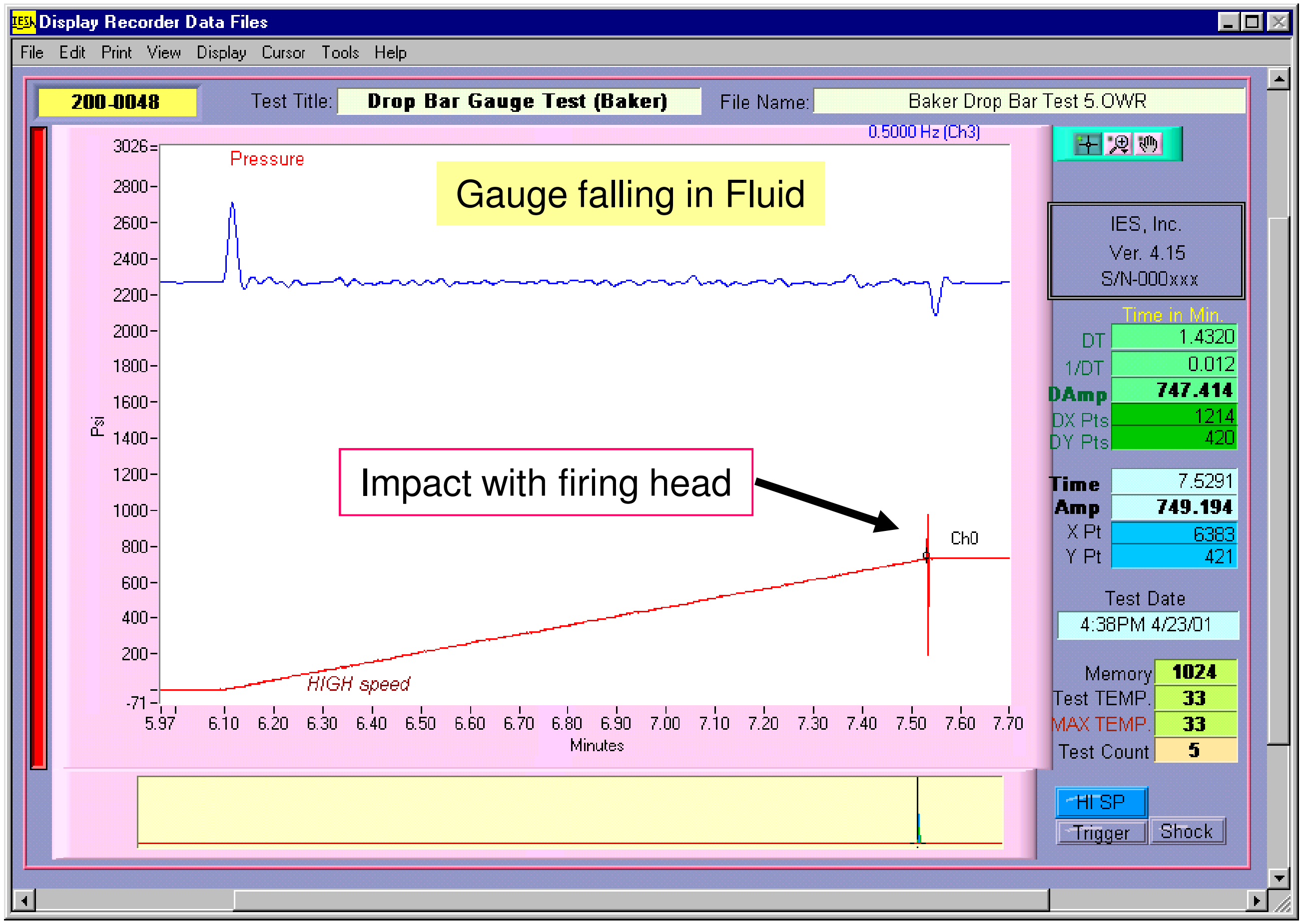
Drop Bar Gauge Test
1500 fluid, 12 ft restriction, firing head.
Well pressured up until burst disk failed.



Drop Bar Gauge Test
1500 fluid, 12 ft restriction, firing head.
Well pressured up until burst disk failed.



Drop Bar Gauge Test
1500 fluid, 12 ft restriction, firing head.
Well pressured up until burst disk failed.



Drop Bar Gauge Test
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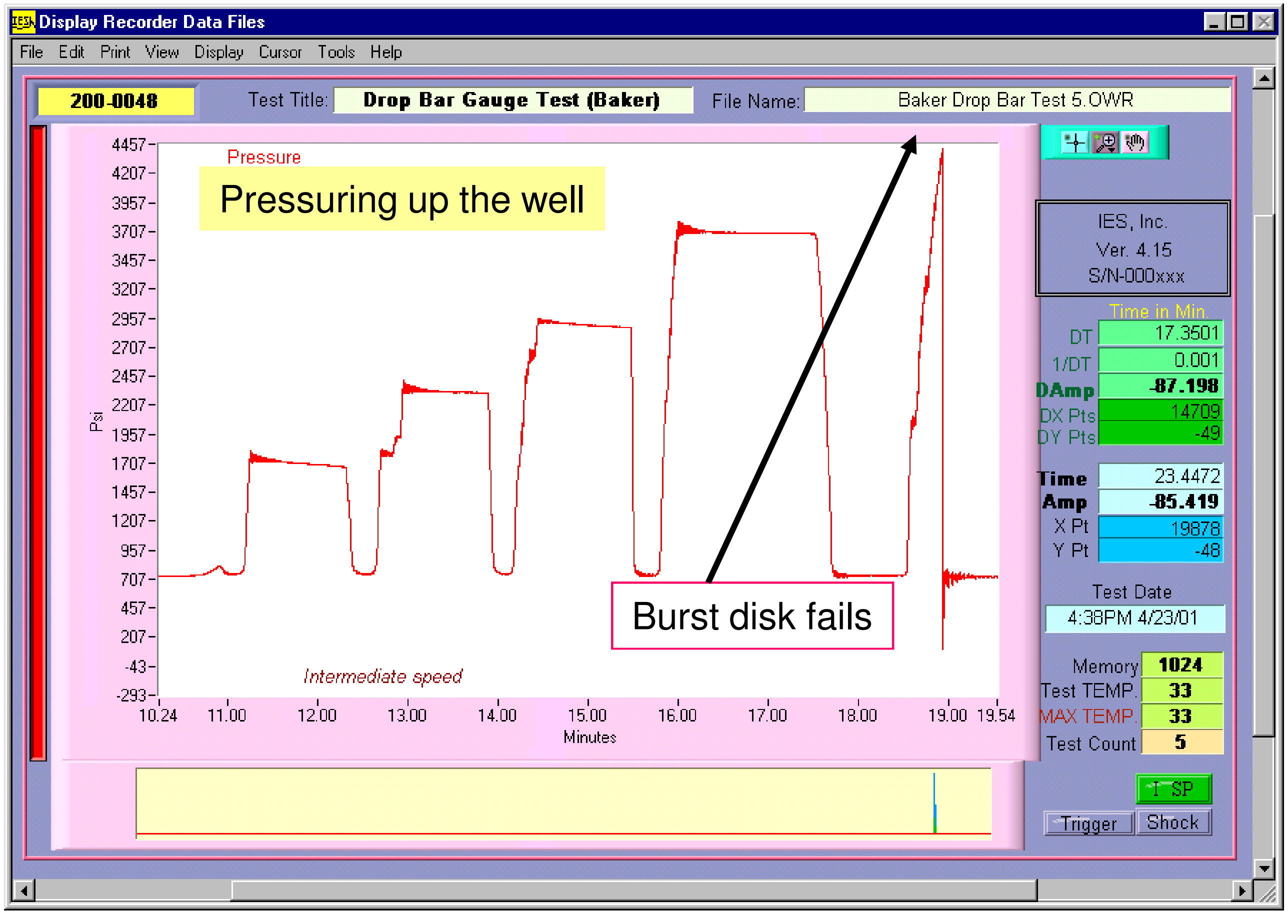

Drop Bar Gauge Gauge Test
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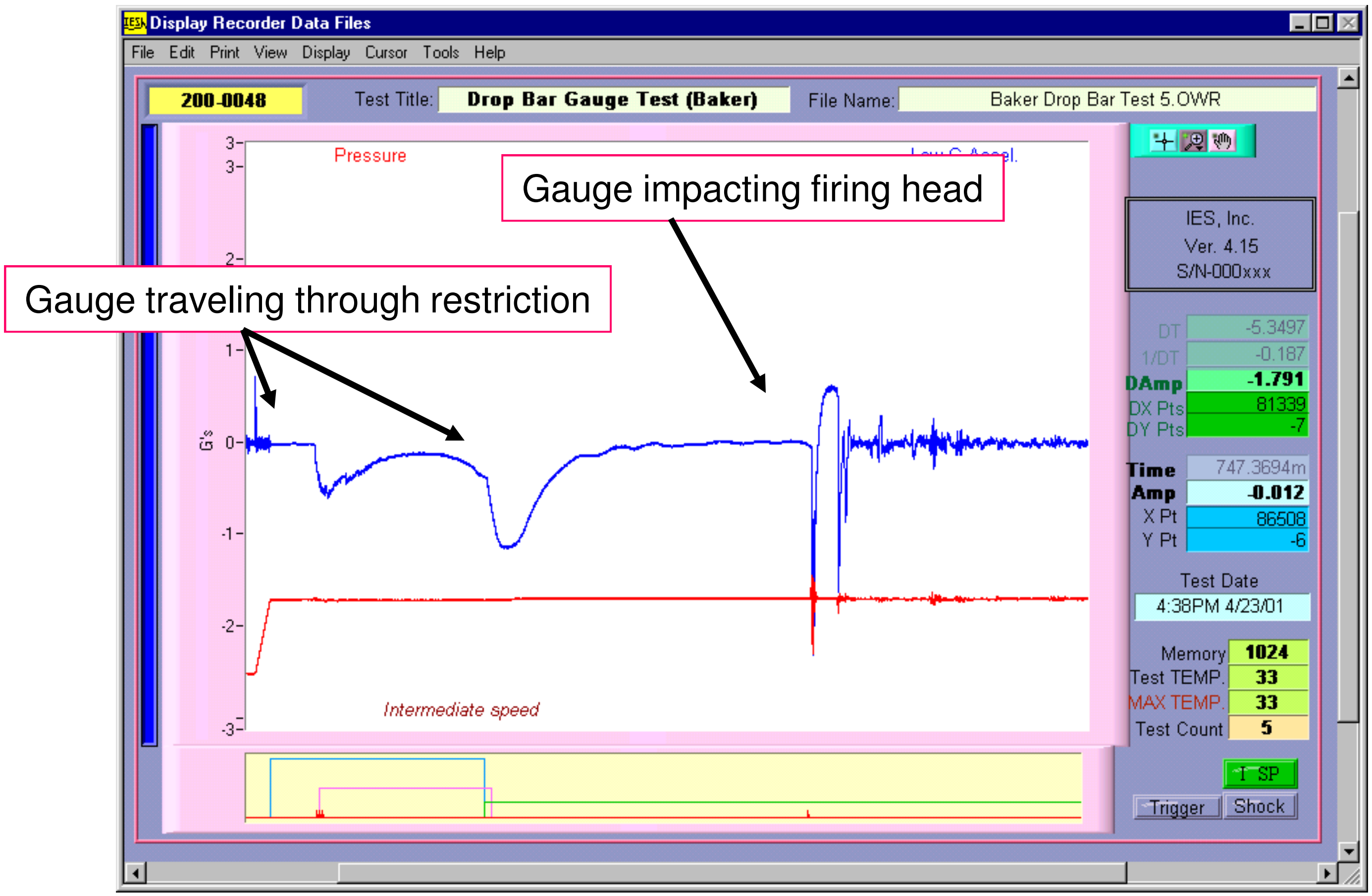

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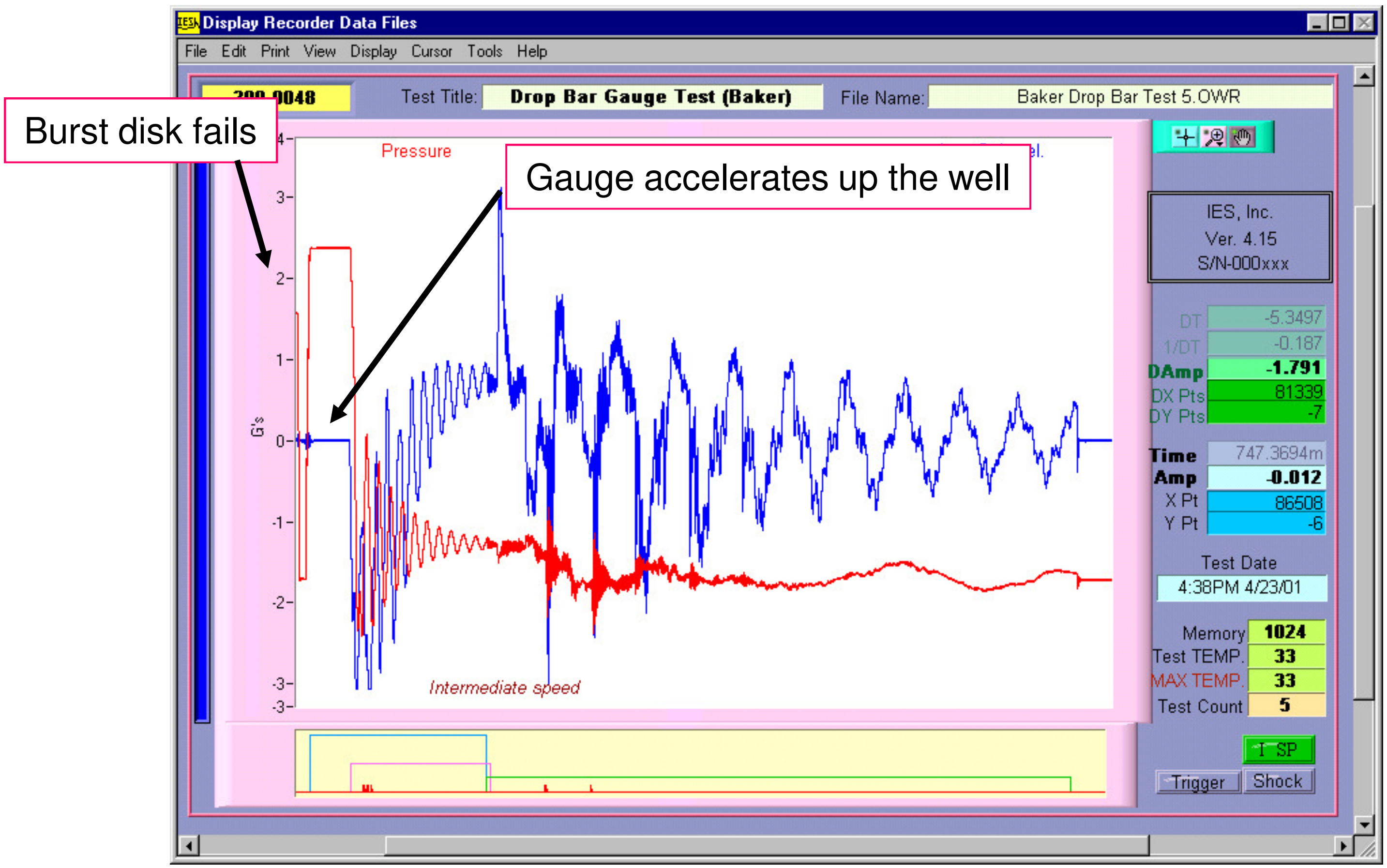

Drop Bar Gauge Test
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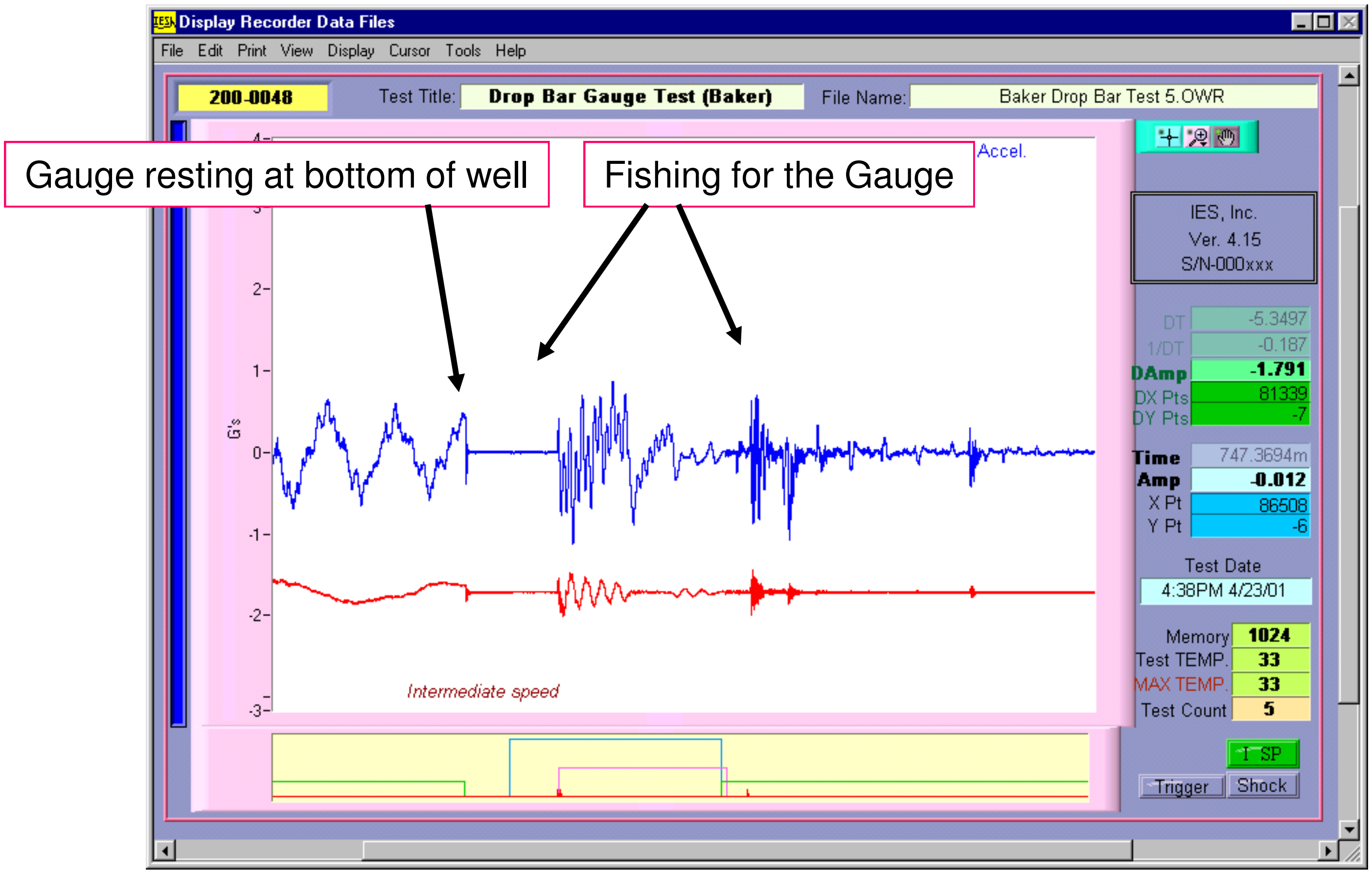
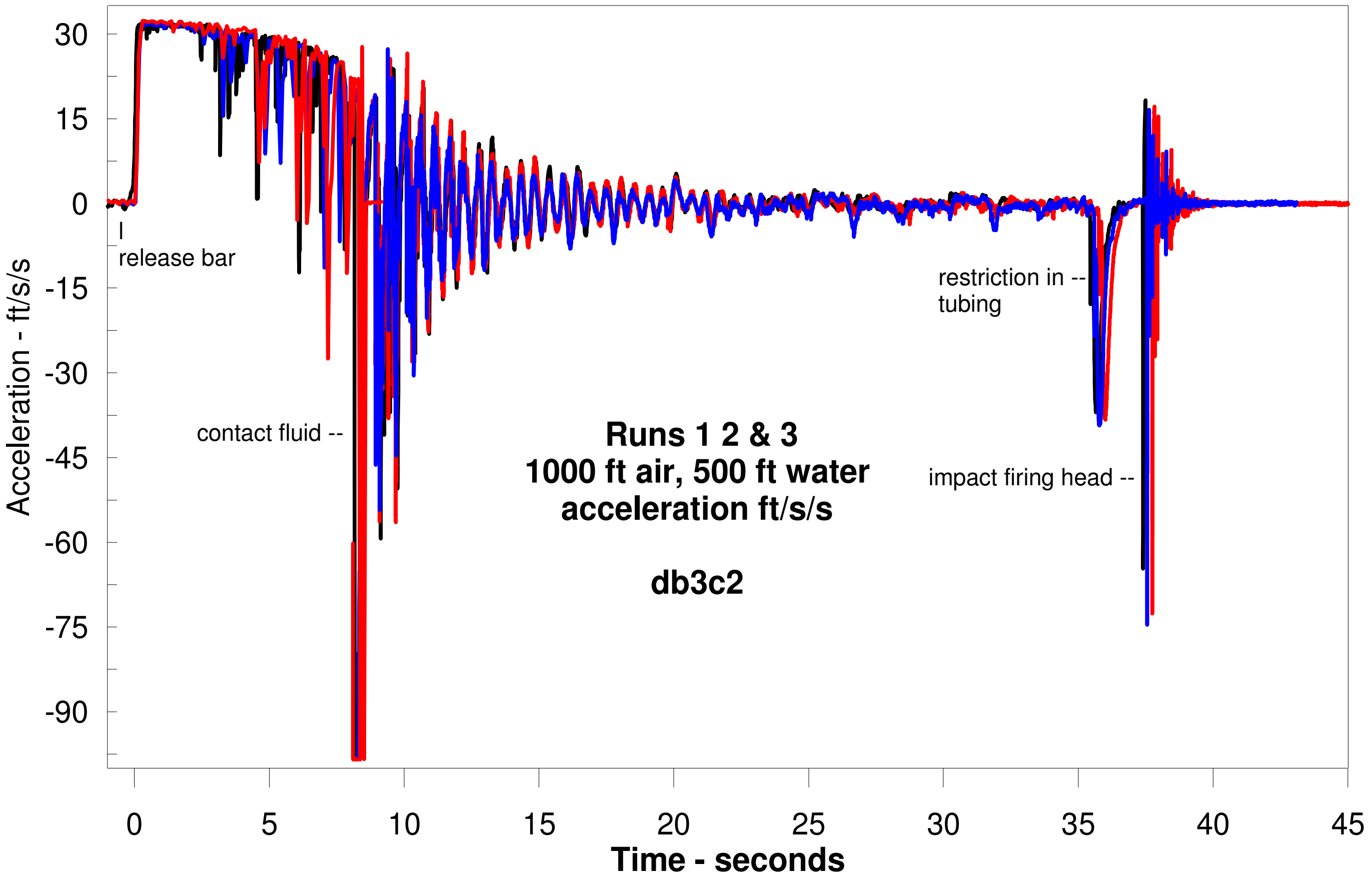
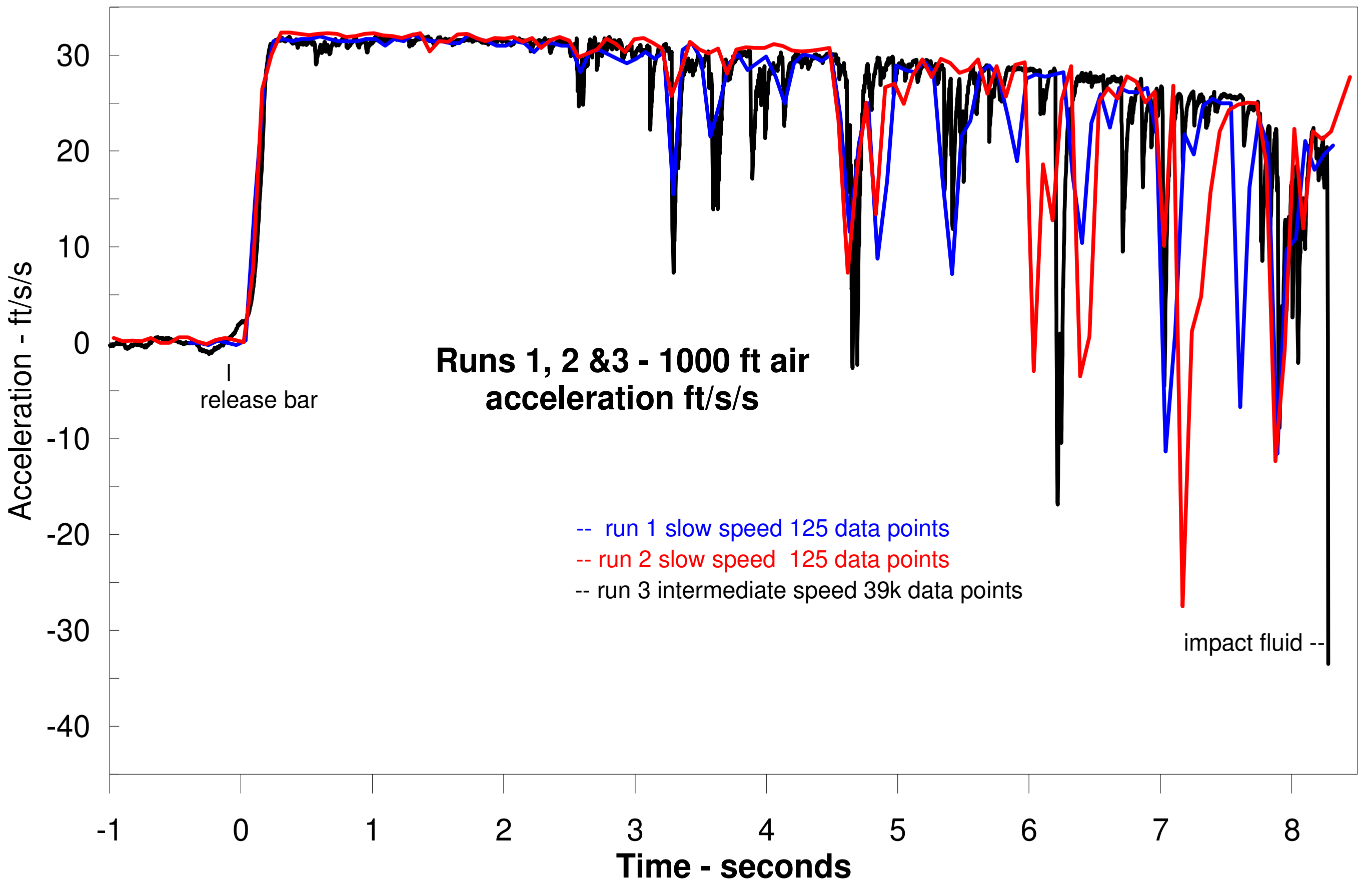


Drop Bar Gauge data is very repeatable.



Drop Bar Gauge accelerating through the air.

The slow speed and intermediate speed data is very similar.



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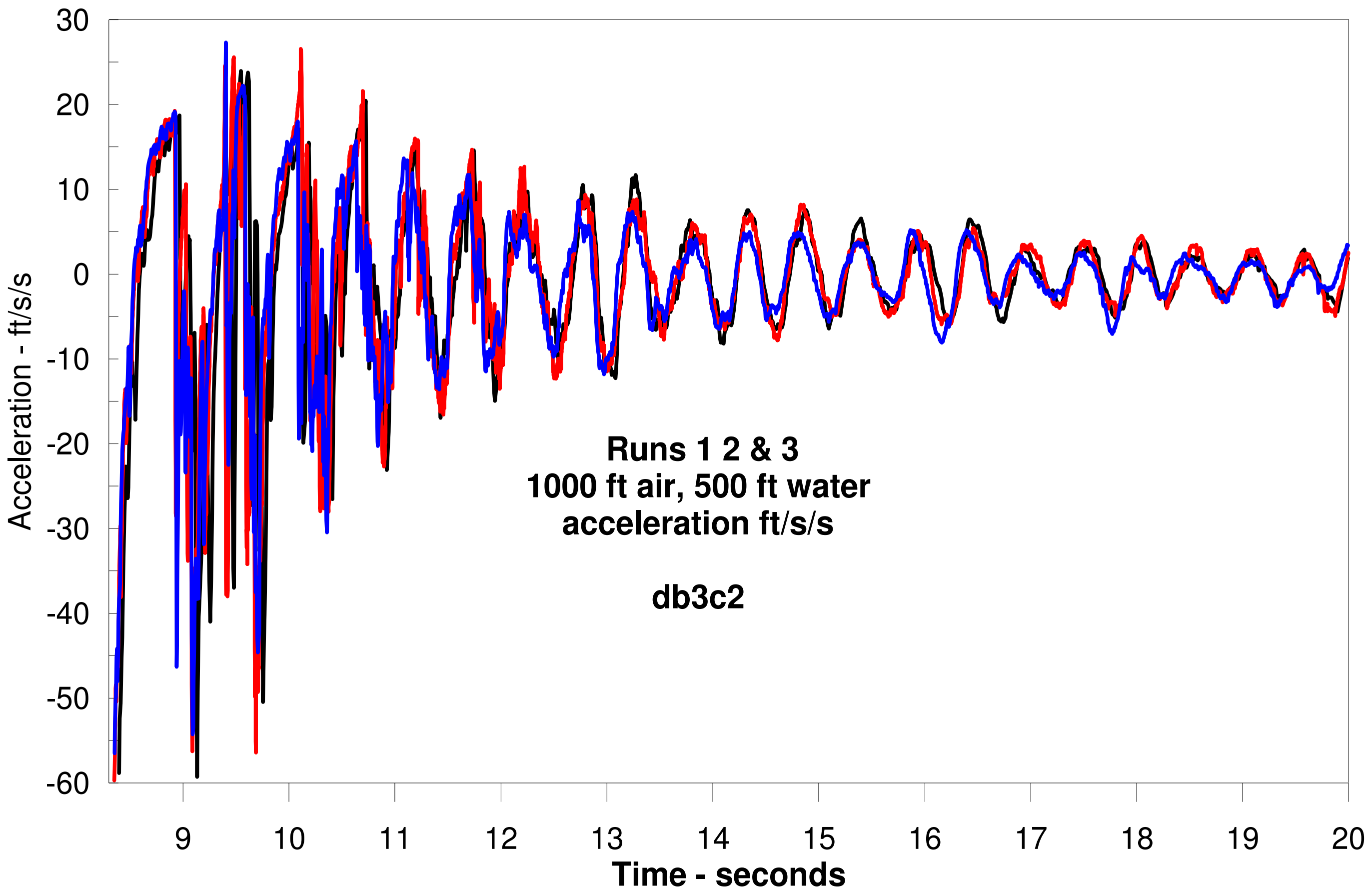
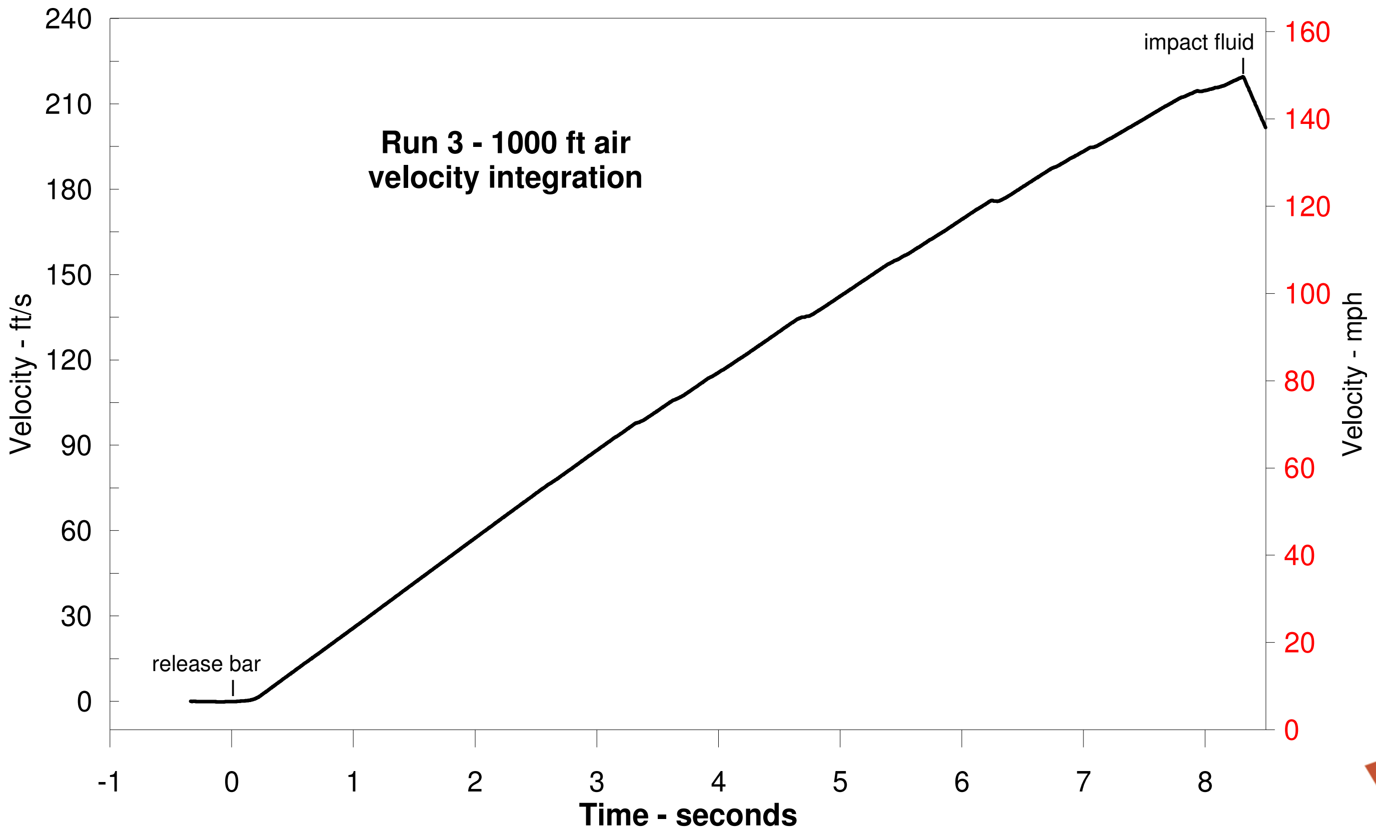


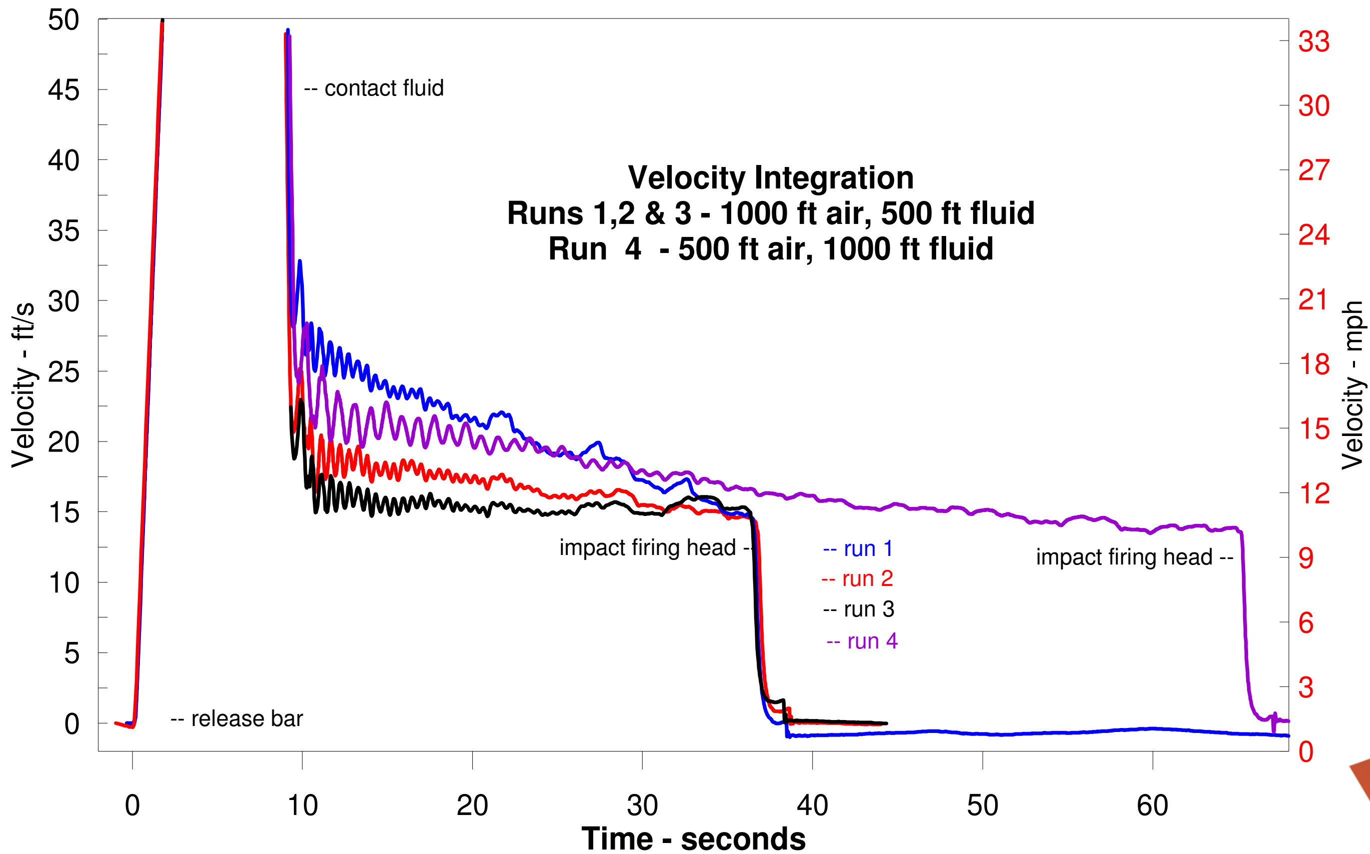
This is the velocity of the Drop Bar Gauge through the air.

This uses the acceleration recorded with the Low G accelerometer, which is integrated to give you velocity data.



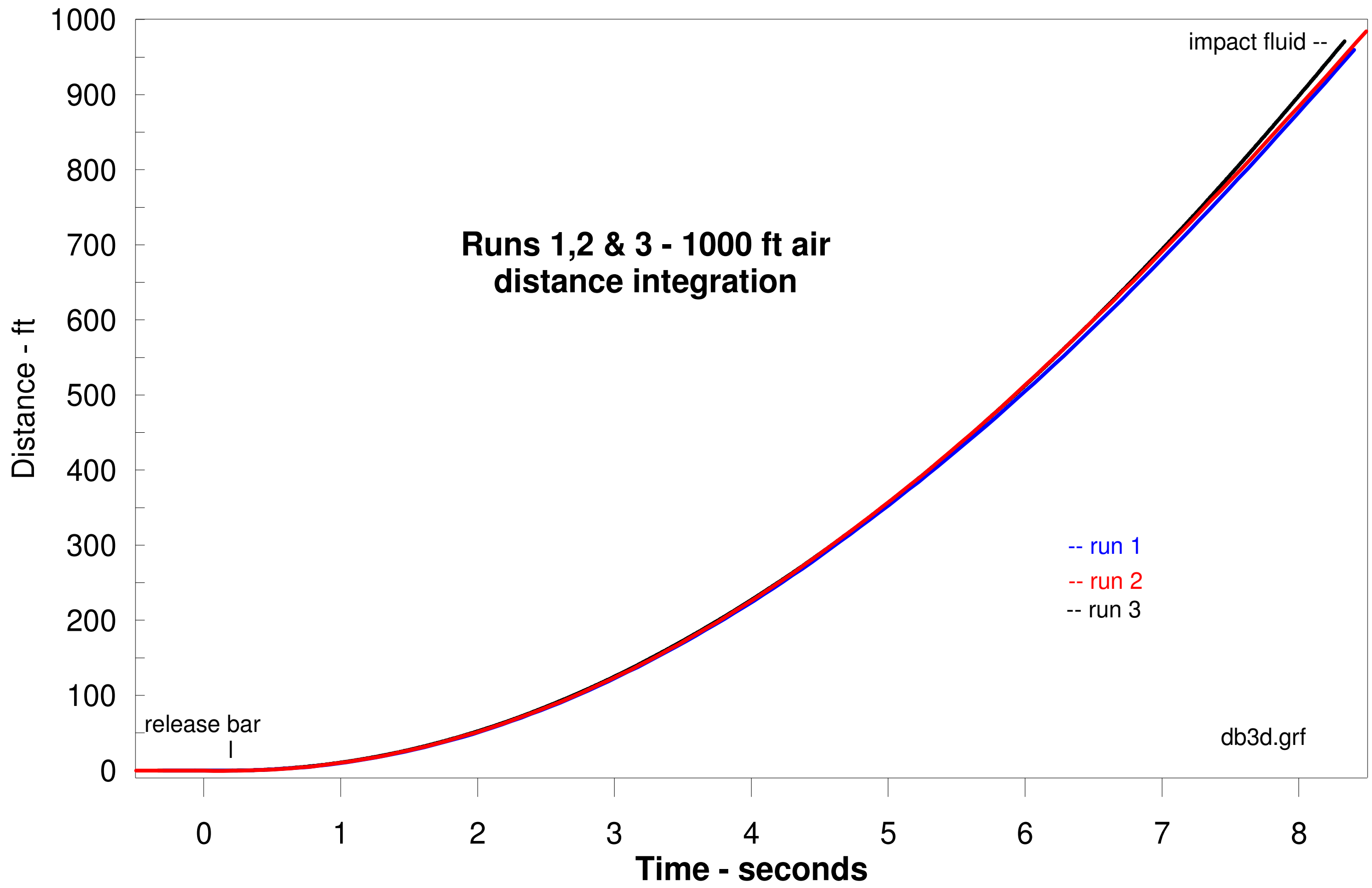
This is the velocity of the Drop Bar Gauge through the air.

This uses the acceleration recorded with the Low G accelerometer, which is integrated to give you velocity data.

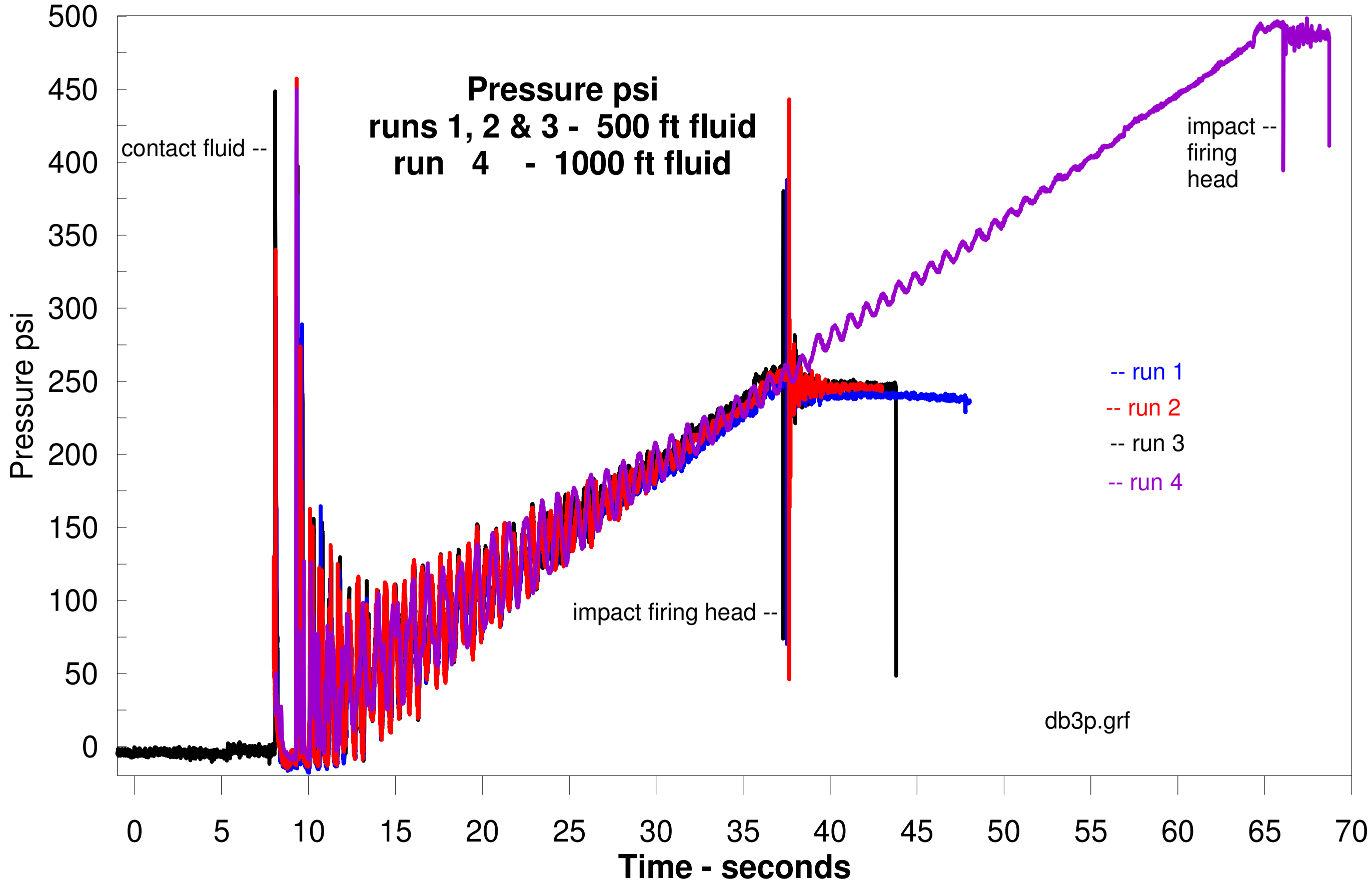


This is the distance traveled for the Drop Bar Gauge through the air.

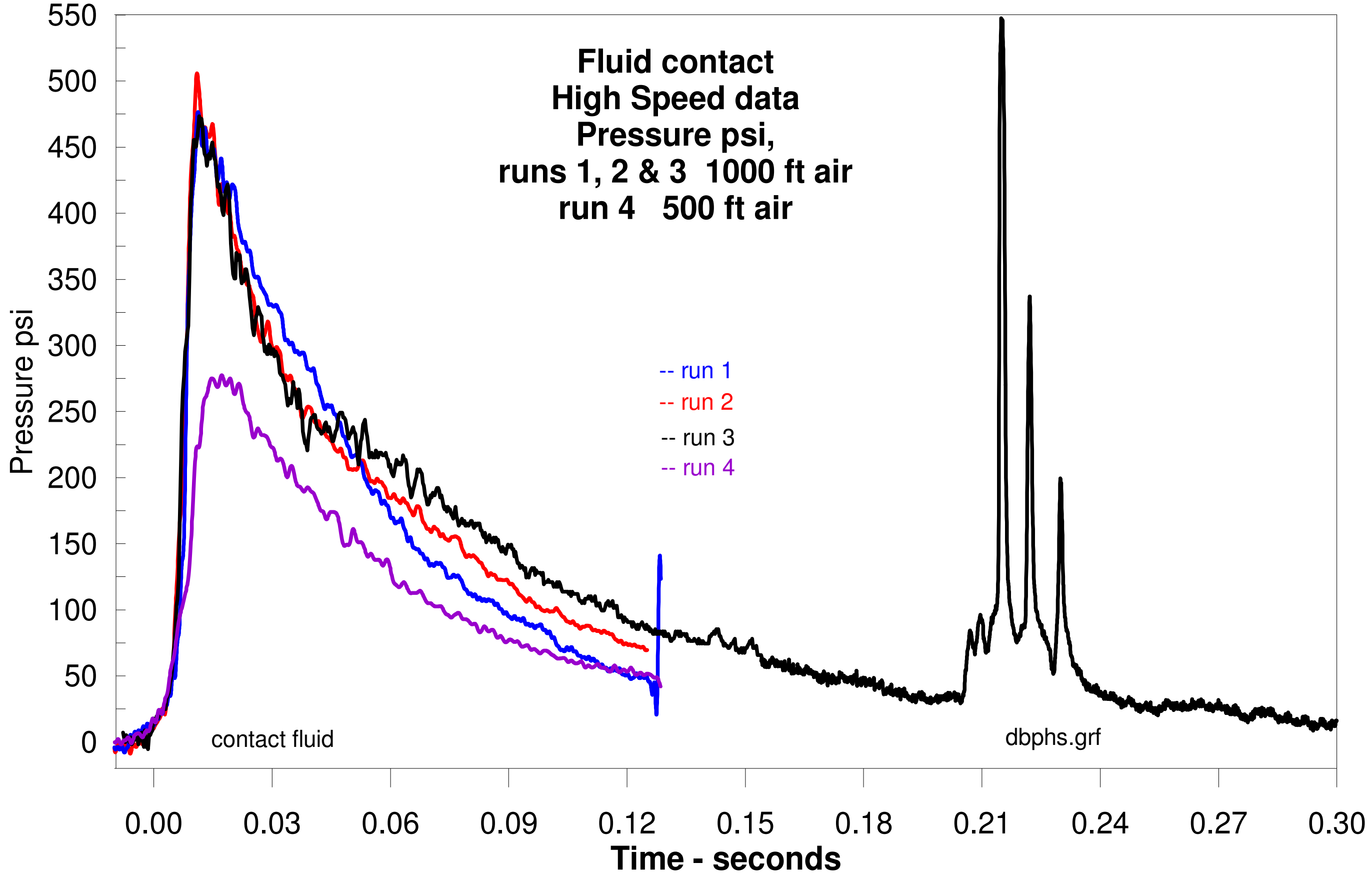
This uses the acceleration recorded with the Low G accelerometer, which is integrated twice to give you distance data.



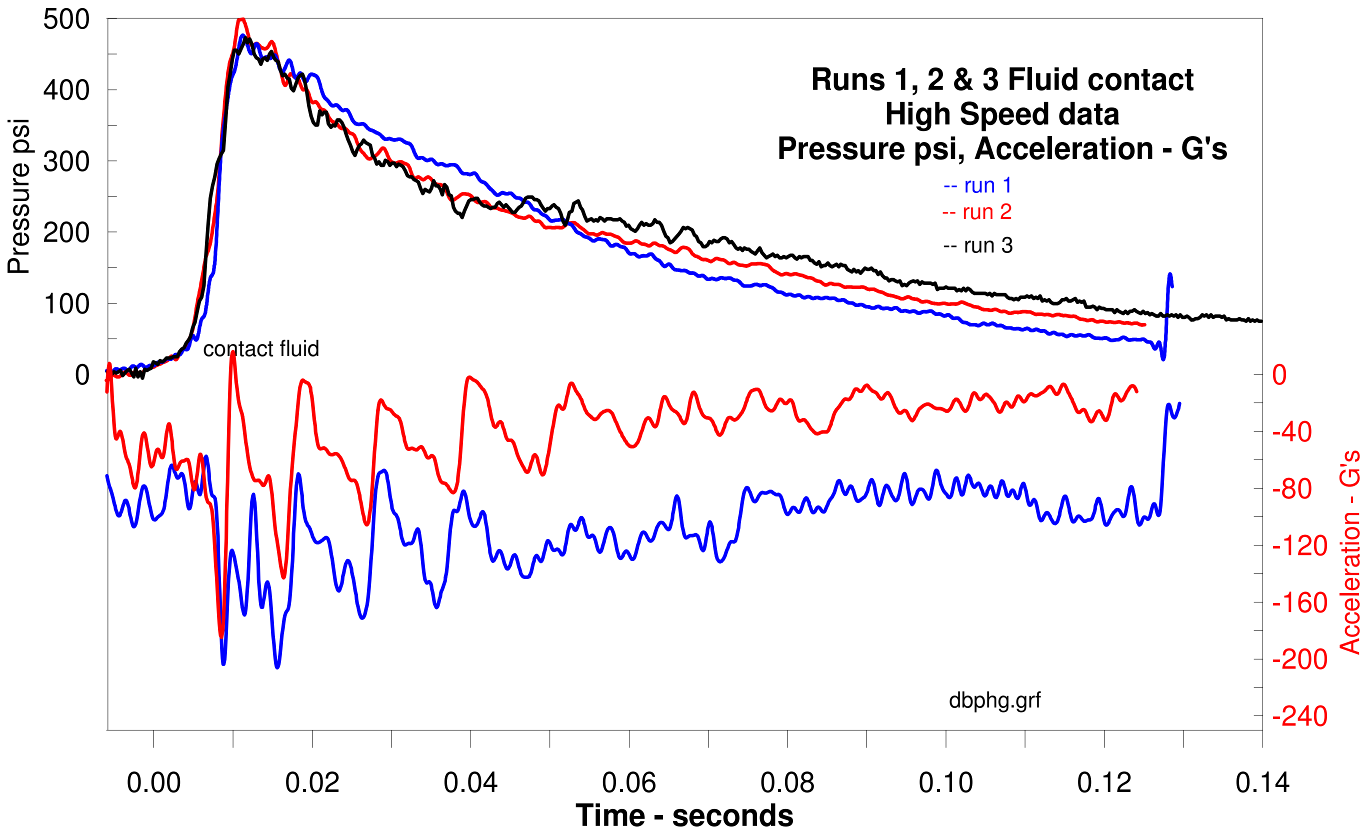
Pressure data for the Drop Bar Gauge as it travels through the fluid.



Impact of the Drop Bar Gauge with the fluid.
The pressure 'spike' for run #4 is not as high because if fell only 500 feet before impact with the fluid.



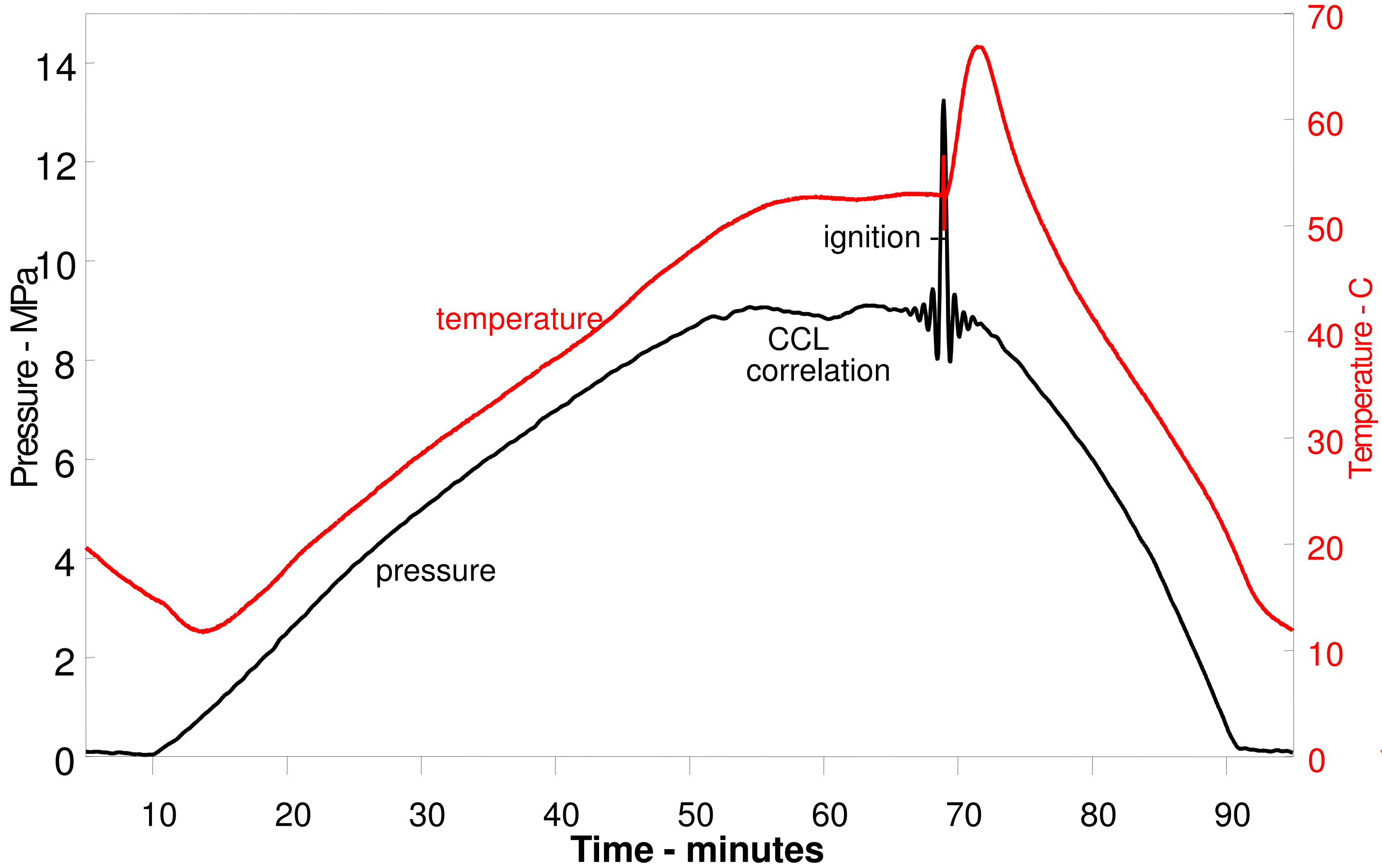
Impact of the Drop Bar Gauge with the fluid.
The High G accelerometer shows the force of impact with the fluid.



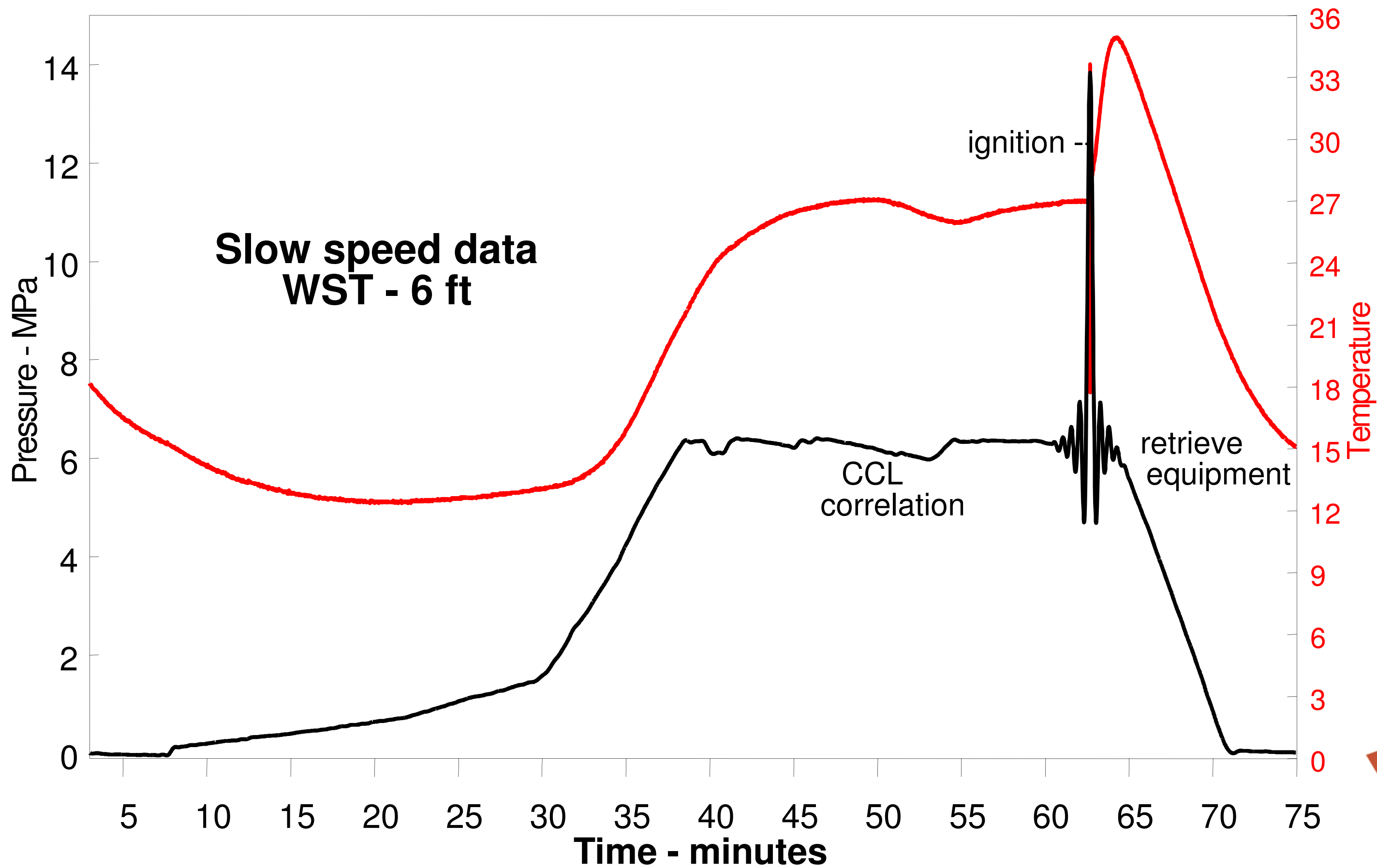
# RTD Data

- Shows what happens to the well temperature after a gun fires
- Useful in fine-adjusting the pressure profile

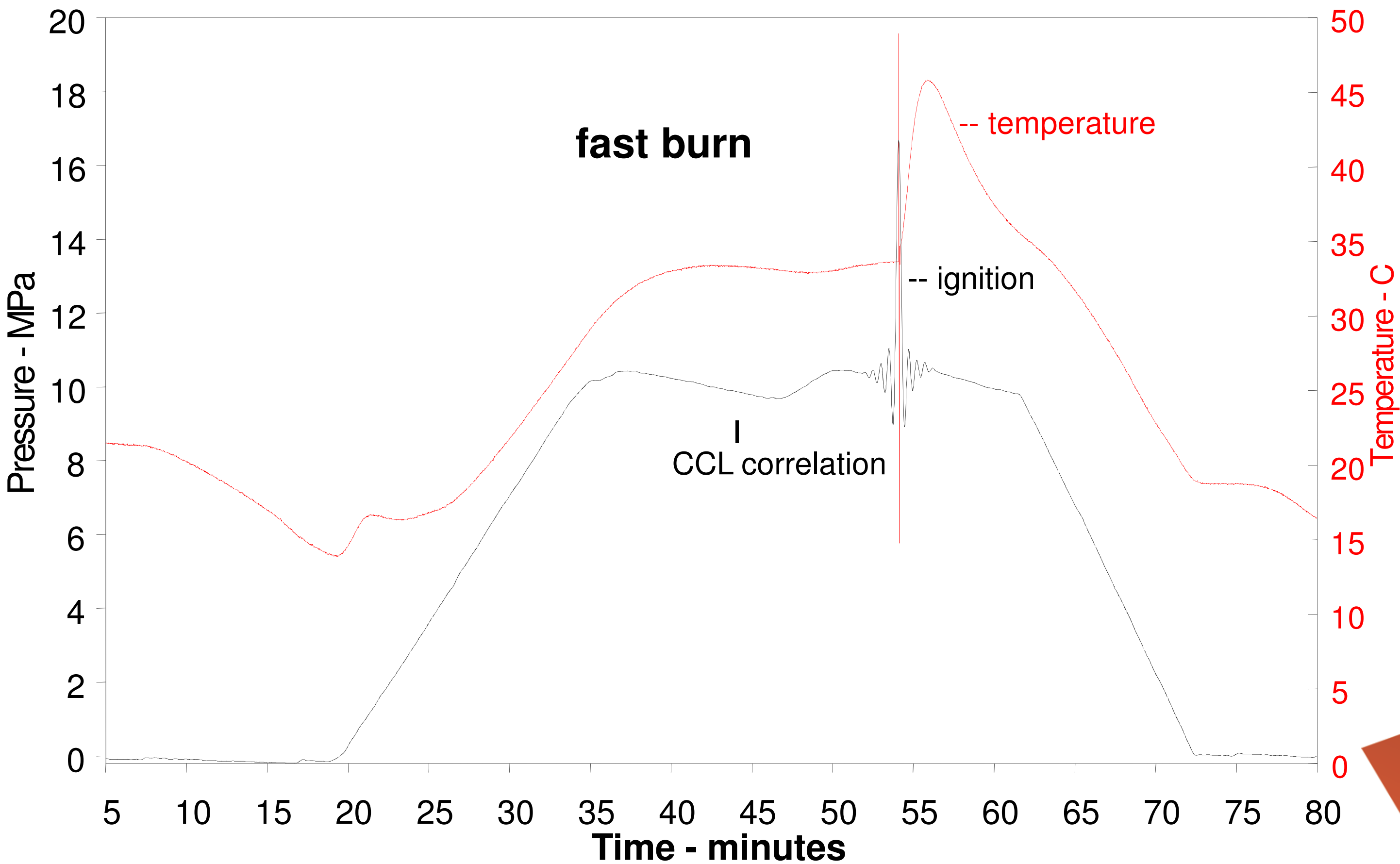
The Series 200 gauge has a RTD. We see a temperature increase after a gun goes off.



The Temperature increase is seen on both Propellant and Perforating tools

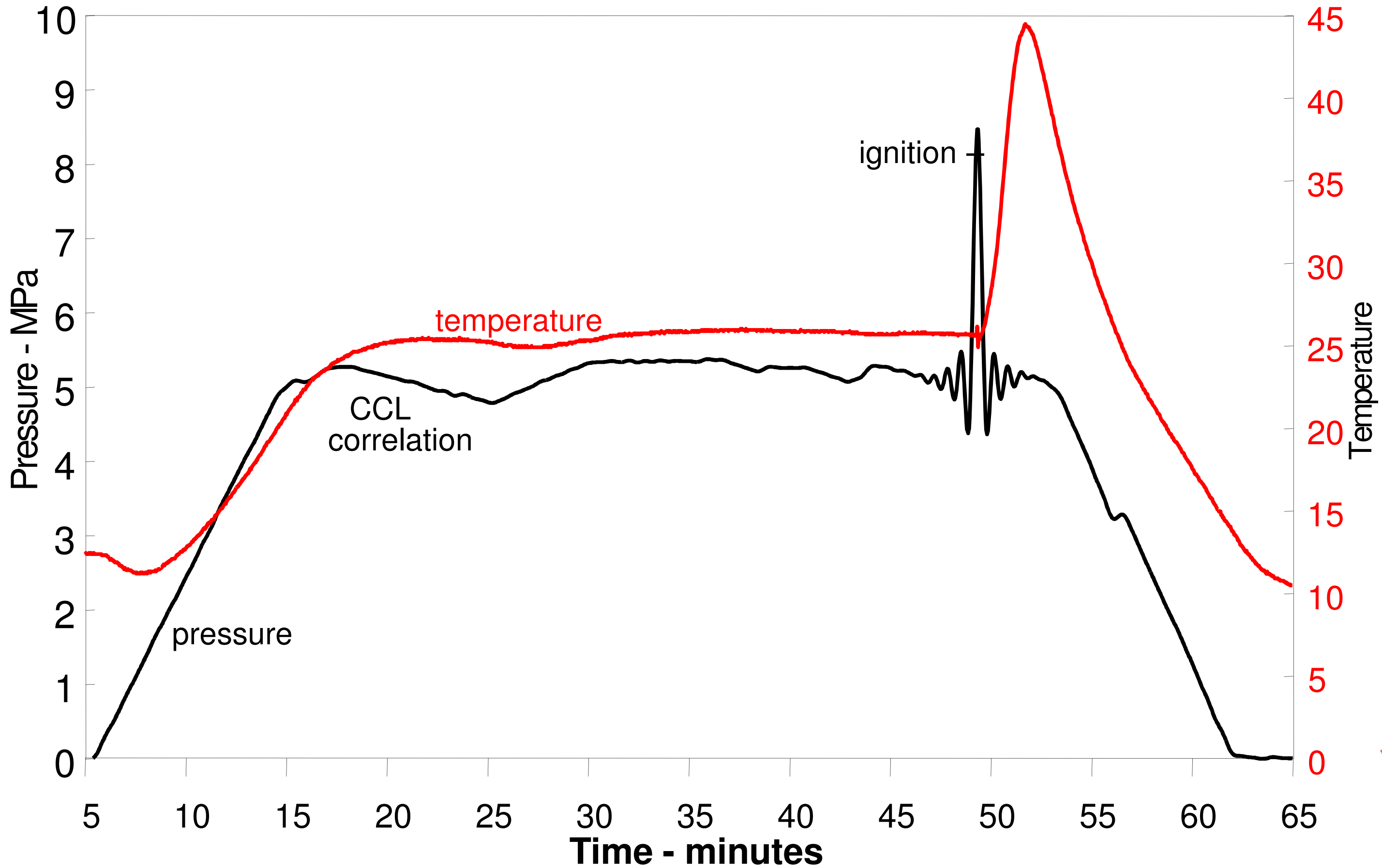


As predicted by thermodynamics, the temp loss is somewhat proportional to tool burn efficiency. From fast burning tools we have seen ~10 °C increase.



A slow burning tool (same: propellant volume, depth, casing size and well fluid shows a temp increase of almost 20 C).

In new tool design, we need to be aware that there is a time limit before the propellant burn may start to "cook" the formation. This is probably in the 1 second range.



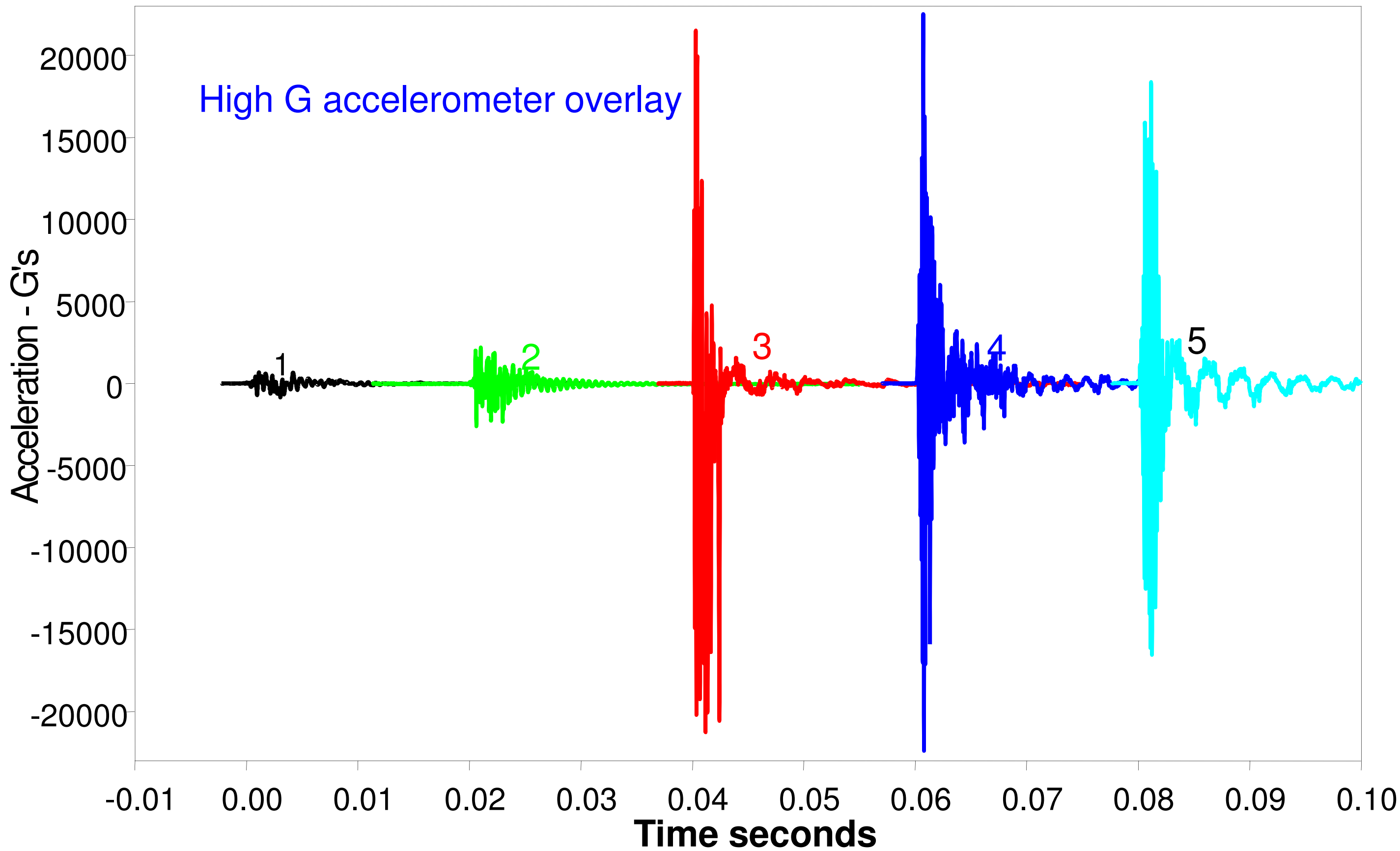
# High G Acceleration Data
## (60,000 G's)

- Measures how much vibration and energy occurs during a shot.

- Useful in tool failure analysis and tool design and development, by measuring the downhole environment.

A High G accelerometer shows the relative “vibration” forces the recorder sees. This plots shows 5 shots - the shock mitigater was used for shots 1 and 2...

This shows two things: first, how the High G accelerometer is useful in seeing what kind of vibration levels exist, and second, how useful the shock mitigater is in protecting the gauge from high energy vibrations.

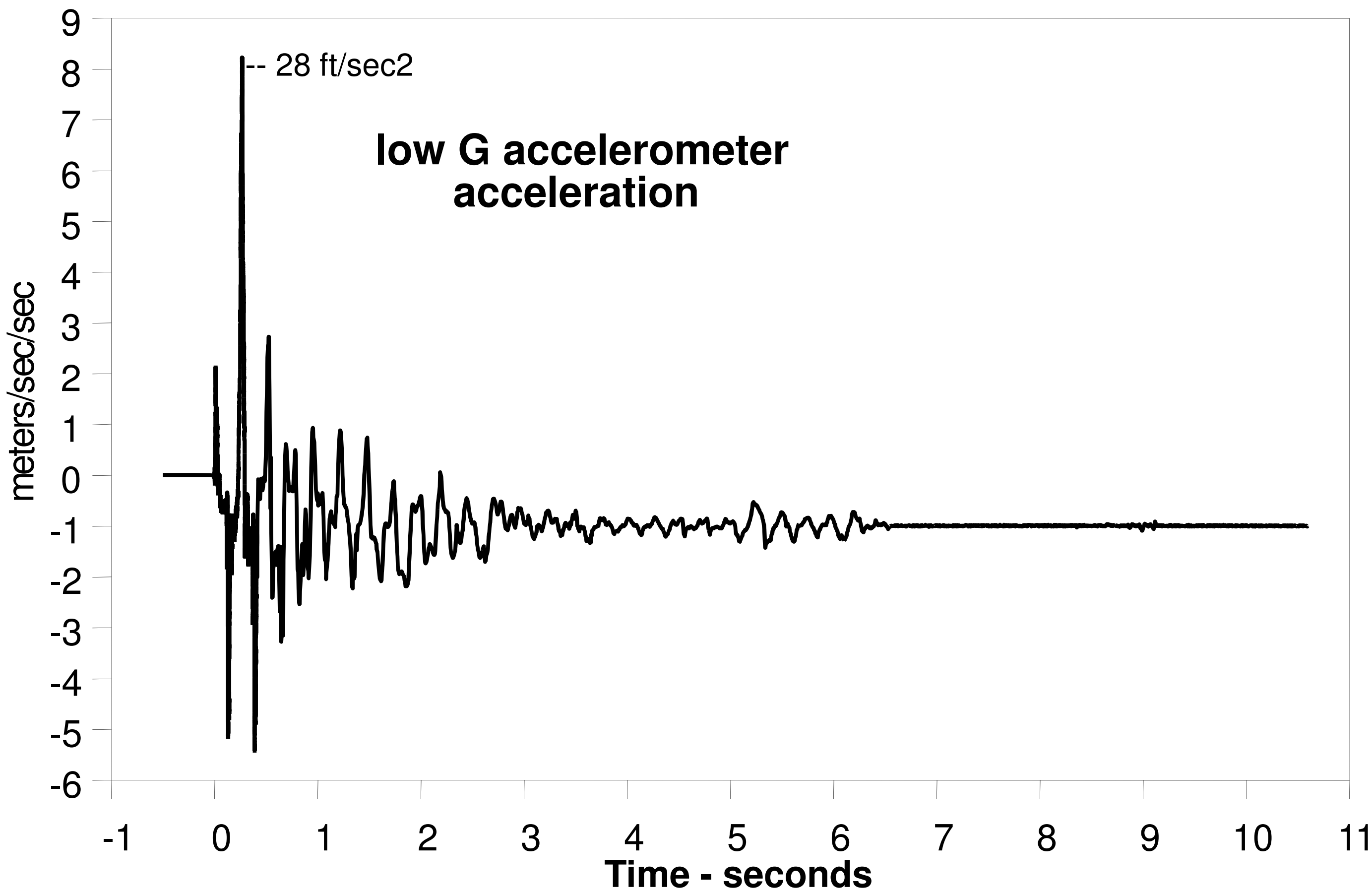


# Low G Acceleration Data

- Measures how much tool velocity and movement occurs during a shot.

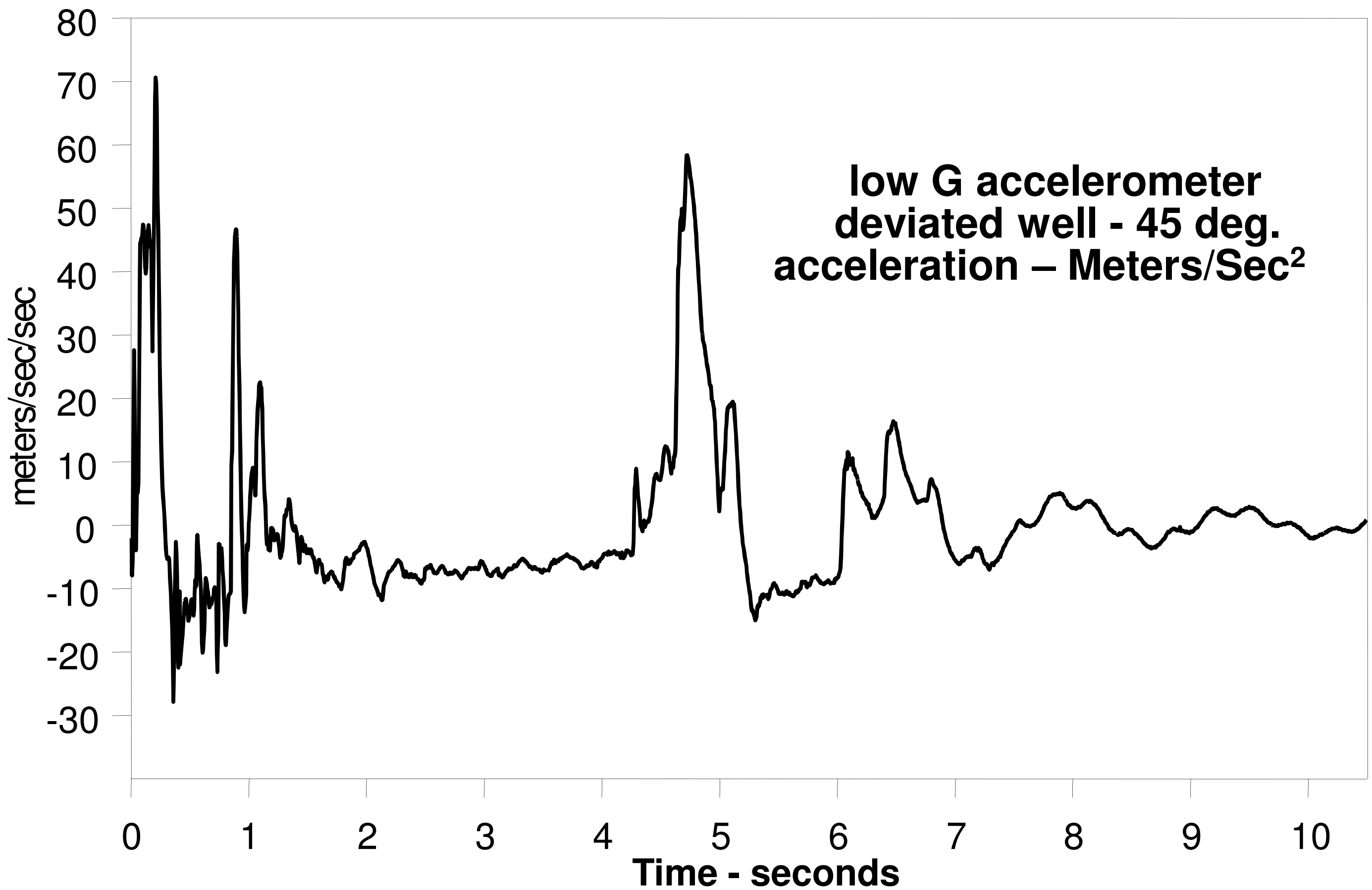
- Useful in tool failure analysis and tool design and development.

The Low G accelerometer has provided interesting and useful data. This shot was a small tool - 3 3/8 x 3.28ft gun with 3 ft of sleeve in a vertical well. The surface reaction was minimal, *BUT* the max acceleration recorded was 28ft/sec$^2$, indicating the violent movement, up and down, of the tool down hole....

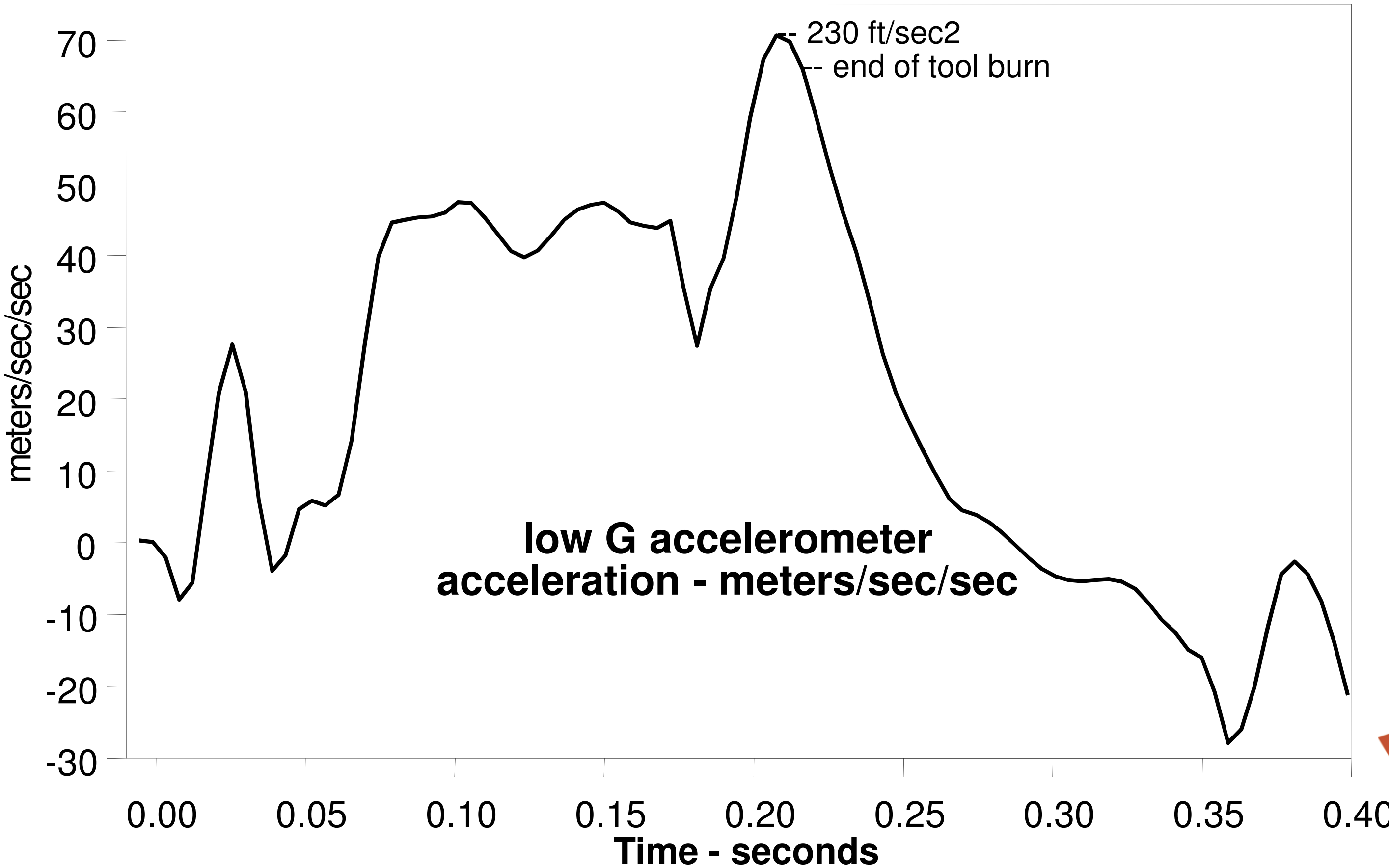


In this shot, the well was deviated 45 degrees and the propellant burned slowly with a low pressure - producing a violent surface reaction - the wire line laid on the ground for about 7 seconds.

(You can see the activity settle down after 7 sec)



An expanded plot of the previous data - the max acceleration was 230 ft/sec2 and significant tool burn seems to be at 220 milliseconds

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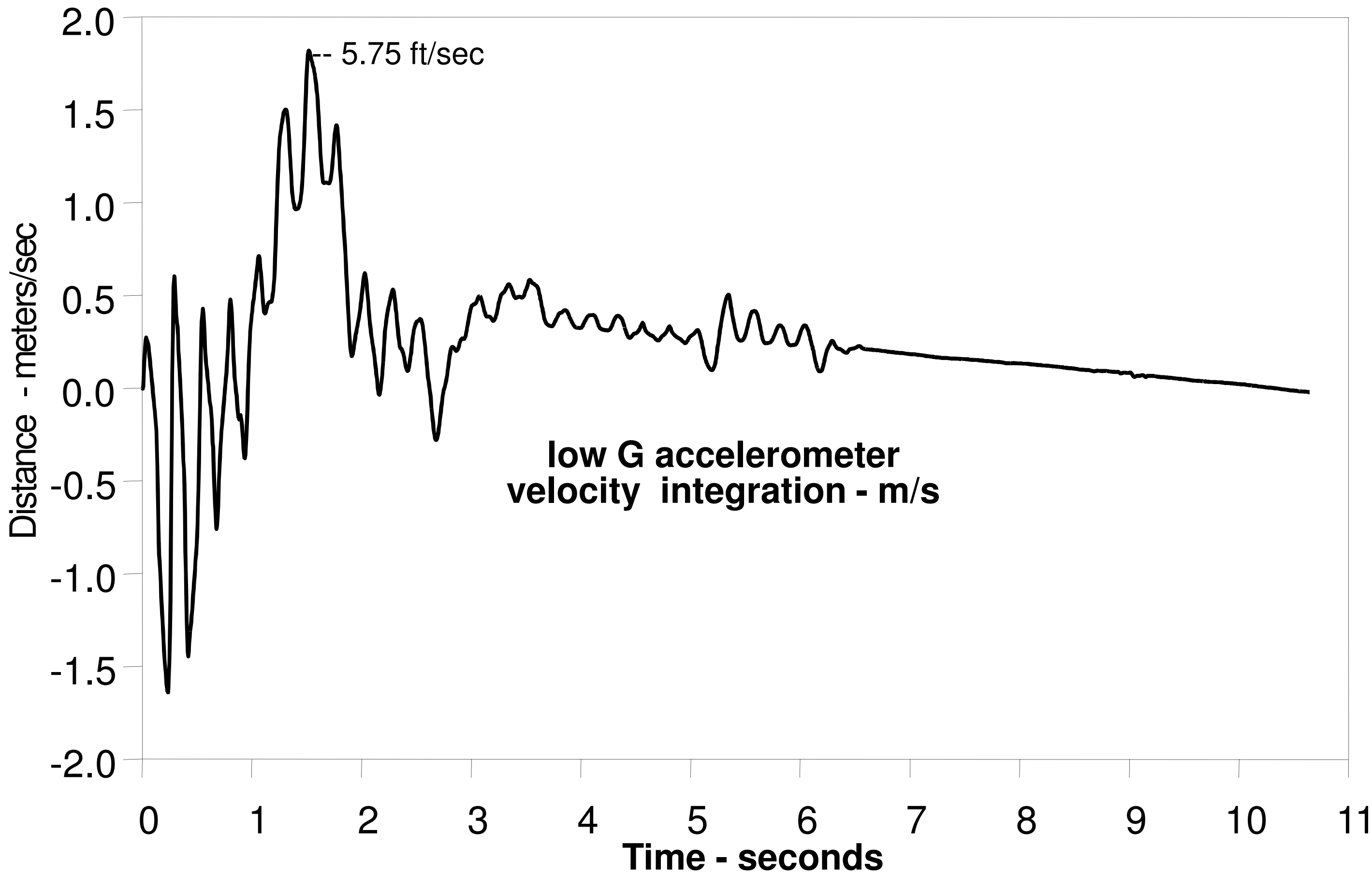
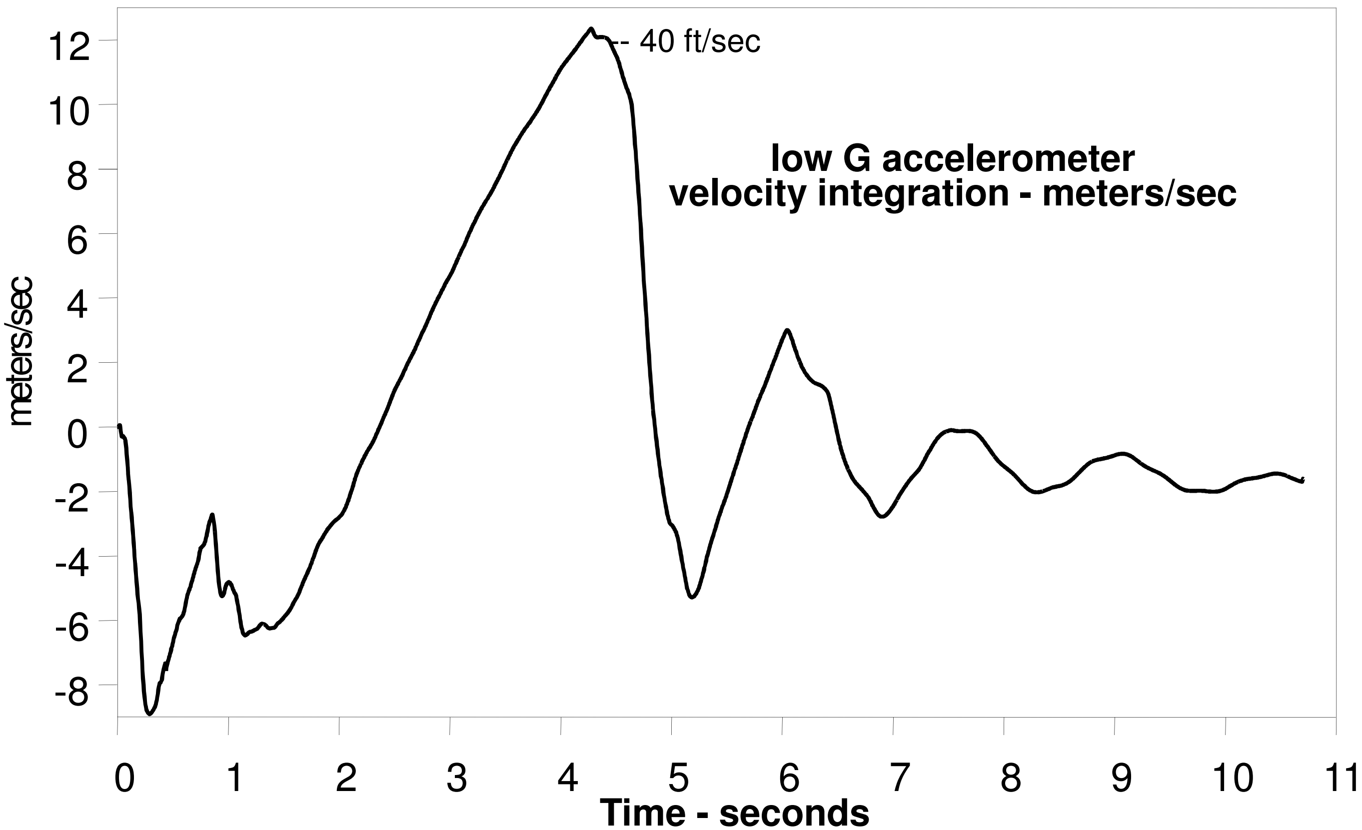
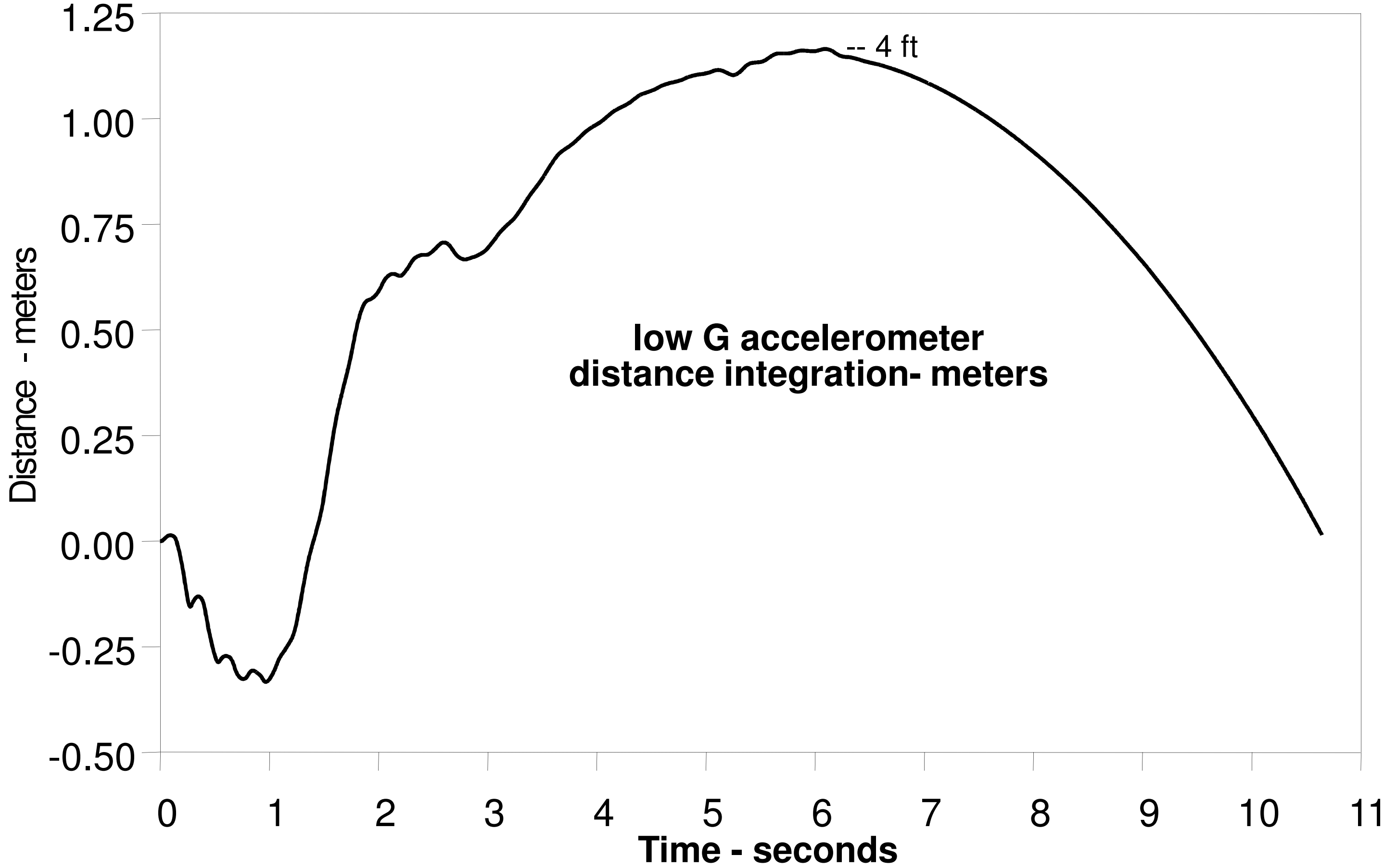
The velocity integration shows the max velocity of the small tool to be 5.75 ft sec



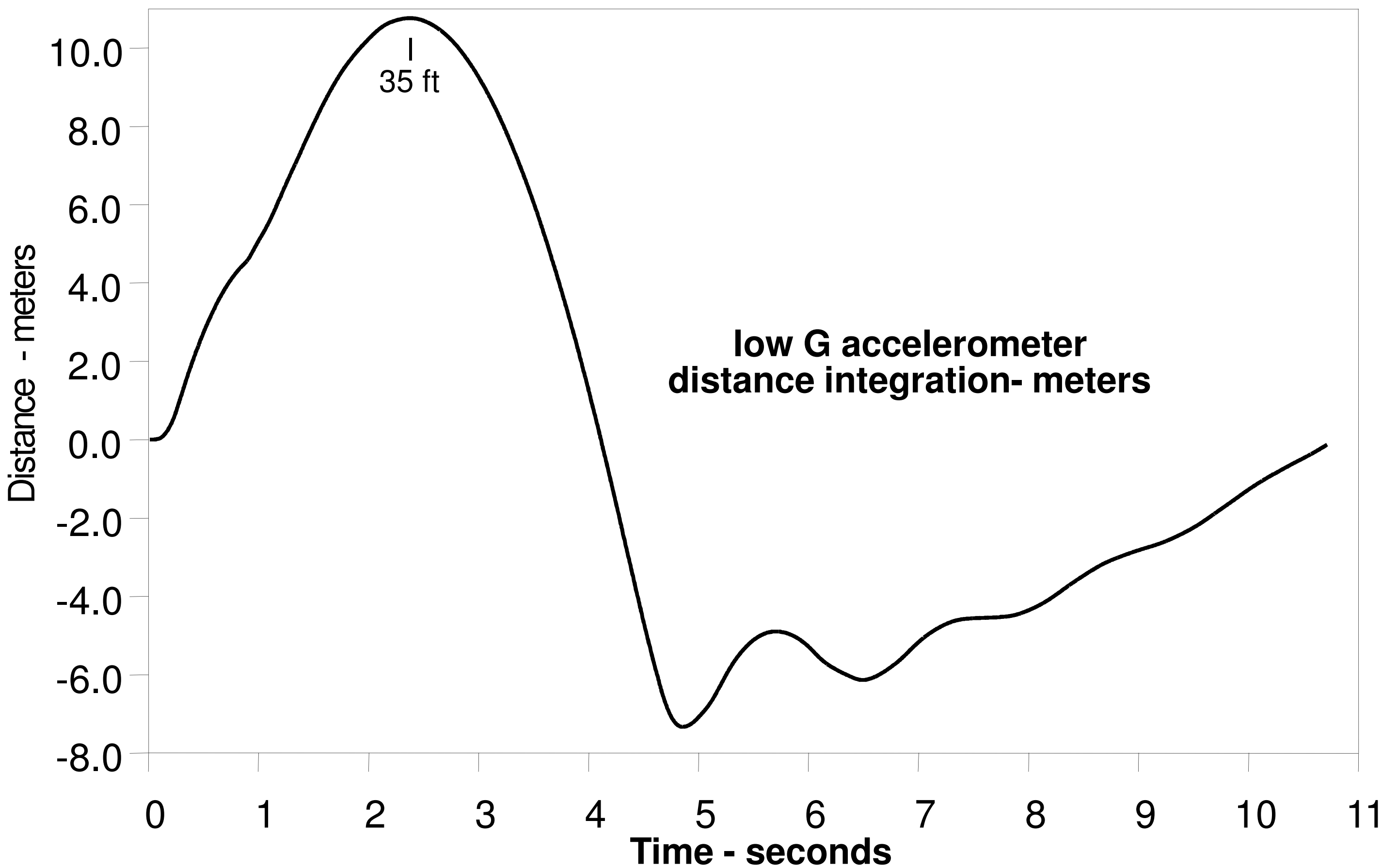
The slow burning tool, in the deviated well, took off at 40 ft/sec about 4 seconds after the burn.



The distance integration shows the maximum tool movement at 4 ft.

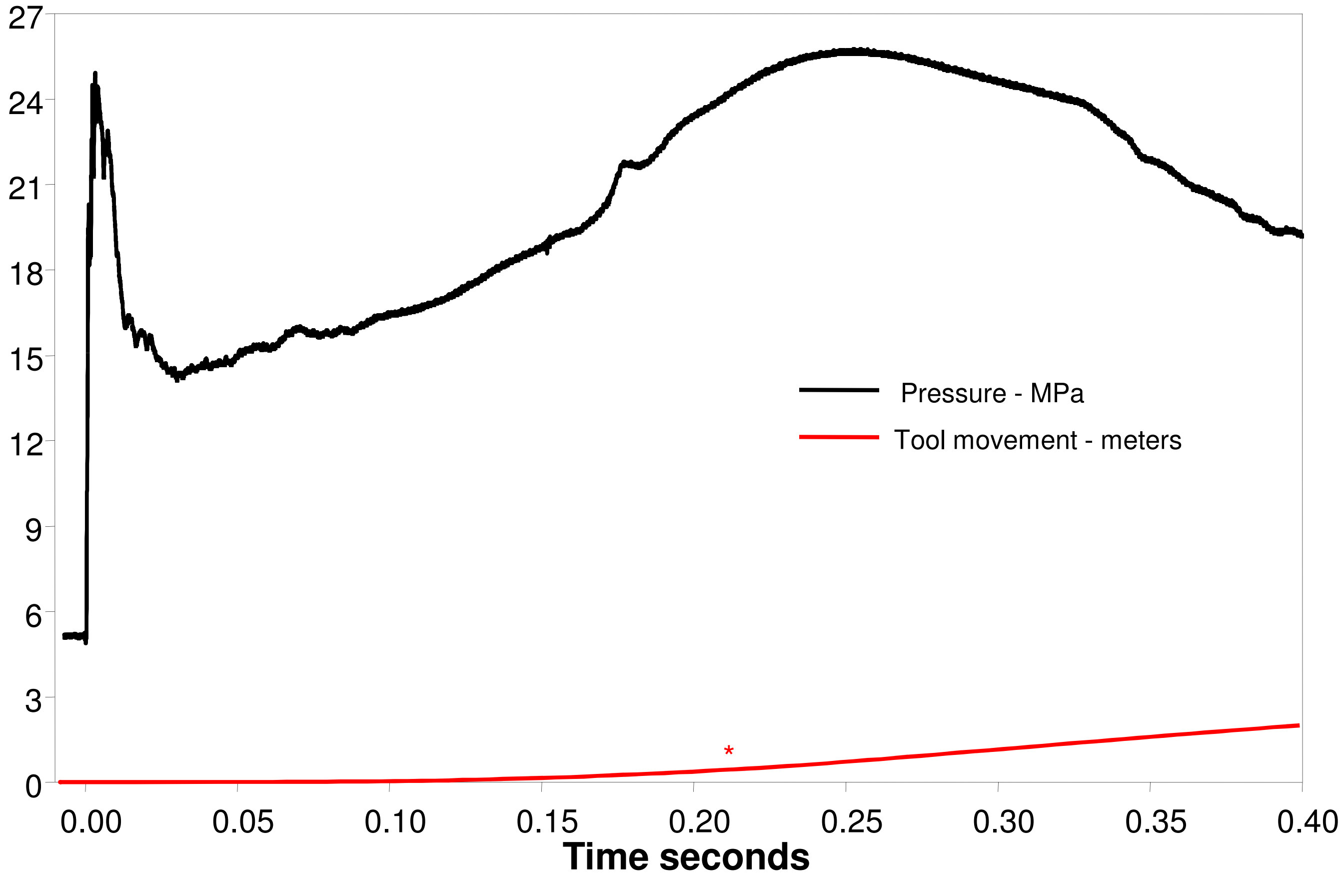


In this well, the tool moved 35 ft. This was an extremely deviated well, on wire line, in hard rock.

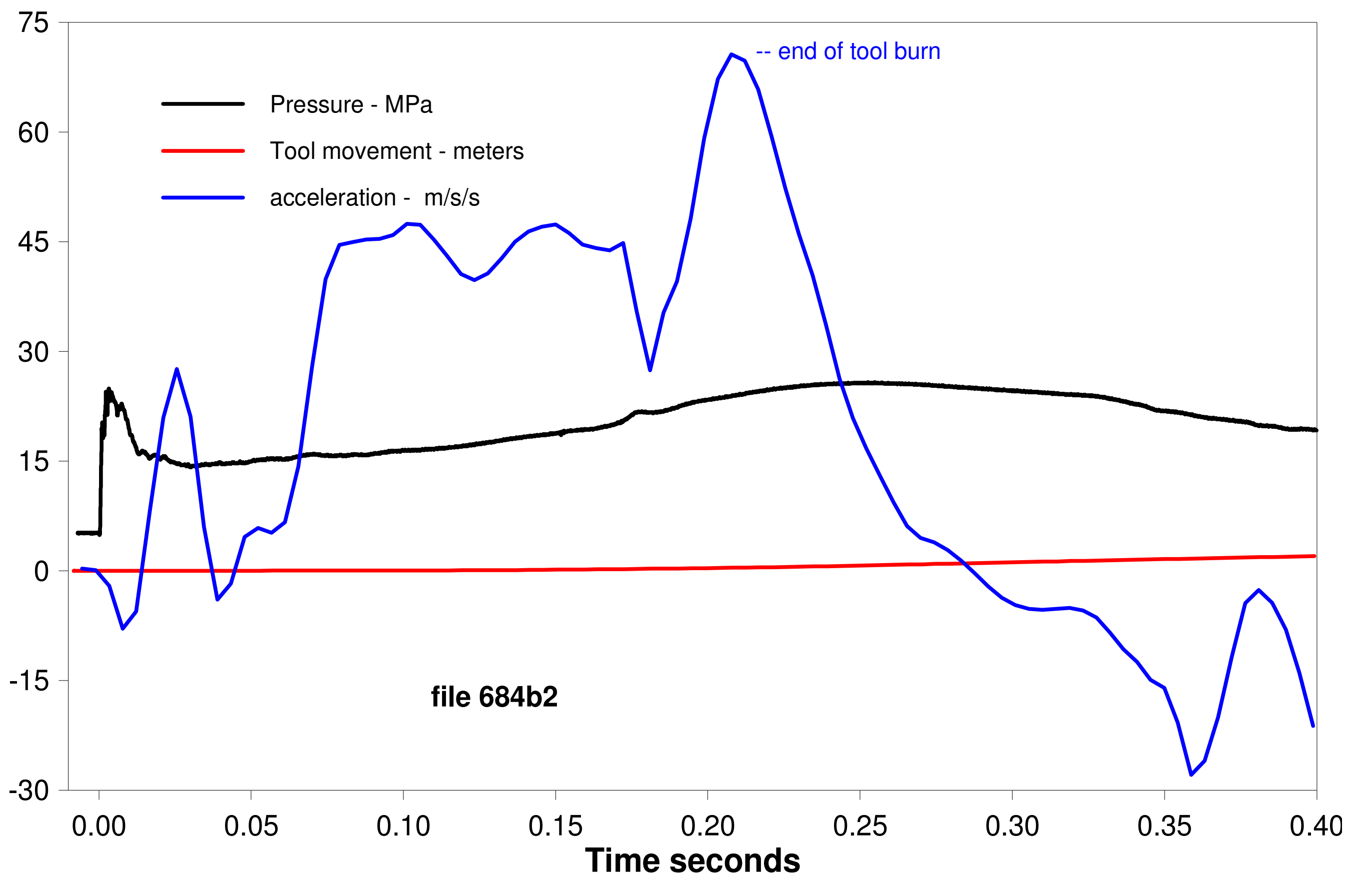


This is an overlay of the slow tool burn pressure and the distance integration. At 220 millisec, when significant burn seems to have ended, the tool has moved 1.5 ft.

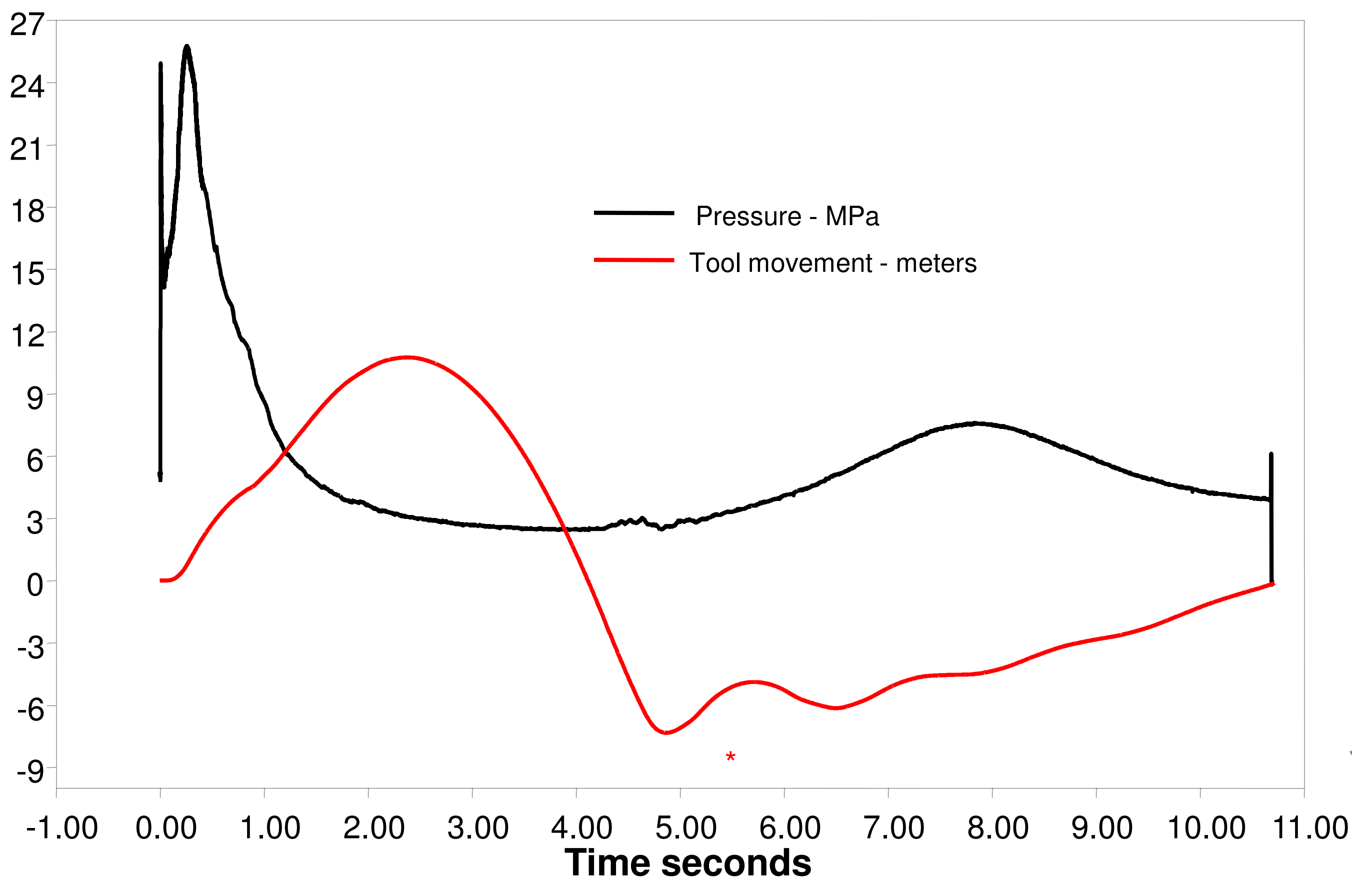
There is a time limit for propellant burn when using wire line.  In short (3ft) intervals the tool could be off depth before the burn ends.



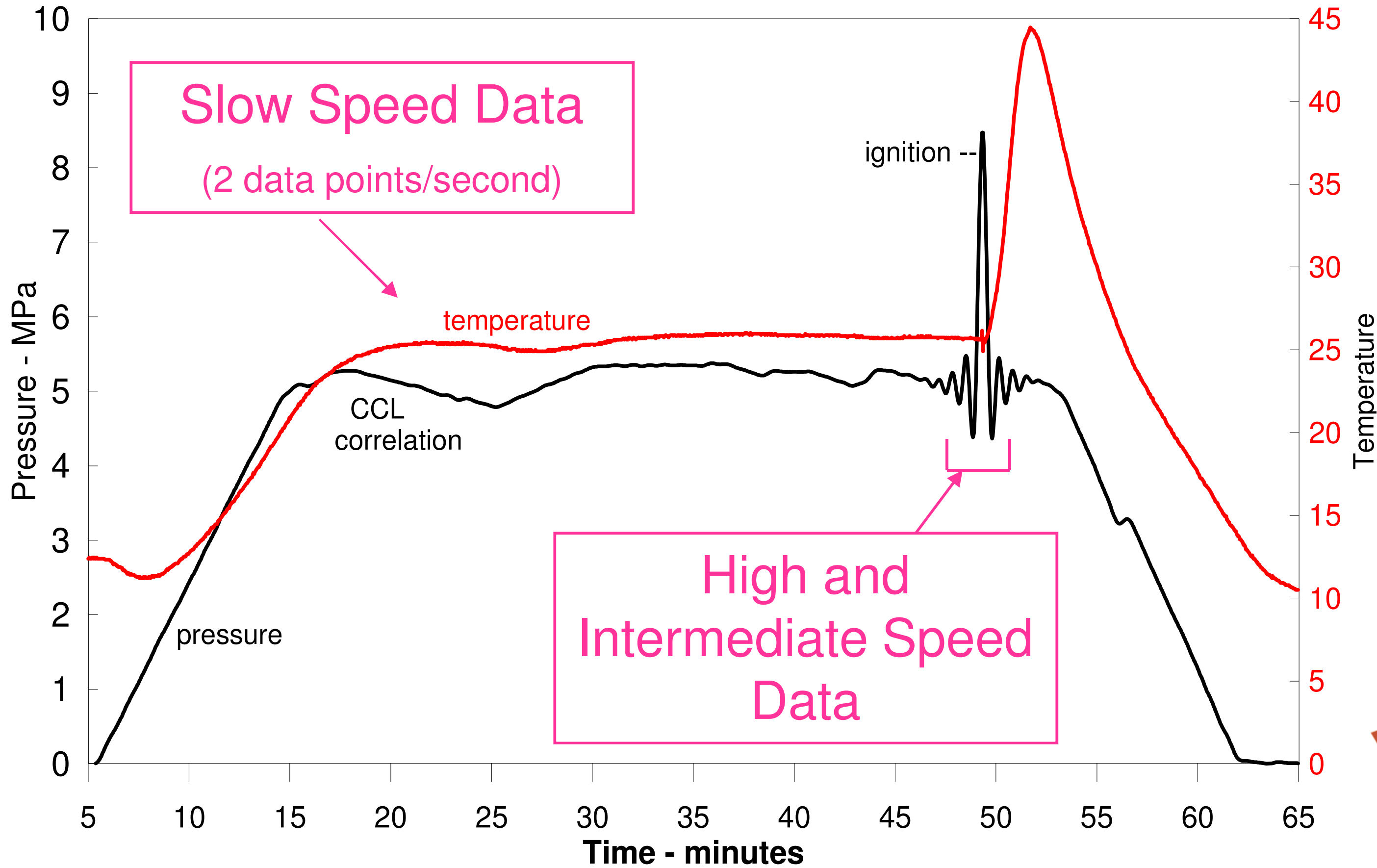
Pressure, Tool Acceleration, and Tool Movement Overlay for the first 400 Milliseconds.



Same data as previous slide, but showing 11 seconds of pressure/tool movement.

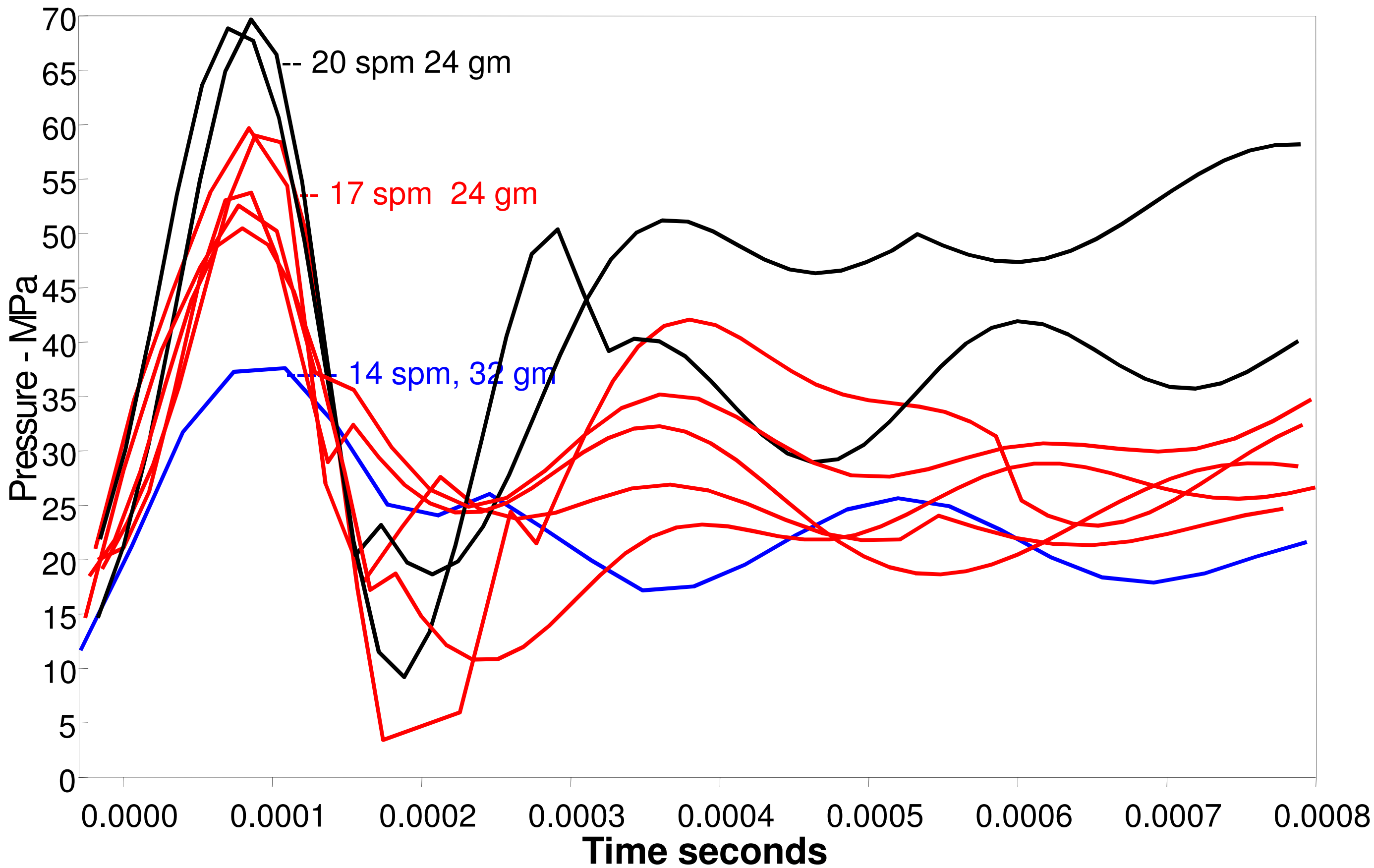


The Slow Speed data shows the overall test.



Using Fast Speed data (115,000 data points/second) to show Perforating Charge Burn Rate.

Perforating pressure profiles overlaid on each other…

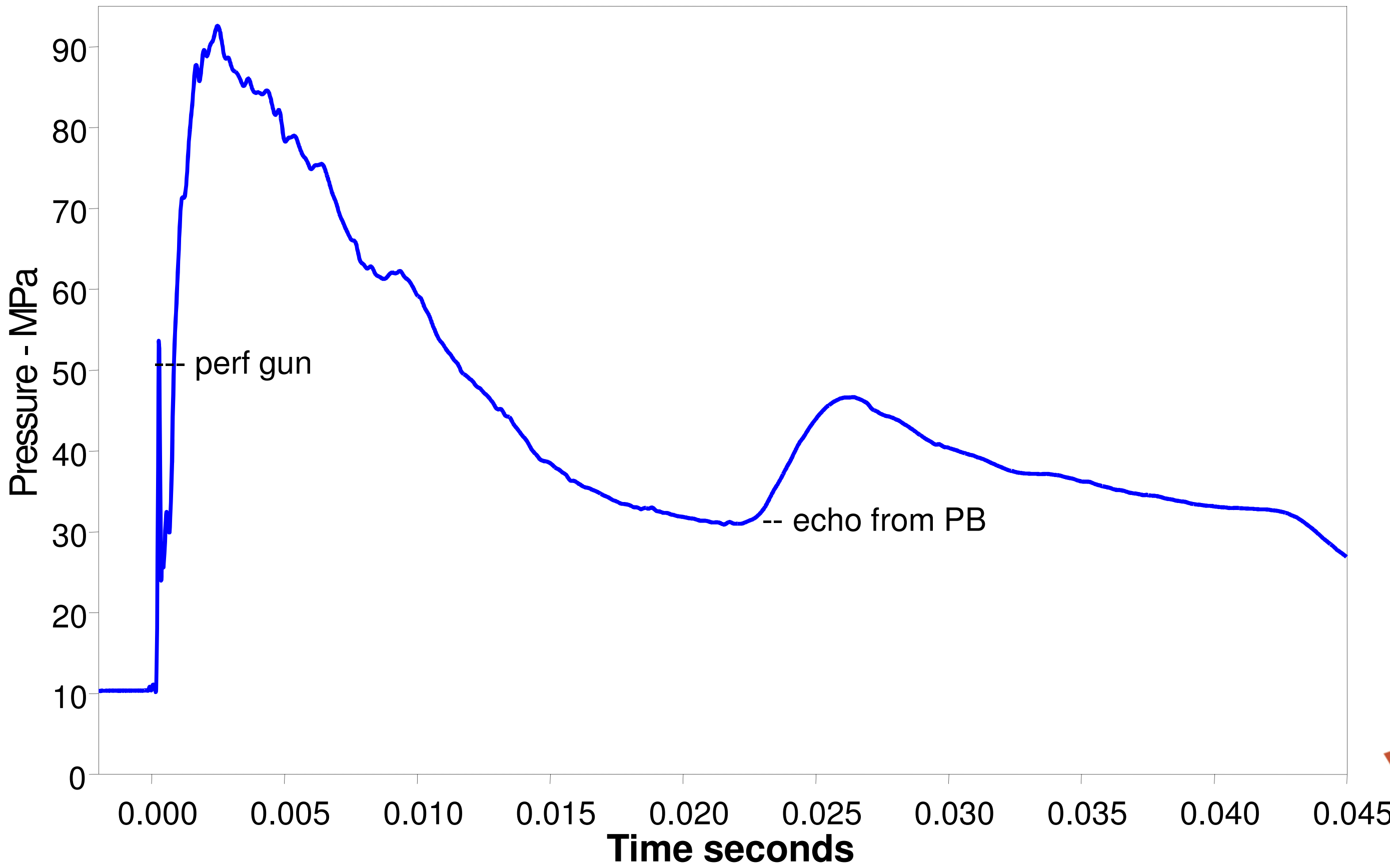


# Fast Speed Data

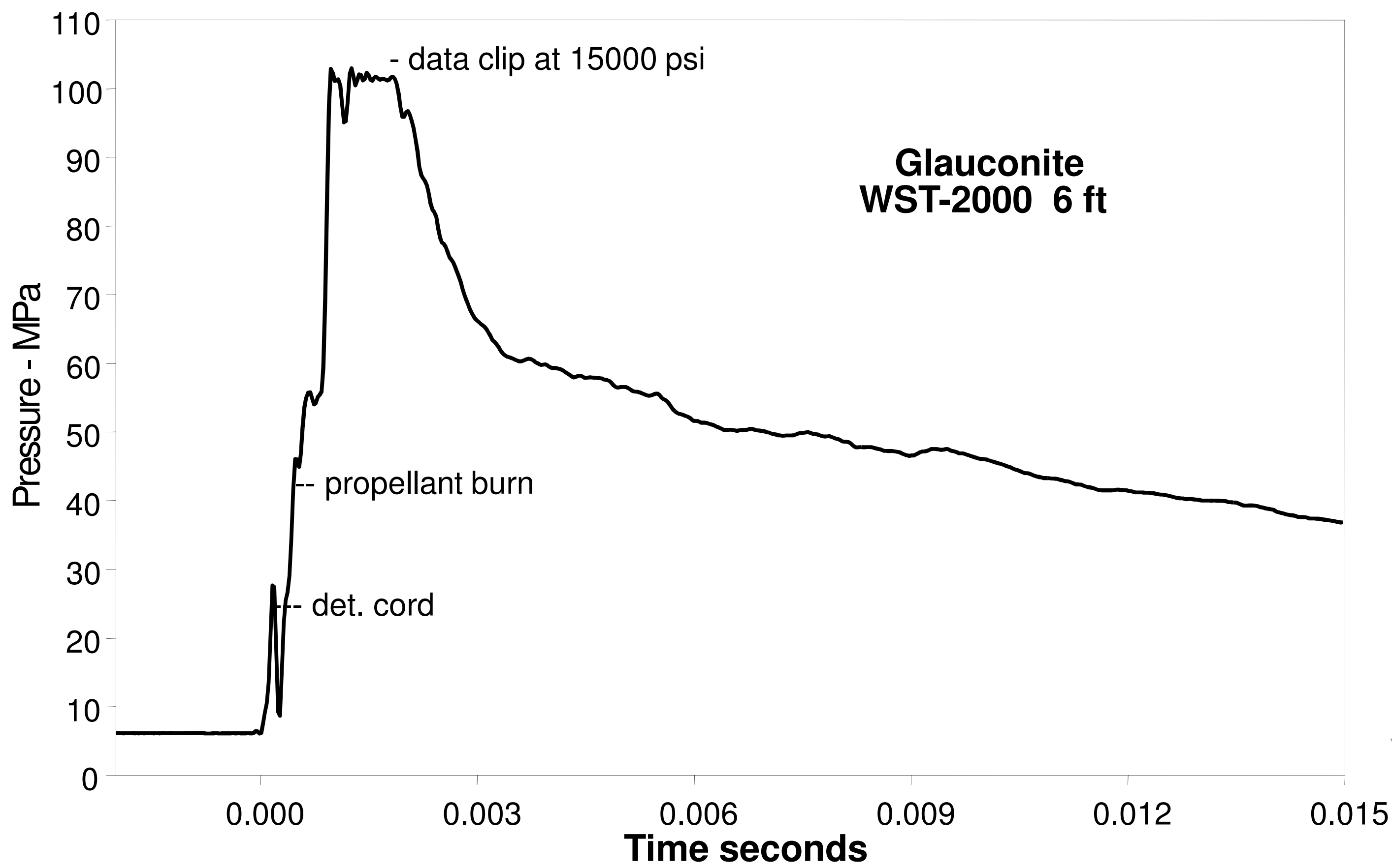
(115,000 data points per second)

- Fast Speed data shows how ***different*** each propellant or perforating burn is for the different well conditions

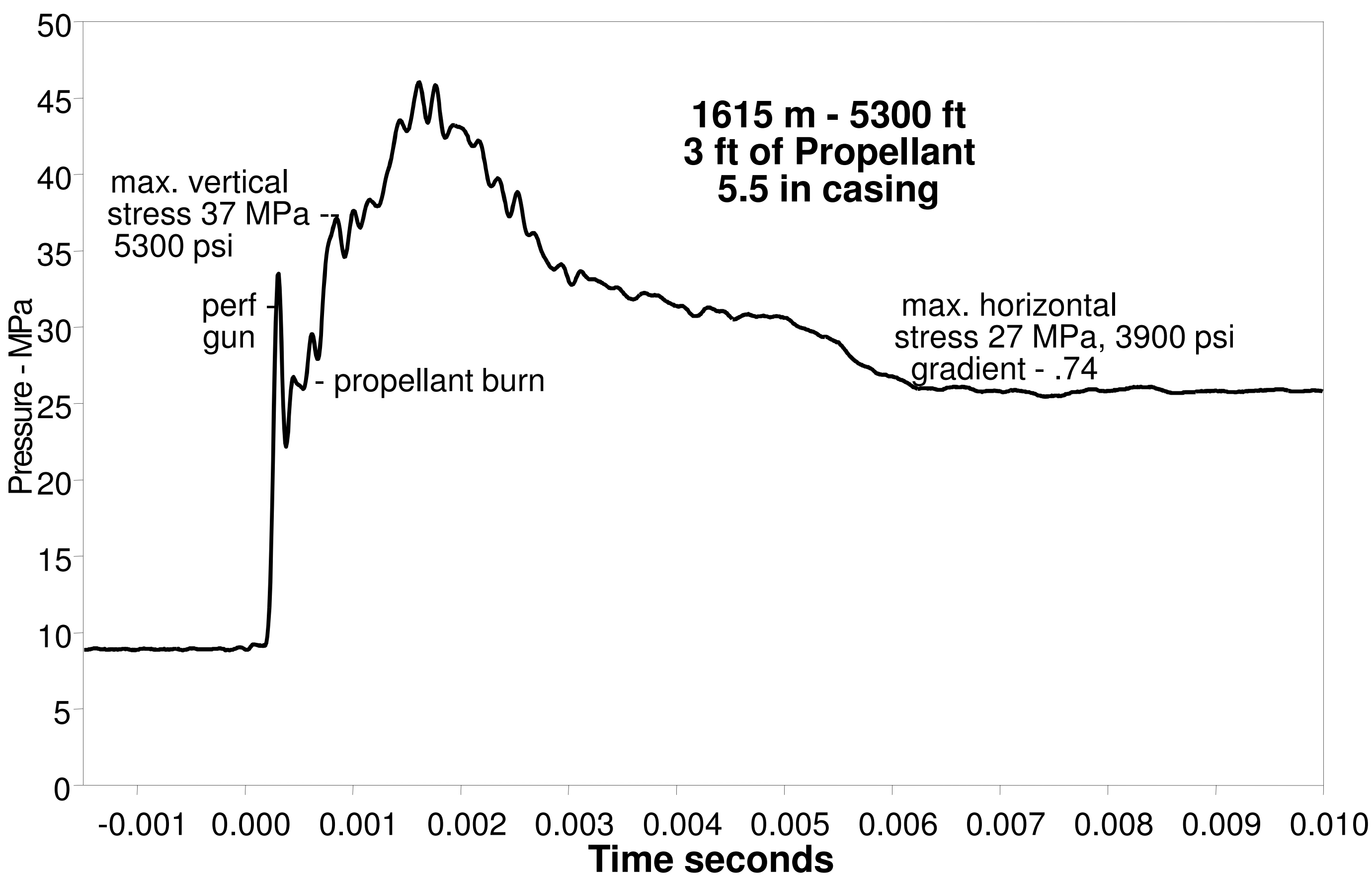
A fast burning tool shows a peak pressure 13,500 psi.



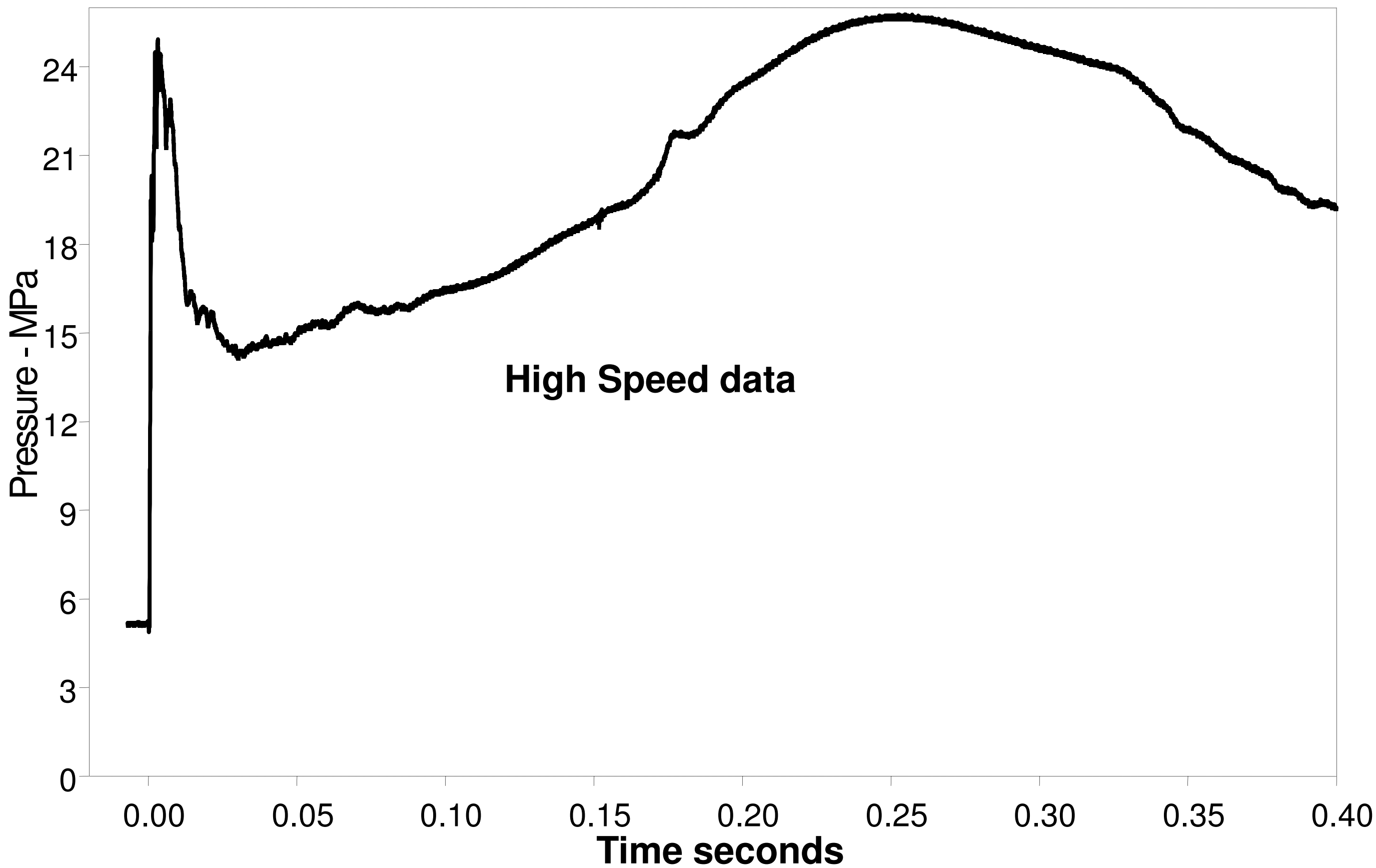
A WST propellant tool in a hard, tight sand



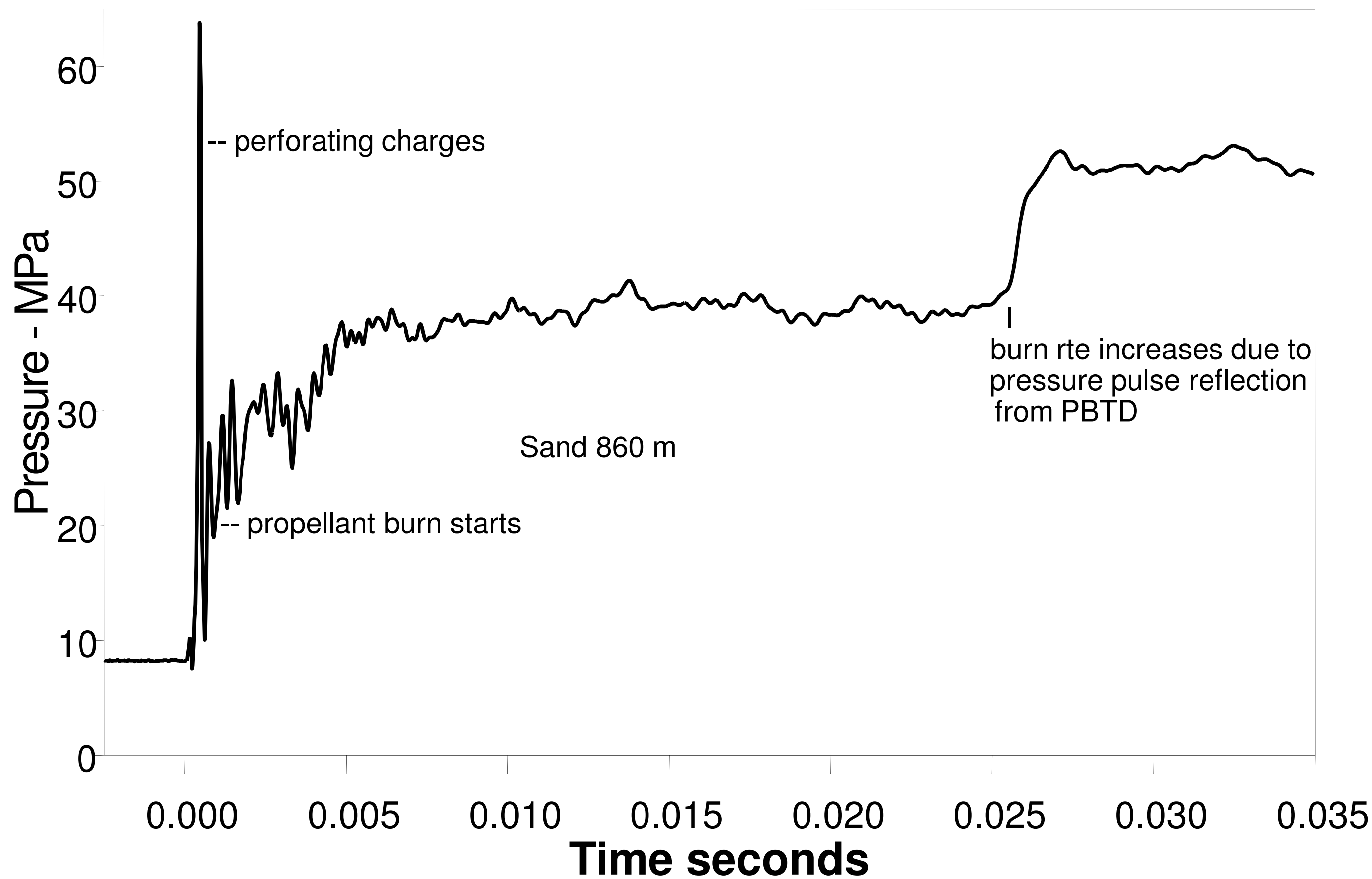
Small Propellant tools can provide a lot of info



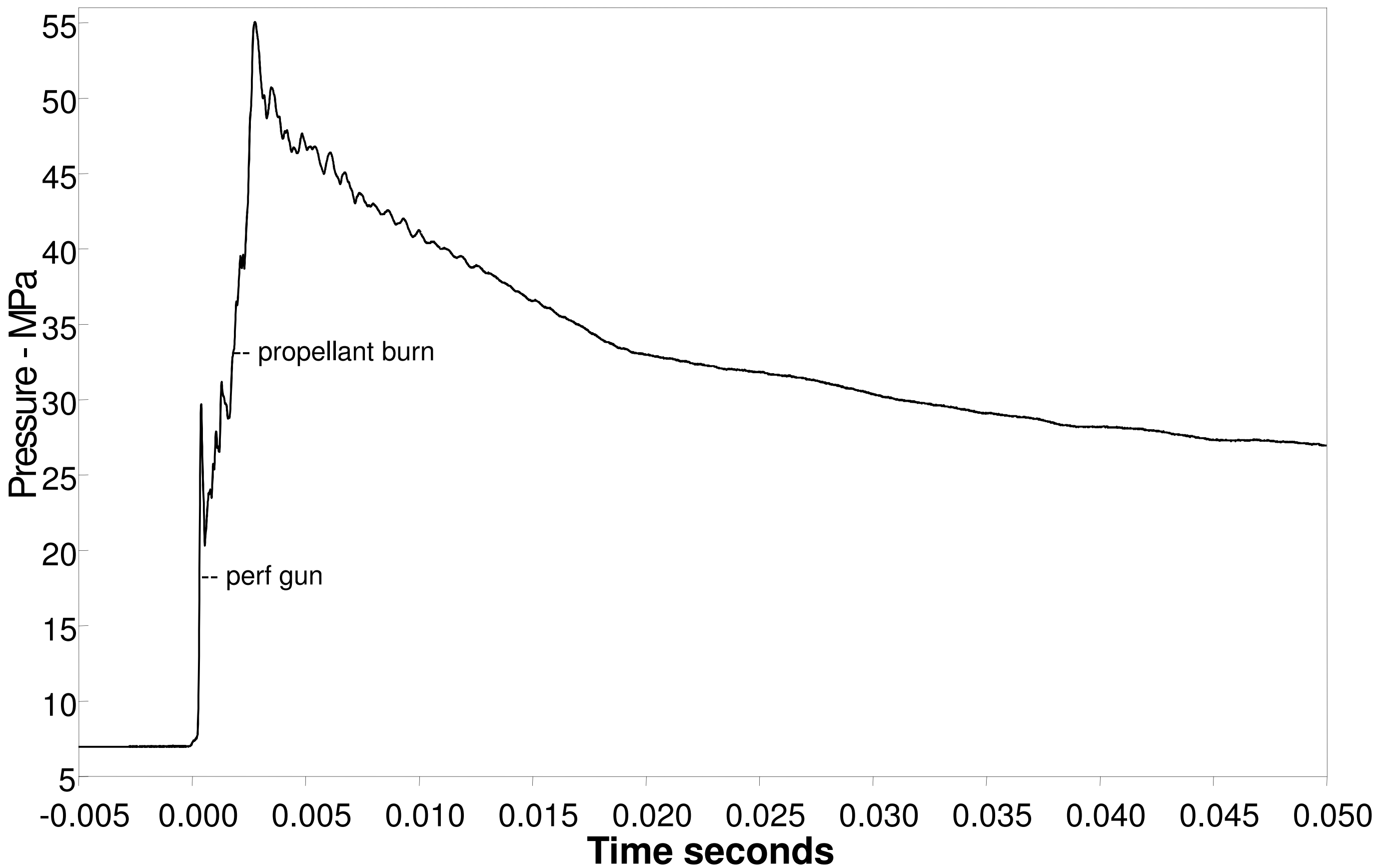
Fast Speed Data



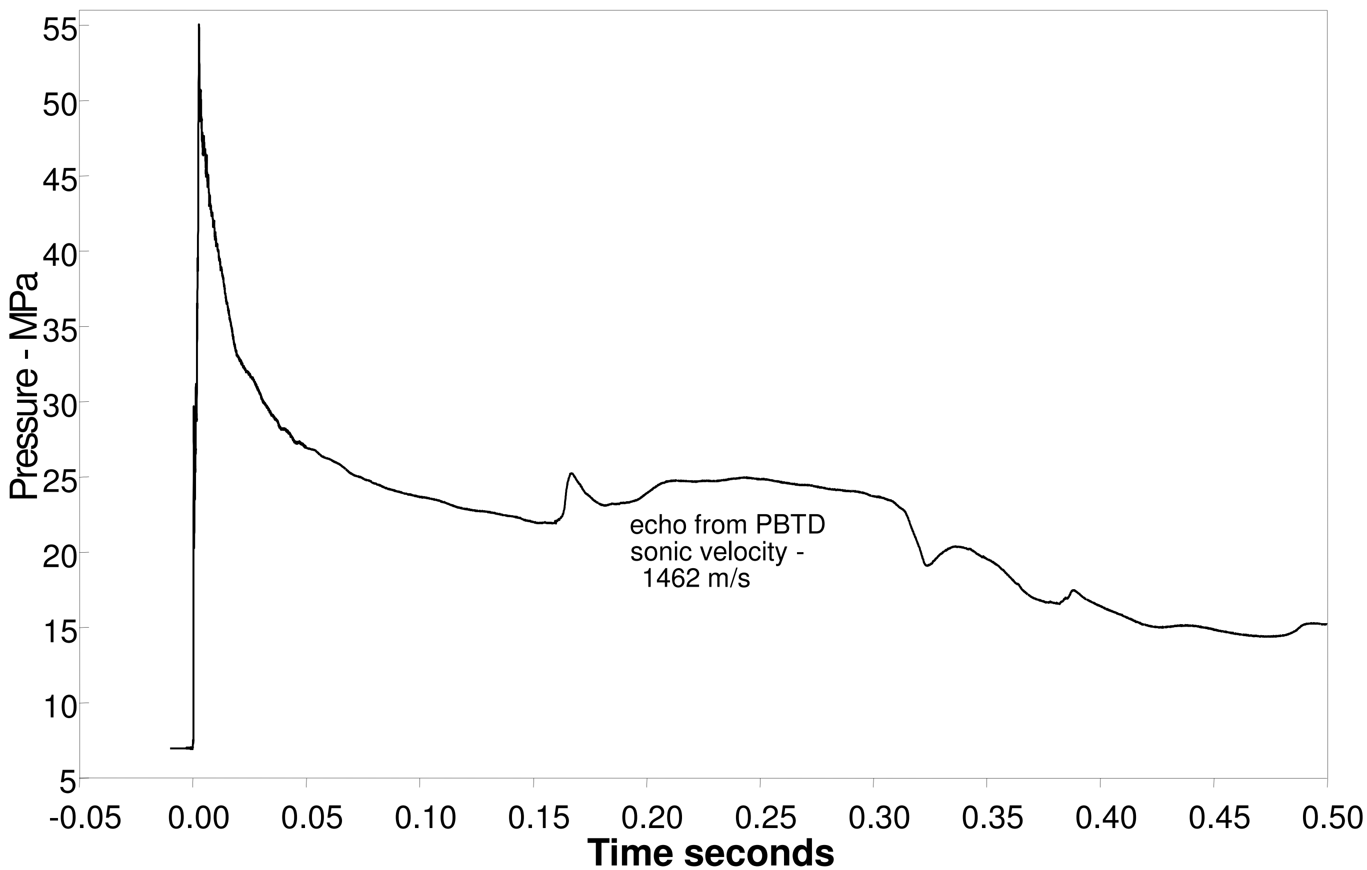
Increased Propellant burn from reflected pressure.



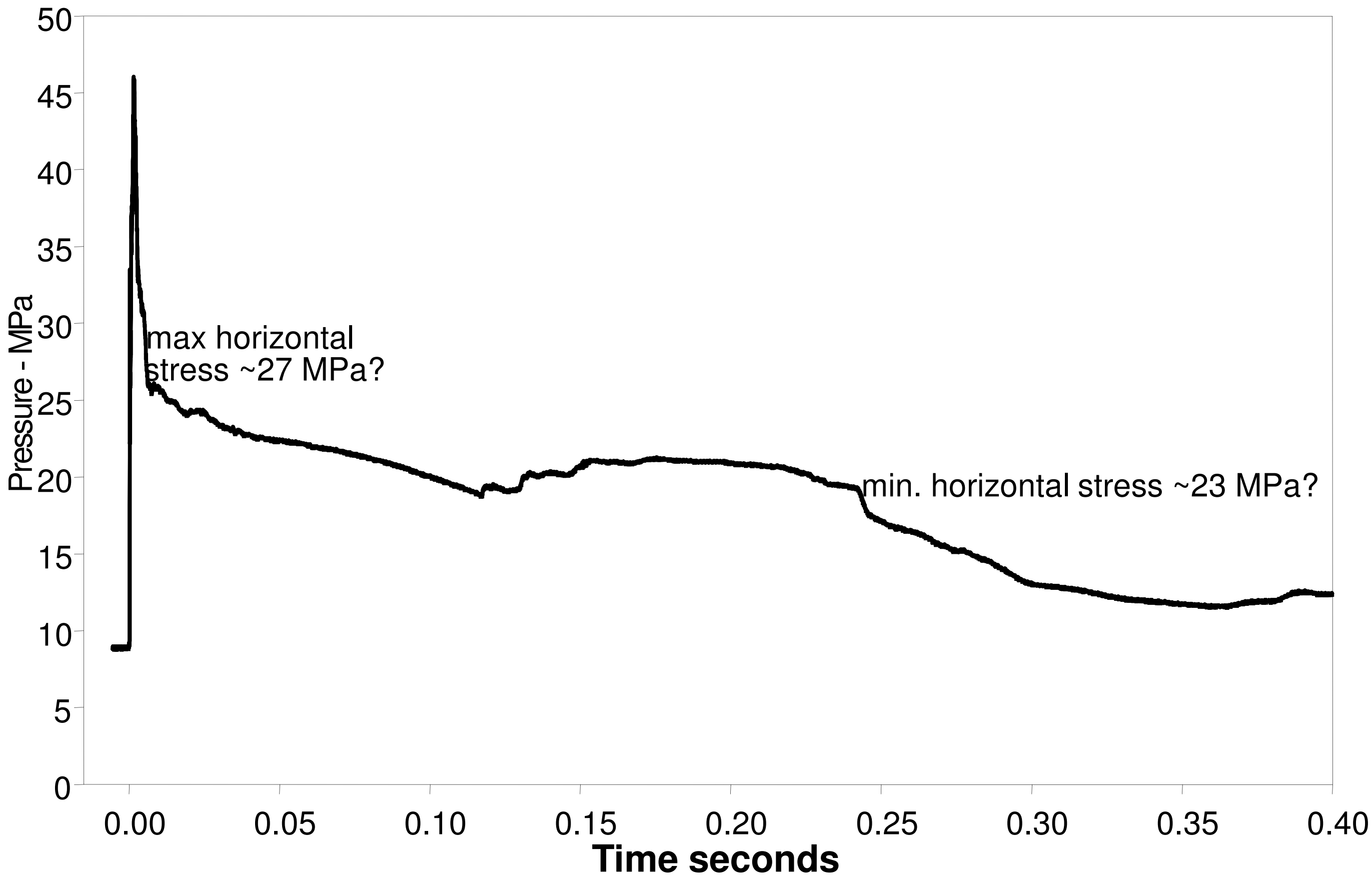
Fast Speed Data



Fast Speed Data showing echo from PBTD.



Fast Speed data showing max and min horizontal stress.

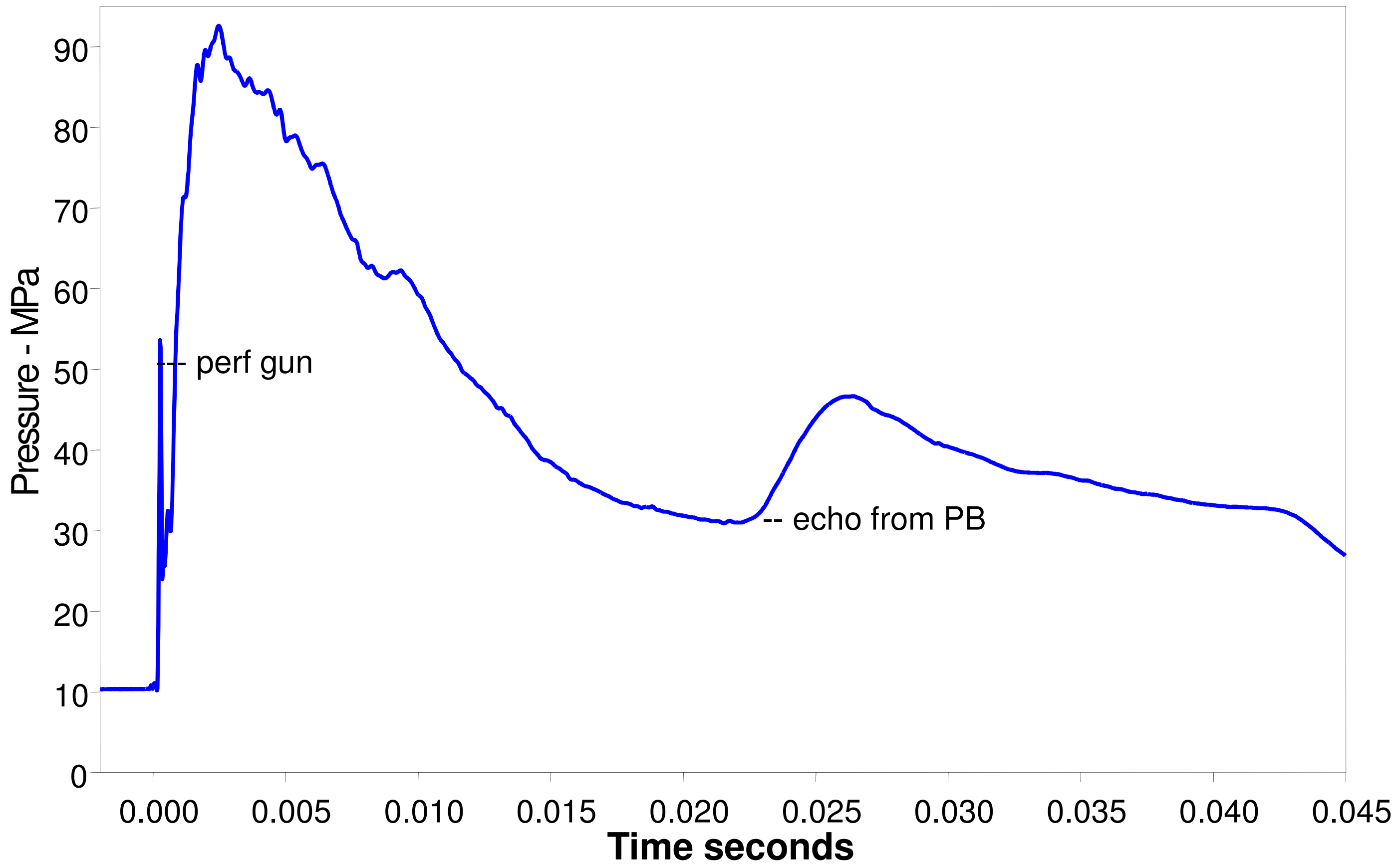


# Fast Speed Data

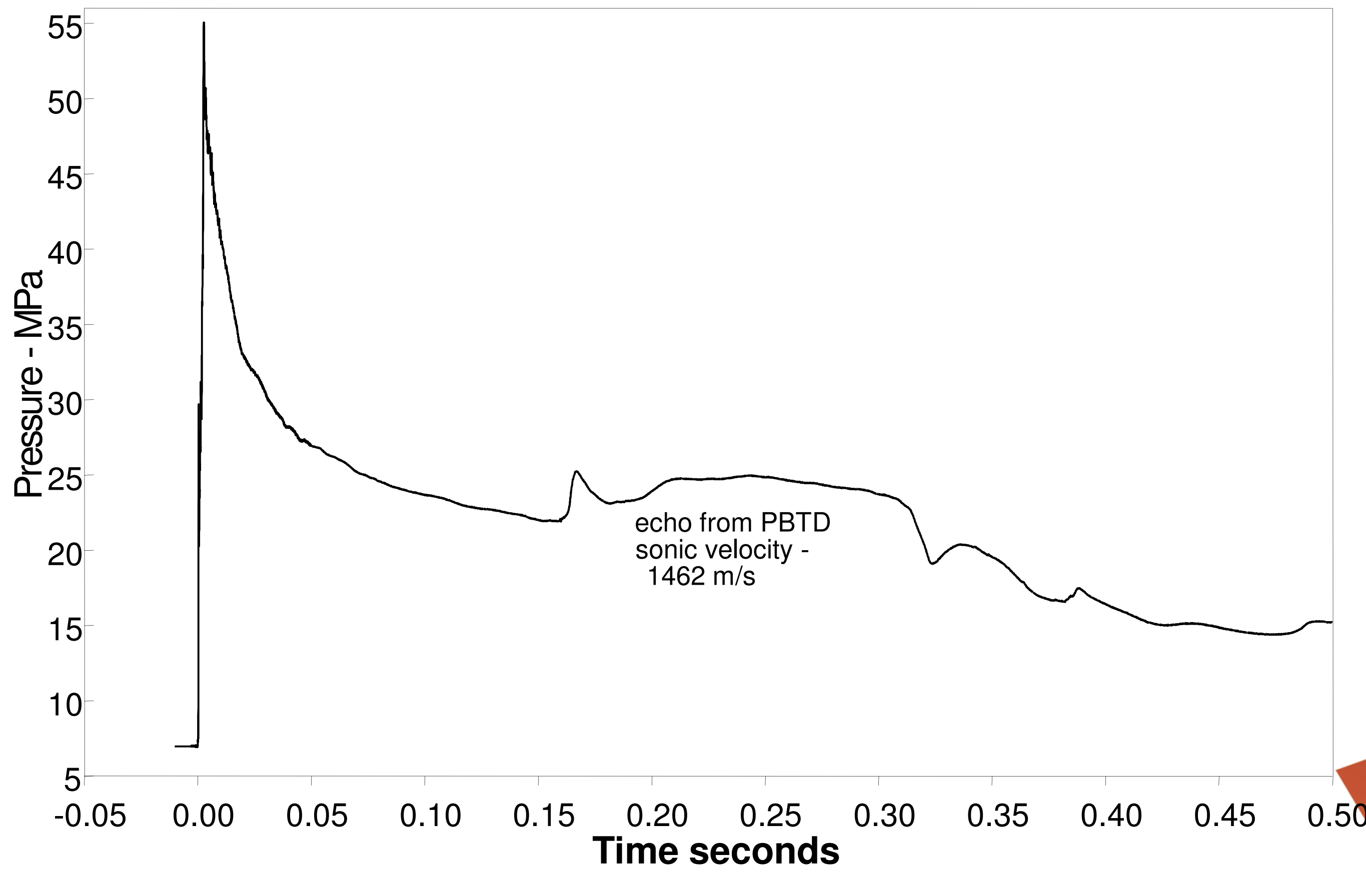
(115,000 data points per second)

- Fast Speed data shows the reflection of pressure from the bottom of the well

Pressure reflection from the PB



Pressure reflection from the PB

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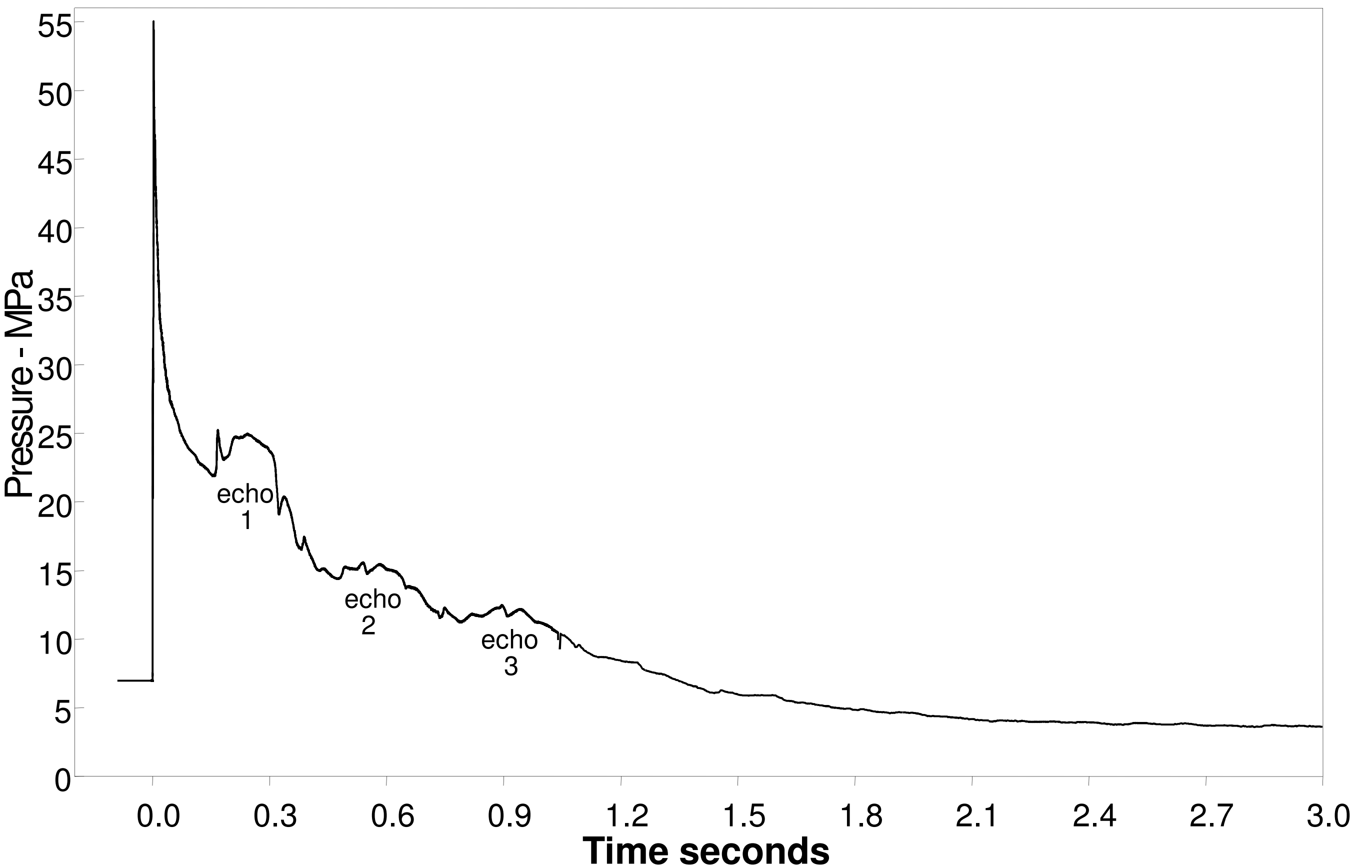
Intermediate Speed Data showing multiple PB echoes.



# Intermediate Speed Data

(up to 15,000 data points per second)

- Useful in determining formation pressure and temperature just after a shot

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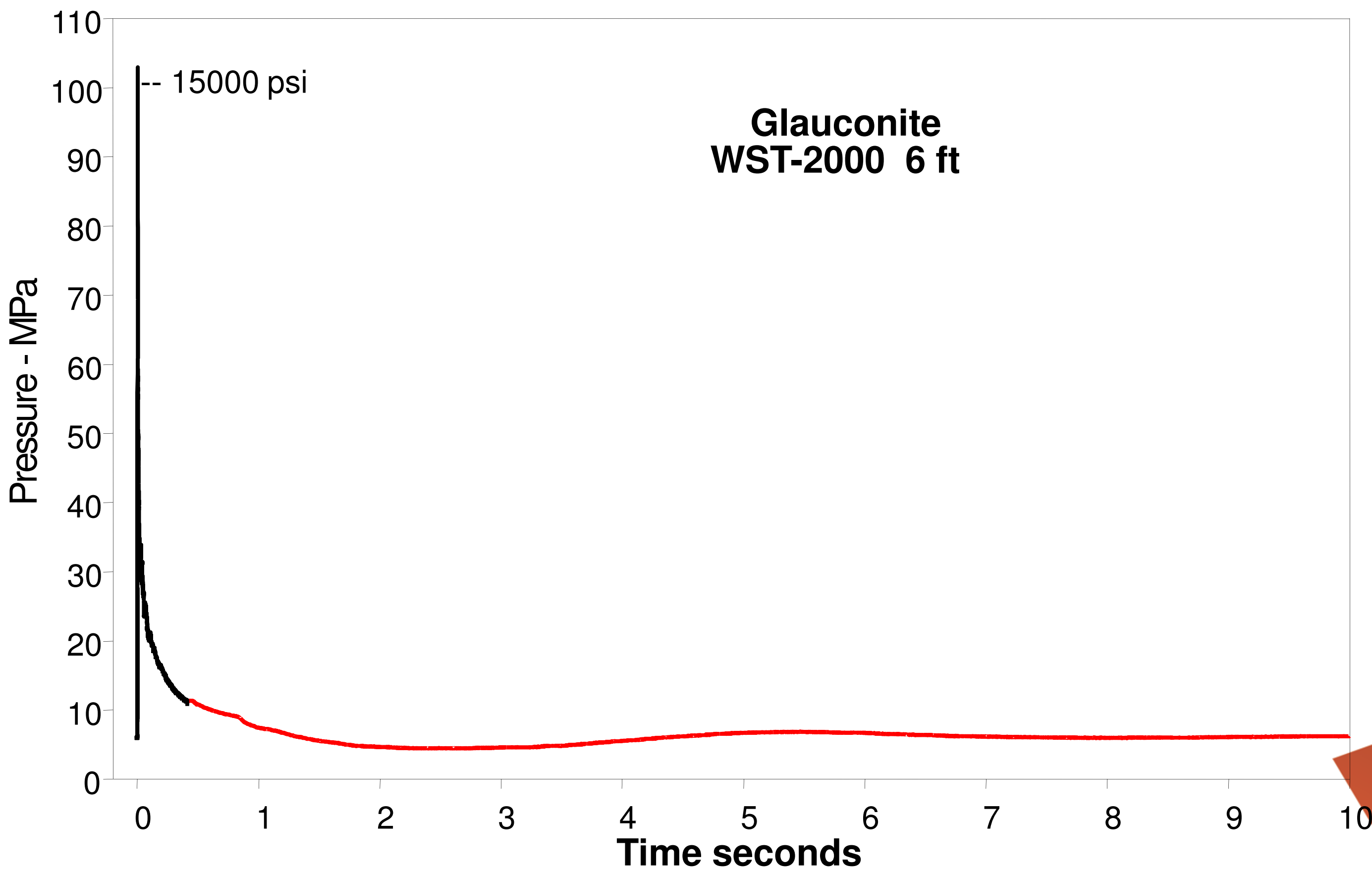
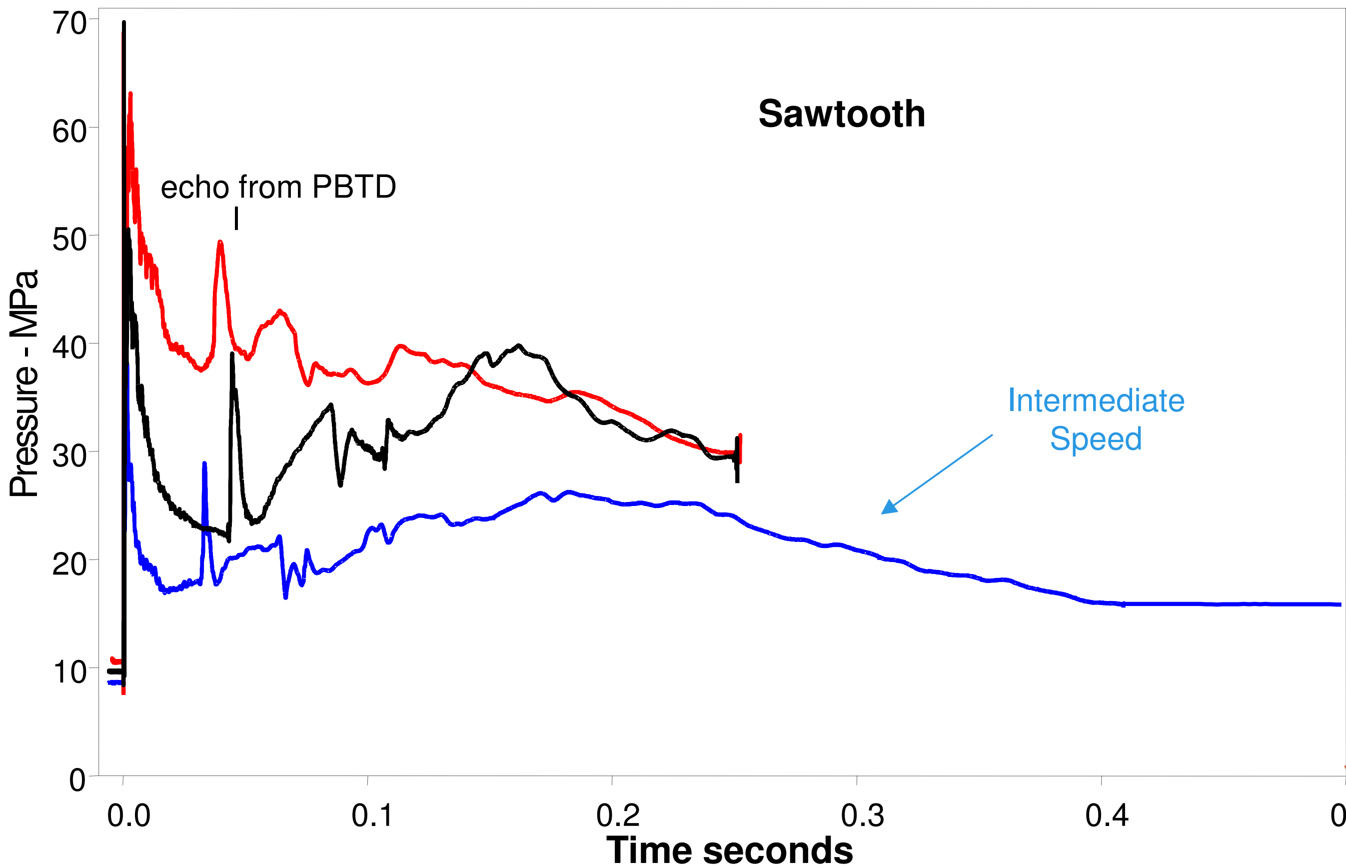
The 11 second plot of a fast burn shows much less post burn activity from the high pressure shot.

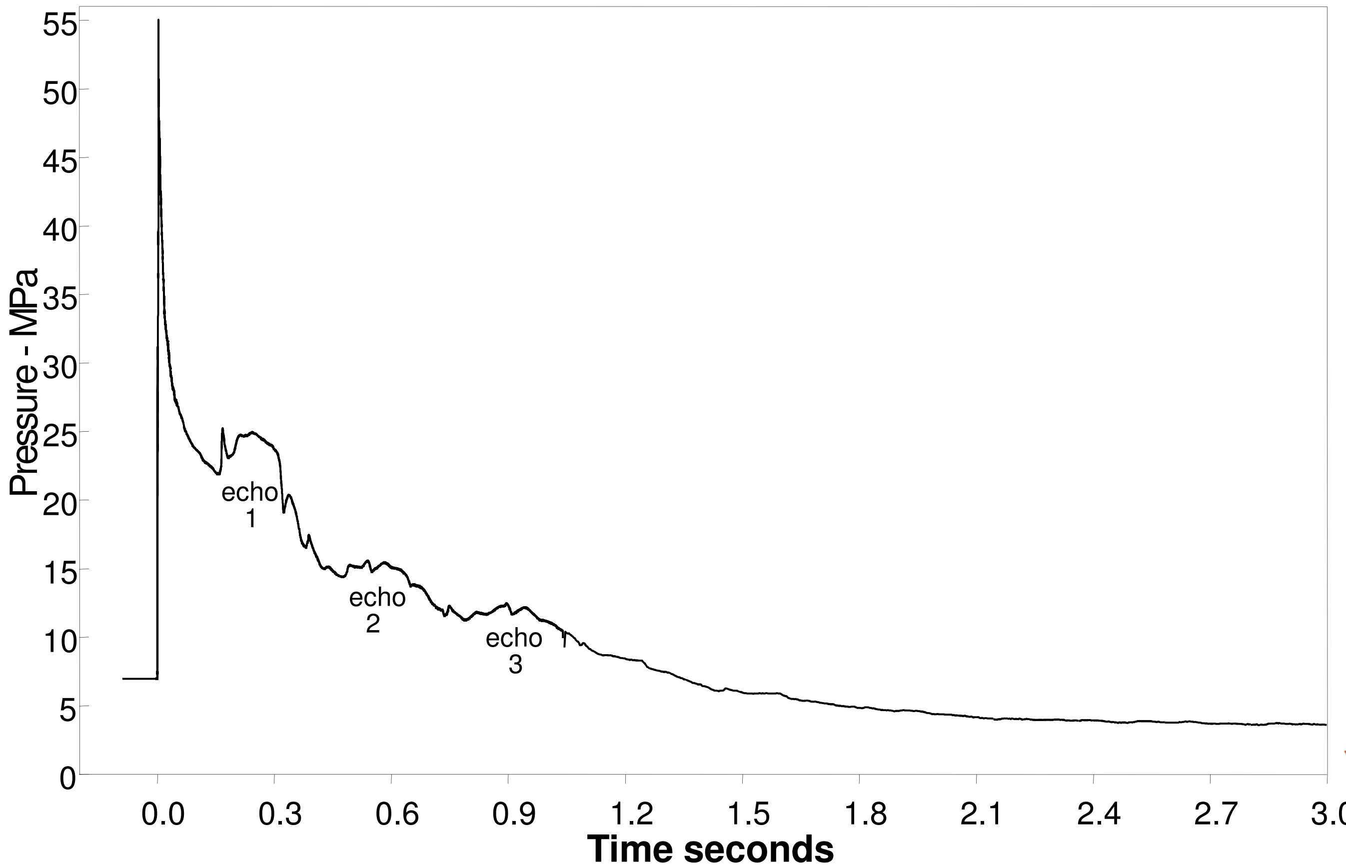


The addition of the **Intermediate Speed** is critical to looking for formation properties in the data. We tend to overload the formations on a regular basis and the pressure fall off has not usually reached the desired level before the end of the high speed window. This is an overlay of two runs *WITHOUT* Intermediate Speed and one run *WITH* Intermediate Speed. In this formation it commonly takes > 0.4 seconds for the pressure to drop to that equal to the rock horizontal stress.

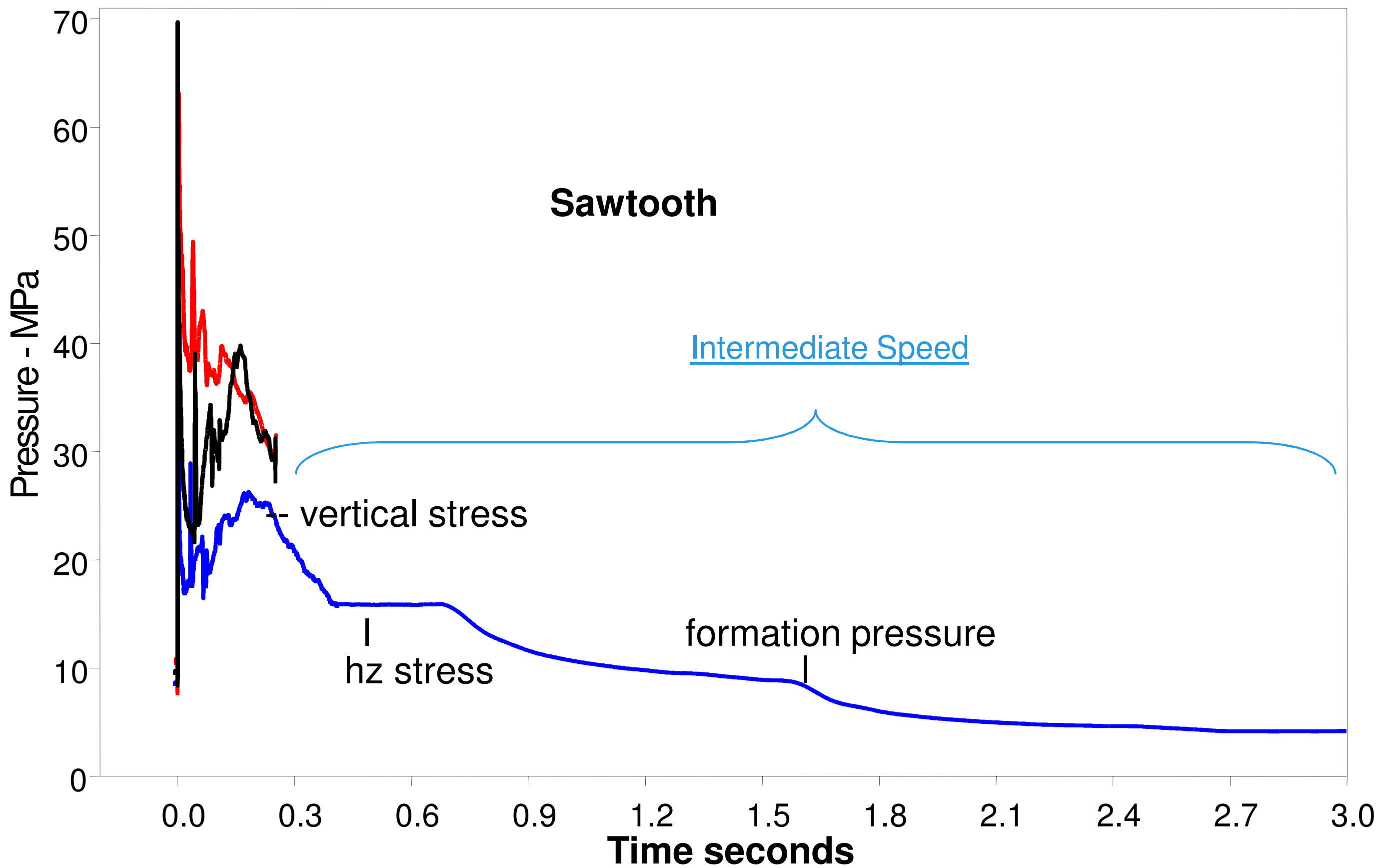



IES GLOBAL

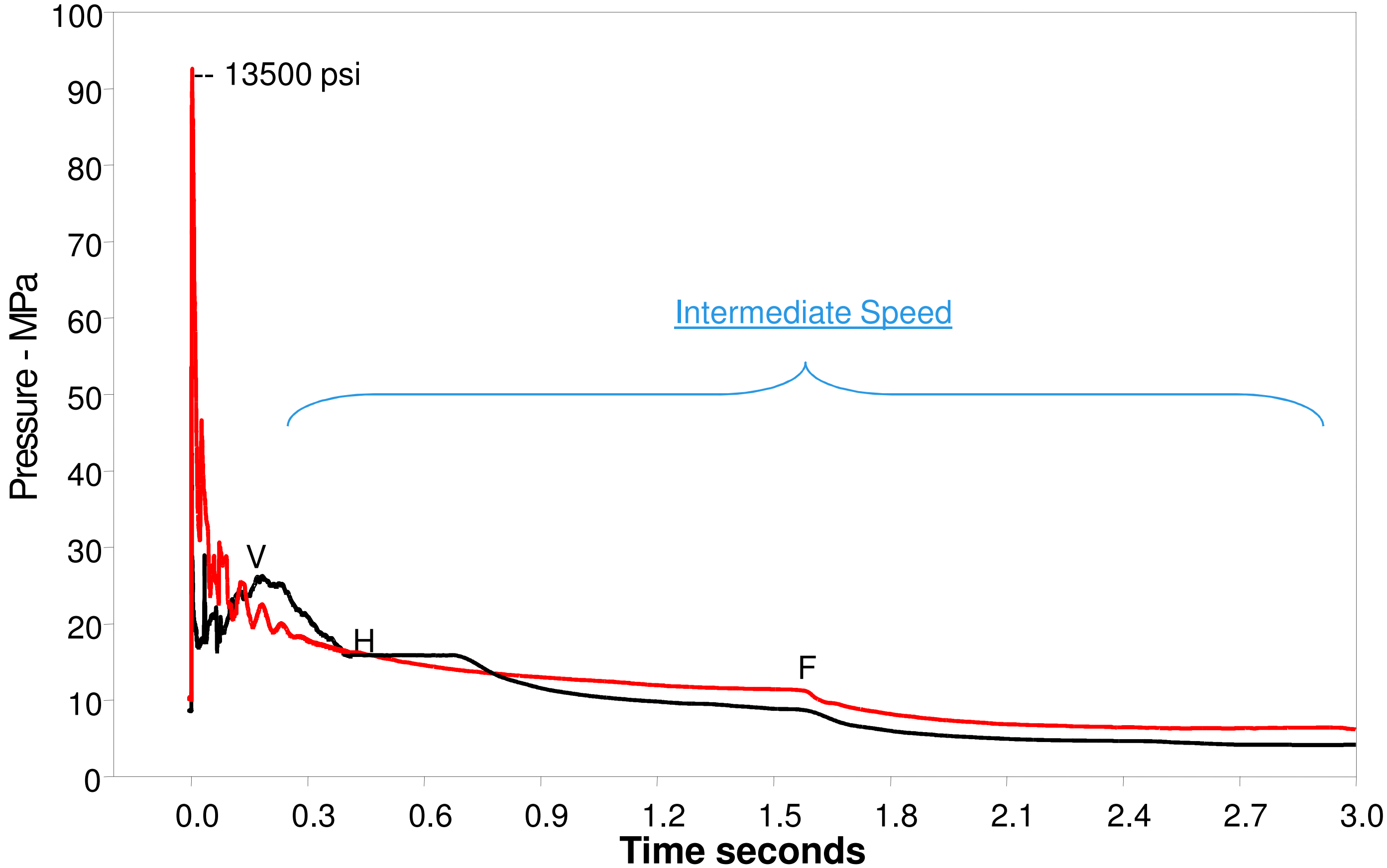
Intermediate Speed Data showing multiple echoes.



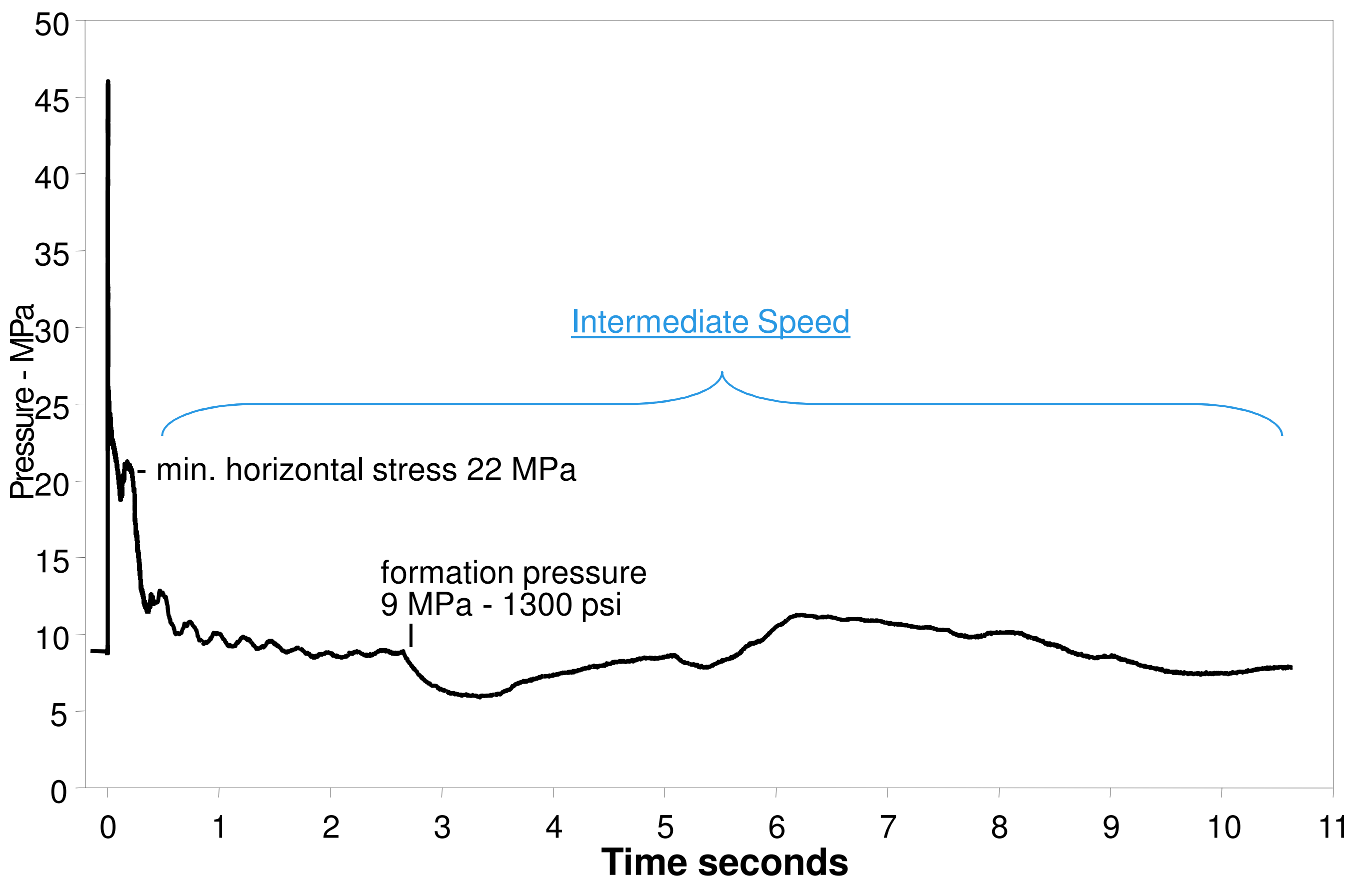
And it takes 1.6 seconds for the pressure to fall to that equal to formation pressure.



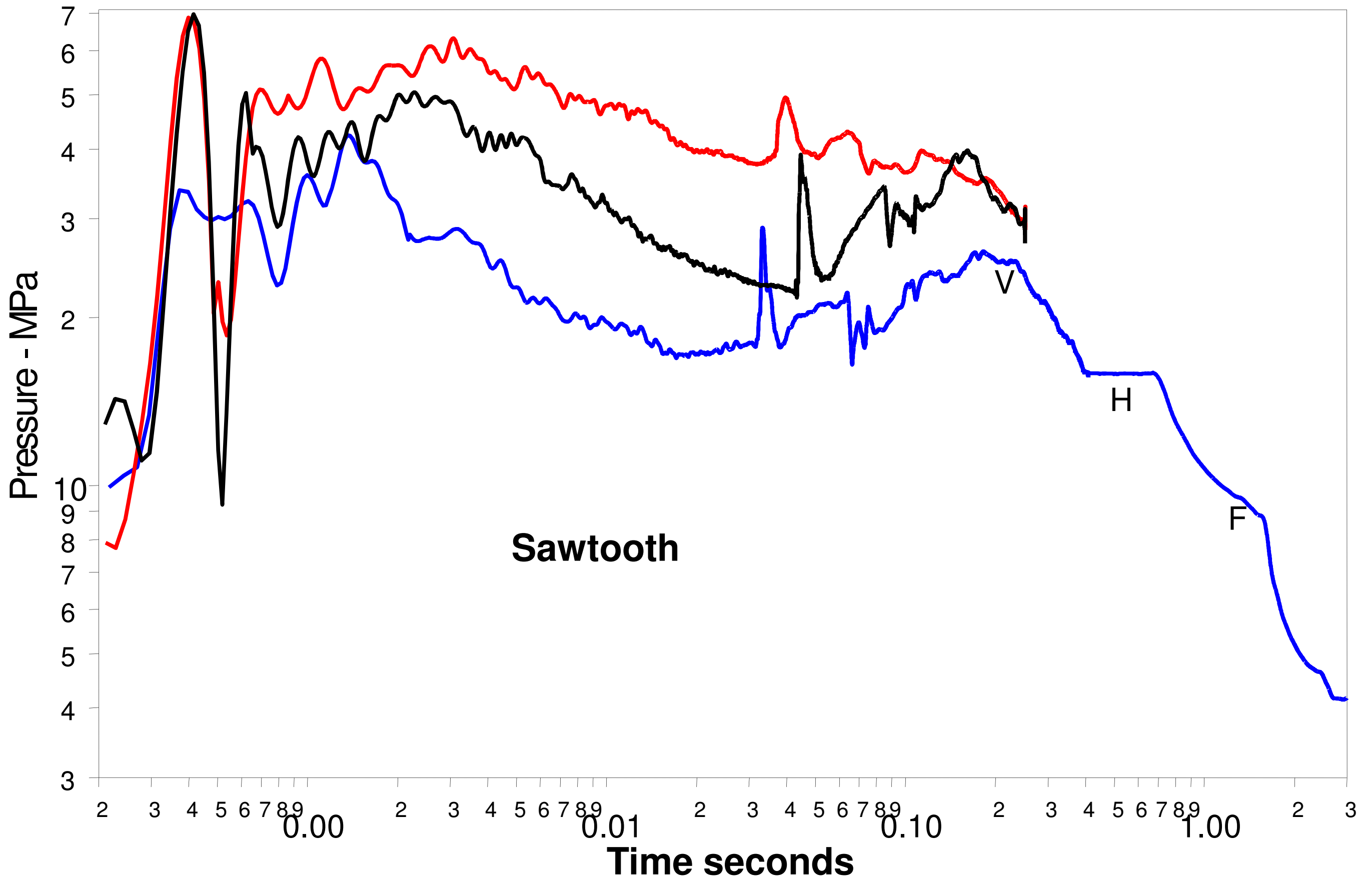
The same extended time window is needed for most shallow sands.



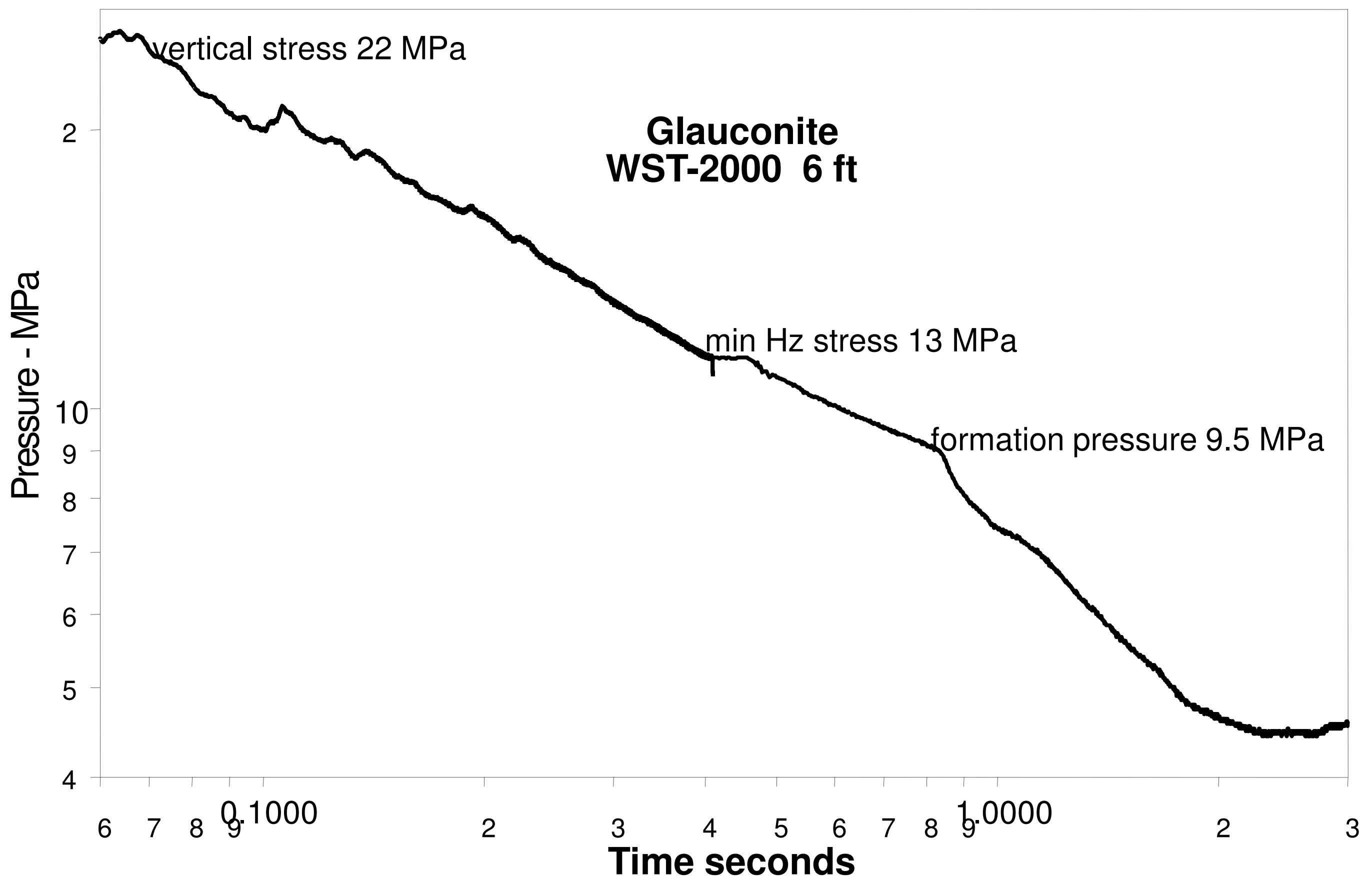
In this shot - it took >2.5 seconds to bleed down to formation pressure. Here is a good example of using Intermediate Speed.



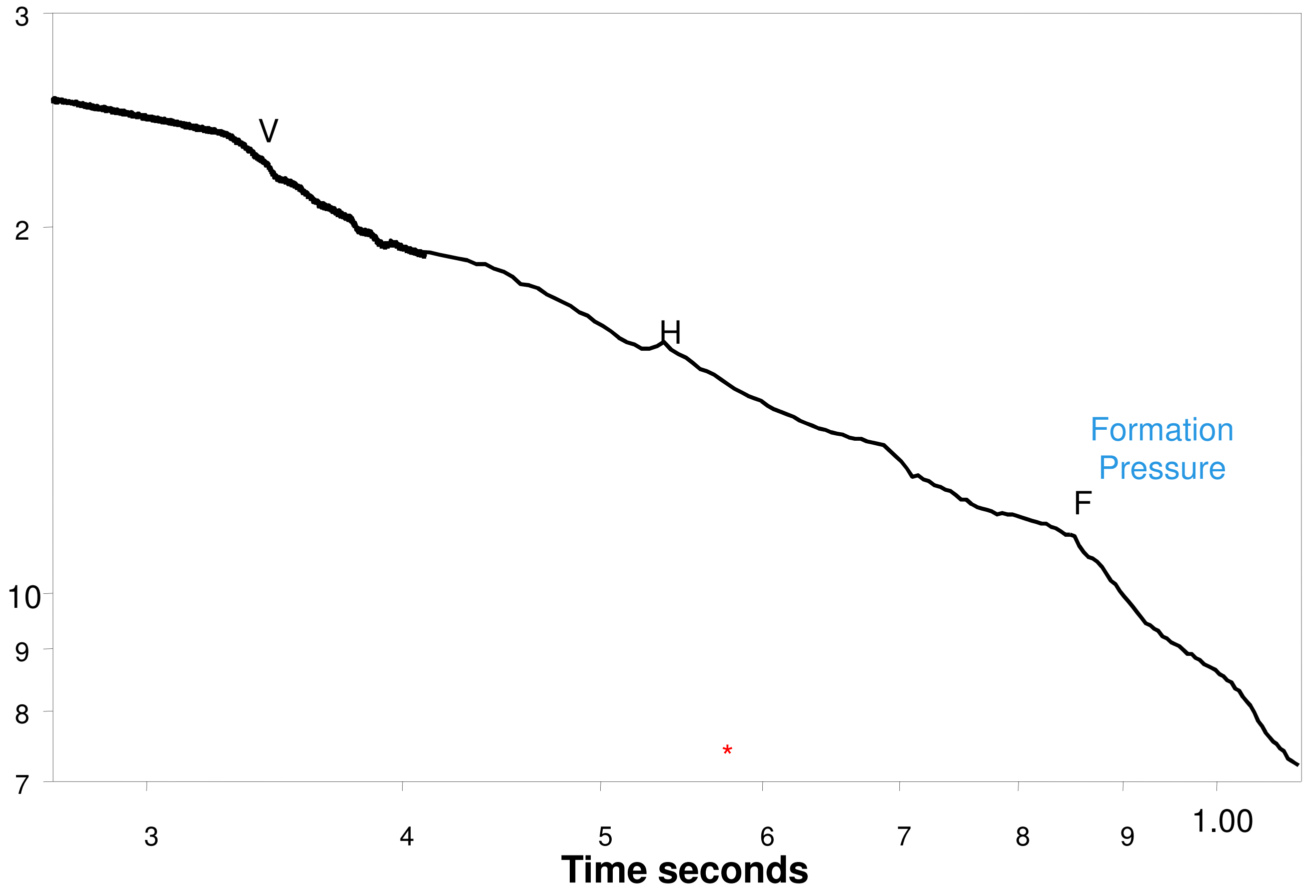
Again - this unit slope area was missed by limited time windows of the old version recorder/gauges, which did not have the Intermediate Speed option.



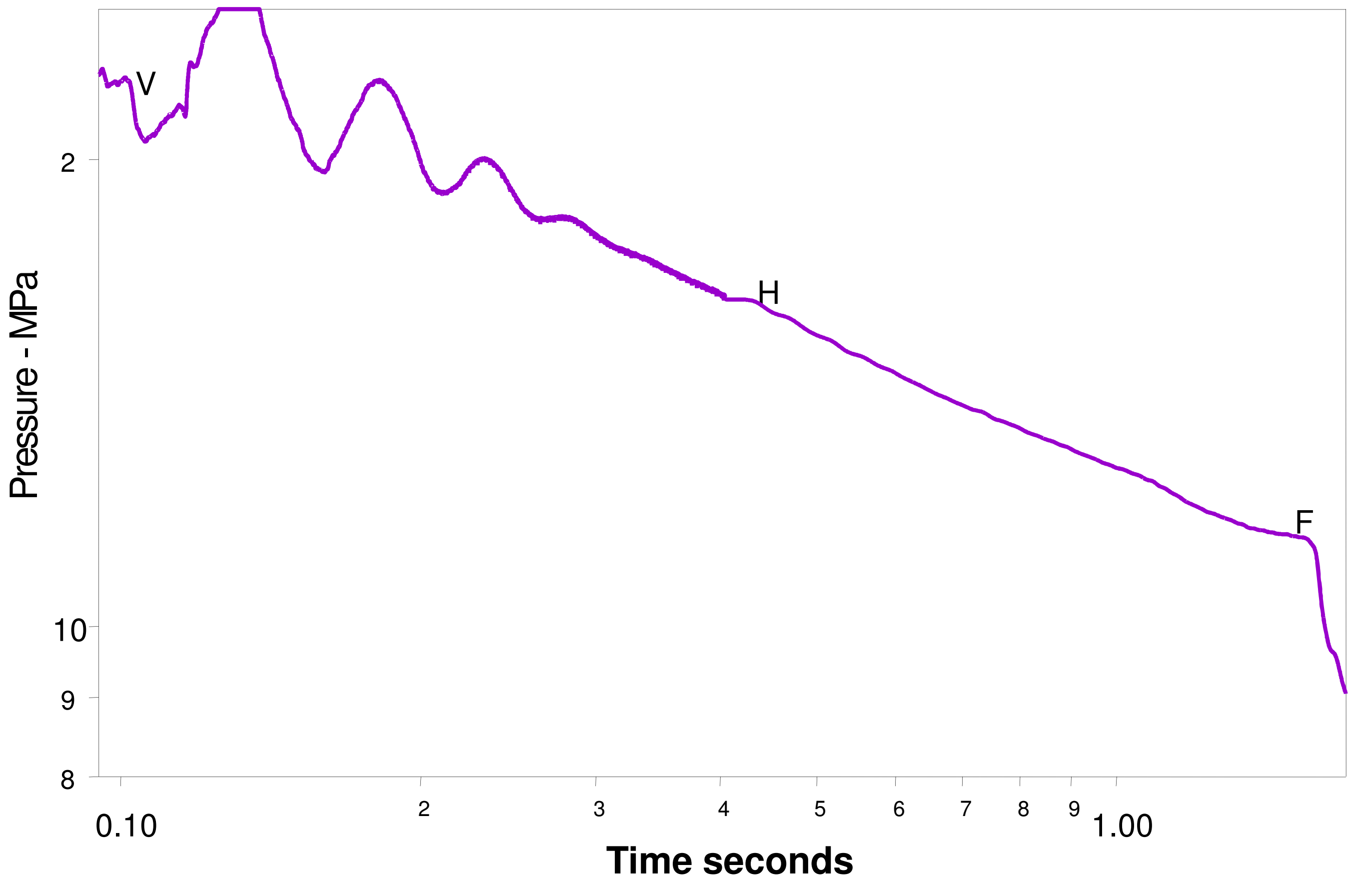
Unit slope from WST data, using Fast and Intermediate Speeds.



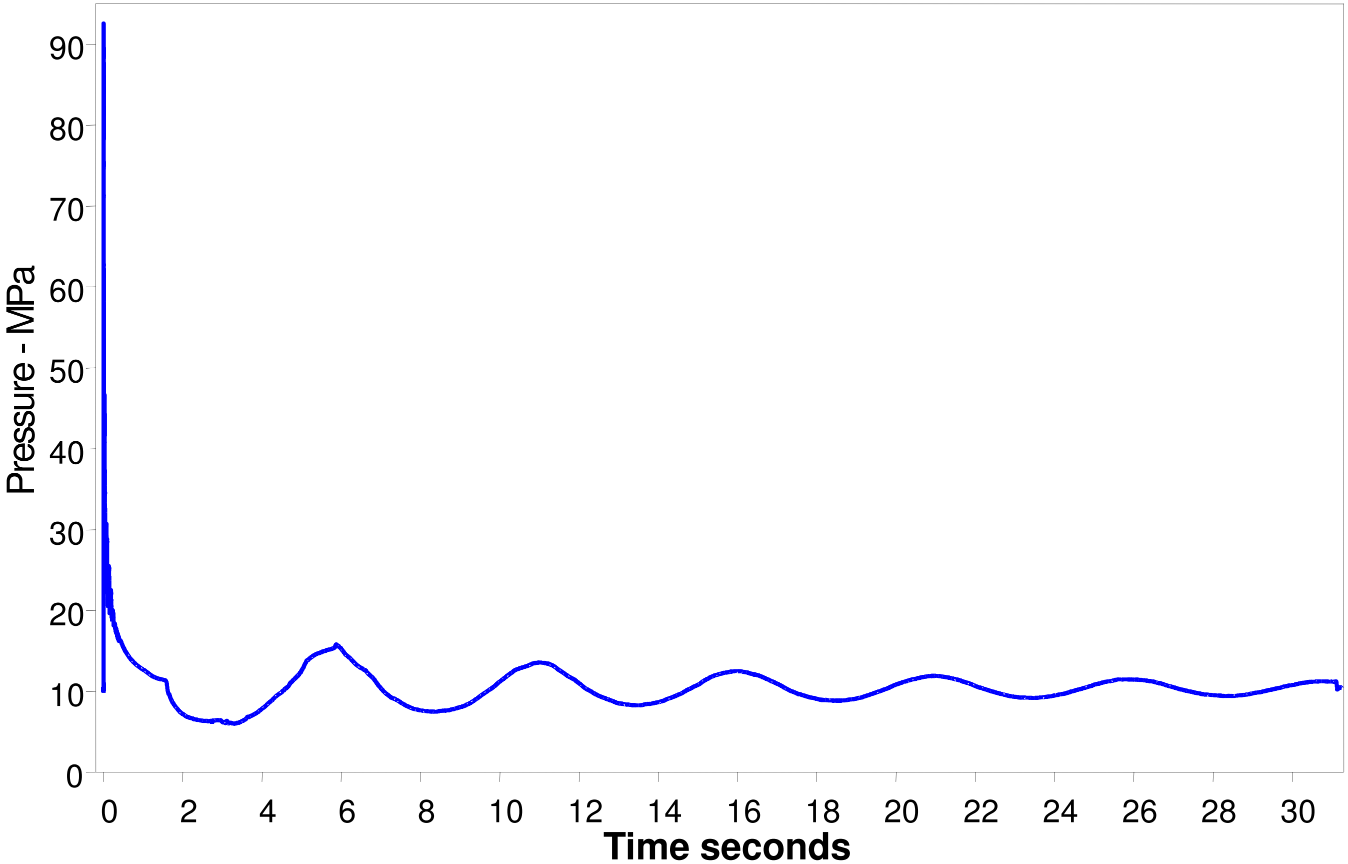
This is the unit slope from the tool that burned too slowly - note it took 9 seconds to get to formation pressure.



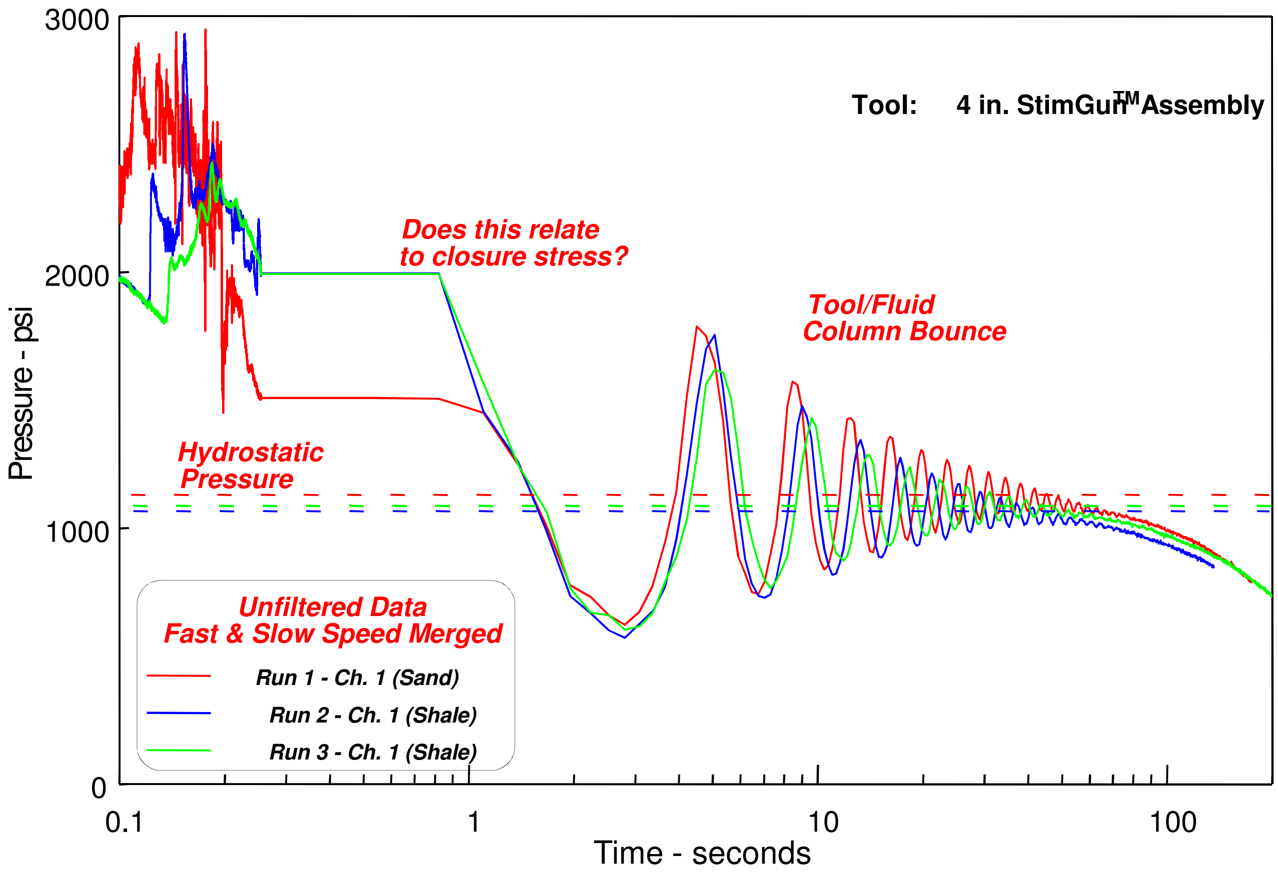
This show the effect of an echo from plug back on the slope area



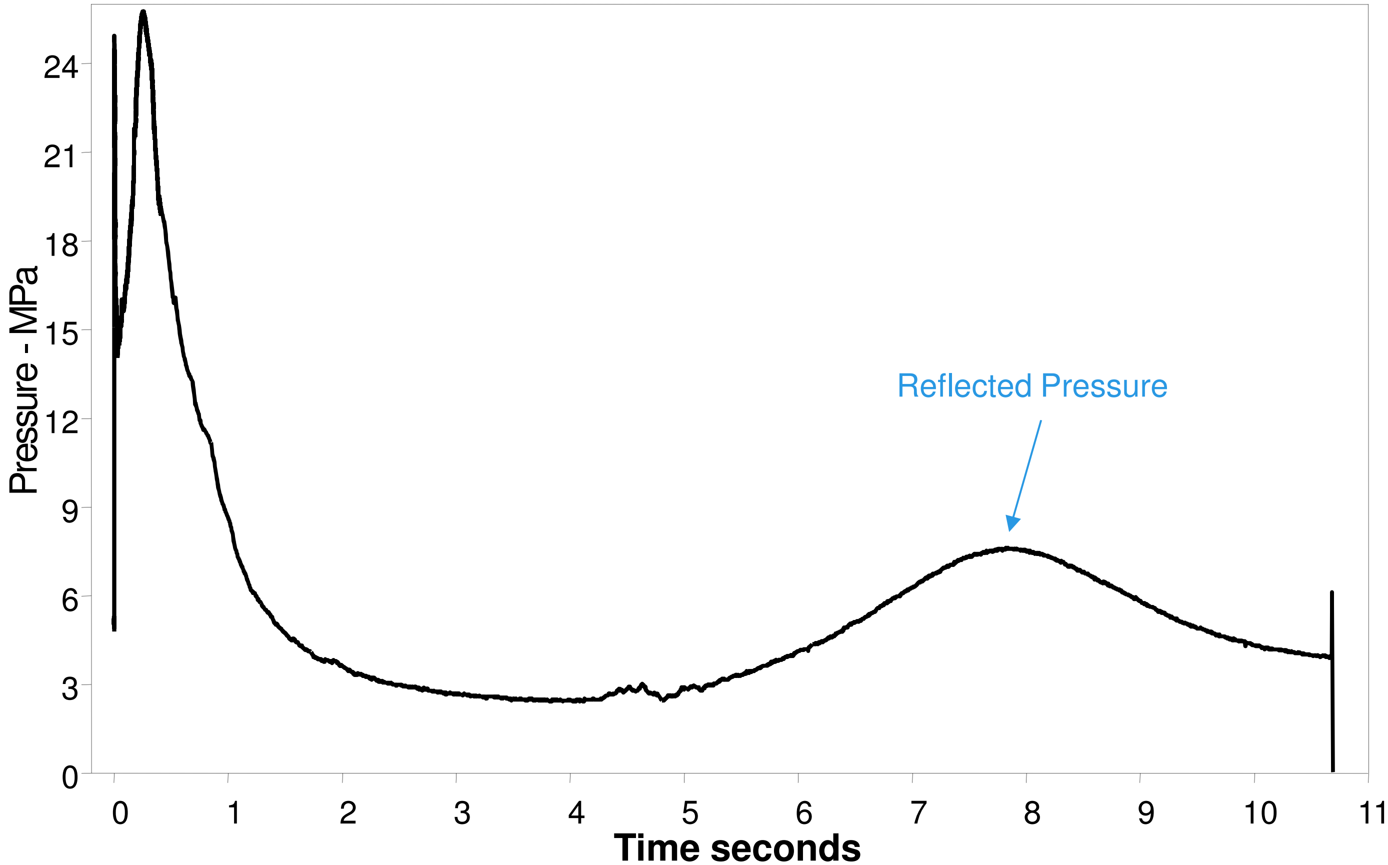
This is a 30 second "Fast Speed / Intermediate Speed" window. Fast sampling rates now allow excellent resolution for any desired window from milliseconds to hours. This will give us very good records of post stimulation well pressure and is invaluable to EOB and combination EOB Stim Gun jobs. This also reopens the possibility of getting formation information from perforating guns.



Using Intermediate Speed to show Fluid Bounce.



Intermediate Speed can show significant events *well after* the tool has stopped burning.



# IES Gauge Data

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