Southwestern Petroleum Short Course
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PLUNGER FALL VELOCITY CONSIDERATIONS

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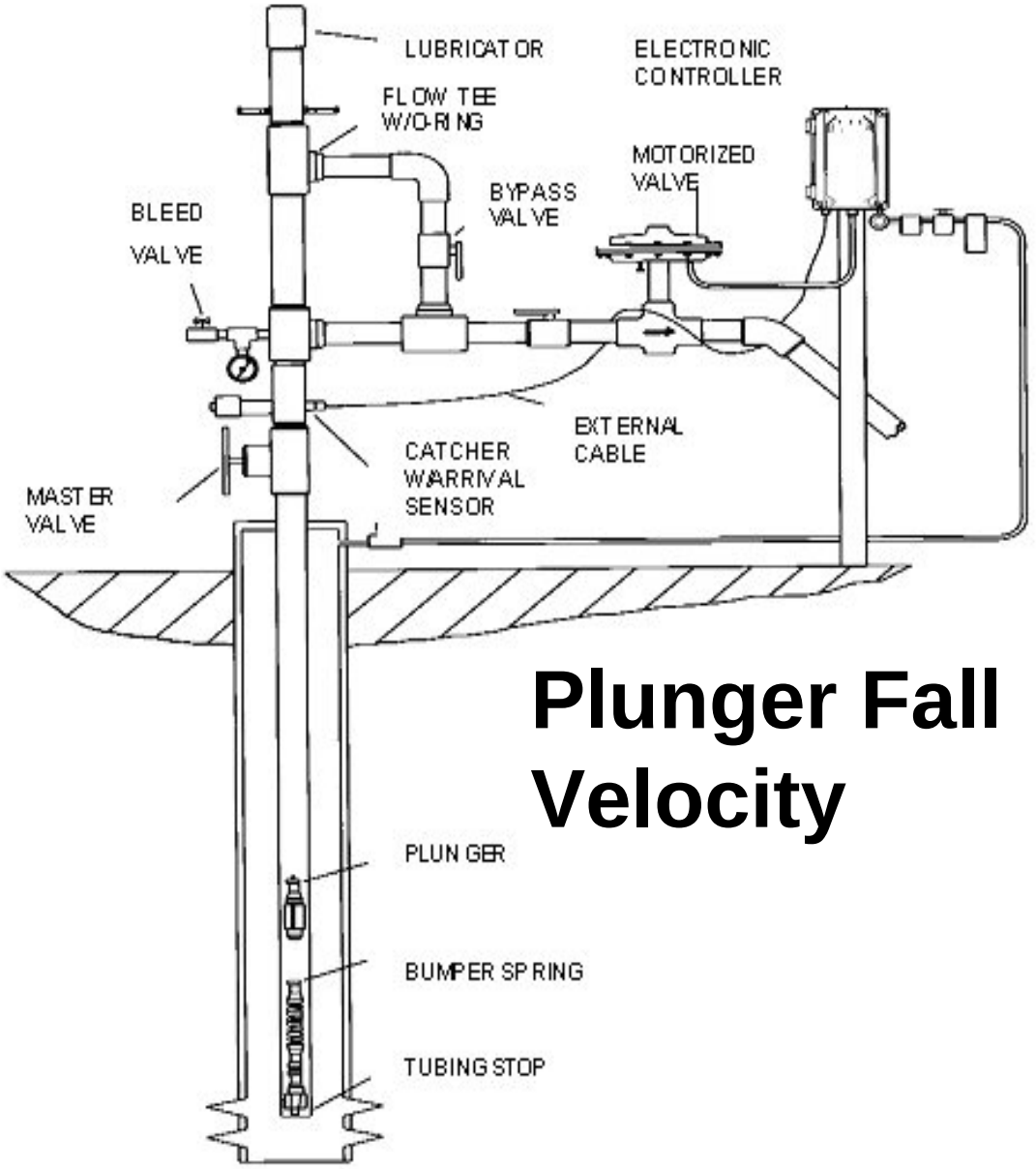
Introduction

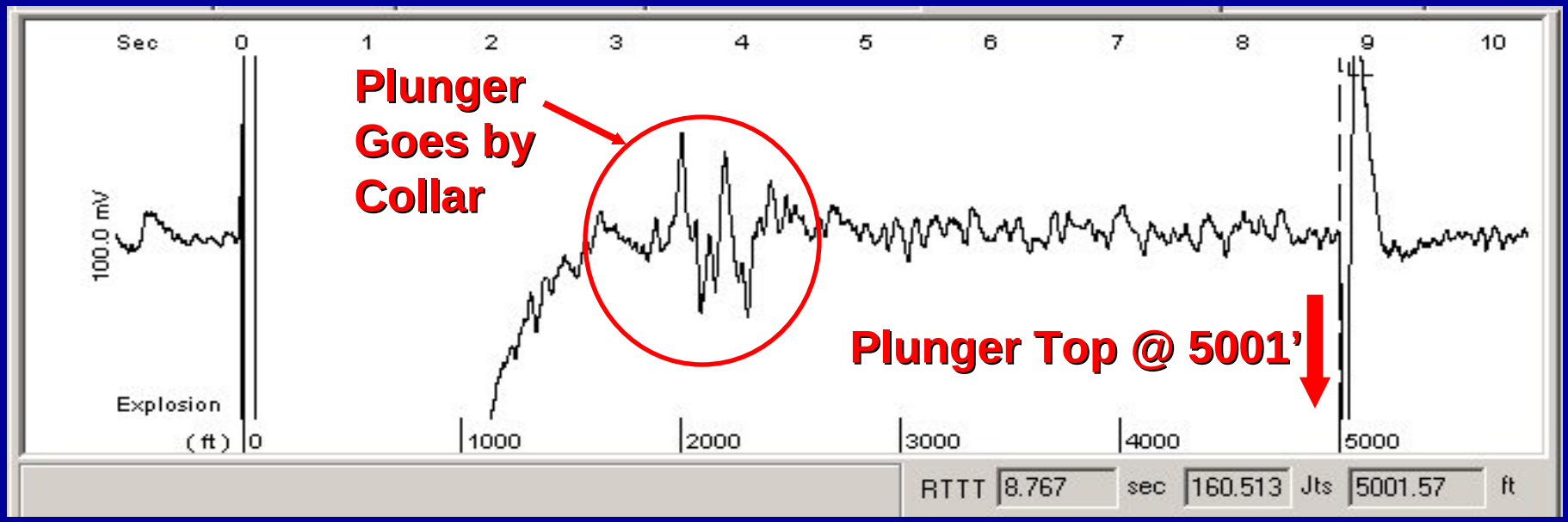


Plunger Fall Velocity

1. Data used to correlate construction features of plungers to fall velocity
2. Some features cause a plunger to fall rapidly, while other features cause a plunger to have a slower fall velocity.
3. Well conditions (gas flow rate and pressure) have significant impact on plunger fall velocity.
4. Use plunger fall velocities to determine shut-in time
   a. 1 Velocity not accurate
   b. Impacted by many parameters
5. Setting controller to the shortest shut-in time wil maximize oil and gas production

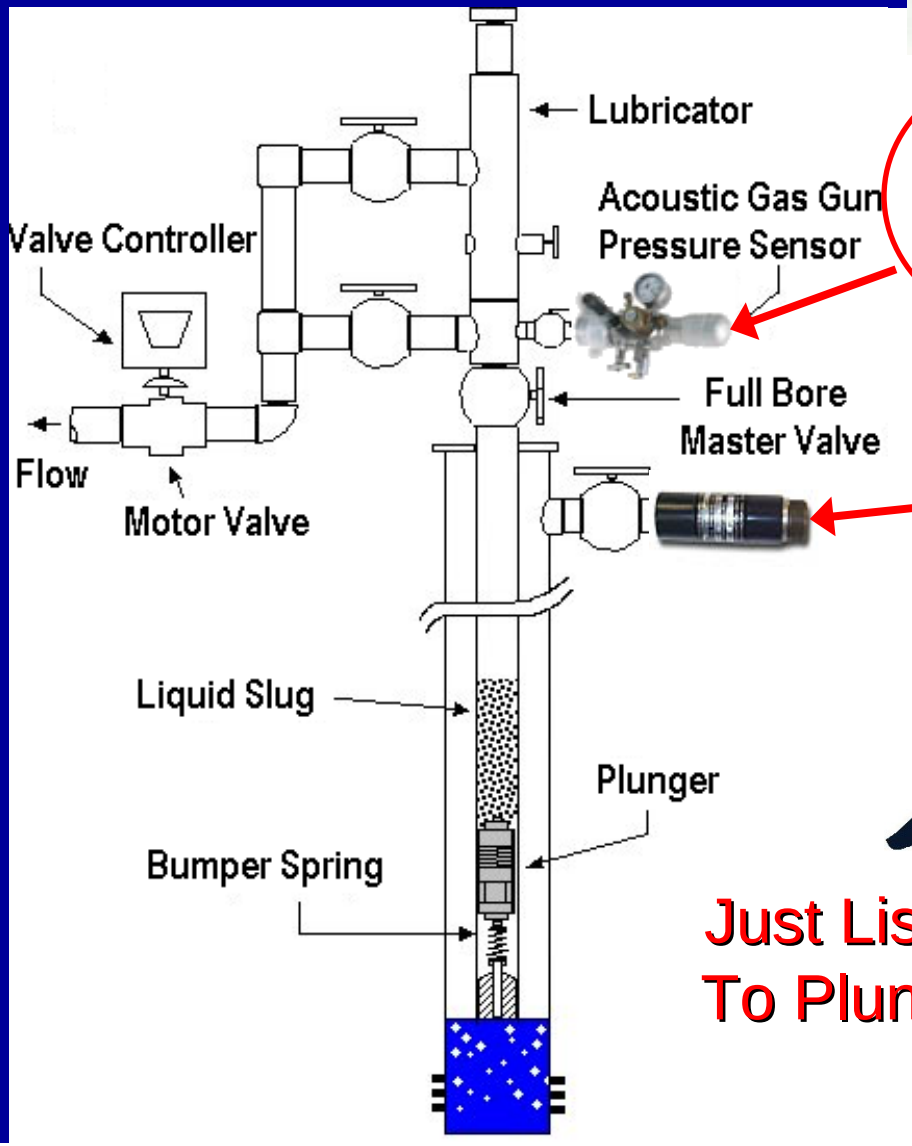
Less Accurate: Determine Fall Velocity by Shooting Fluid Level to Plunger Top

1. BECAUSE, Pressure Wave from Shot Pushes Plunger
2. Can Shoot to Top of the Plunger
3. Echo off Top of Most Plungers (Not Two Piece)
4. See If the Plunger Falls Below Liquid at Bottom



How: Listen to Plunger Signals During Shut-in

1) 3 Channel High Frequency (30Hz or greater) Data Acquisition
2) Tubing
   a) Pressure
   b) Acoustic signal
3) Casing pressure



Pressure sensor & microphone

Pressure sensor

Just Listen To Plunger

Equipment on Well

Plunger Cycle

Plunger lift operation cycle can be divided into three parts:

1) **Shut-in:** Surface valve closed, flow shut-in, plunger falls down the tubing. Goal of the operator or controller is to try to achieve Shut-in of the well for the shortest amount of time possible, But long enough for plunger to reach bottom. And long enough for the pressure to build high enough to bring the plunger back to surface.

How long does it take plunger to get to bottom during shut-in?

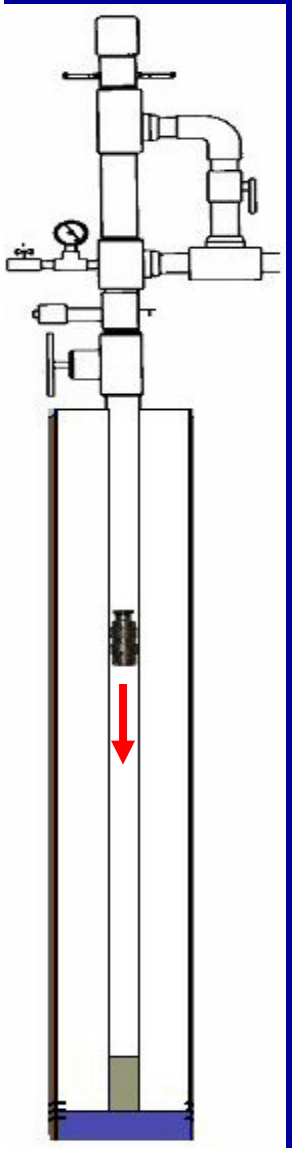
2) **Unloading:** Surface valve open and pressure stored in the casing lifts the accumulated liquid and plunger to the surface

3) **After-flow:** Surface valve open and well continues to flow after plunger reaches the surface. Plunger held at surface by differential pressure from flow of gas up the tubing. Well is producing gas. Most liquid produced from the formation tends to fall back, accumulating at the bottom of the tubing. The goal of the operator or controller is to Flow the well only until the well begins to load with liquids.

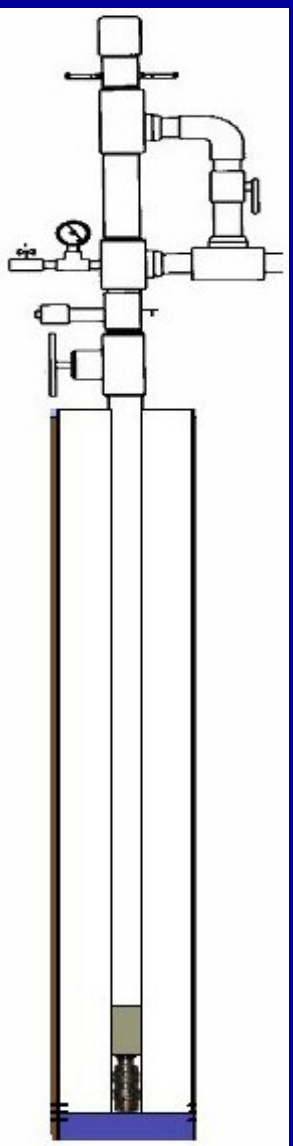
Thanks: Dan Phillips and Scott Listiak

Conventional Plunger Cycle

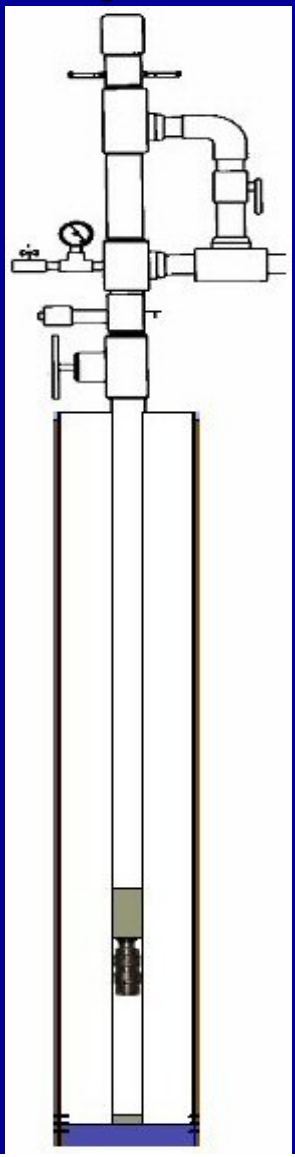
[A] Valve Closes, Shut-in Begins and Pressure Starts Increasing



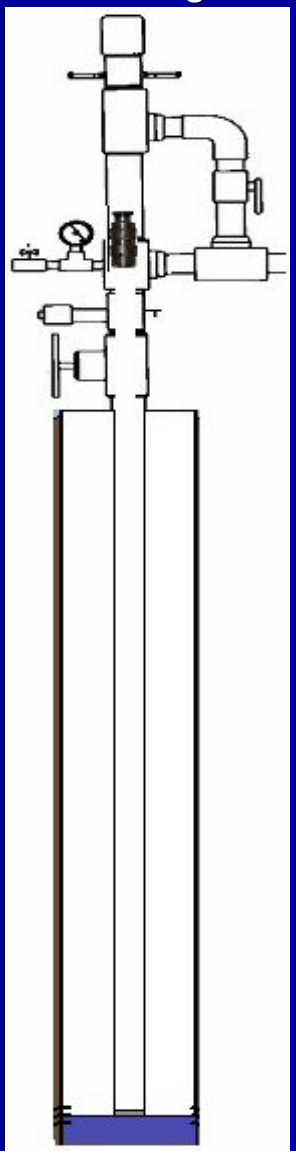
[2] Shut-in Valve Closed, w/ Pressure Increasing



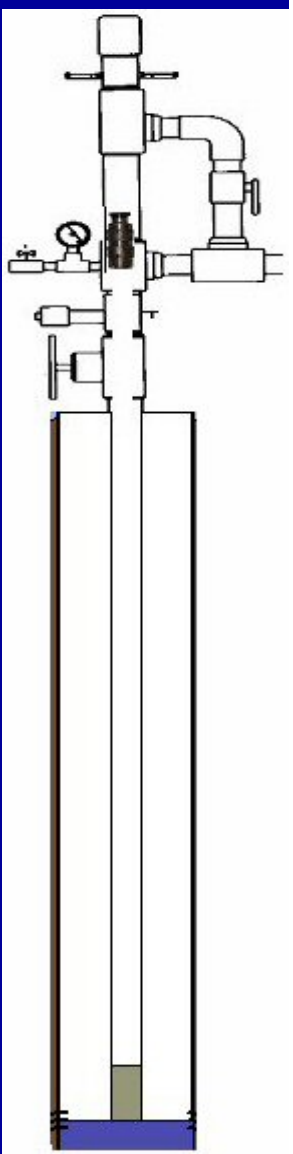
[B] Valve Opens, Unloading Begins



[4] Plunger Arrives, Tubing Pressure Spike Maximum, After-flow begins



[C] Valve Closes, Cycle Repeats



ycle 90 Min.

Plunger Cycle Events	Elapsed Time Minutes	Tubing Pressure psi (g)	Casing Pressure psi (g)
[A] Valve Closes (Shut In Begins)	2.267	137.0	192.7
[1] Plunger Hits Liquid	47.467	235.5	273.1
[2] Plunger On Bottom	59.283	235.5	290.7
[B] Valve Opens (Unloading Begins)	69.267	272.8	306.0
[3] Liquid Arrives	79.550	126.3	235.1
[4] Plunger Arrives	80.717	206.2	231.5
[C] Valve Closes (Shut In Begins)	91.333	126.2	171.4

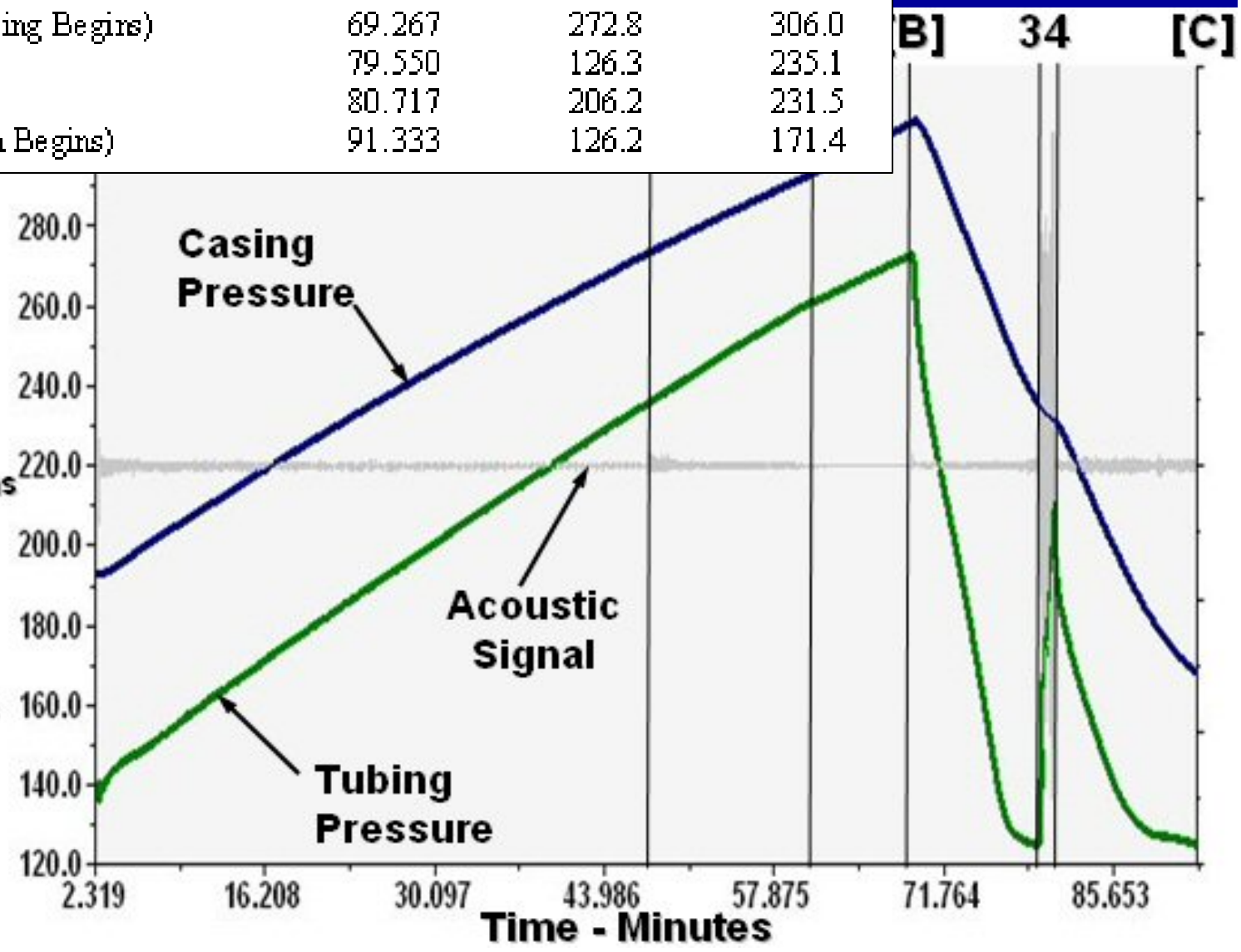
Increasing

1. Plunger hits Liquid
2. Plunger on Bottom

[B] Valve Opens, Unloading Begins

3. Liquid Arrives, Tubing Pressure at Minimum
4. Plunger Arrives, After-flow begins Tubing Pressure Maximum Spike

[C] Valve Closes, Cycle Repeats

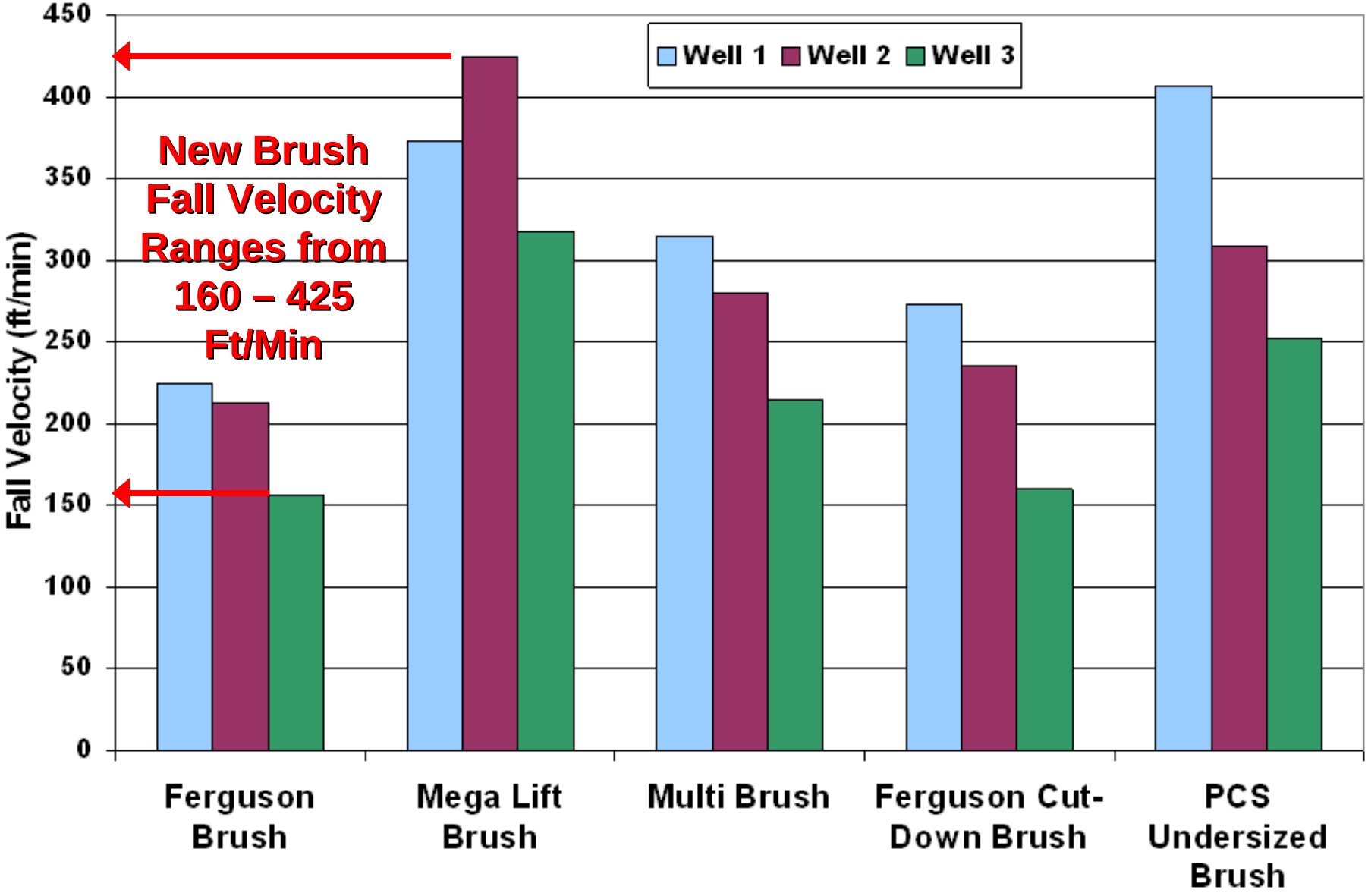


What do we know?

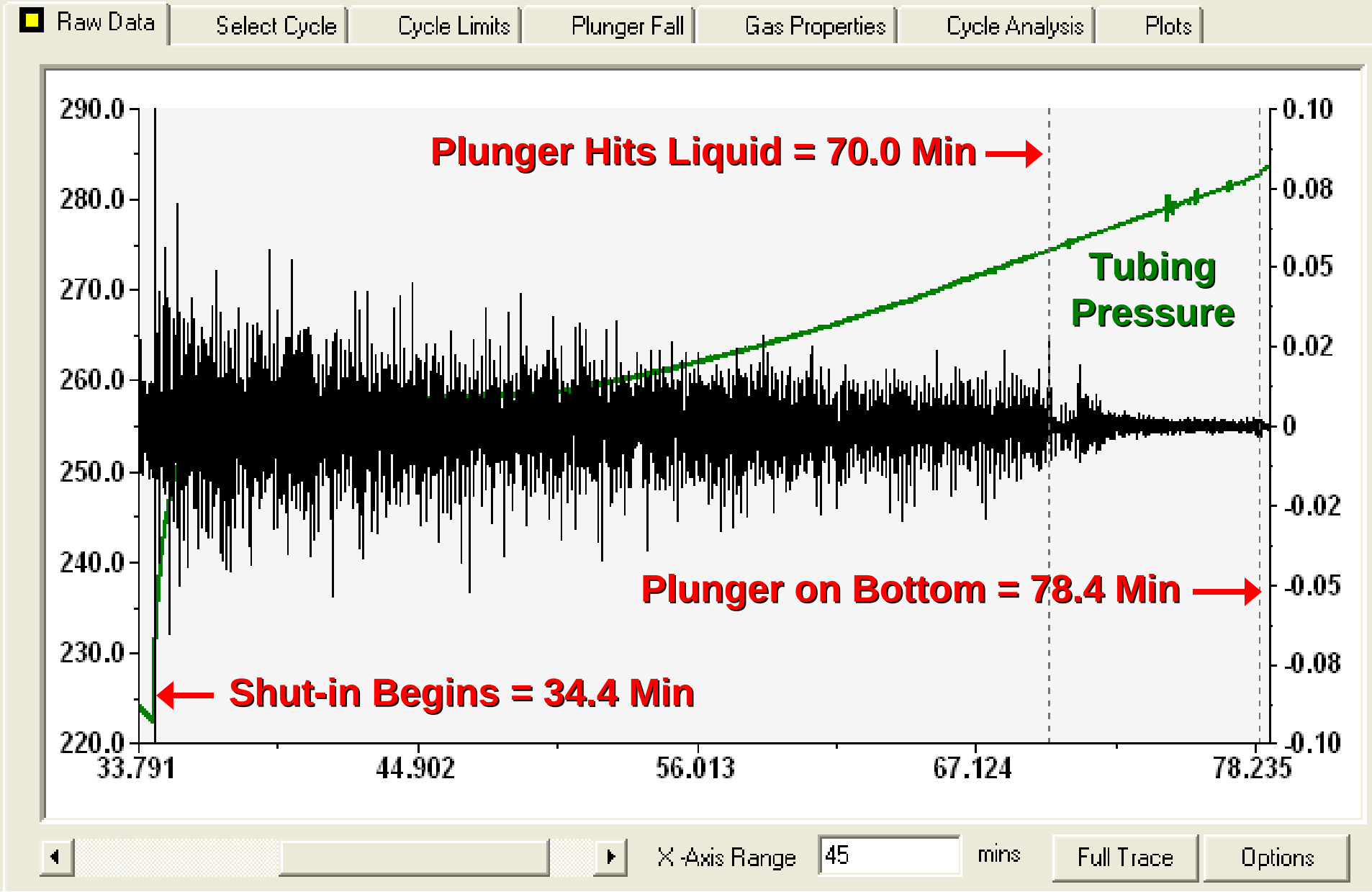
Rowlan, O.L., McCoy, J.N., and Podio, A.L, "Determining How Different Plunger Manufacture Features Affect Plunger Fall Velocity" SPE 80891, presentation at the SPE Production and Operations Symposium held in OKC, OK, U.S.A., 23–25 March 2003

1. Measured plunger fall velocities for grooved, ultra seal, dual pad and brush type are much less than ***1000 ft/min***.
2. Two-Piece & Bypass Plungers are fast! (Generally > 1000 ft/min)
3. Worn 2 3/8 brush type plungers (408-477 ft/min). New brush plungers fall slow. Fall Velocity changes w/ wear.
4. 2 3/8" Dual pad type plungers (259-265 ft/min).
5. Increasing the diameter from 2.375" to 2.875" resulted in the pad type plunger falling slower (>200 ft/min).
6. Improving the seal on a dual pad plunger (Ultra Seal) results in even slower fall velocities (159 ft/min).
7. Solid Plungers are "fast" 300-400 Ft/Min.
8. In the same well new plungers fall slower when compared to the same type of older/worn plunger.

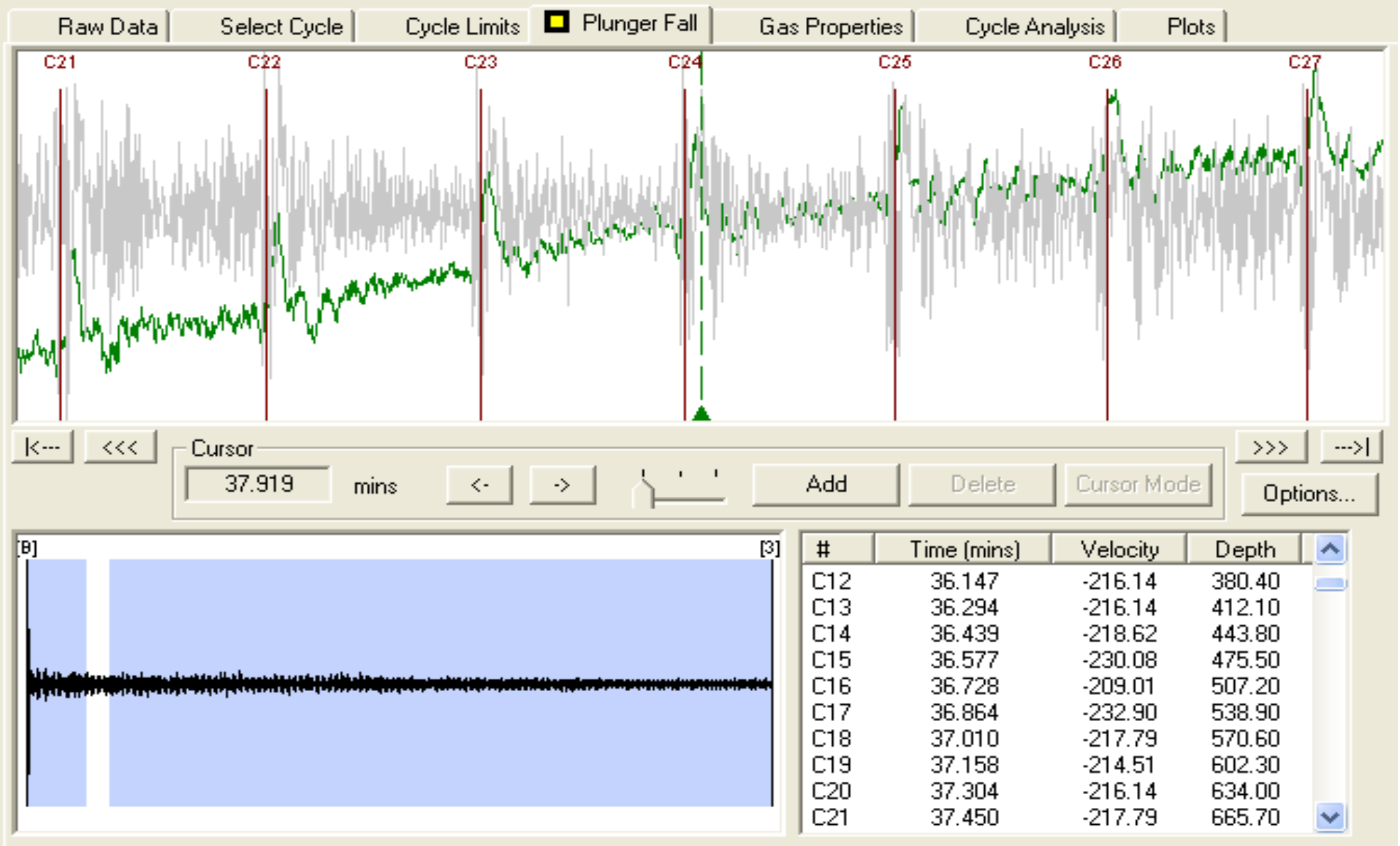
Manufacturer Designed Brush Stiffness and Seal Impact Fall Velocity



Acoustic Signal During Shut-in Period



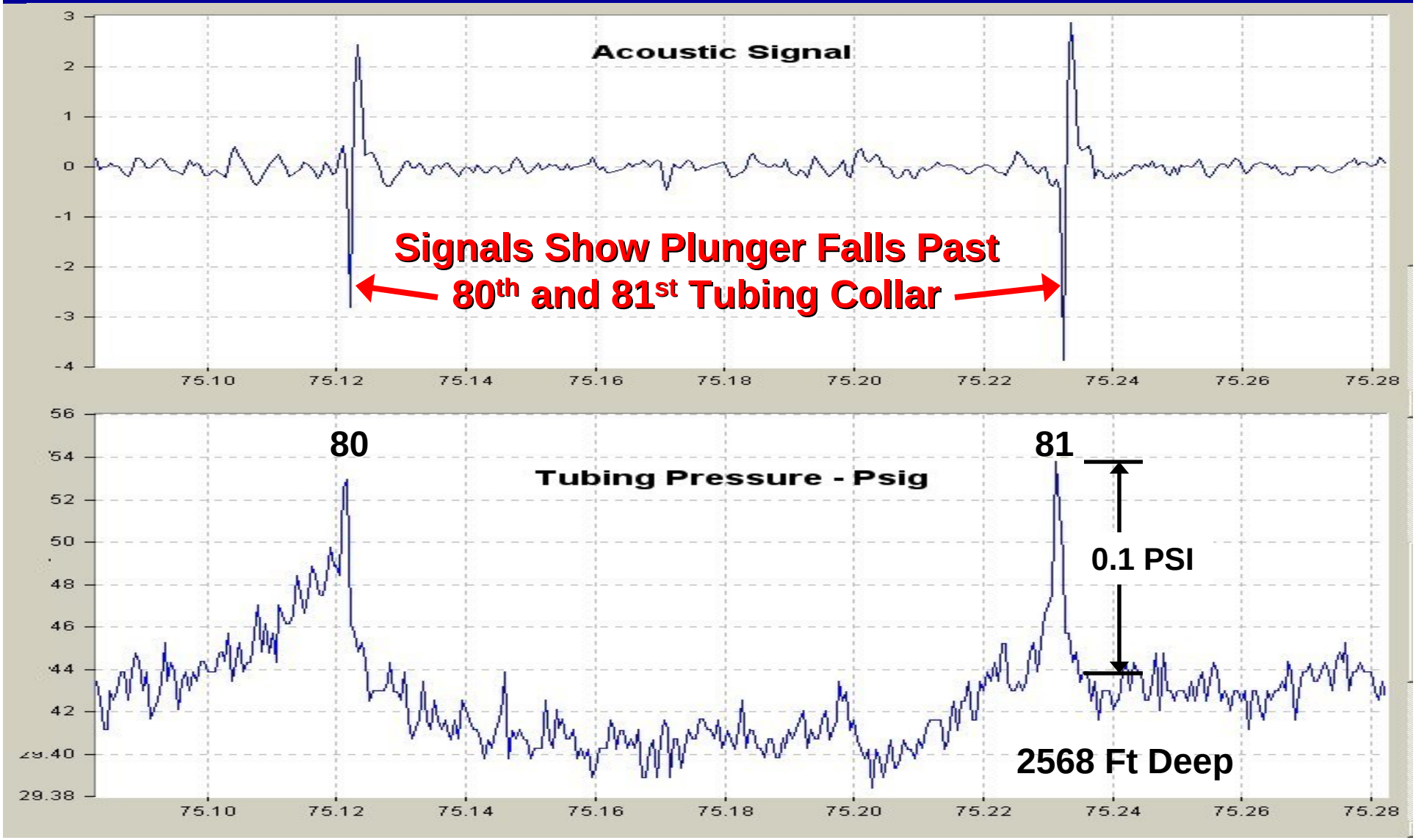
Count Signals from Plunger Falling thru Collar: Acoustic/Pressure Signal During Shut-in (1 minute)



#	Time (mins)	Velocity	Depth
C12	36.147	-216.14	380.40
C13	36.294	-216.14	412.10
C14	36.439	-218.62	443.80
C15	36.577	-230.08	475.50
C16	36.728	-209.01	507.20
C17	36.864	-232.90	538.90
C18	37.010	-217.79	570.60
C19	37.158	-214.51	602.30
C20	37.304	-216.14	634.00
C21	37.450	-217.79	665.70

1800 Data Points in the Acoustic Signal During 1 Minute

Passive Monitoring Requires
High Resolution Pressure & Acoustic Data



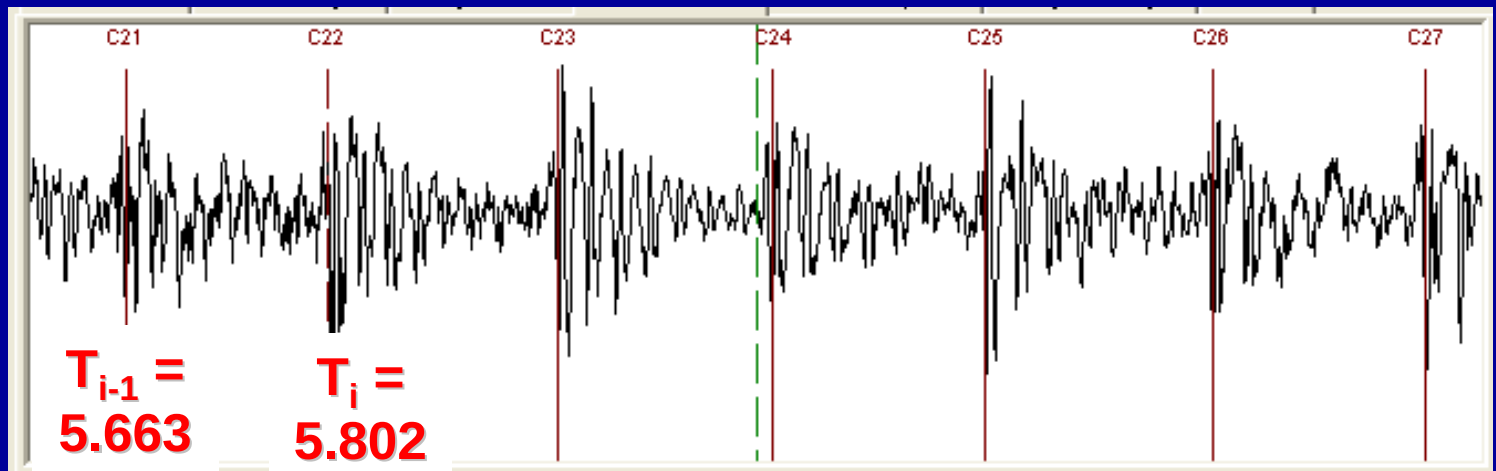
Velocity: Plunger Fall Speed Between Two Consecutive Counted Collars

D_{i-1} = 676.2

D_i = 708.4

Plunger Velocity @ Joint 22 equals the change in depth divided by the change in elapsed time.

Velocity = $(D_i - D_{i-1}) / (T_i - T_{i-1})$ = -230.9 ft/min

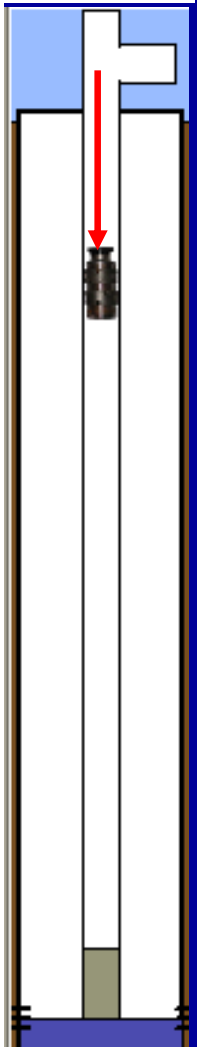


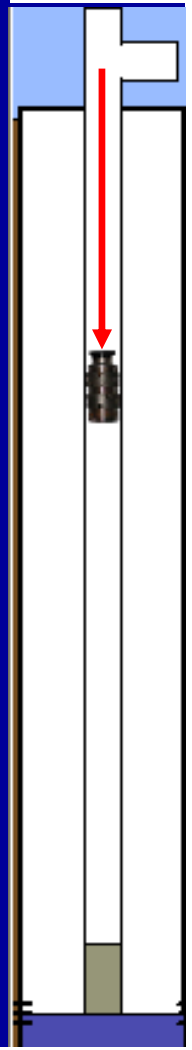
T_{i-1} = 5.663

T_i = 5.802

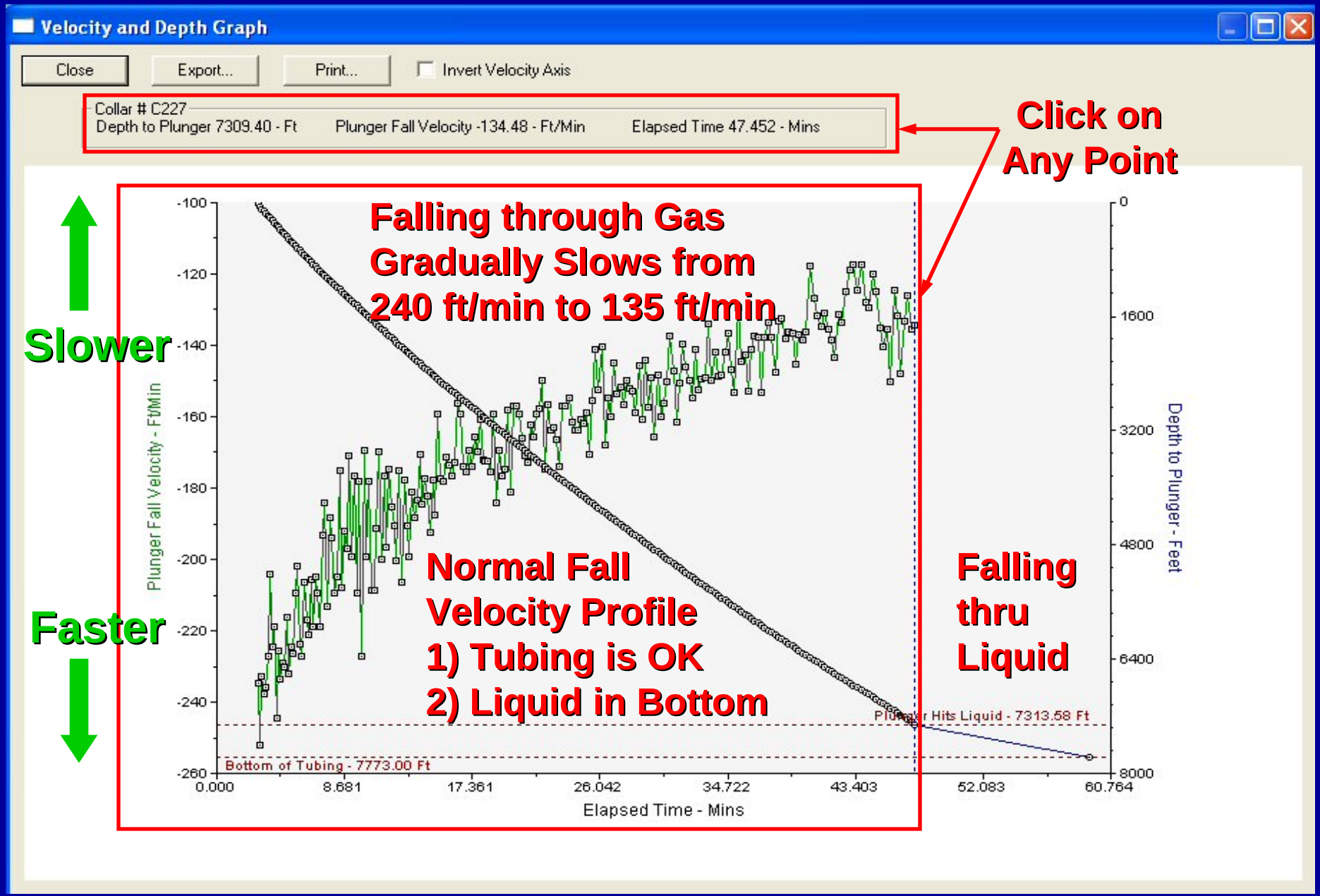
#	Time (mins)	Velocity	Depth
C19	5.359	-209.24	611.80
C20	5.519	-201.95	644.00
C21	5.663	-223.78	676.20
C22	5.802	-230.92	708.40
C23	5.961	-203.37	740.60
C24	6.109	-217.08	772.80
C25	6.254	-221.22	805.00
C26	6.411	-205.53	937.20
C27			369.40
C28			901.60

Each Joint

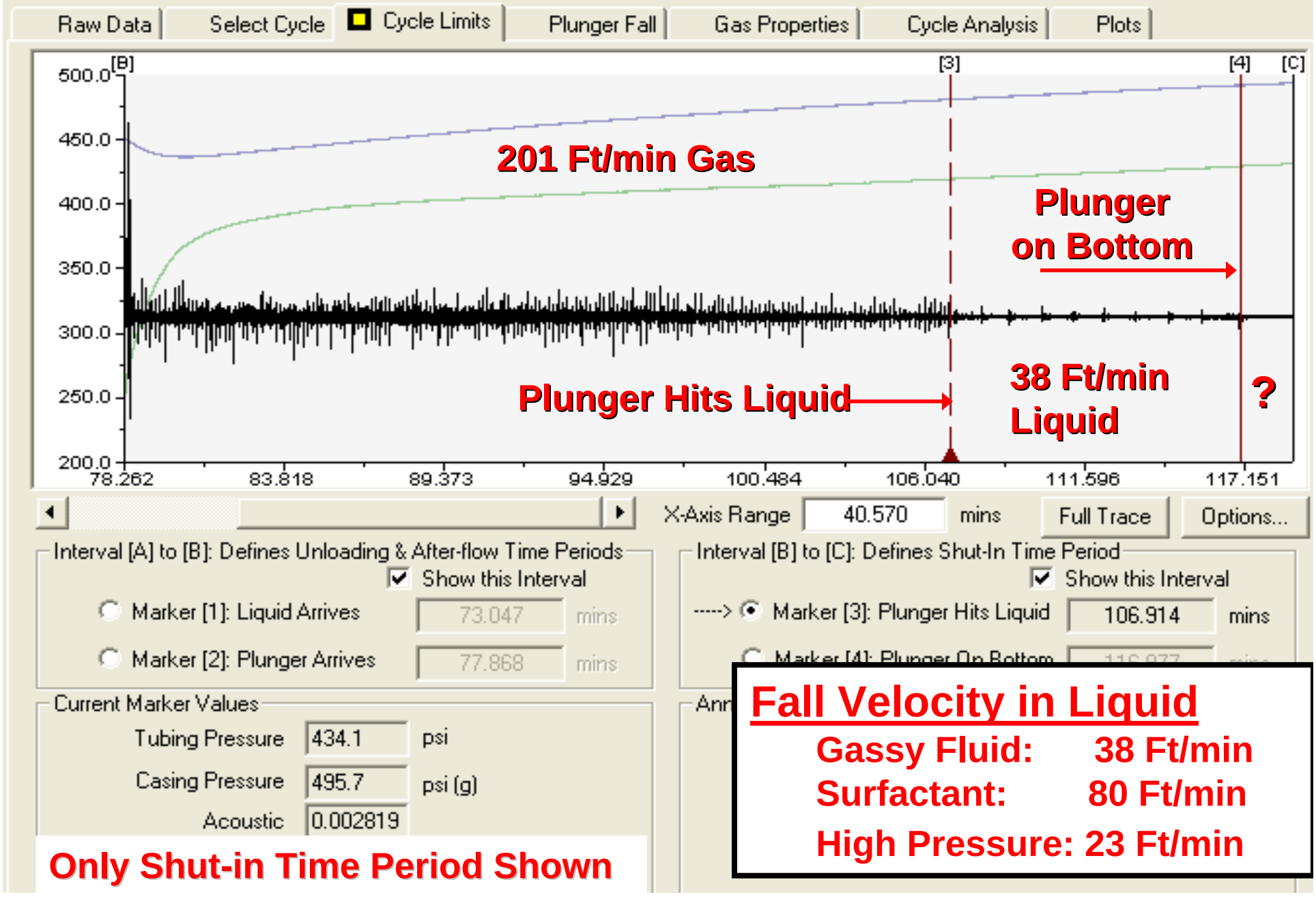




Normal Fall Velocity [During Shut-in]



Take Guess Work Out of Setting Shut-in Time

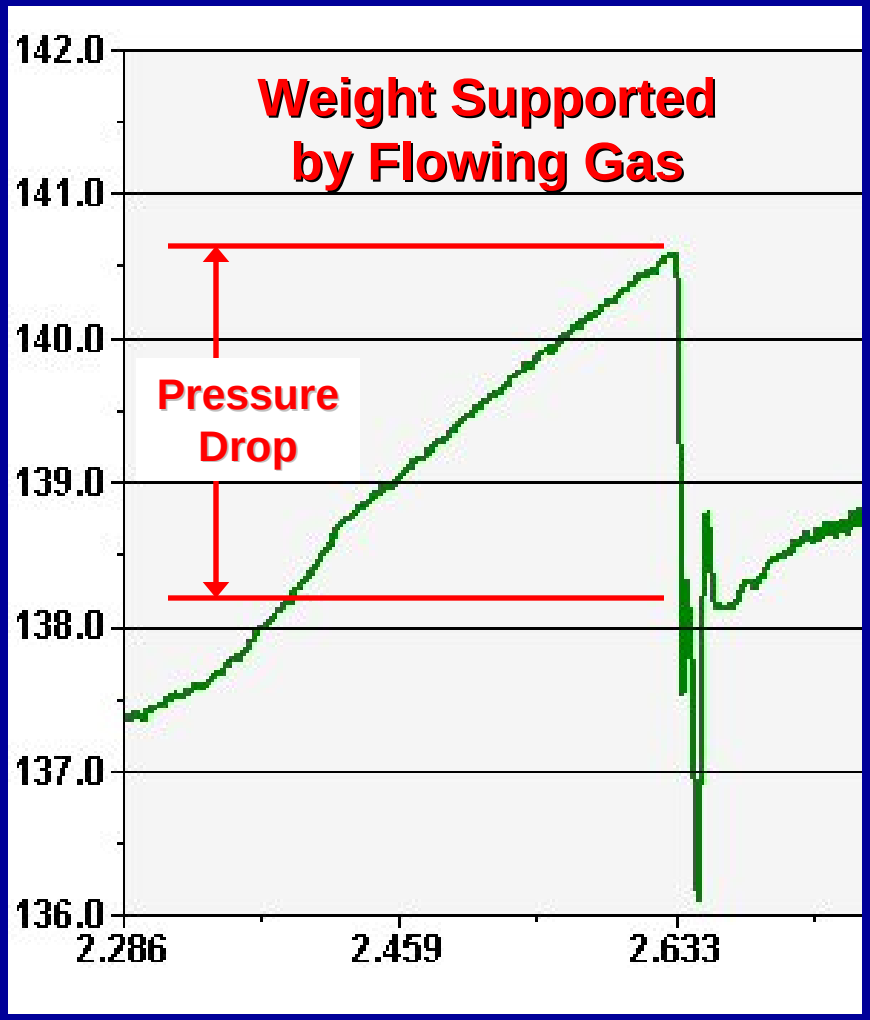


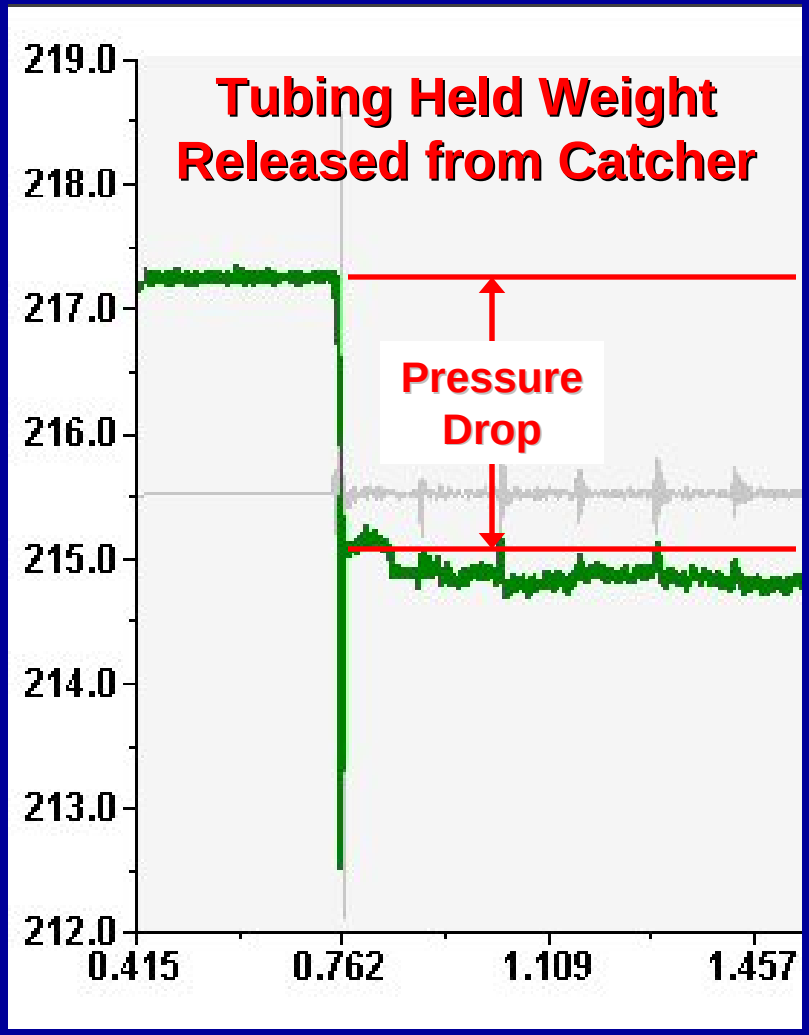
Only Shut-in Time Period Shown

Fall Velocity in Liquid

Gassy Fluid: 38 Ft/min
Surfactant: 80 Ft/min
High Pressure: 23 Ft/min

When Shut-in Begins the Tubing Pressure Instantly Drops when Plunger Starts to Fall

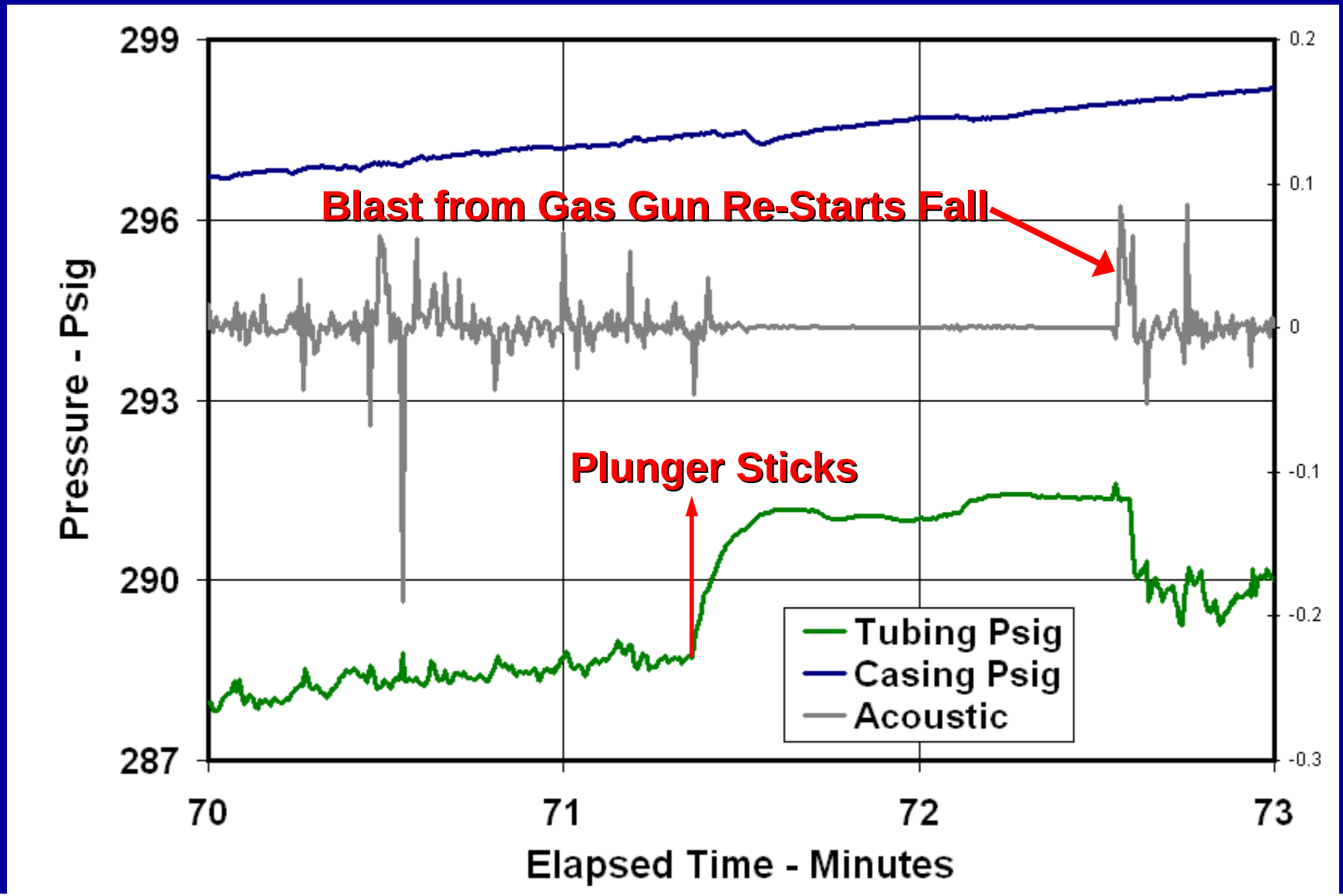




Pressure Drop = Weight / Area

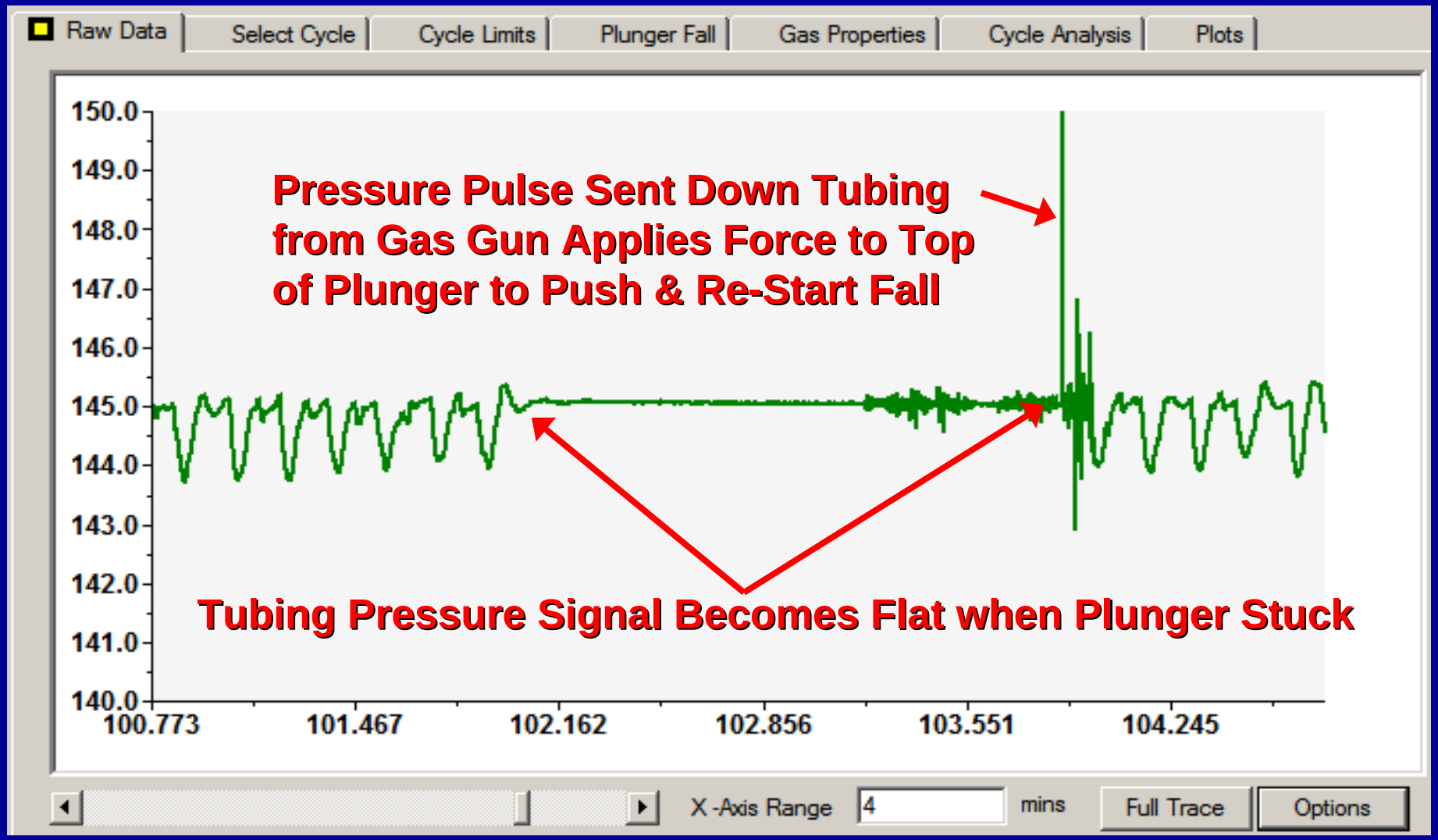
Plunger weight (8 lbs) / Area of 2-3/8”

Identify When Plunger Becomes Stuck Pressure Increases By ~3 psi

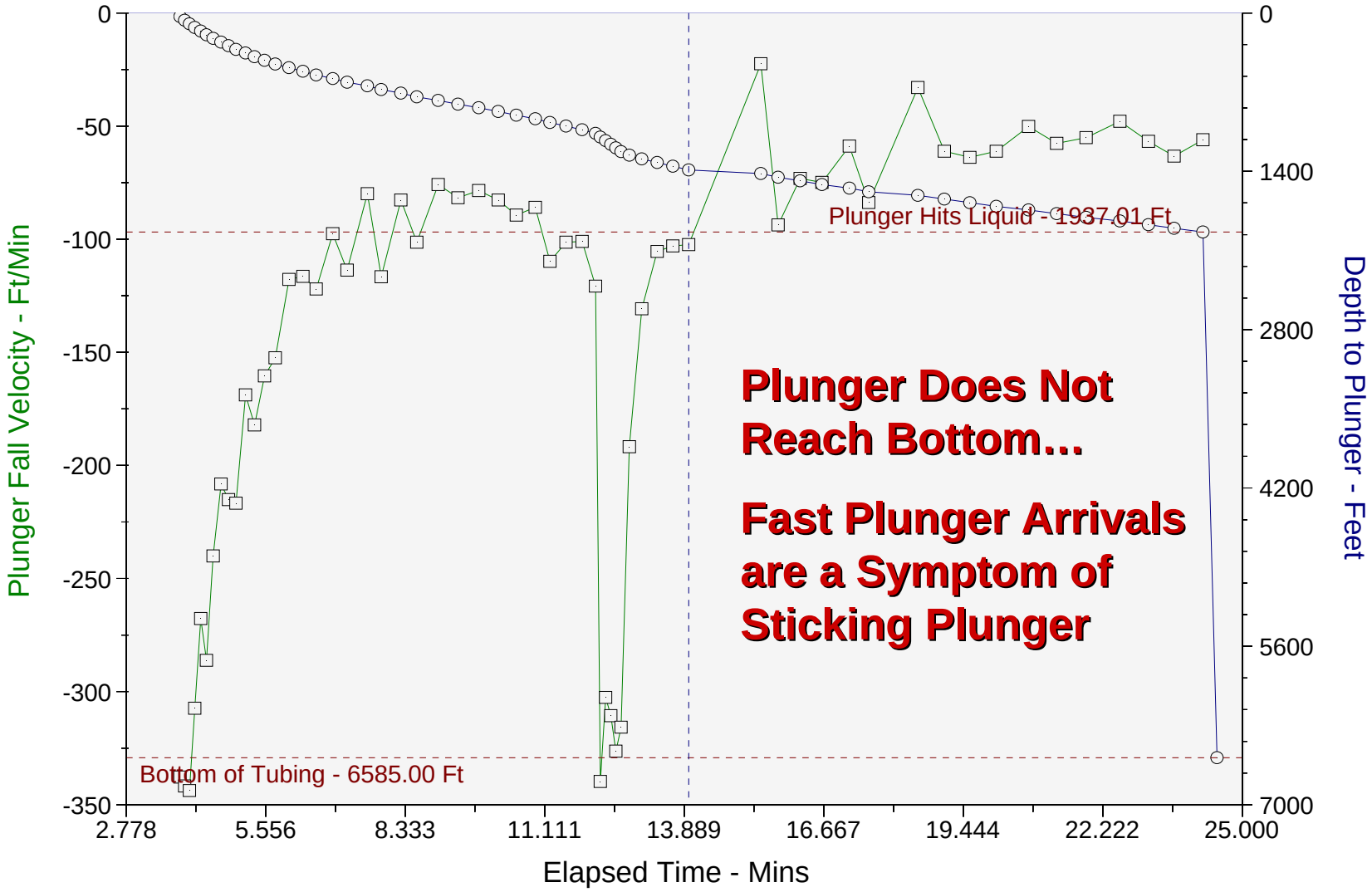


Paraffin Stops Plunger Fall

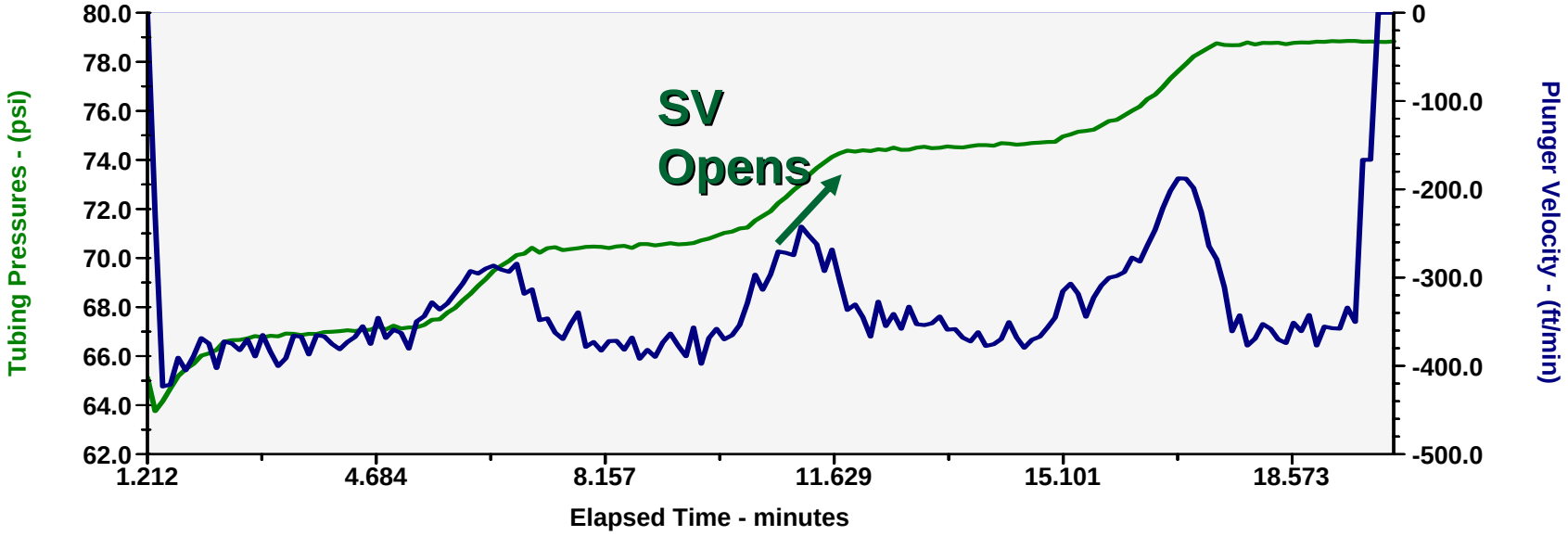
9 Shots Used to Push Plunger to Bottom

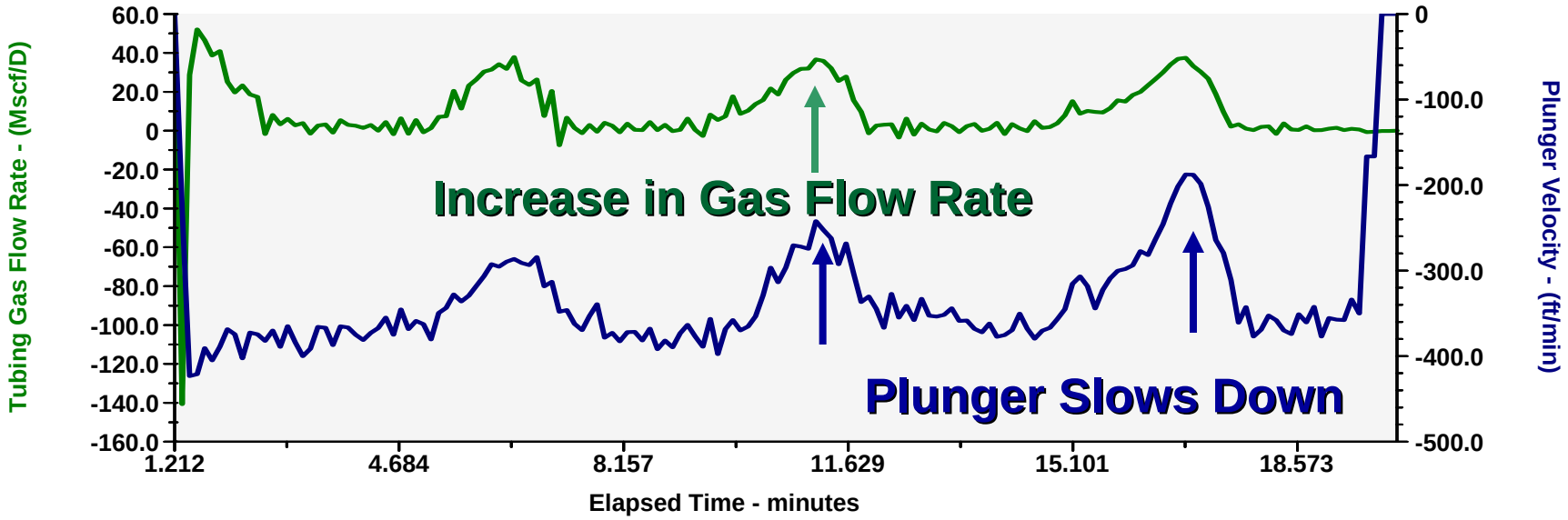


Chemical Treatment Down Tubing Tends to Slow/Stops Plunger Fall

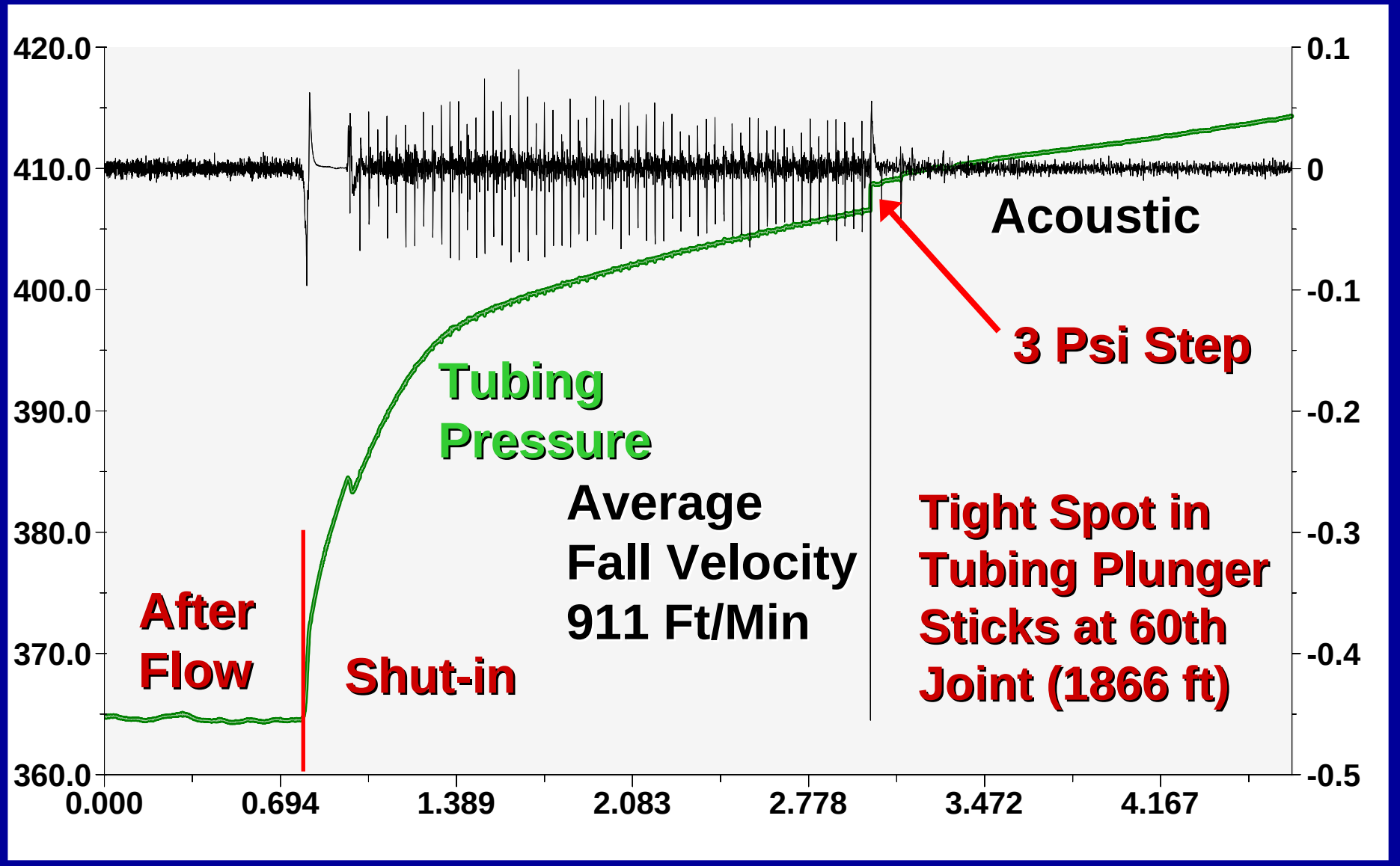


Increase in Gas Flow Rate Past Plunger Results in Plunger Slowing Down…

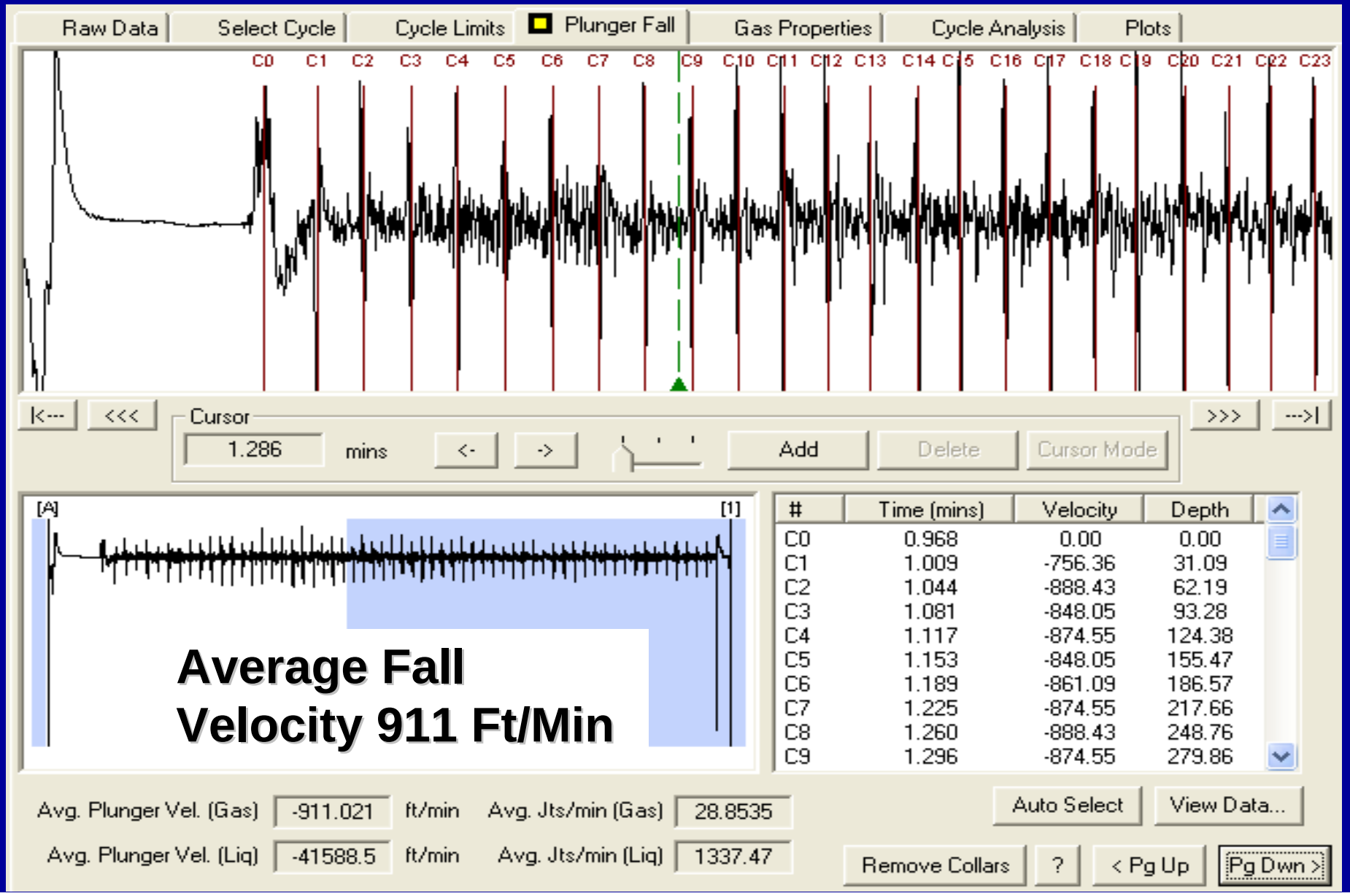




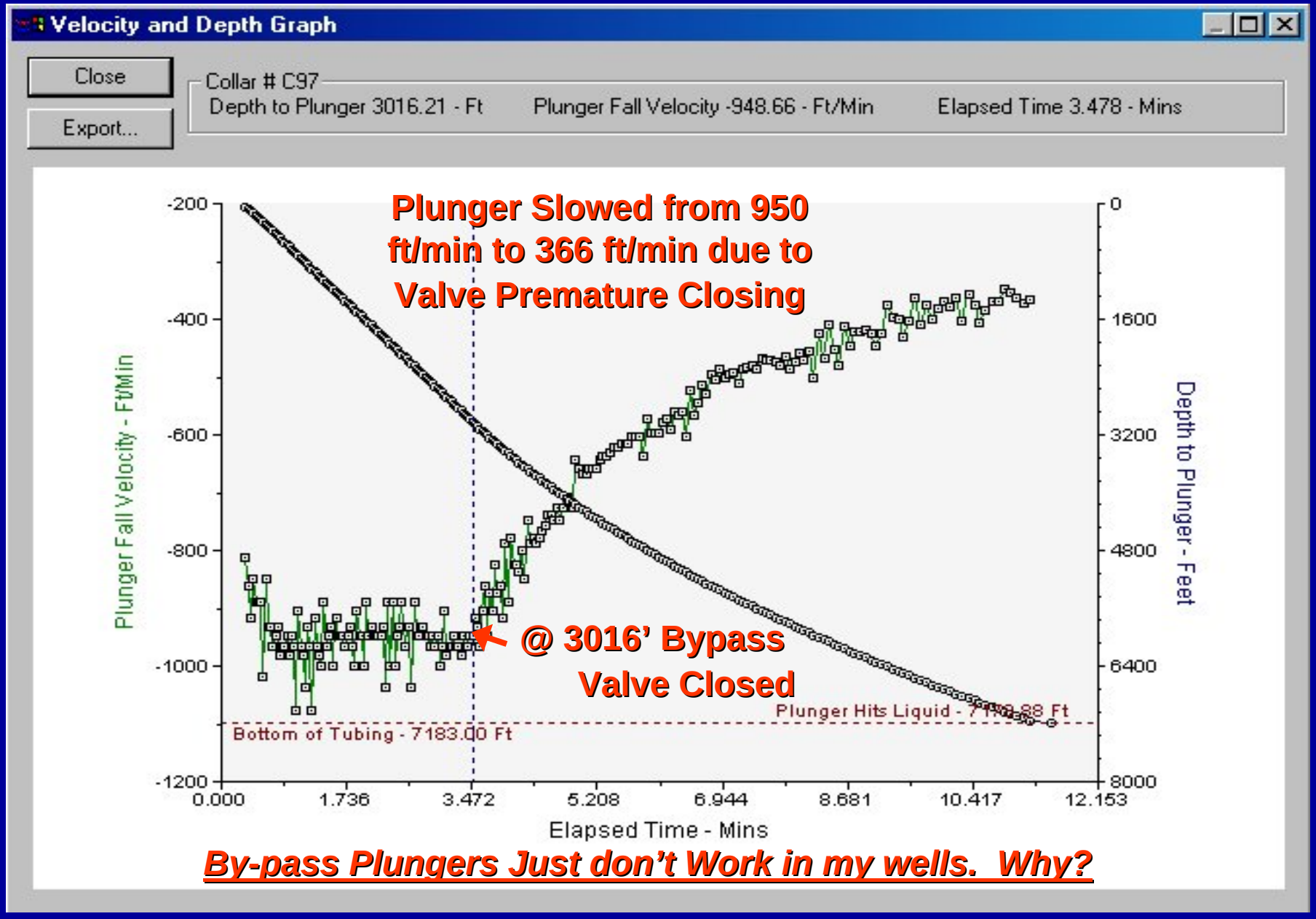
2 3/8” By-Pass Shut-in Period
Notice Pressure and Acoustic Signals



Count Signals from Plunger in Collar: Acoustic Signal During Shut-in (1 minute)

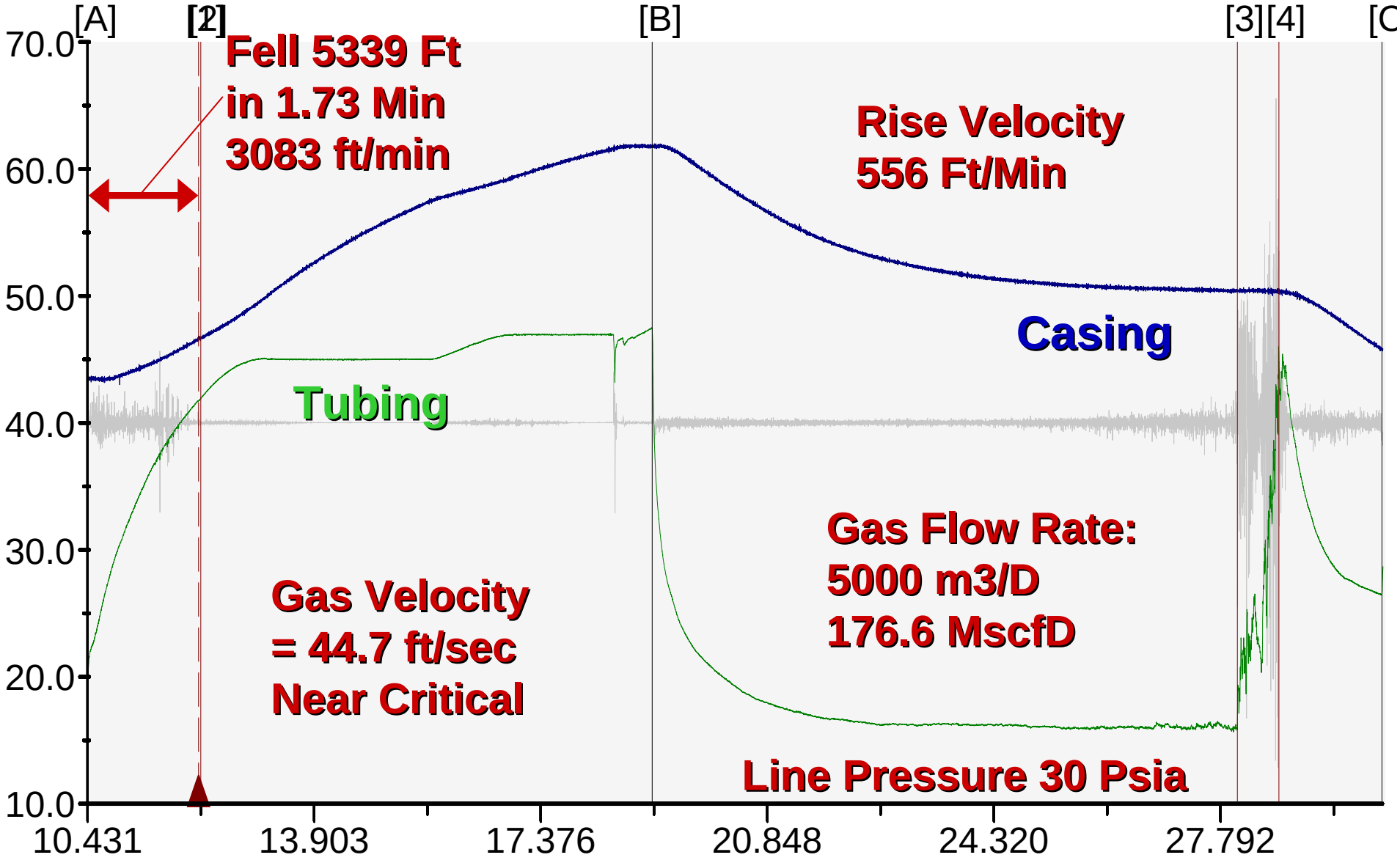


Fall Velocity – Bypass Valve Closes

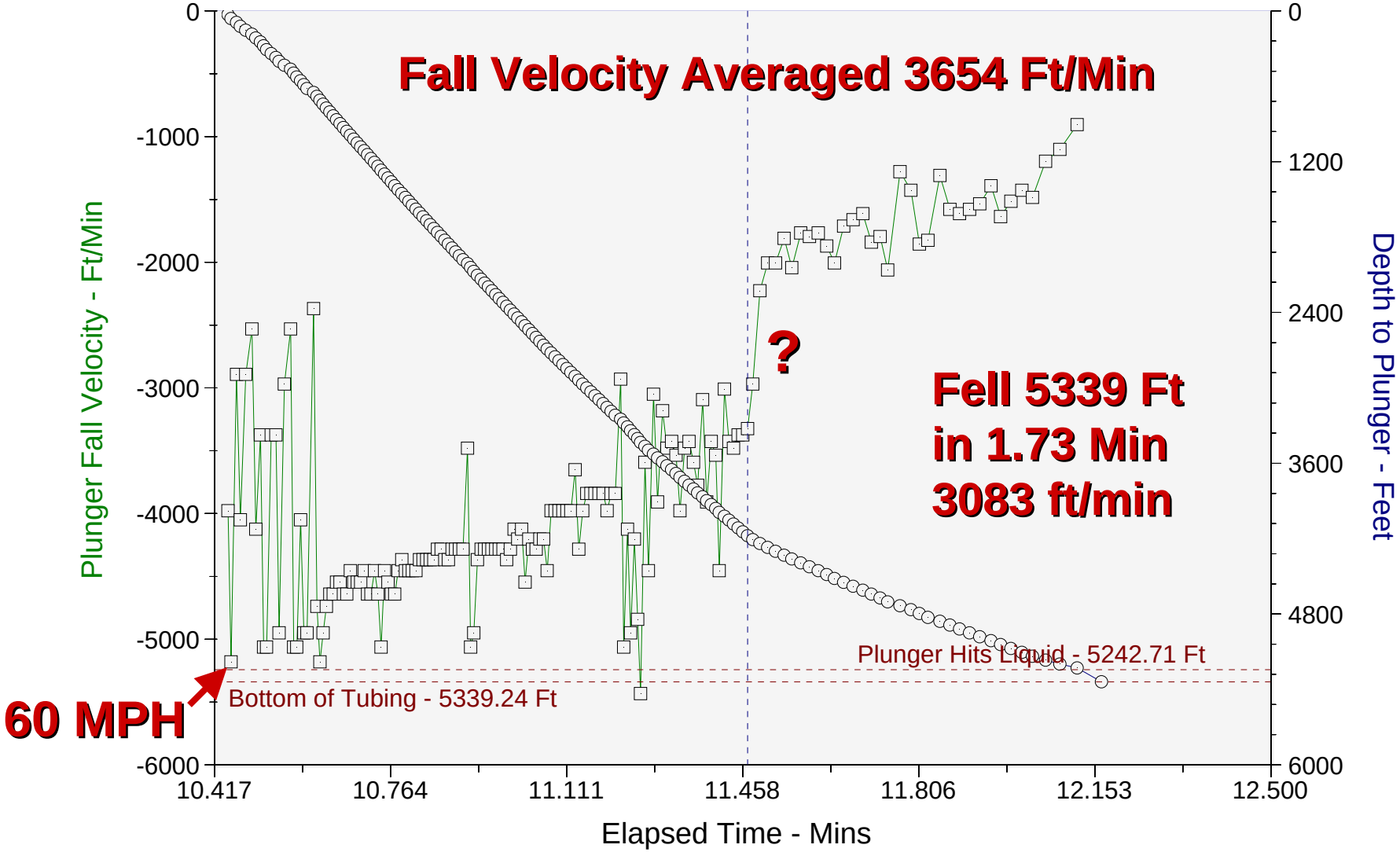


By-pass Plungers Just don't Work in my wells. Why?

2 7/8 inch Bypass Plunger w/ Standing Valve Hits at Bottom *Very* Hard ~ almost 60 Mile/Hr

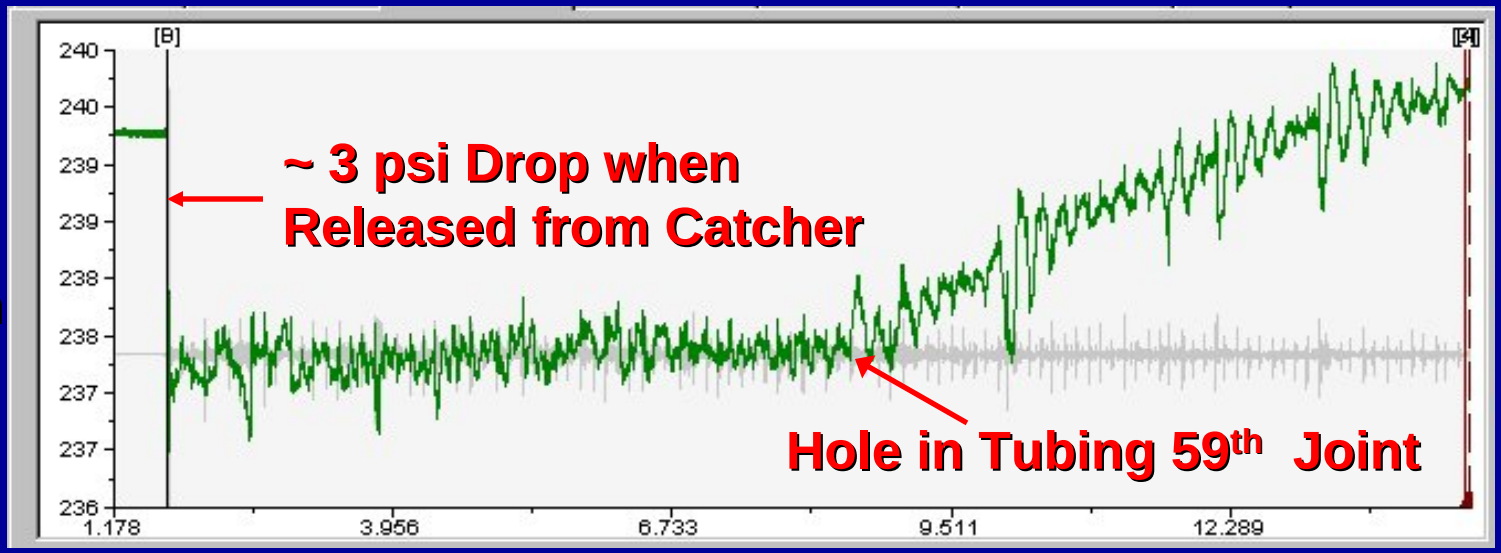


2 7/8 inch Bypass Plunger
Fall Velocity Range 5000-1000 ft/min

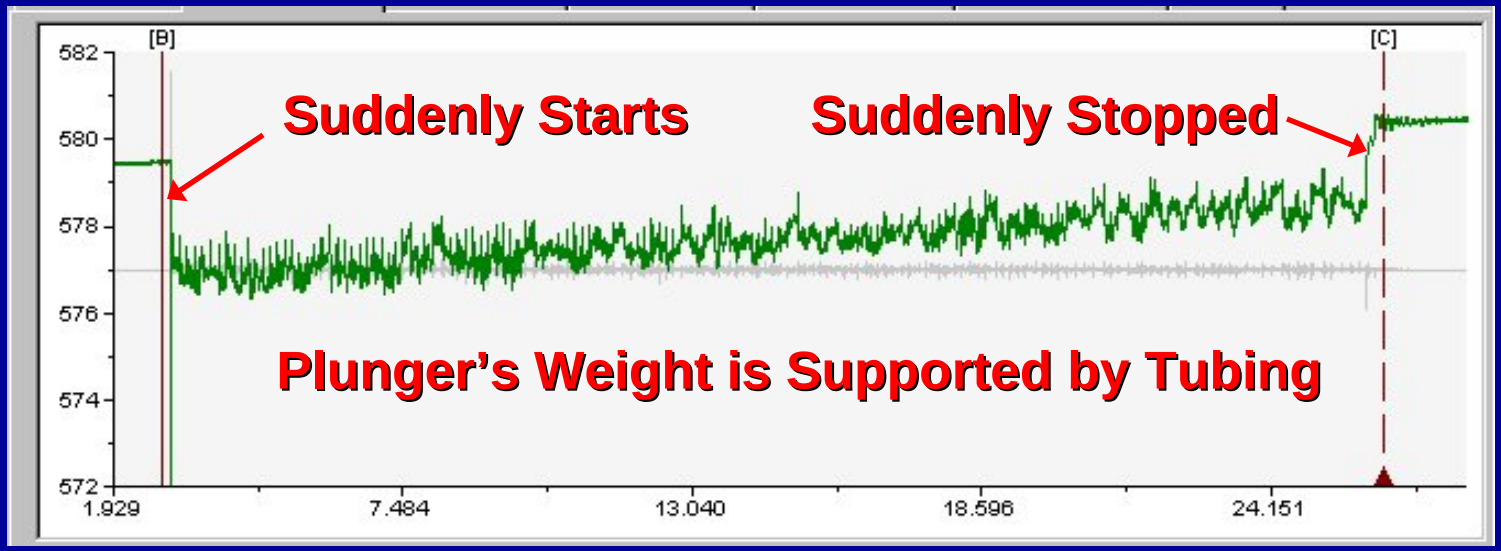


Tubing Pressure Helps to Identify Downhole Problems

Plunger falls Past Hole at 1872 feet and Pressure from Casing Flows Into Tubing



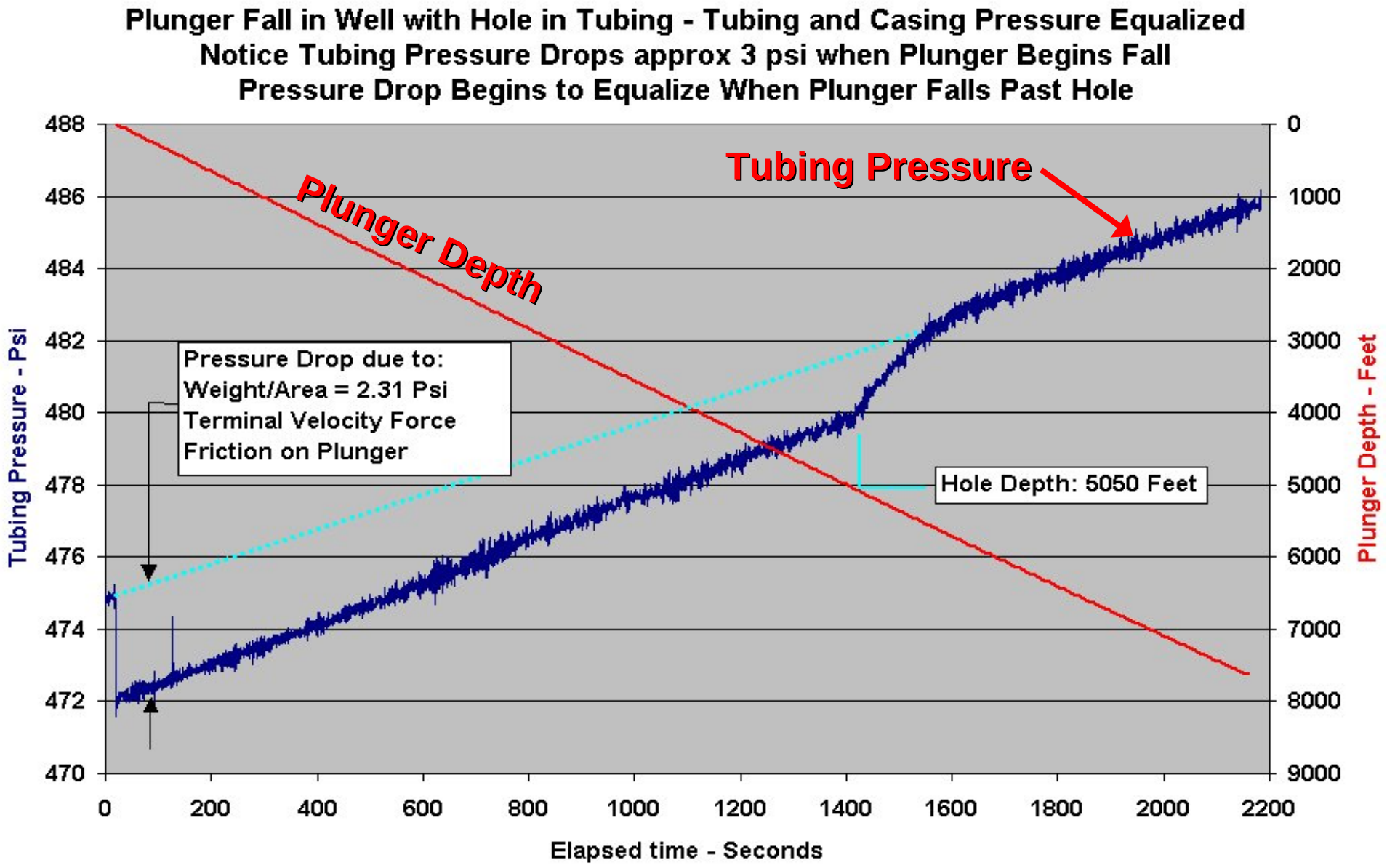
Rapid Tubing Pressure Increase if Plunger has Sudden Stop



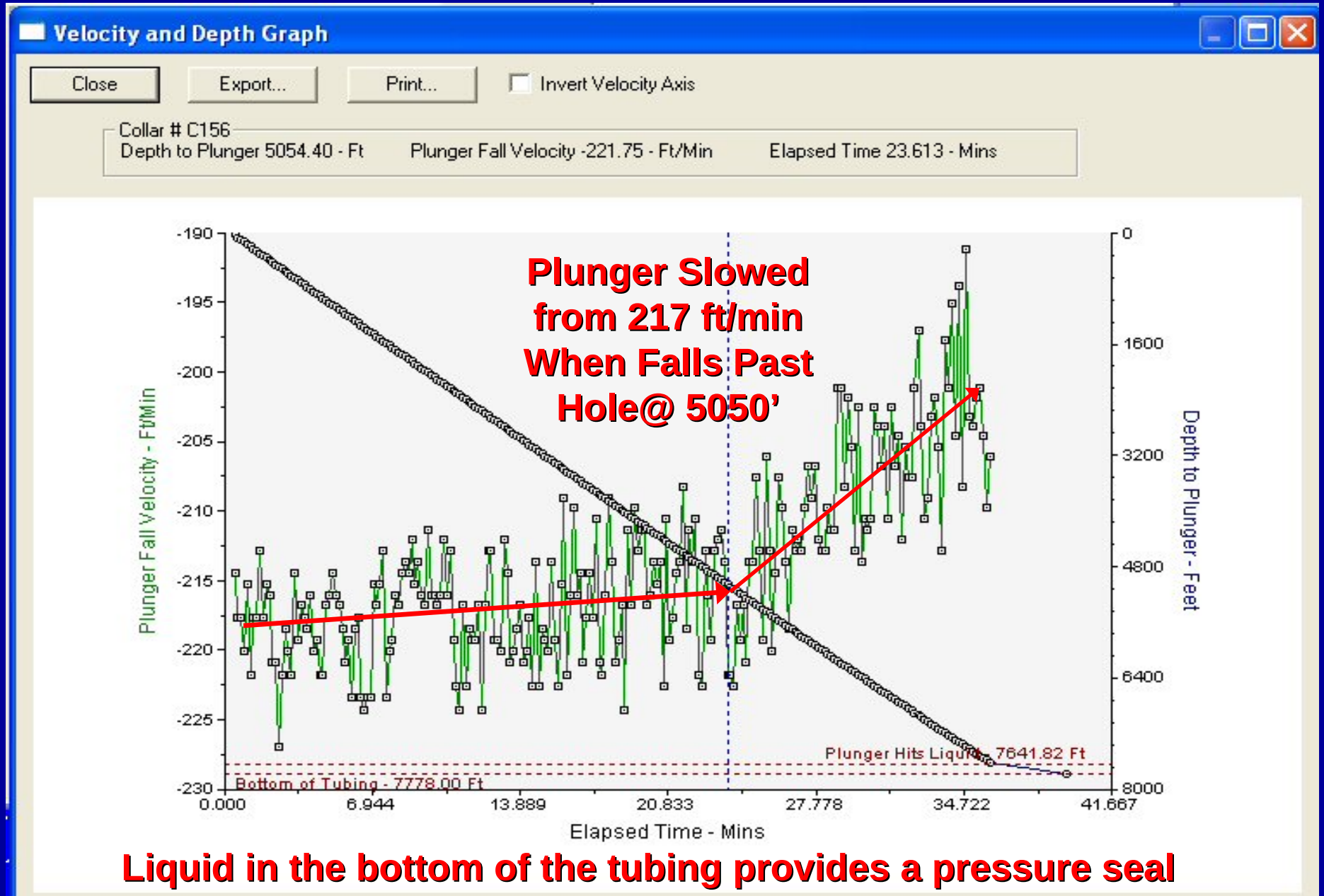
Hole in Tubing

1) Hole was 156 jts from surface or 5054' based on 32.4' joint lengths
2) Hole measured with micrometer to be 0.160” by 0.125”.

Pressure Increases as Plunger Falls Past Hole

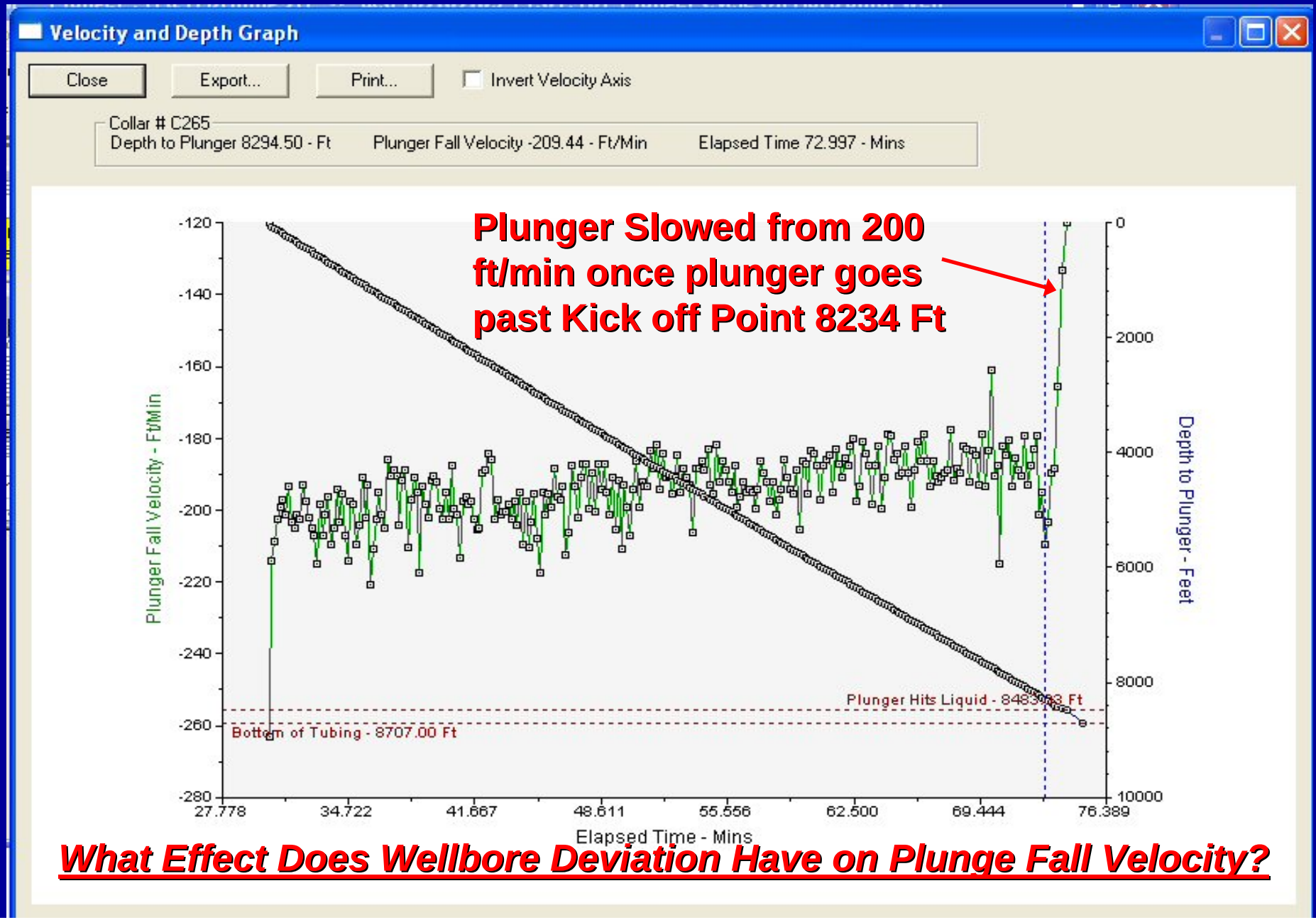


Plunger Fall Velocity Slows Past Hole



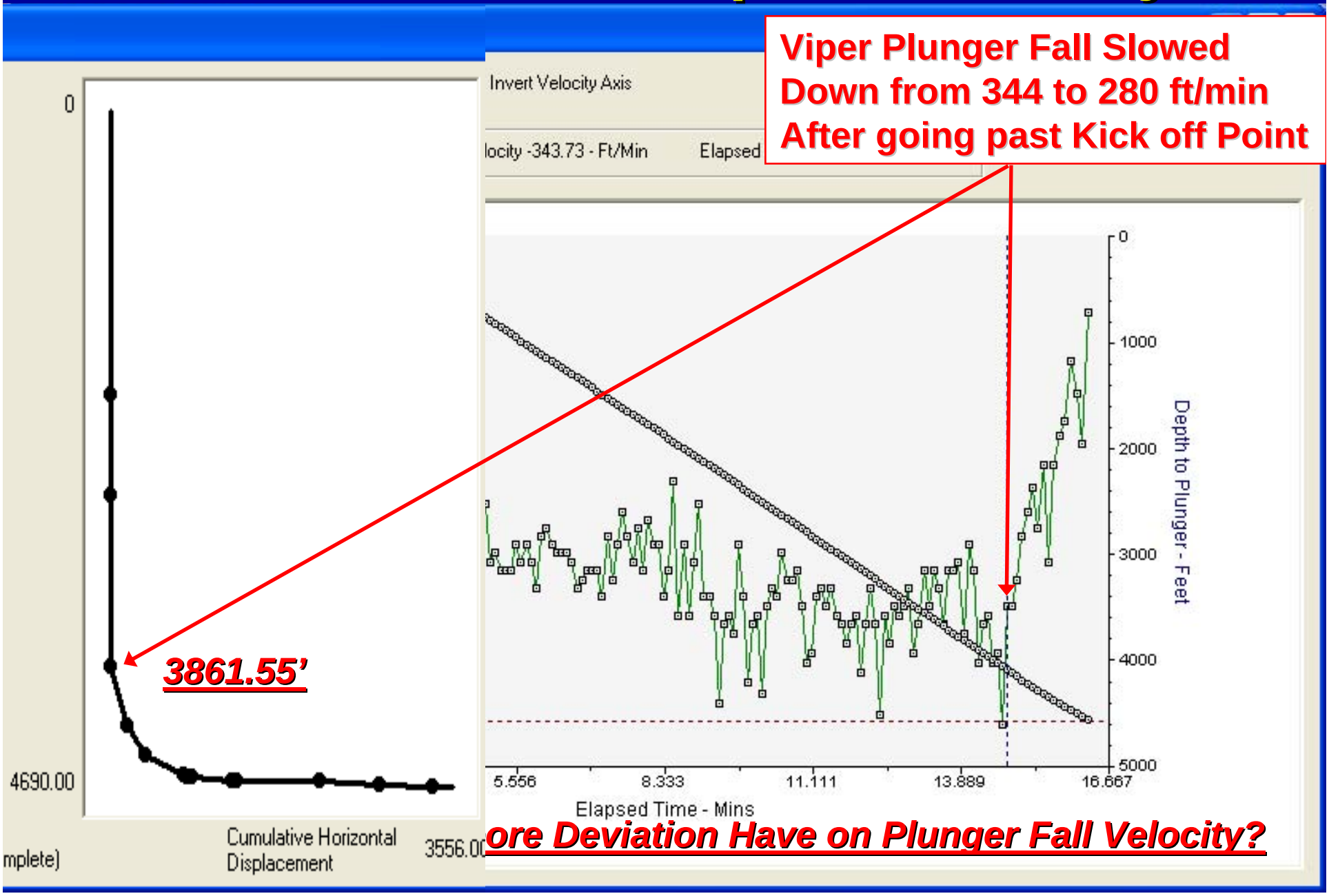
Liquid in the bottom of the tubing provides a pressure seal

Fall Velocity Slows in Deviated Well

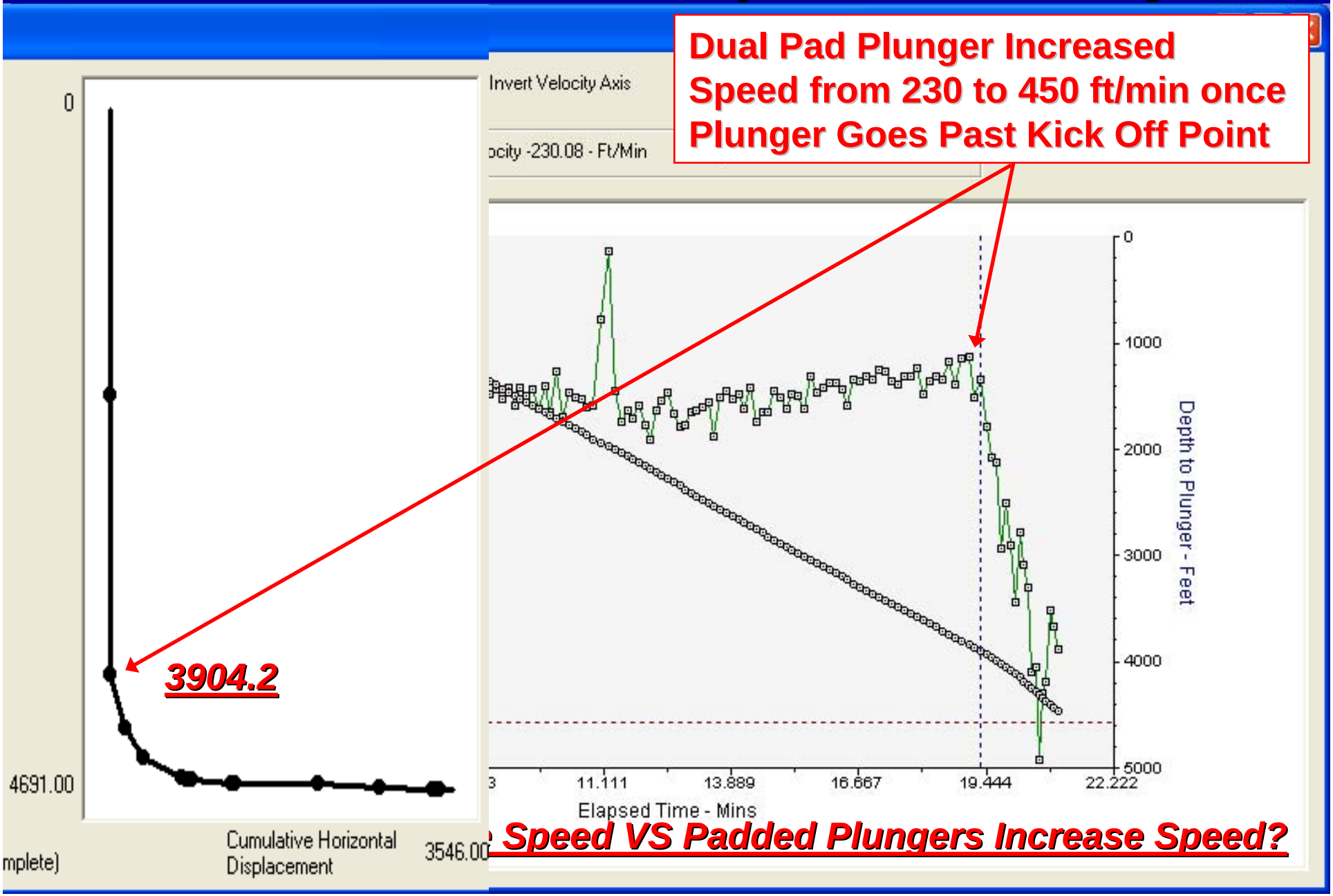


What Effect Does Wellbore Deviation Have on Plunge Fall Velocity?

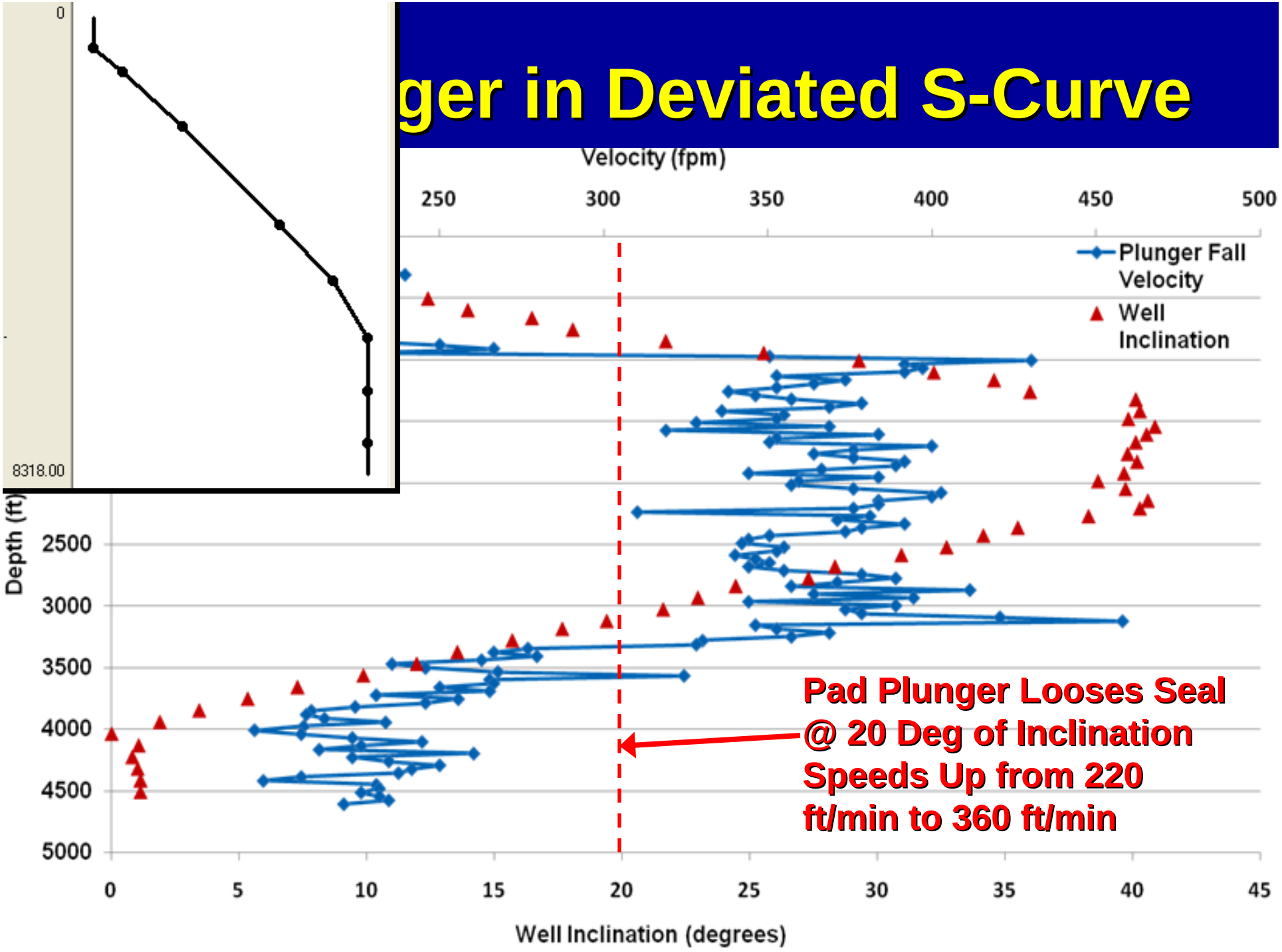
Horizontal Well Impacts Velocity



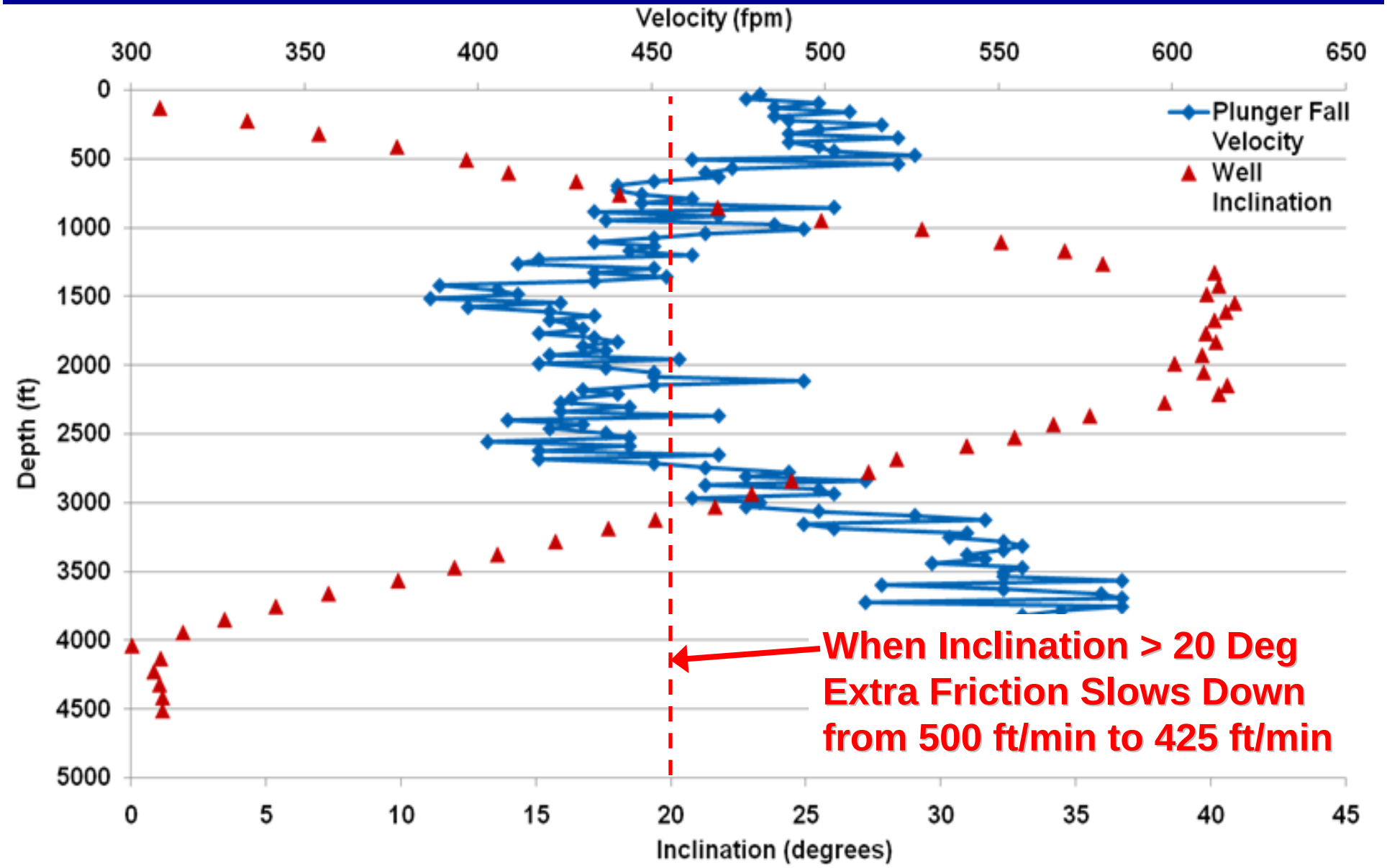
Horizontal Well Impacts Velocity



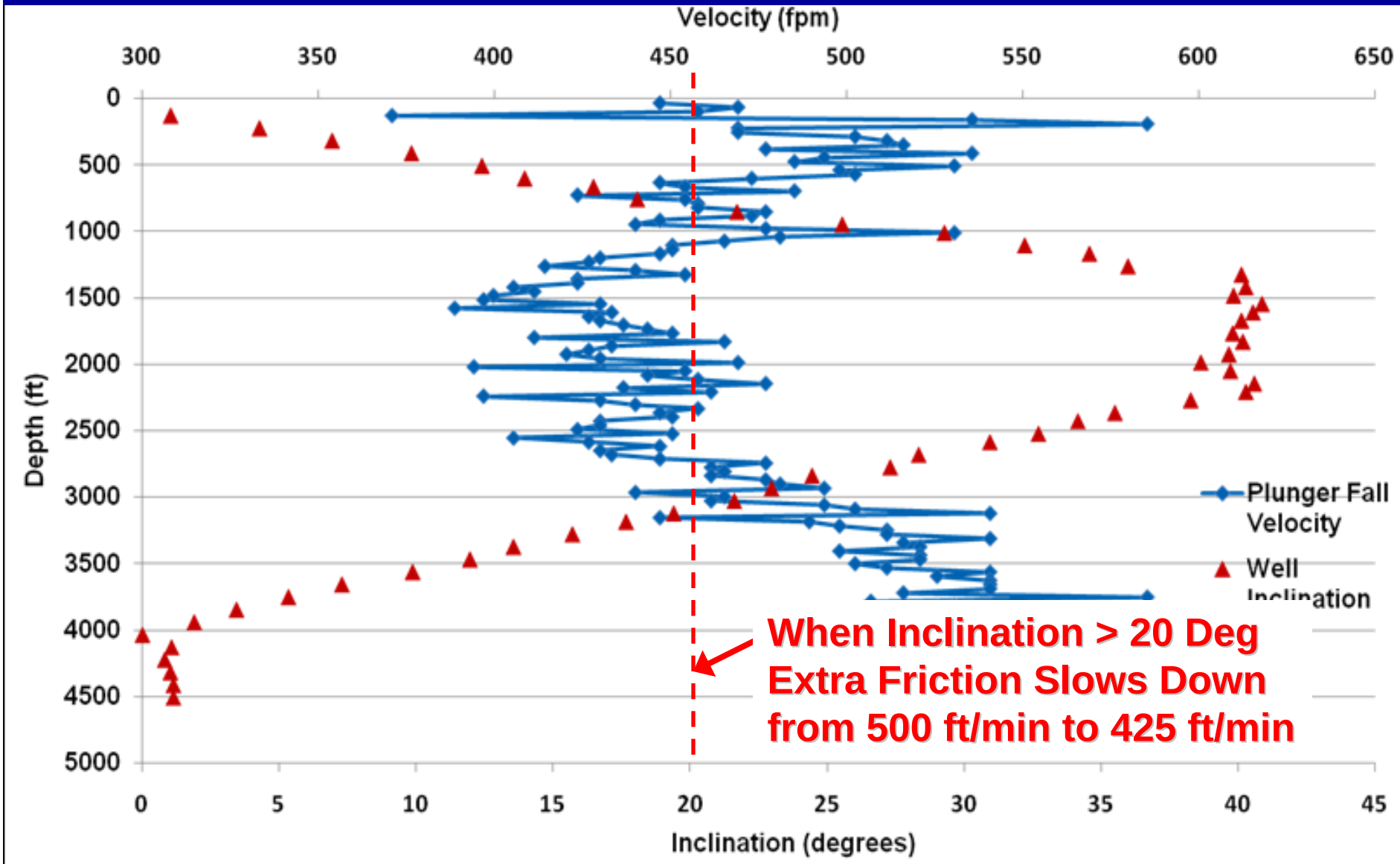
ger in Deviated S-Curve



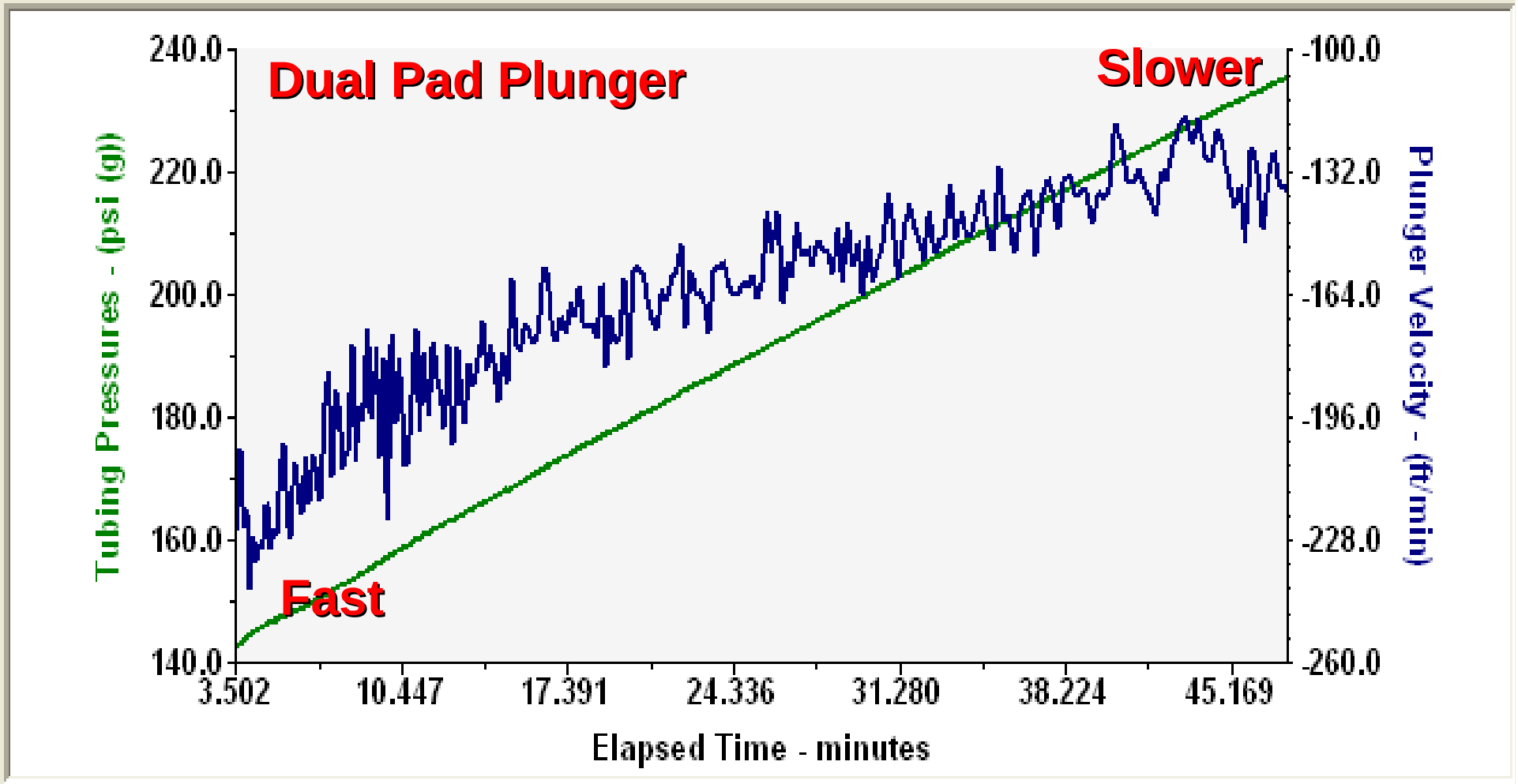
Brush Plunger in Deviated S-Curve



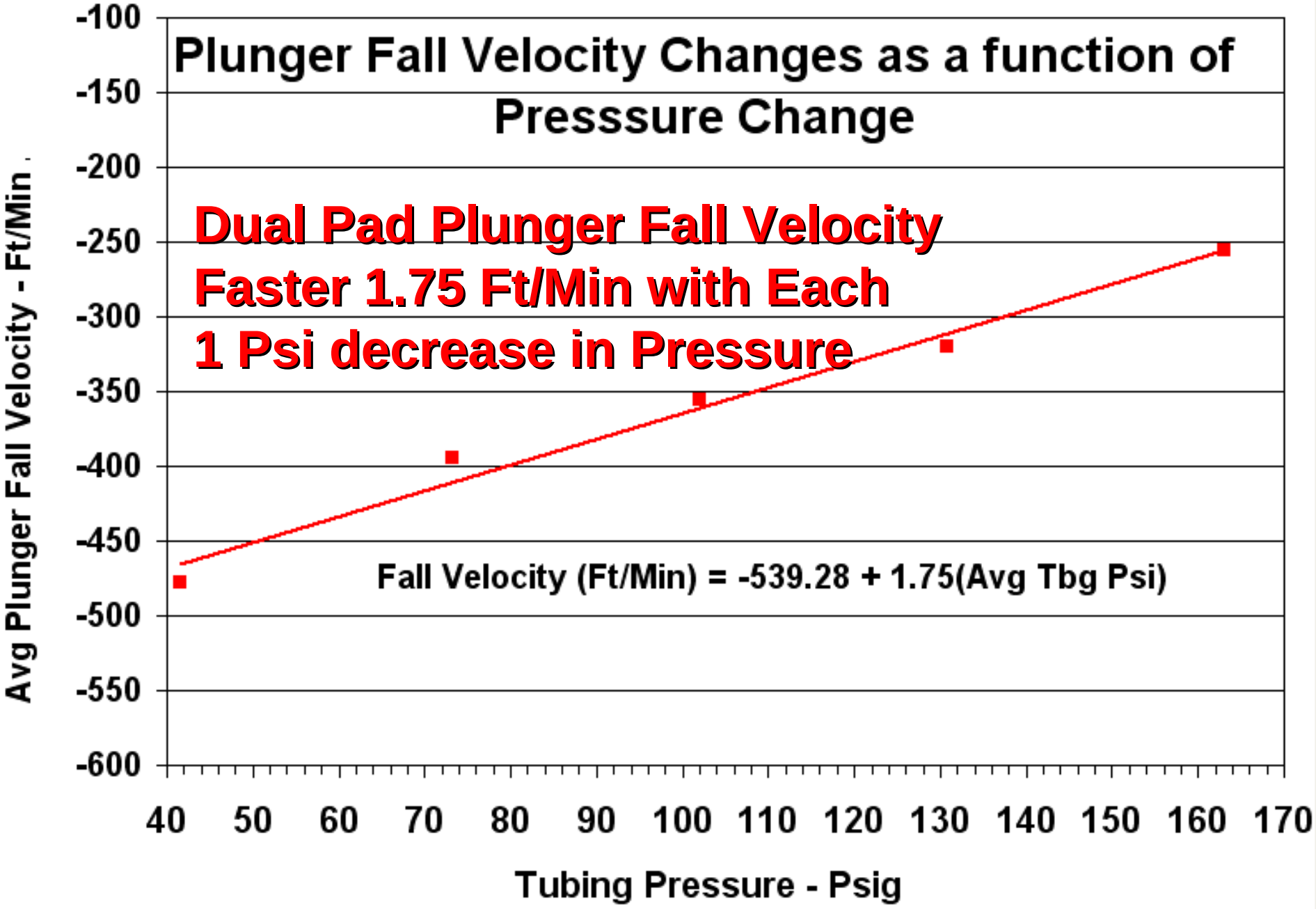
Solid Plunger in Deviated Well



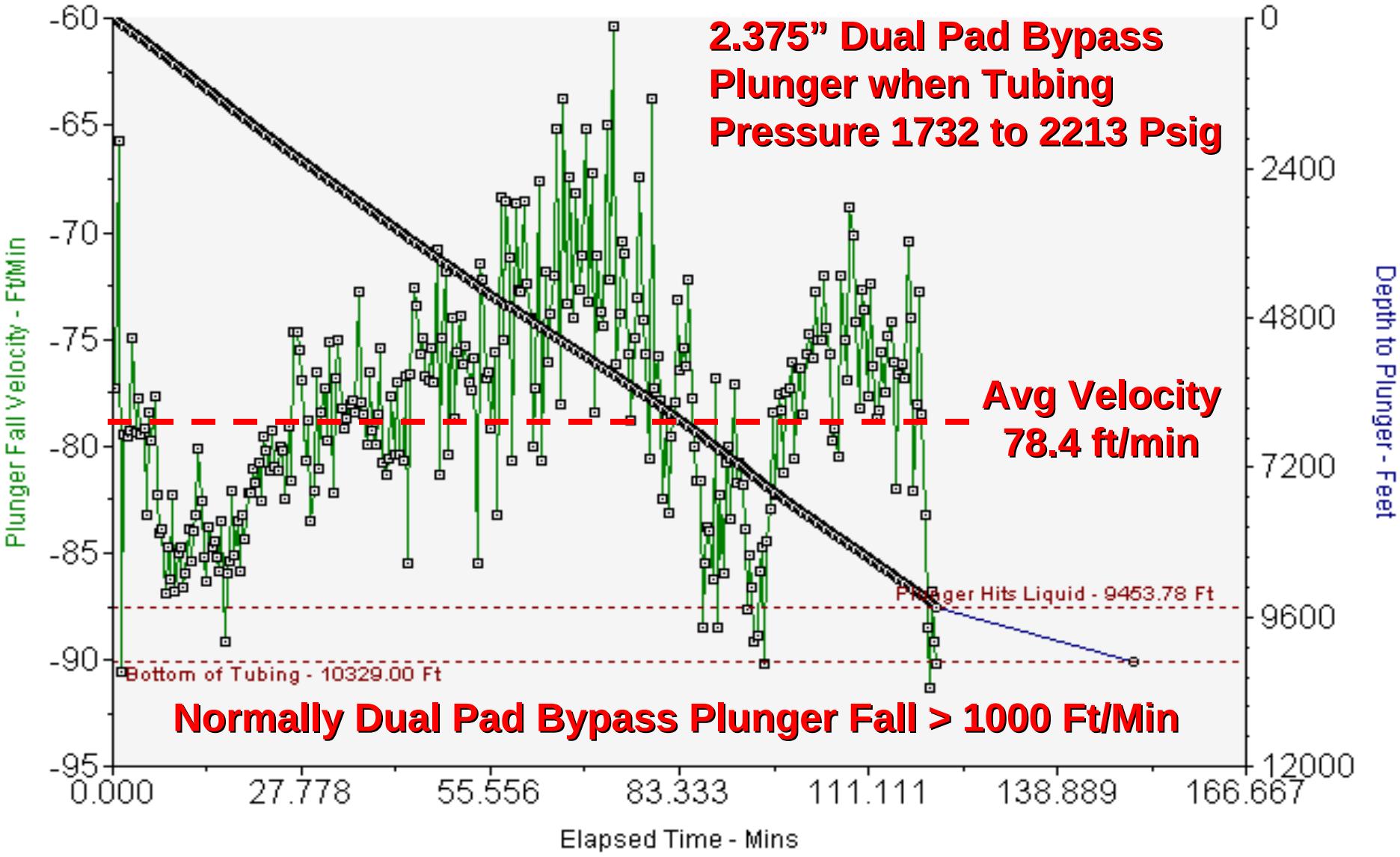
Fall Velocity is Faster at Low Pressures Slows as Pressure Increases



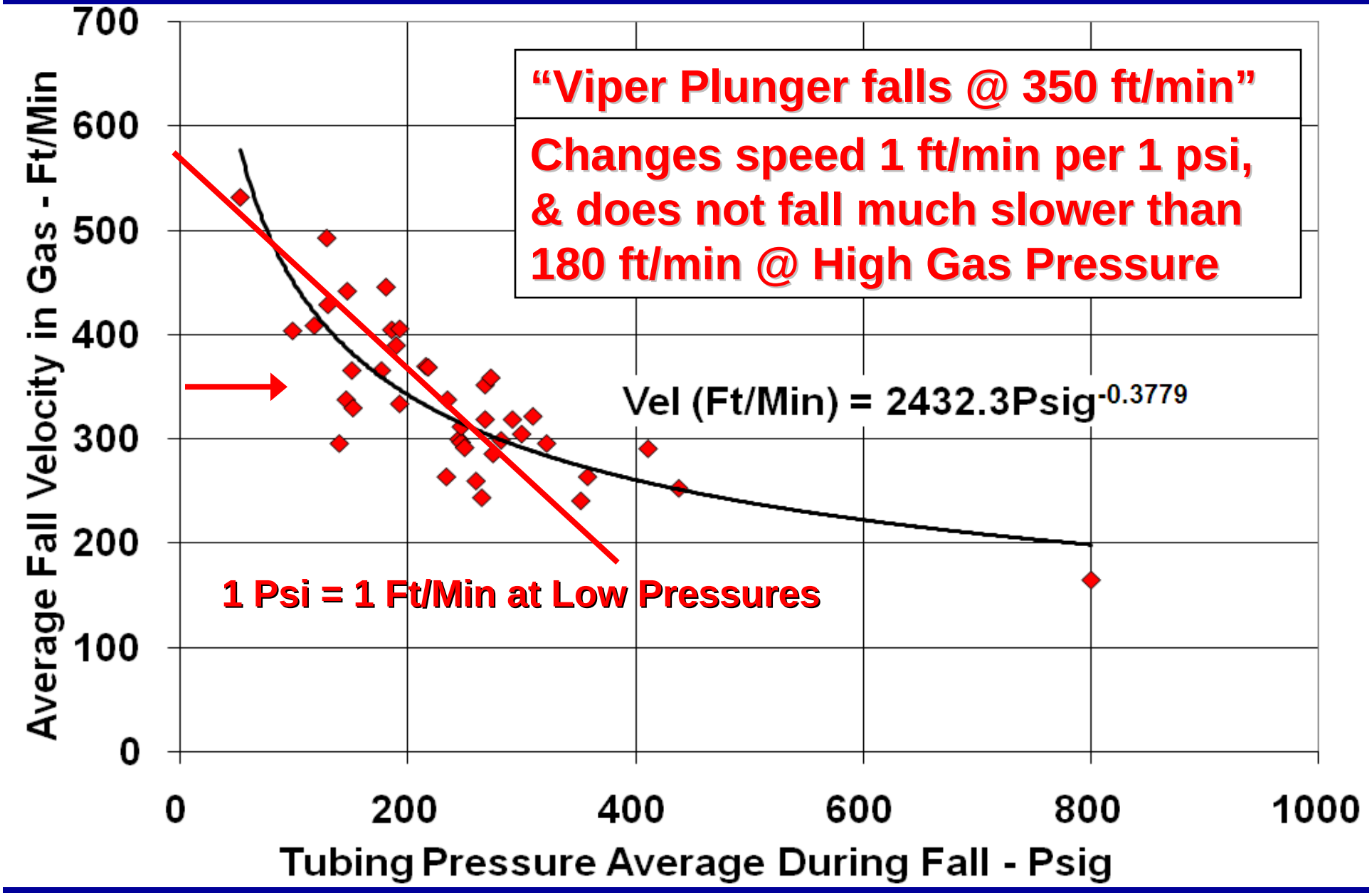
Fall Velocity Increases as Pressure Drops



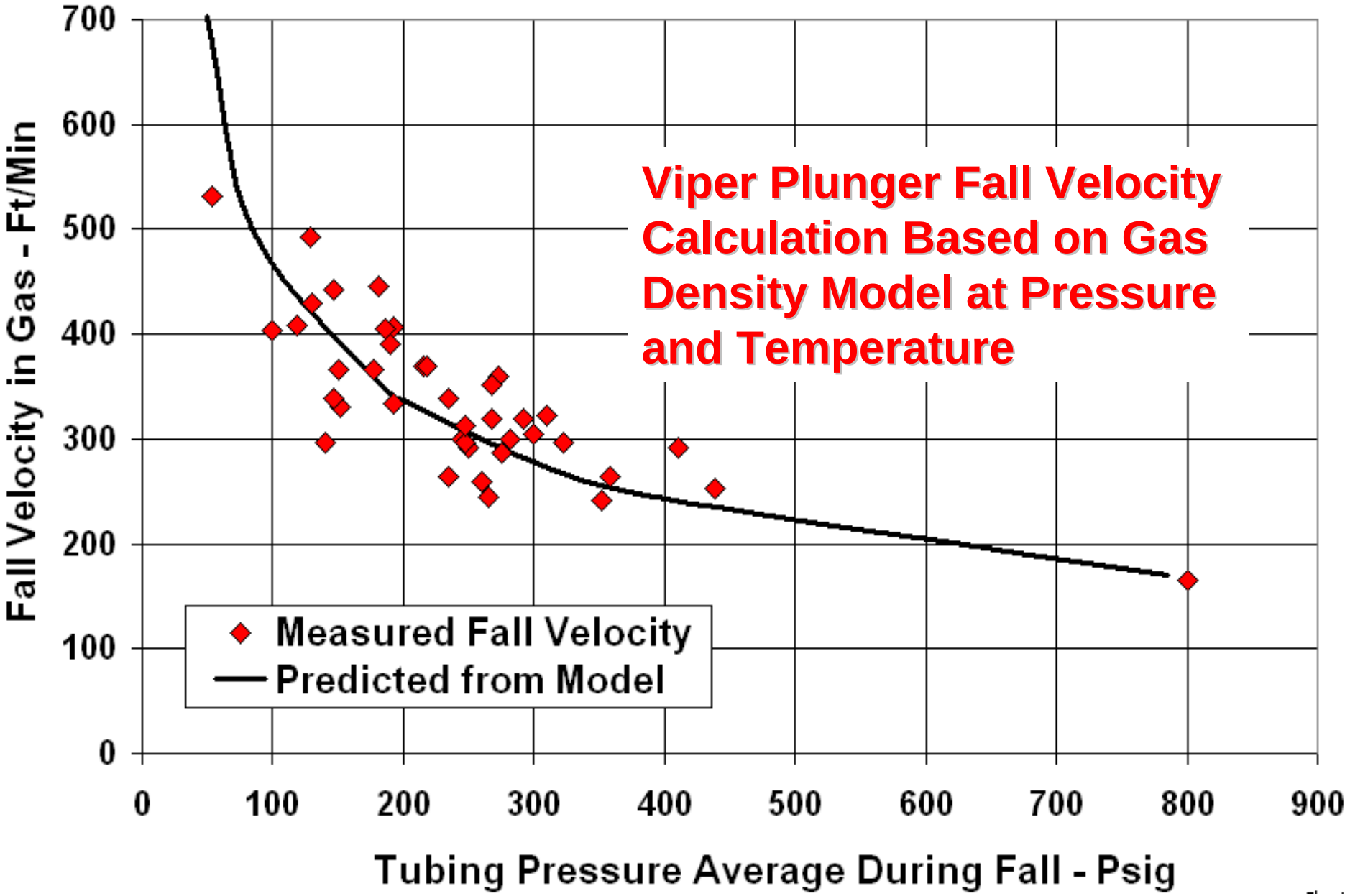
Bypass Slow at High Pressure
Shut-in Time needs to be 2.66 Hours



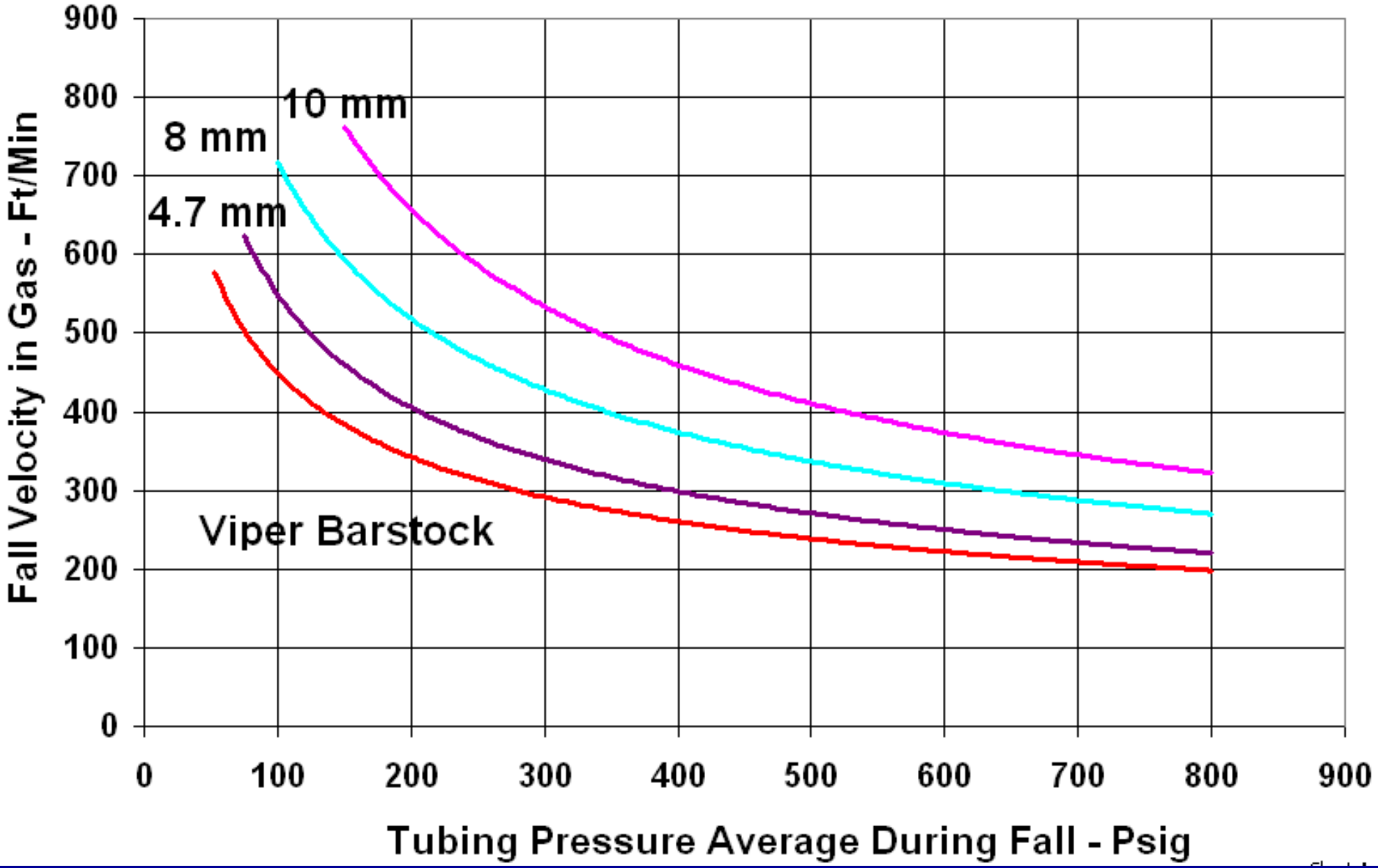
Fall Velocity Change is Non-Linear w/ Pressure



New Fall Velocity Model Based on Gas Density

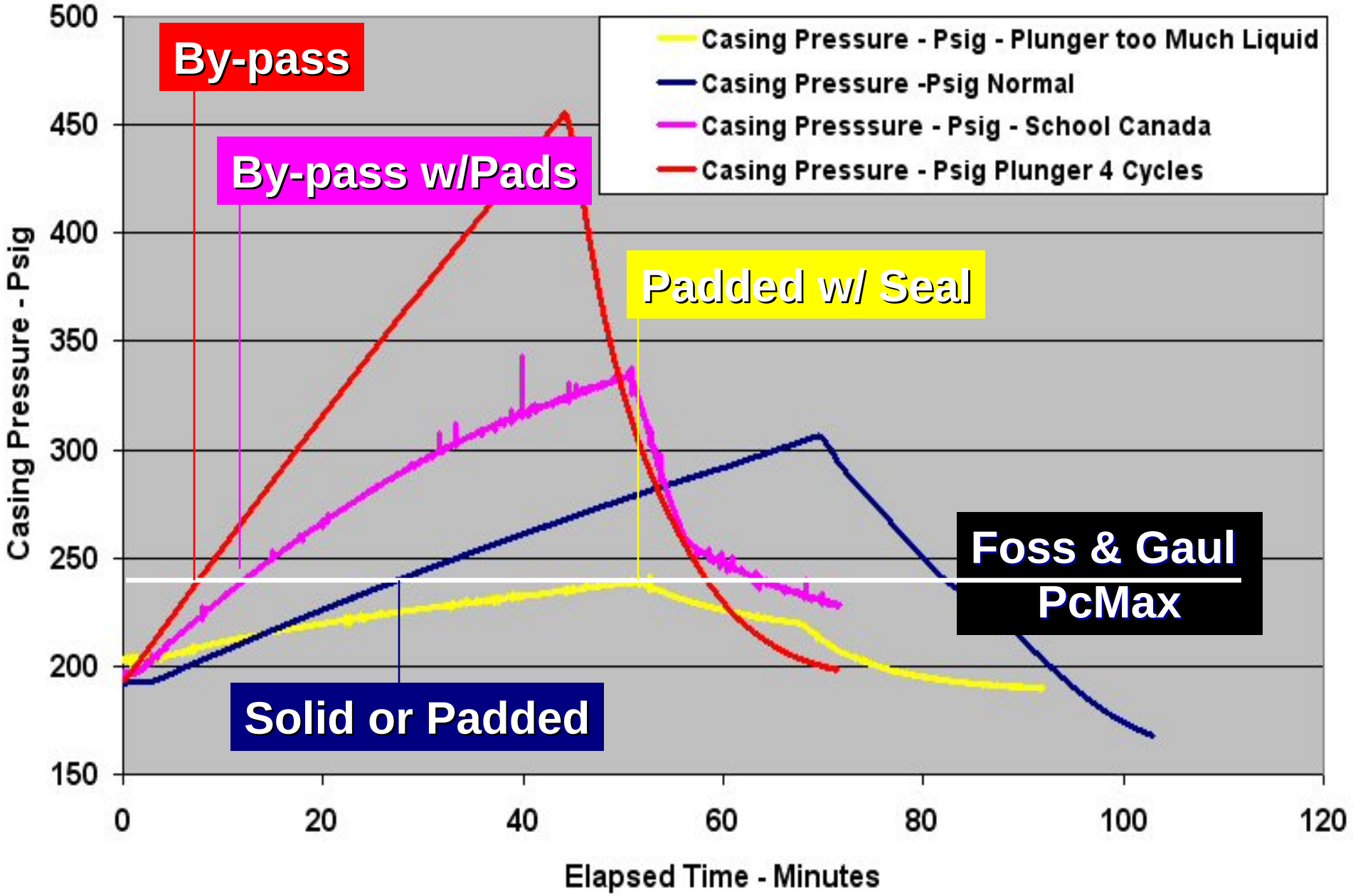


Control Fall Velocity with Orifice Size



Plunger Fall Velocity Determined by Orifice Selection

"*Select Correct Plunger for the Well*" some wells need fast plungers and some wells casing pressure builds slowly



Plunger Fall Velocity Impacted By:

1. Diameter of Plunger – Larger Diameter Falls Slower
2. Effectiveness of Seal between Plunger and Tubing – Better Seal Plunger Falls Slower
3. Brush stiffness – If the Bristles do not provide a effective seal then the plunger falls faster
4. Increased friction due to contact with the tubing – Plunger Falls Slower
5. Old age/increased wear – as the plunger wears out the worn plunger falls faster
6. If Gas can pass through plunger (i.e. Bypass) – then a plunger falls faster
7. When the plunger becomes stuck and stops – usually indicated by a 3 psi increase in pressure
8. If the Tubing is Sticky – the plunger falls slower

Plunger Fall Velocity Impacted By:

9. Wellbore Deviation – more than 20 degrees of deviation impacts plunger fall velocity
   a. Padded Plungers Faster due to Loss of Seal
   b. Solid Plungers Slower due to Increased Friction
10. Gas Flow Rate Into The Tubing – gas flow into tubing reduces plunger fall velocity
11. Pressure or Density of Gas
   a. High Pressure and plunger fall is Slow
   b. Low Pressure and plunger fall is Fast
12. Liquids increase density – plunger falls slow
   a. Surfactant lightens gradient and plunger falls faster, but more time may be required
   b. High pressure also causes plunger to fall more slowly through liquid

Plunger Life Cycle

1. Well is flowing above critical with all flow in Mist flow, no liquid gradient at any time.
2. Well begins to bubble and slug (Usually high speed bypass candidate if +15 ft/s velocity is available.)
3. Well begins to have difficulty maintaining seal due to velocity getting below 15 ft/s (usually good application for padded bypass plunger)
4. Well requires shut-in time to build pressure to maintain velocity of plunger (quick-drop application).
5. Well requires build time (conventional plunger lift applicable as fall time is not important)
6. Well requires substantial build time (high efficiency seals require more fall time but have a better seal).
7. Economics need to be reviewed for rod pump, compression, chamber lift or other forms of lift.

Questions?