Ask Echometer Online Seminar – September 2, 2020

Three Main Causes of Incomplete Pump Fillage

TOTAL ASSET MONITOR (TAM)

http://www.echometer.com/Software/Total-Asset-Monitor

"Dynamometer Workshop", Taylor, Fernandez, Rowlan, Podio, Ask Echometer Online Seminar – July 15, 2020

"The Use of Polished Rod Velocity and MPRL/PPRL Ratio as an Indicator of Failure Frequency". SWPSC 2018

"Gas Separator Selection and Performance", McCoy, Rowlan, Ellithorp, Podio, SWPSC 2107

"The Three Causes of Incomplete Pump Fillage and How to diagnose them correctly from Dynamometer and Fluid Level Surveys", McCoy, Rowlan, Podio SWPSC 2010

Presenters: Carrie-Anne Taylor and O. Lynn Rowlan

Q & A: Gustavo Fernandez and Echometer Engineering and Support

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Download the Session 16 PDF Bundle and TAM Example Data from

https://echometer.com/Support/AskEchometer

Variety Of "Secrets" For Producing Sucker Rod Lifted Wells

- Another term for “secrets” would be recommended practice.
- Some of these practices include properly installing equipment in the well, providing proper chemical treatments, preventing rod on tubing wear, identifying cause of well failures, and periodic surveillance of the well.
- Dynamometer and fluid level surveys are used to identify when the well is properly operating and when there are operating problems.
- Frequently rod pumped wells fail due to the exact same problem.
- Therefore these recommended practices must not be known by the operator or must be “secrets”.

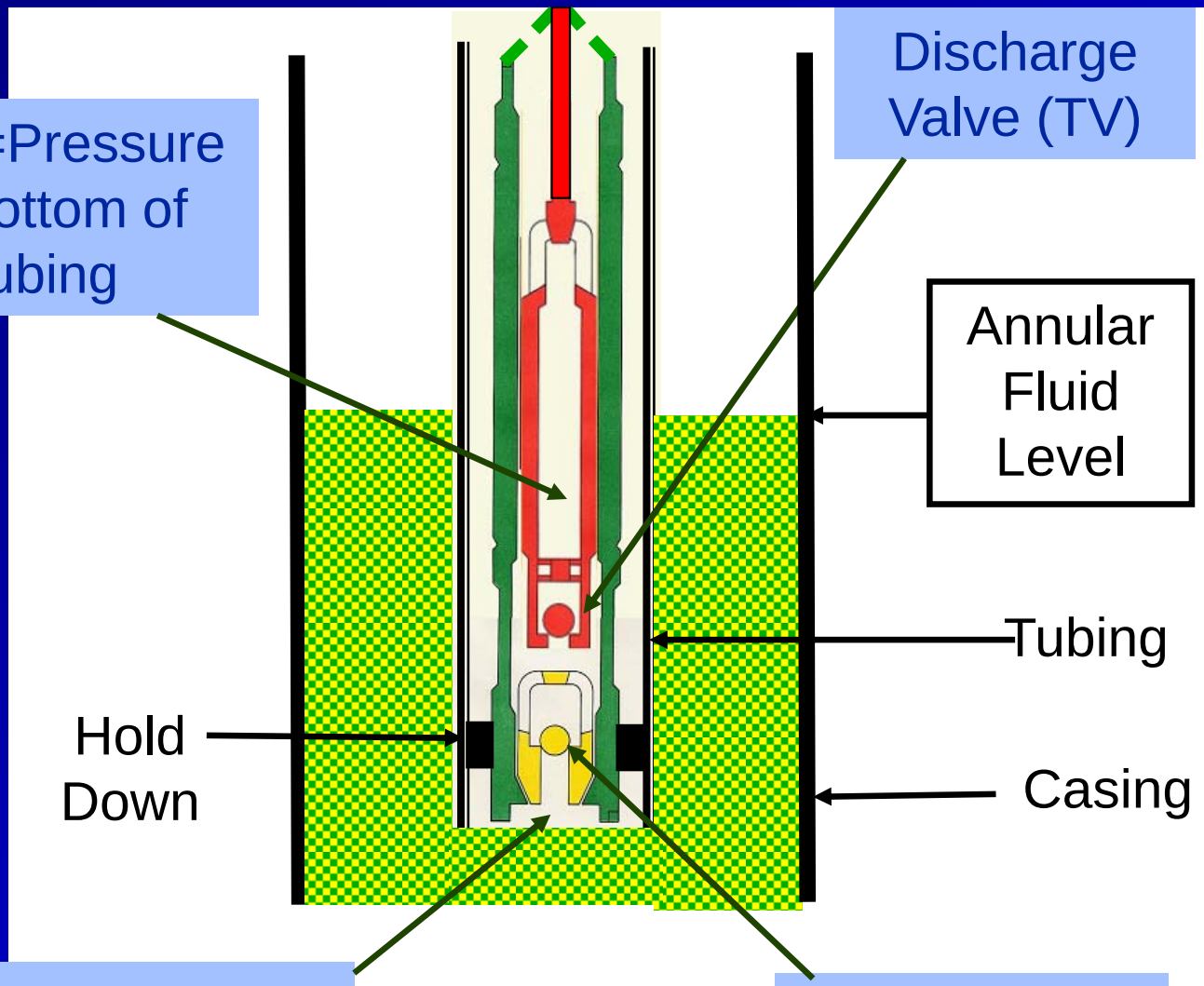
Focus on "Secrets" For Producing Sucker Rod Lifted Wells

- But, probably the Top “SECRET” is to produce wells with complete liquid pump fillage.
- More efficient operations and lower failure rate will result, if wells are operated with a pump filled with liquid.
- Presentation will show how incomplete pump fillage is causing problems to the operation of sucker rod lifted wells.

Basic Pump Action

- Valve opens when pressure below valve greater than pressure above valve.
- Valve closes by flow.
- Pressure in barrel is a function of plunger travel and compressibility of fluid in barrel.
- Discharge pressure is pressure at bottom of tubing (PDP)
- Intake pressure is controlled by casing pressure and fluid column in annulus (PIP)
- Rod loading from pump is controlled by difference in pressure above and below traveling valve.

Sucker-Rod Pump



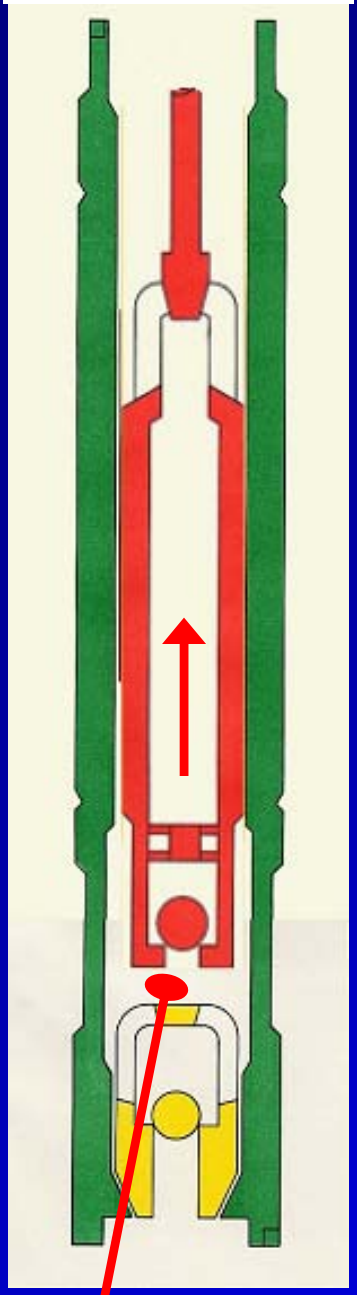
Barrel (Green)

Plunger (Red)

<u>Standing valve</u> is the intake valve, fixed to tubing considered to be stationary, and acts as a check valve to keep well fluid in the tubing on the downstroke.

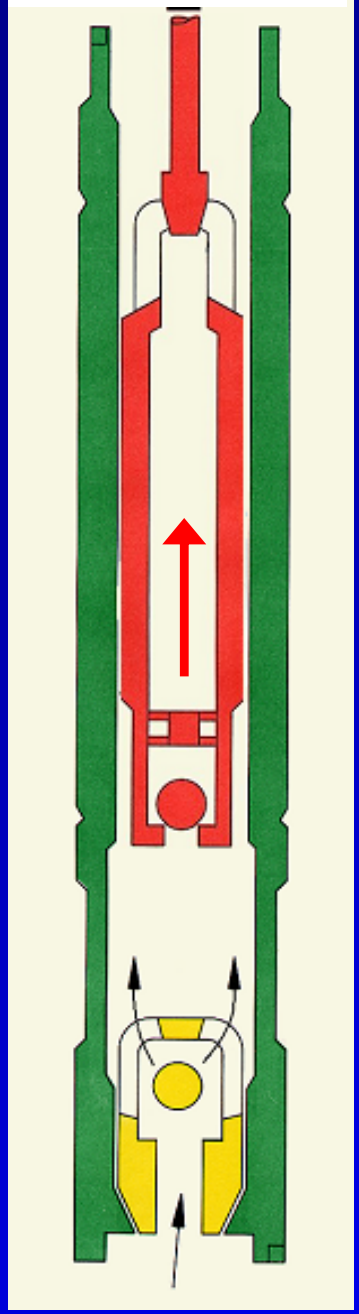
<u>Traveling valve,</u> is the discharge valve, moves with the plunger. Acts as a check valve to keep well fluid in the tubing on the upstroke

TV Close



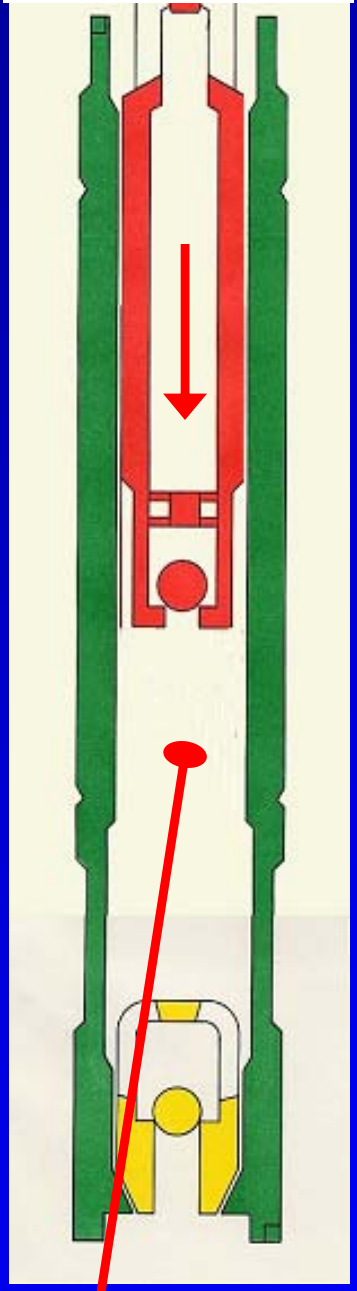
Expansion
A-B

SV Open



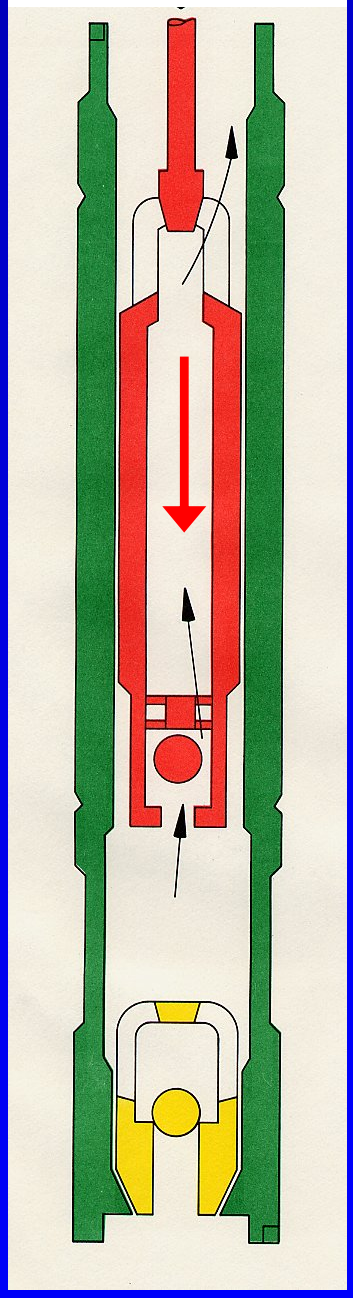
Intake Cycle
B-C

SV Close



Compression
C-D

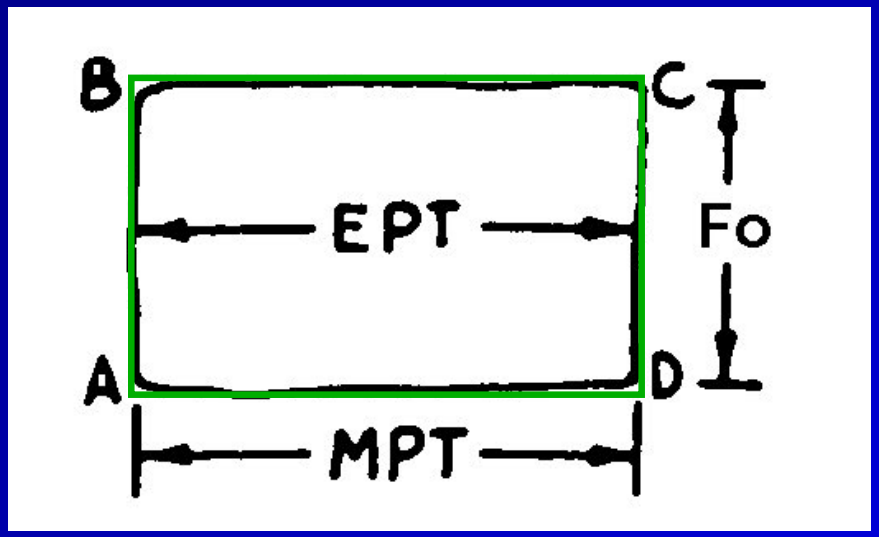
TV Open



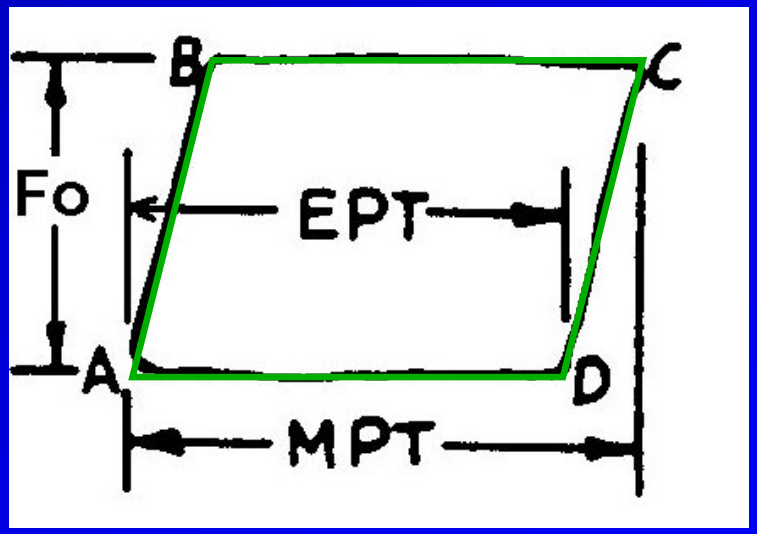
Discharge Cycle
D-A

Pump Cards: Normal Full Pump

Tubing anchored, EPT=MPT.

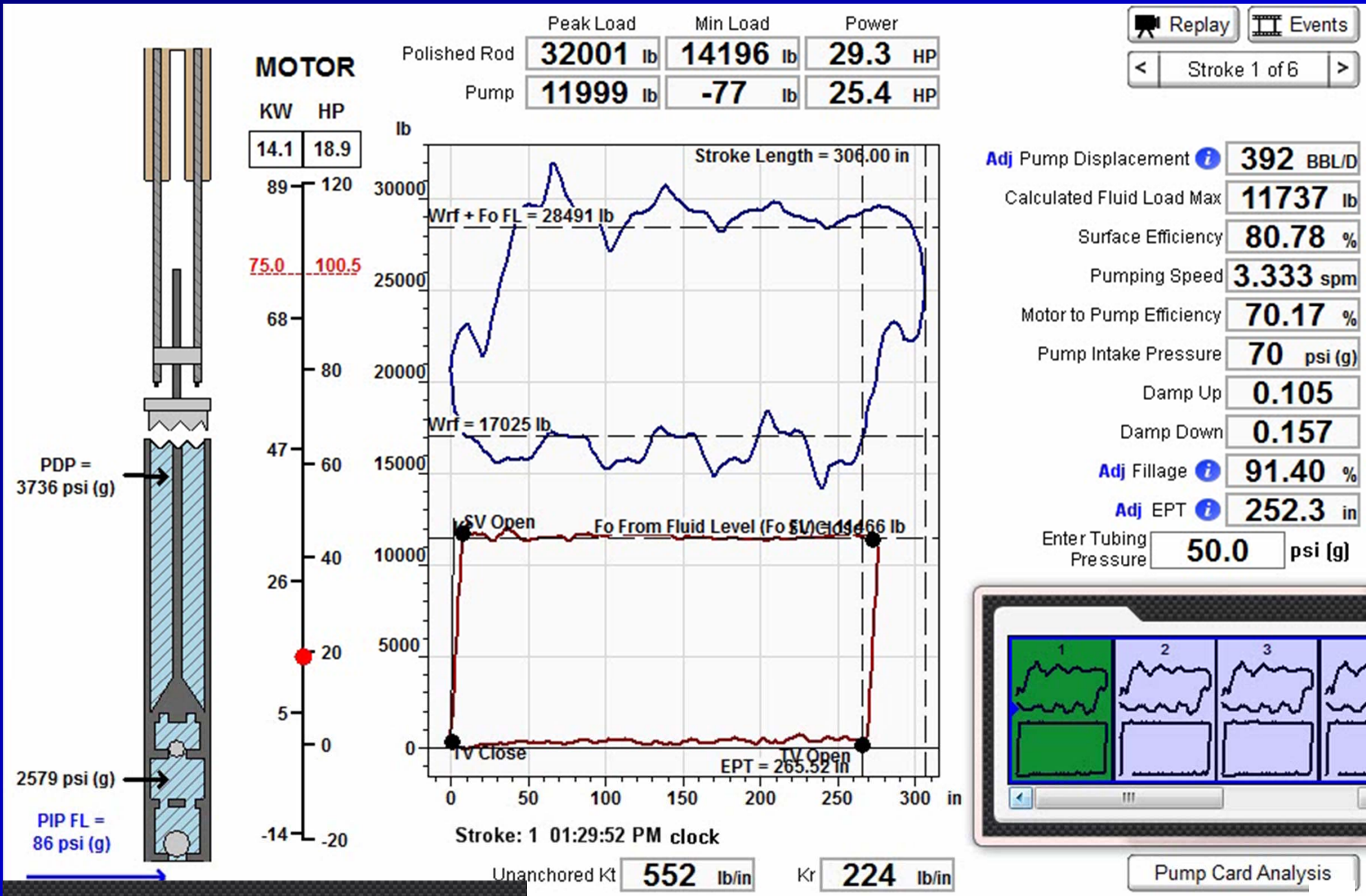


Unanchored tubing, EPT<MPT

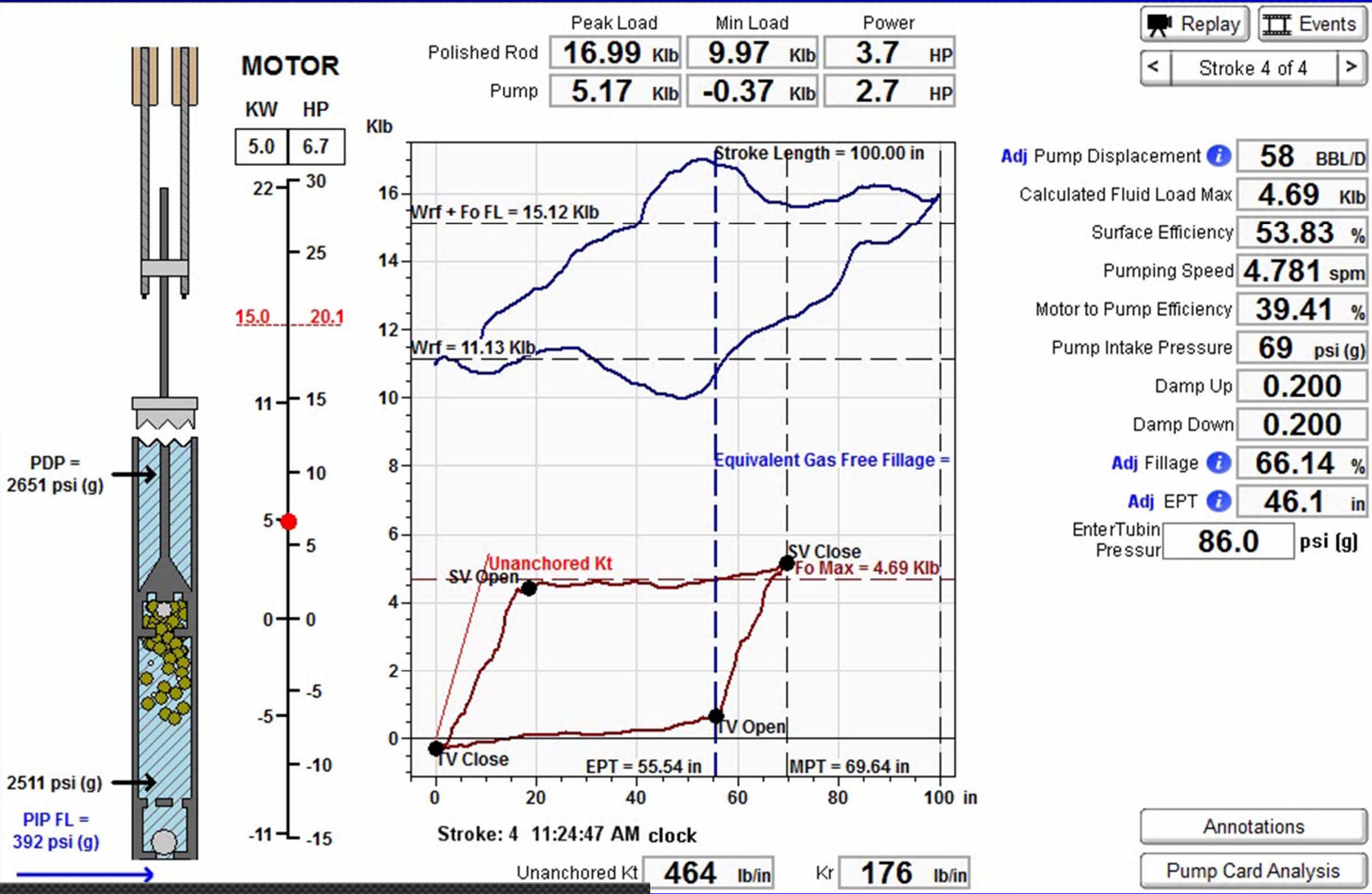


1. **Pumping-Full of Liquid**
2. **No gas in Pump.**
3. **Valves Not Leaking**
4. **Pump functioning properly.**

Anchored Tubing – Full Pump

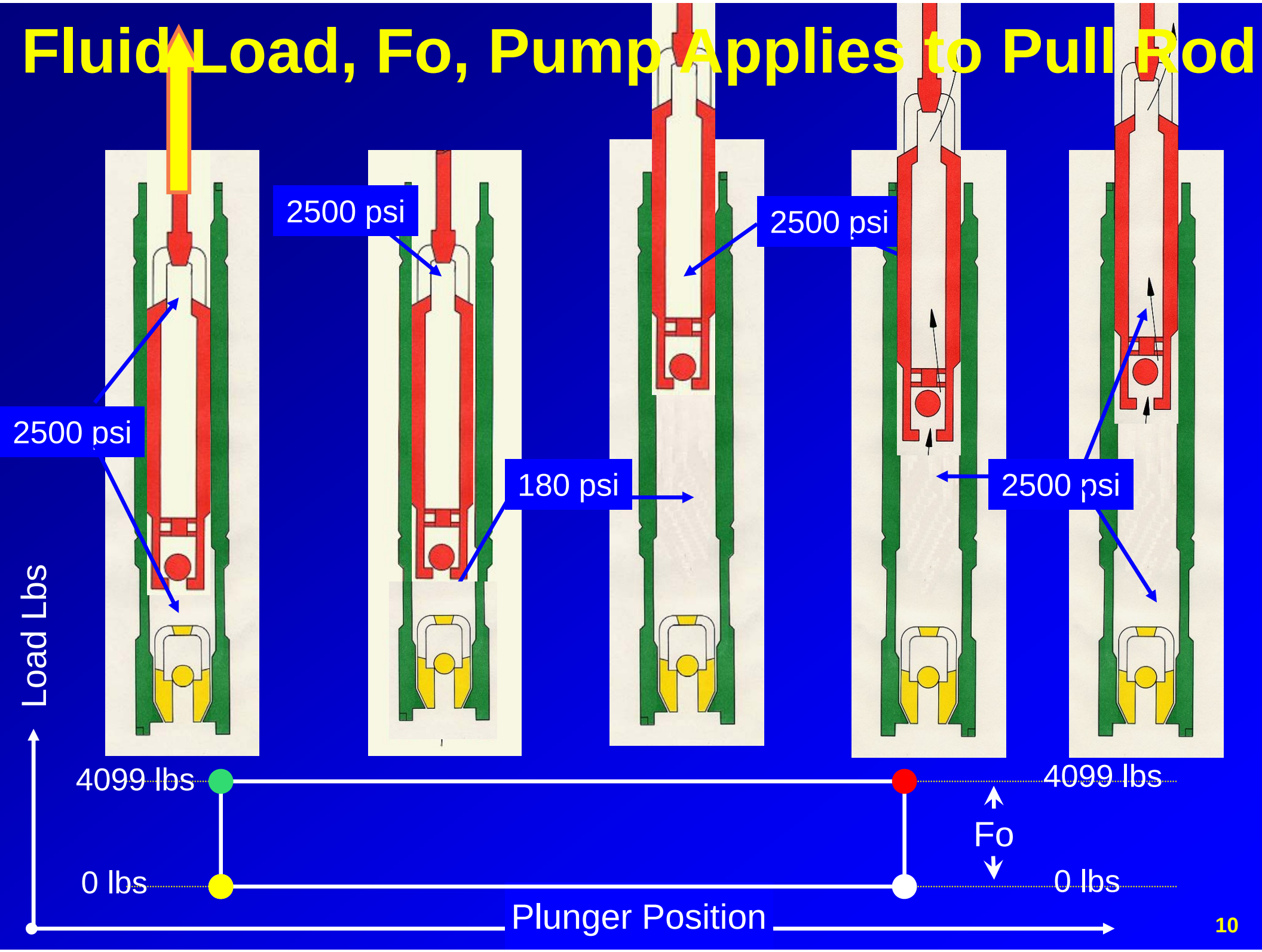


Unanchored Tubing – Full Pump



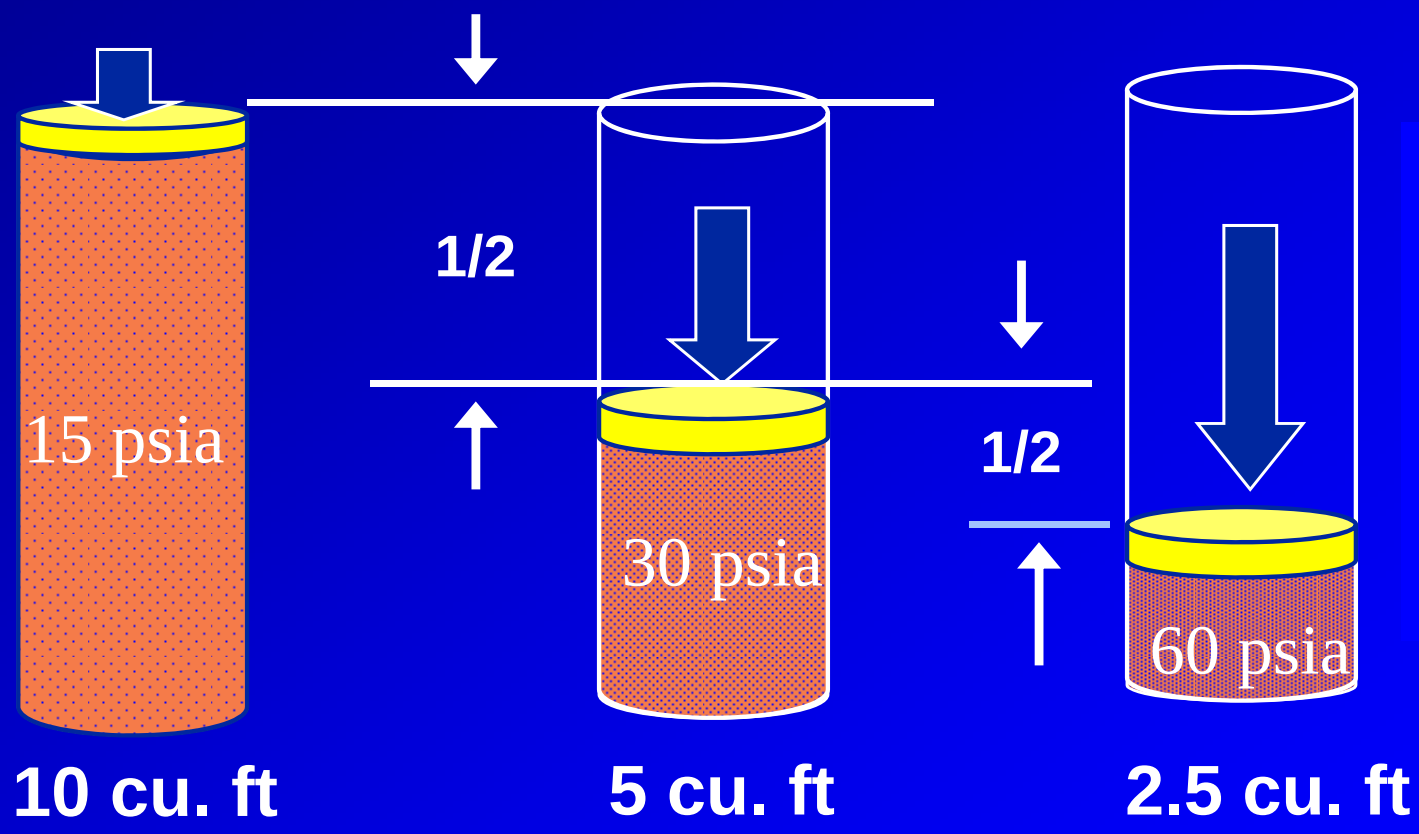
Echometer Online : Incomplete Pump Fillage : Anchored but NOT Set

Fluid Load, Fo, Pump Applies to Pull Rod



Behavior of Gas Inside Pump Chamber

Gases are much more compressible than liquids:
Large* change in volume is required to change pressure *significantly



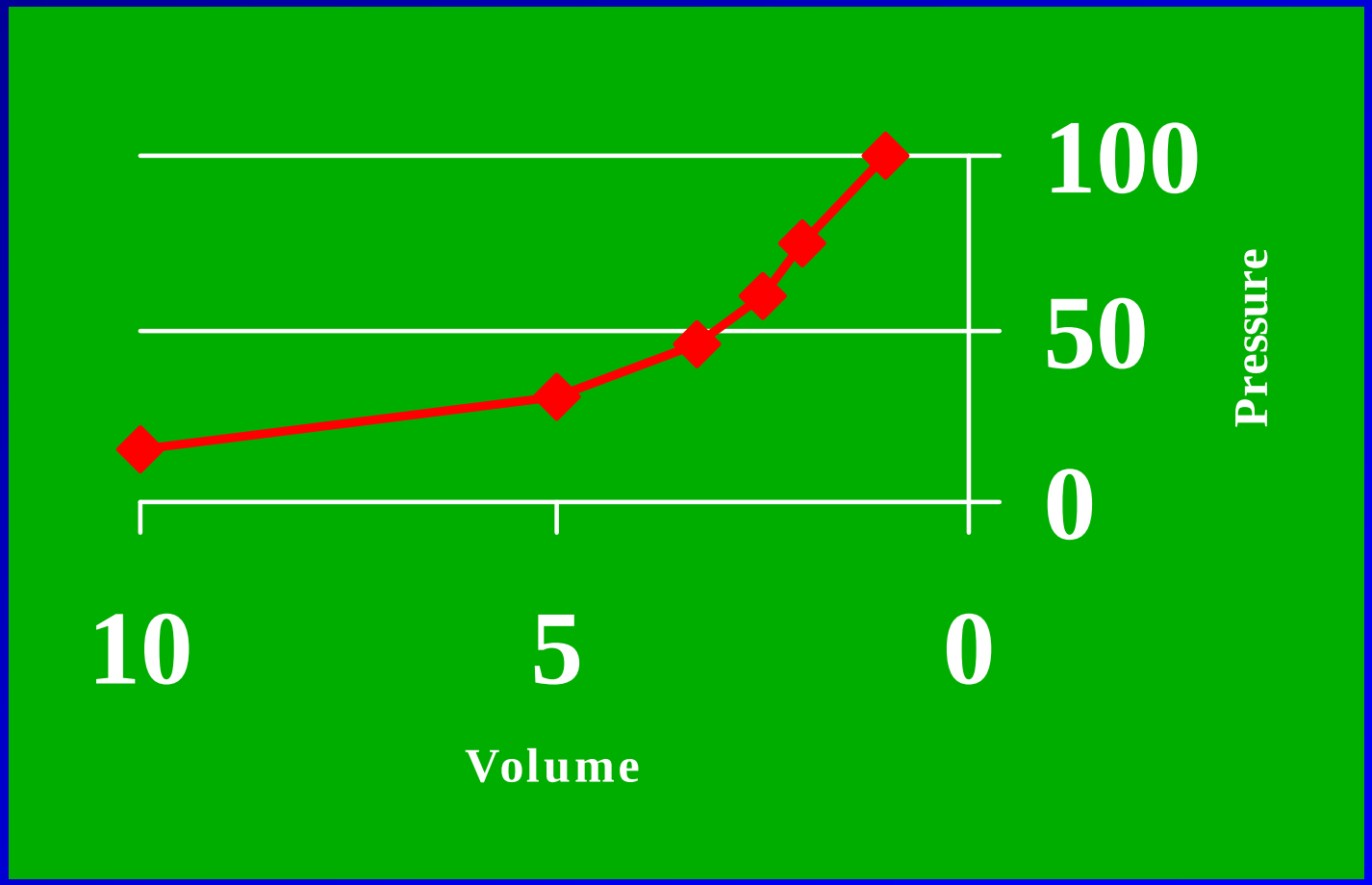
Plunger moves ½ the distance to bottom of the barrel and pressure only doubles

Compression of Gas at Constant Temperature

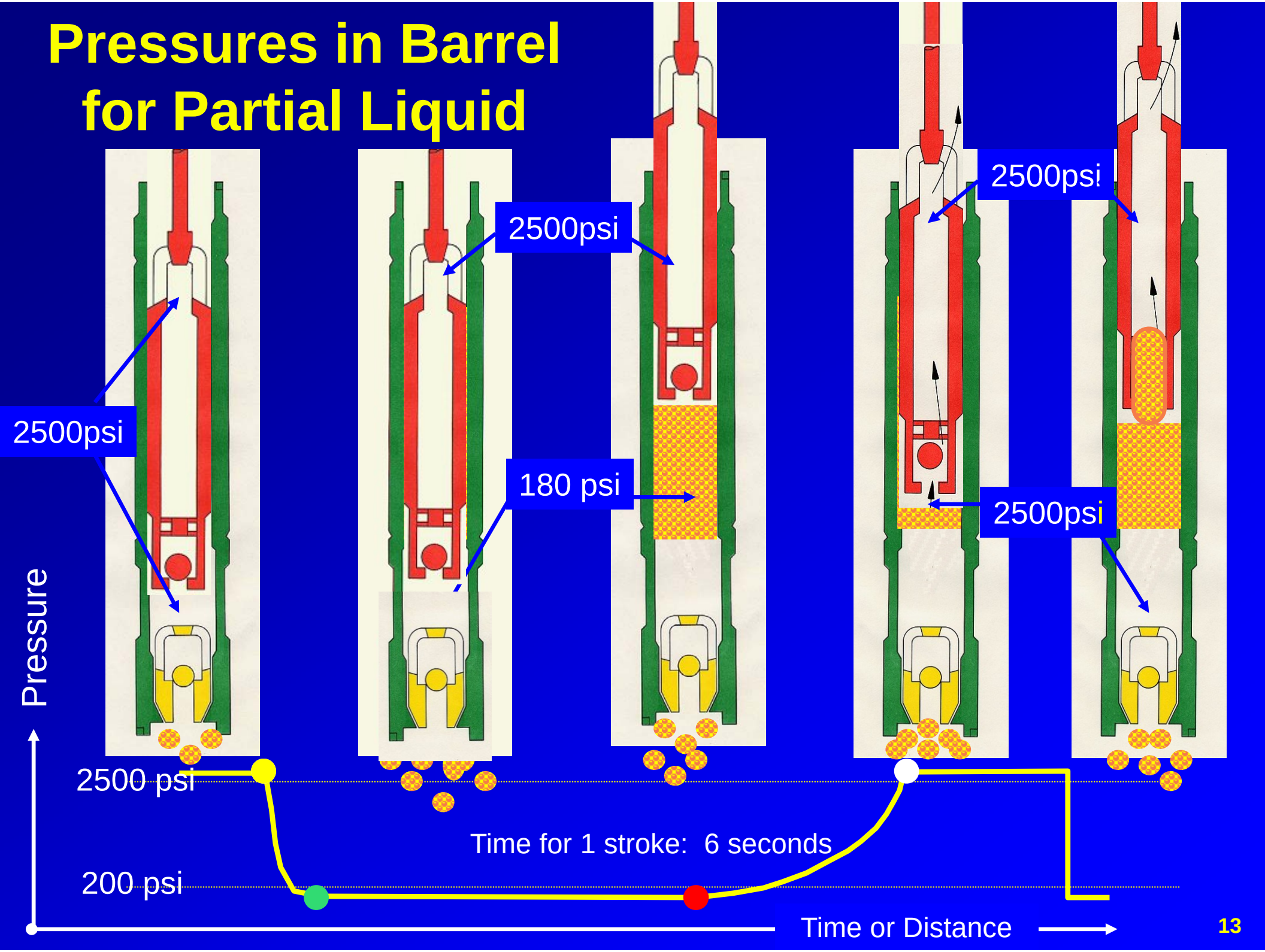
Gas Compression

Constant temperature, ideal gas

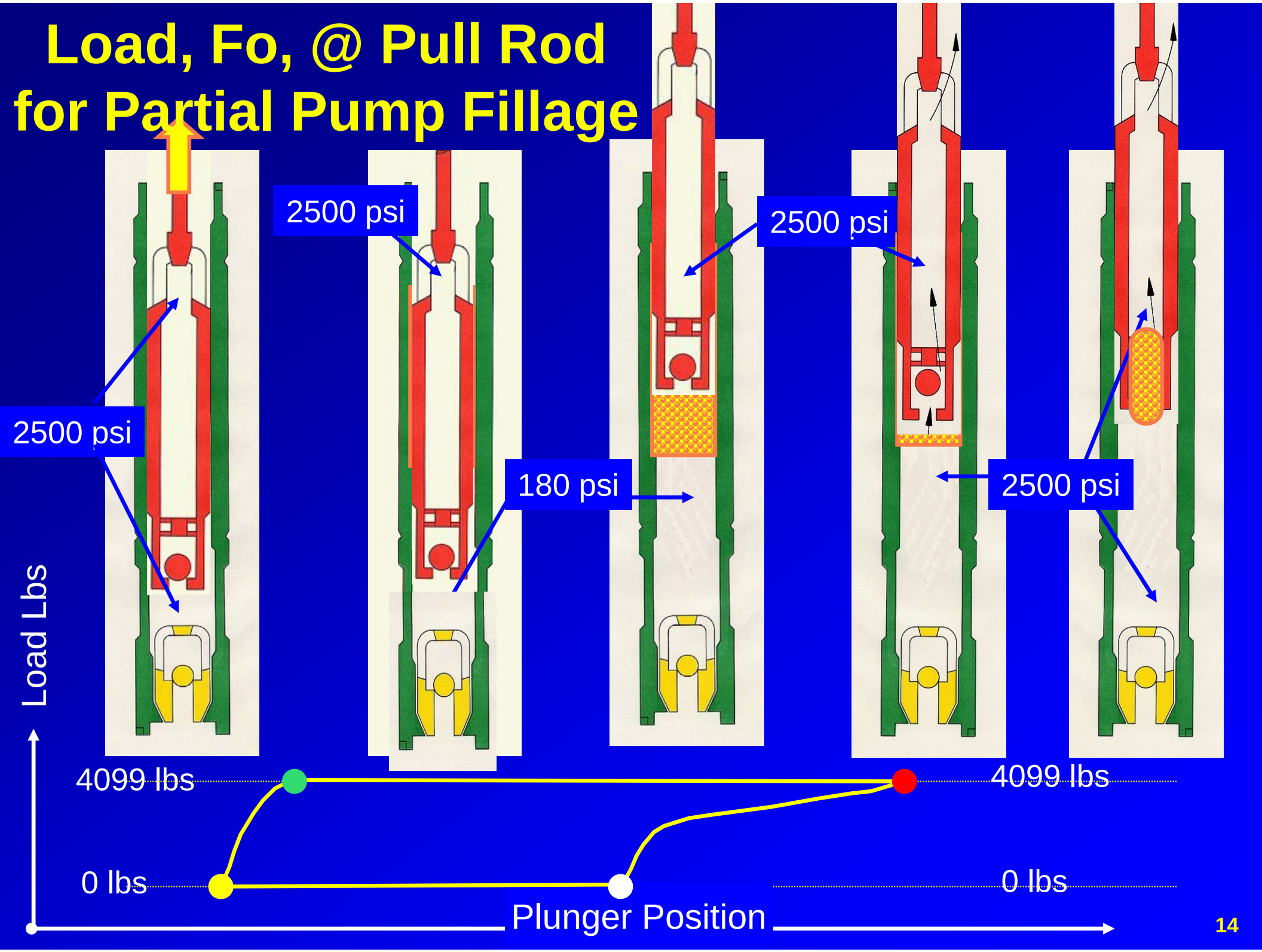
$$P_1 * V_1 = P_2 * V_2$$



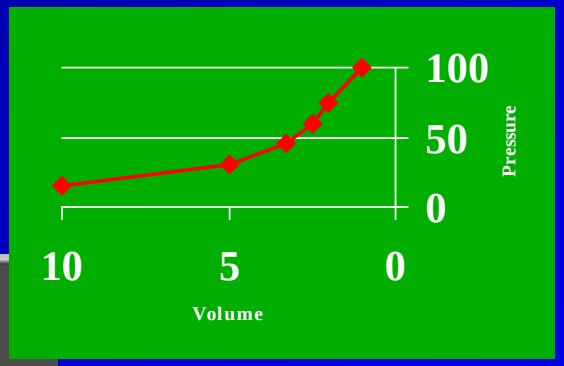
Pressures in Barrel for Partial Liquid

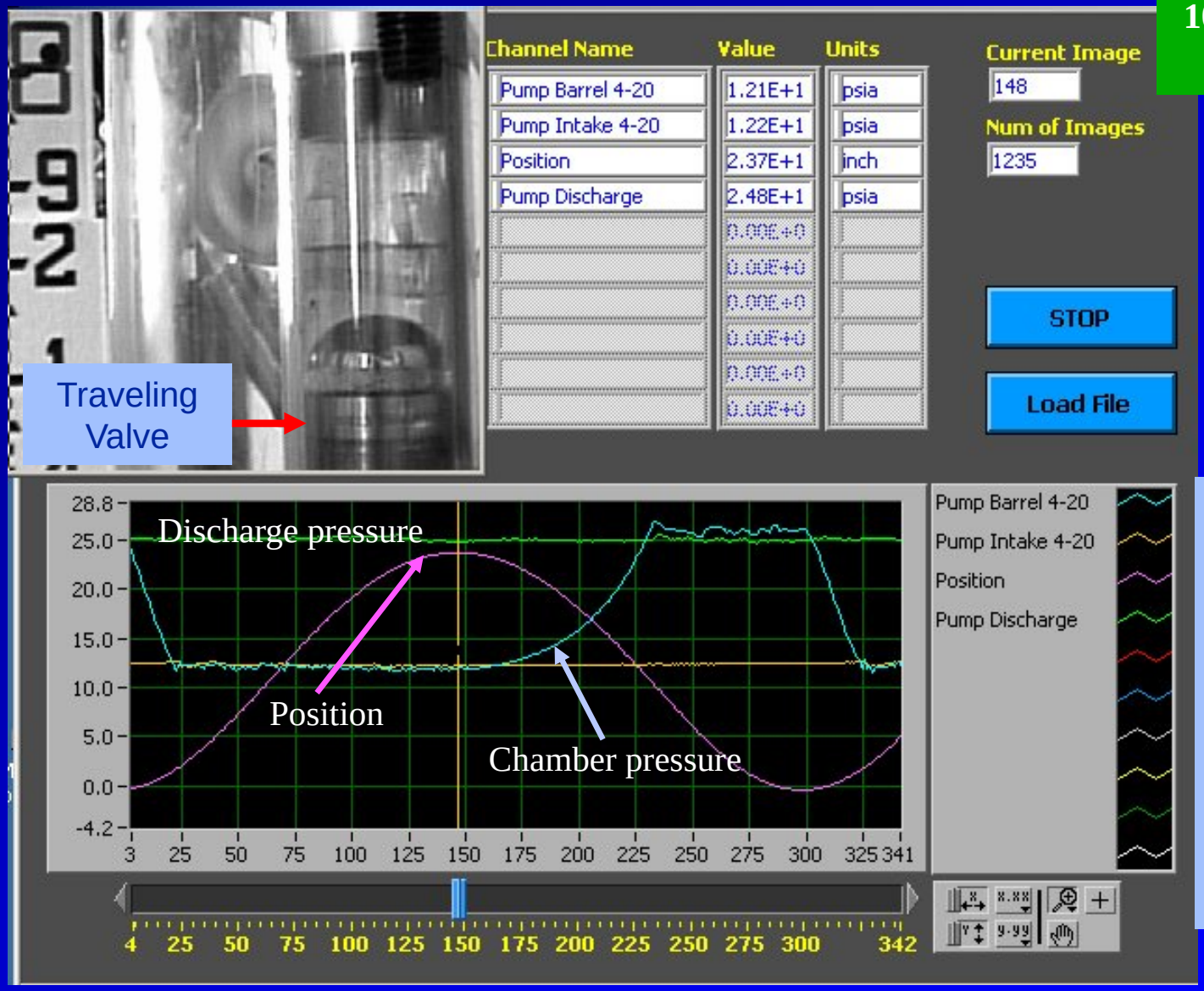


Load, Fo, @ Pull Rod for Partial Pump Fillage

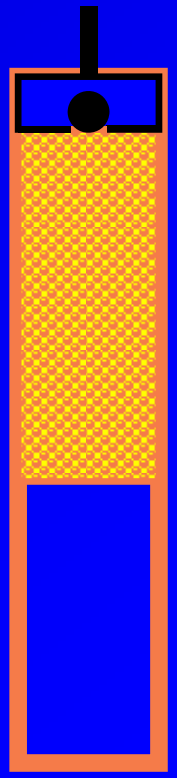


Compression Cycle

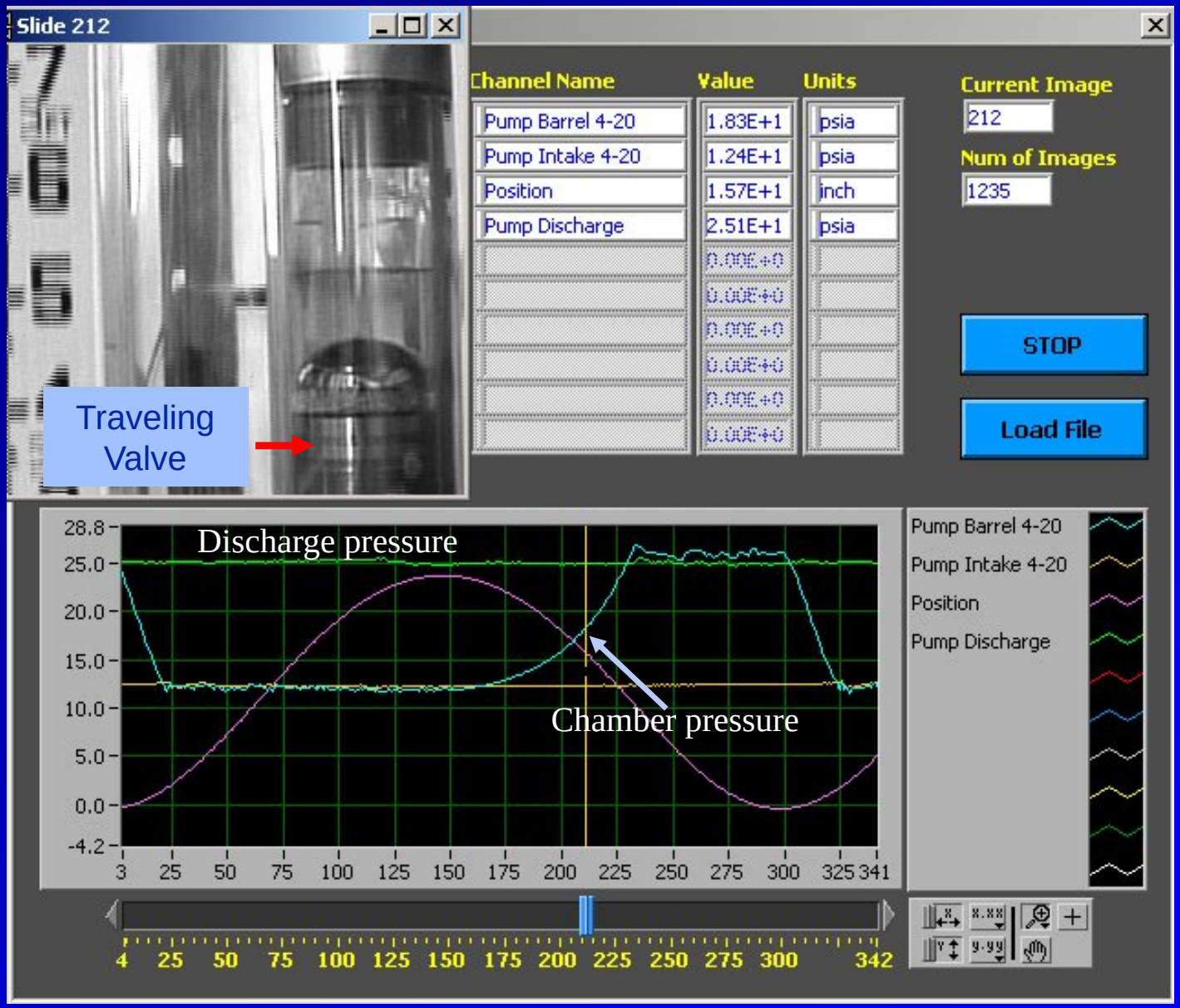




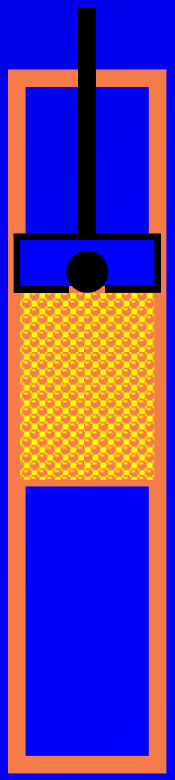
Plunger at top at 23.7 inch from bottom



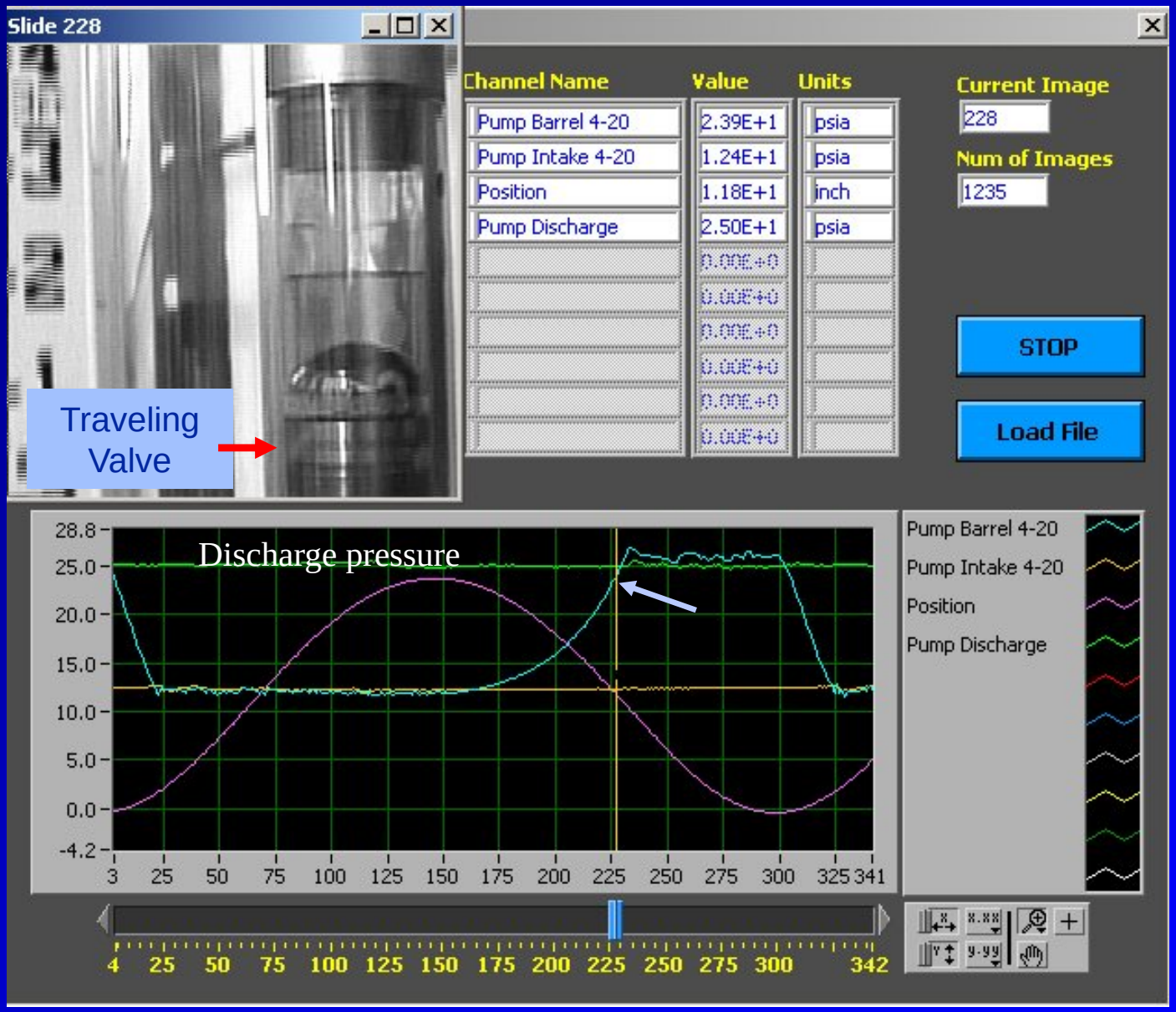
Downstroke



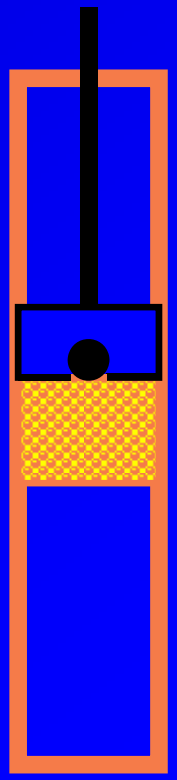
Plunger Falling and at 15.7 inch from bottom



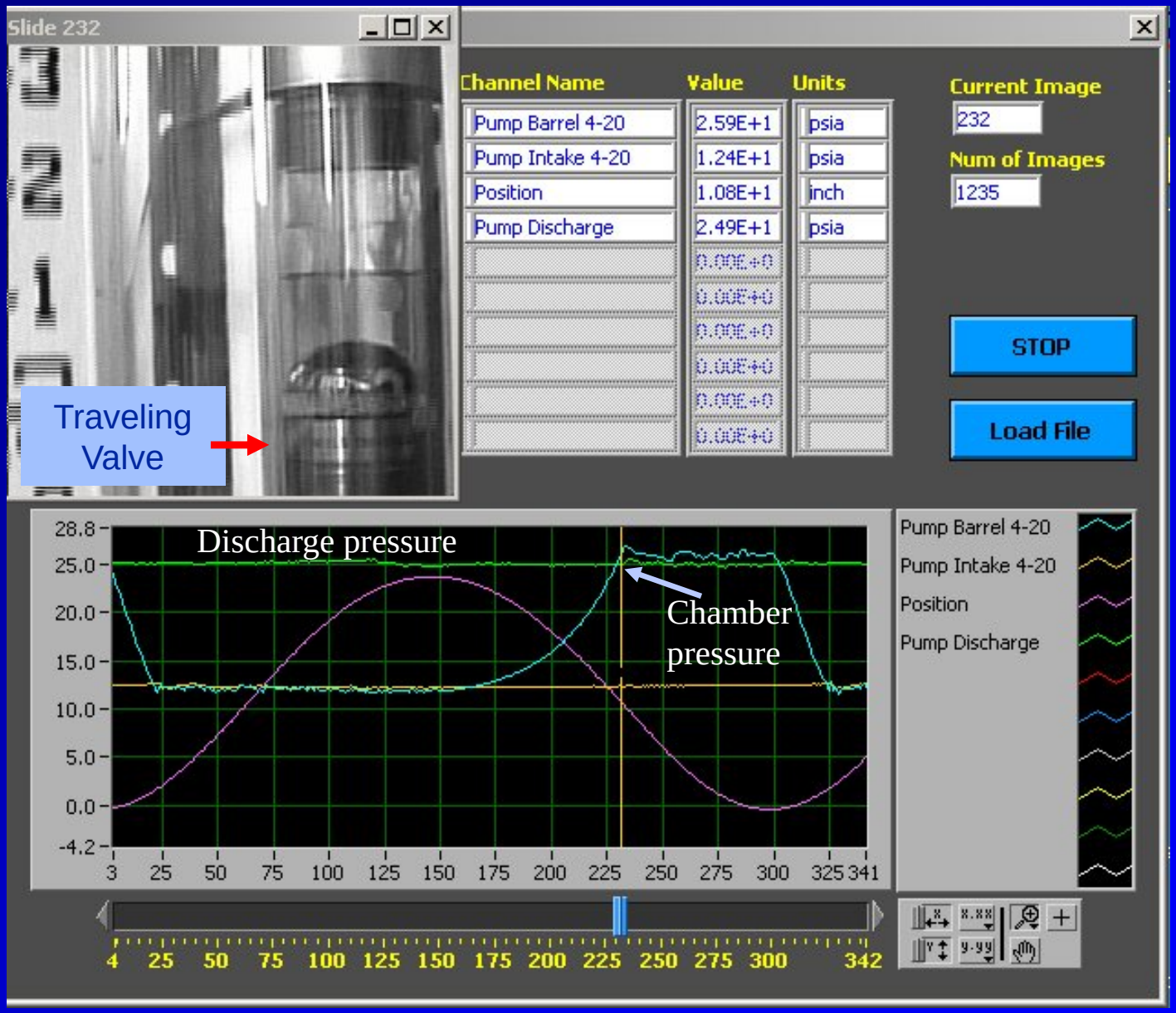
Downstroke



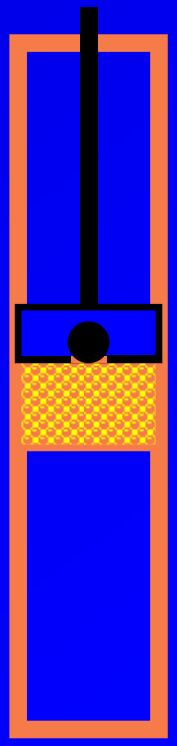
Plunger Falling and at 11.8 inch from bottom



Downstroke

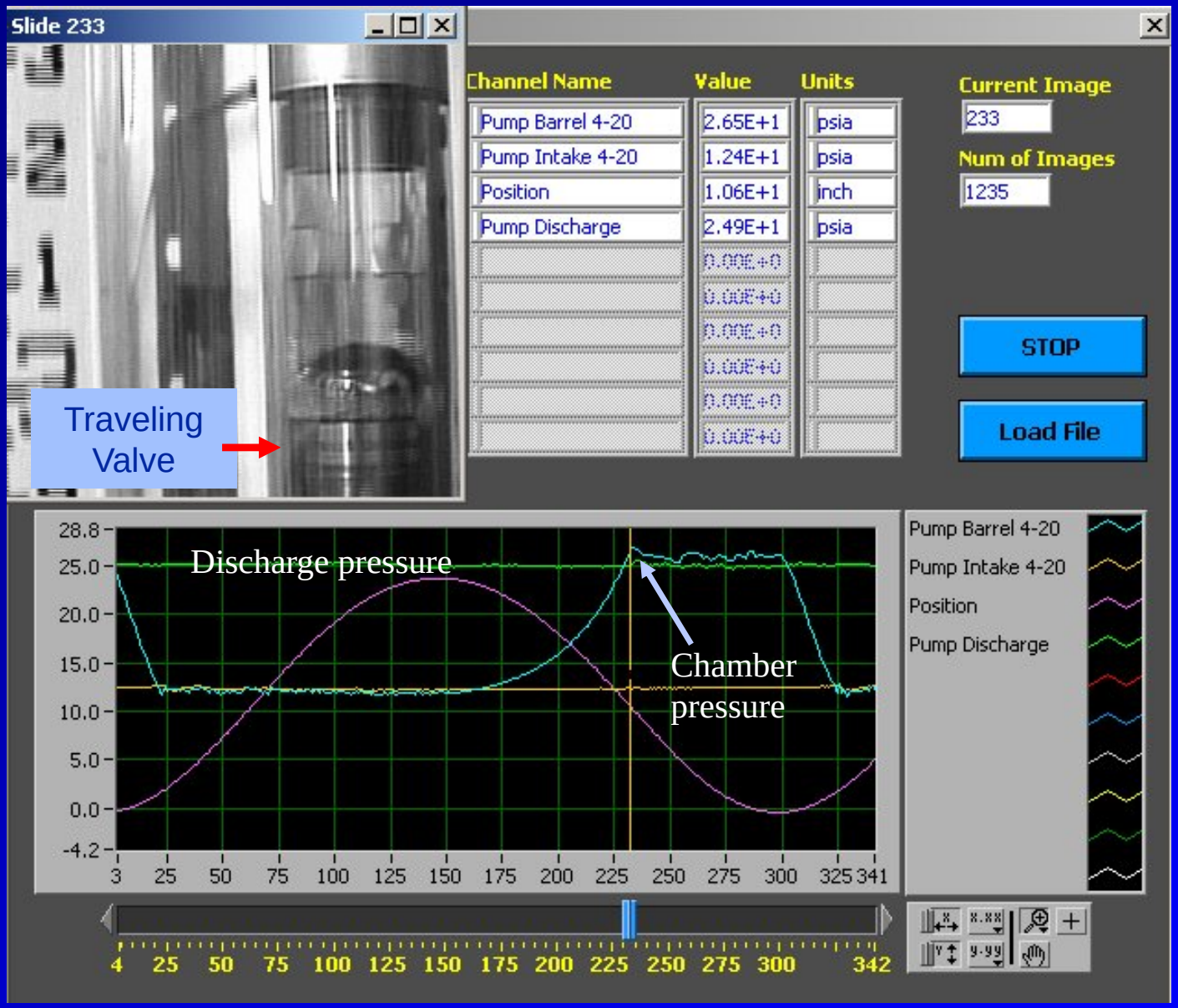


Plunger Falling and at 10.8 inch from bottom

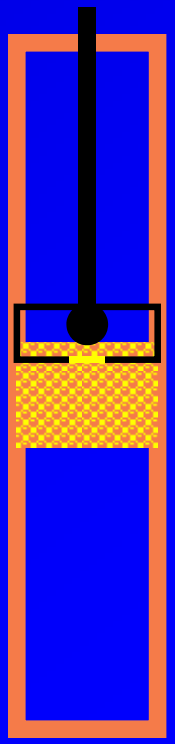


TV Beginning to Open

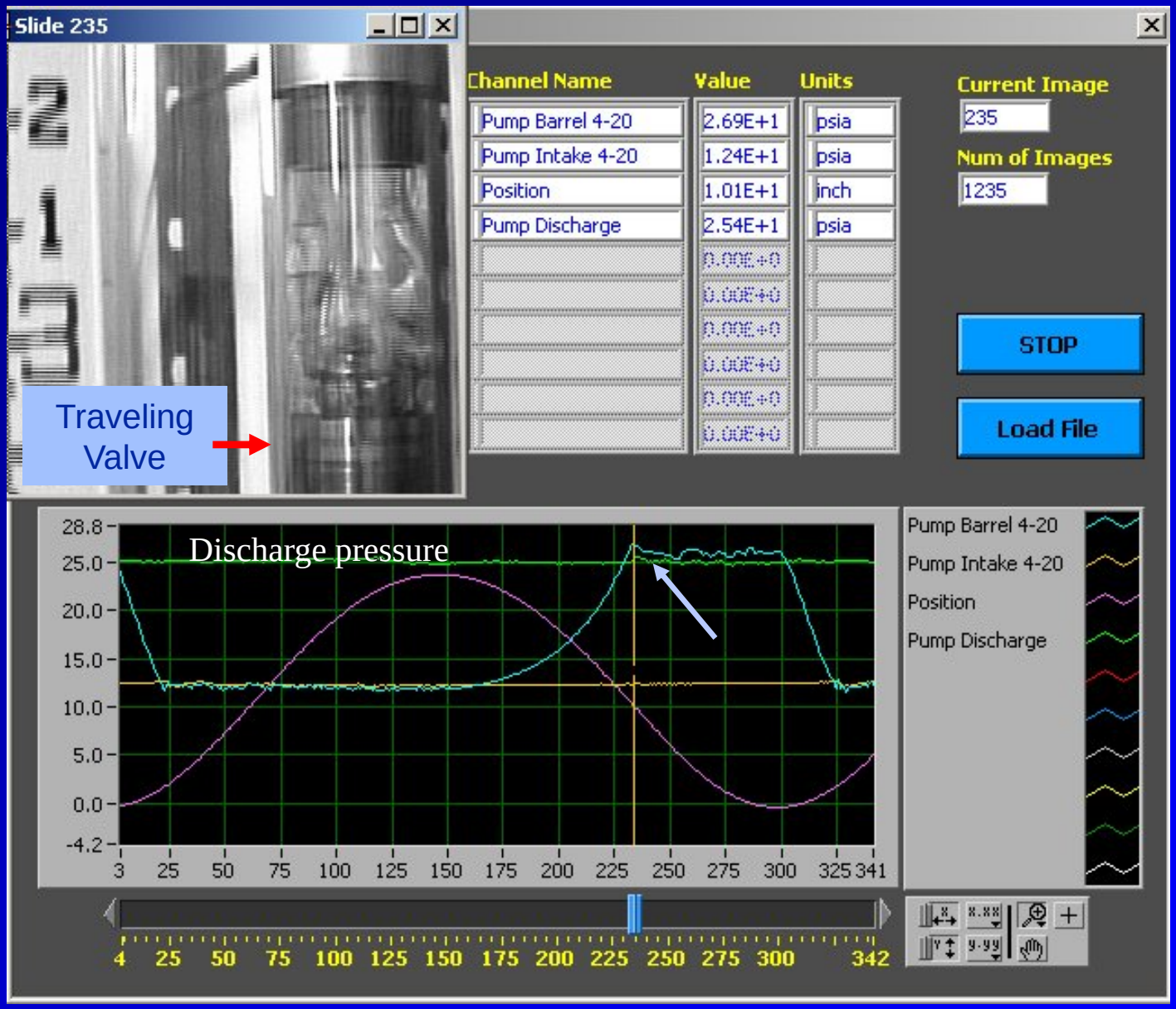
When Compression Creates Chamber pressure > Discharge pressure



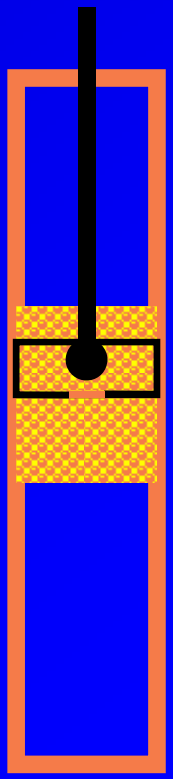
Plunger Falling and at 10.6 inch from bottom



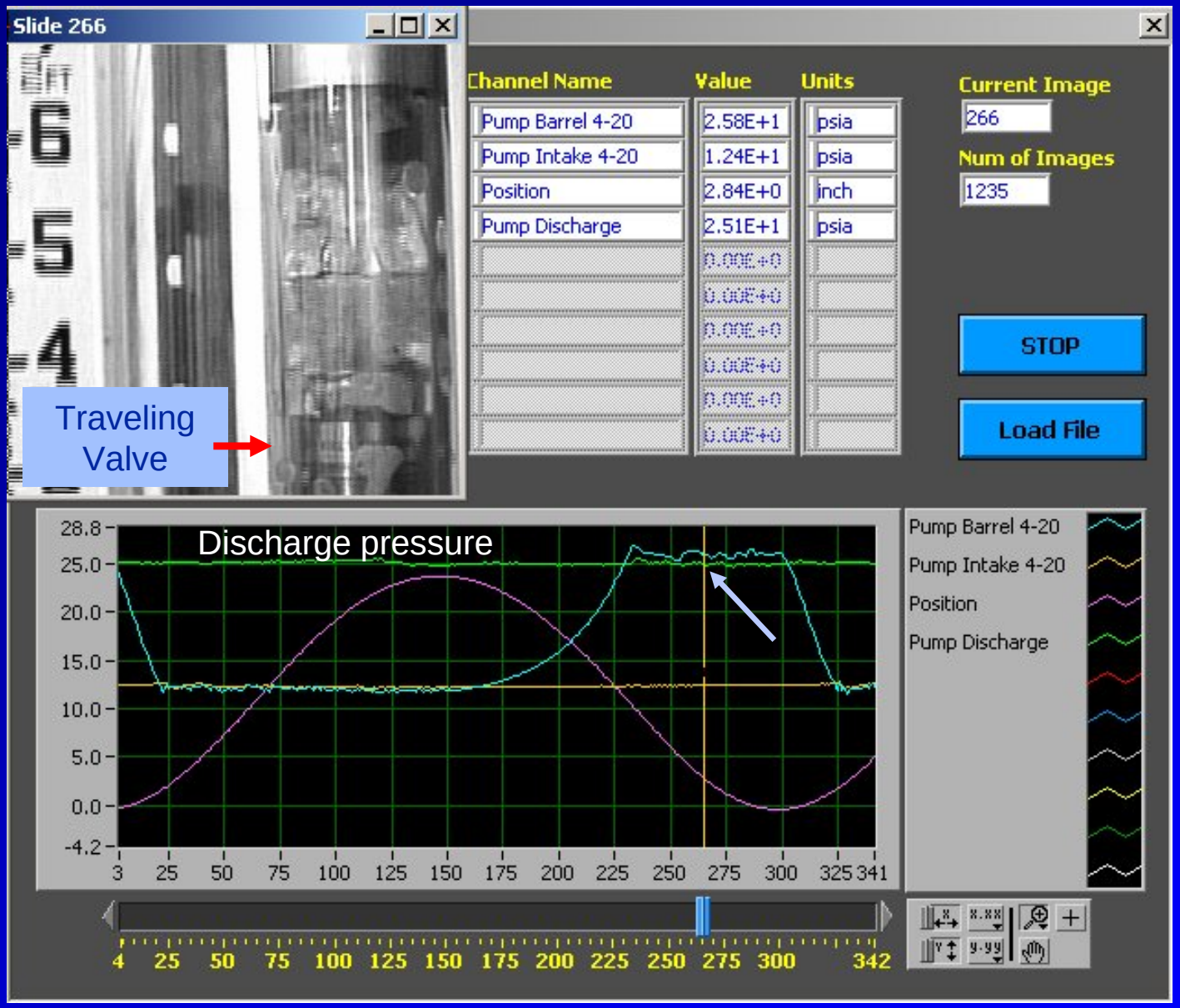
Gas Starts Flowing Through TV



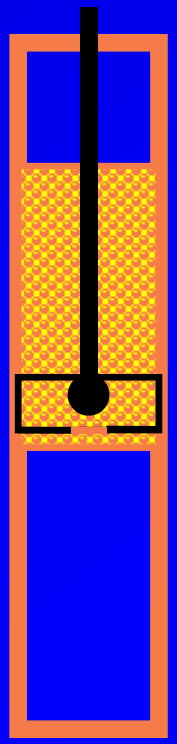
Plunger Falling and at 10.1 inch from bottom



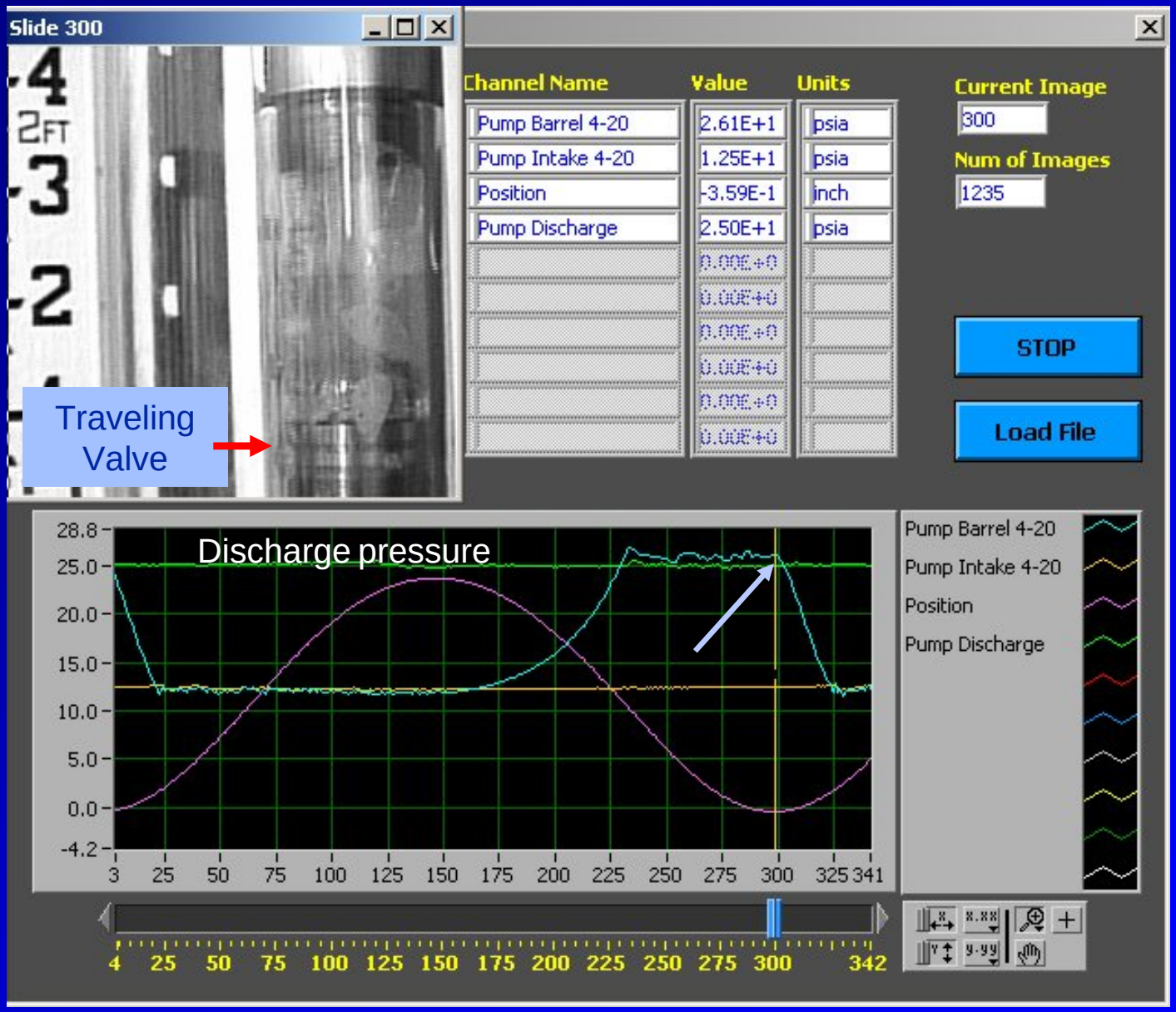
Gas Flow then Liquid Flow



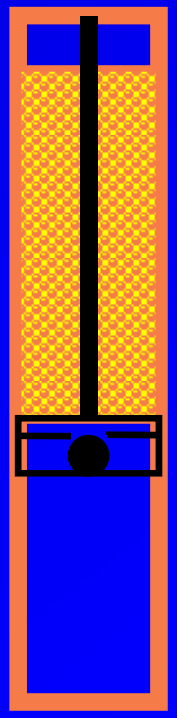
Plunger Falling and at 2.8 inch from bottom



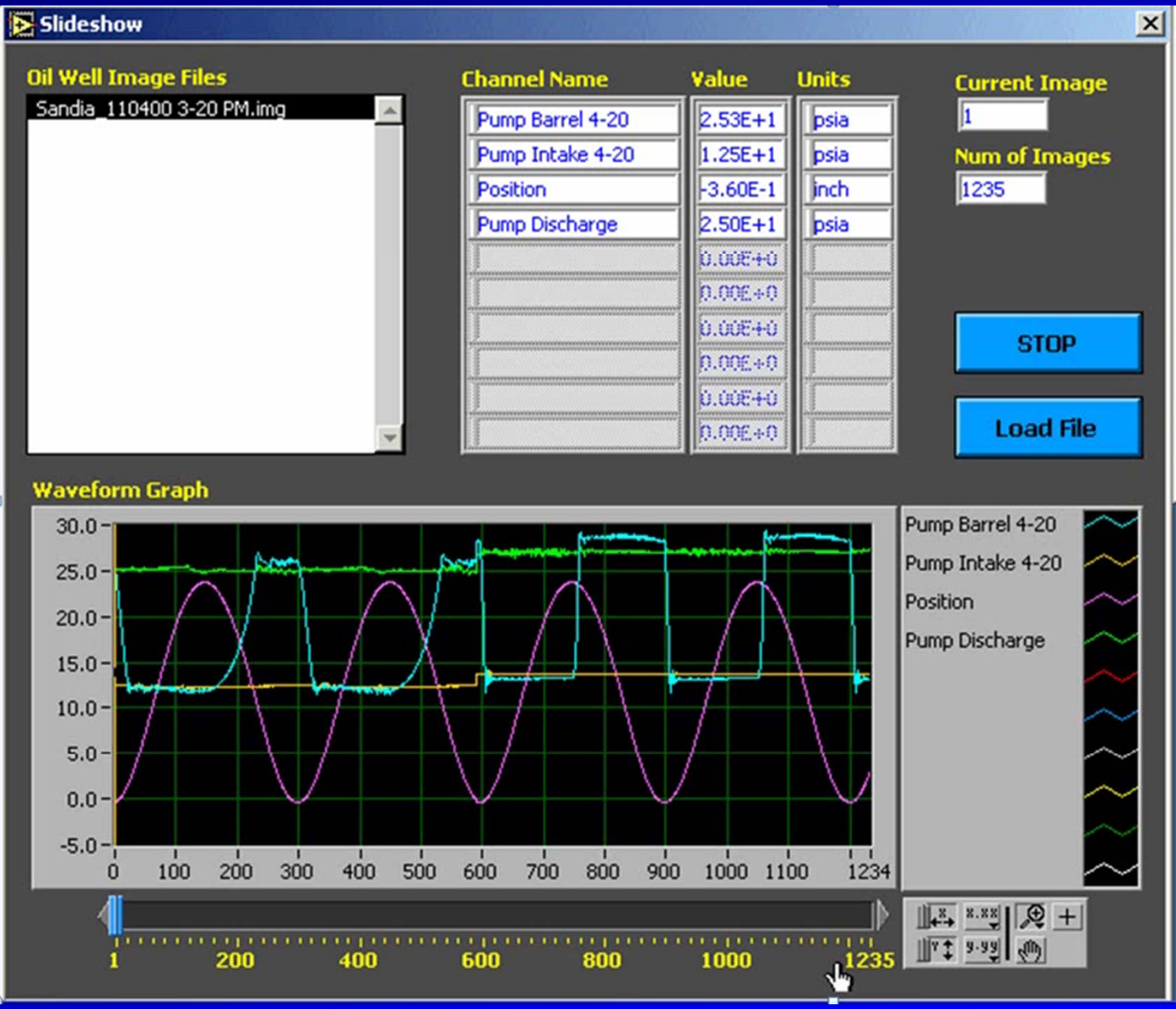
Bottom of Downstroke

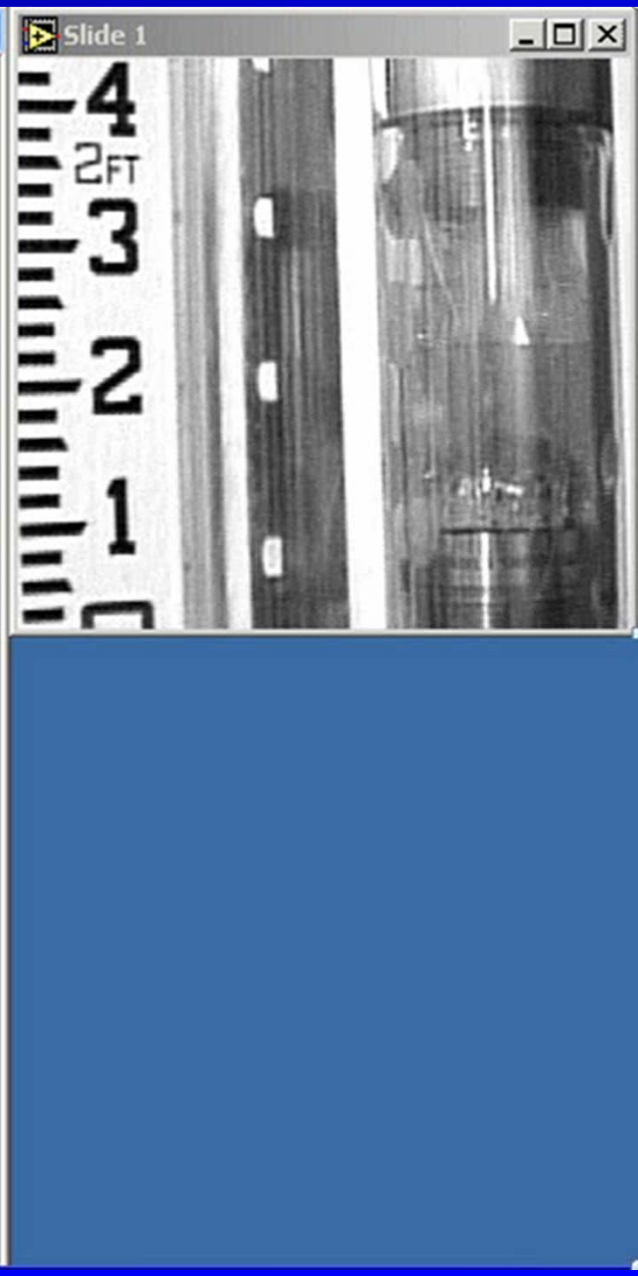


Plunger at bottom



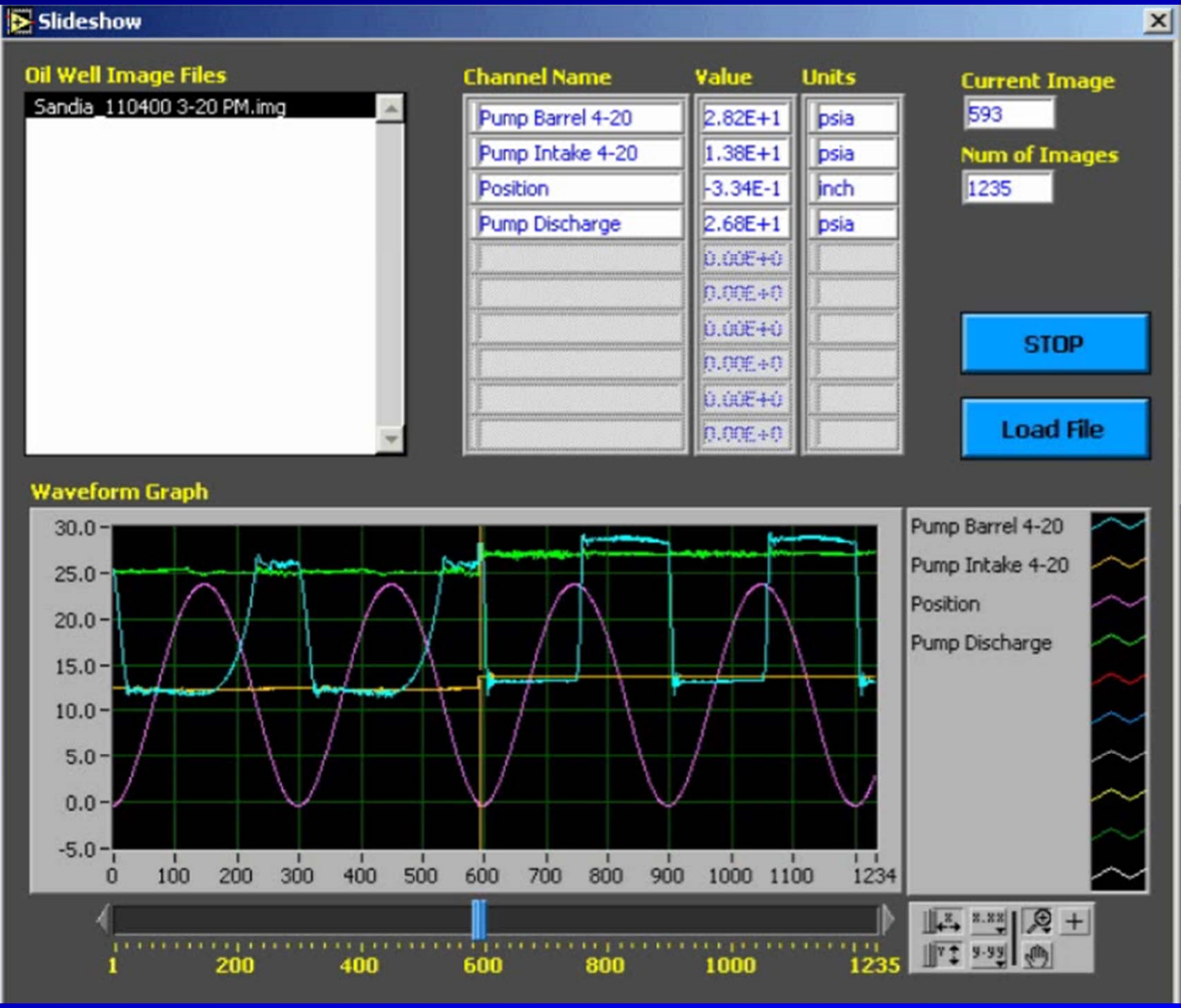
Pump Partially Filled With Gas





Pump_GasInterference.wmv

Pump Filled With Liquid



Pump_FilledWithLiquid.wmv

API Rod Pump Designation

PUMP DESIGNATION

The basic types of pumps and letter designation covered by this specification are as follows:

Type of Pump	Letter Designation: Metal Plunger Pumps, Heavy-Wall Barrel	Metal Plunger Pumps, Thin-Wall Barrel	Soft-packed Plunger Pumps, Heavy-Wall Barrel	Soft-packed Plunger Pumps, Thin-Wall Barrel
Rod Pumps				
Stationary Barrel, Top Anchor	RHA	RWA	.....	RSA
Stationary Barrel, Bottom Anchor	RHB	RWB	.....	RSB
Traveling Barrel, Bottom Anchor	RHT	RWT	.....	RST
Tubing Pumps	TH	.....	TP	.....

Complete pump designations include: (1) nominal tubing size, (2) basic bore diameter, (3) type of pump, including type of barrel and location and type of seating assembly, (4) barrel length, (5) plunger length, and (6) total length of extensions when used, as follows:

XX - XXX X X X X X - X - X

- Total length of extensions, whole feet.
- Nominal plunger length, feet.
- Barrel length, feet.
- Type seating assembly; C — Cup type; M — Mechanical type
- Location of seating assembly; A — Top; B — Bottom; T — Bottom, traveling barrel
- Type barrel; H — Heavy-wall, W — Thin-wall (For metal plunger pumps); S — Thin-wall, P — Heavy-wall (For soft-packed plunger pumps)
- Type pump; R — Rod; T — Tubing
- Pump bore (basic): 125 — 1¼ in. (31.8 mm); 150 — 1½ in. (38.1 mm); 175 — 1¾ in. (44.5 mm); 178 — 1 25/32 in. (45.2 mm); 200 — 2 in. (50.8 mm); 225 — 2¼ in. (57.2 mm); 250 — 2½ in. (63.5 mm); 275 — 2¾ in. (69.9 mm)
- Tubing size; 15 — 1.900 in. OD. (48.3 mm); 20 — 2⅜ in. OD. (60.3 mm); 25 — 2⅞ in. OD. (73.0 mm); 30 — 3½ in. OD. (88.9 mm)

Example: A 1¼ in. (31.8 mm) bore rod type pump with a 10 ft. (3.048 m) heavy wall barrel and 2 ft. (0.610 m) of extensions, a 4 ft. (1.219 m) plunger, and a bottom cup type seating assembly for operation in 2-3/8 in (60.3 mm) tubing, would be designated as follows:

20-125 RHBC 10-4-2

20-125 RHBC 10-4-2

2-3/8 Tubing

1-1/4 Bore

Rod Heavy Bottom Cup

10 ft long barrel

4 ft plunger

2 ft extension

Echometer Online : Incomplete Pump Fillage : Normal Dyno

(((ECHOMETER)))

Setup Hardware

Base not connected

Pick Well

Normal Dyno

Gun

LL: 2355 ft

Production: 01/01/00
77 BOPD
487 BWPD

LL:06/07/00 01:38:55PM

Zoom | Edit

HT 1074 | Optional | Optional

Quick View | Detailed View

02/16/02
06:03:42PM

New | Delete | Insert Version | Change Version Date

Well Conditions | Mechanical Wellbore | Lift System | Survey | Producing Interval | Tubular Markers | Well Description

Lift System Type

Select Lift System: Rod Pump

Surface Unit and Torque | Prime Mover | Rod String and Pump

Polished Rod

Polished Rod Diameter ___ in

API Pump Designation

Tubing Size

25 | 225 | T | H | B | M | 22 | 4 | 0 | 0

Done

Pump

Intake Depth: 4836.0 ft

Pump Run Date: 2/16/2002

API Pump Designation

25-225 THBM 22-4

Pump Length: 22.0 ft

Plunger Length: 48.000 in

Plunger Diameter: 2.250 in

Plunger Clearance: 0.003 in

Type:
- Top Hold Down
- Bottom Hold Down
- Tubing Pump
- Traveling Barrel

Change Template... | Summary | Undo | Save | Close

Help

363 psi (g)

0 20 40 60 80 100 120 140 160

Stroke: 5 00:00:45

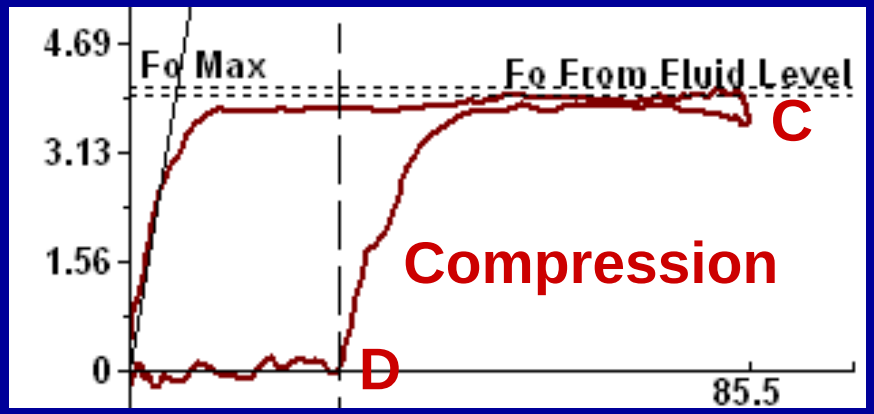
Unanchored Kt 924 lb/in

Kr 321 lb/in

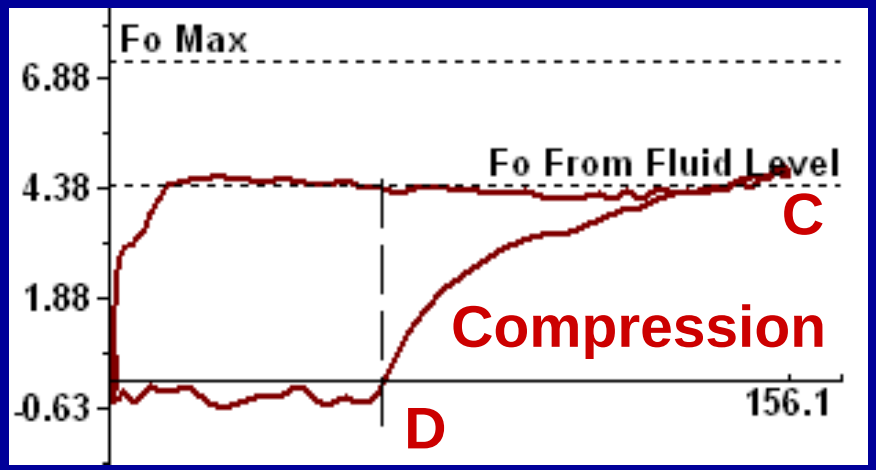
Incomplete Pump Fillage

The 3 Main Causes of Incomplete Lquid Pump Fillage

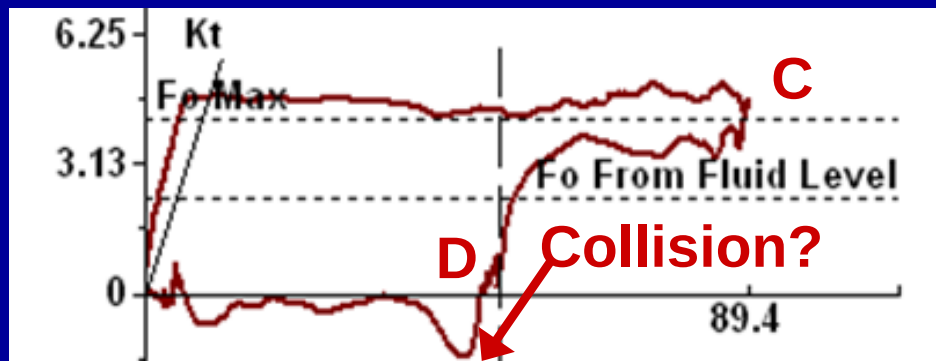
1. **<u>Fluid Pound</u> - Not enough liquid to fill the pump barrel: well inflow less than pump displacement, pumped off.**



2. **<u>Gas Interference</u> - Both gas and liquid at pump intake pressure fill pump barrel during the upstroke.**



3. **<u>Flow into pump intake choked</u> - flow through SV is zero or less than plunger displacement.**



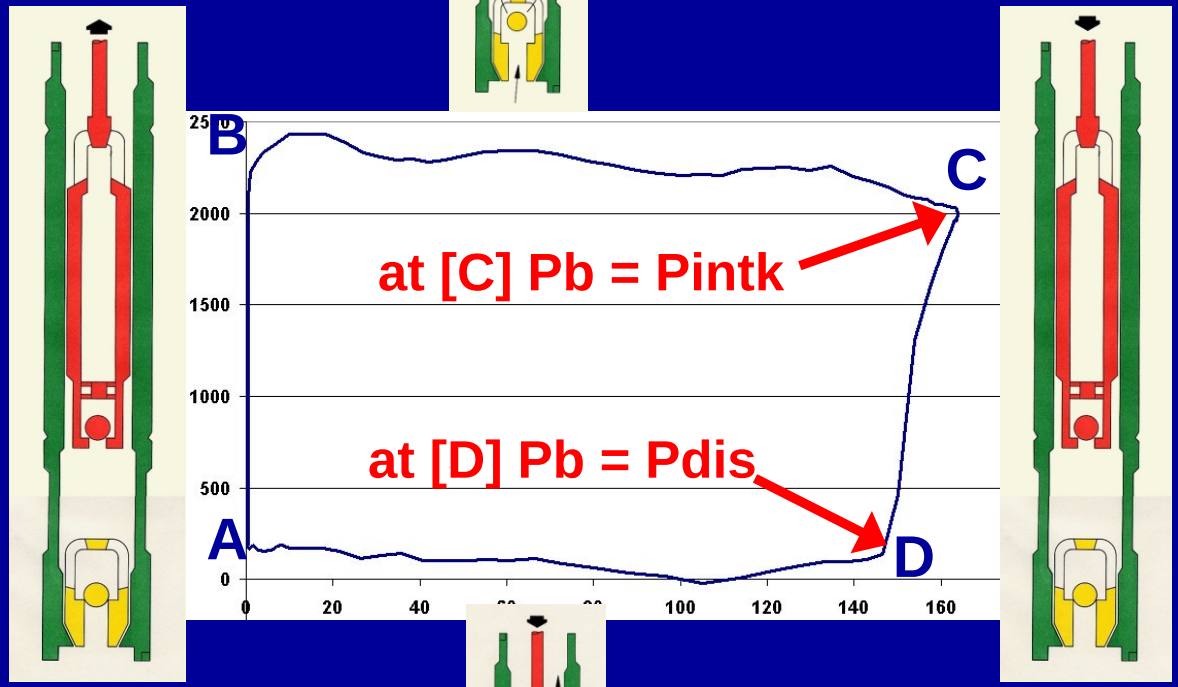
Incomplete Pump Fillage

Occurs from C to D on Pump Card

Steps C - D in Pump Operation

Pump is a Compressor

PDis - Discharge Pressure
PB - Pressure in Barrel
Pintk - Intake Pressure

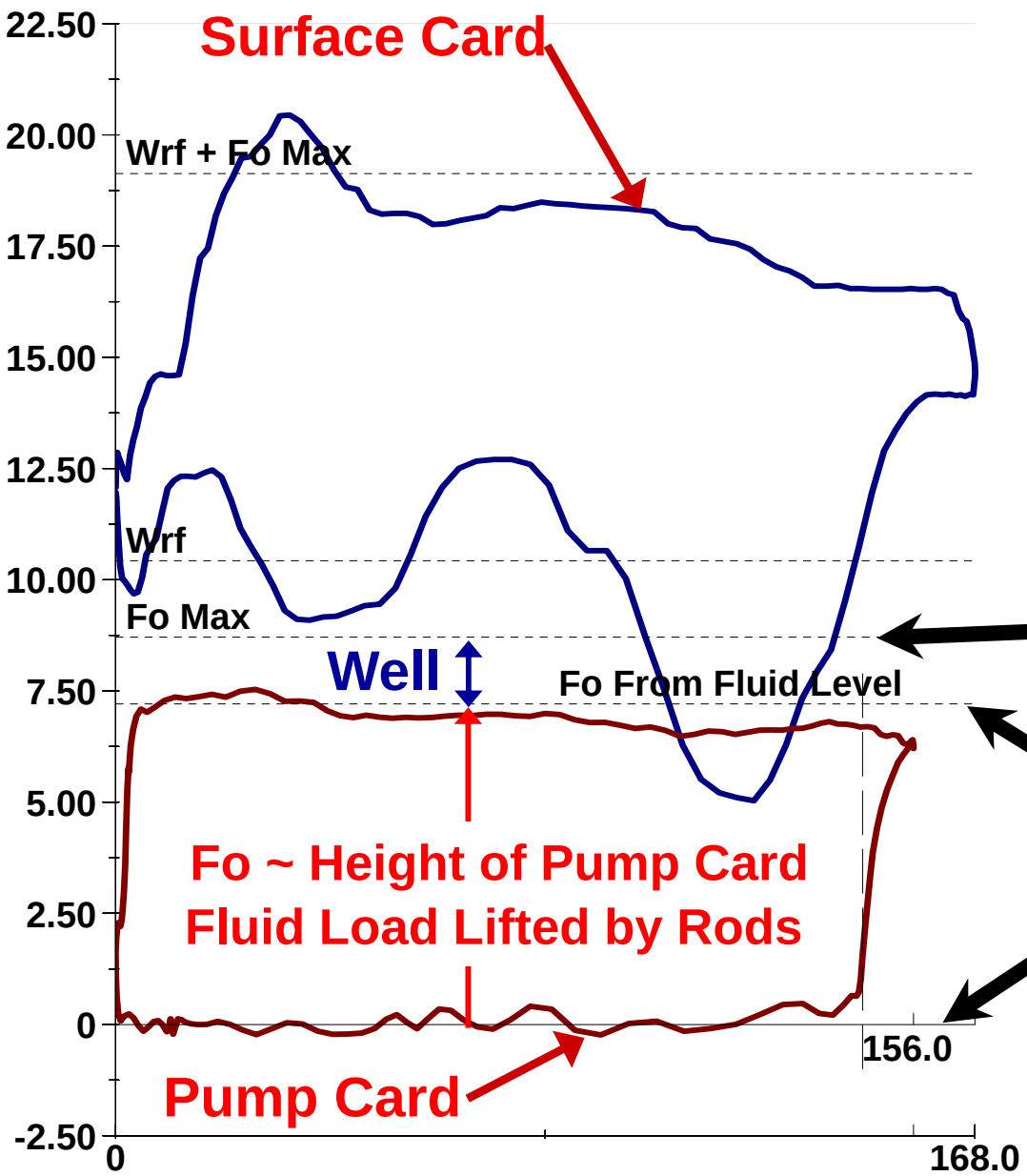


C) Standing Valve closes, when plunger reaches top of stroke, rods start to un-stretch to transfer fluid load, Fo, from rods [C] onto tubing [D].

D) Standing valve Opens when pressure in pump barrel >= Pump Discharge Pressure, PDis.

C-D) Plunger applies pressure to fluids inside pump barrel, to compress fluids in Pump barrel and increase pressure.

Pump Card Rests on Zero Load Line on Down Stroke. Pump Card Near Fo From Fluid Level on Up Stroke.



Calculated Pump Card Loads:

SV Open Upstroke:

Fo Max = (Pdis – 0)*Ap

Fo = (Pdis - Pintk)*Ap

TV Open Downstroke:

Fo = 0

Pump Card Reference Lines:

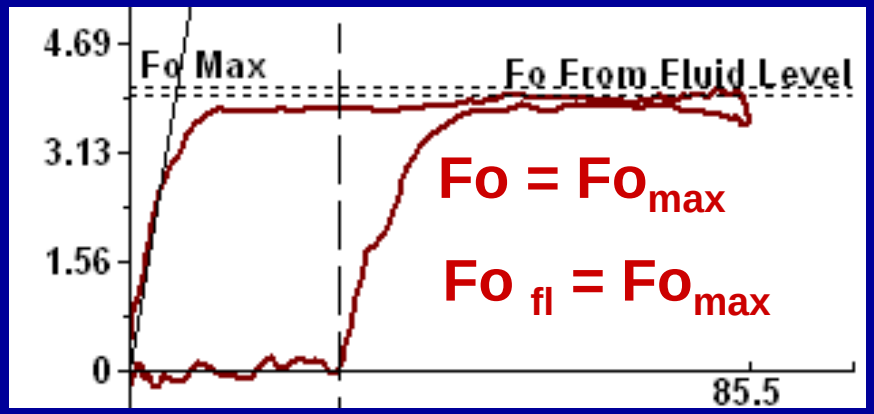
1. ***Fo Max*** **- assumes pump intake pressure is zero, where well provides no help in lifting the fluid to the surface.**
2. ***Fo From Fluid Level*** **- assumes pump intake pressure determined from fluid level shot, where well's PIP provides help in lifting the fluid.**
3. ***Zero Load Line*** **– assumes pressure above and below the plunger are equal; no friction due to fluid displacing through SV on down stroke**

Echometer Online : Incomplete Pump Fillage : Normal Dyno

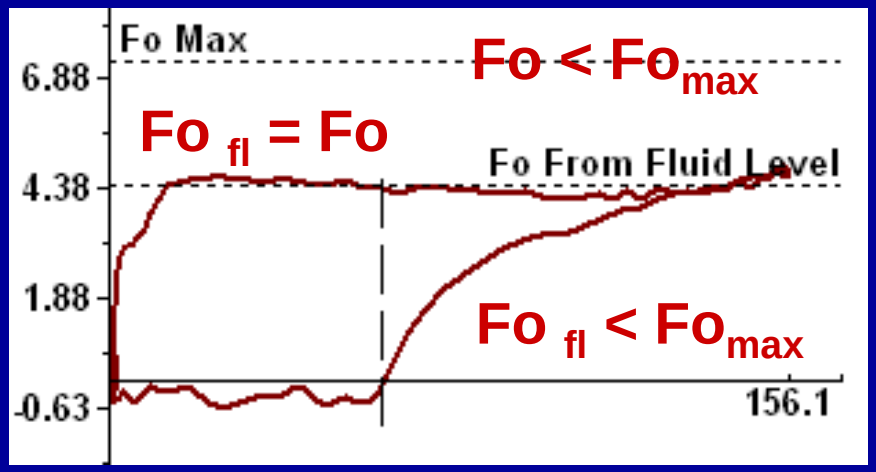
Fo loads measured Dynamometer or calculated From Fluid Level.

Incomplete Pump Fillage

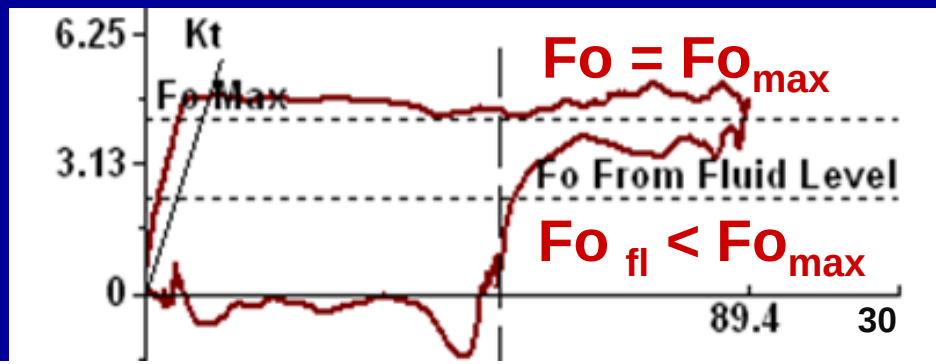
1. <u>Fluid Pound</u> – Rod Loading is Fomax, Pintk is low, Pb = Pintk.



2. <u>Gas Interference</u> - Rod Loading is Fo fl, Pintk is high, Pb = Pintk.



3. <u>Flow into pump intake choked</u> - Rod Loading is Fomax, Pintk is high, Pb = Zero (0); much << Pintk.

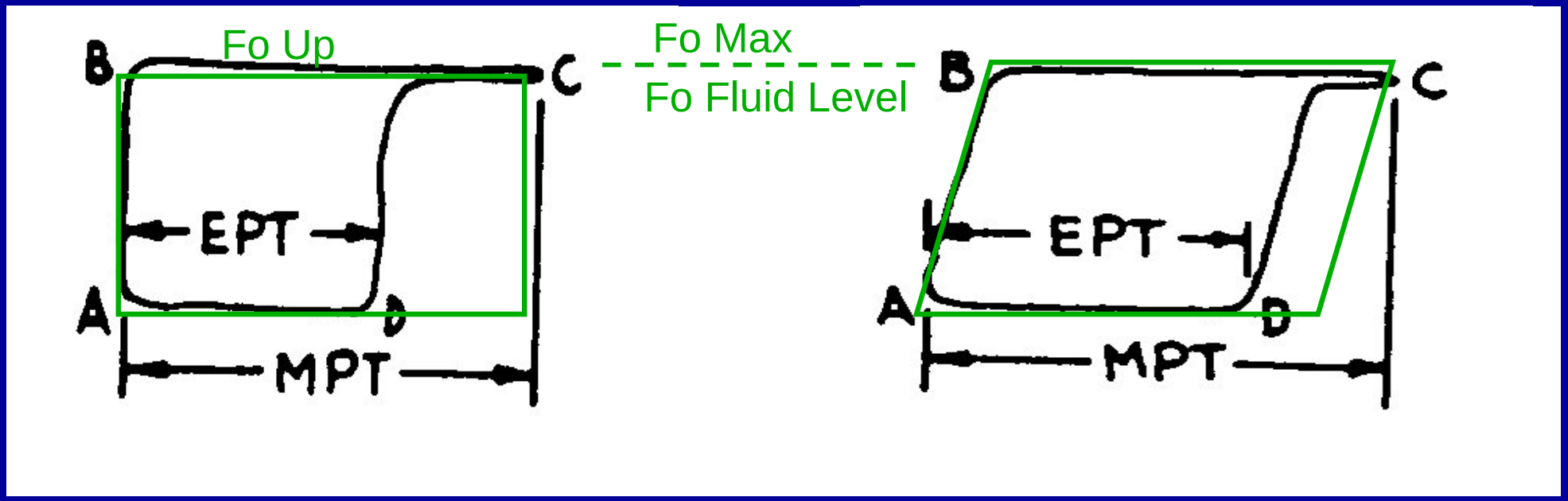


#1 Cause: Pumped Off ~ PIP is Low

Not enough liquid to fill the pump chamber: well's liquid inflow rate less than net pump displacement

Tubing anchored, EPT<MPT.

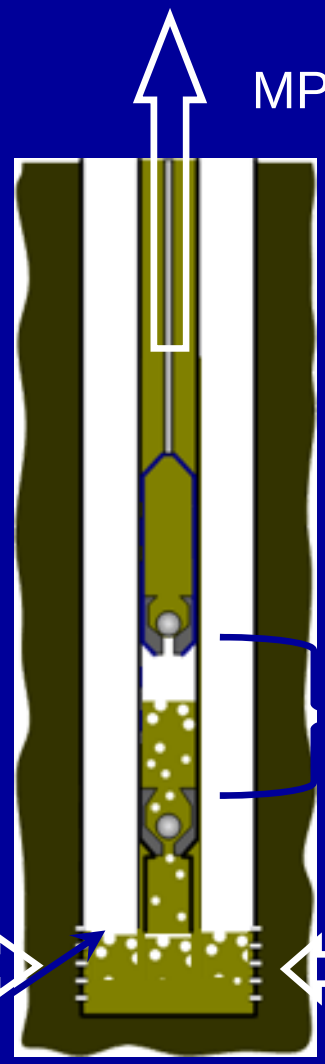
Unanchored tubing, EPT<MPT



Well is pumped off. Pump components are functioning properly. BUT, sudden unloading fluid load off rods results in rod slap, wear, pin breaks and reduced equipment life! Shoot fluid level to verify pump intake not blocked and fluid level at pump intake.

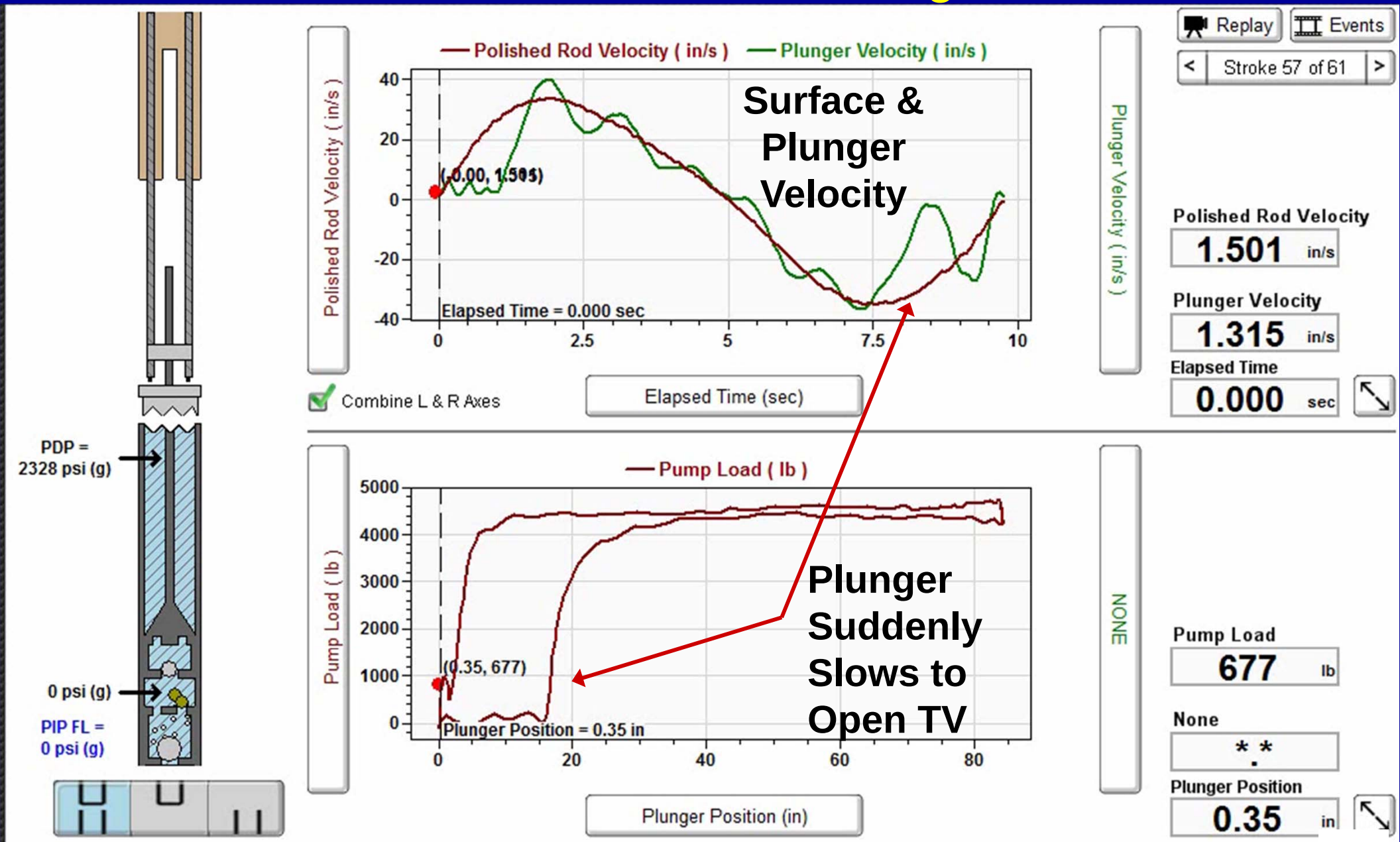
Partial Liquid Fillage due to Pump-off

Formation max liquid inflow is less than the Maximum Pump Displacement

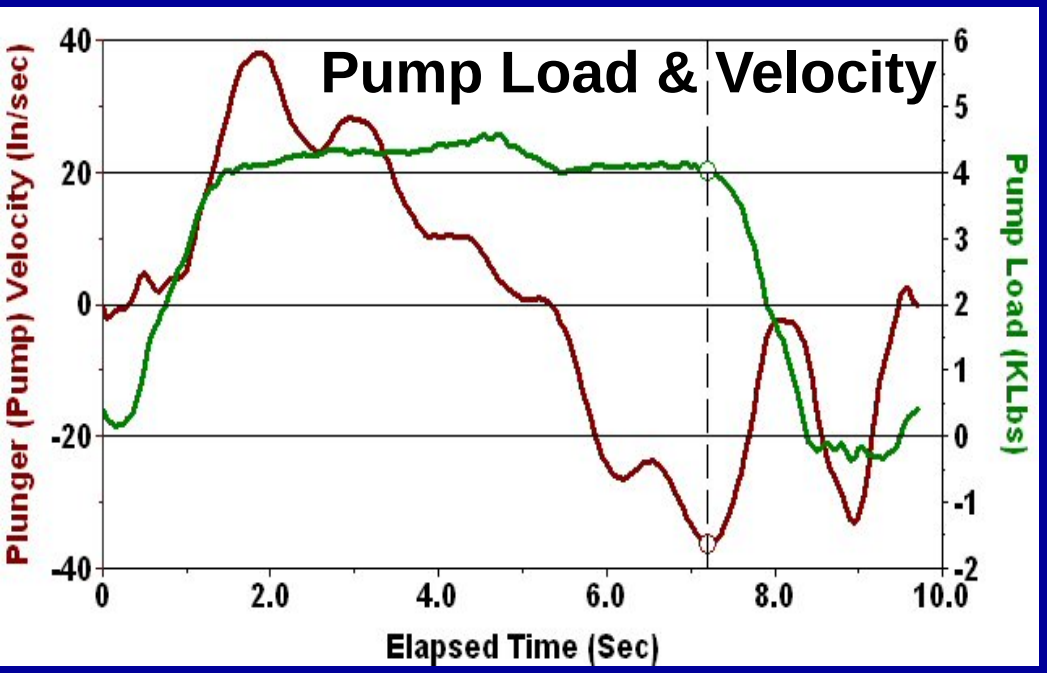


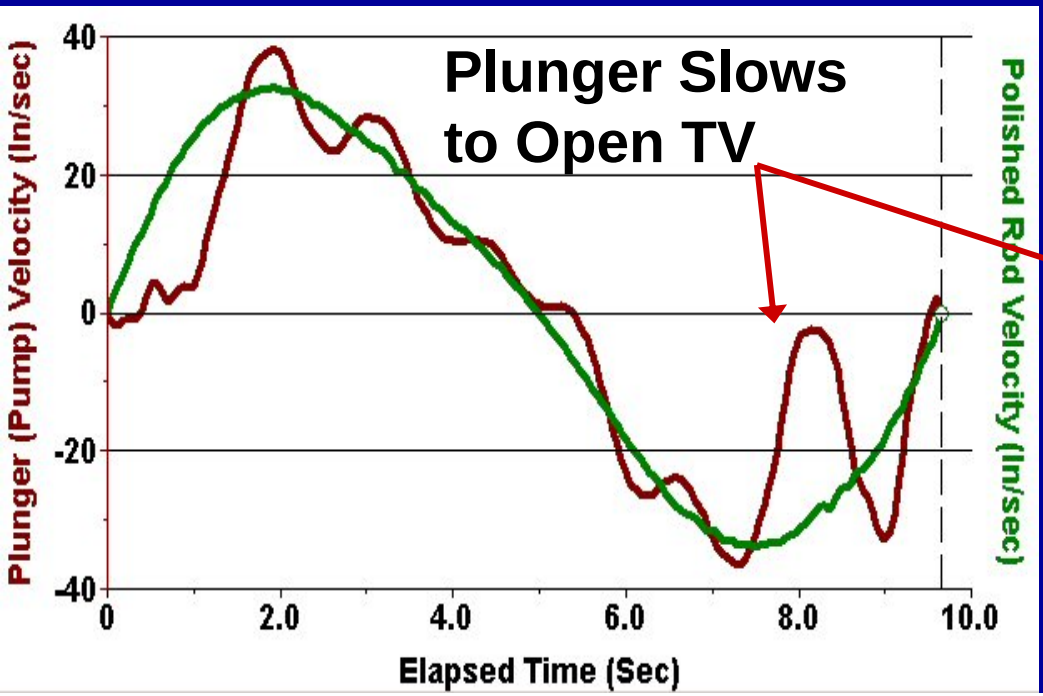
Liquid Level will be *AT or Near* the pump intake depth

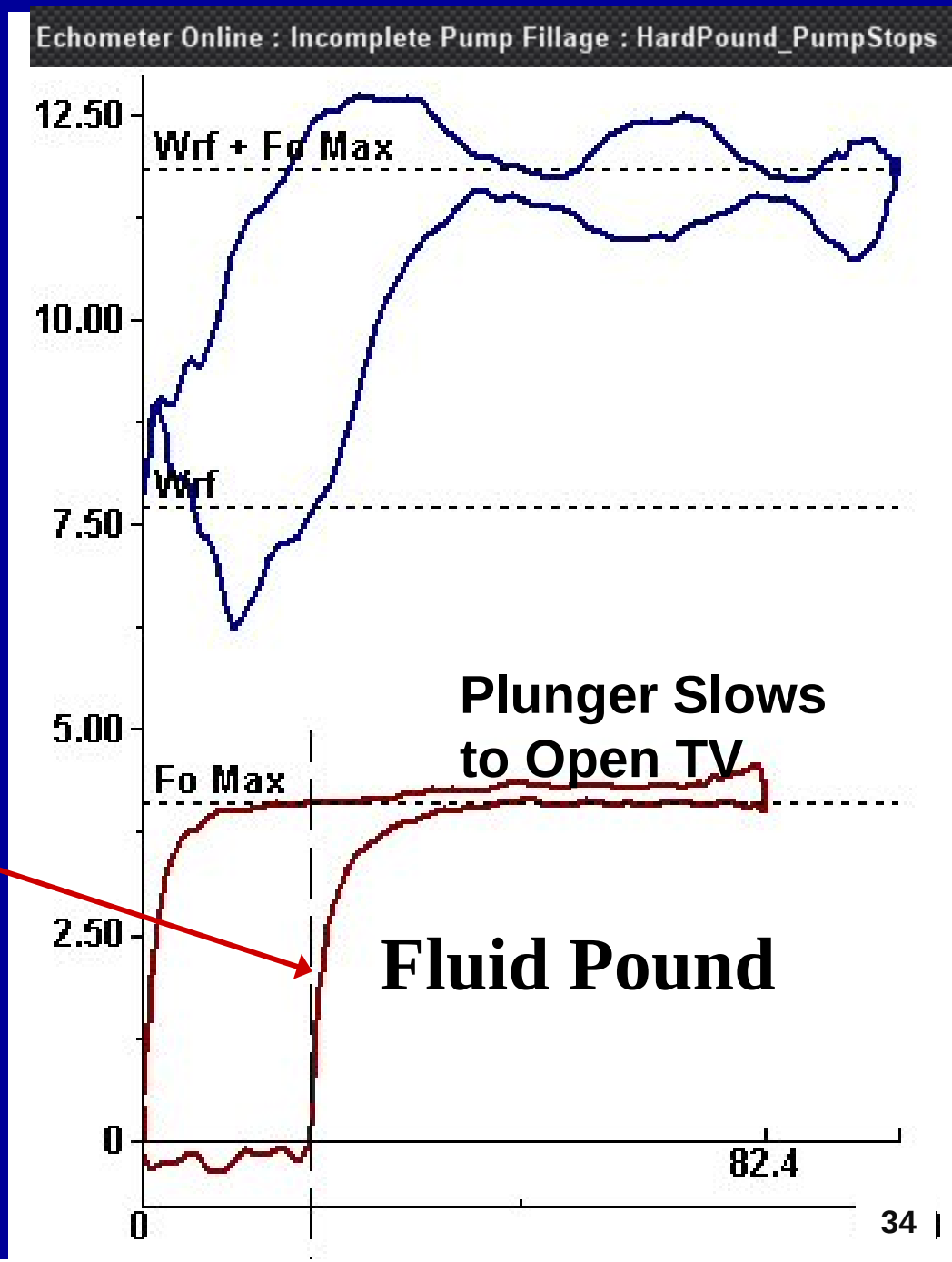
When Pumped Off the Plunger velocity Quickly change from very fast to slow To Open the TV as Pump Load drops to Zero… We Call Sudden Load Change Fluid Pound



Rods Buckle (Train Wreck Effect)



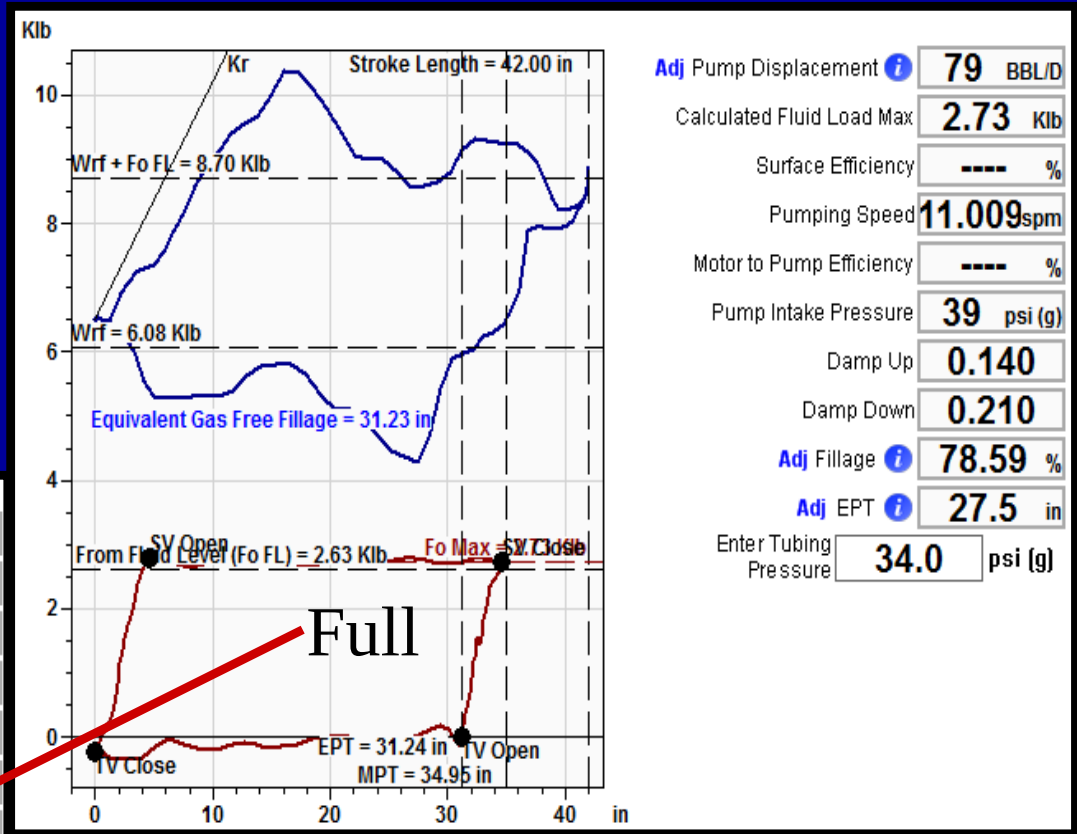


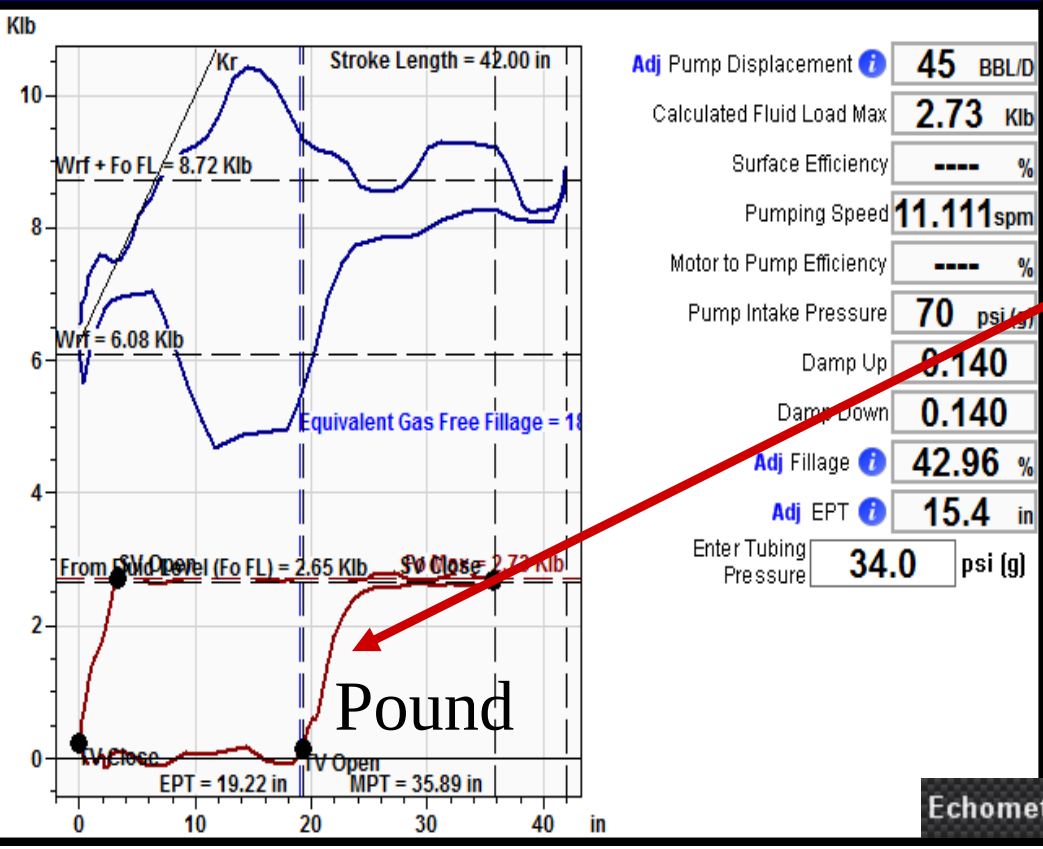


Control Run Time When Pump Displacement Exceeds Inflow From Well

Same Well with Full Pump
Open TV only when Pump Full

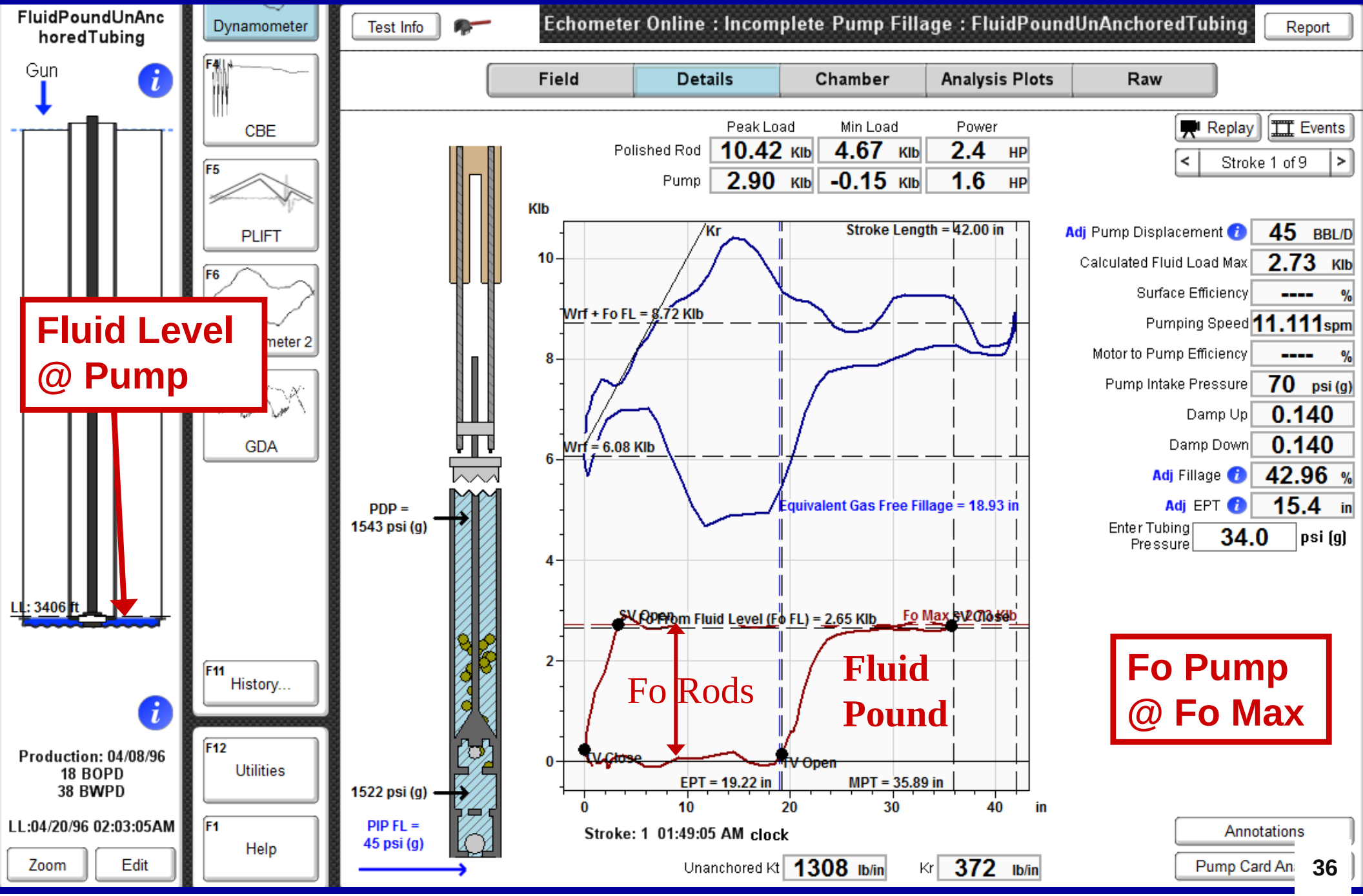
Pump Capacity Exceeds Inflow of Fluids from Well.





Controlling Pump Run Time Improves Efficiency, Reduces Shock Loads, and Reduces Failures.

Fluid Pound - Fluid Level @ Pump
Timer or Pump Off Controller or VSD Candidate

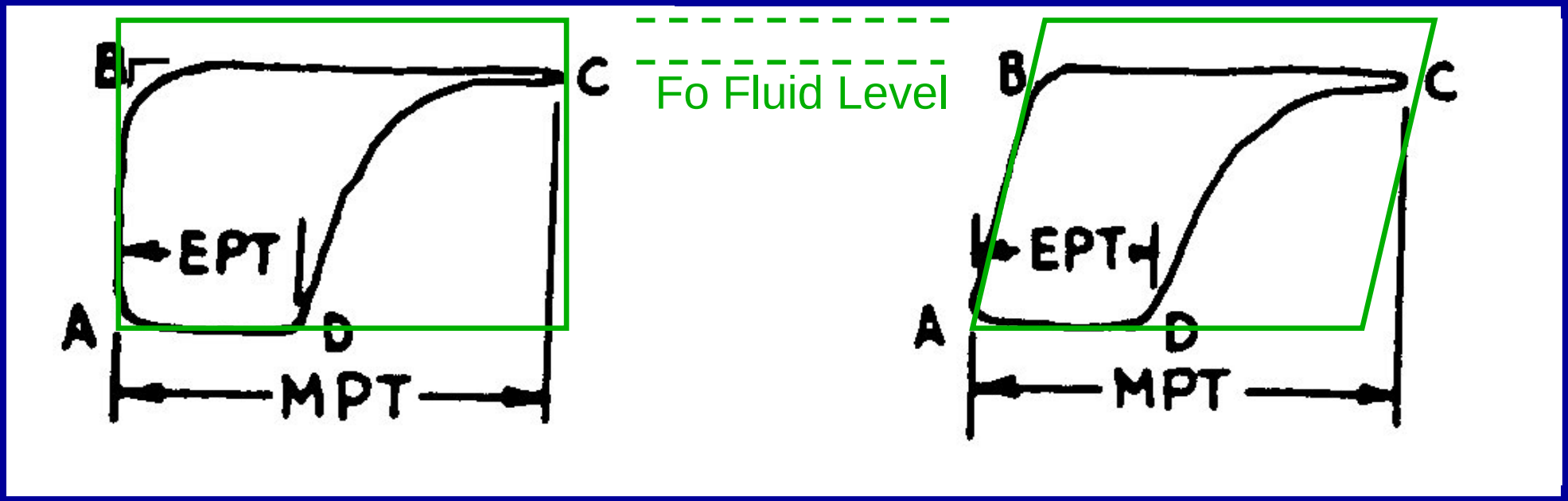


#2 Cause: Gas Interference Pump Card

Tubing anchored, EPT<MPT.

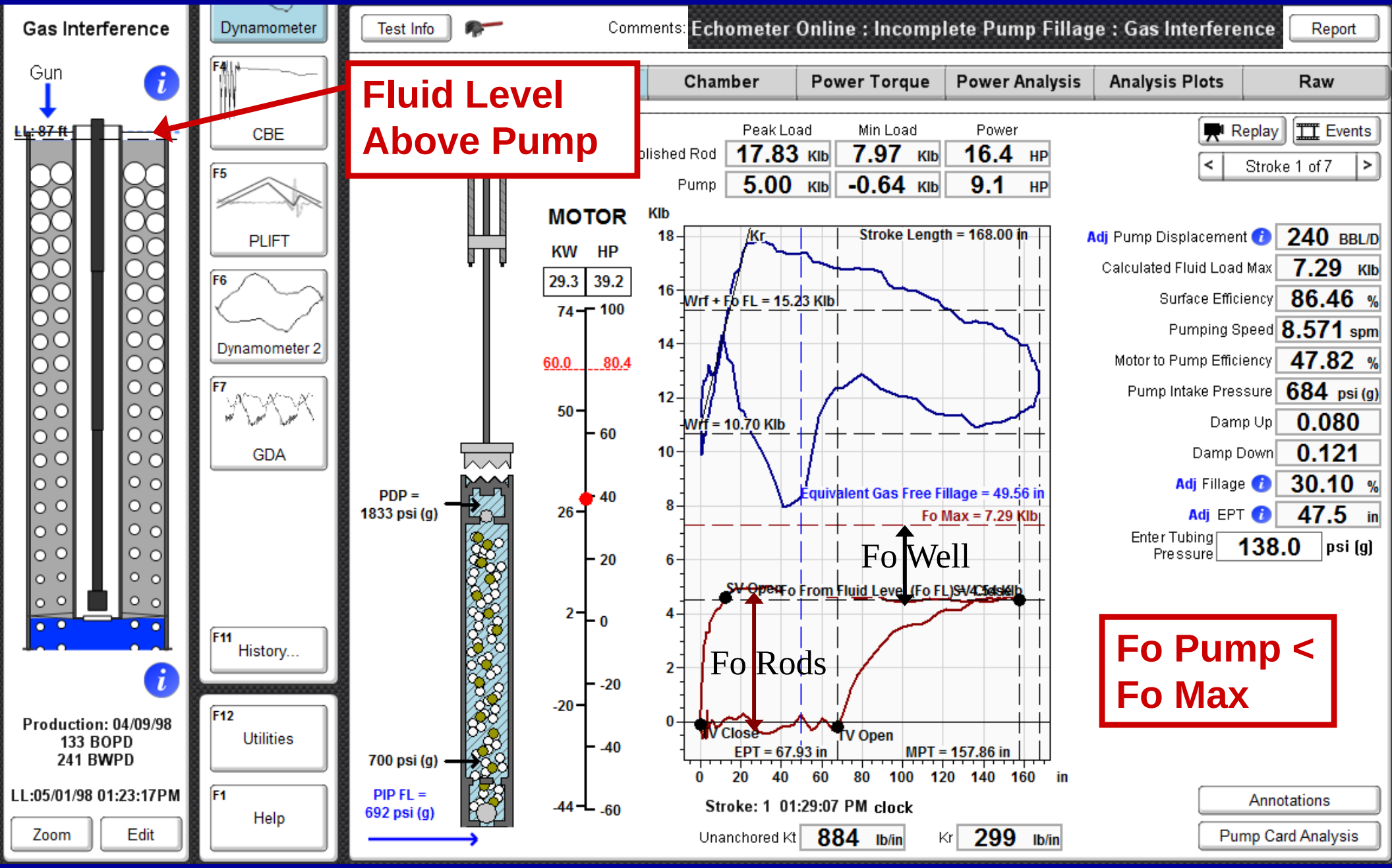
Fo Max

Unanchored tubing, EPT<MPT



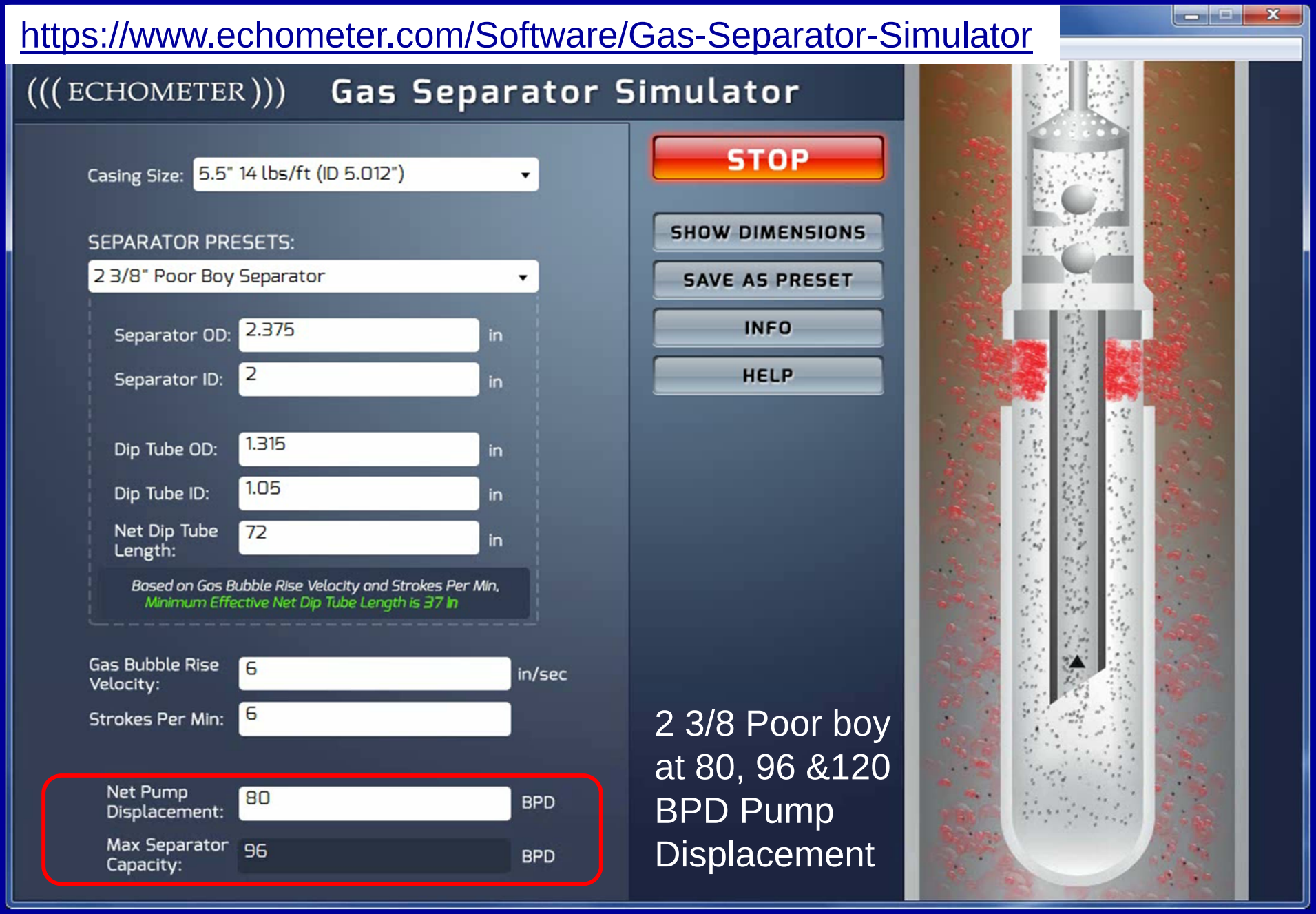
Gas Interference is causing decrease of EPT. Pump components are functioning properly. Usually unstable pump fillage and EPT changes from stroke-to-stroke. When gas interference is present expect increased rod-on-tubing wear due to rod buckling compressing gas in pump barrel.

Gas Interference: Incomplete Pump Fillage and High Fluid Level



Down Hole Gas Separator Capacity Must Exceed Net Pump Displacement

https://www.echometer.com/Software/Gas-Separator-Simulator



2 3/8 Poor boy at 80, 96 &120 BPD Pump Displacement

Casing Size Limits Gas Separator Capacity Limits Maximum Liquid Production Rate

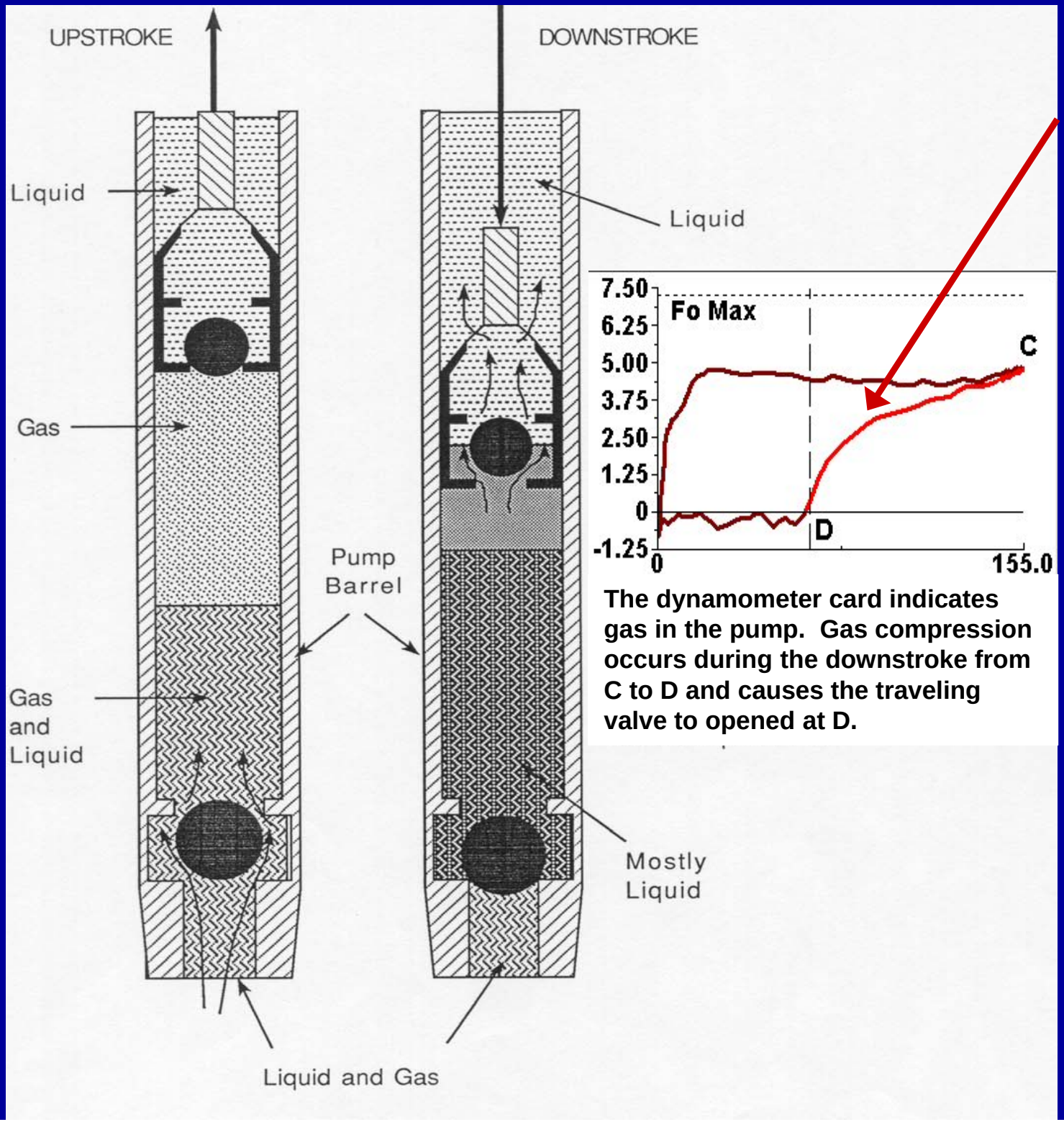
Casing Size Inch	Max Separator Size Inch	Tubing Collar OD Inch	Separator Barrel OD Inch	Separator Capacity BPD
4.5	2 3/8	3.063	3.063	275
5.5	2 7/8	3.668	3.668	445
7.0	3 1/2	4.500	4.500	644
7.0	4	5.000	5.000	833
7.0	4 1/2	5.560	5.500	1044

4.5 13.5# Casing ID 3.92 inch
5.5 17# Casing ID 4.89 inch
7.0 26# Casing ID 6.276 inch

Gas Separator Recommendations

- Use the Echometer Gas Separator Simulator Software Program to determine downhole gas separators capacity based on net pump displacement rates, size of separator, planned SPM and a gas bubble rise velocity.
- Casing size restricts the maximum size gas separator that can be installed in a well.
- Operators can analyze a particular separator configuration and view how the gas separator separates the liquid from the gas and also determine separator capacity.
- Gas Separators having separation capacity exceeding the pump displacement should be used to produce sucker rod lifted wells.

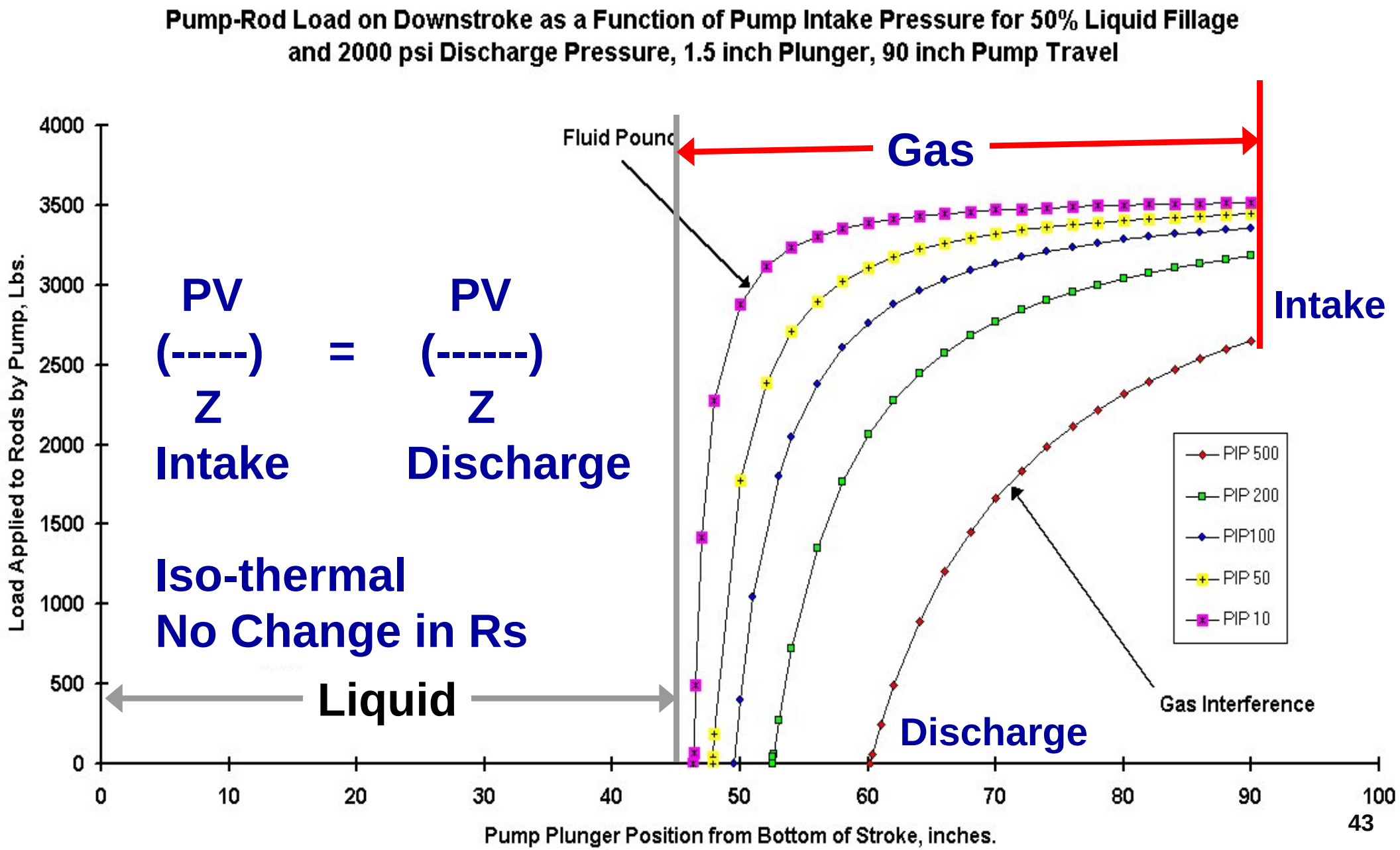
Gas Compression



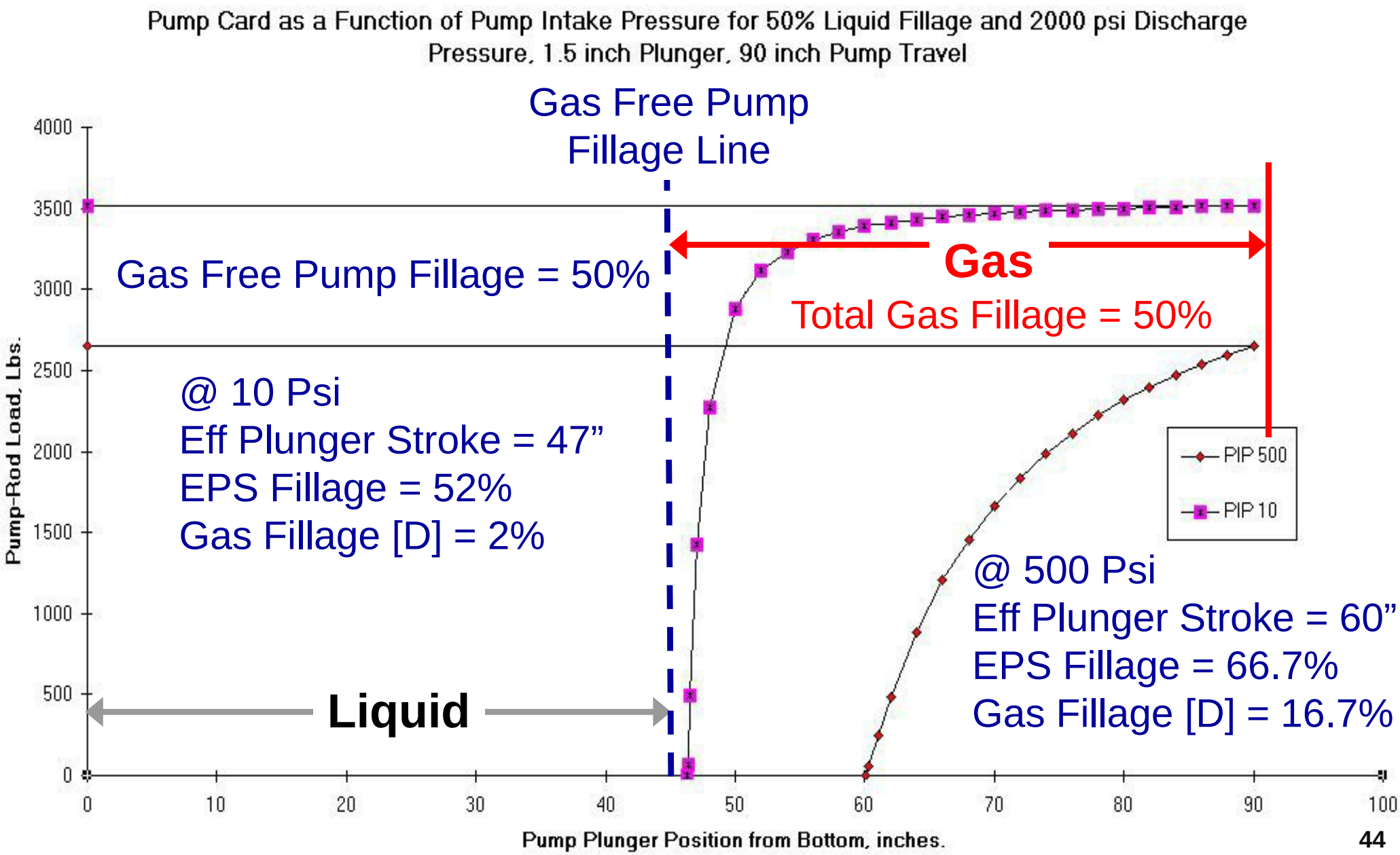
The dynamometer card indicates gas in the pump. Gas compression occurs during the downstroke from C to D and causes the traveling valve to opened at D.

Traveling valve opens when pressure in barrel exceeds the pressure at the pump discharge at the bottom of the tubing.

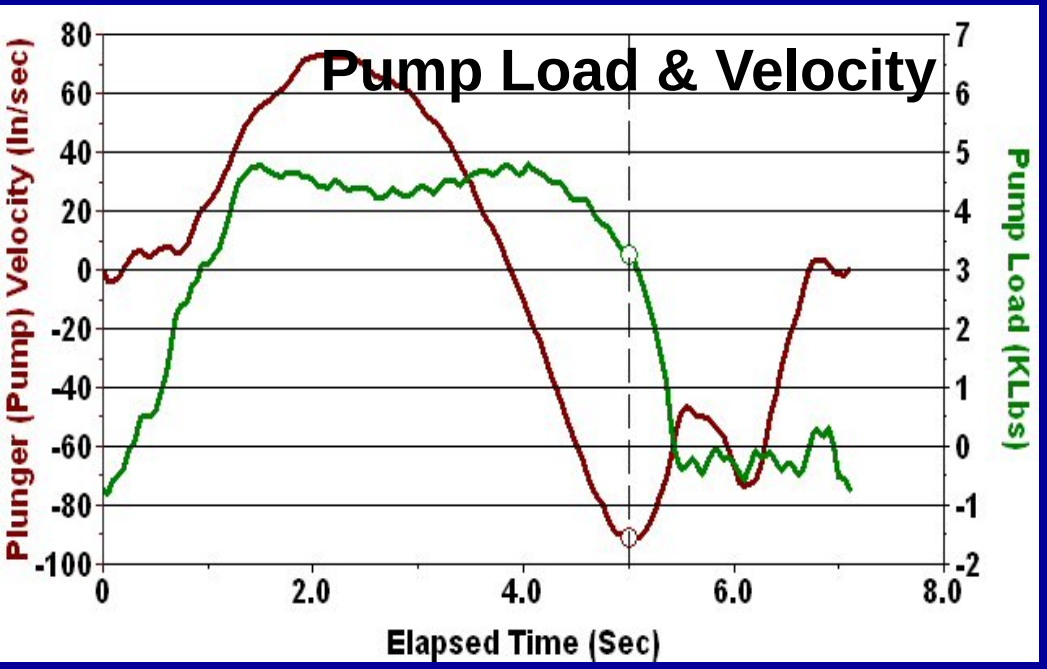
Effect of PIP on Gas Interference and Fluid Pound

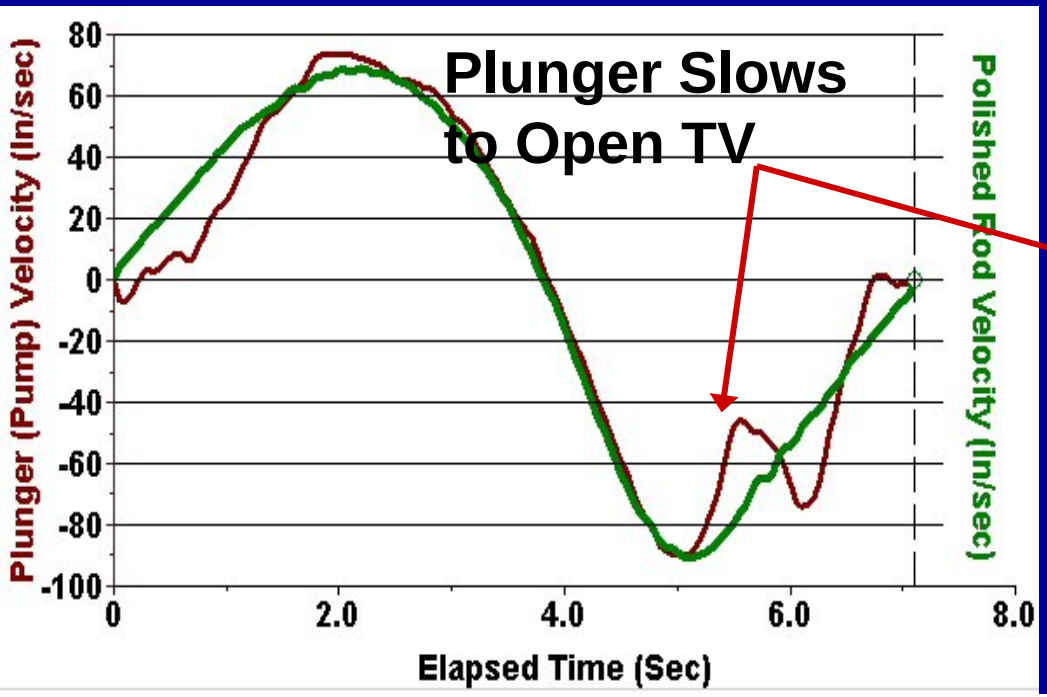


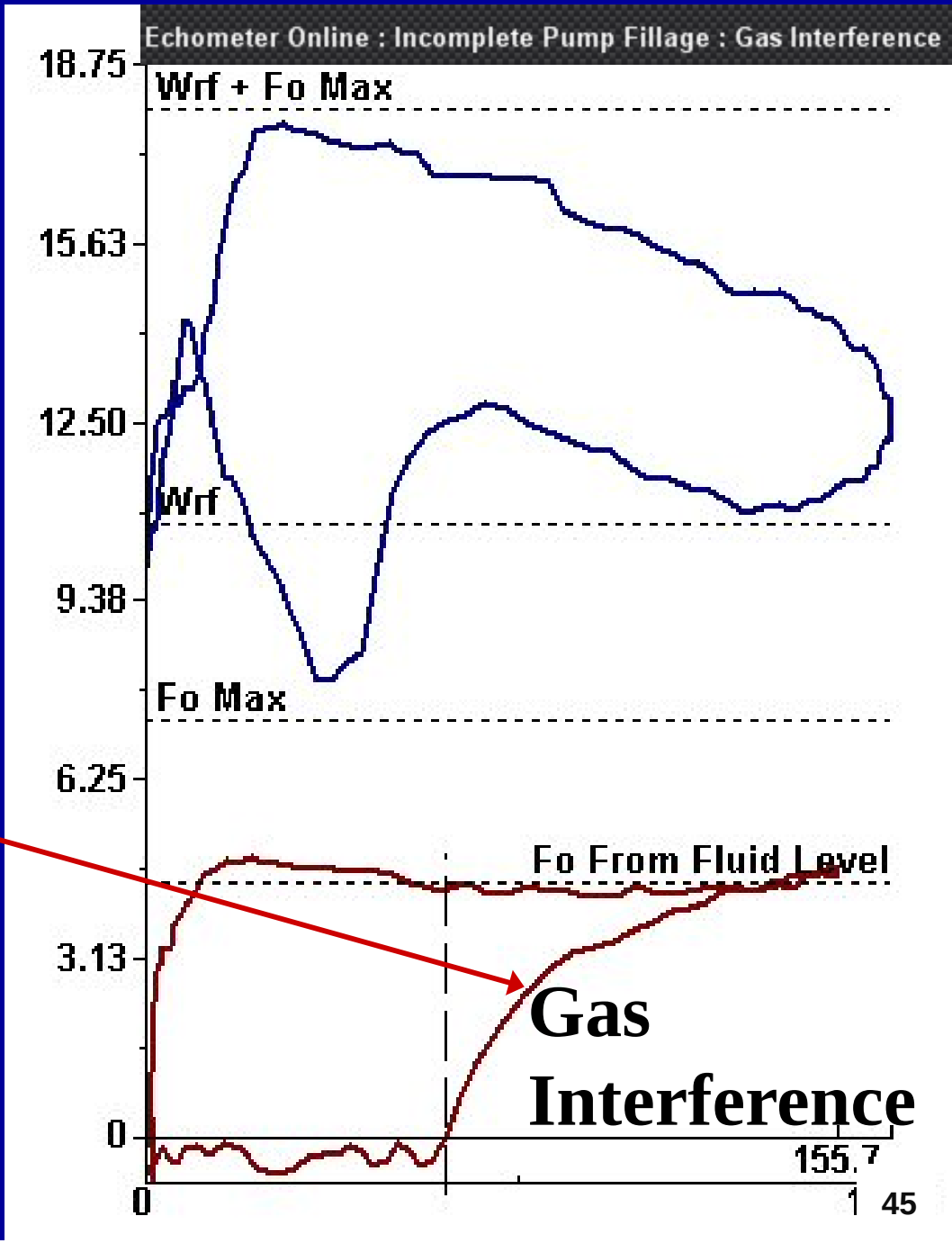
Effect of PIP on Fillage of Pump Card



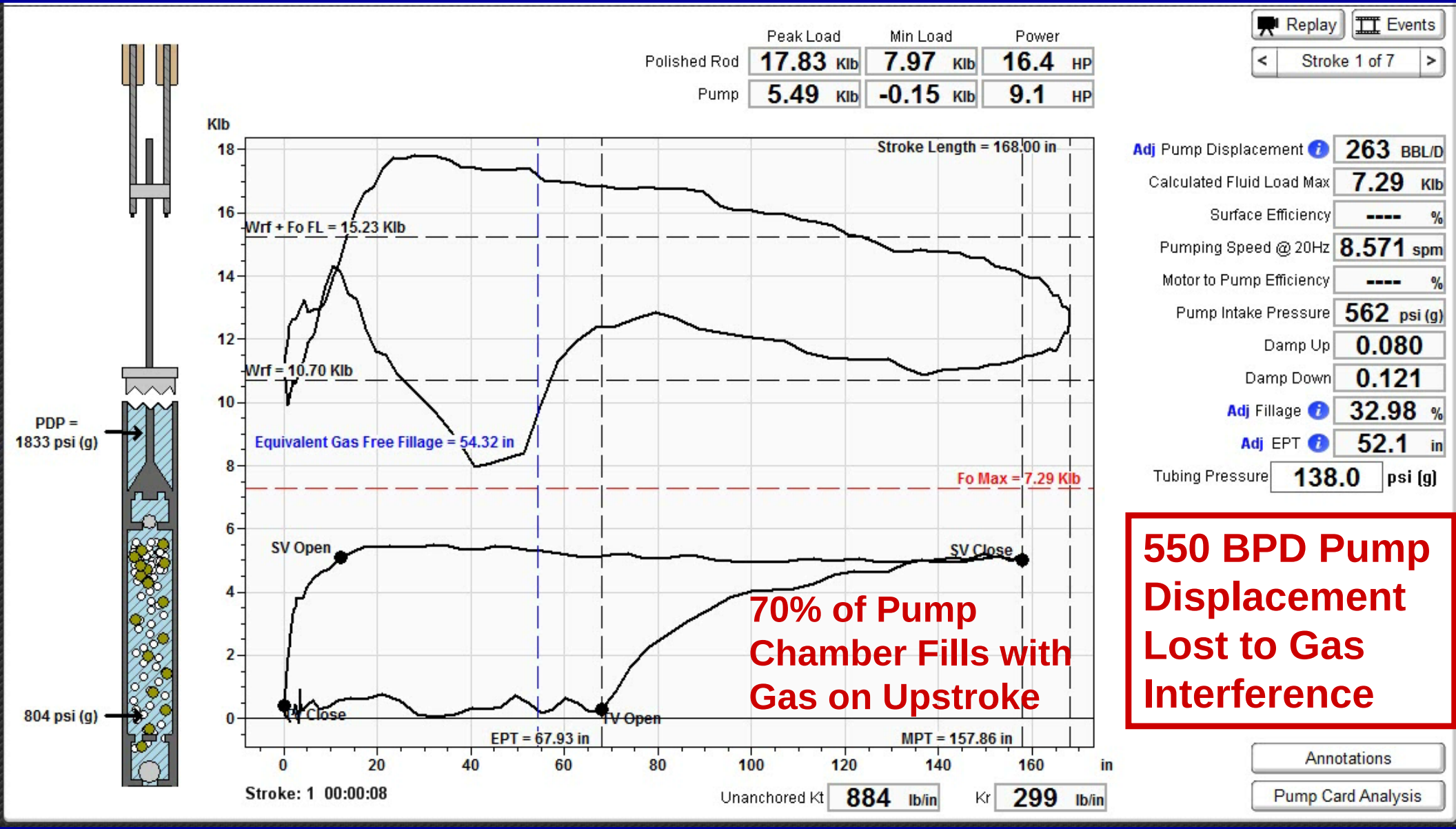
Rods Buckle (Train Wreck Effect)







Equivalent Gas Free Pump Fillage Line Traveling Valve Opens with Pressure

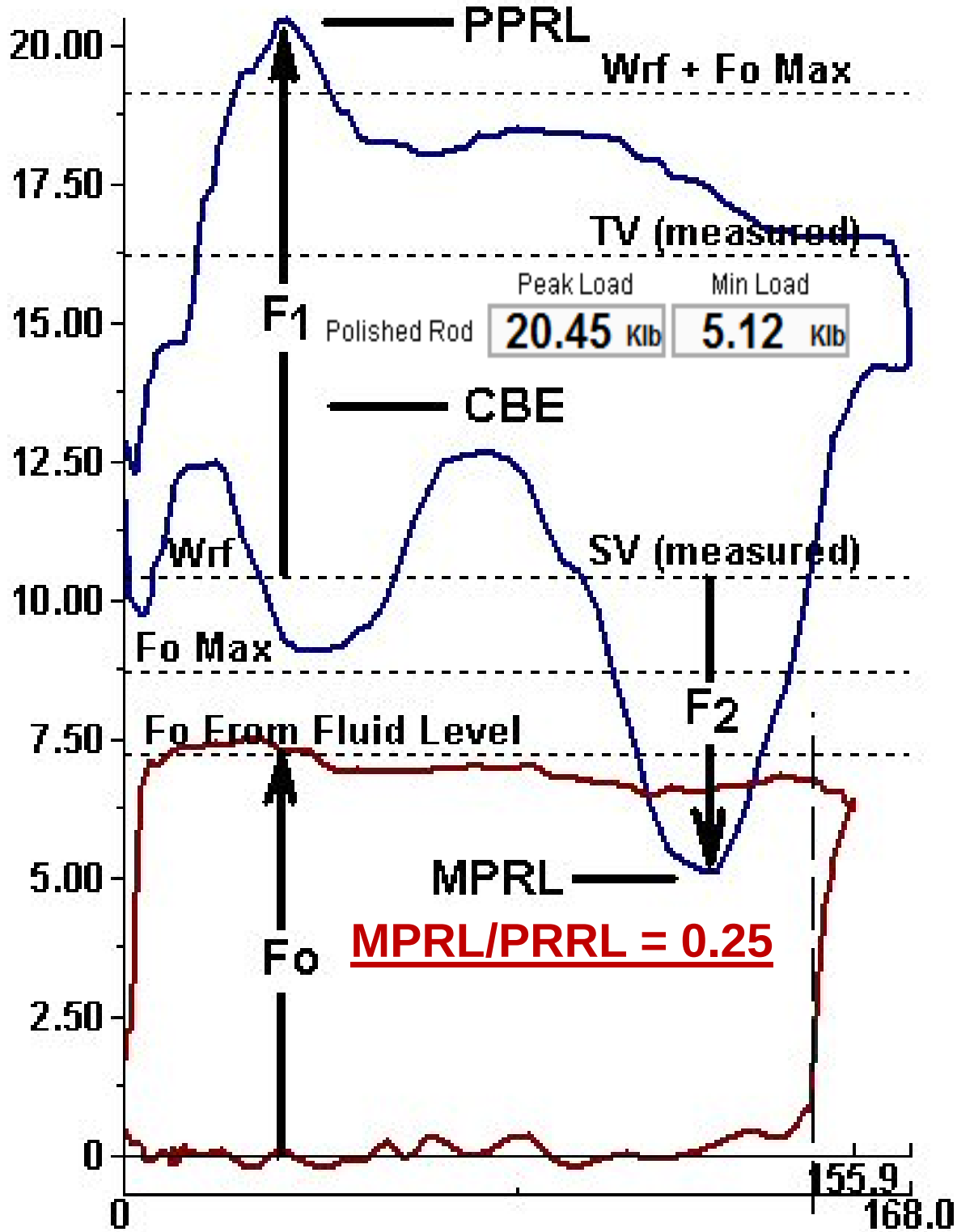


550 BPD Pump Displacement Lost to Gas Interference

70% of Pump Chamber Fills with Gas on Upstroke

Gas Compression and Train Wreck Effect

1. Gas Compression occurs when the pump barrel is partially/filled with gas.
2. Sudden opening of TV reduce equipment life
   a) Is it uphole compression whacking rods against the tubing
   b) Pin failures due to rod slap loosening the couplings
3. Rod buckling up the hole occurs when the pump slows down to compress the gas and liquid in the pump
4. Rods must apply a force to increase the pressure inside the barrel to greater than the discharge pressure.
5. Rods above the pump go into compression and buckle when the pump velocity decreases in order to increase the pressure inside the pump.



Echometer Online : Incomplete Pump Fillage : Normal Dyno

MPRL/PRRL > 0.1 per each 2500'/pump depth

TV Weight of Rods in Fluid, Wrf, plus the Fluid Load, Fo, plunger is applying to the rods.

Wr fluid = Wr air - Buoyancy

Fo fluid load the pump applies to the rod string.

F1 dynamic force required at the surface to apply a static force Fo at the pump..

F2 dynamic surface force due to transferring the Fo carried by the traveling valve to the standing valve.

Pump Depth = 4836

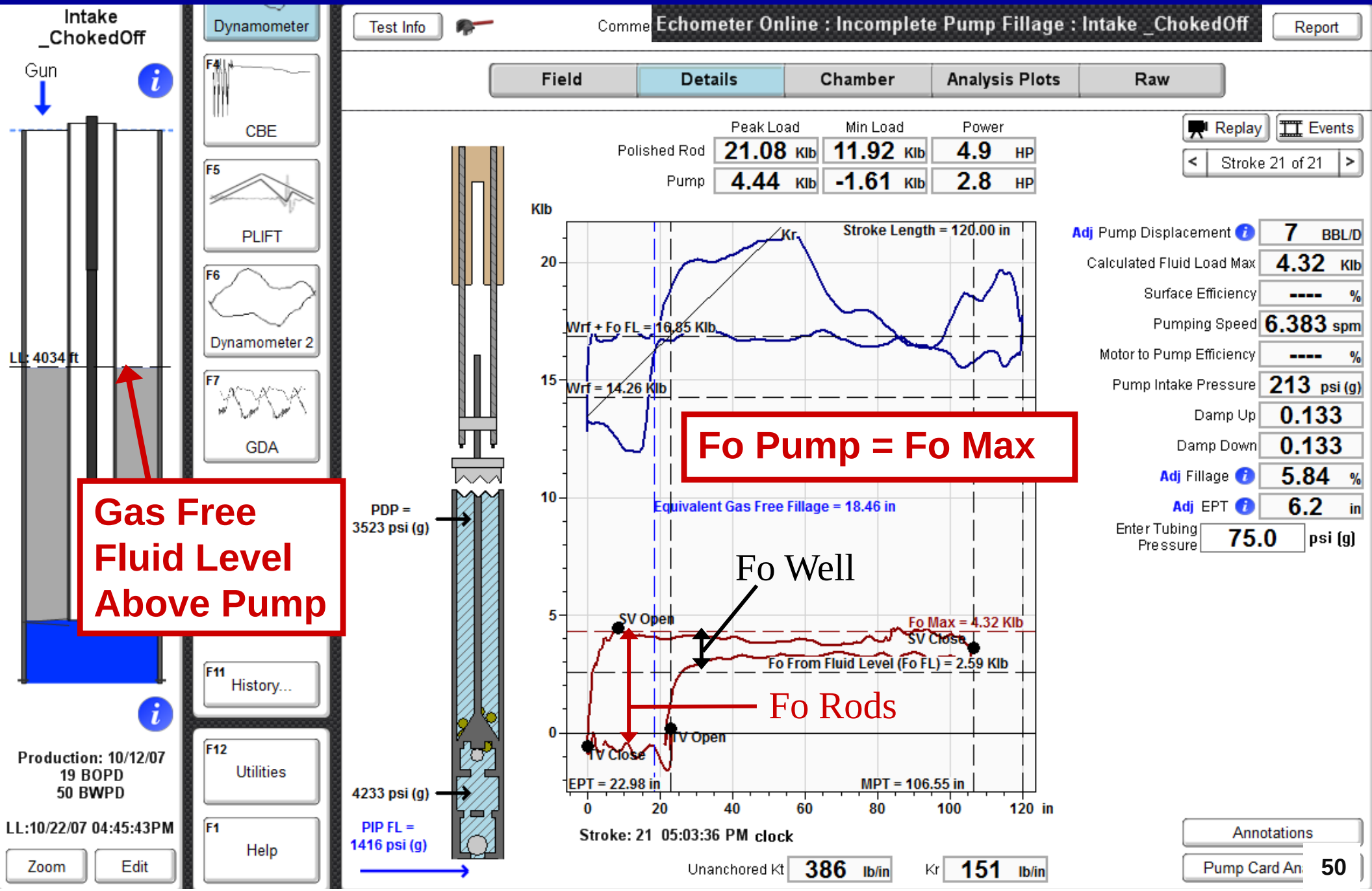
MPRL/PRRL Limit = 1.9

OK 0.25 > 0.19

Fluid Pound and Rod Buckling

1. Fluid Pound may not be Exactly Correct Term
   a. Occurs with incomplete pump fillage at low pump intake pressure
   b. Forces at pump may not cause trouble
   c. Up-hole rod compression and rod on tubing wear is the likely problem
2. Low Pressure Gas in the pump causes fluid pound
   a) Pump stops just as bad if the gas is in the 100-200 psi range,
   b) Rod on tubing wear can be worse at higher intake pressures
3. Traveling valve opens when pressure in barrel exceeds discharge pressure at the bottom of the tubing.
   a) TV always opens before hitting fluid (except blocked intake)
   b) Plunger maybe a 1/16th inch away when "fluid pound“ occurs

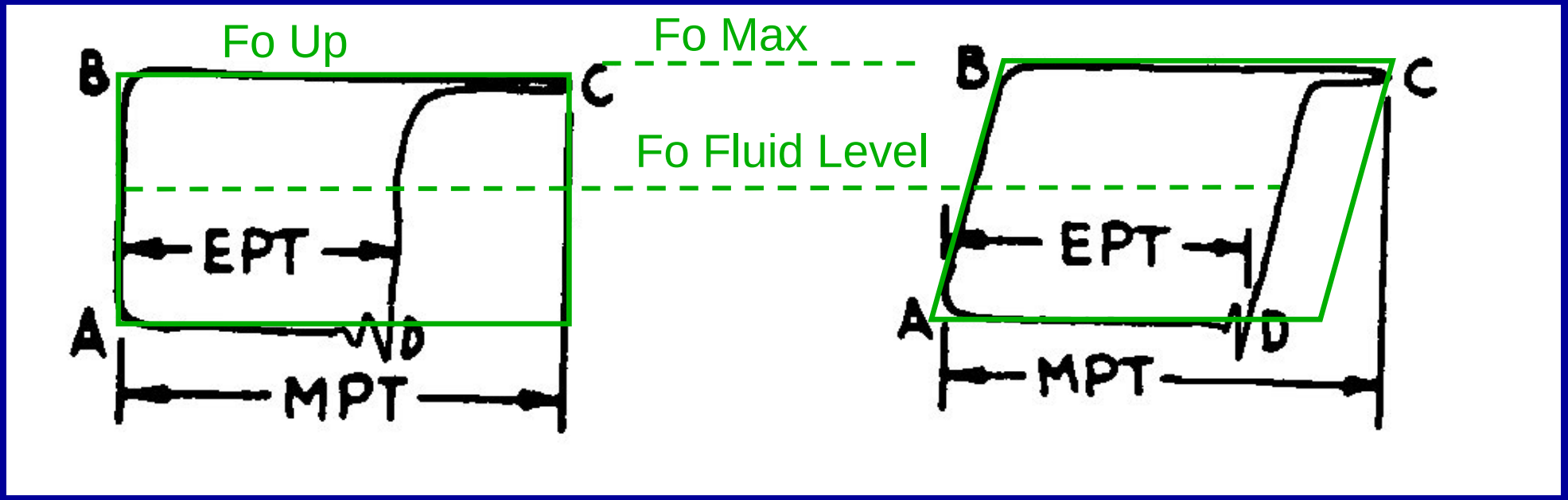
#3 Cause: Flow into Pump Choked Off w/ Severe Fluid Pound Pump Card and High Fluid Level



#3 Cause Pump Cards: Severe Fluid Pound – Blocked Pump Intake

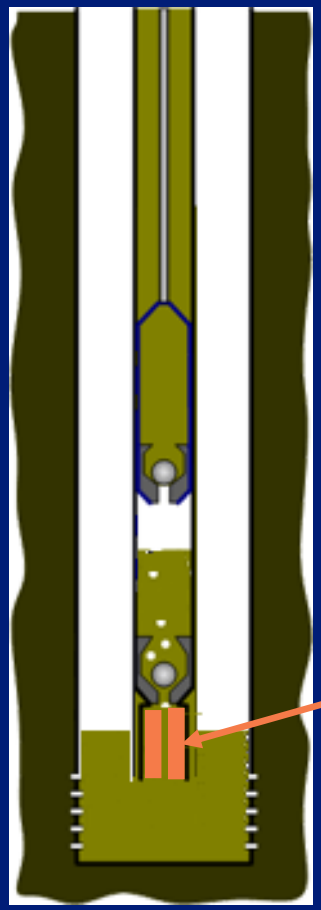
Tubing anchored, EPT<MPT.

Unanchored tubing, EPT<MPT



Severe fluid pound, usually occurs when the intake into the pump is completely blocked off. Strainer nipple, pump intake below fill, standing valve stuck shut can starve pump. Stuffing box leak and reduced equipment life result! Shoot fluid level to verify pump intake is blocked and fluid level above pump intake

Cause # 3 - Partial Liquid Fillage due to Pump Intake Restriction/Plugged

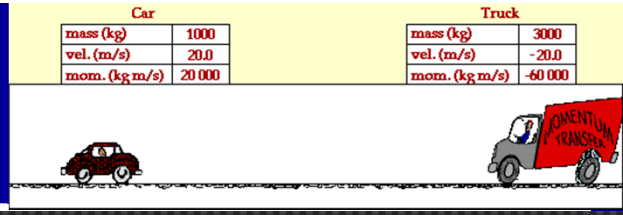


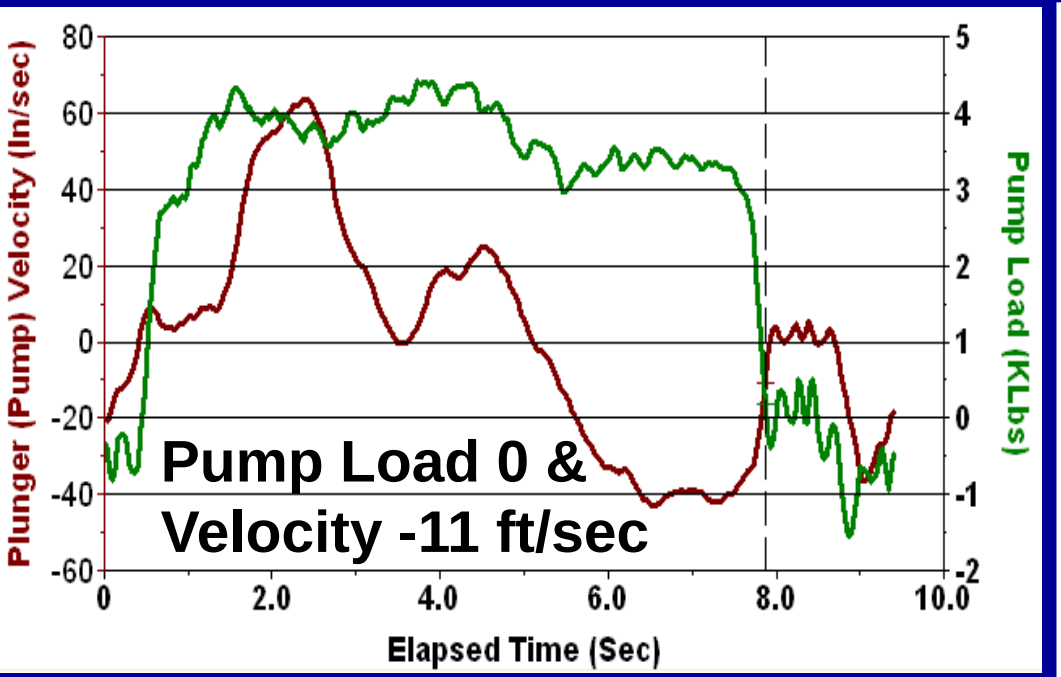
Plugged Intake: “starved pump or choked pump”

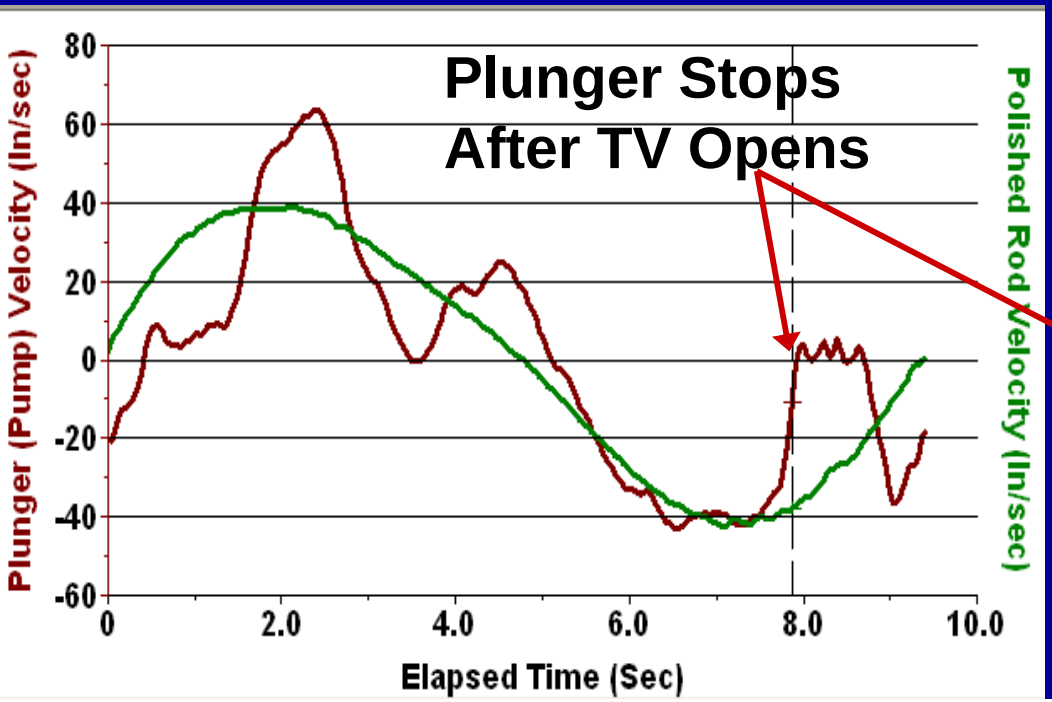
Paraffin or solids or scale buildup or long and thin dip tube or clogged strainer nipple or viscous heavy crude

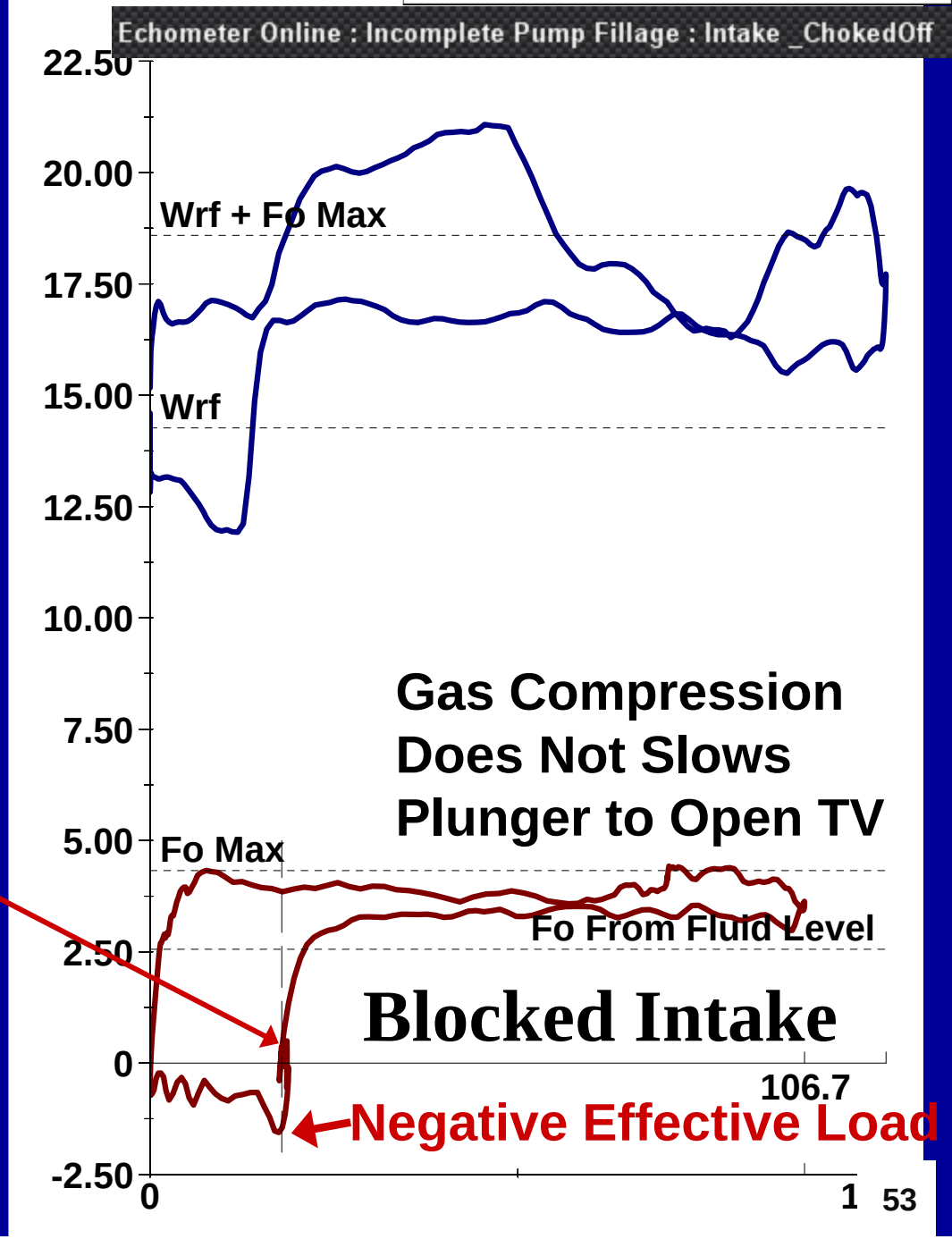
Gas-free Liquid Level *Above* the pump intake plenty of fluid above pump

Rods Buckle (Collision with Liquid)

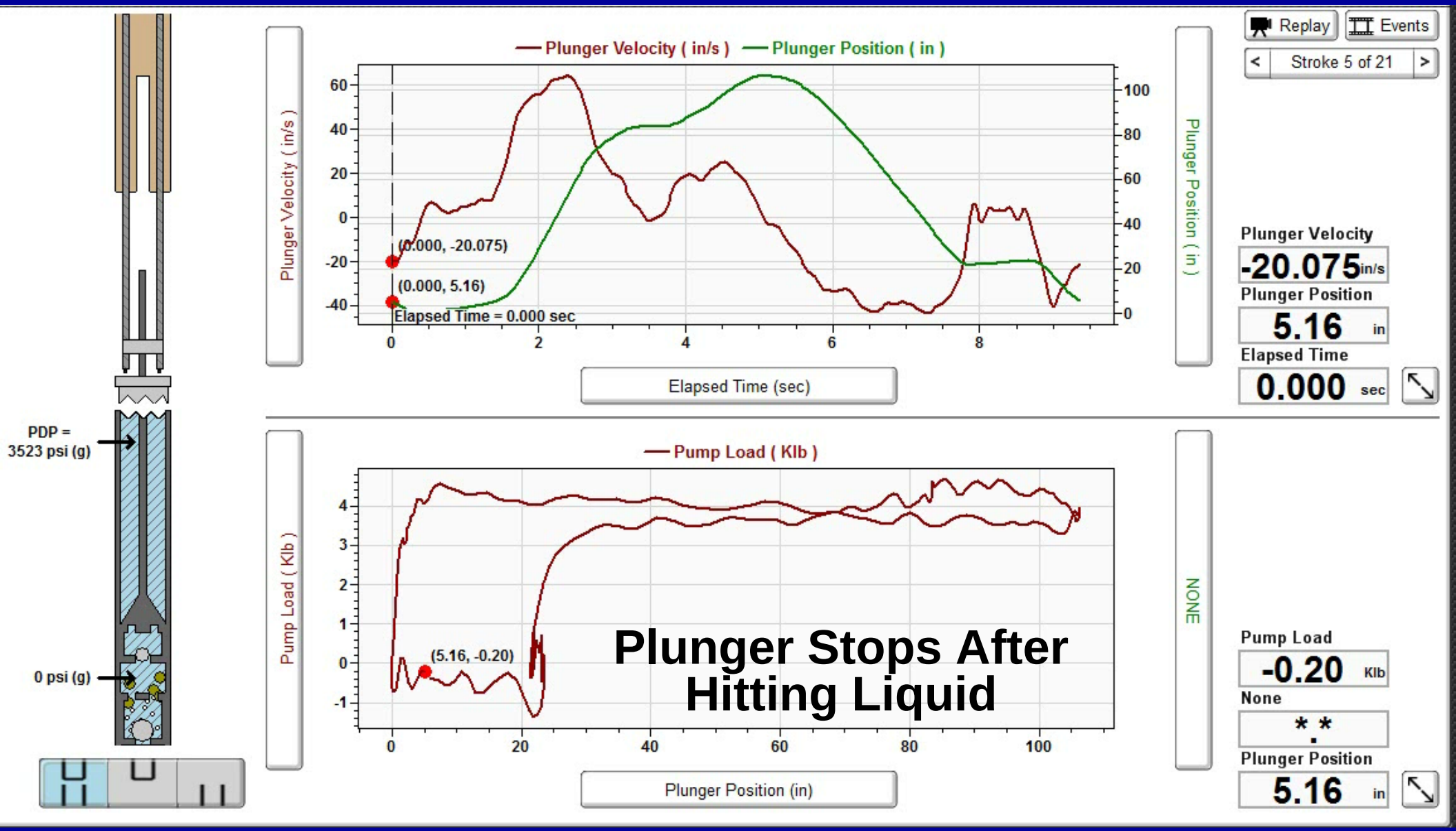








Blocked Strainer NO Flow at Surface



Echometer Online : Incomplete Pump Fillage : Intake _ChokedOff

Incomplete Pump Fillage

1) Fo, Pump Load location w/ respect to Zero, Fo From Fluid Level, and Fo Max Load Lines are Used to Identify Incomplete Pump Fillage.
2) Fluid Pound and Blocked Intake Pump cards look similar except that:
   - Fluid Pound – Fluid level at Pump
   - Blocked Intake – Fluid Level High above Pump
3) Fluid Pound and Gas Interference both have gas in the pump that must be compressed from [C-D]
4) When the Intake is Blocked, then no gas is in the pump barrel and Plunger "Pounds" the Fluid inside the Pump Barrel.
5) Negative Load seen when Plunger ***Hits*** Liquid

Problems Associated with Pumping Off more than 2% of Run Time

Constant Pump Off causes vibration throughout the whole system. This causes:

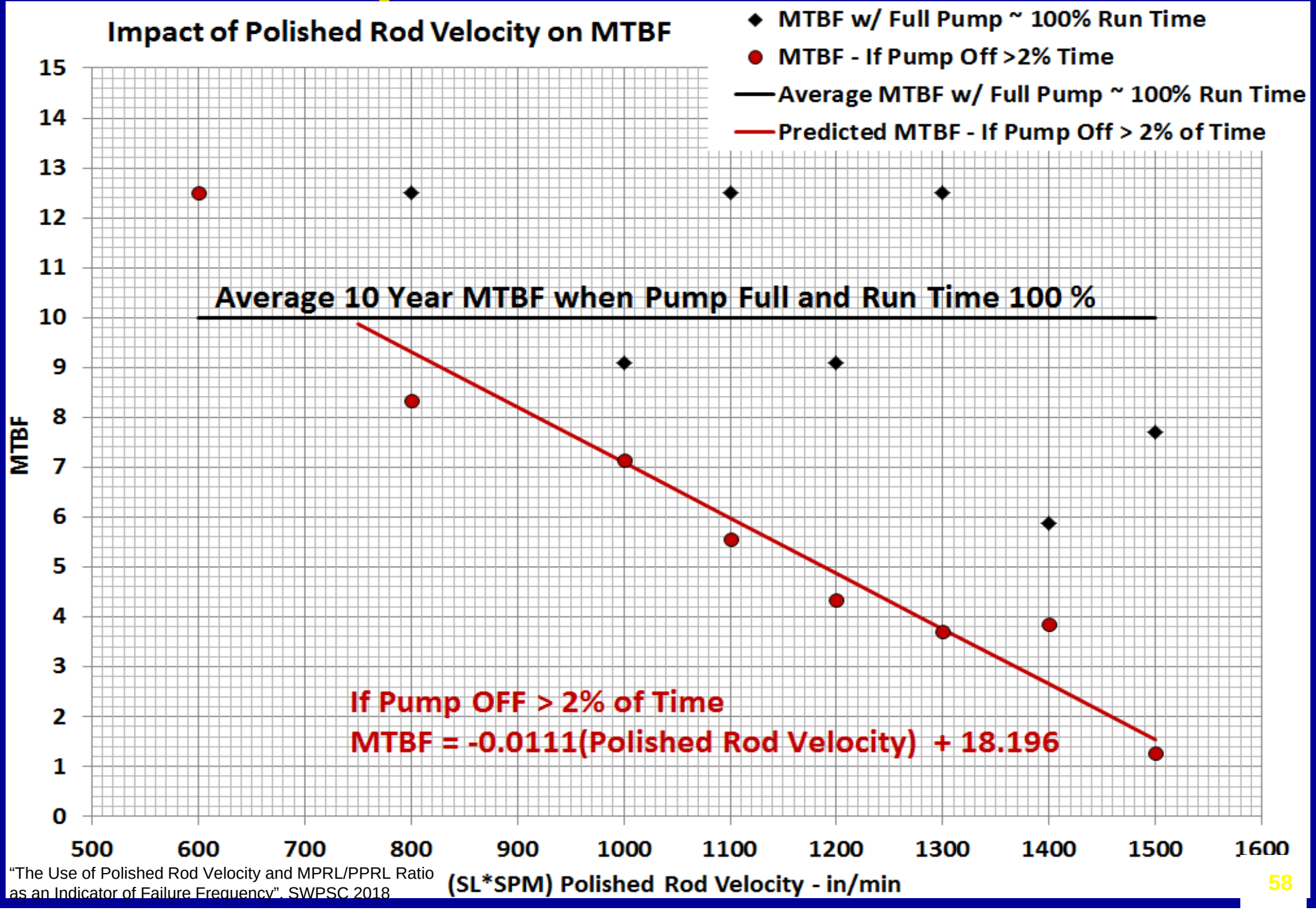
- Rod buckling
- Pump wear
- Rod on Tubing wear
- Vibration stresses
- Severe rod loading changes
- Pumping unit vibration

Data from more than 6000 sucker rod lifted wells shows impact of incomplete pump fillage on run life

- When the pump is filled with liquid then the pump load transfer occurs at/near the bottom and top of the pump stroke.
- This field collected dynamometer data is from 6000 different SR wells
- There is a significant increase in failure rate when NOT transferring pump load at bottom and top of the pump stroke

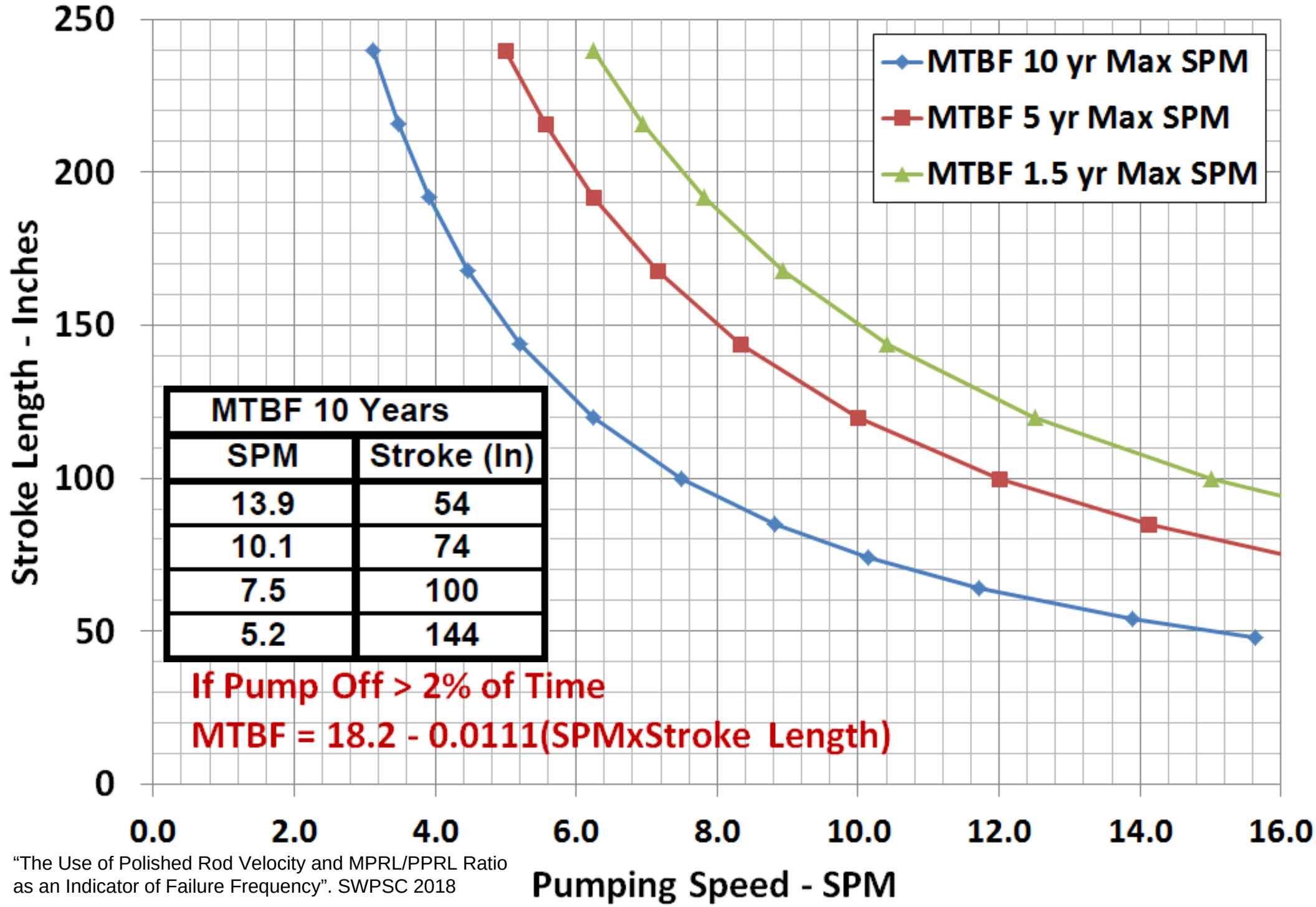
"The Use of Polished Rod Velocity and MPRL/PPRL Ratio as an Indicator of Failure Frequency". SWPSC 2018

Full Pump MTBF for SPM x Stroke



"The Use of Polished Rod Velocity and MPRL/PPRL Ratio as an Indicator of Failure Frequency", SWPSC 2018

MTBF vs SPM x Stroke, If Pump Off > 2% of Time



MTBF 10 Years	
SPM	Stroke (In)
13.9	54
10.1	74
7.5	100
5.2	144

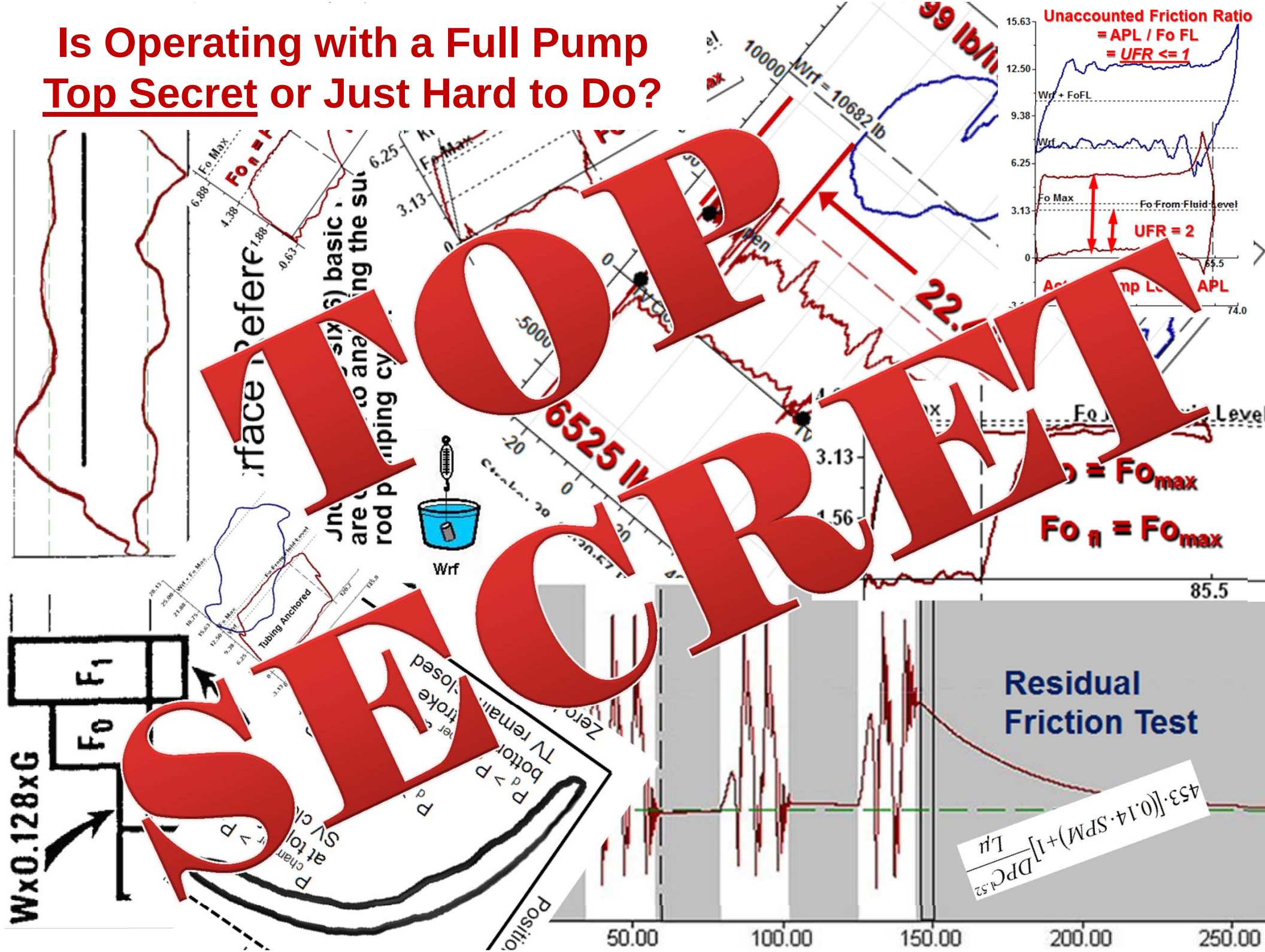
"The Use of Polished Rod Velocity and MPRL/PPRL Ratio as an Indicator of Failure Frequency". SWPSC 2018

Conclusions

1. "**Long and Slow**" OR "**Short and Fast**" is **NOT** the way to go.
2. Operating with a pump filled with liquid is the way to go.
2. Maintain high pump volumetric efficiency:
   - Match pump displacement with wellbore inflow.
   - Pump a Full Stroke of liquid by controlling run time with a POC or Timer or VSD or ….
   - Eliminate Gas interference.
3. Gas Interference requires an efficient downhole gas separation with capacity exceeding the net pump displacement
4. Full pump fillage requires controlling the run time to match the pump displacement to the well inflow rate

Focus on Operating Sucker Rod Lifted Wells with Pump Full of Liquid

- **"The Way to Go" is to produce wells with complete liquid pump fillage.**
- **Less problems, more efficient operations and lower failure rate will result, if wells are operated with a pump filled with liquid.**
- **Incomplete pump fillage is a significant factor causing problems to the operation of the well.**

- ***Be <u>determined</u> to operate your pump filled with liquid, plus do not forget to apply other recommended practices.***

Is Operating with a Full Pump
Top Secret or Just Hard to Do?