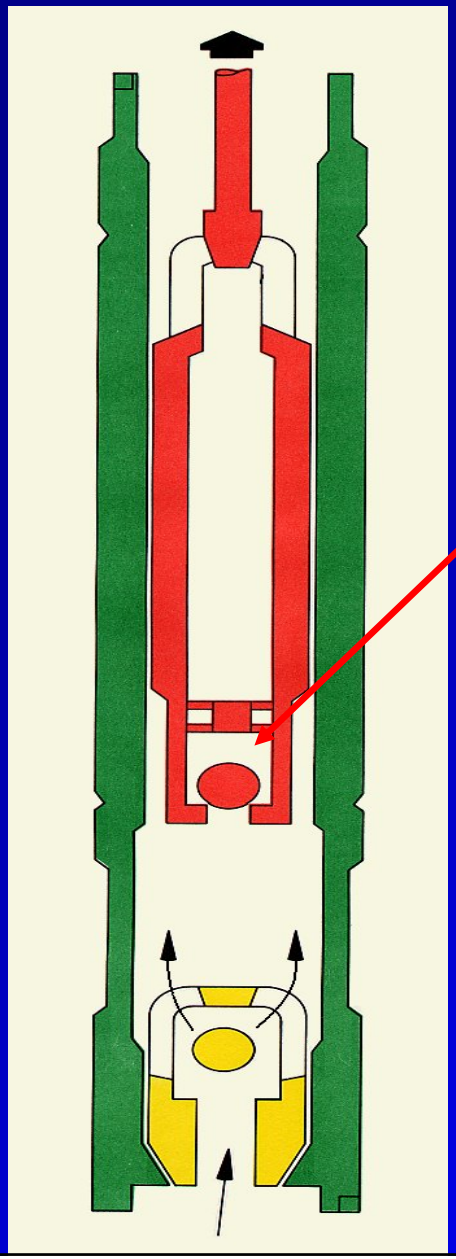
Dynamometer Analysis:

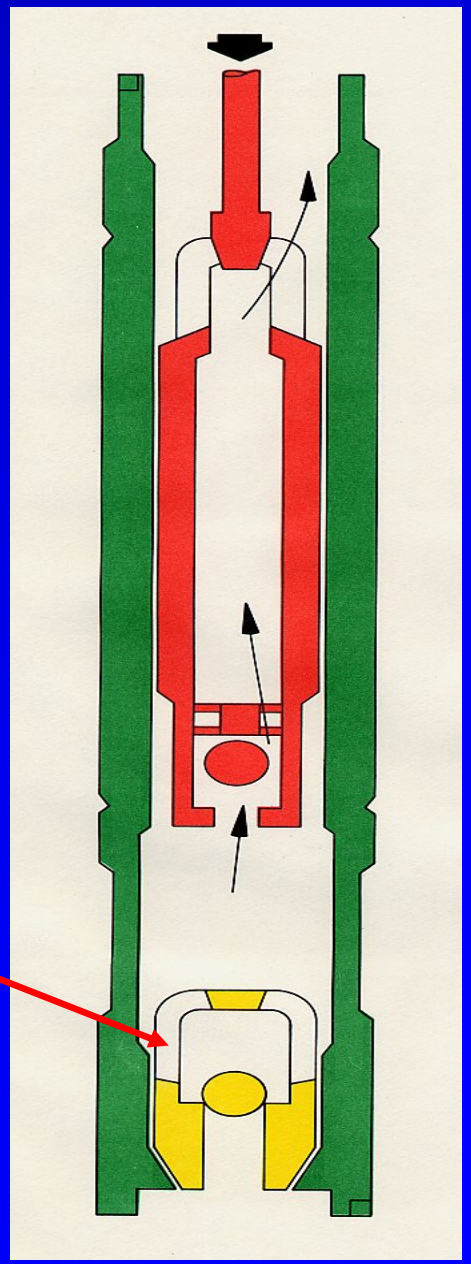
1. Introduction
2. Leaky Pumps
3. Incomplete Pump Fillage

Rod Pump Valve Operation



1) **Traveling valve**, discharge valve, moves with the rod string. Acts as a check valve to keep well fluid in the tubing on the upstroke

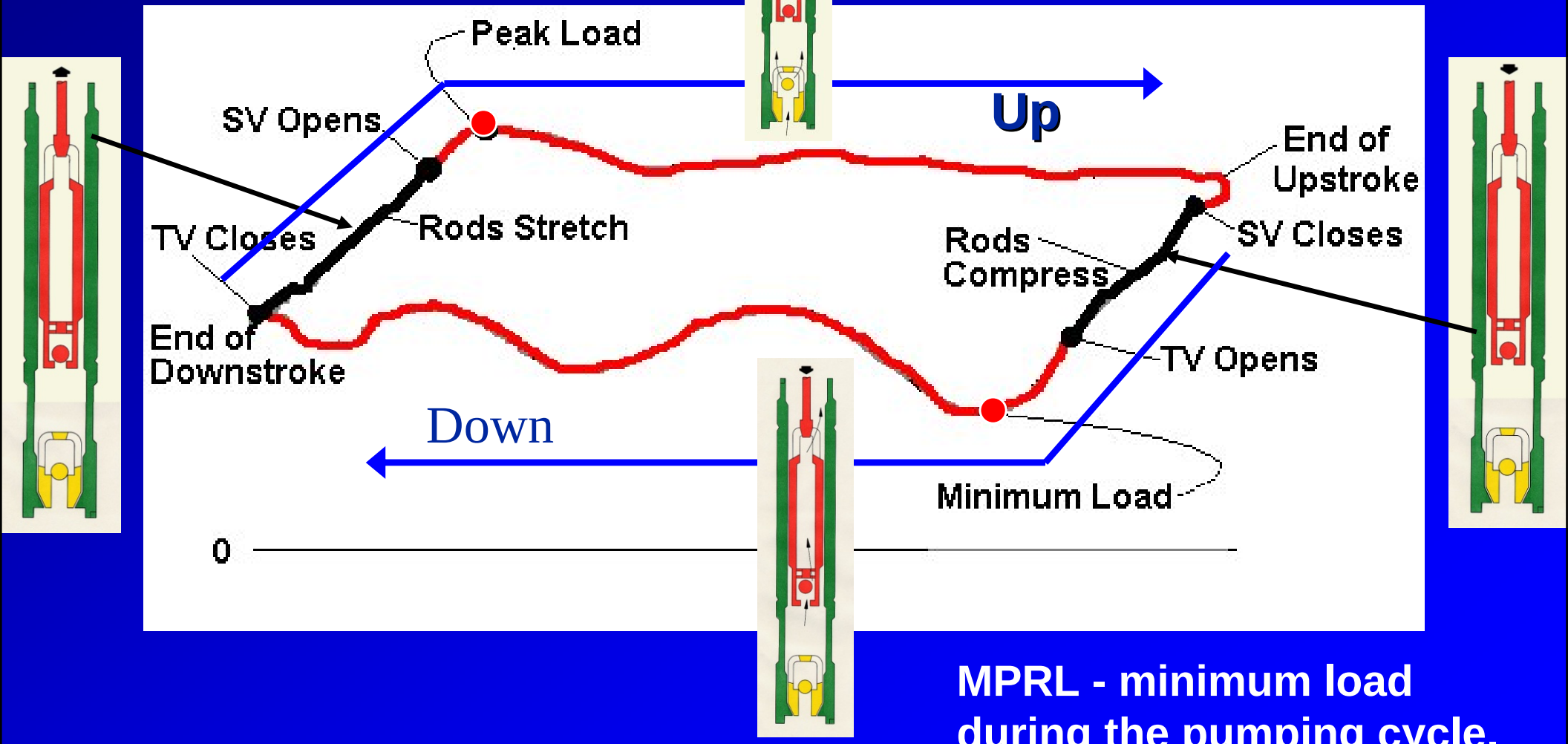
2) **Standing valve**, intake valve, fixed to tubing considered to be stationary, and acts as a check valve to keep well fluid in the tubing on the downstroke.



Surface Dynamometer Pumping Cycle

PPRL - maximum load during the pumping cycle.

Sequence of events during one pumping cycle



MPRL - minimum load during the pumping cycle.

Steps in the Pump Operation

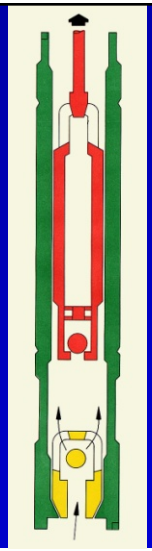
A) Start of the upstroke, the traveling valve and standing valve are both closed.

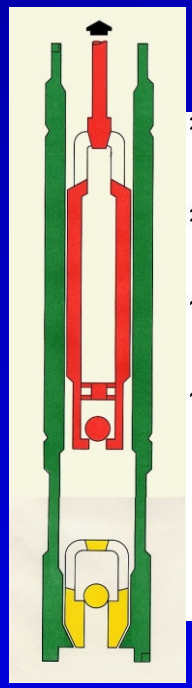
B) Standing Valve opens, when rods stretch to pick up fluid load, Fo, from tubing.

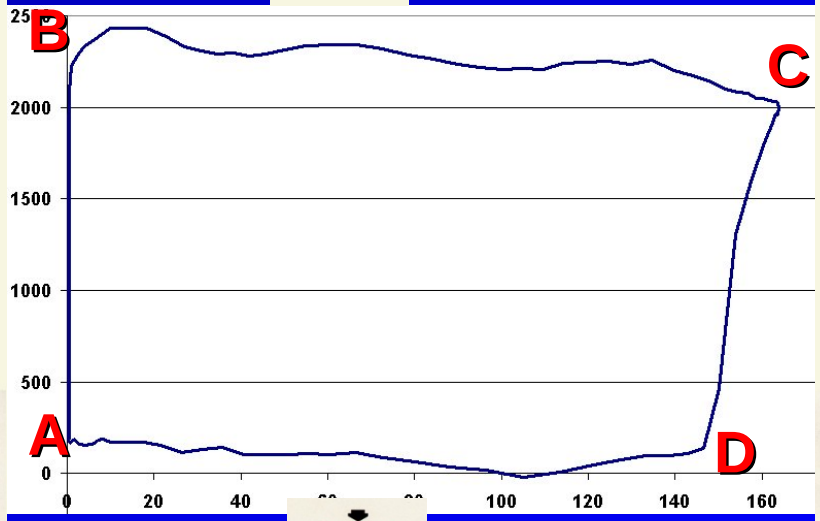
B-C) Fluid load, Fo, is carried by the rods as well fluids are drawn into the pump.

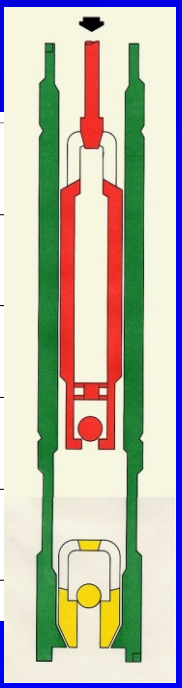
C) Standing valve closes, and the traveling valve remains closed. C-D pressure inside the pump increases until it is slightly greater than the pump discharge pressure.

D) Pump discharge pressure (Pd) equals static tubing pressure (Pt), and the traveling valve opens. Fluid load, Fo, is carried by tubing.





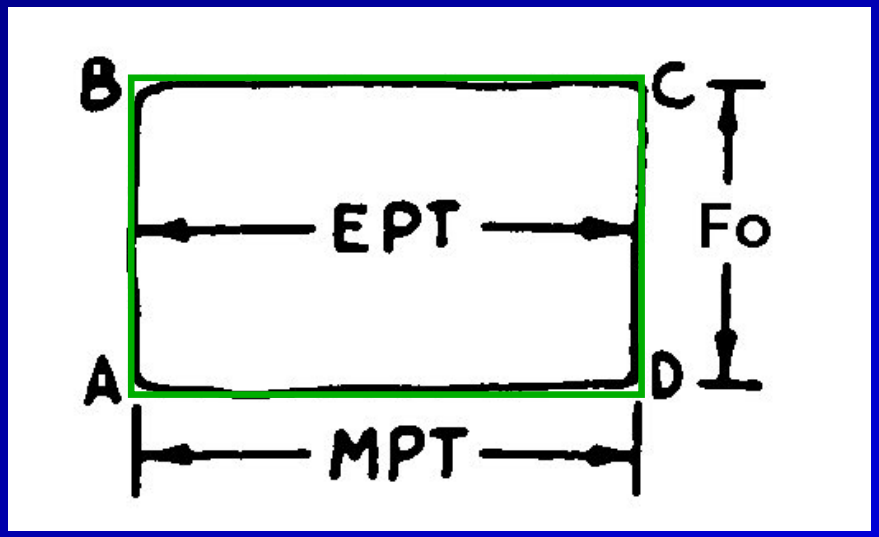




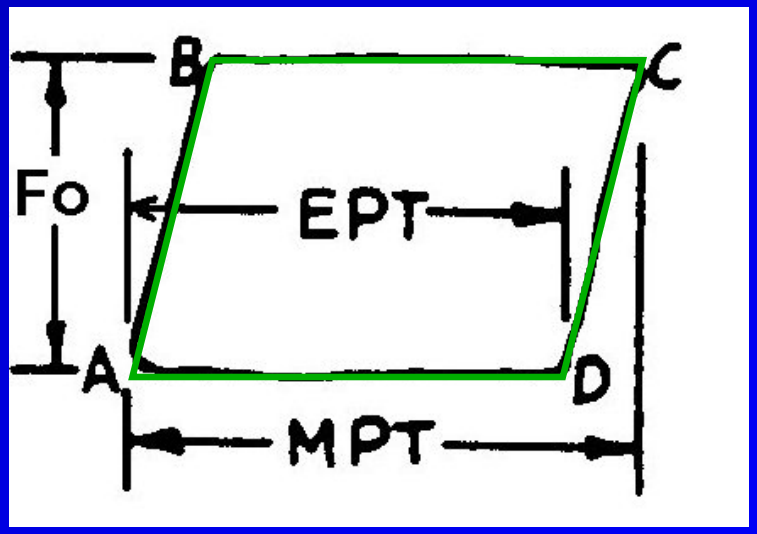
D - A, the fluid in the pump is displaced through the traveling valve into the tubing and **ZERO** fluid load is on rods.

Synthetic Pump Cards: Normal Full Pump

Tubing anchored, EPT=MPT.

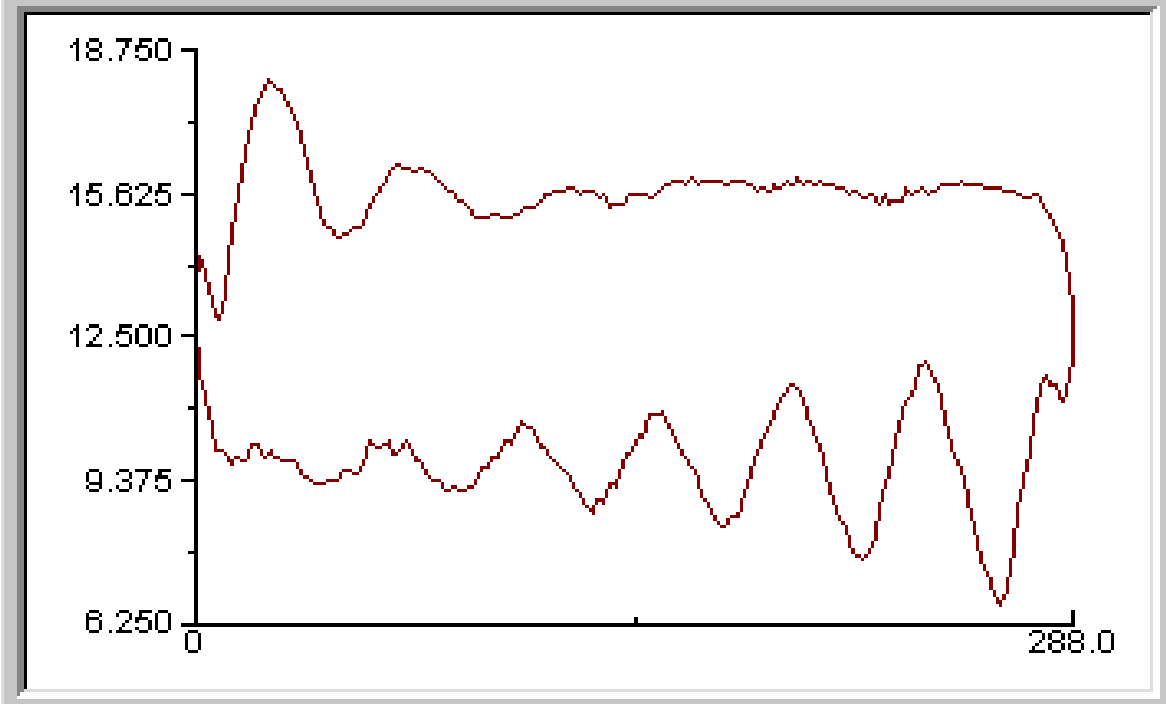


Unanchored tubing, EPT<MPT

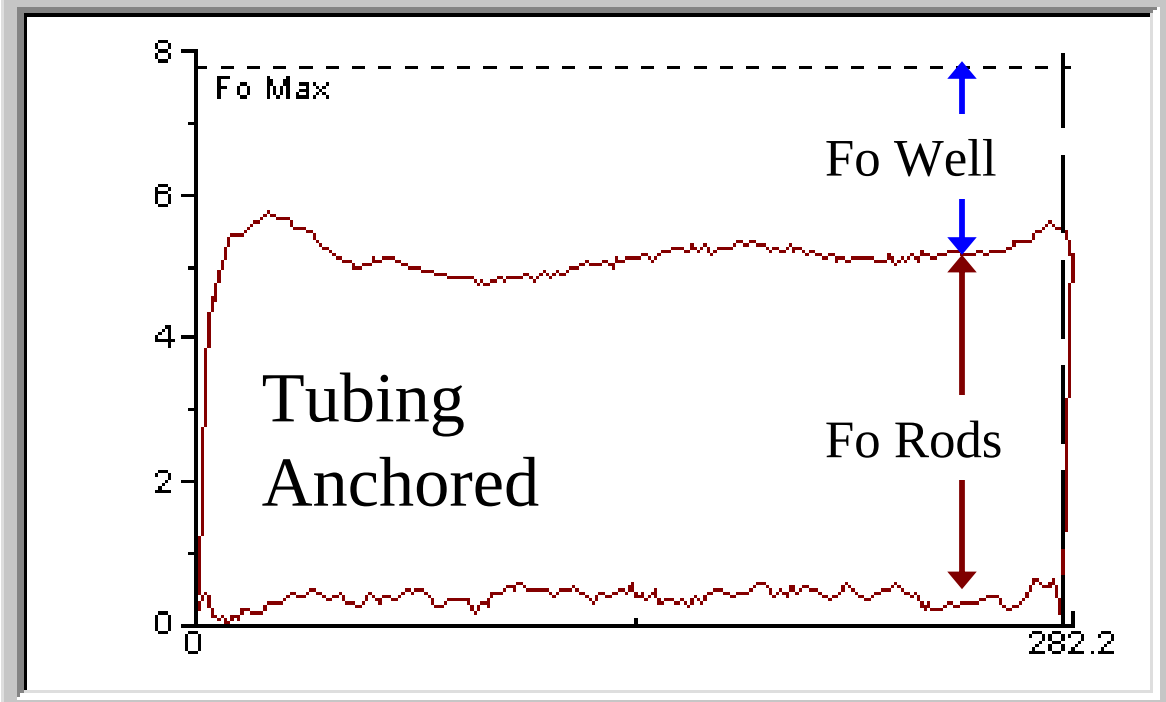


1. **Pumping-Full of Liquid**
2. **No gas in Pump.**
3. **Valves Not Leaking**
4. **Pump functioning properly.**

Load (K-Lbs) vs Polished Rod Pos. (in)



Load (K-Lbs) vs Plunger Pos. (in)



PRT352

PPRL	18105	PPUMPL	5743
MPRL	6659	MPUMPL	-0

Calculated Fluid Load	7793	lb
Polished Rod Power	16.1	HP
Polished Rod / Motor Eff.	74.6	%
Strokes Per Minute	3.75	
Pump Card HP	12.6	HP
Pump / Motor Eff.	58.3	%
Pump Displacement	618.3	STB/D
Pump Intake Pressure	681.2	psi (g)
Damp Up	0.05	
Damp Down	0.05	
Tubing Pressure		psi (g)

<< Reset

Pump Fillage Adjustment

< --- Left | Right --- >

Fillage 99.09 %

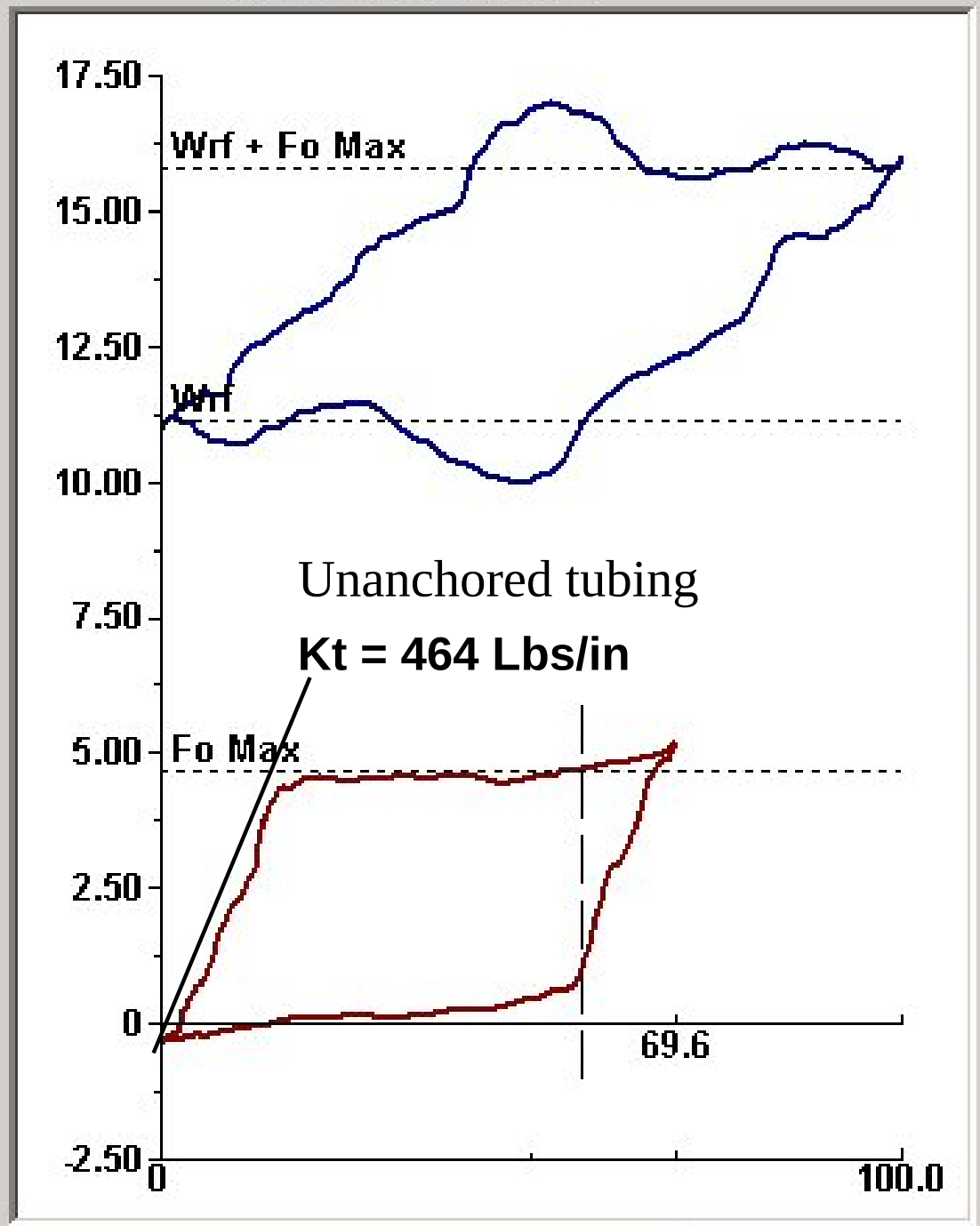
Approx. Best Pos.

Stroke 1

? | < Pg Up | Pg Dw

Raw Data | Overlay | Dyna Cards | Torque | Rod Loading | Load/Current | Power Torque | Power F

Load(K-Lbs) vs Position (in)



Kr 176 lb/in Kt 464 lb/in Dyna Card Options...

HLT002

PPRL	16990	PPUMPL	5177
MPRL	9974	MPUMPL	-356

Calculated Fluid Load Max	4686	lb
Polished Rod Power	3.7	HP
Polished Rod / Motor Eff.	54.1	%
Strokes Per Minute	4.80	
Pump Card HP	2.7	HP
Pump / Motor Eff.	39.5	%
Pump Displacement	71.5	BBL/D
Pump Intake Pressure...	65.3	psi (g)
Damp Up	0.1	
Damp Down	0.1	
Tubing Head Pressure	86.0	psi (g)

<< Reset

Effective Plunger Stroke

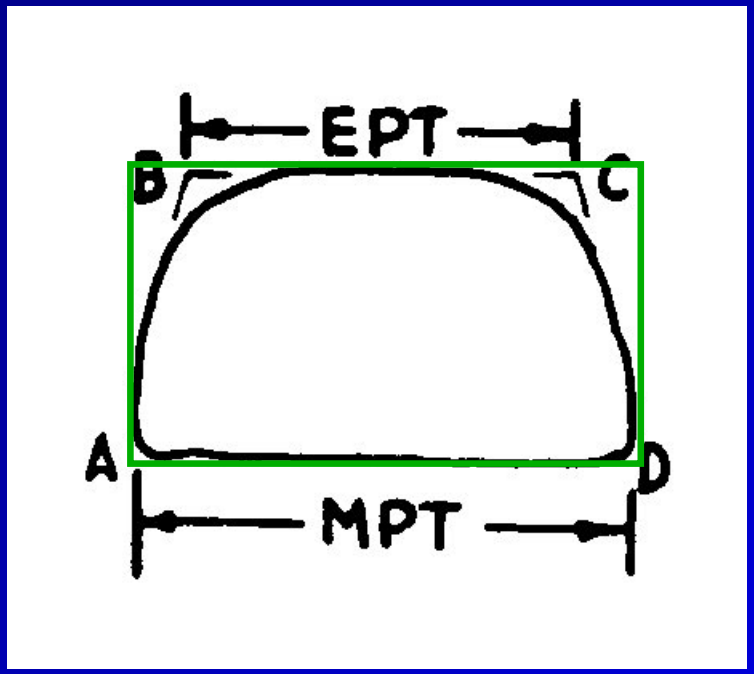
< --- Left | Right --- > | Approx. Best Pos.

81.54 % 56.8 in

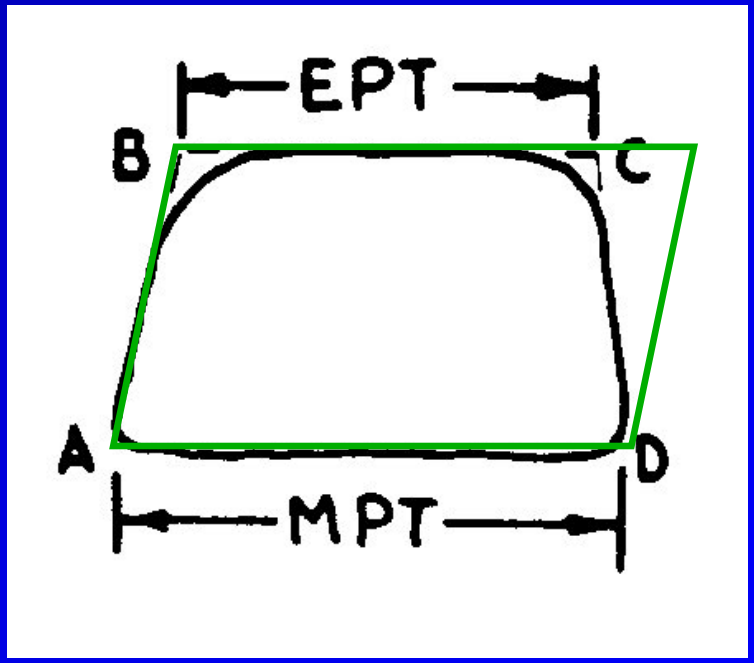
Stroke 4 ? < Pg Up Pg Dwn >

Synthetic Pump Cards: Leaking Traveling Valve or Plunger

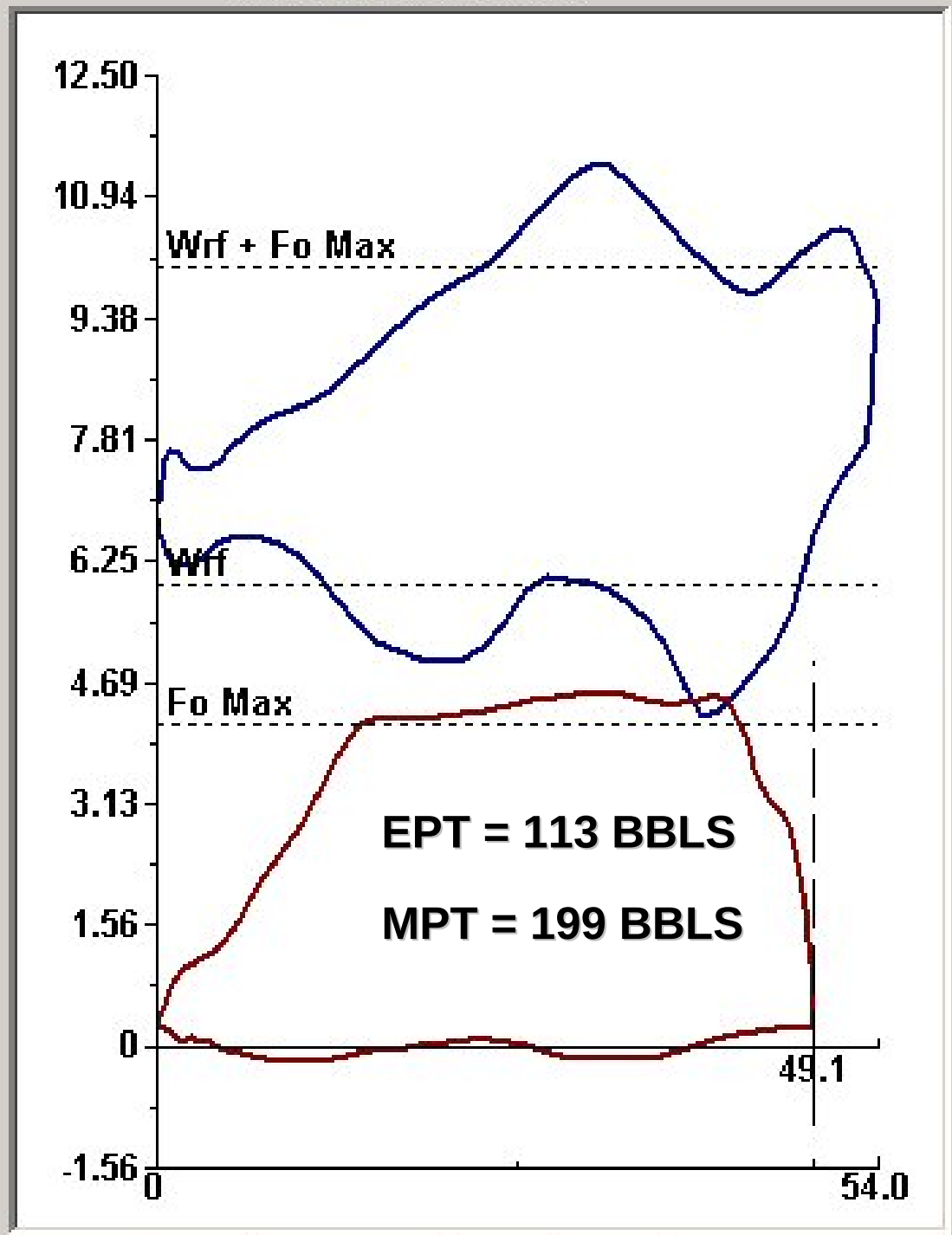
Tubing anchored, EPT<MPT.



Unanchored tubing, EPT<MPT



Leaking traveling valve, TV, or excessive plunger slippage causes delay in picking up fluid load from A to B and premature unloading from C to D. The SV stays on seat due to leakage into the barrel, therefore the traveling valve, TV, is effective only during a portion of the upstroke.



PRT138

PPRL	11351	PPUMPL	4552
MPRL	4260	MPUMPL	-193

Calculated Fluid Load Max	4071	lb
Polished Rod Power	5.9	HP
Polished Rod / Motor Eff.		%
Strokes Per Minute	11.32	
Pump Card HP	5.0	HP
Pump / Motor Eff.		%
Pump Displacement	198.5	BBL/D
Pump Intake Pressure...	2.7	psi (g)
Damp Up	0.05	
Damp Down	0.05	
Tubing Head Pressure	30.0	psi (g)

<< Reset

Effective Plunger Stroke

< --- Left | Right --- > | Approx. Best Pos.

100.00 % 49.1 in

Stroke 1

? | < Pg Up | Pg Dwn >

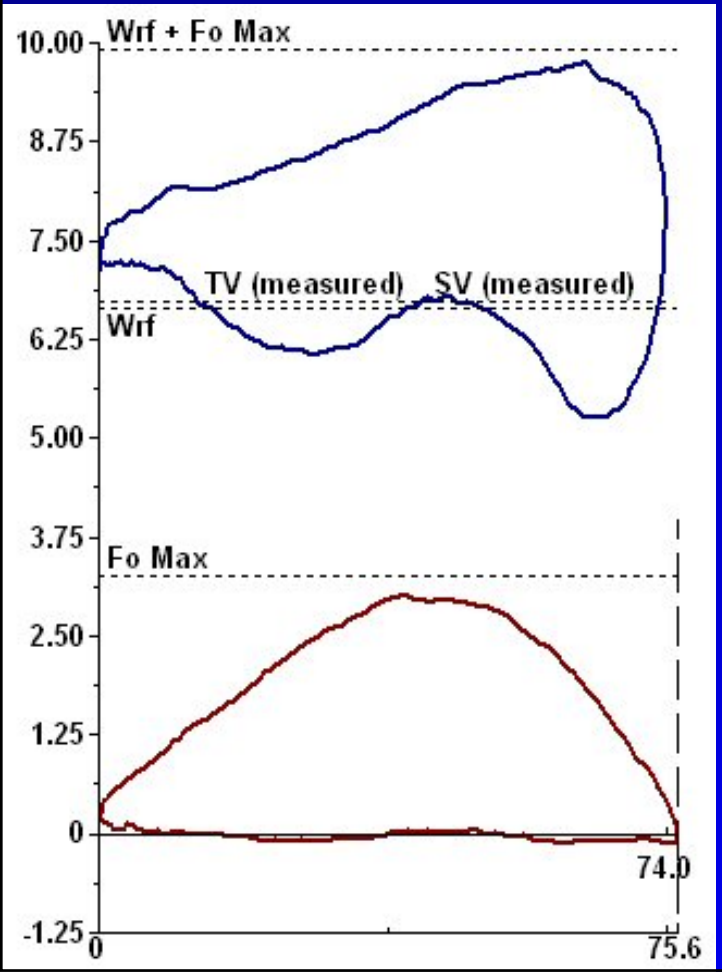
Kr 322 lb/in Kt 1181 lb/in Dyna Card Options...

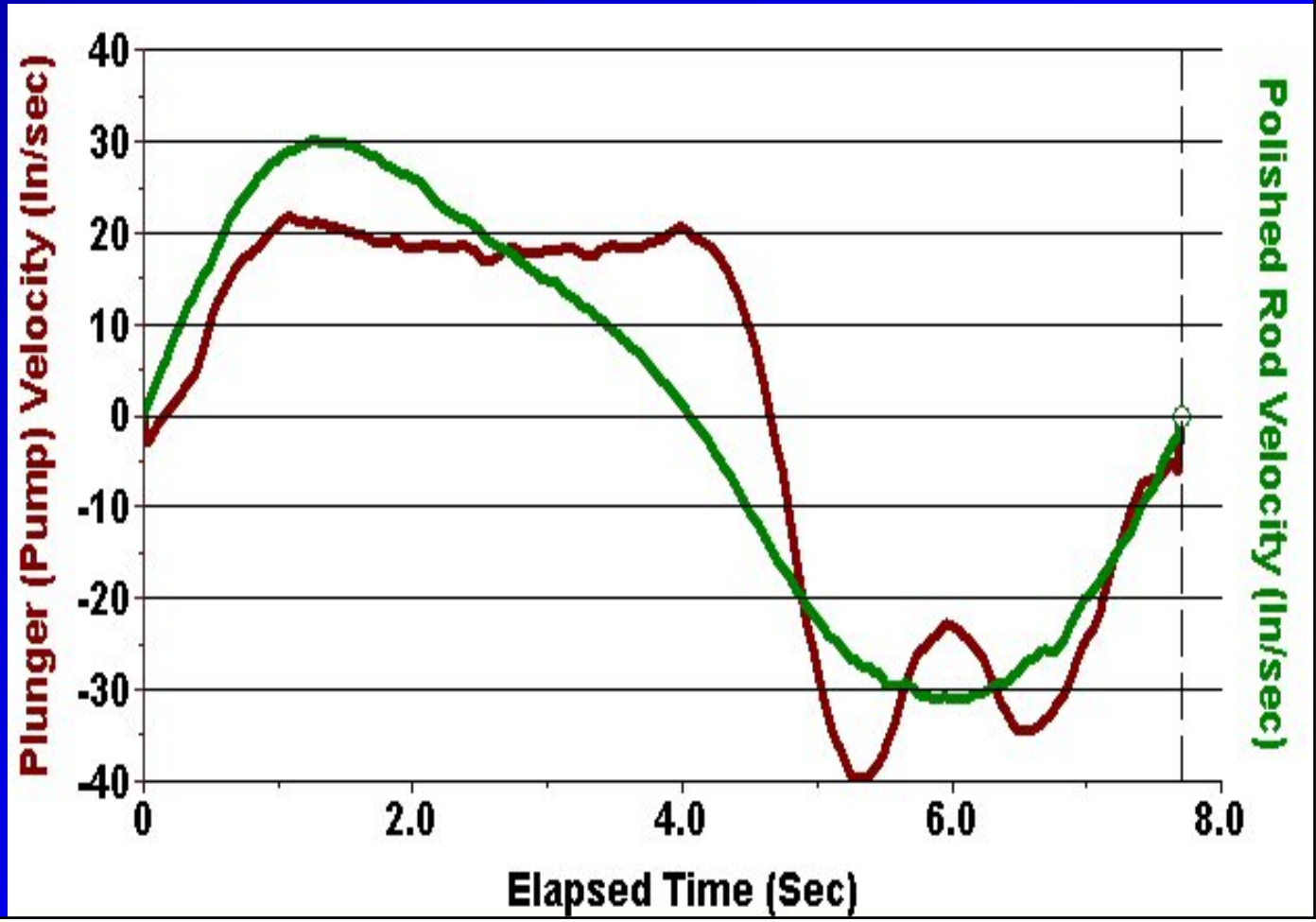
Example of Large TV Leakage Rate:
PR load drops immediately after rods are stopped on upstroke.

Worn-out Plunger and/or Barrel, or a Bad TV, or both.

Plunger Velocity Constant on Up Stroke

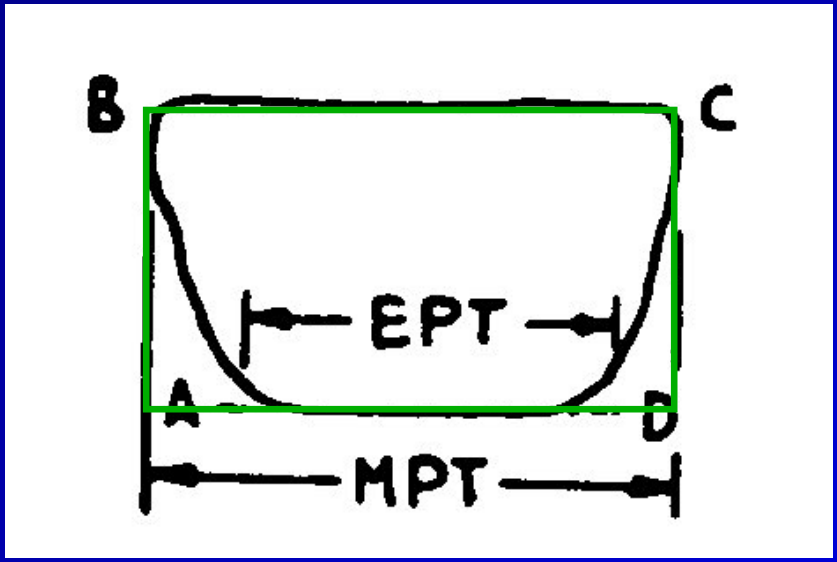
1. No Fluid Produced to Surface
2. Increase in Fluid Load causes some Rod Stretch
3. Plunger Appears to Act as Choke as a Constant Rate of fluid leaks past Plunger
4. Constant Plunger Velocity of 20 in/sec due to constant Leakage Rate past Plunger.



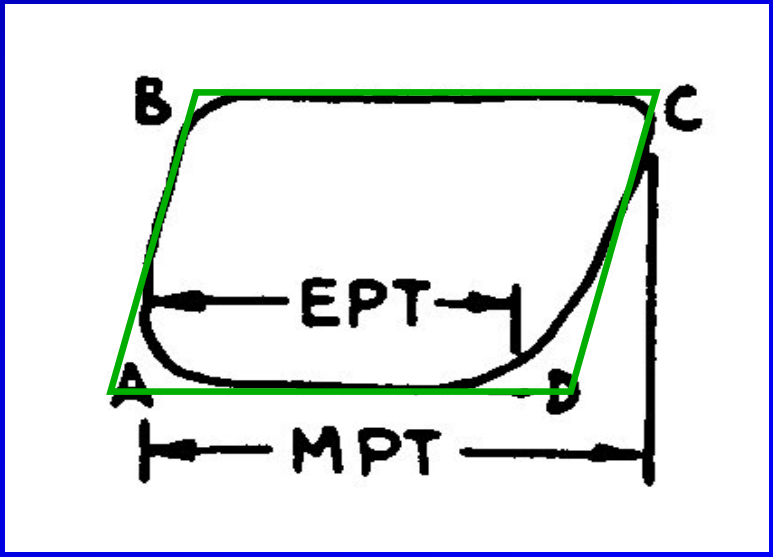


Synthetic Pump Cards: Leaking Standing Valve

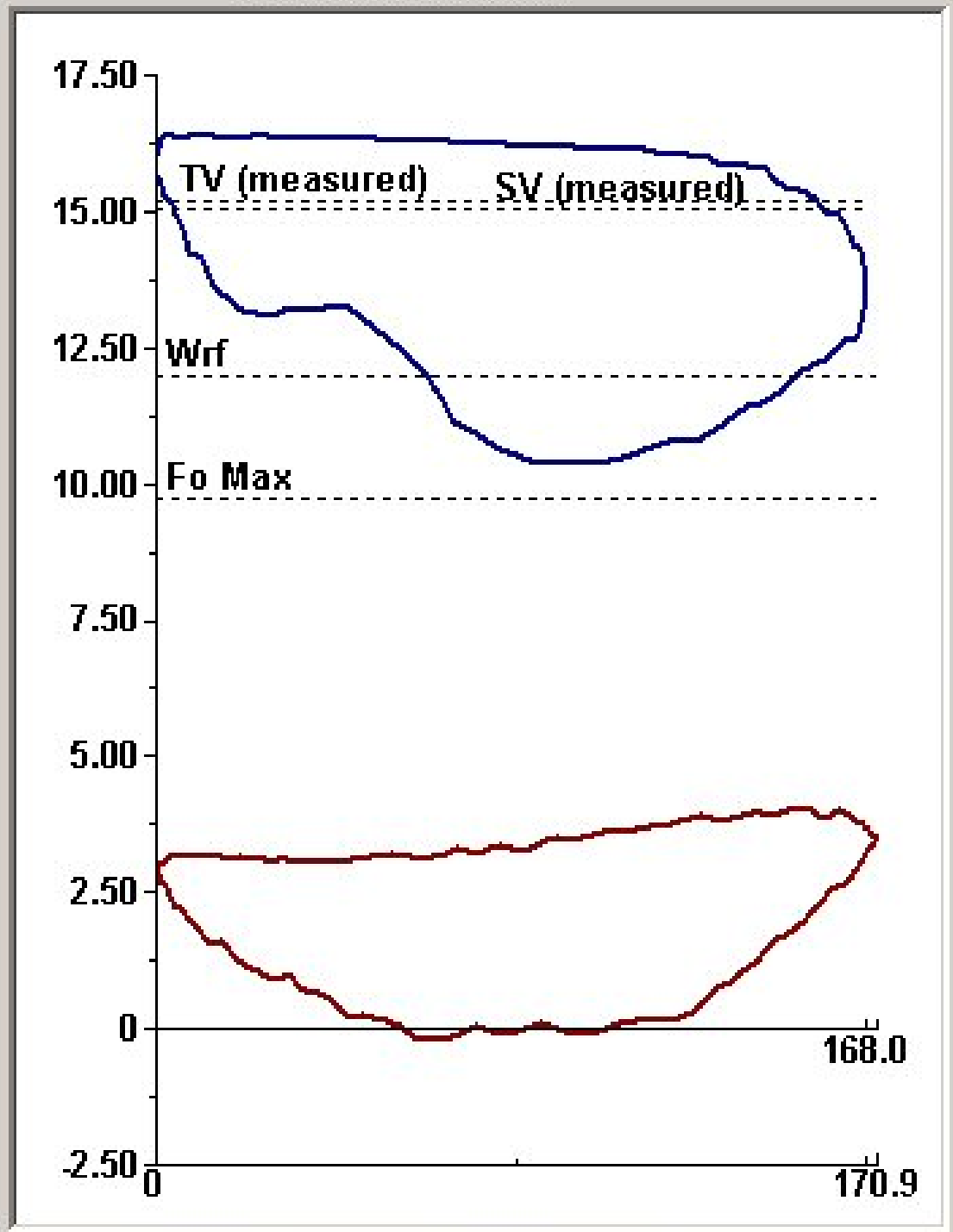
Tubing anchored, EPT<MPT.



Unanchored tubing, EPT<MPT



Leaking standing valve, SV, causes premature loading of rods from A to B, and a delay in unloading from C to D. The standing valve is supposed to be on seat from A to D holding fluid in the tubing. Fluid leaks past the standing valve on the downstroke and the SV is effective only during a portion of the downstroke.



HLT023

PPRL	16407	PPUMPL	4026
MPRL	10378	MPUMPL	-212

Calculated Fluid Load Max	9738	lb
Polished Rod Power	11.8	HP
Polished Rod / Motor Eff.		%
Strokes Per Minute	6.82	
Pump Card HP	7.8	HP
Pump / Motor Eff.		%
Pump Displacement	626.6	BBL/D
Pump Intake Pressure...	1551.3	psi (g)
Damp Up	0.04	
Damp Down	0.04	
Tubing Head Pressure	150.0	psi (g)

<< Reset

Effective Plunger Stroke

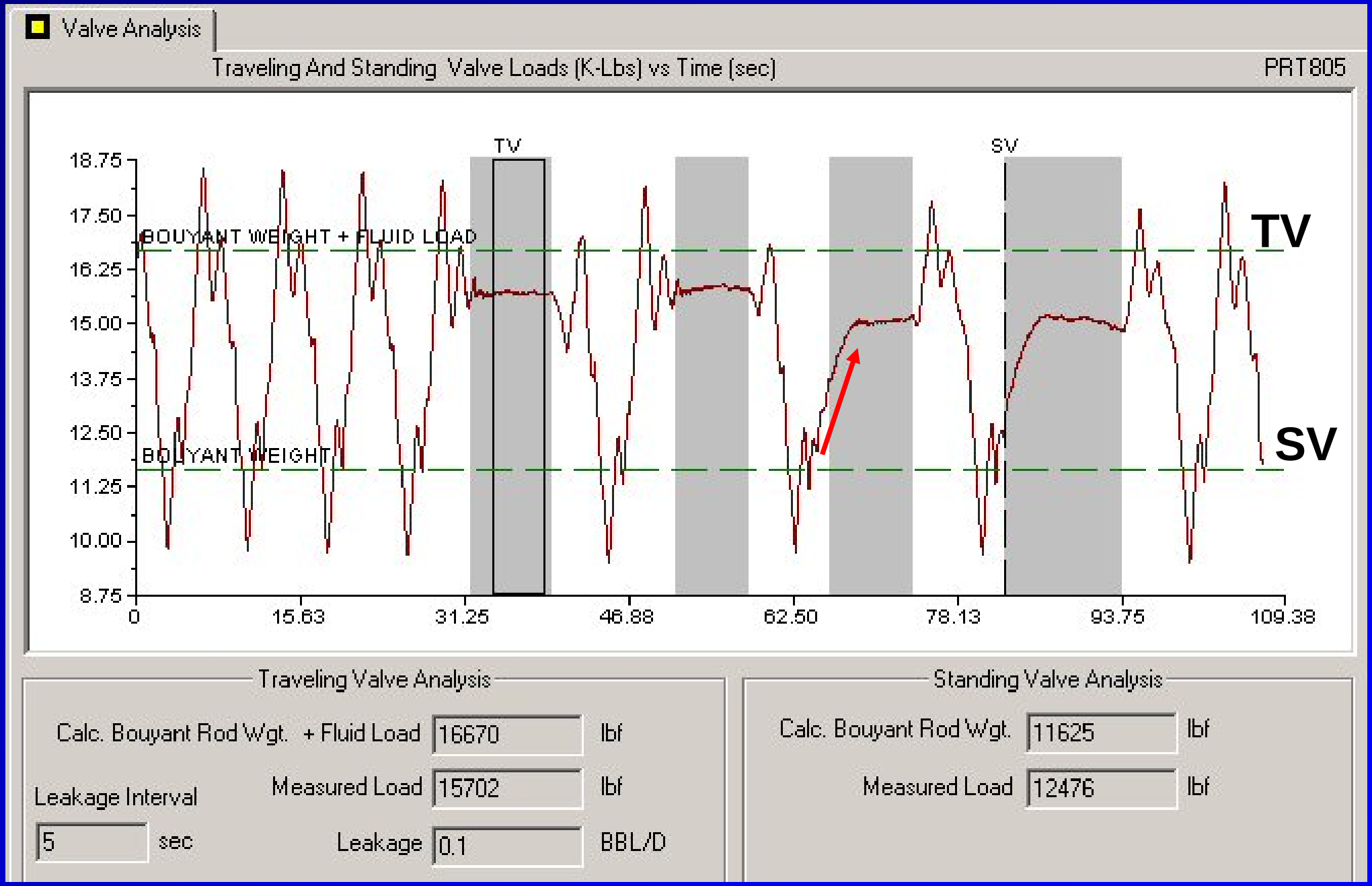
< --- Left | Right --- > | Approx. Best Pos.

91.09 % 155.7 in

Stroke 1 ? < Pg Up Pg Dwn >

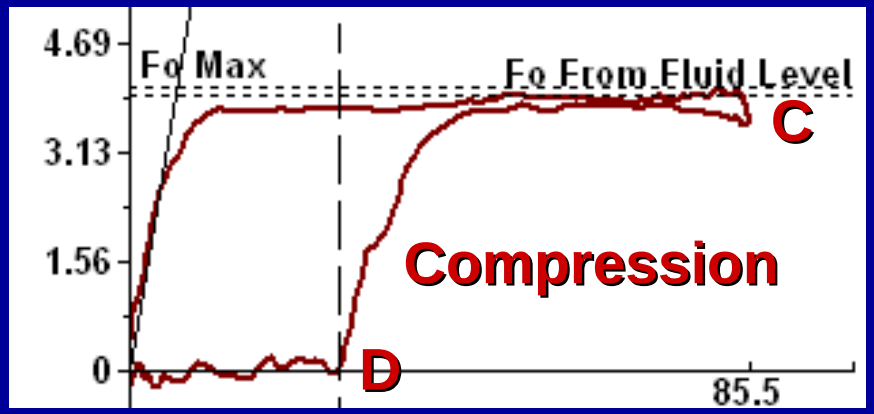
Kr 299 lb/in Kt 833 lb/in Dyna Card Options...

SV Check Shows Leak

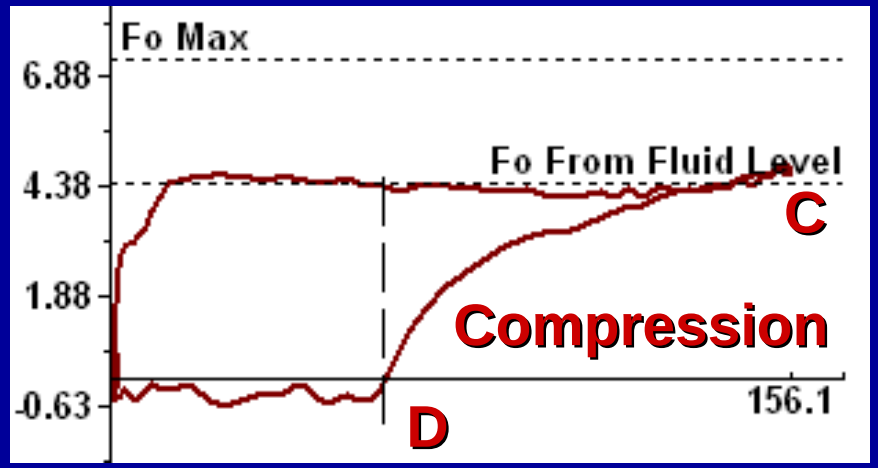


Incomplete Pump Fillage

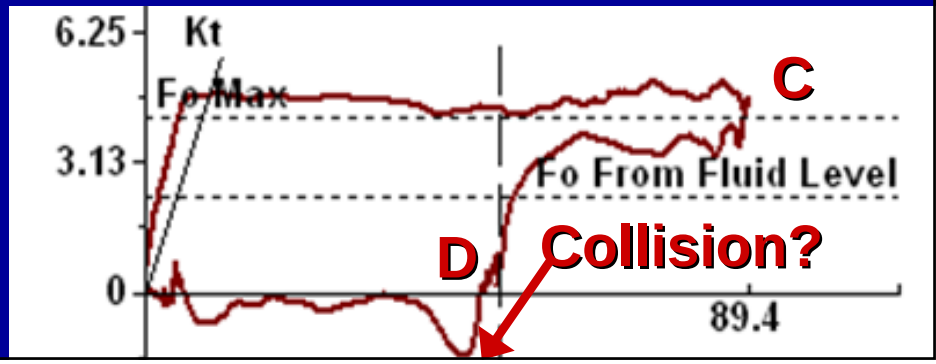
1. Fluid Pound - Not enough liquid to fill the pump barrel: well inflow less than pump displacement, pumped off.



2. Gas Interference - Both gas and liquid at pump intake pressure fill pump barrel during the upstroke.



3. Flow into pump intake choked - flow through SV is zero or less than plunger displacement.



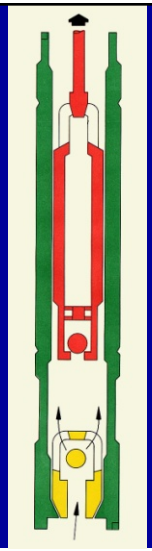
Incomplete Pump Fillage

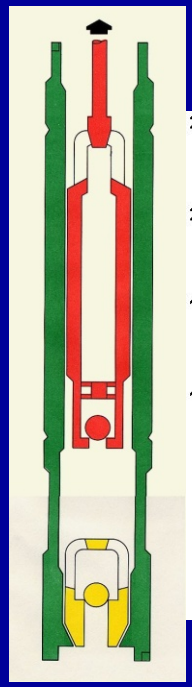
Occurs from C to D on Pump Card

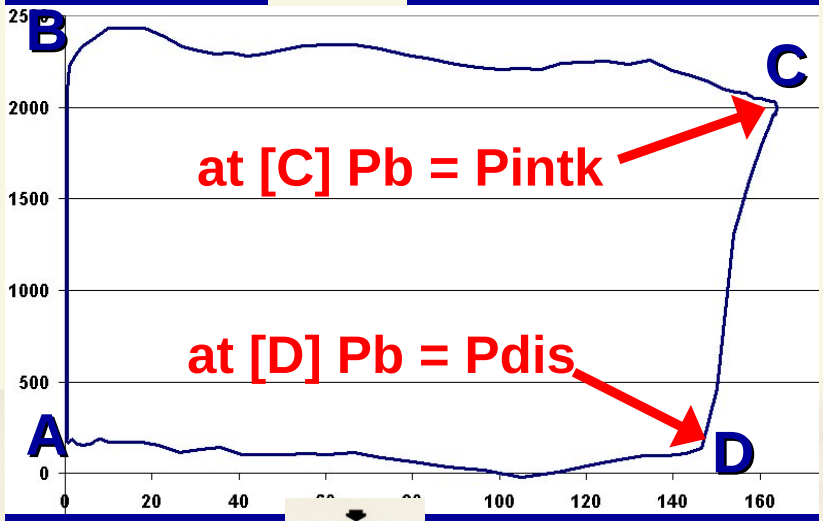
Steps C - D in Pump Operation

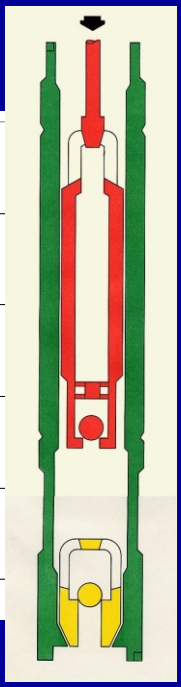
Pump is a Compressor

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









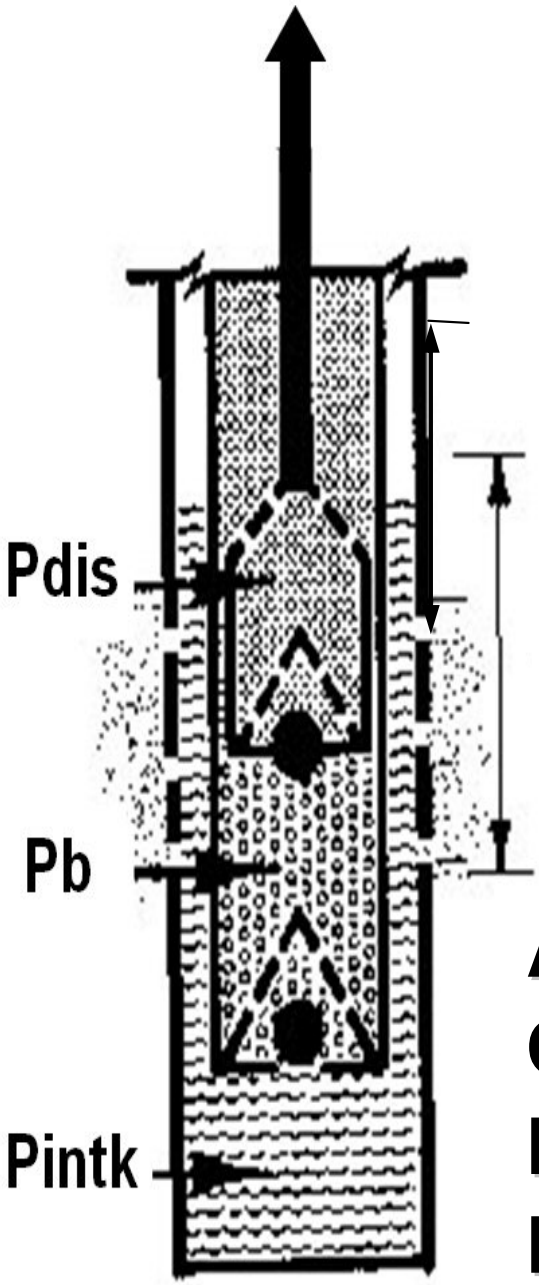
C) Standing Valve closes, when plunger reaches top of stroke, rods start to un-stretch to transfer fluid load, Fo, from rods [C] onto tubing [D].

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.

Transfer Fluid Load from C to D

from Rods to Tubing

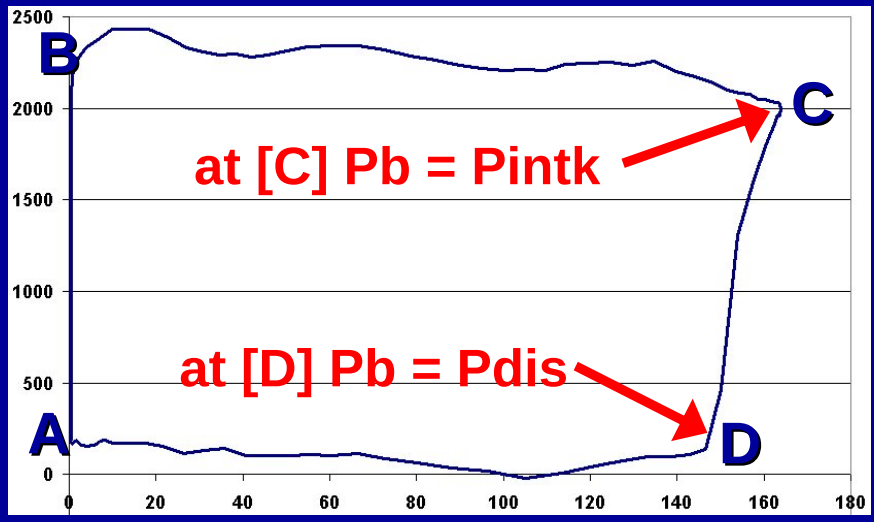


At [C] SV
Ball Seats
Pdis > Pb
Pb = Pintk

Plunger Stroke Length

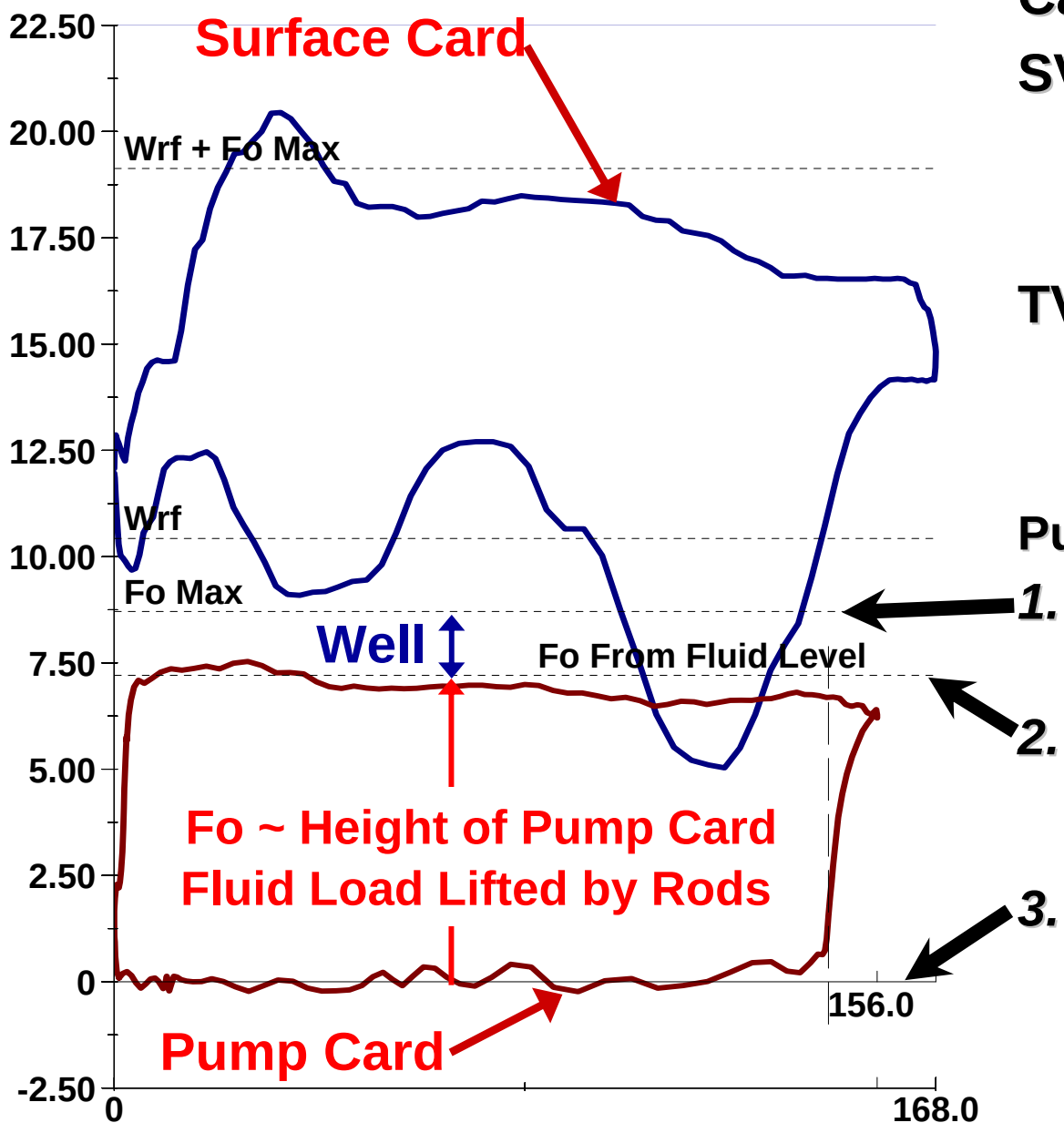
At [D] TV Opens
Pdis = Pb
Pb > Pintk

@ [C] Fo = Fluid Load
Pb = Pintk
(Pdis-Pintk)*Area Pump



@ [D] TV Opens
Fo = 0
Pb = Pdis
(Pdis - Pdis)*Area Pump

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

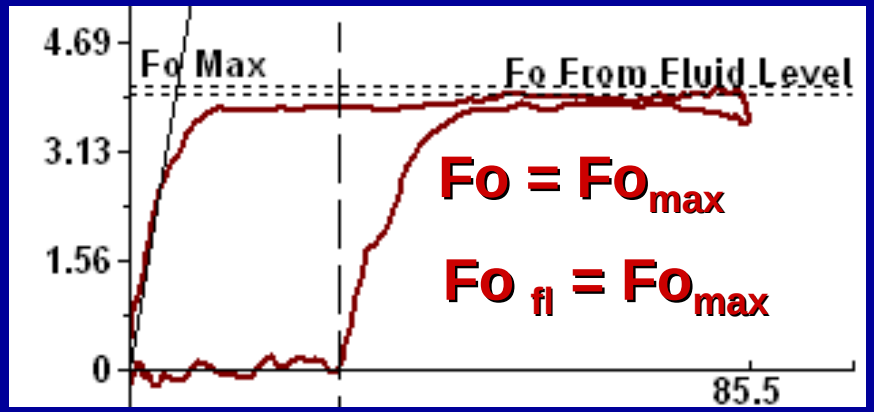
Fo loads measured Dynamometer or calculated From Fluid Level.

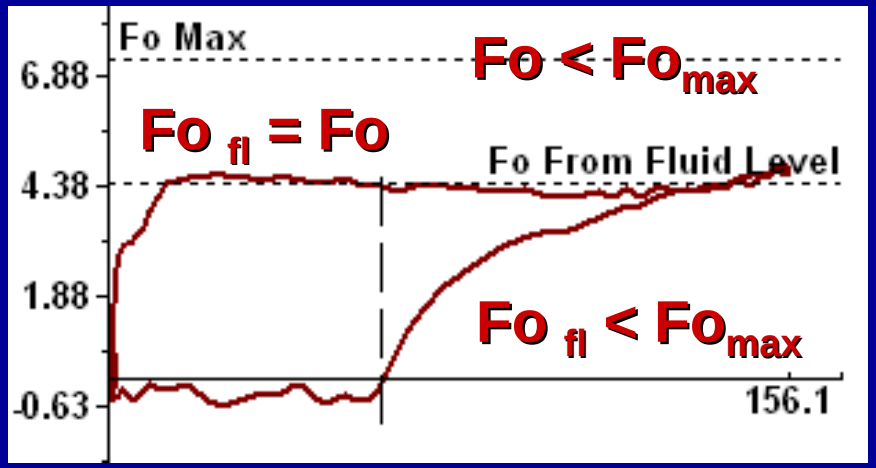
Incomplete Pump Fillage

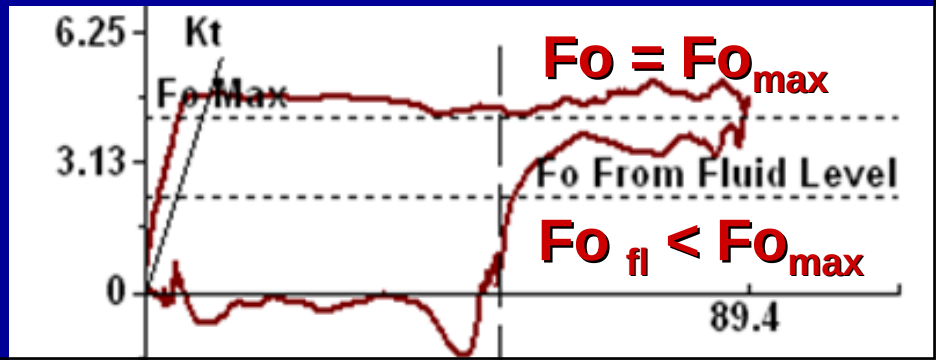
1. Fluid Pound – Rod Loading is Fomax, Pintk is low, Pb = Pintk.

2. Gas Interference - Rod Loading is Fo fl, Pintk is high, Pb = Pintk.

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



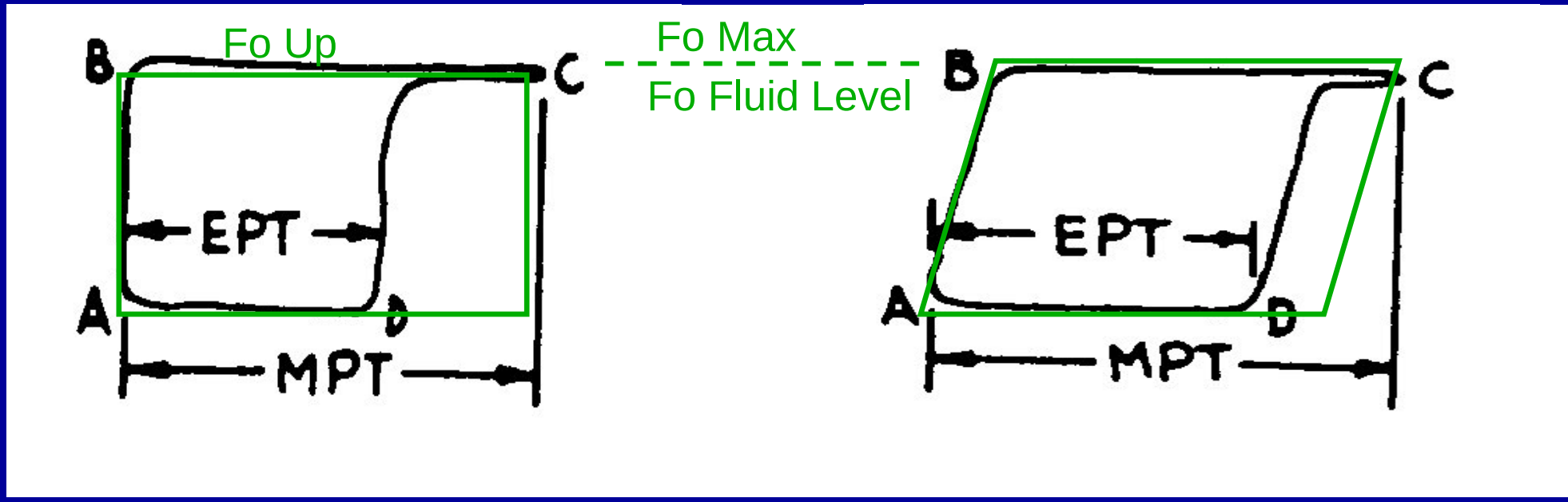




Synthetic Pump Cards: Fluid Pound ~ PIP is Low

Tubing anchored, EPT<MPT.

Unanchored tubing, EPT<MPT

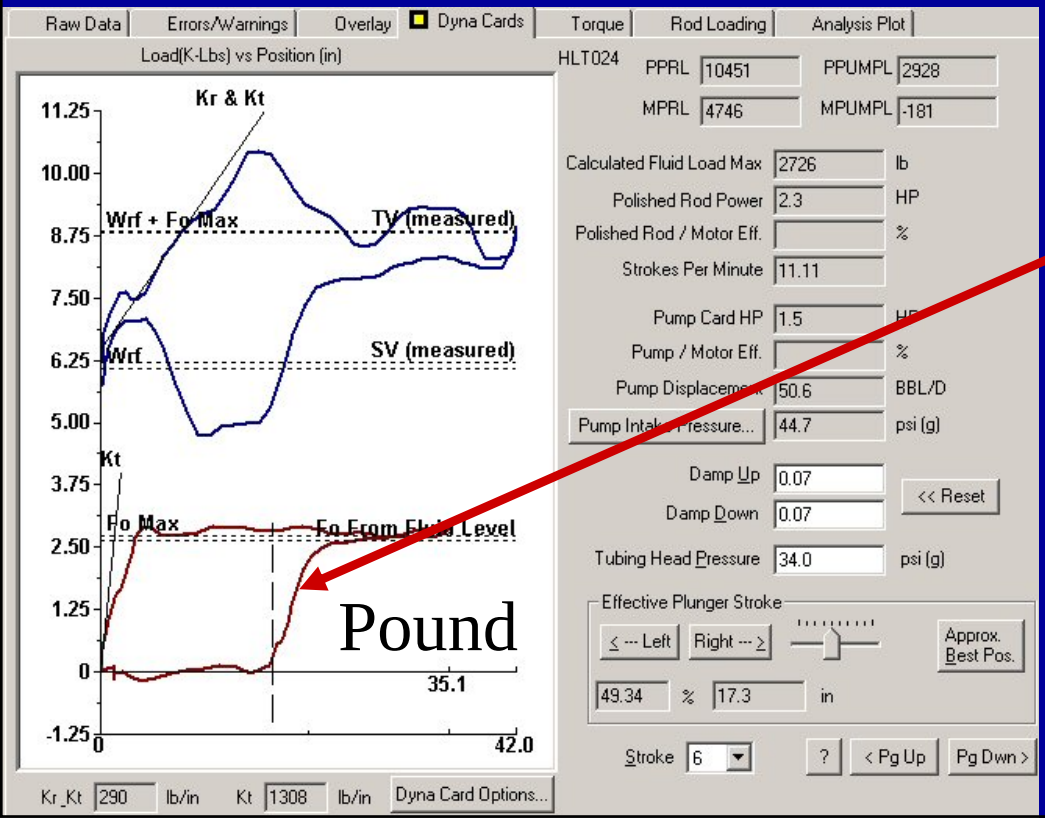


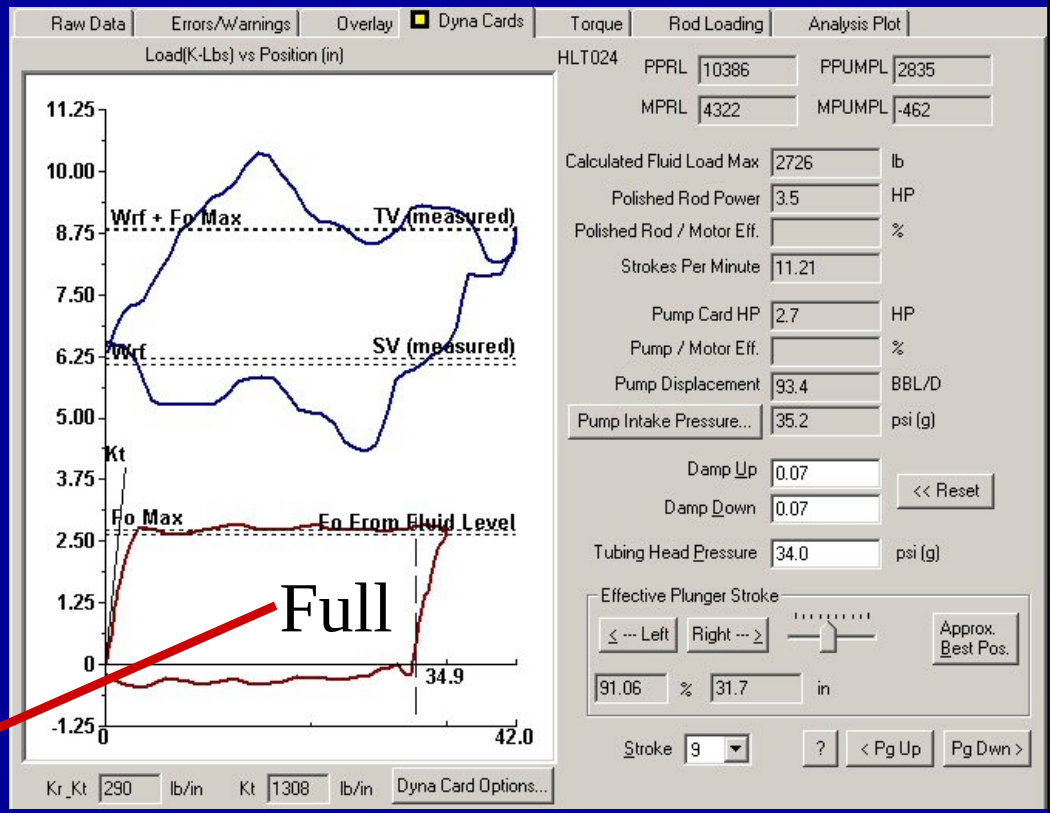
Fluid pound - well being pumped off. Pump components are functioning properly. BUT, sudden unloading of rods results in rod buckling and reduced equipment life! Shoot fluid level to verify pump intake not blocked and fluid level at pump intake.

Control Run Time When Pump Displacement Exceeds Inflow From Well

Same Well with Full Pump
Open TV only when Pump Full

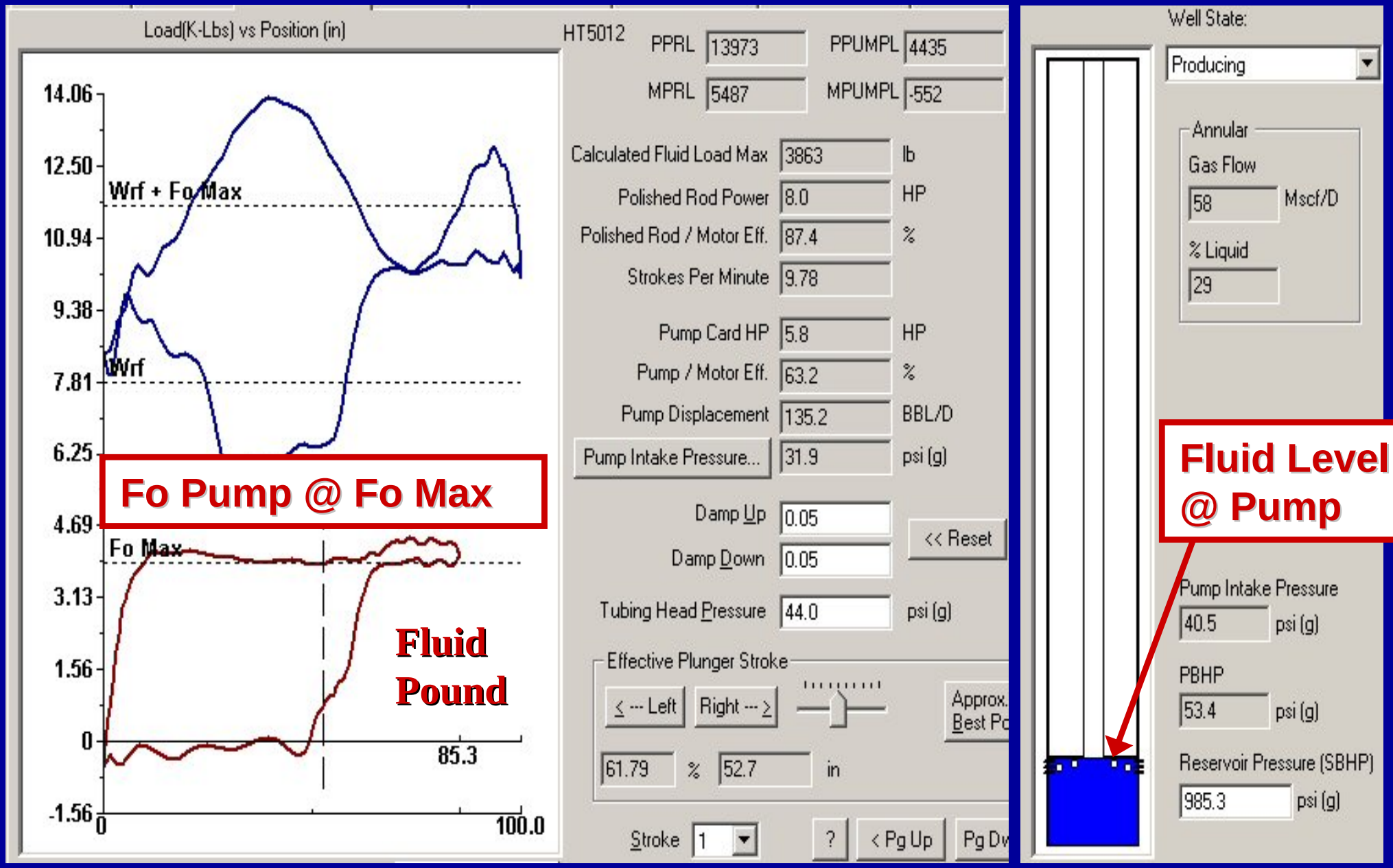
Pump Capacity Exceeds
Inflow of Fluids from Well.





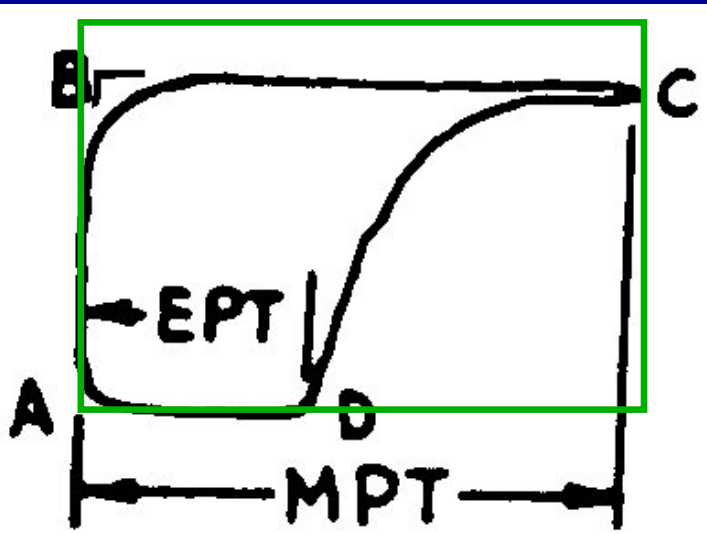
Controlling Pump Run Time Improves Efficiency, Reduces Shock Loads, and Reduces Failures.

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



Synthetic Pump Cards: Gas Interference

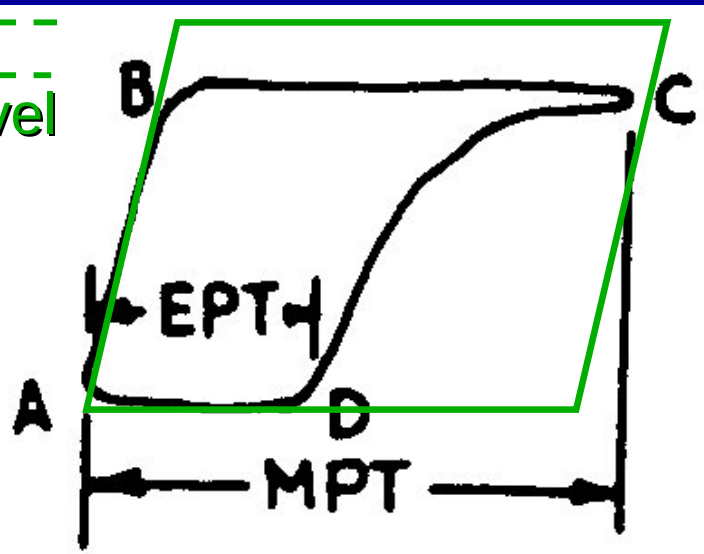
Tubing anchored, EPT<MPT.



Fo Max

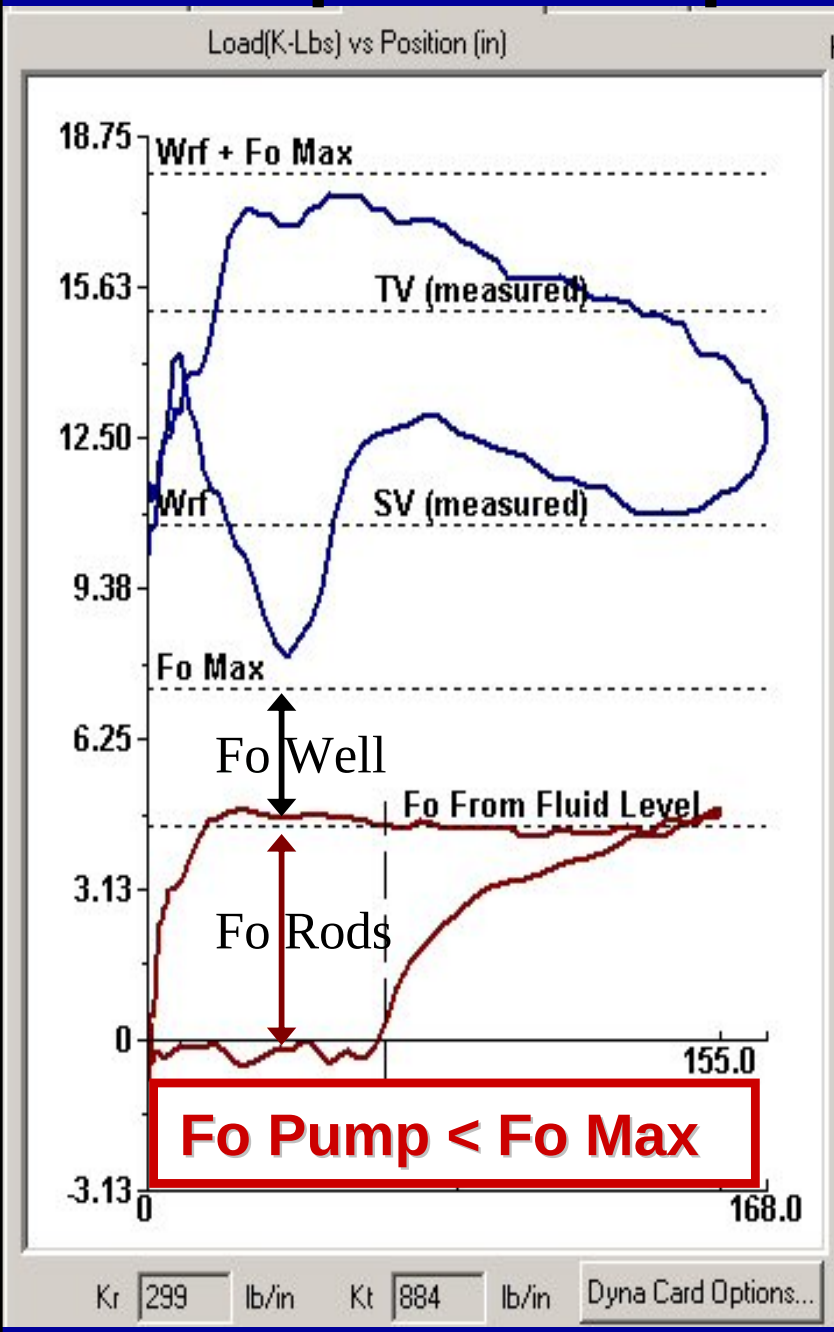
Fo Fluid Level

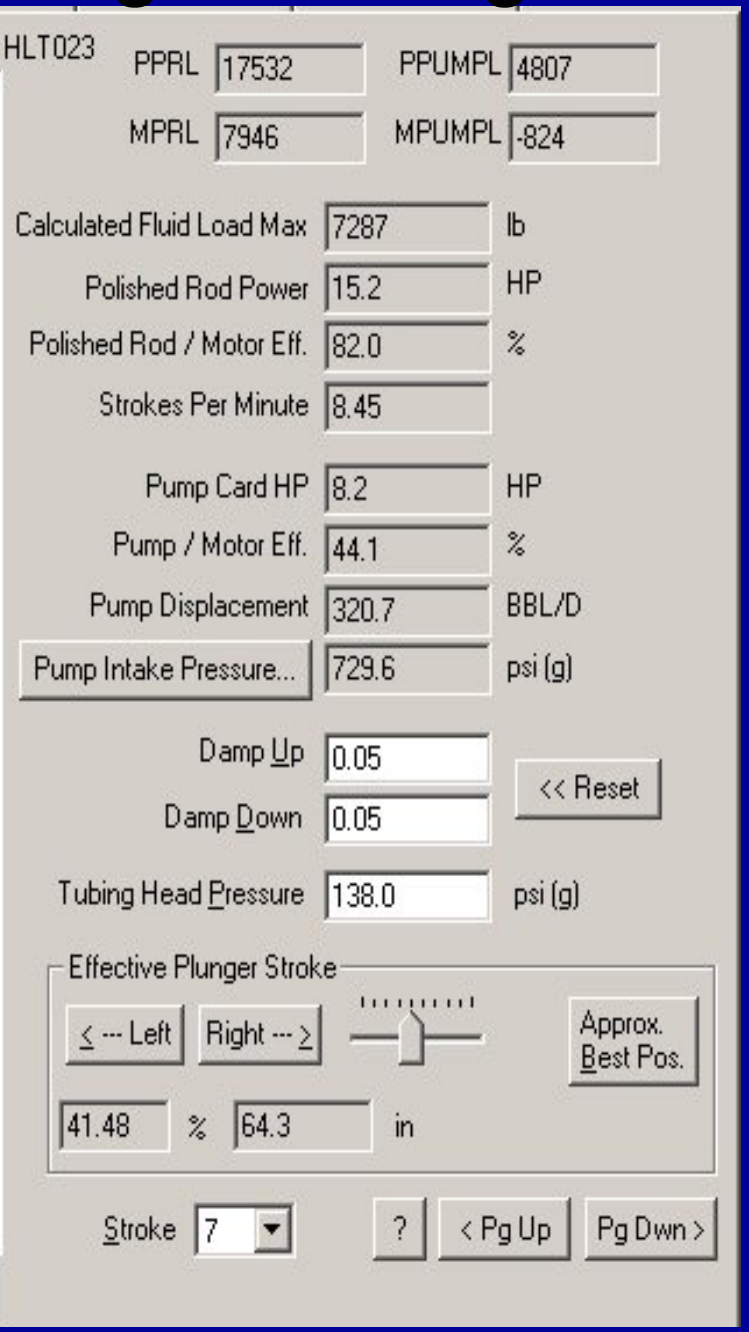
Unanchored tubing, EPT<MPT

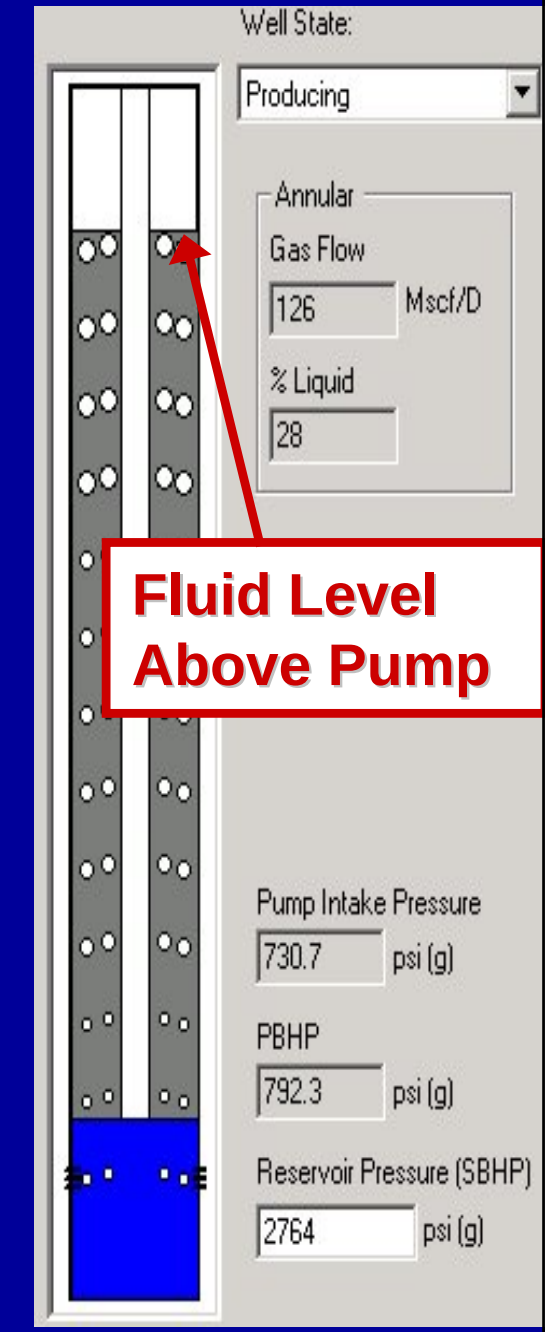


Gas Interference is causing decrease of EPT. Pump components are functioning properly. Usually unstable pump fillage and EPT changes from stroke-to-stroke. When gas interference is present expect increased rod-on-tubing wear due to rod buckling compressing gas in pump barrel.

Gas Interference: Incomplete Pump Fillage and High Fluid Level

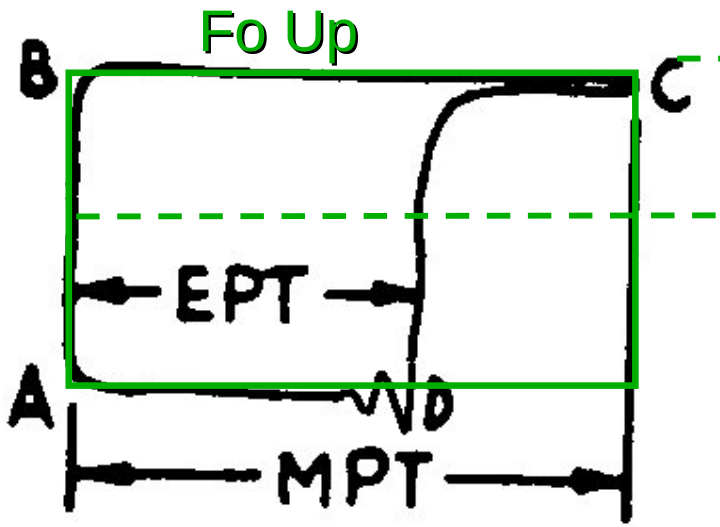




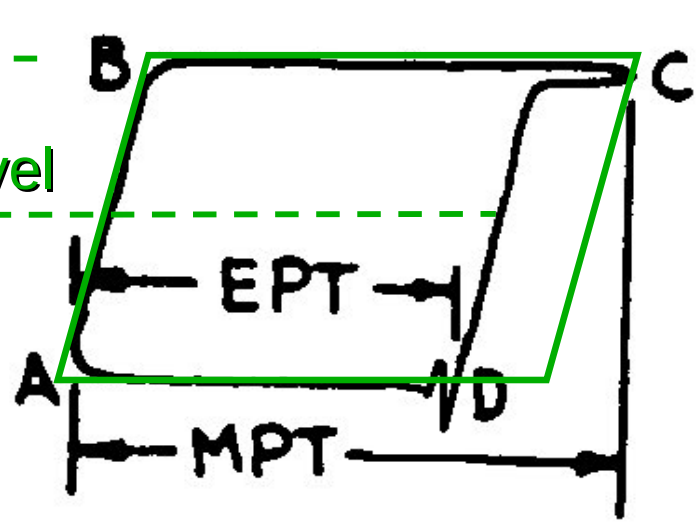


Synthetic Pump Cards:
Severe Fluid Pound – Blocked Pump Intake

Tubing anchored, EPT<MPT.

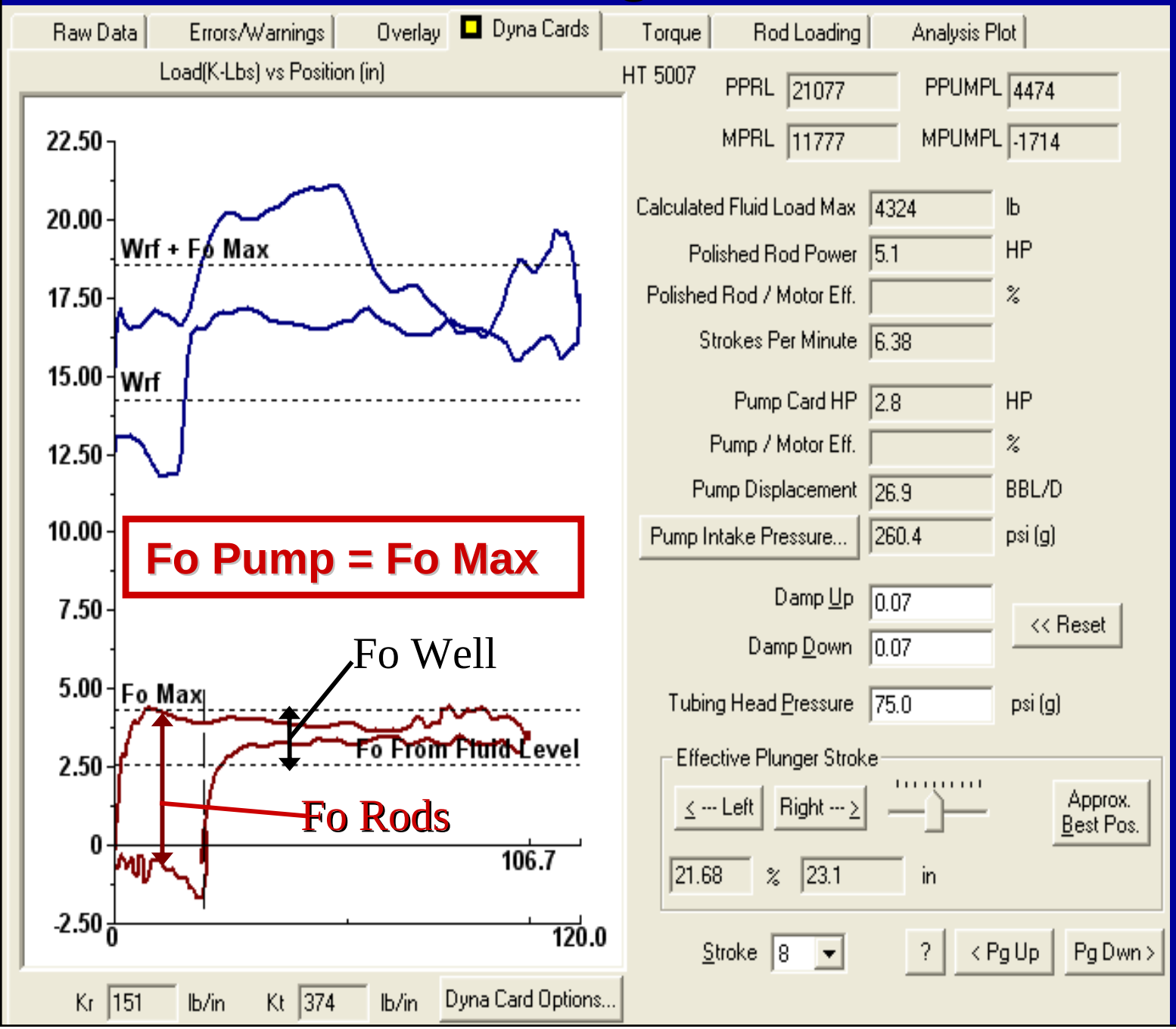


Unanchored tubing, EPT<MPT

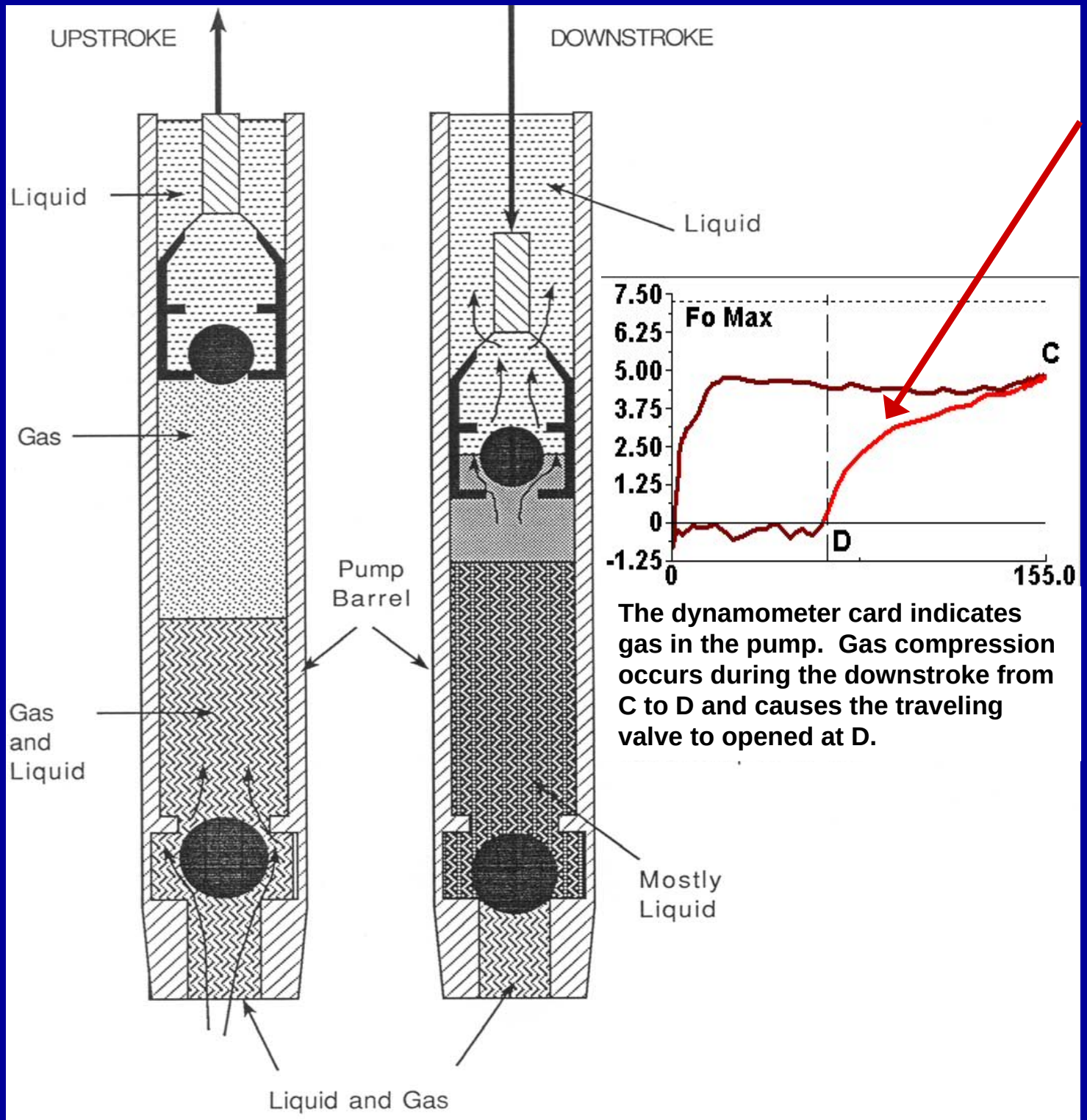


Severe fluid pound, usually occurs when the intake into the pump is completely blocked off. Strainer nipple, pump intake below fill, standing valve stuck shut can starve pump. Stuffing box leak and reduced equipment life result! Shoot fluid level to verify pump intake is blocked and fluid level above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

Severe Fluid Pound: Flow into Pump Choked Fluid Pound and High Fluid Level



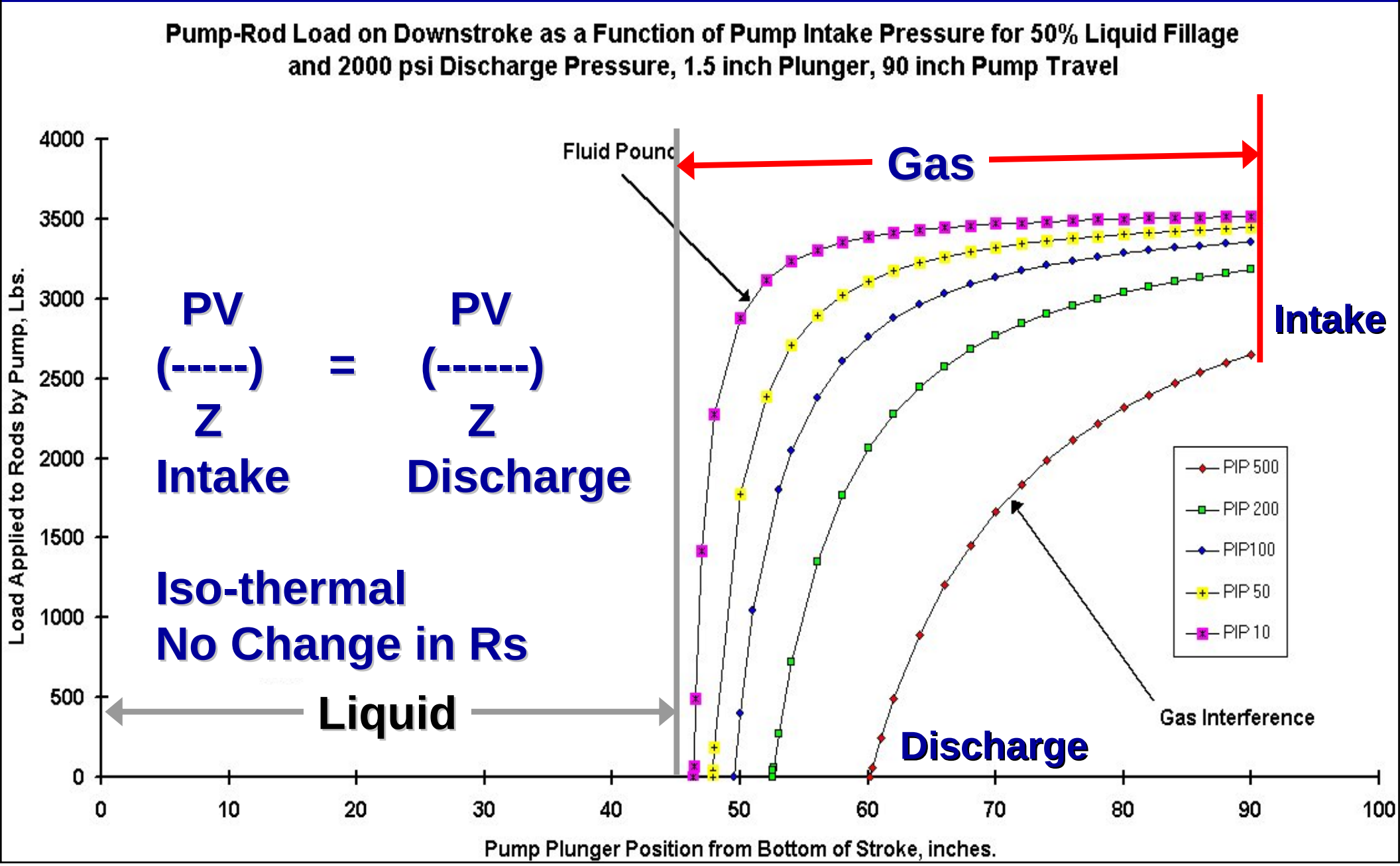
Gas Compression



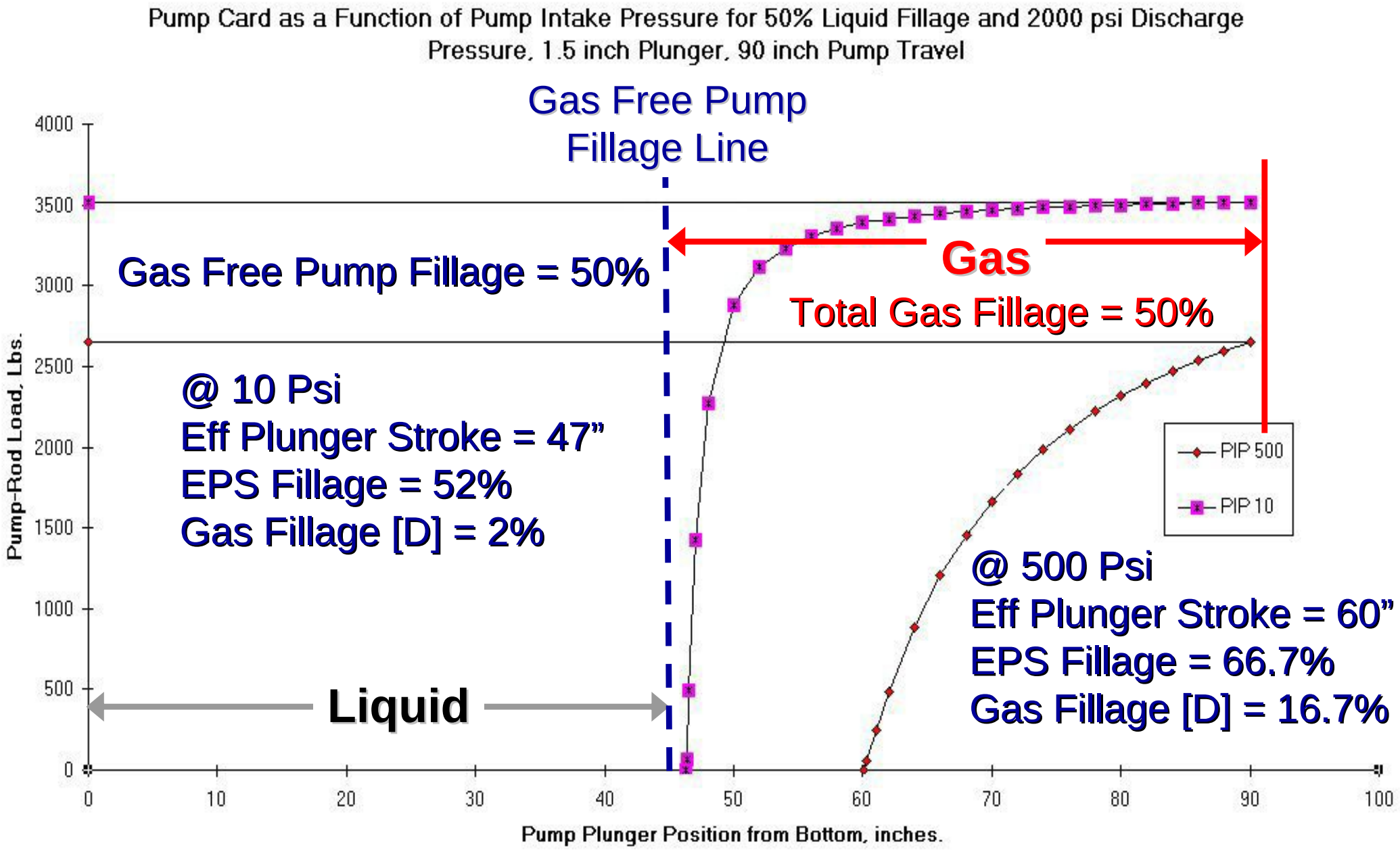
The dynamometer card indicates gas in the pump. Gas compression occurs during the downstroke from C to D and causes the traveling valve to opened at D.

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

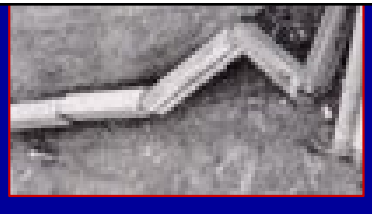
Effect of PIP on Gas Interference and Fluid Pound

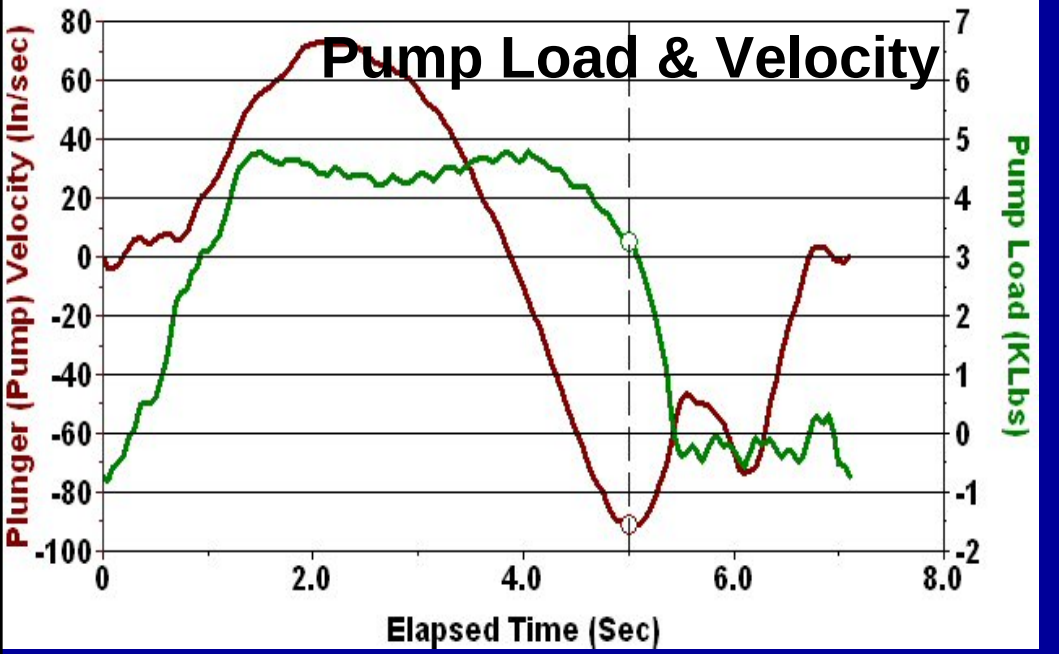


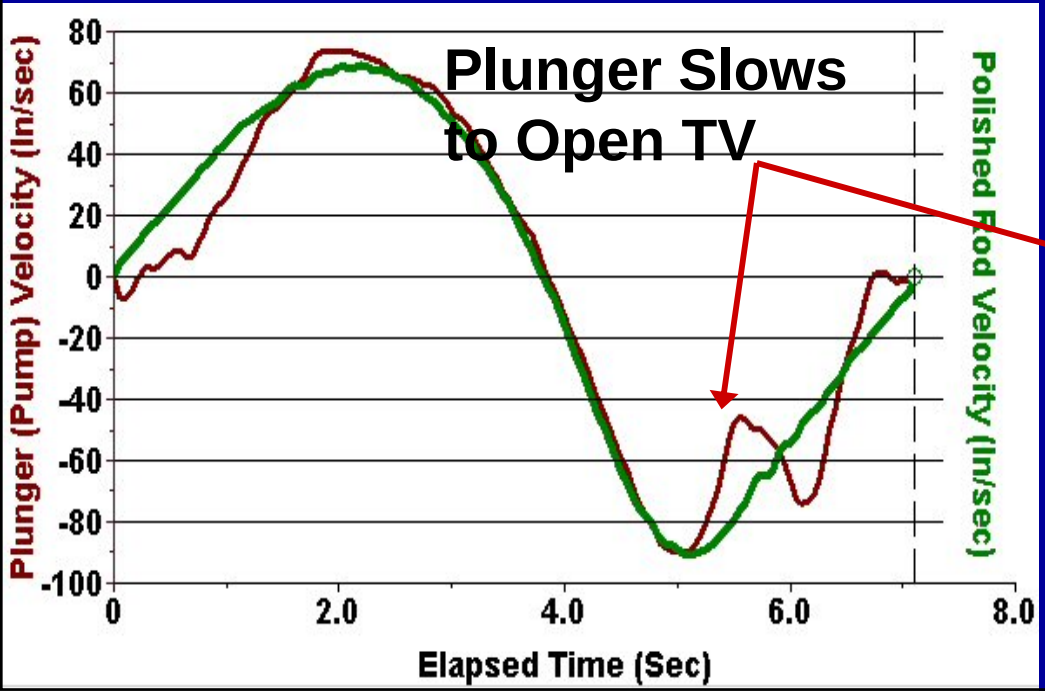
Effect of PIP on Fillage of Pump Card

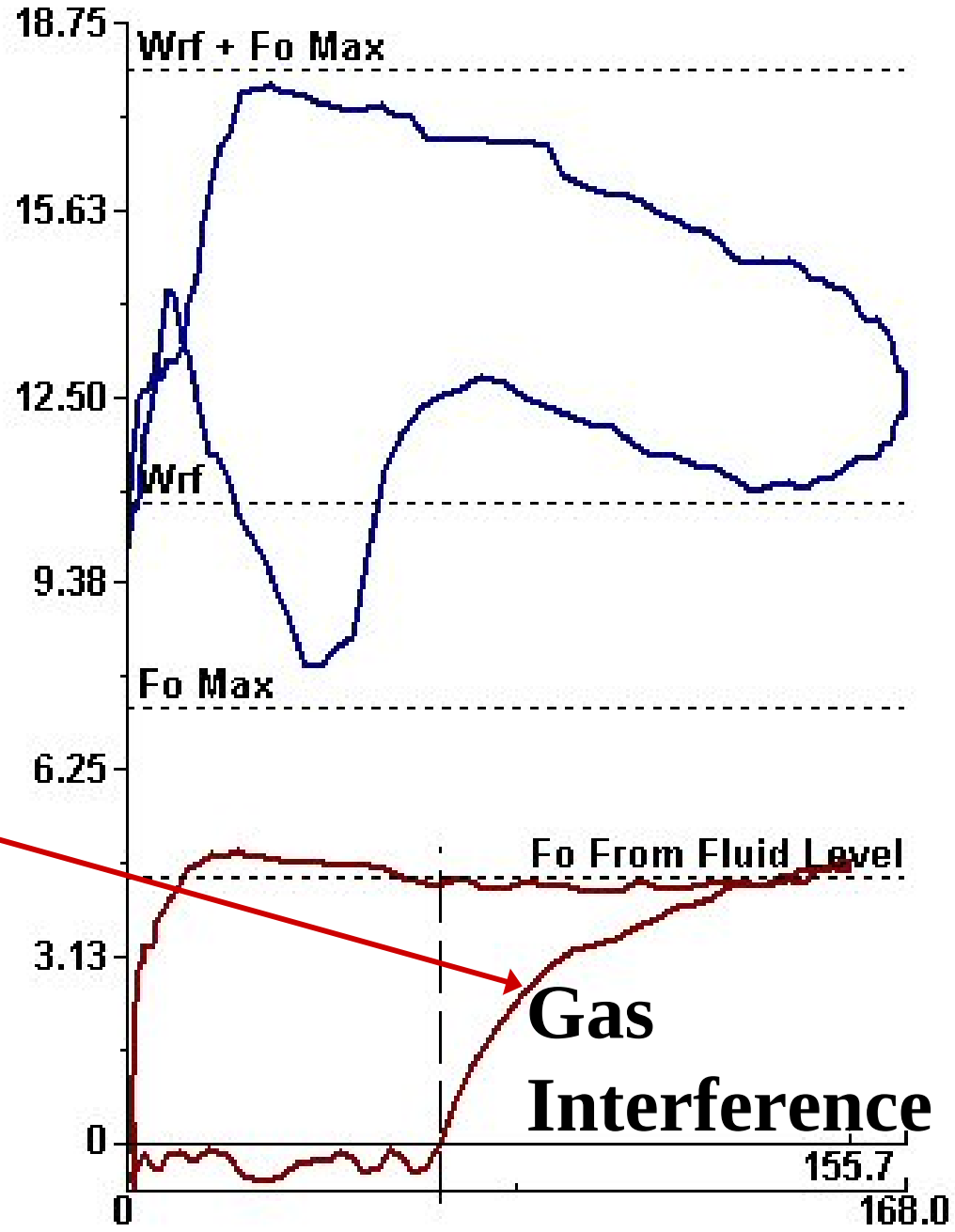


Rods Buckle (Train Wreck Effect)

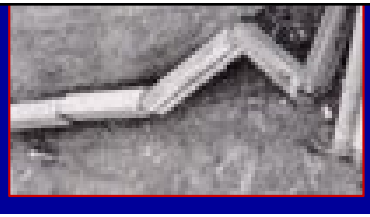


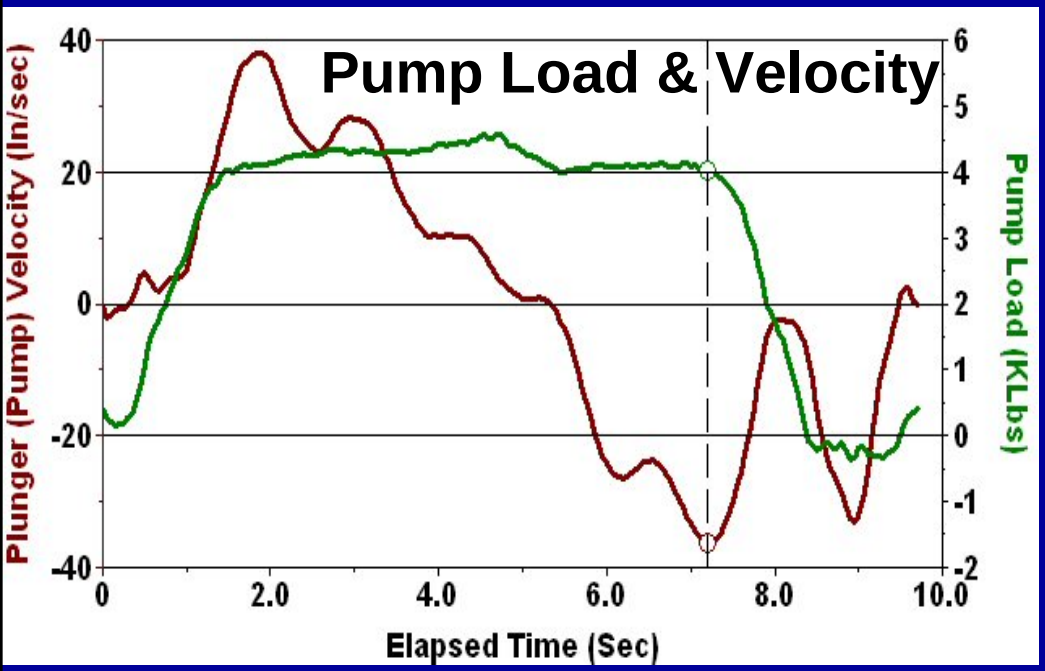


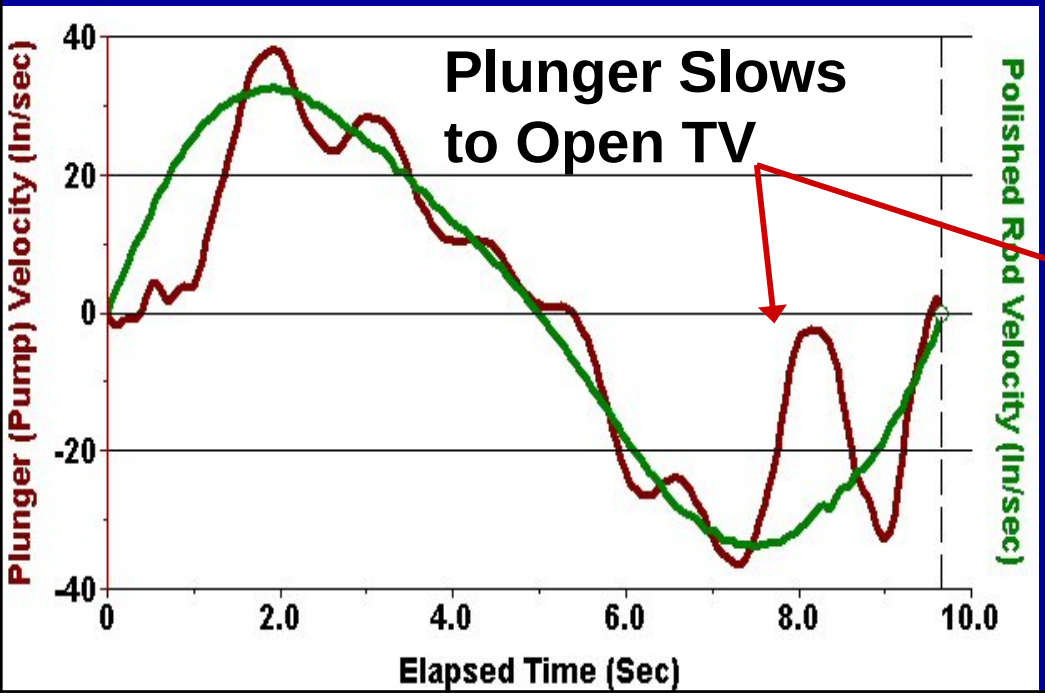


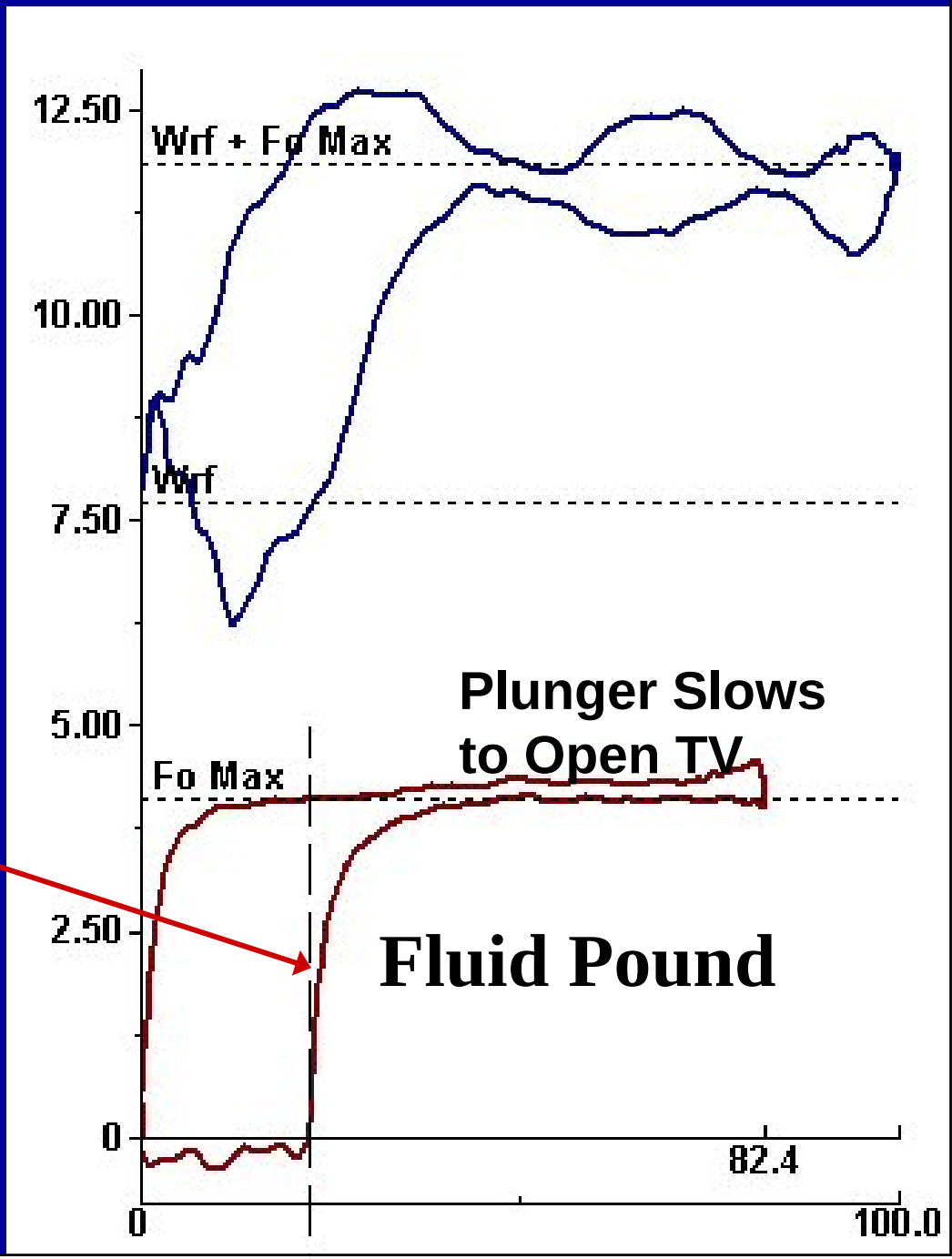


Rods Buckle (Train Wreck Effect)









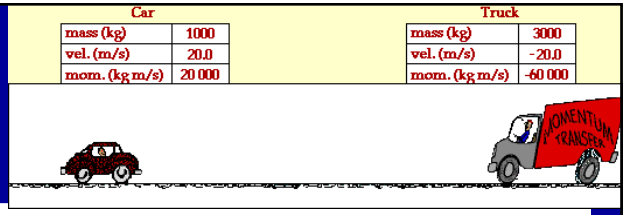
Gas Compression and Train Wreck Effect

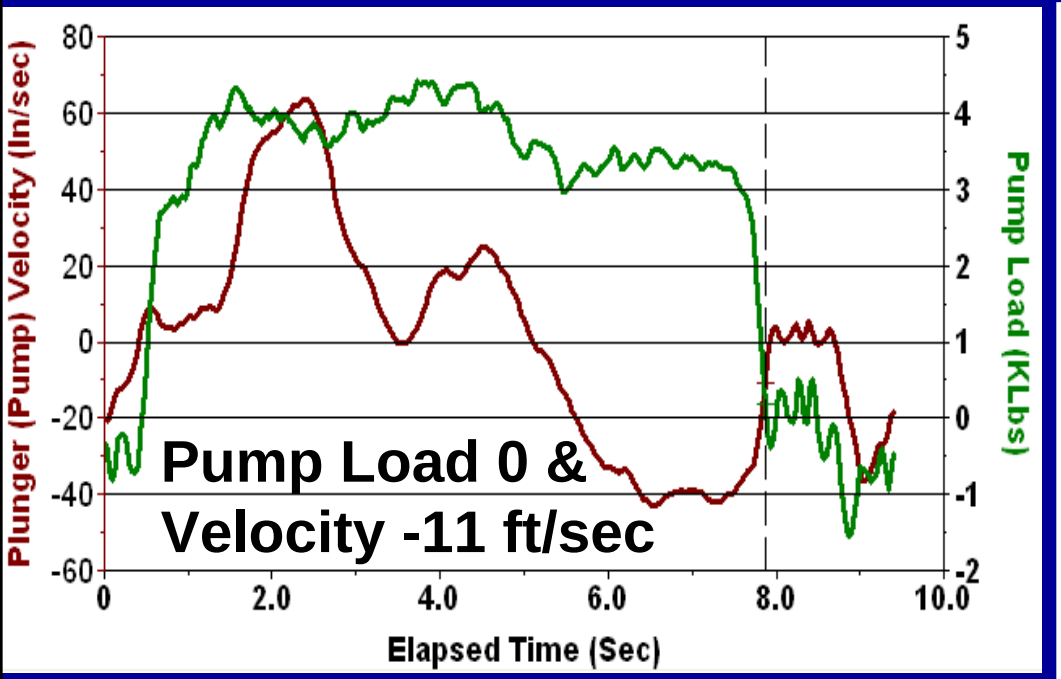
1. Gas Compression occurs when the pump barrel is partially/filled with gas.
2. Sudden opening of TV reduce equipment life
   a) Is it uphole compression whacking rods against the tubing
   b) Pin failures due to rod slap loosening the couplings
3. Rod buckling up the hole occurs when the pump slows 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.

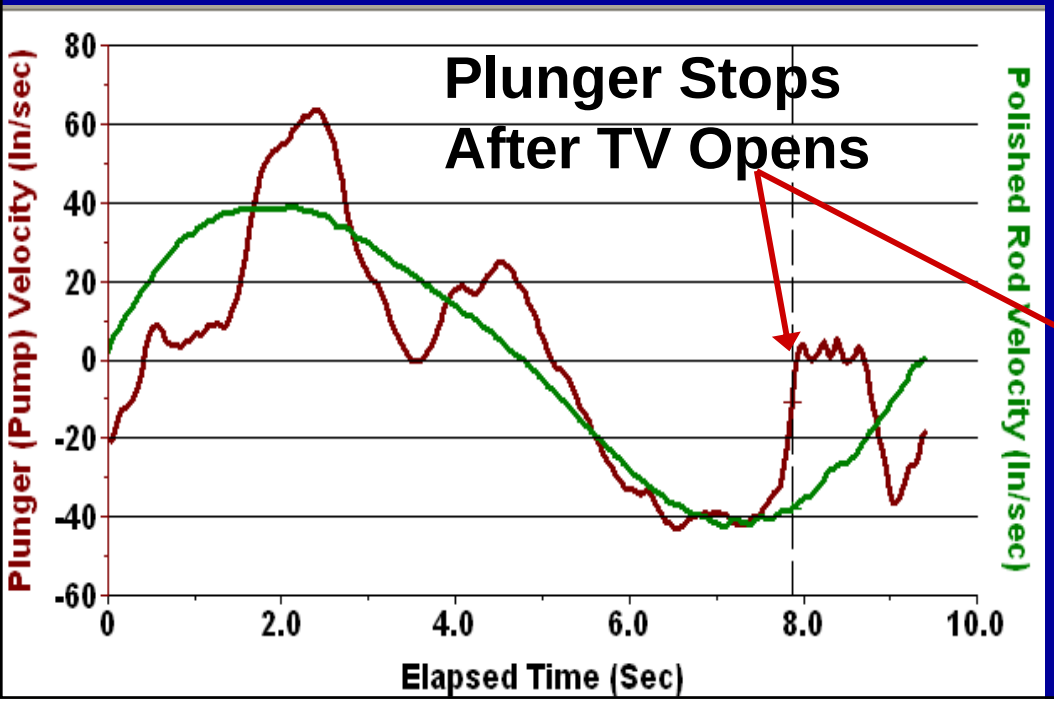
Fluid Pound and Rod Buckling

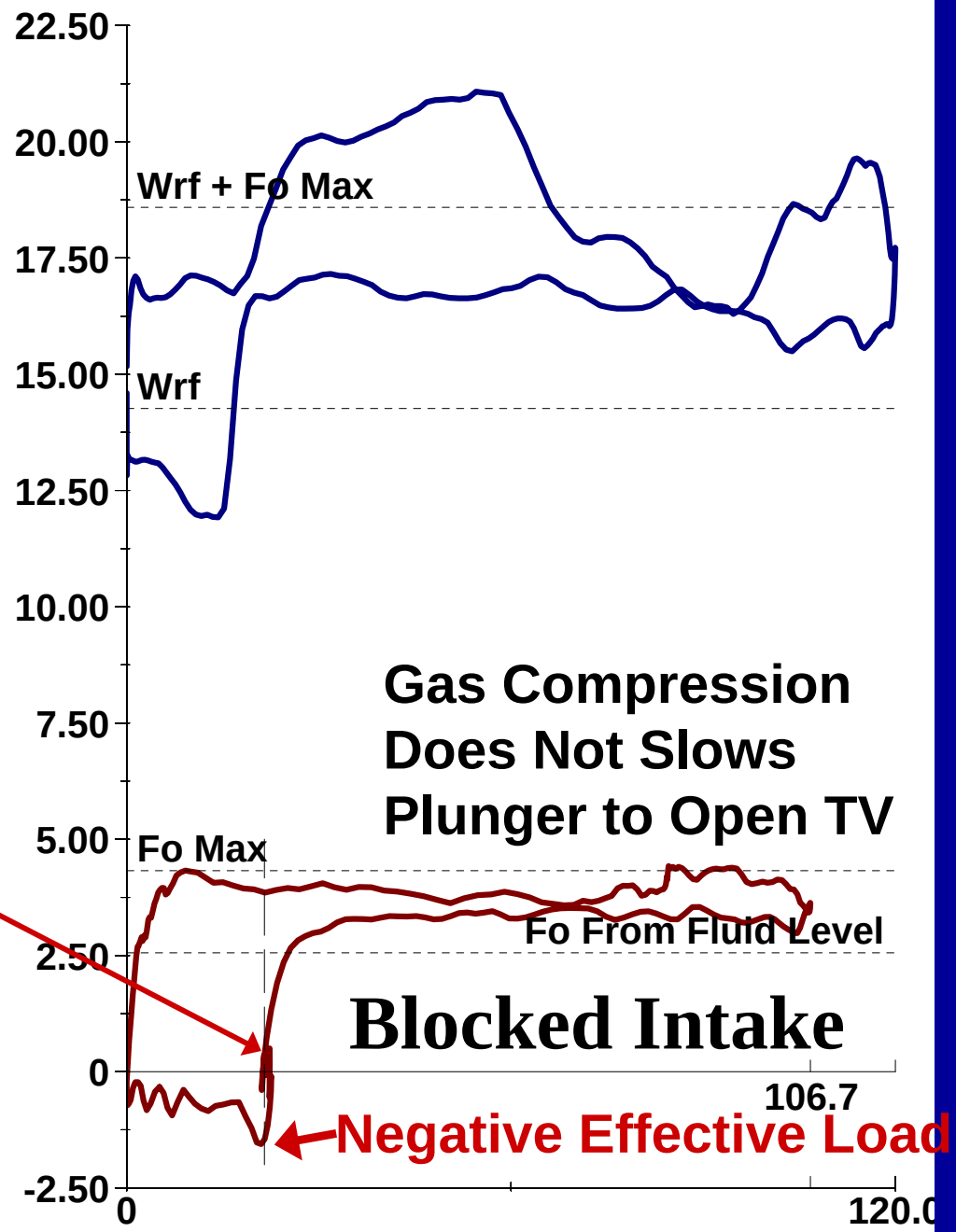
1. Fluid Pound may not be Exactly Correct Term
   a. Occurs with incomplete pump fillage at low pump intake pressure
   b. Forces at pump may not cause trouble
   c. Up-hole rod compression and rod on tubing wear is the likely problem
2. Low Pressure Gas in the pump causes fluid pound
   a) Pump stops 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

Rods Buckle (Collision with Liquid)



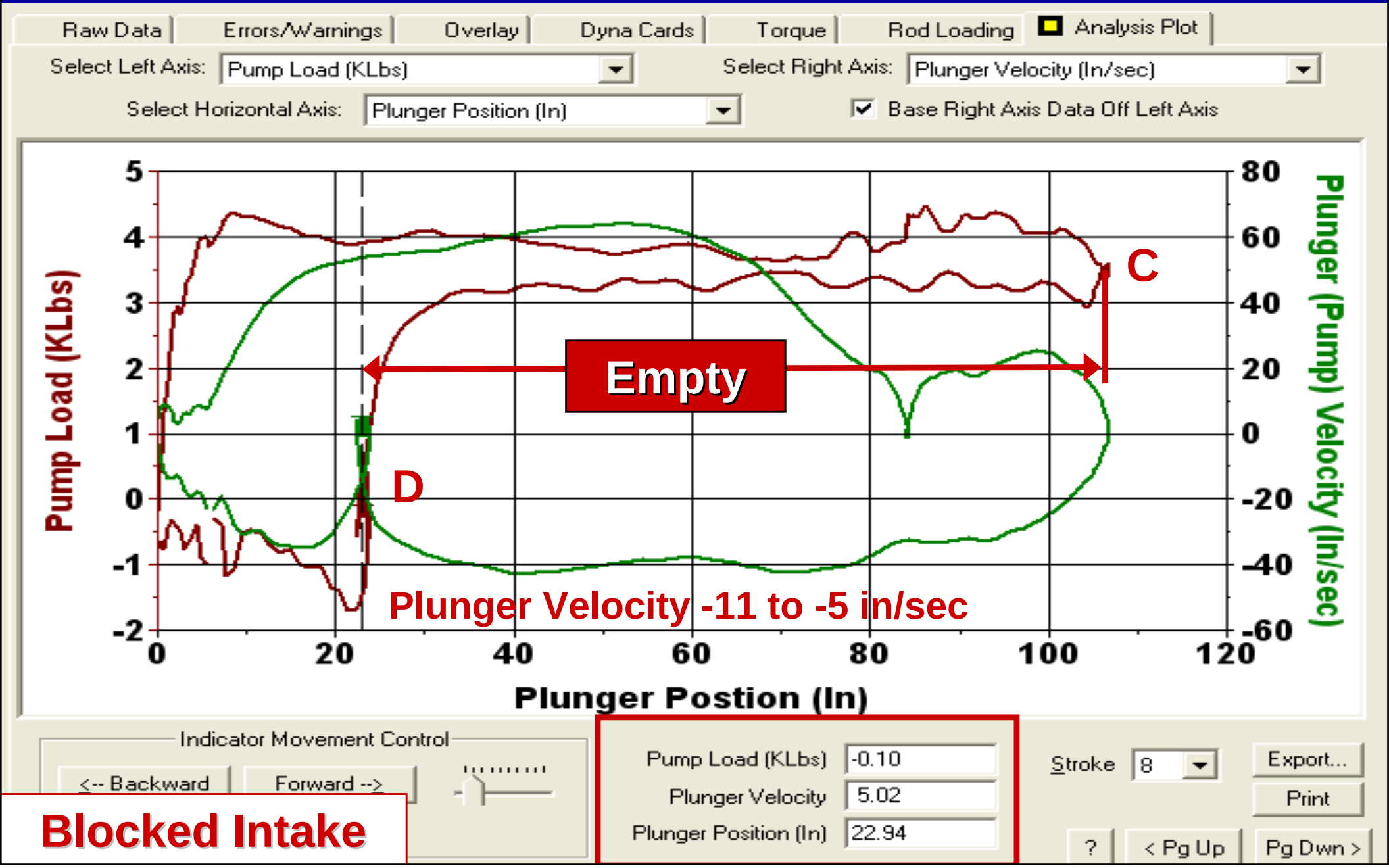






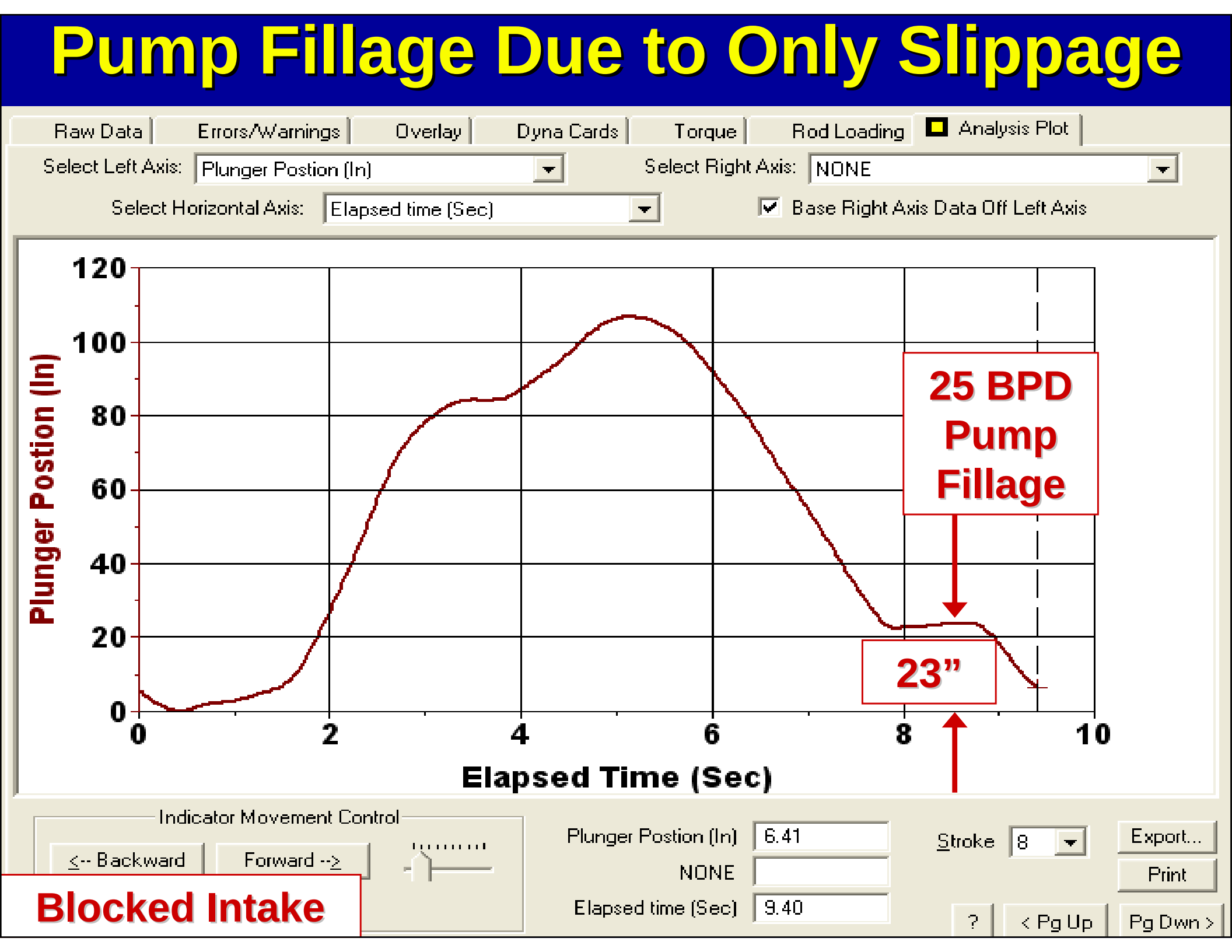
Slippage Between Plunge/Barrel Fills Pump

0 BBLS in Tank ~ Pump Disp 26.9 BPD



Blocked Intake

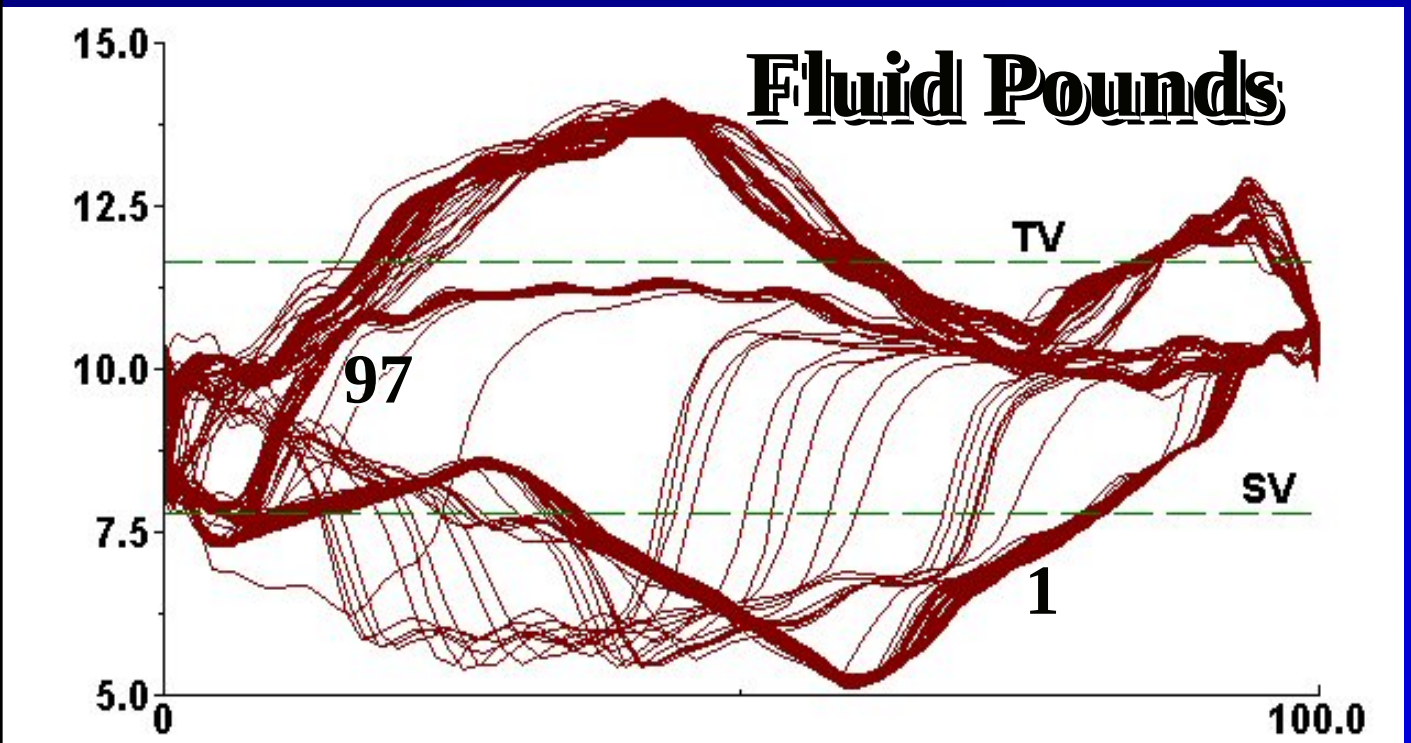
Pump Fillage Due to Only Slippage

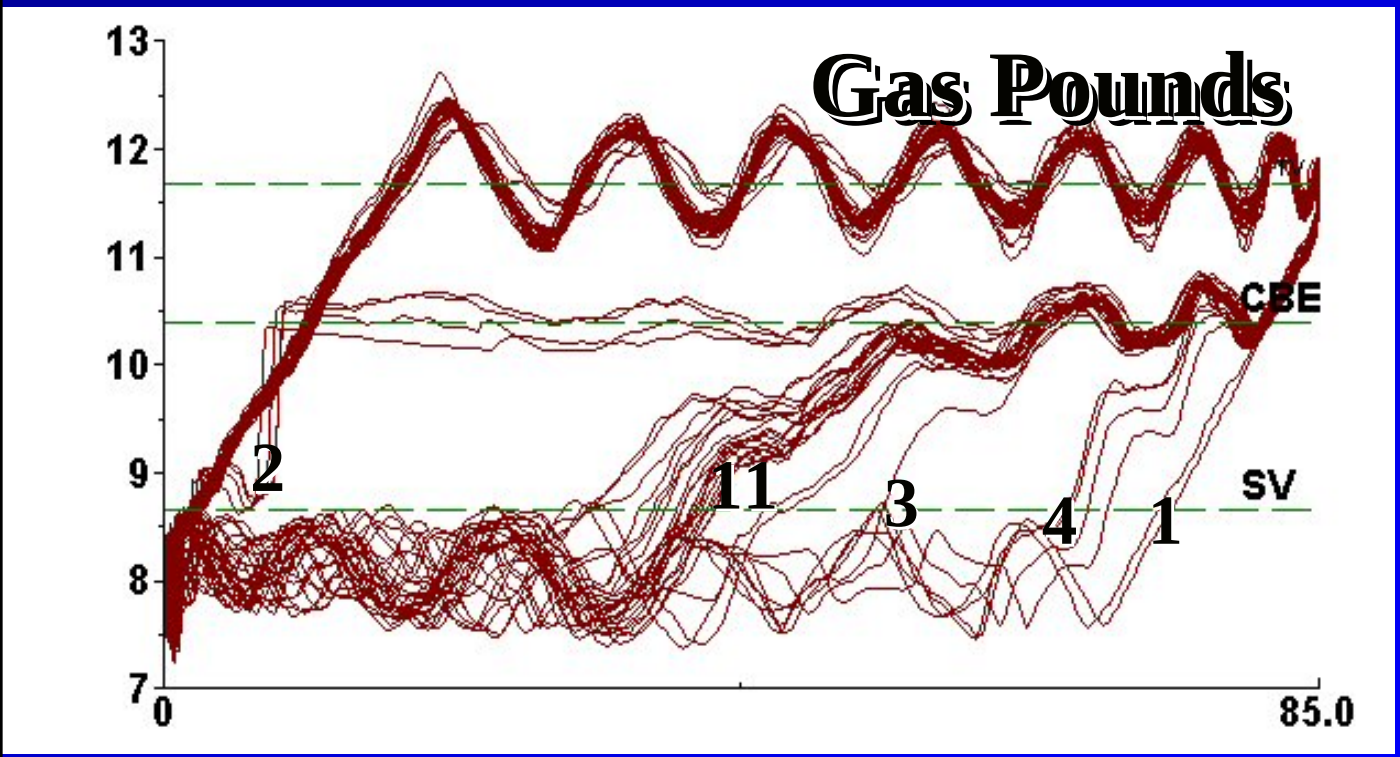


Blocked Intake

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



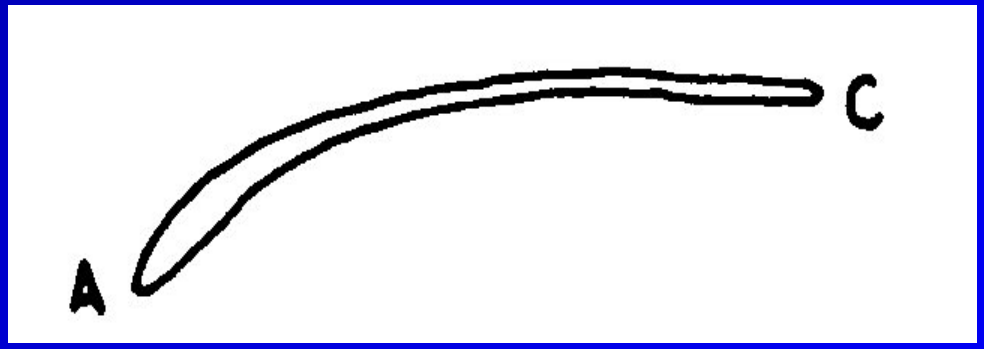


Fluid Pound & Gas Pounds A gas pound (Lower Left) does not move progressively to the left. It moves back and forth and jumps around on the trace as more or less gas enters the pump and changes where the valves close and open during the downstroke portion of the pumping cycle.

Synthetic Pump Cards: Gas Locked Pump

Gas Locked Pump...Both valves remain closed because the static tubing pressure, (P_t), is greater the pump discharge pressure, (P_{barrel}), which is also greater than the pump intake pressure, P_{int}. The compression ratio of the sucker rod pump is too small, with the result that neither valve opens until the clearance space between valves fills by leakage of fluids past the plunger, or the fluid level is allowed to rise so that a smaller compression ratio is required to force gas from the pump into the tubing. The pressure relations are:

Tubing anchored or unanchored

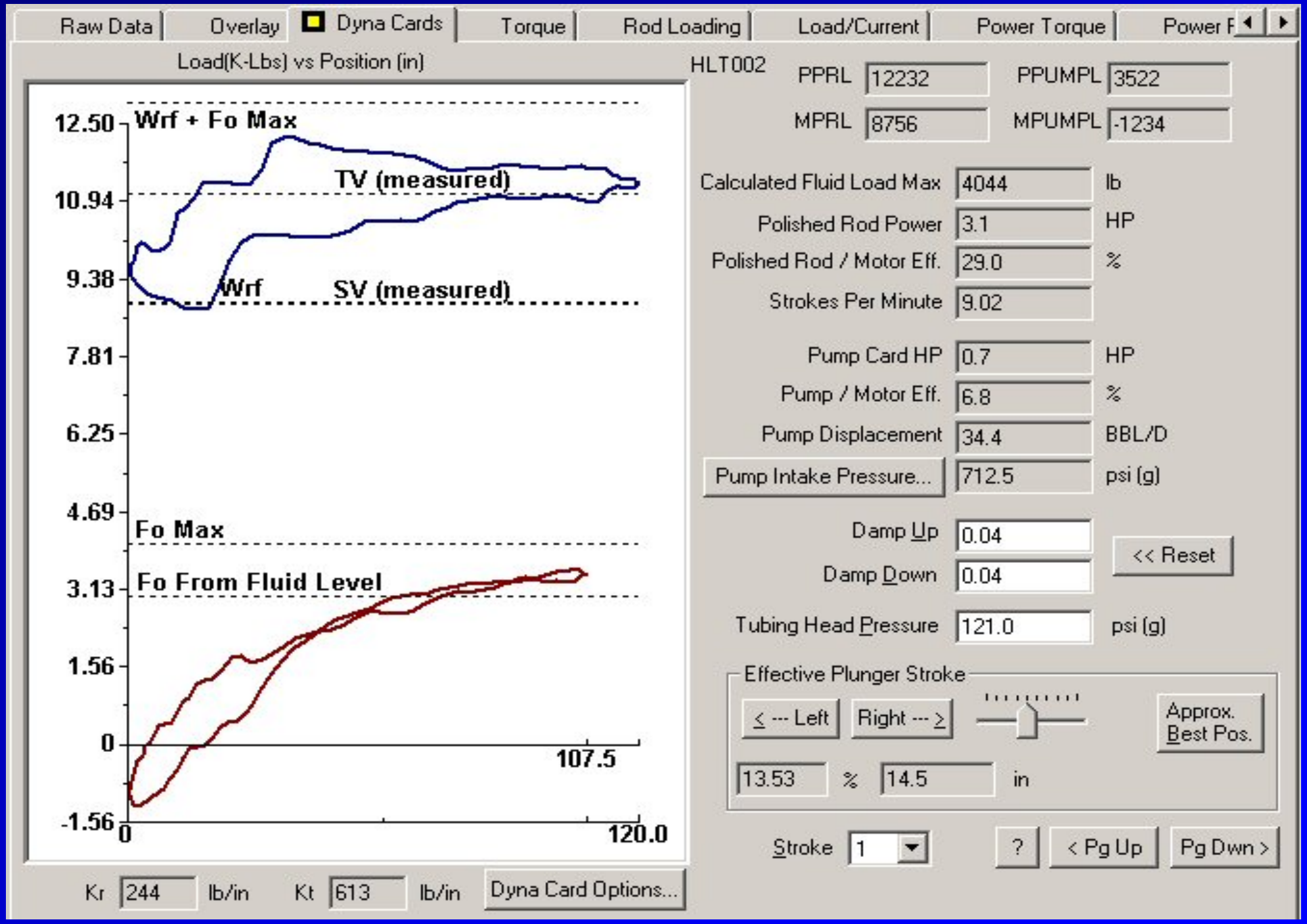


$$P_t > P_{barrel} > P_{int}$$

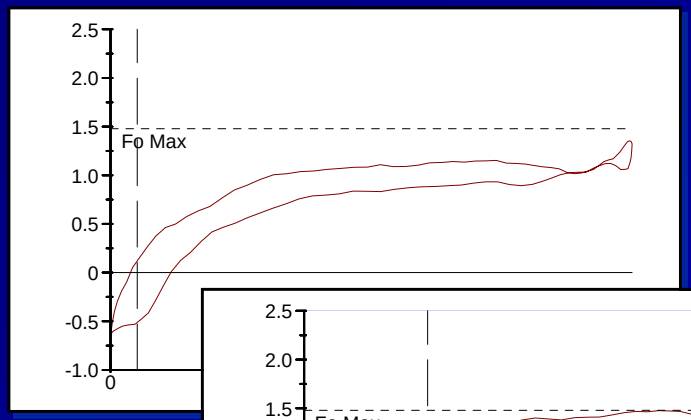
$P_t > P_{barrel}$ at bottom of stroke

$P_{barrel} > P_{int}$ at top of stroke

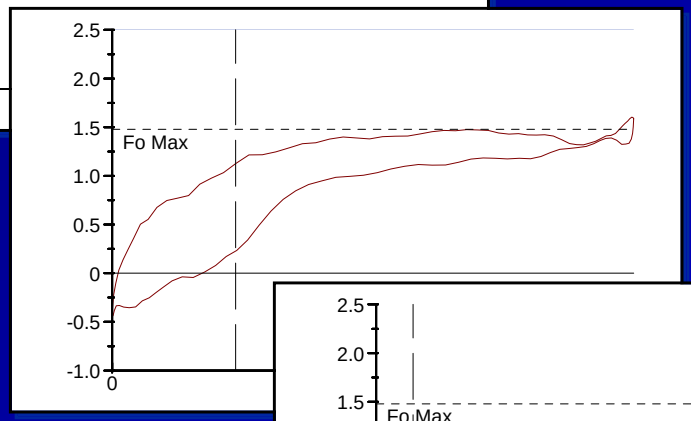
Almost Gas Locked



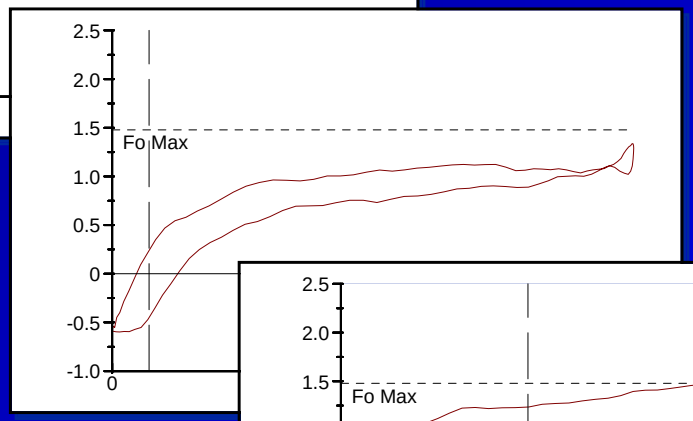
Gas Lock Cycles



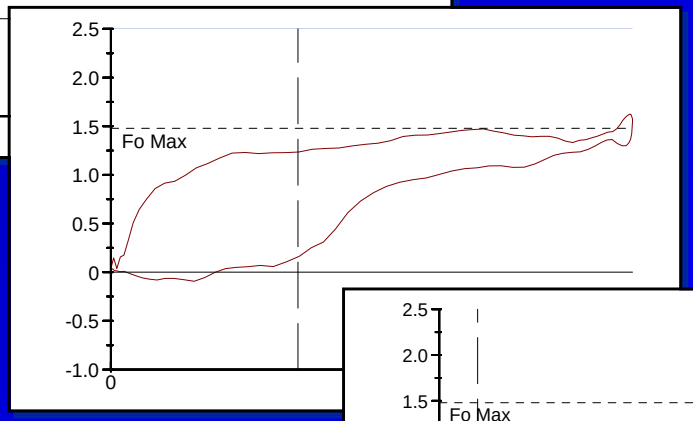
Stroke 45



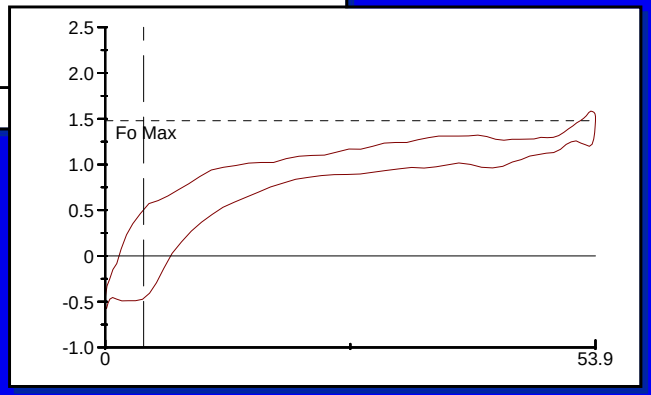
Stroke 51



Stroke 77



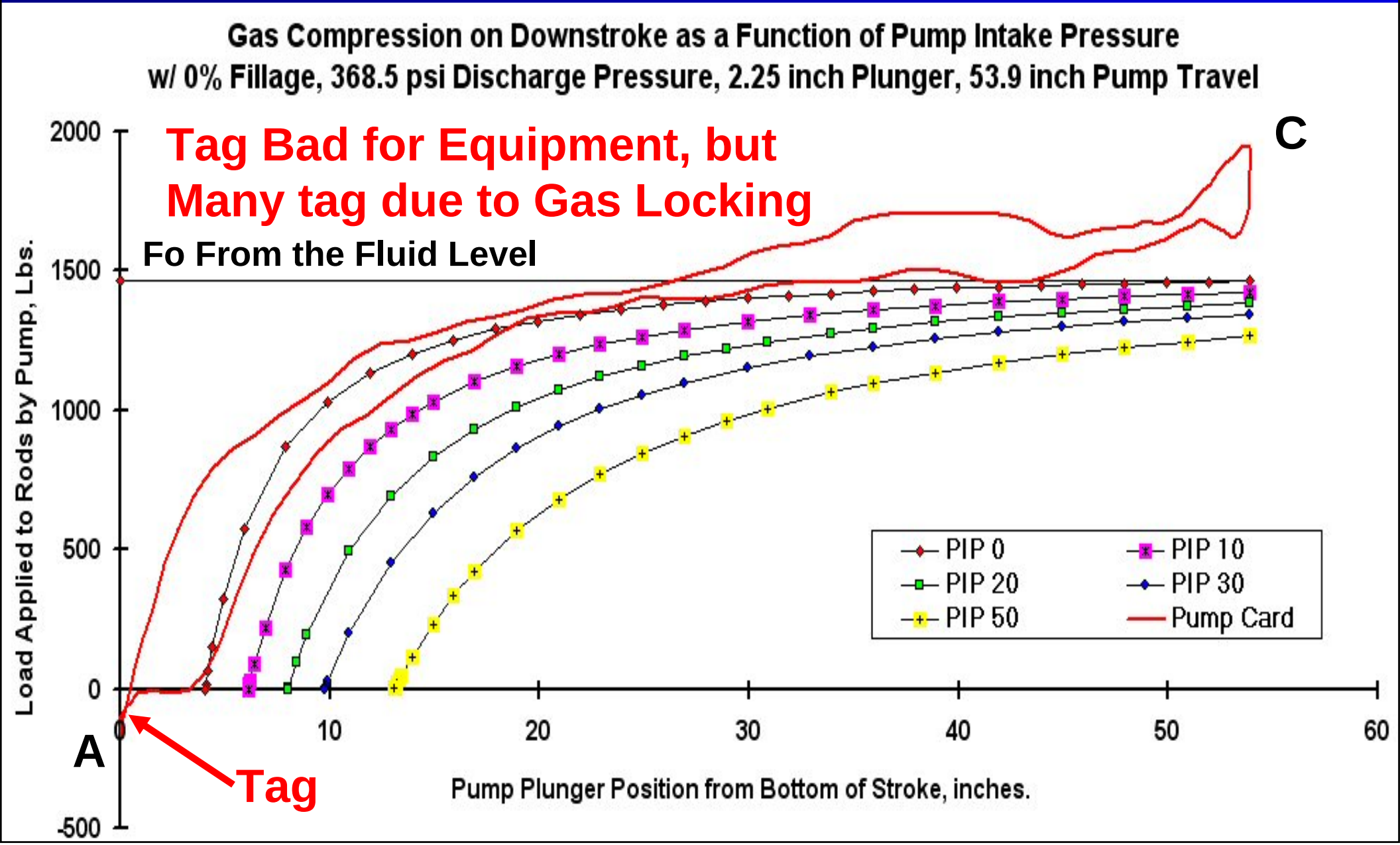
Stroke 84

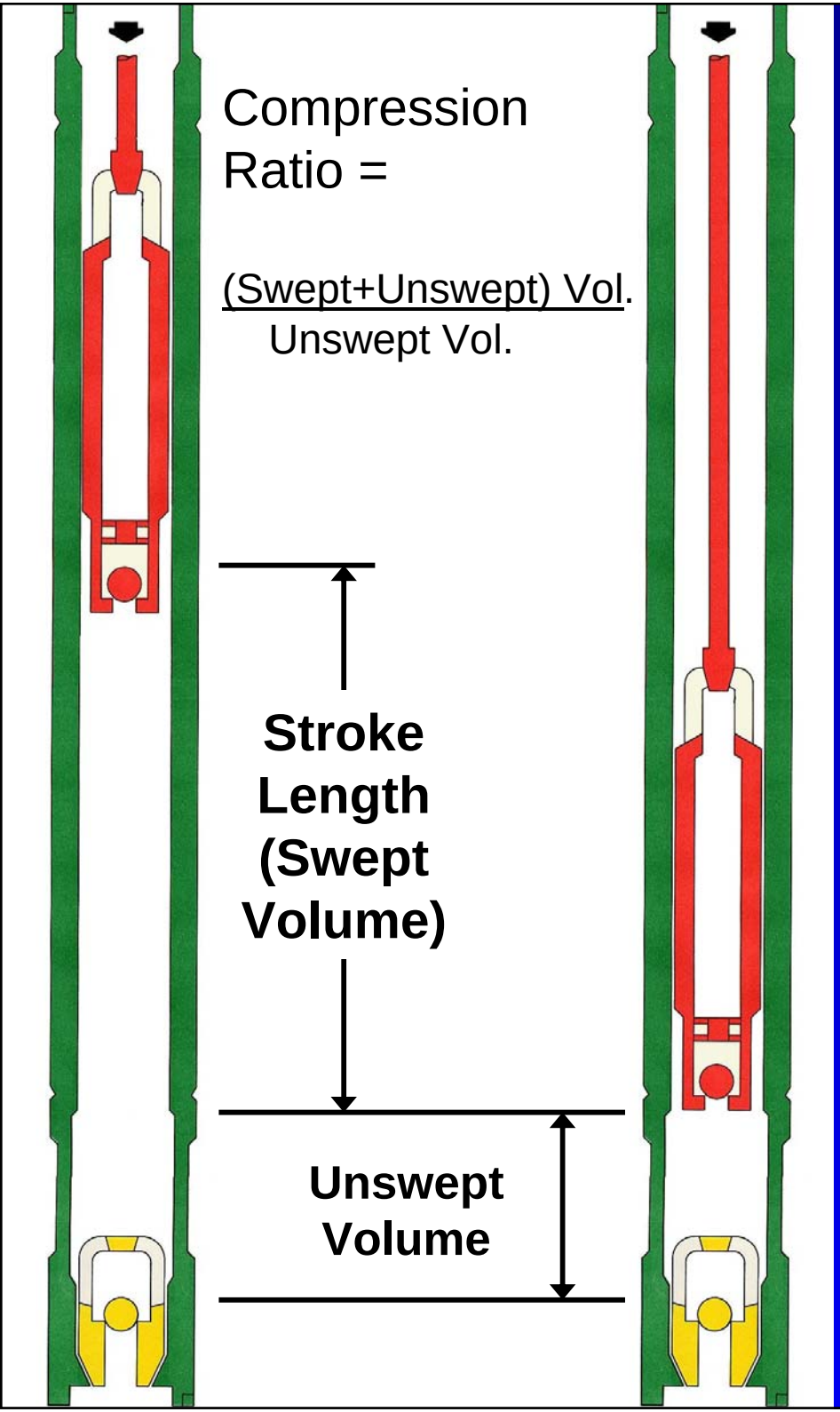


Stroke 139

Gas Lock Occurs, When Both:

1) Point "A" is Above 0 Line
2) Point "C" is Below Fo From the Fluid Level





High Compression Ratio Helps Prevent Gas Lock But, Space Pump High or High Tubing Pressure and Gas Lock Possible

Example:
2-1/4” plunger
53.9” downhole stroke length
6 cubic inches unswept volume
(214.4 + 6) / 6 = 36.7

Pump Barrel Pressure =
(Intake Press) times (C R)
Example:
14.7 psia Intake Pressure
36.7 compression ratio, C R
14.7 times 36.7 = 539.7 psia
539.7 > 368.5 Pump Discharge Pressure

Questions