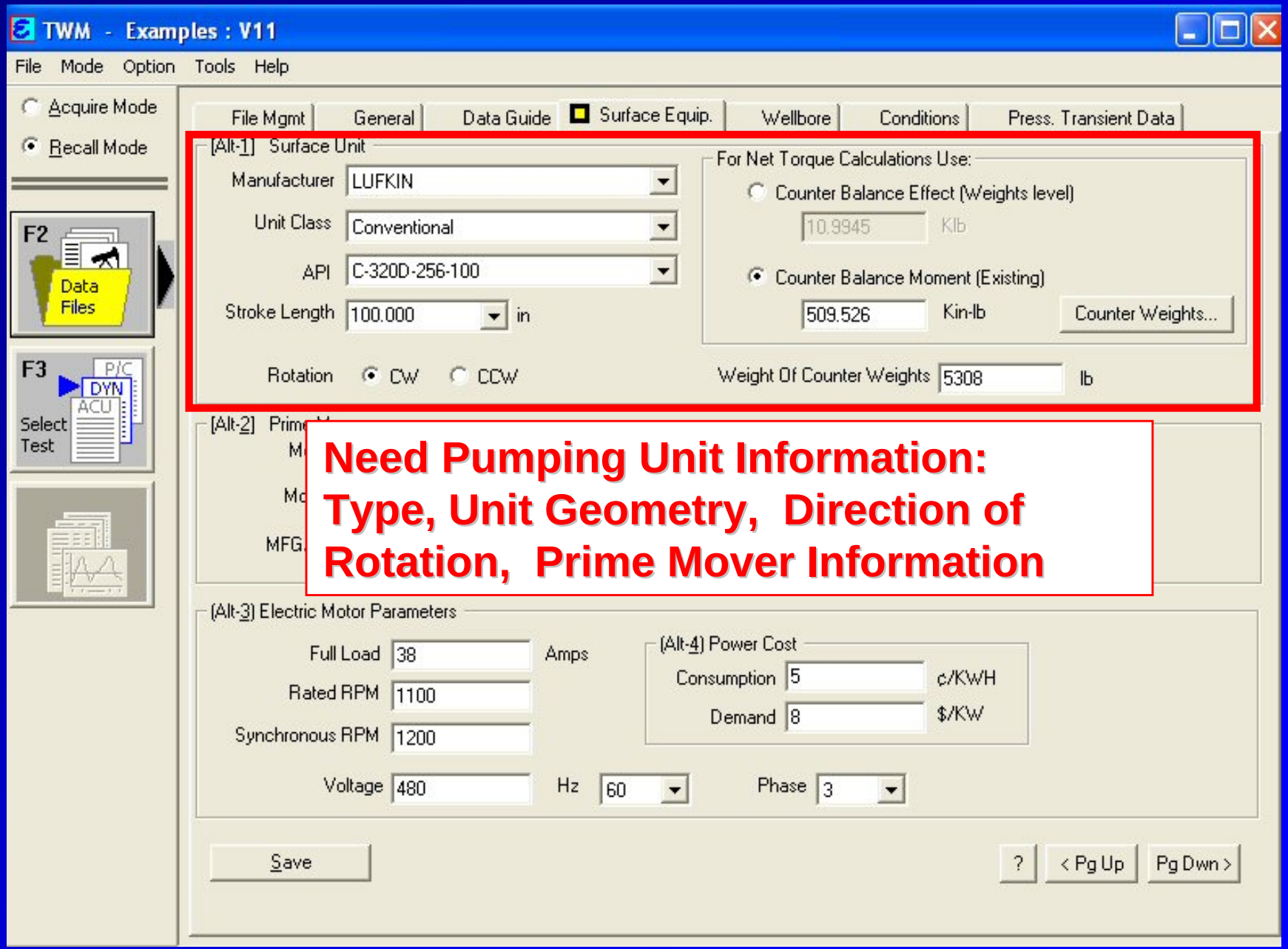
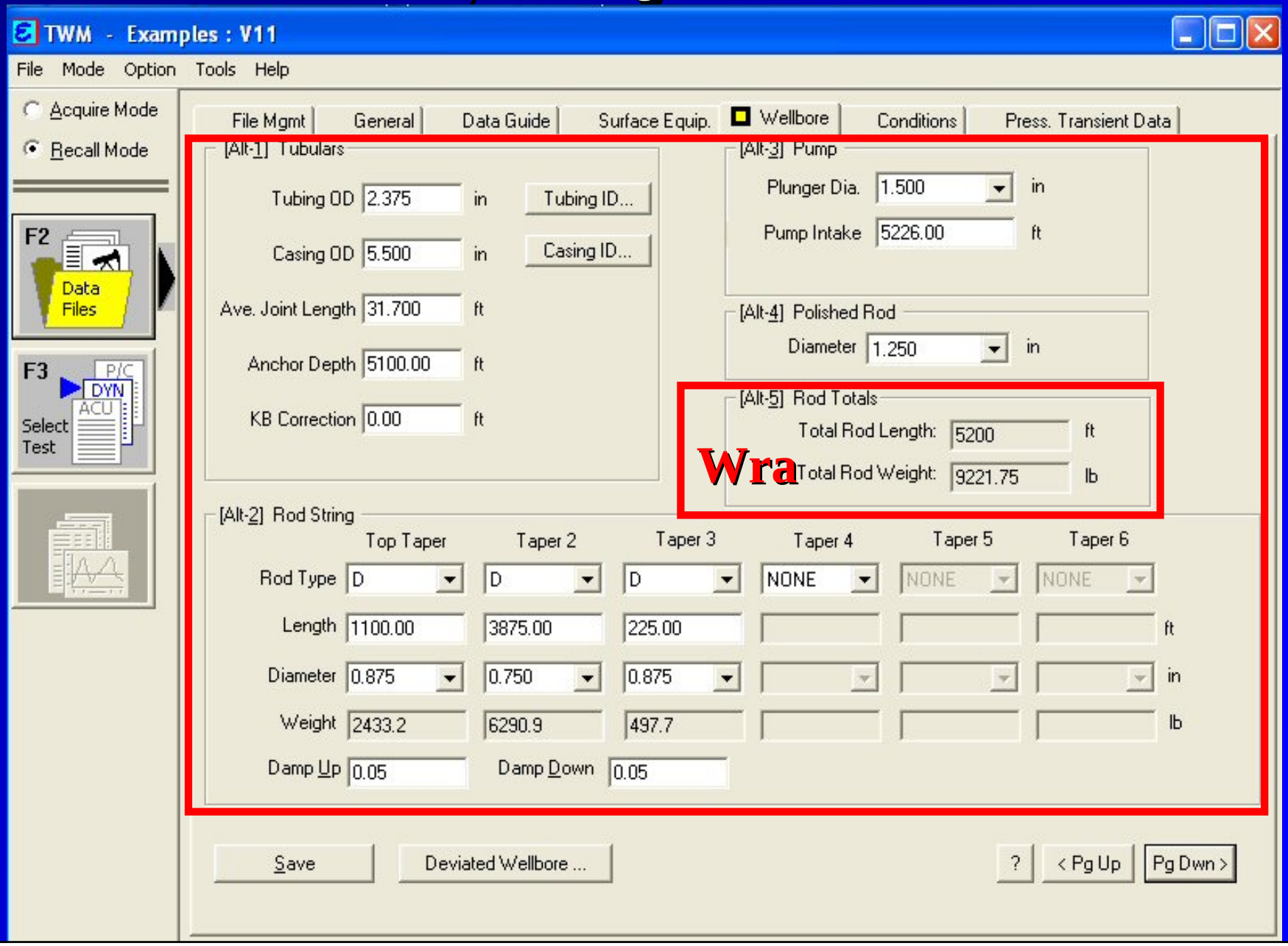
Surface and Pump Card Reference Loads

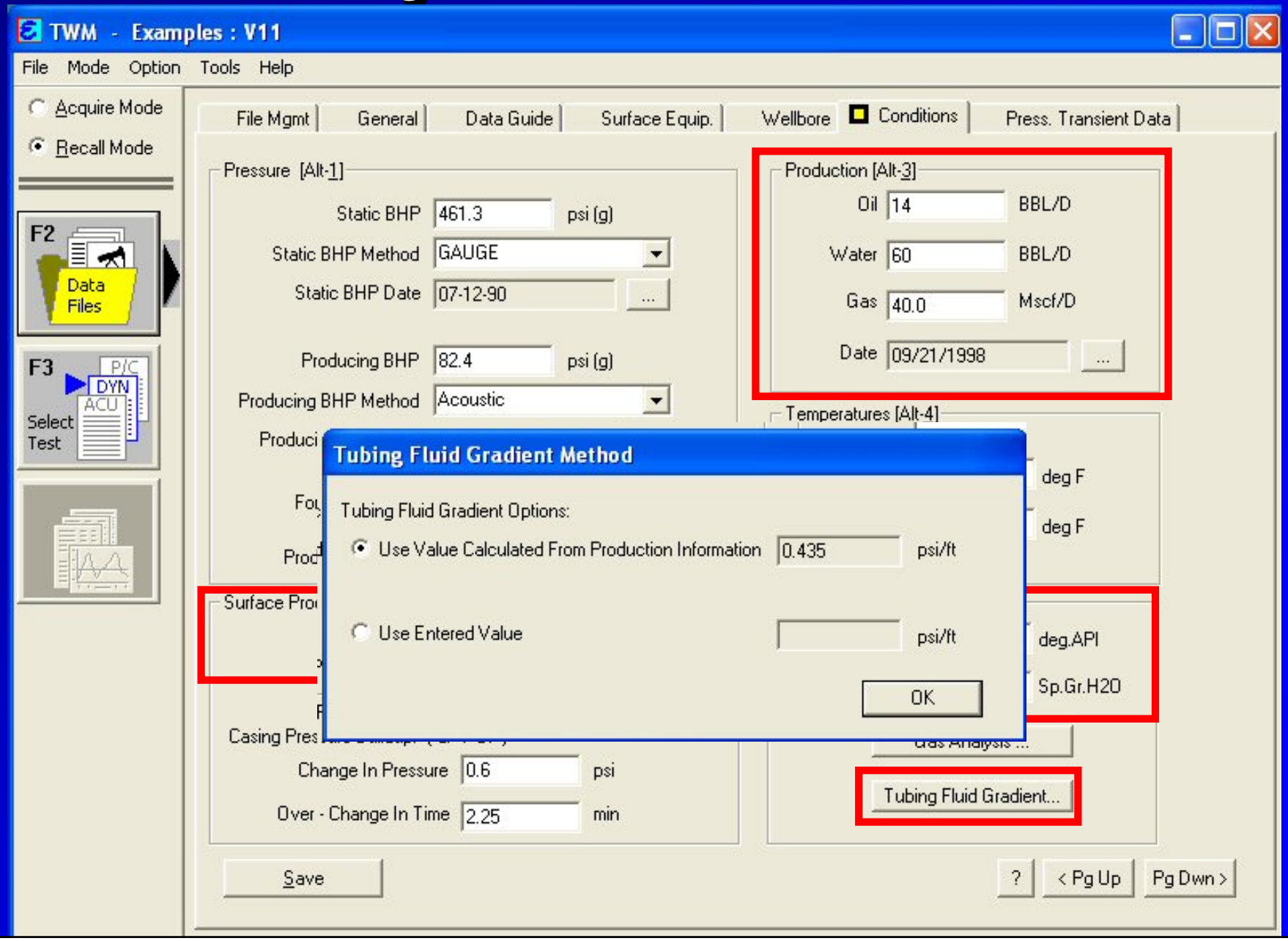
Analysis of Dynamometer Measurements w/ Dyno Cards, Valve Test and Analysis Plots



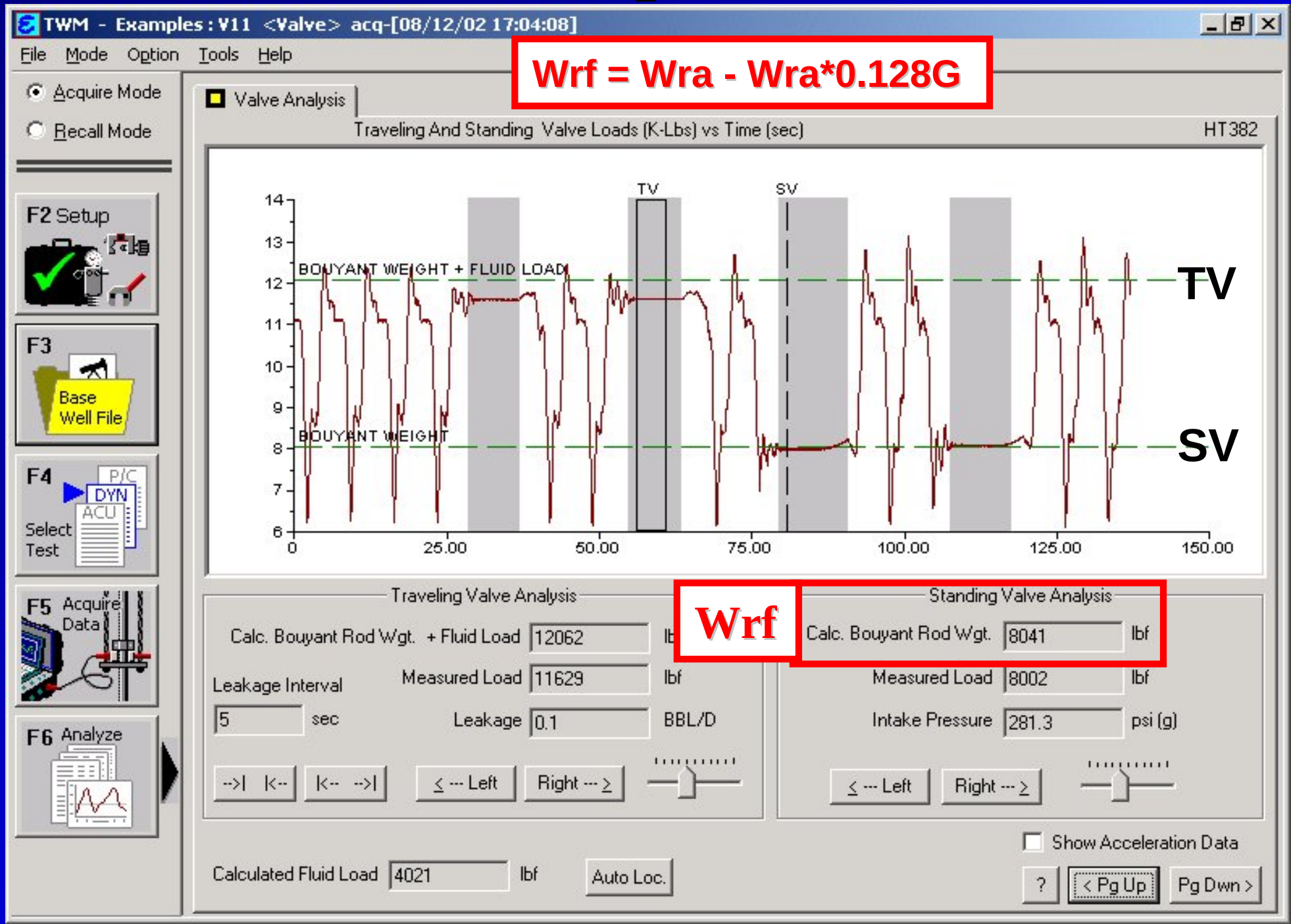
Well Bore Tab Need: Rod Types, Rod Lengths, Rod Diameters, Pump Plunger Diameter, Pump Intake Depth, Polished Rod Diameter, Tubing Size



Conditions Tab Need: Producing & Static BHP, Fluids' gravities, and Production rates, Tubing Head Pressure ---- Tubing Fluid Gradient



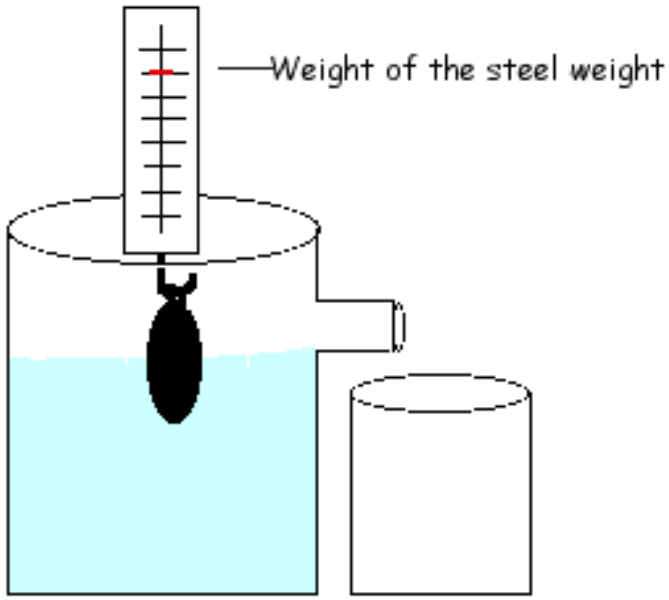
Measured & Computed Valve Loads

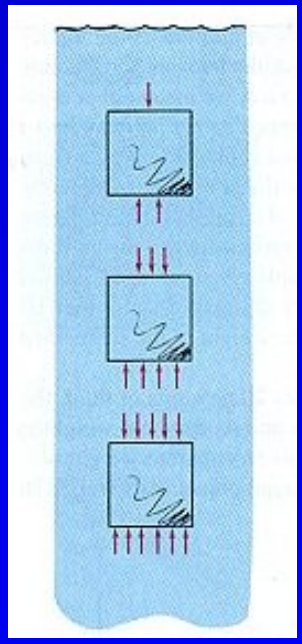


Buoyancy Force, Fb

Steel Rods ~ Fb = Wra*0.128*G

Buoyancy Force not depend on depth or pressure

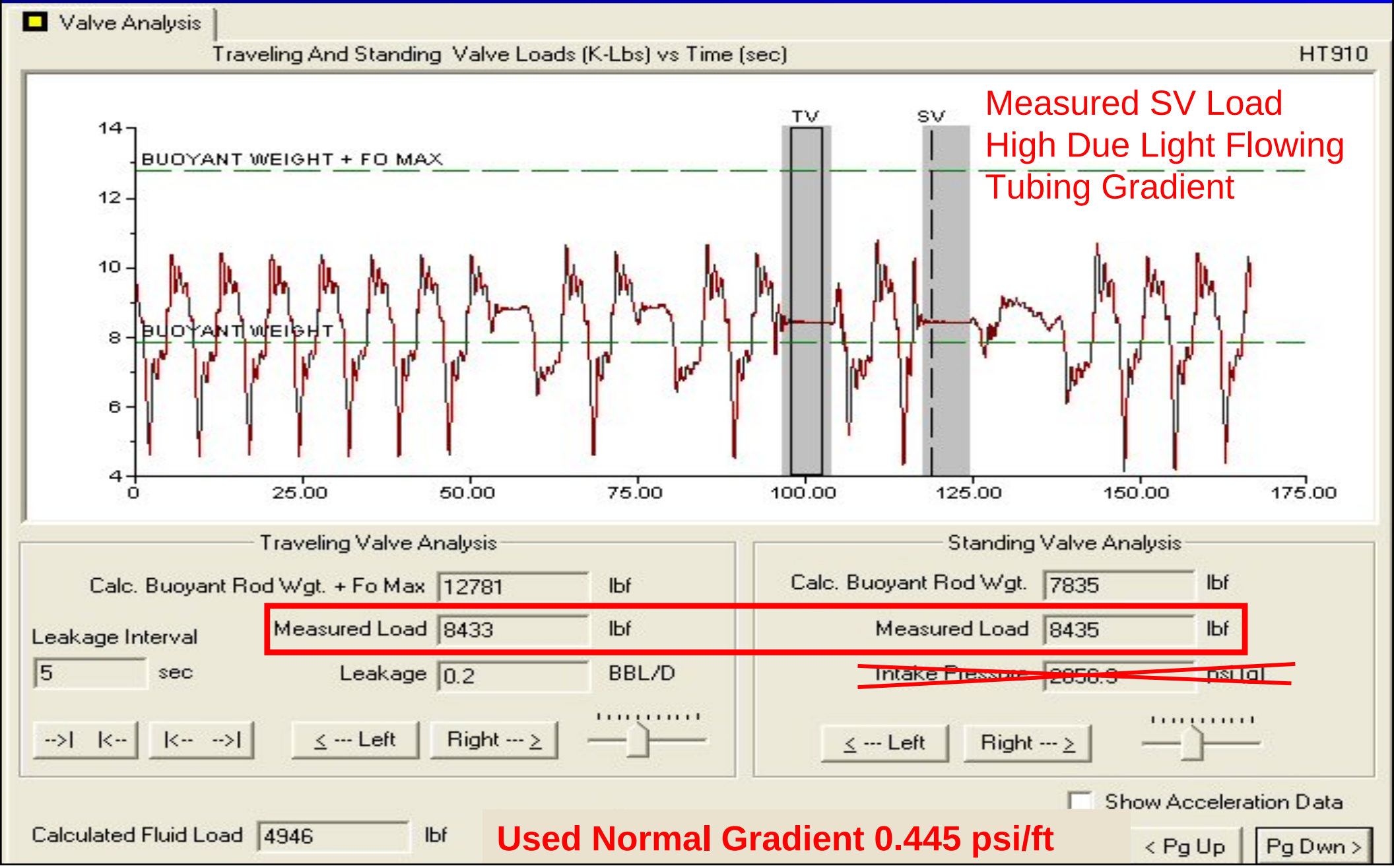




Buoyant force is due the density of the fluid displaced by each rod.

Wrf = Wra – Fb

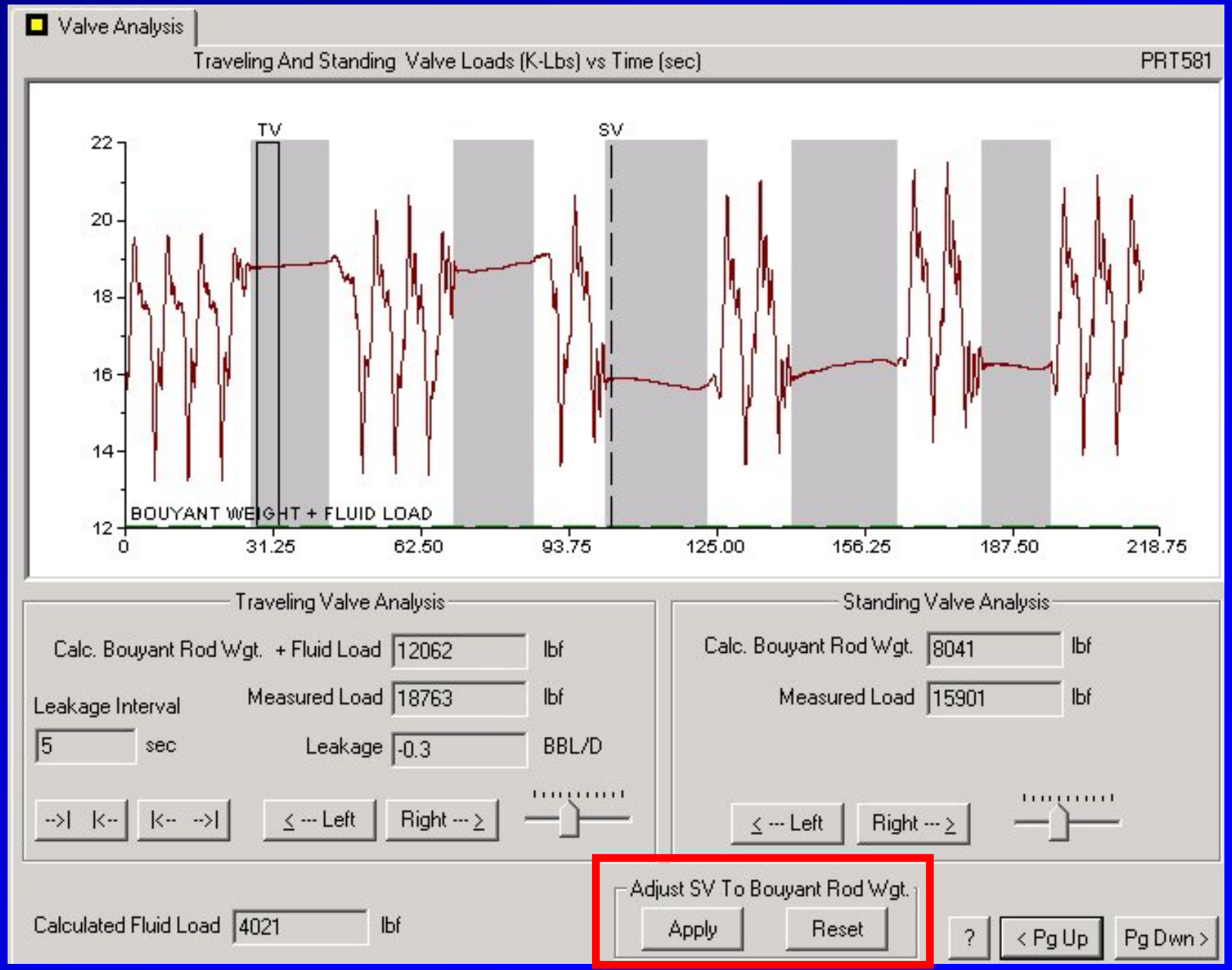
Symptoms of Well Flowing up Tubing and/or Casing: Measured TV and SV loads Approximately Equal



If PRT Used for Valve Checks

1. Verify Correct SV Check Load is Selected

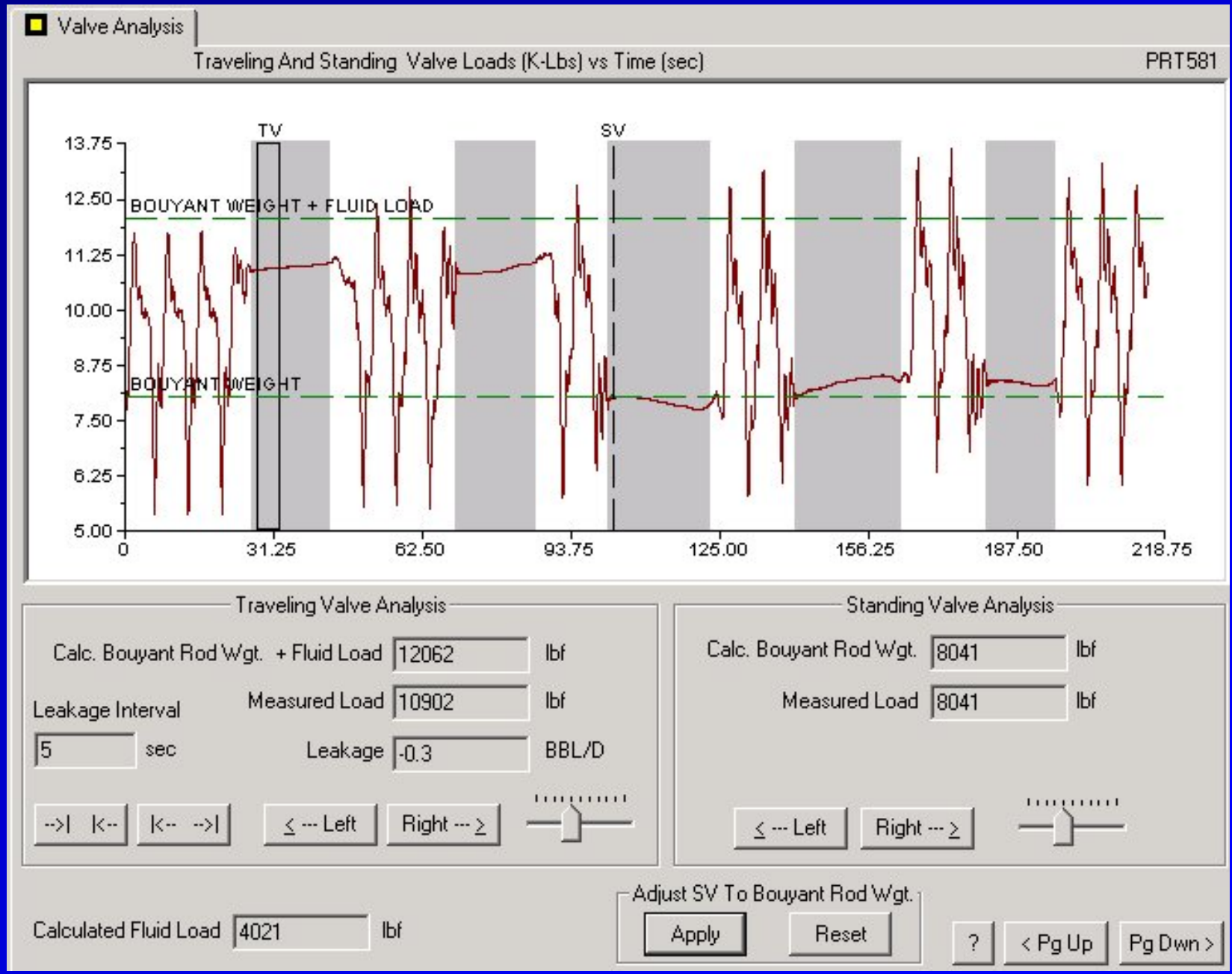
2. Click **Apply** button to Adjust SV to Buoyant Rod Wgt.

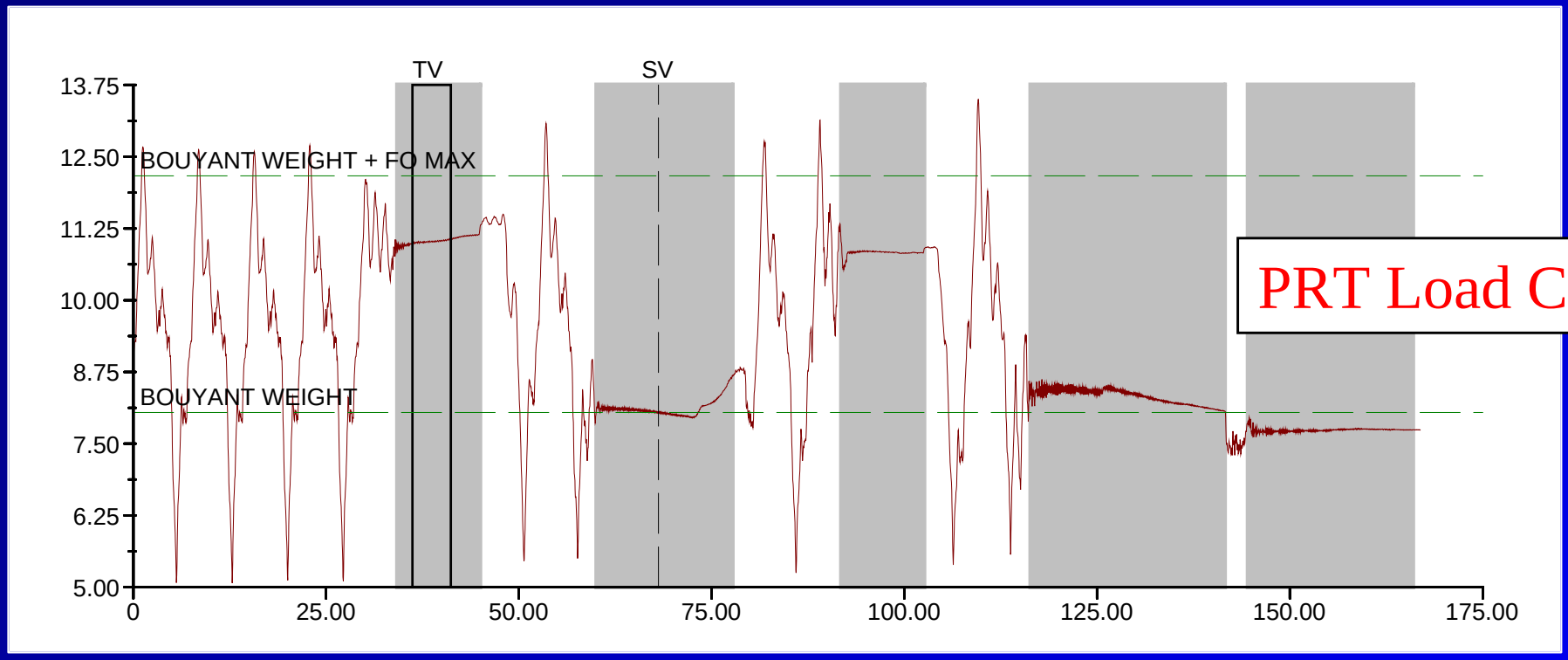


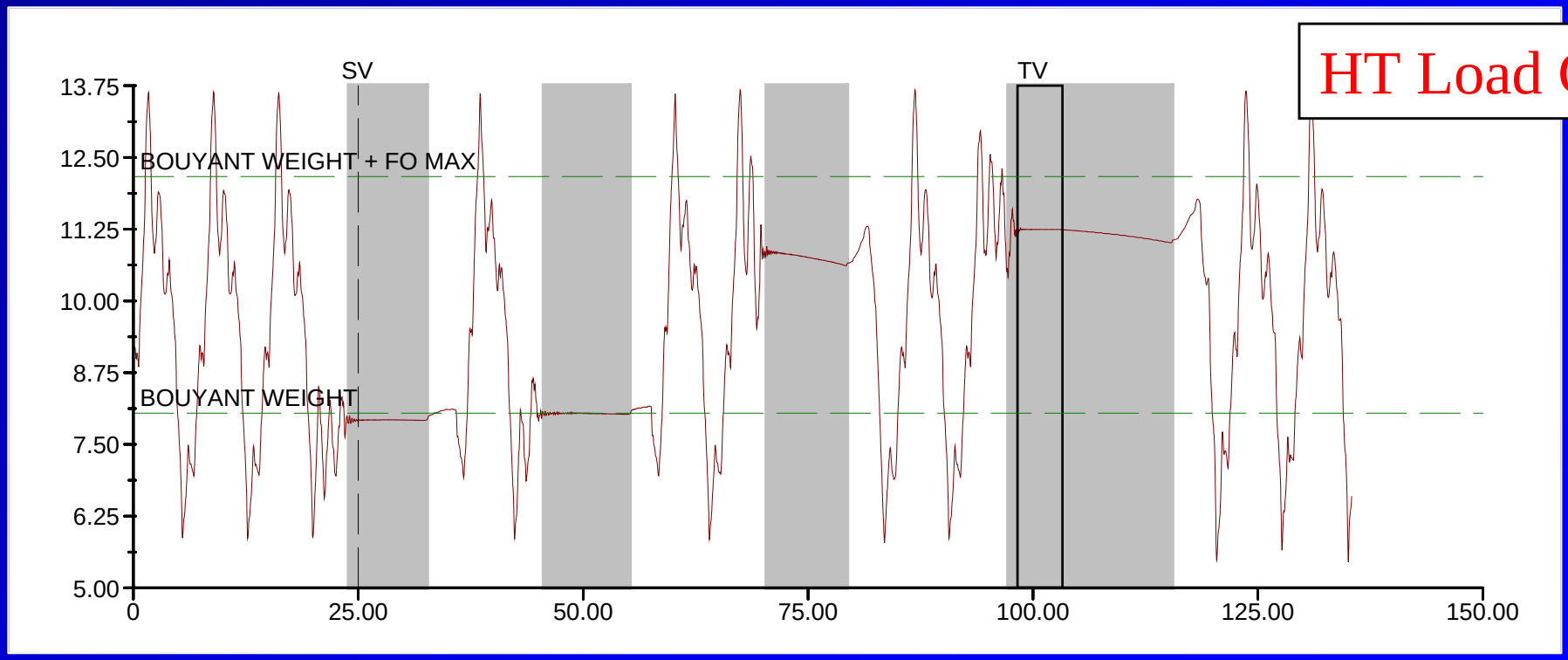
If PRT Used for Valve Checks

1. After Clicking **Apply** button to Adjust SV to Buoyant Rod Wgt.

2. The Selected SV Check Load is adjusted to exactly match the Calc. Buoyant Rod Wgt.

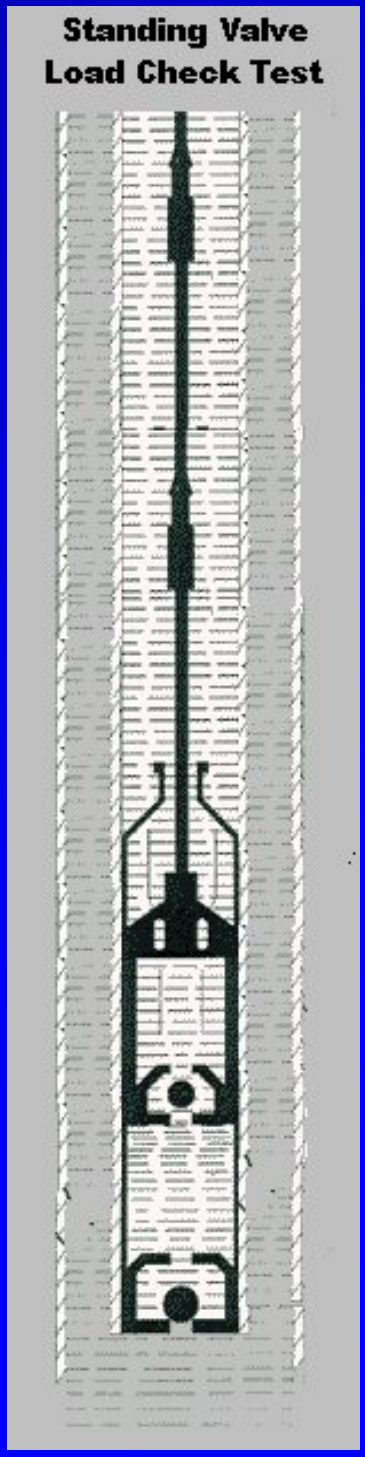



TV
SV
13.75
12.50
11.25
10.00
8.75
7.50
6.25
5.00
BOUYANT WEIGHT + FO MAX
BOUYANT WEIGHT
0
25.00
50.00
75.00
100.00
125.00
150.00
175.00
PRT Load Cell

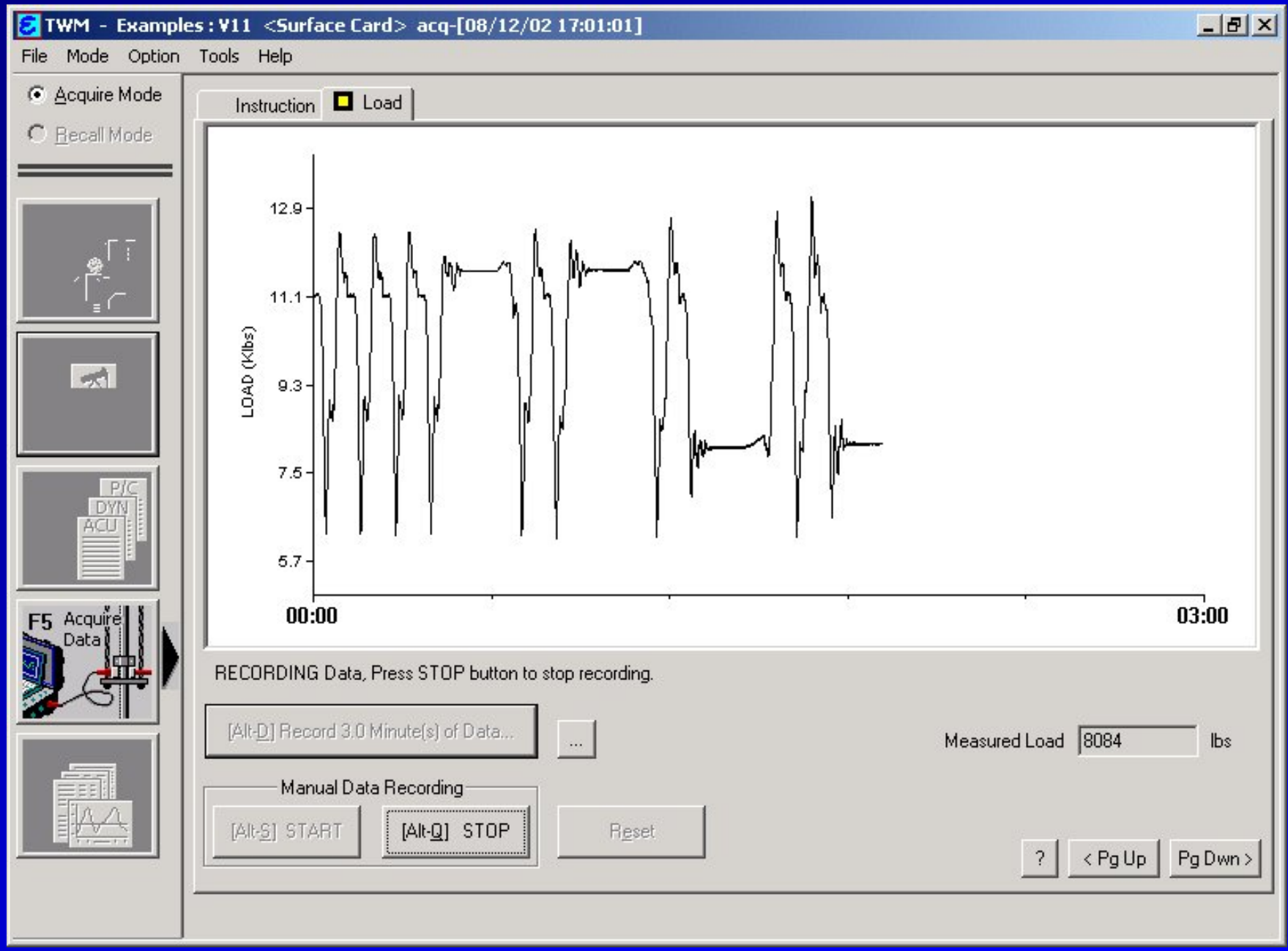

SV
TV
13.75
12.50
11.25
10.00
8.75
7.50
6.25
5.00
BOUYANT WEIGHT + FO MAX
BOUYANT WEIGHT
0
25.00
50.00
75.00
100.00
125.00
150.00
HT Load Cell

Standing Valve Check Procedure

Standing valve check load is taken during the down stroke by gently using the brake to bring the pumping unit to a stop about ¼ from the bottom of the stroke.



Perform Two Standing Valve Checks

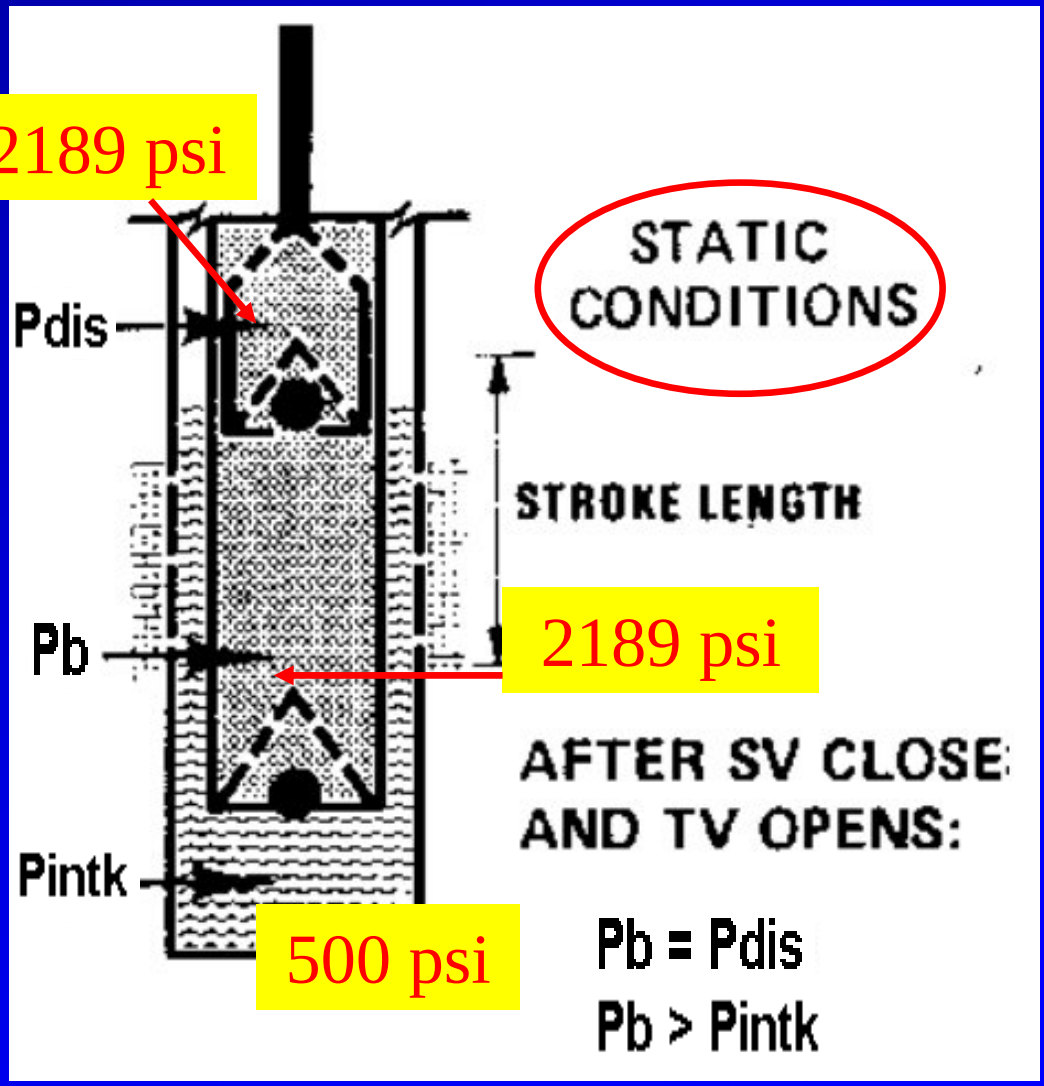


On Downstroke: Check Standing Valve Load

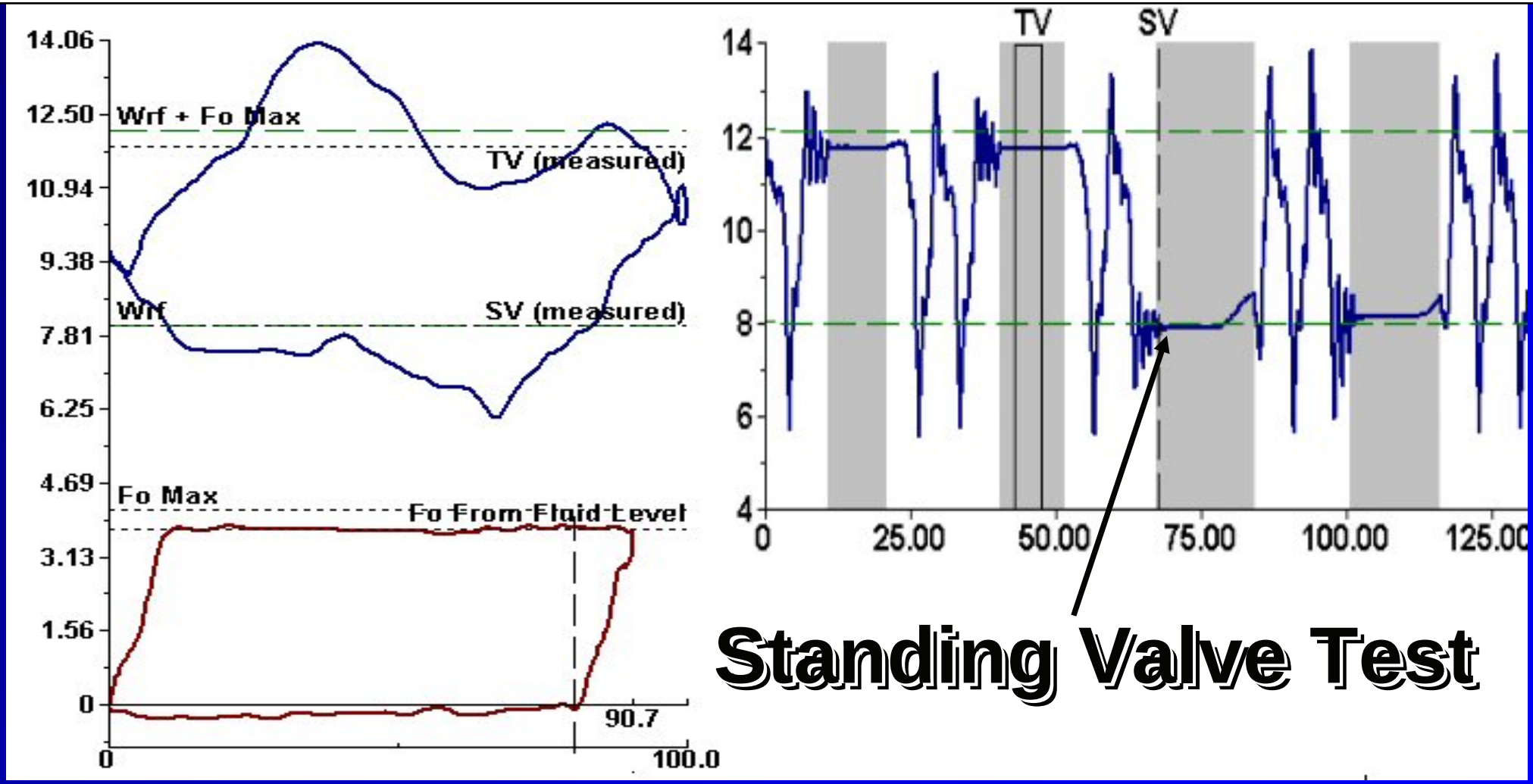
1) Pumping cycle was interrupted on the Downstroke when the TV was open and SV was closed for a standing valve load check.

2) Static pressures across the plunger are equal for SV Load Check(shown).

3) SV load measures the weight of the rods buoyed in the tubing fluid.



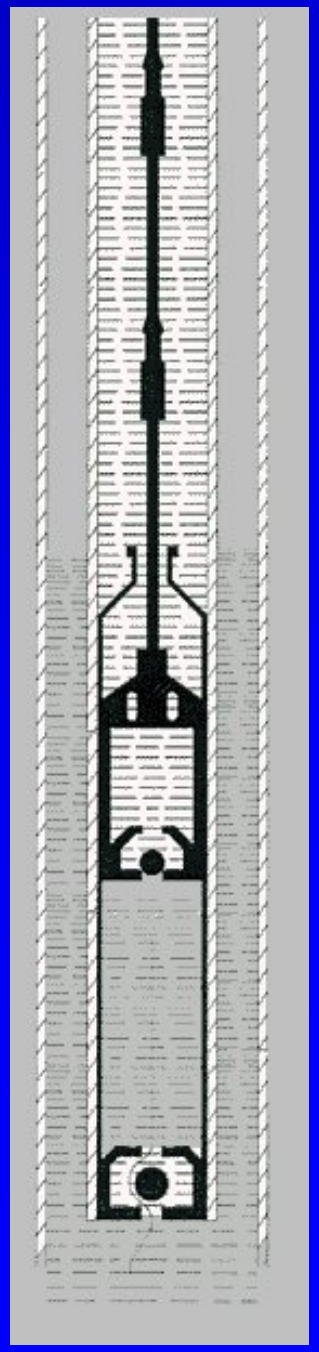
$$SV = W_{ra} - W_{ra} * 0.128 * SG_{tbg}$$



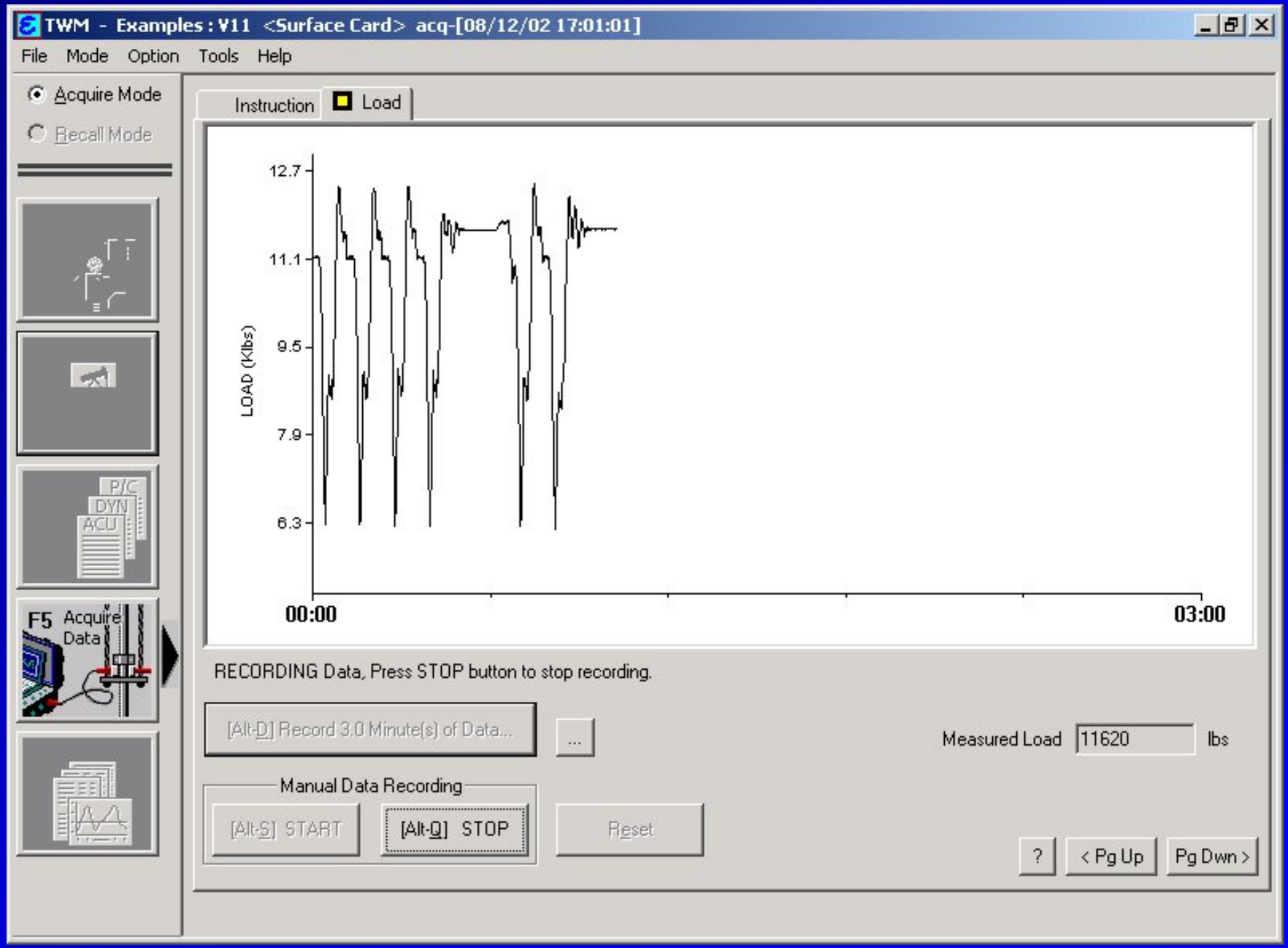
Standing Valve Load Test (above right) is a representative and correctly taken standing valve test load. The load trace is located at the standing (SV) load line and is sometimes called Wrf. The rod string load is measured, not the load on the "standing valve". This test records the load on the sucker rod string when it is immersed in well fluid and the standing valve is not leaking. SV load trace will usually be a flat line showing no weight gain unless the standing valve is leaking, or there is leakage from the pump or tubing.

Traveling Valve Check Procedure

The traveling valve check load test is taken during the upstroke by gently using the brake to bring the pumping unit to a stop about ¼ from the top of the stroke.



Perform Two Traveling Valve Checks

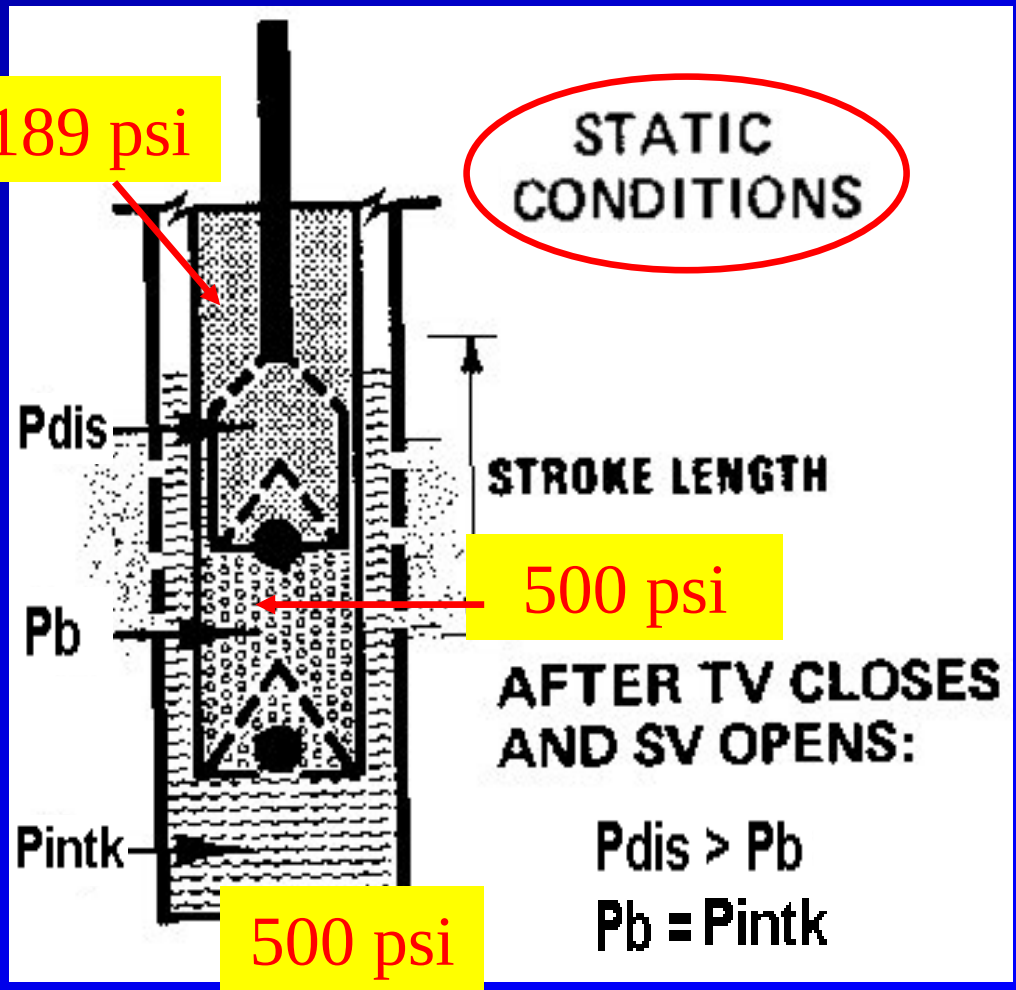


On Upstroke:
Check Traveling Valve Load

1) Pumping cycle was interrupted on the Upstroke when the TV was closed and SV was open for a traveling valve load check.

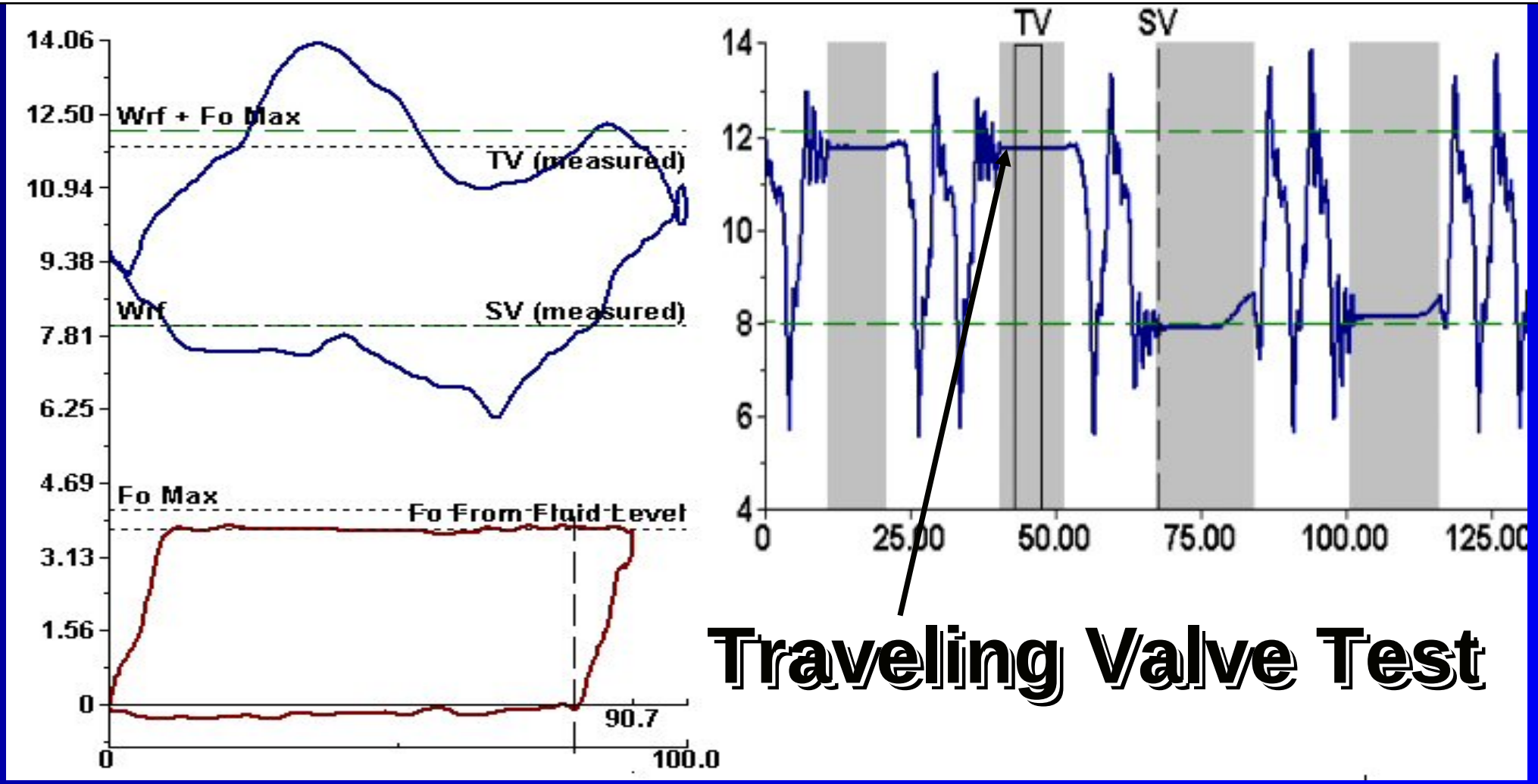
2) Pressure inside the pump are equal to the pump intake pressure.

3) When stopped on upstroke TV Check weighs = Wrf + Fo.

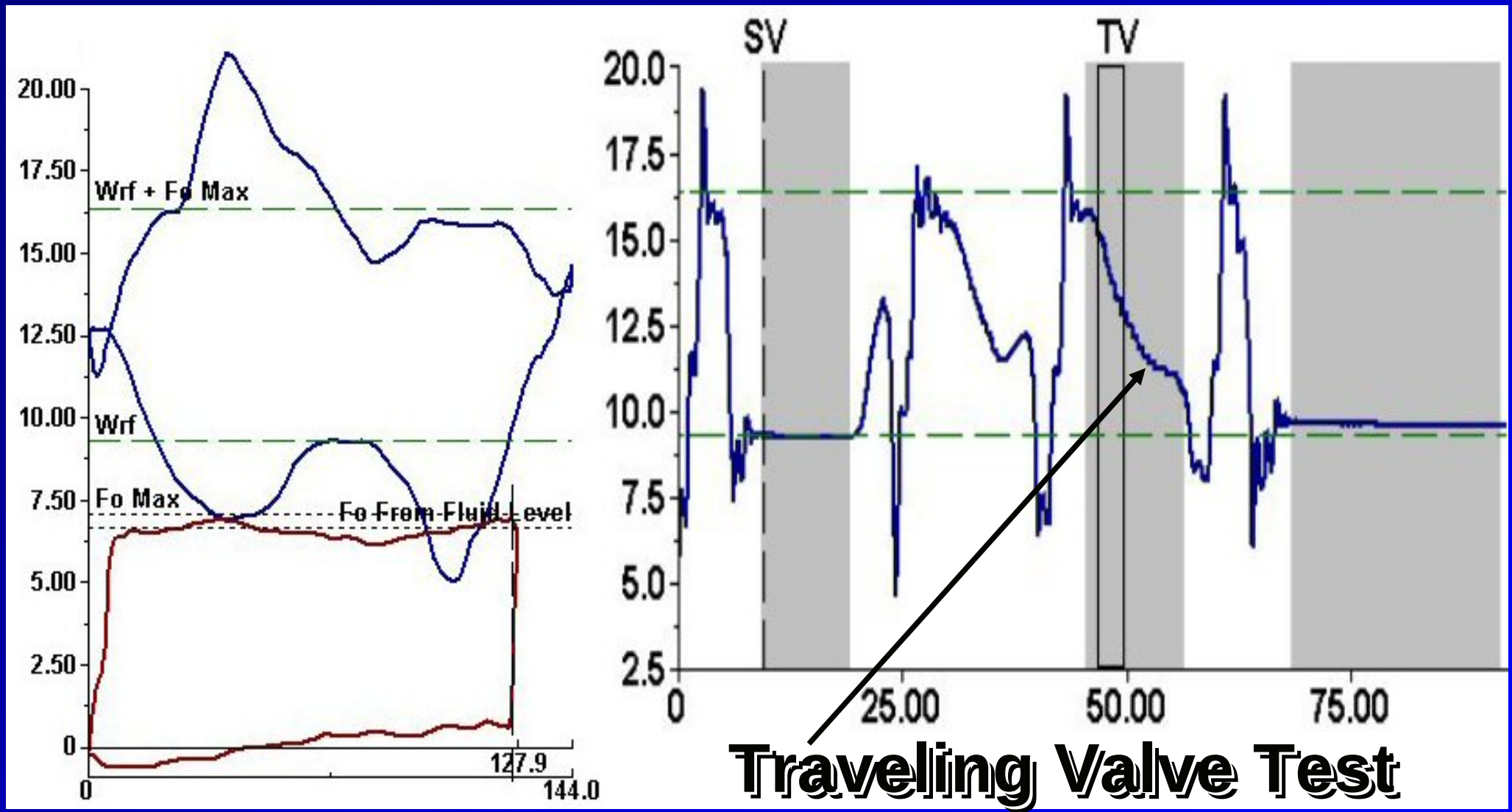


$$\Delta P_p = P_{dis} - P_{intk}$$

$$F_o = \Delta P_p * A_p$$



Traveling Valve Load Test (above right) is a representative and correctly taken traveling valve load test. This load trace is located at the traveling (TV) load line and is sometimes called Wrf + Fluid Load. The test records the load on the rod string immersed in well fluid, plus the fluid load applied to the rod string by the pump plunger. When the traveling valve is not leaking, the load trace will usually be a flat line showing very little weight loss of the fluid load. Normally, the TV load leaks between the pump plunger and barrel clearances.

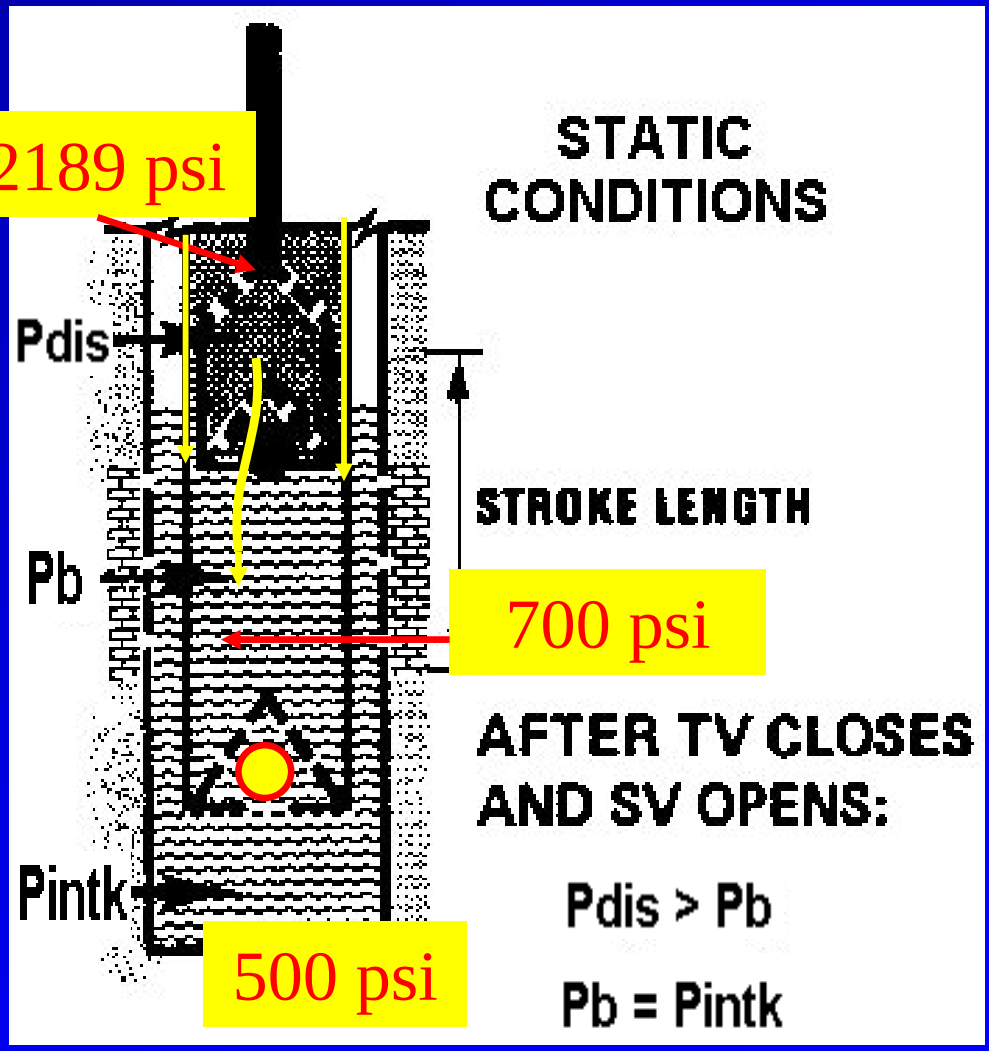


Traveling Valve Load Test showing load loss during the traveling valve check. The weight loss is usually associated with a leaky traveling valve or slippage of fluid due to the diametric clearances (0.008" above) between the pump plunger and the pump barrel. This load must be taken while the pumping unit is stopped on the upstroke. After the pumping unit stops, the TV load should be approximately equal to the Wrf + Fo from the Fluid Level.

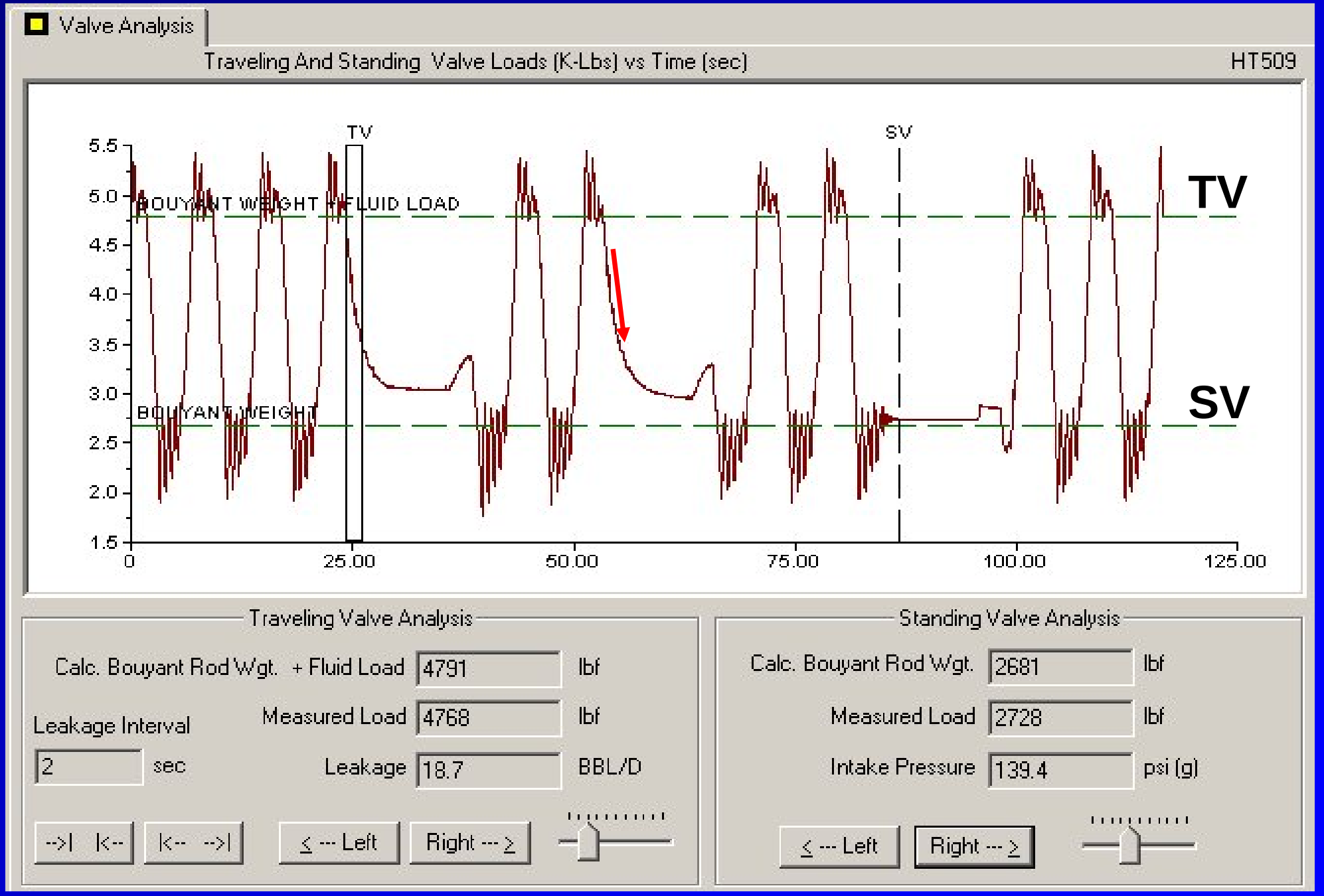
TV Leaks

Possible problems:
worn plunger or barrel, pitted ball, cut seat, tubing leak, or well flowing off.

1. Leakage rate indicated by changes in the polished rod load due to changes in the difference in pressure across the plunger
2. Liquid leaking past traveling valve and/or plunger enters pump barrel and increasing pressure.
3. Differential pressure decreases across plunger.
4. Pump load on the rods decreases, resulting in a decreasing polished rod load.



TV Check Shows Leaks



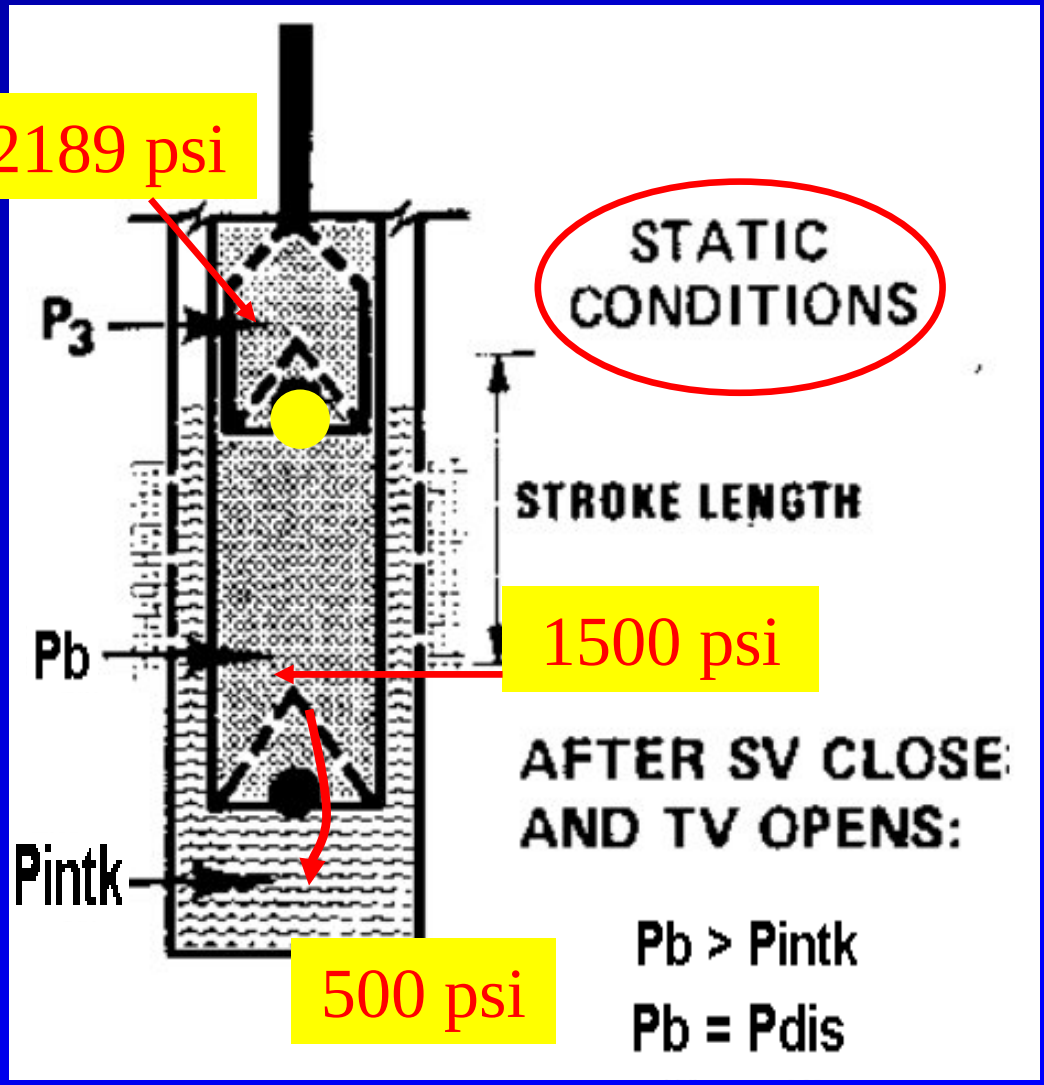
SV Leaks

1. Liquid leaking past standing valve leaves pump barrel and decreasing pressure.

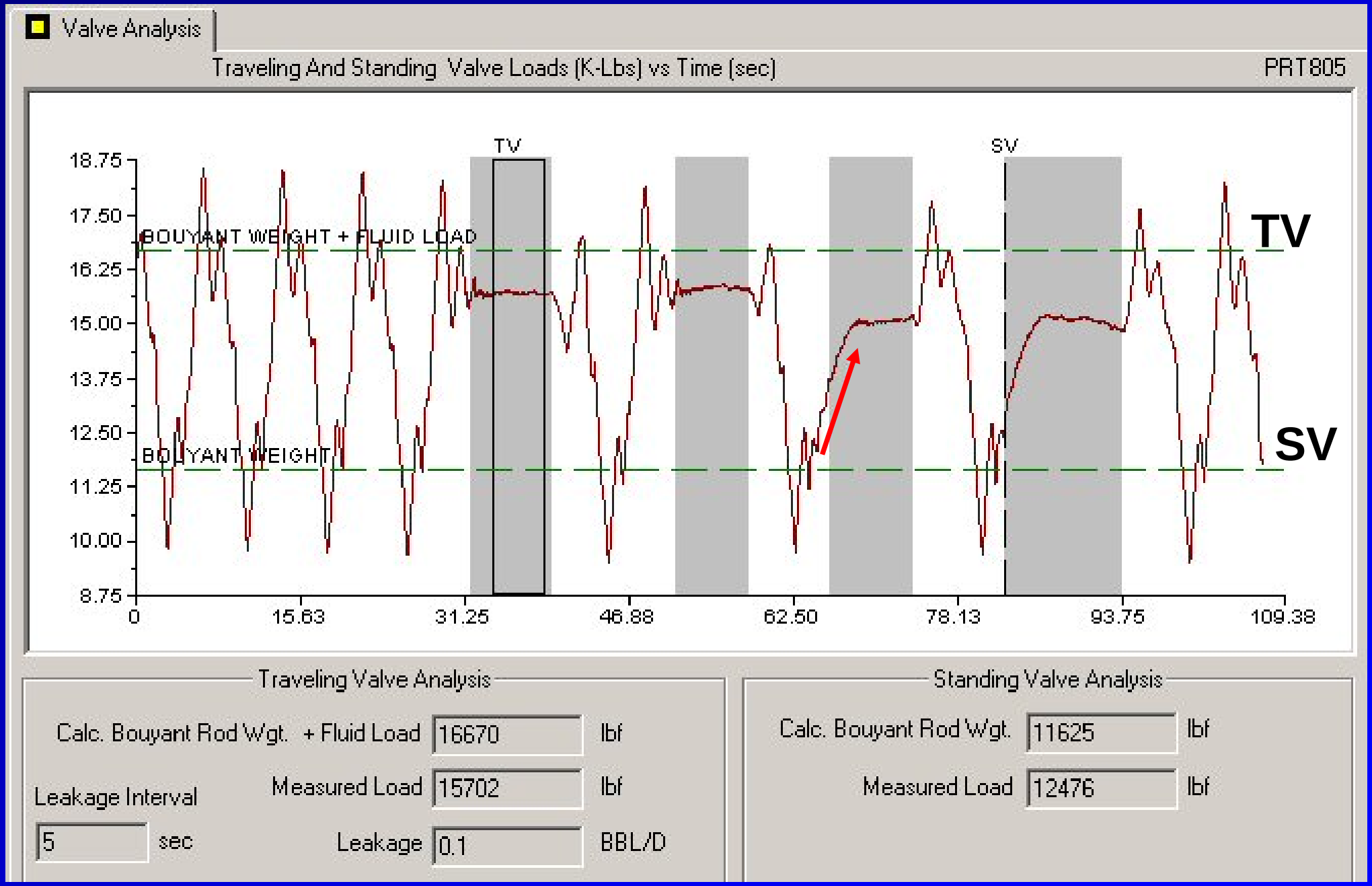
2. The leak causes increasing differential pressure across plunger, and results in the plunger applying fluid load to rods.

3. Both pump rod load and polished rod load increases.

Possible problems:
pitted ball, cut seat, hole in pump barrel, or damaged pump parts.

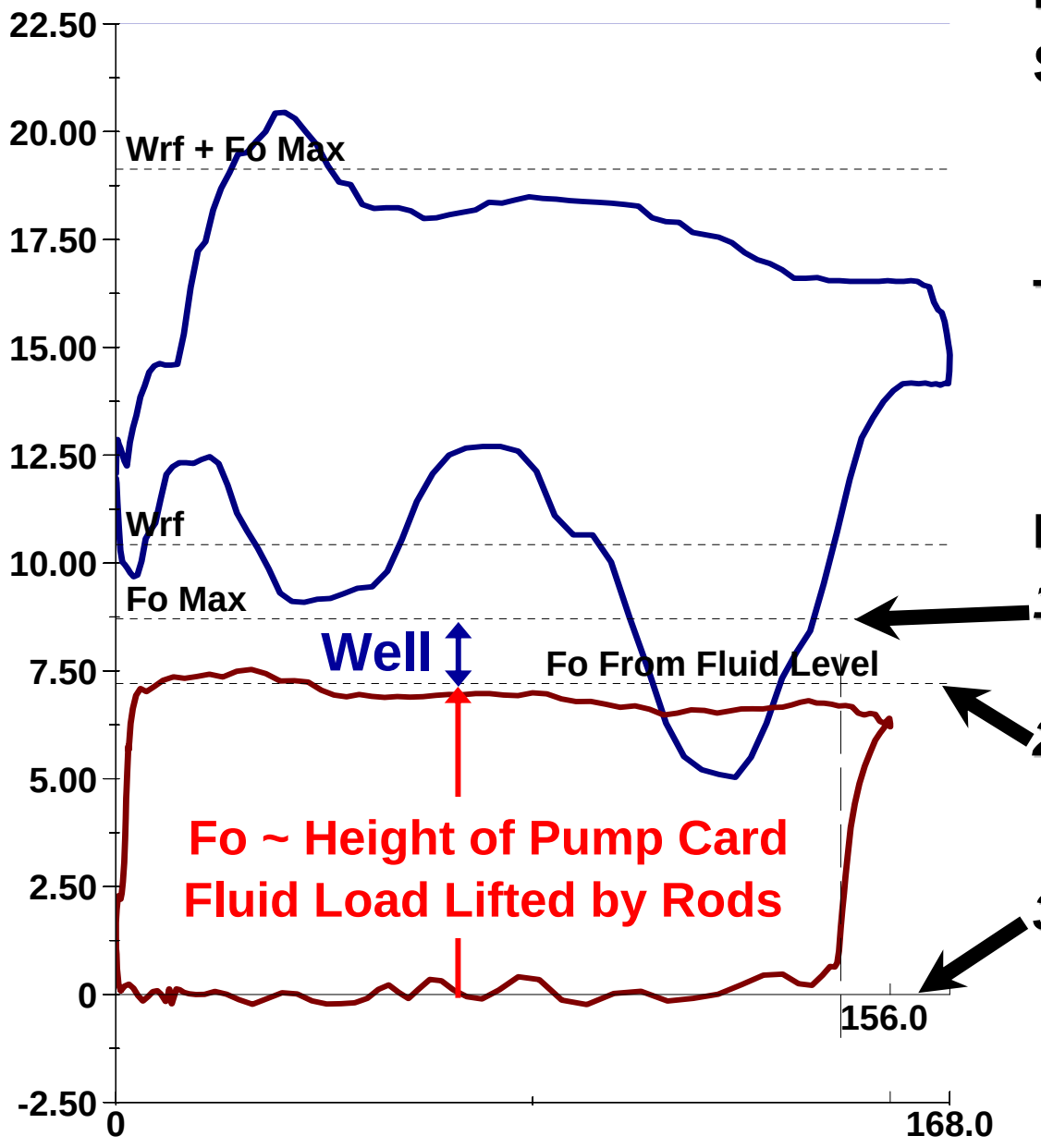


SV Check Shows Leak



Pump Card Reference:

Zero Load Line ~ Down Stroke
Fo From Fluid Level ~ Up Stroke



Normal Pump Card Loads:

SV Open Upstroke:

$Fo\ Max = (Pdis - 0)*Ap$

$Fo = (Pdis - Pintk)*Ap$

TV Open Downstroke:

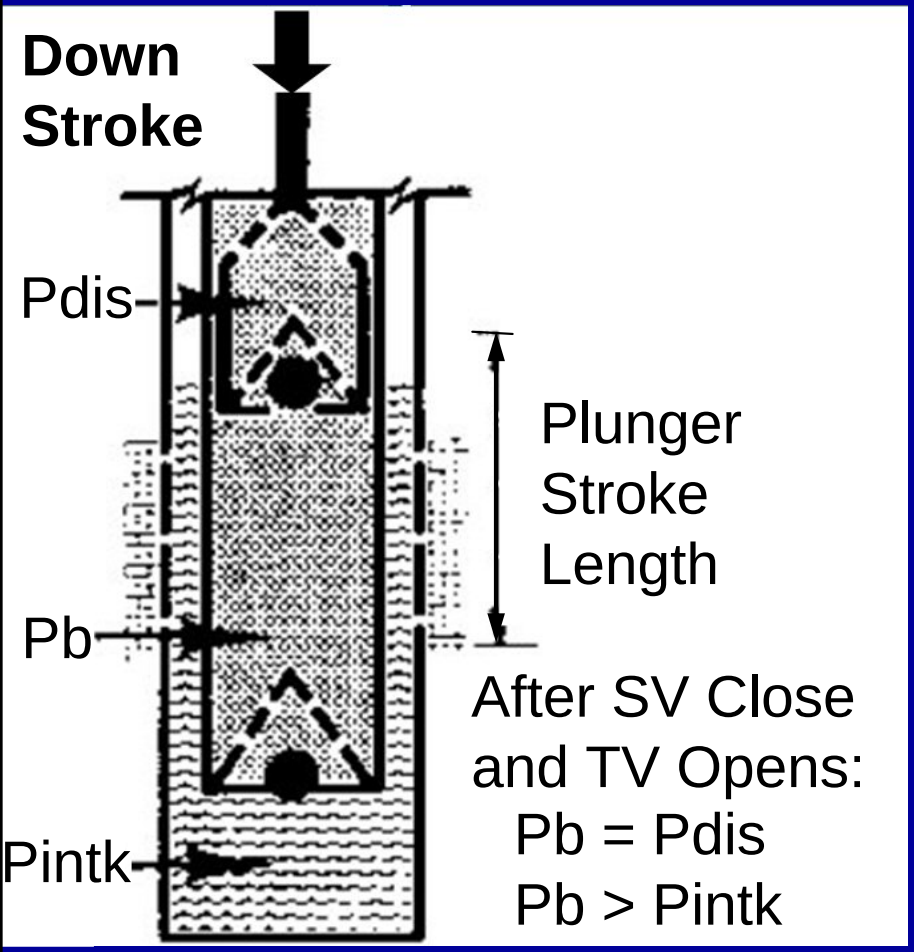
$Fo = 0$

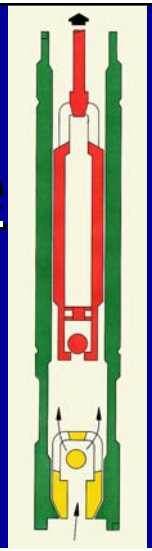
Reference Lines:

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

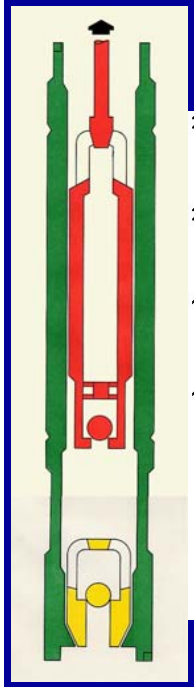
Zero Load Line

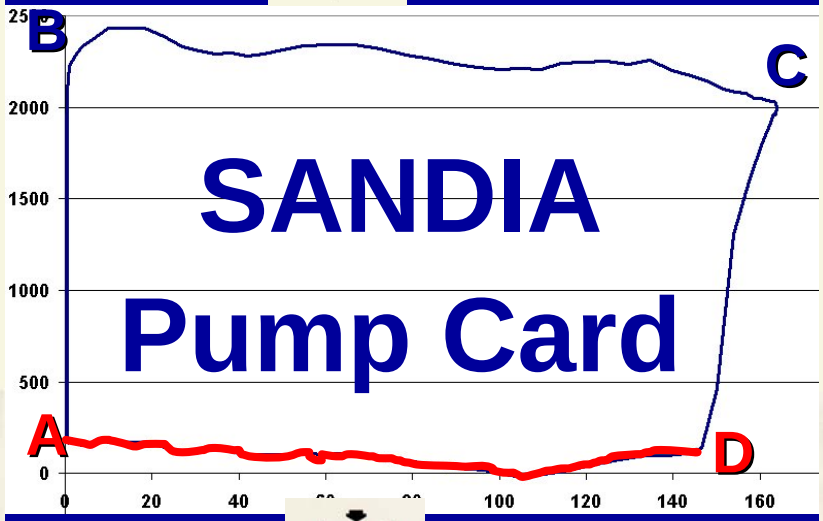
Load Reference Line ~ Down Stroke

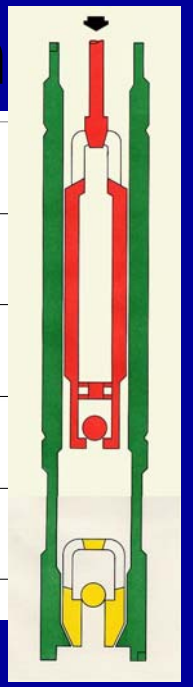




Steps in the Pump Operation





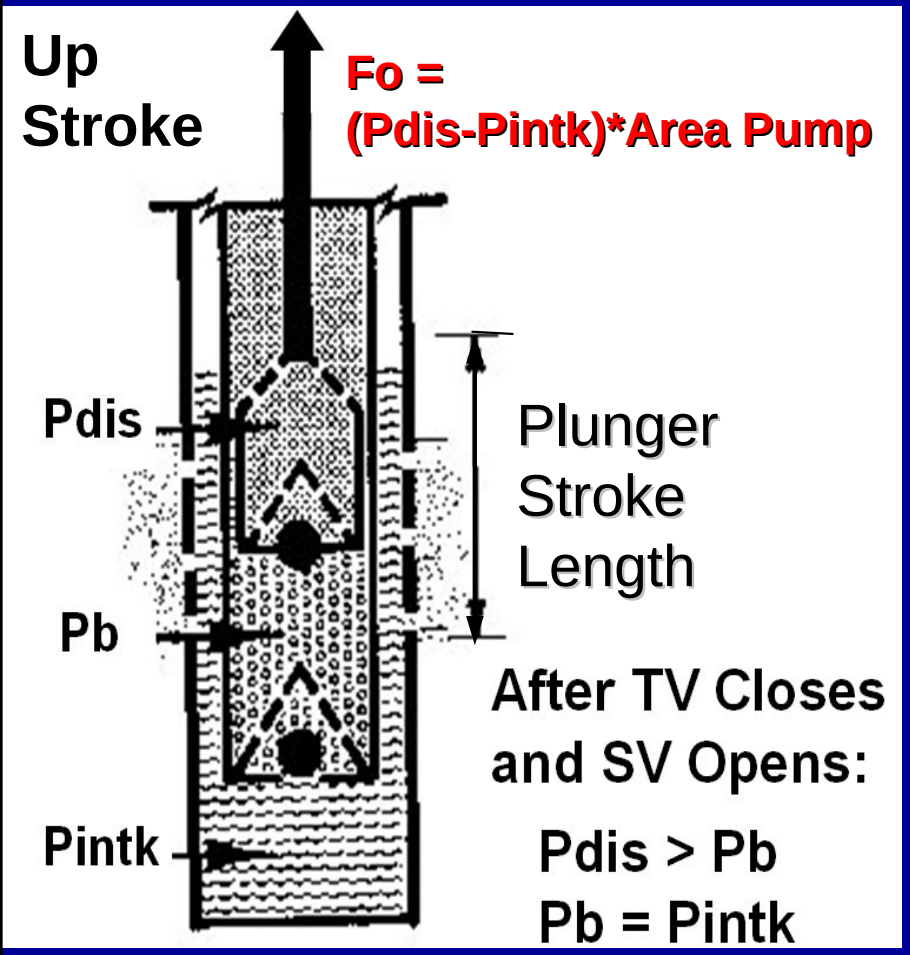


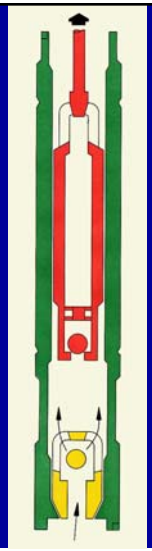
D) Pump discharge pressure (Pdis) equals the static tubing pressure (Pb), and the traveling valve opens. Pdis now carried by tubing.

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

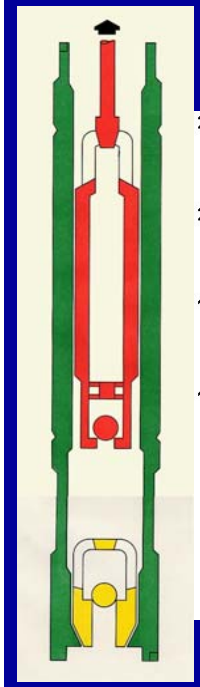
Fo From Fluid Level

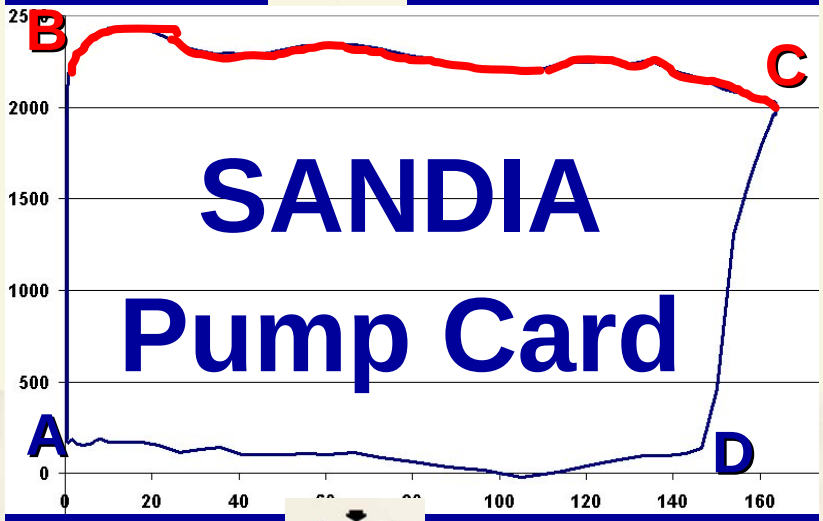
Load Reference Line on Up Stroke

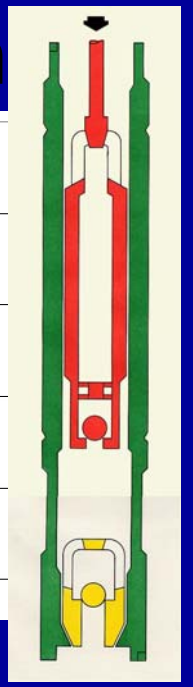




Steps in the Pump Operation







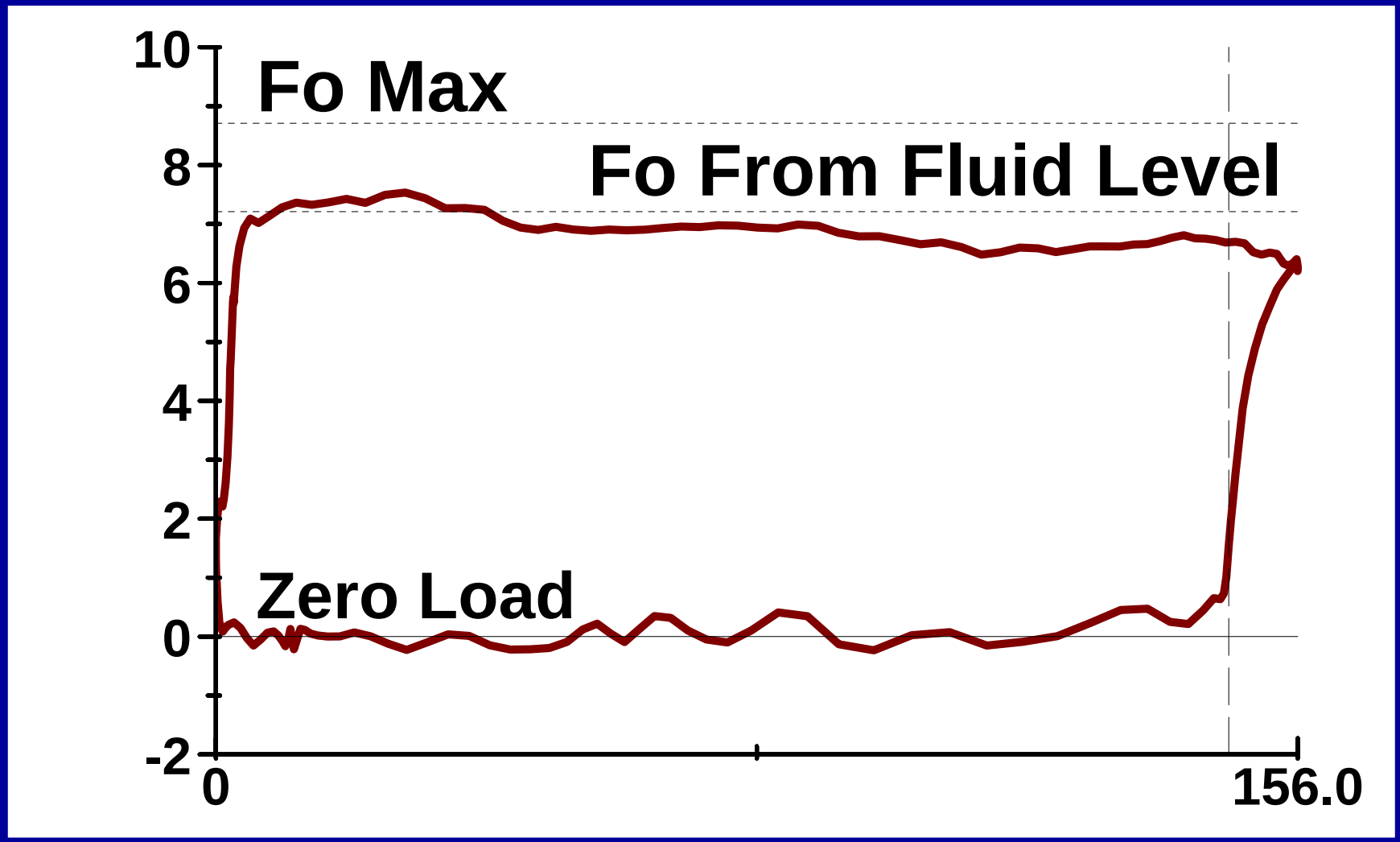
B) Standing Valve opens, when rods stretch to pick up fluid load, Fo, from tubing.

C) Standing valve closes.

B-C Plunger applies Fluid load, Fo, to the rods as well fluids are drawn into the pump.

Reference Loads for the Downhole Pump Card

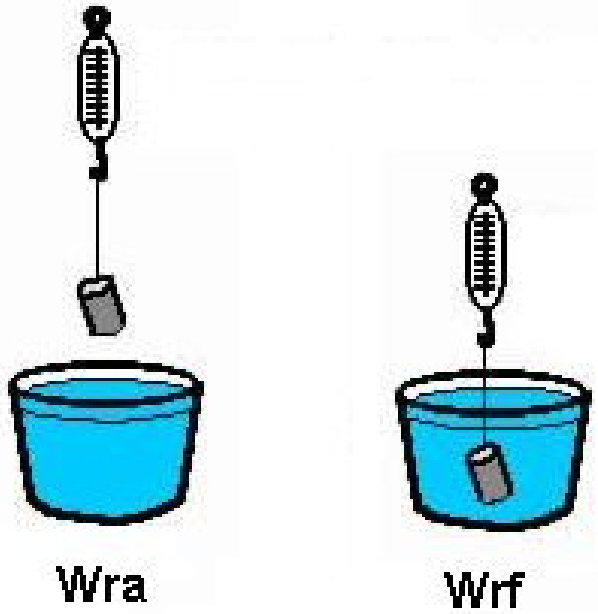
Understanding the pump card basic loads are critical to analyzing and troubleshooting downhole problems:



Buoyancy Force

Acting on a sucker rod was defined long ago.

***Archimedes' Principle*:**
Defines the buoyancy force to be equal to the weight of the volume of fluid displaced by an object.



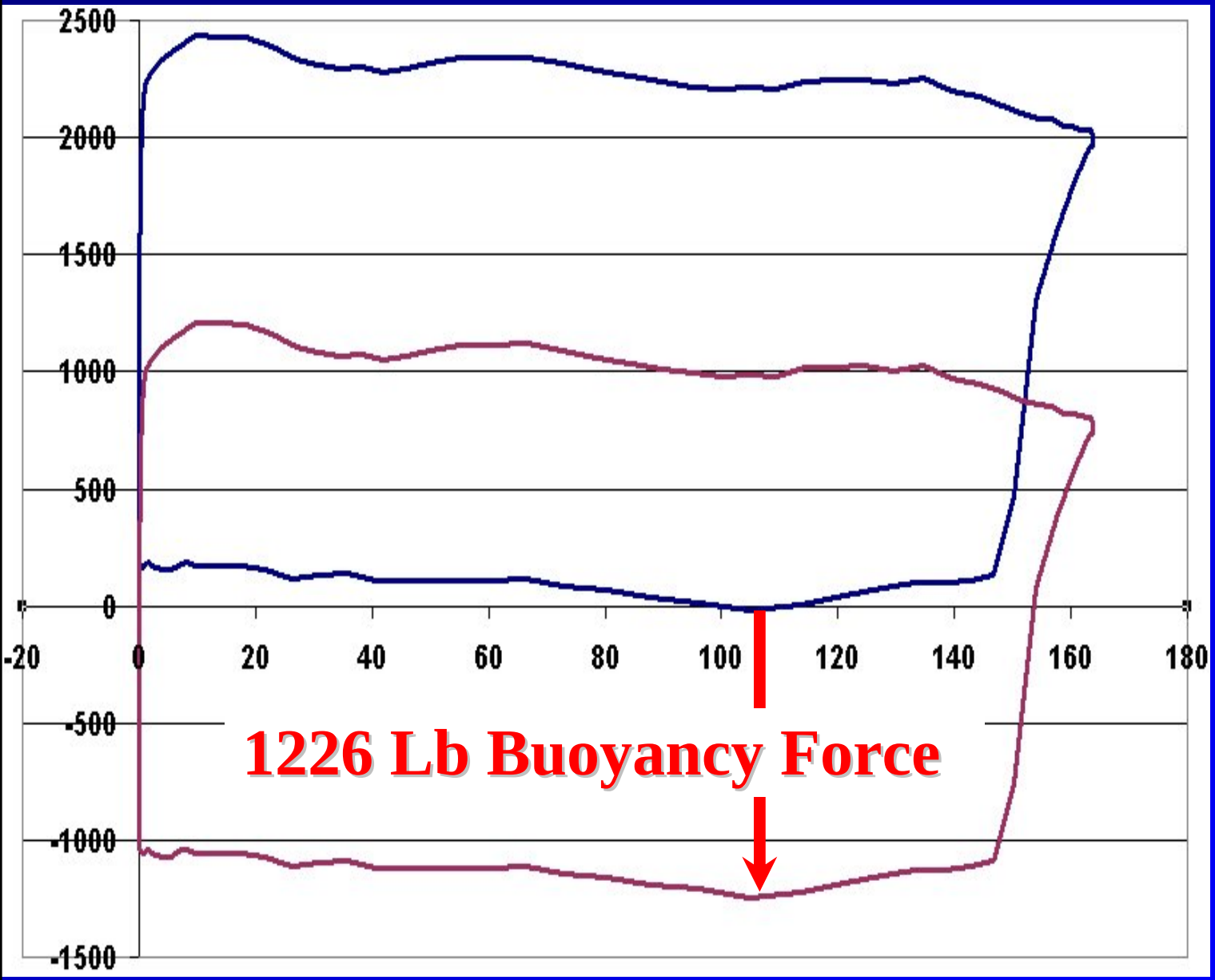
$$Wrf = Wra - 0.128 \times Wra \times SG$$

Wrf - Weight of Rods in Fluid
Wra - Weight of Rods in Air
SG - Tubing Fluid Specific Gravity

Impact of the buoyancy force:

- **Rods suspended in a fluid appears to weigh less, Wrf.**
- **Wrf = Wra, minus the buoyant force, 0.128xSGxWra.**
- **Buoyant force does not depend on the depth (pressure) at which the object is submerged, but the specific gravity, SG, of the fluid displaced.**

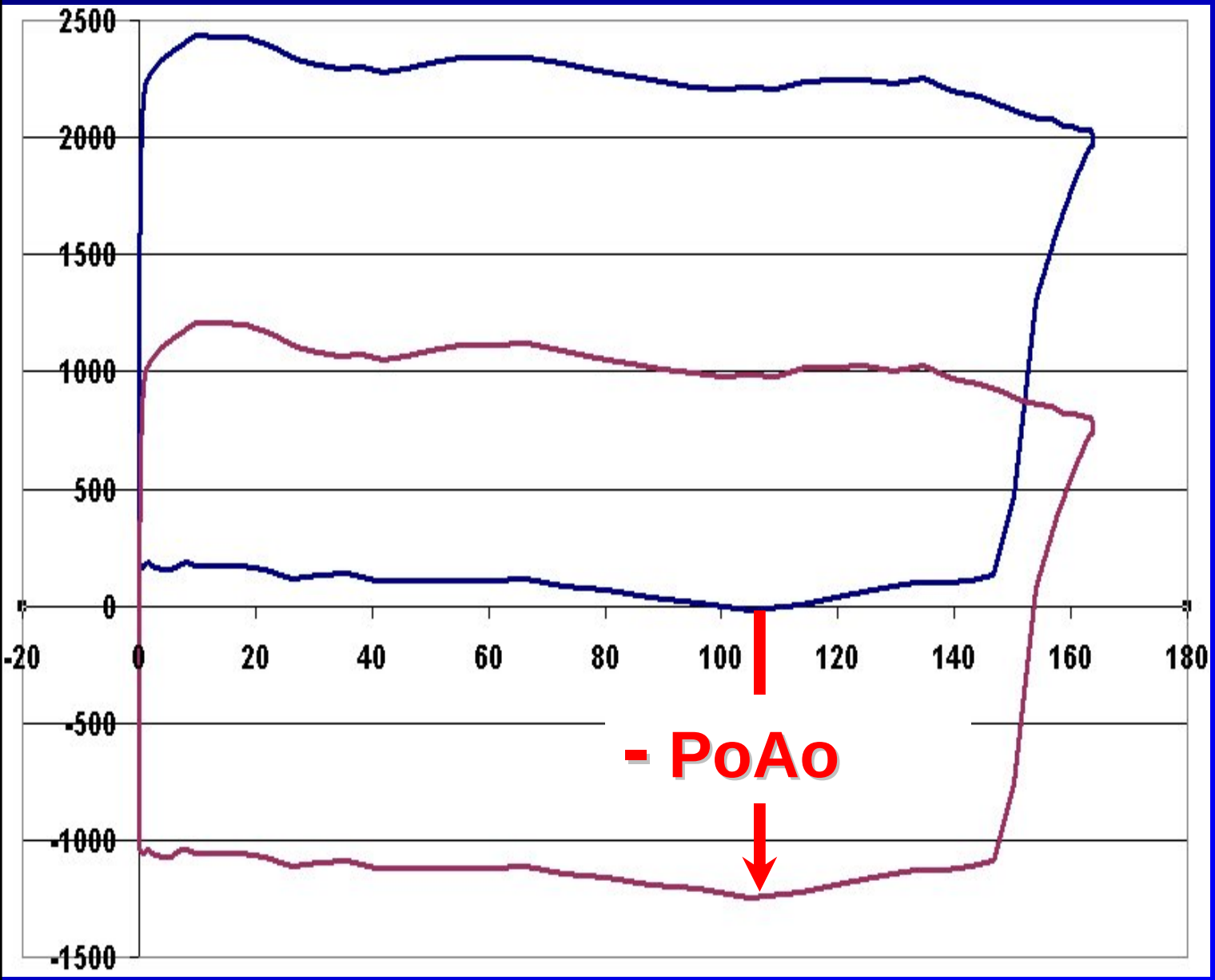
True Load = Dynamic Load - Buoyancy Force



- Solved Wave Eq. without gravity term
- No Buoyancy Effective on Dynamic Pump Loads
- Pump Card loads shifted down below the zero load line.

Predicting Behavior Sucker Rod Systems, S. Gibbs, SPE588, July 1963

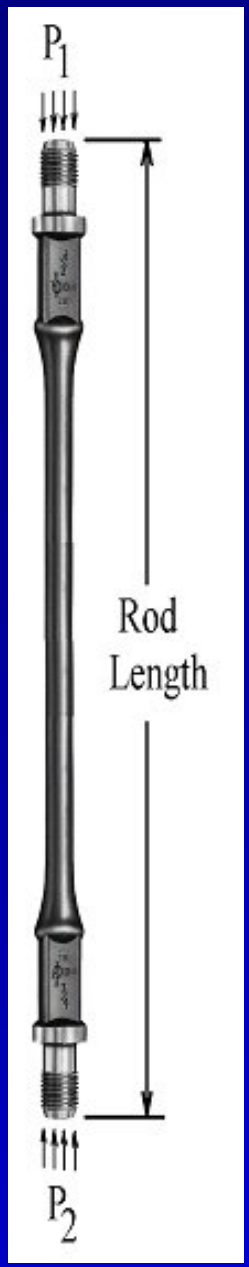
Load(true) = Load(eff) - PoAo



1. Ao is the outside cross sectional area
2. Po is the hydrostatic pressure @ Ao

Interpretation of Calculated Forces on Sucker Rods, J.F.Lea, SPE25416, Feb 1995

Where does “PoAo” come from?



API RP 11L Equation for Calculating Wrf by Displaced Volume

Wrf = Wra – Fbuoy = Wra(1 – 0.128G)

Fbuoy = Wra * 0.128 * SG

Density Ratio (Water/Steel) = 62.4/487.5 = 0.128

Volume(Rod) = Wra/487.5

Fbouy = Volume(Rod) * 62.4 * SG

Volume = Length * Area

Fbouy = Length * Area * Gradient

Buoyancy Force calculated by Pressure Equilibrium PoAo

P1 = Pressure

P2 = P1 + Length * Gradient

Fbuoy = (P2 -P1) * Area = (P1 + Length*Gradient - P1) * Area

Fbuoy = Length*Area*Gradient

Wrf = Wra – AoPo

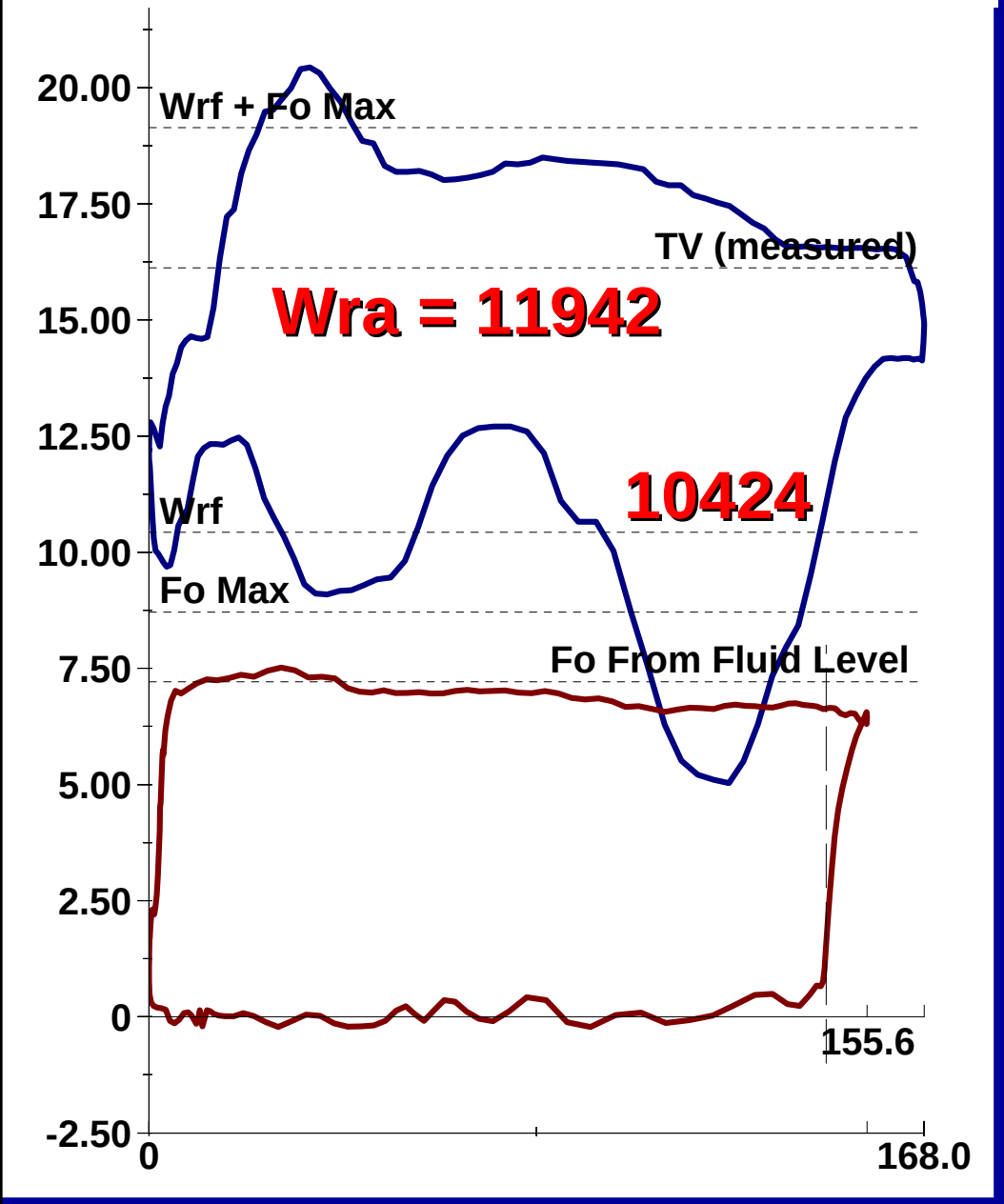
Ao = (wt/ft) / density

= 2.90 / 487.5 x 144 = 0.8566 sq in

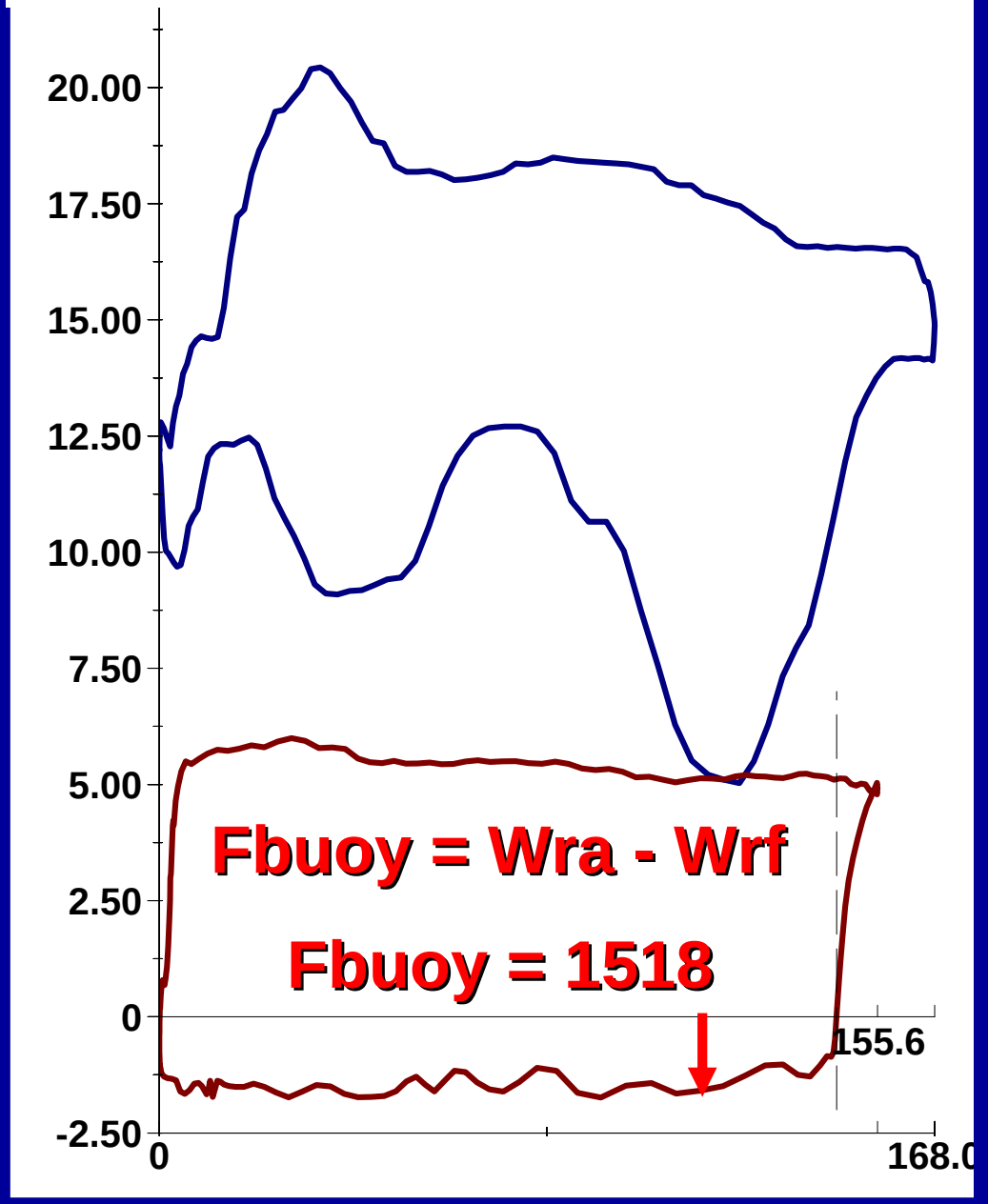
Diameter 1” Rod = 1.044” (True Diameter)

Buoyancy – Tubing Fluid Gradient

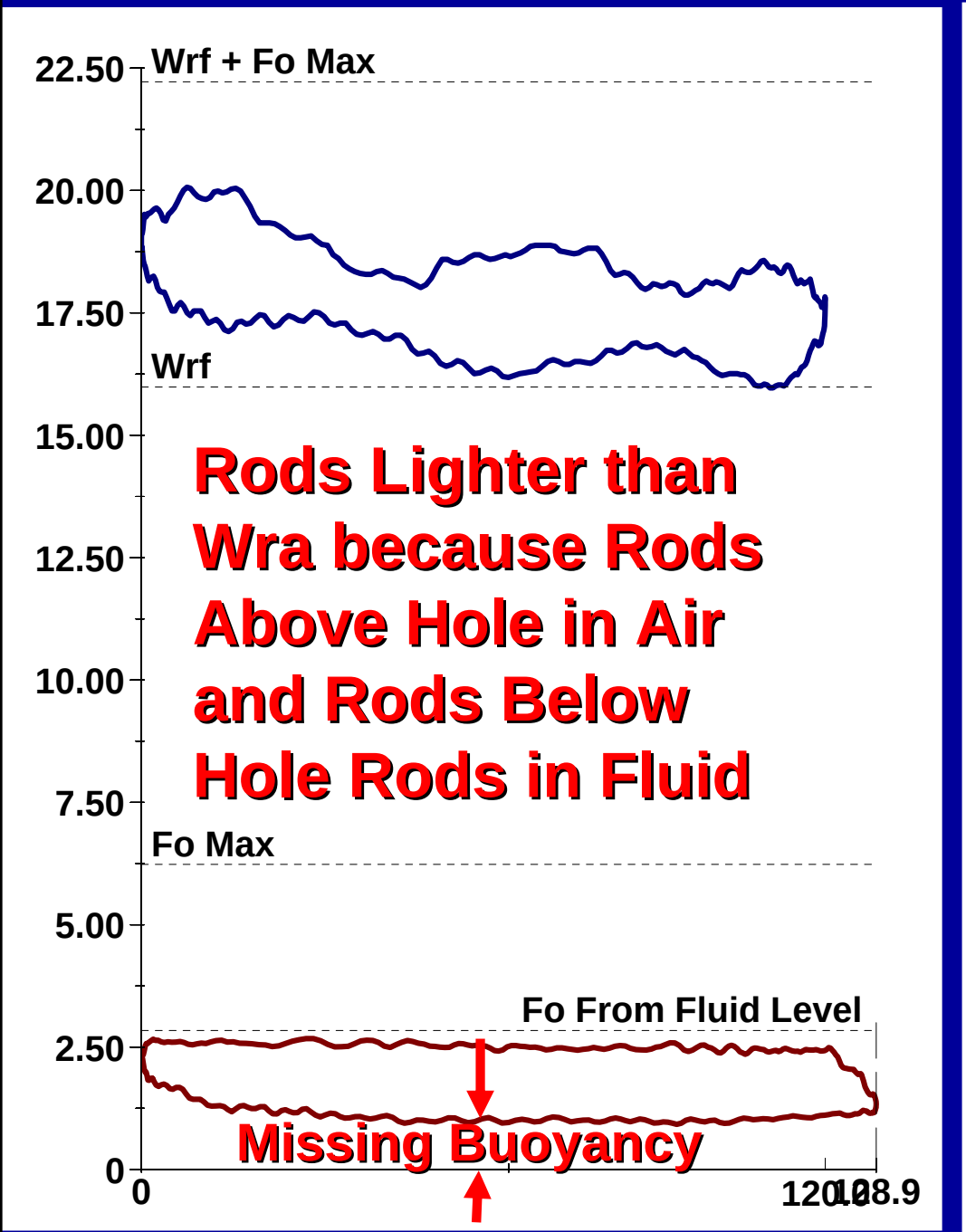
Tubing Fluid Gradient = 0.432

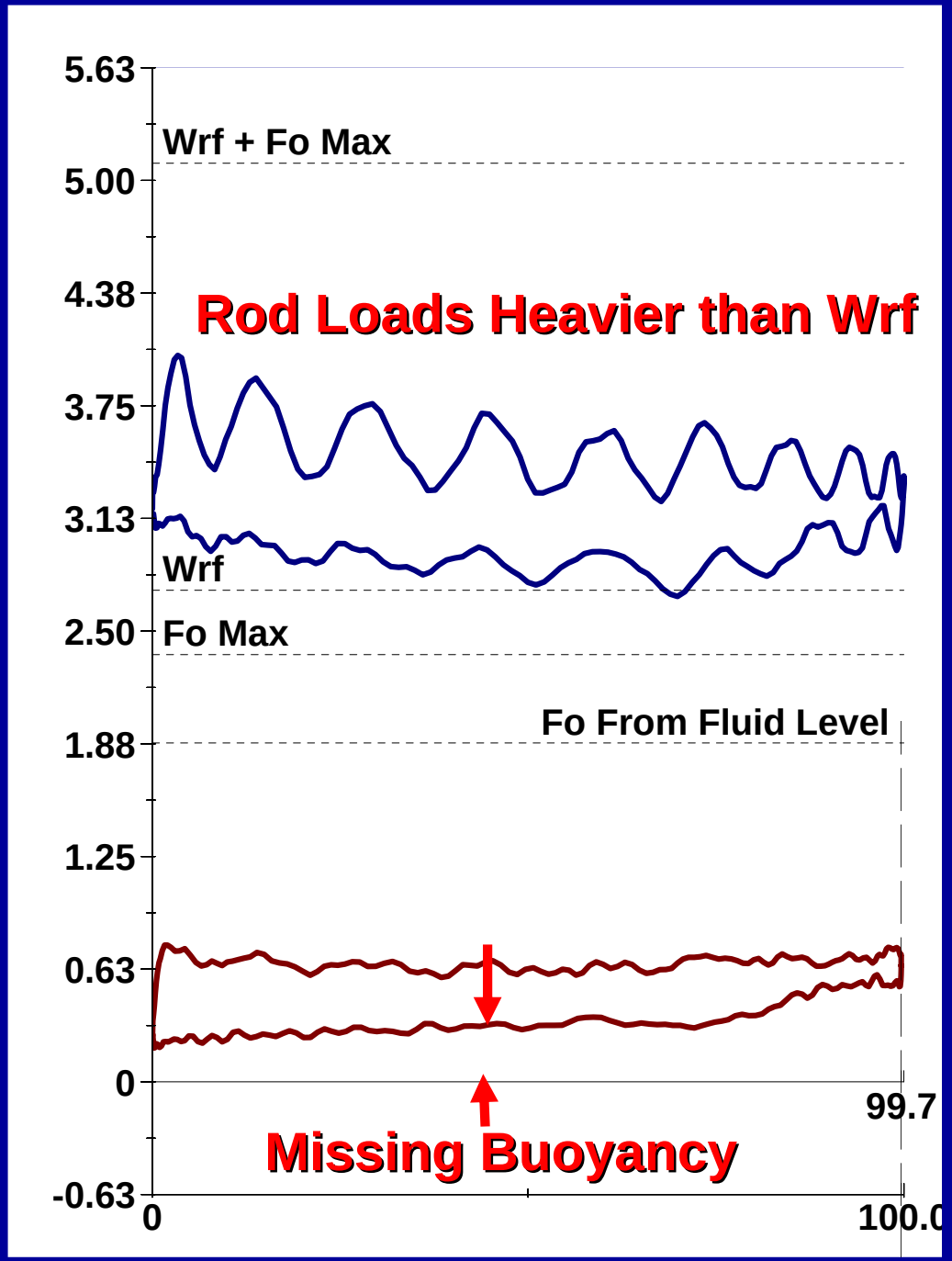


Tubing Fluid Gradient = 0.0

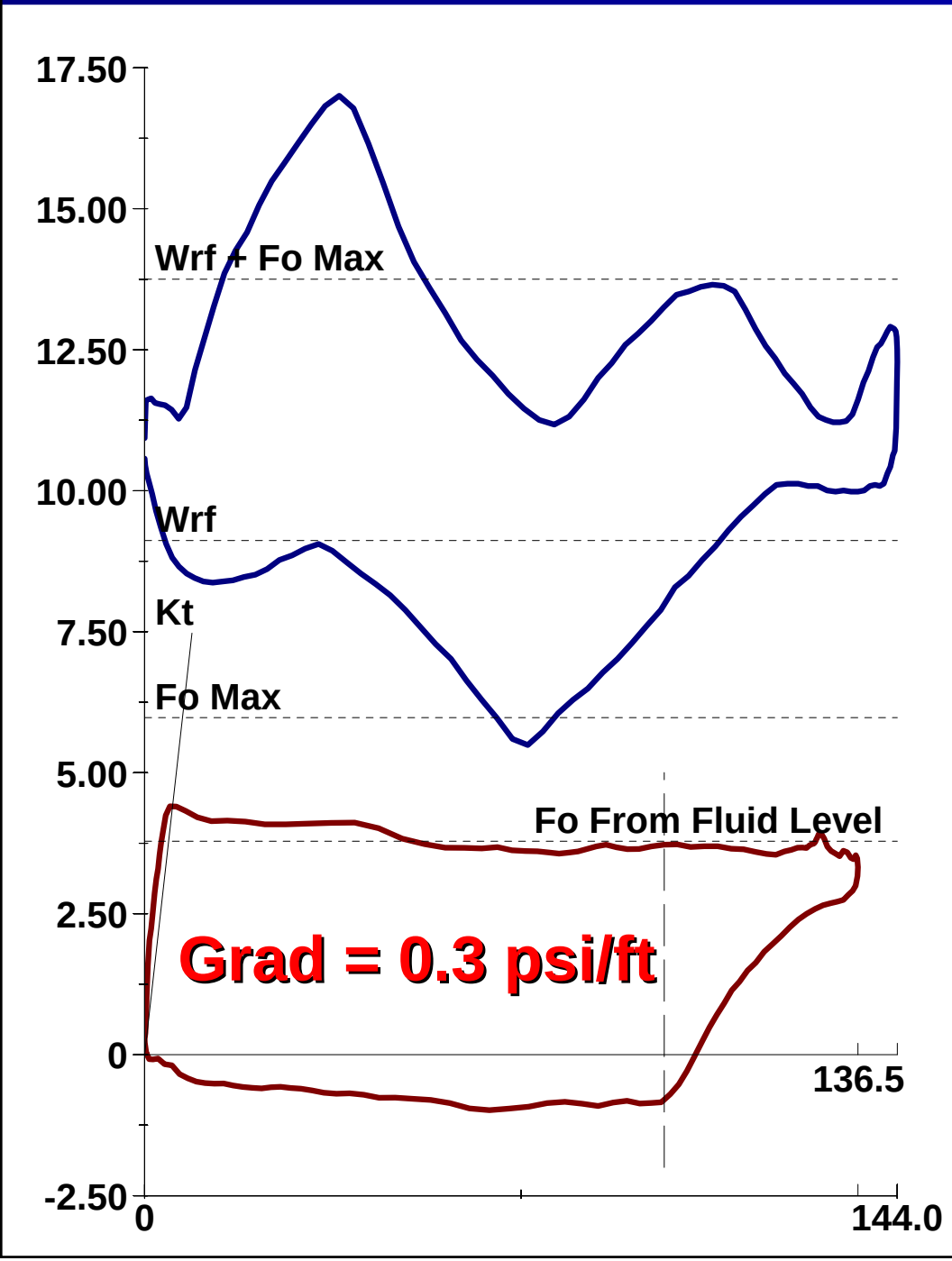


Missing Buoyancy – Hole in Tubing





Tubing Fluid Gradient – Wrf & Pdisp



Casing Pressure | BHP | Collars

Casing Pressure
309.0 psi (g)

Casing Pressure Buildup
11.1 psi
2.50 min

Gas/Liquid Interface Pres.
312.0 psi (g)

Liquid Level Depth
MD 288.80 ft

Pump Intake Depth
MD 5408.46 ft
TVD 5408.46

Formation Depth
MD 5843.18 ft

Well State:
Producing

Annular
Gas Flow
208 Mscf/D
% Liquid
22

Liquid Below Tubing
Oil 0 %
Water 100 %

% Liquid Below Tubing
48 %

Liquid Below Tubing...

Pump Intake Pressure
682.7 psi (g)

PBHP
777.9 psi (g)

Reservoir Pressure (SBHP)
2378.4 psi (g)

Questions ?