

Surface and Pump Card Reference Loads

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

TWM - Examples : V11

File Mode Option Tools Help

Acquire Mode
Recall Mode

F2 Data Files
F3 Select Test
P/C
DYN
ACU

File Mgmt | General | Data Guide | **Surface Equip.** | Wellbore | Conditions | Press. Transient Data

[Alt-1] Surface Unit

Manufacturer: LUFKIN
Unit Class: Conventional
API: C-320D-256-100
Stroke Length: 100.000 in

For Net Torque Calculations Use:
 Counter Balance Effect (Weights level) 10.9945 Klb
 Counter Balance Moment (Existing) 509.526 Kin-lb Counter Weights...
Weight Of Counter Weights: 5308 lb

Rotation: CW CCW

[Alt-2] Prime Mover Information
Mfg
Model
MFG

[Alt-3] Electric Motor Parameters

Full Load: 38 Amps
Rated RPM: 1100
Synchronous RPM: 1200
Voltage: 480 Hz: 60 Phase: 3

[Alt-4] Power Cost
Consumption: 5 c/KWH
Demand: 8 \$/KW

Save ? < Pg Up Pg Dwn >

**Need Pumping Unit Information:
Type, Unit Geometry, Direction of
Rotation, Prime Mover Information**

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

TWM - Examples : V11

File Mode Option Tools Help

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F3 Select Test
P/C DYN ACU

File Mgmt | General | Data Guide | Surface Equip. | **Wellbore** | Conditions | Press. Transient Data

[Alt-1] Tubulars

Tubing OD: 2.375 in
Casing OD: 5.500 in
Ave. Joint Length: 31.700 ft
Anchor Depth: 5100.00 ft
KB Correction: 0.00 ft

[Alt-3] Pump

Plunger Dia.: 1.500 in
Pump Intake: 5226.00 ft

[Alt-4] Polished Rod

Diameter: 1.250 in

[Alt-5] Rod Totals

Total Rod Length: 5200 ft
Total Rod Weight: 9221.75 lb

[Alt-2] Rod String

	Top Taper	Taper 2	Taper 3	Taper 4	Taper 5	Taper 6
Rod Type	D	D	D	NONE	NONE	NONE
Length	1100.00	3875.00	225.00			
Diameter	0.875	0.750	0.875			
Weight	2433.2	6290.9	497.7			
Damp Up	0.05					
Damp Down		0.05				

Save | Deviated Wellbore ... | ? | < Pg Up | Pg Dwn >

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

The screenshot displays the TWM software interface with the 'Conditions' tab selected. The 'Production [Alt-3]' section is highlighted with a red box, showing production rates for Oil (14 BBL/D), Water (60 BBL/D), and Gas (40.0 Mscf/D). A dialog box titled 'Tubing Fluid Gradient Method' is open, showing options for calculating the gradient. The 'Use Value Calculated From Production Information' option is selected, with a value of 0.435 psi/ft. The 'Use Entered Value' option is also visible. The 'Tubing Fluid Gradient...' button at the bottom of the dialog is highlighted with a red box. The 'Surface Production' section is also highlighted with a red box.

Production [Alt-3]

Oil	14	BBL/D
Water	60	BBL/D
Gas	40.0	Mscf/D
Date	09/21/1998	

Tubing Fluid Gradient Method

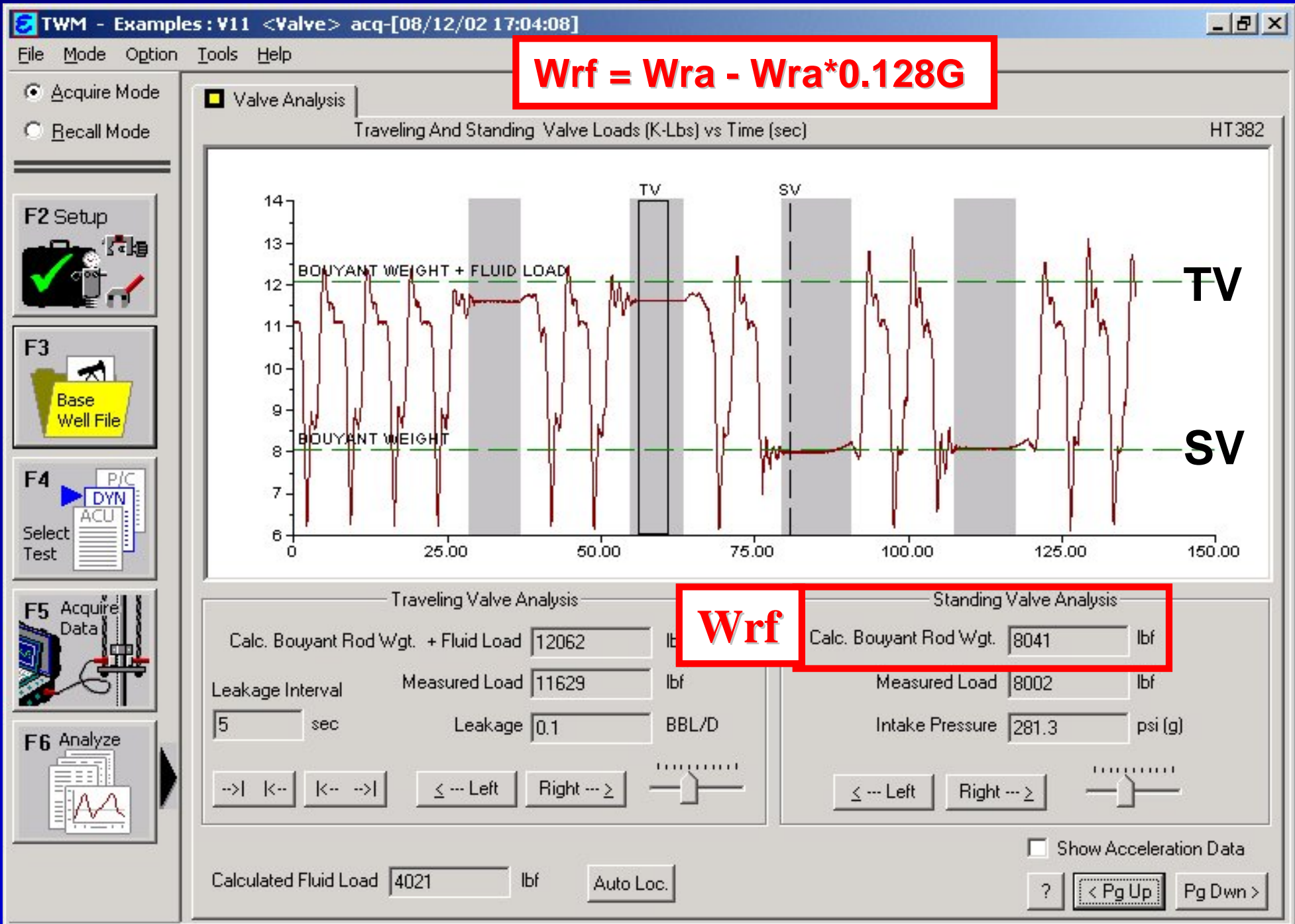
Tubing Fluid Gradient Options:

- Use Value Calculated From Production Information: 0.435 psi/ft
- Use Entered Value: [] psi/ft

OK

Tubing Fluid Gradient...

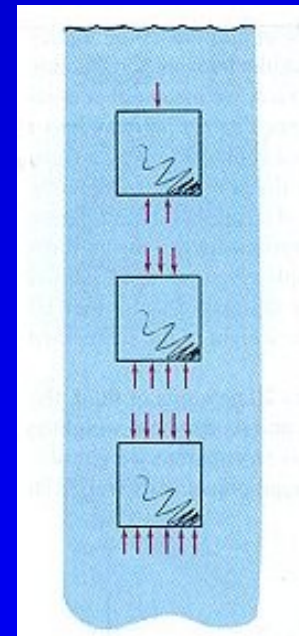
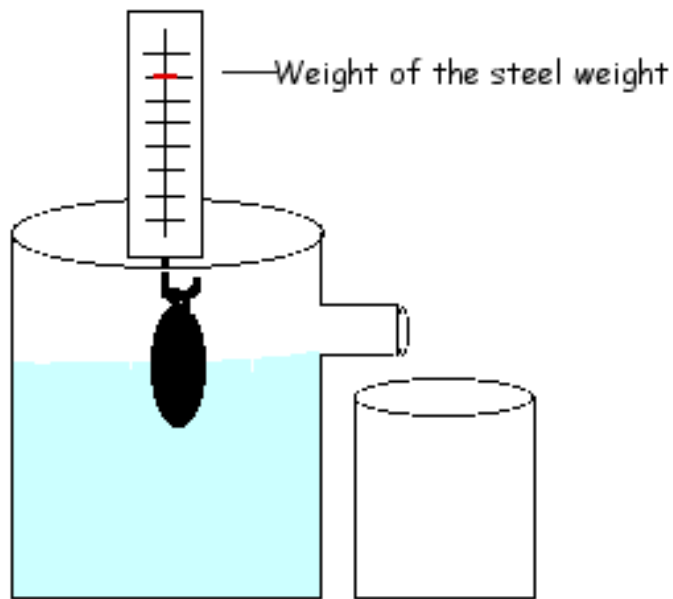
Measured & Computed Valve Loads



Buoyancy Force, F_b

Steel Rods $\sim F_b = W_{ra} * 0.128 * G$

Buoyancy Force not depend on depth or pressure



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

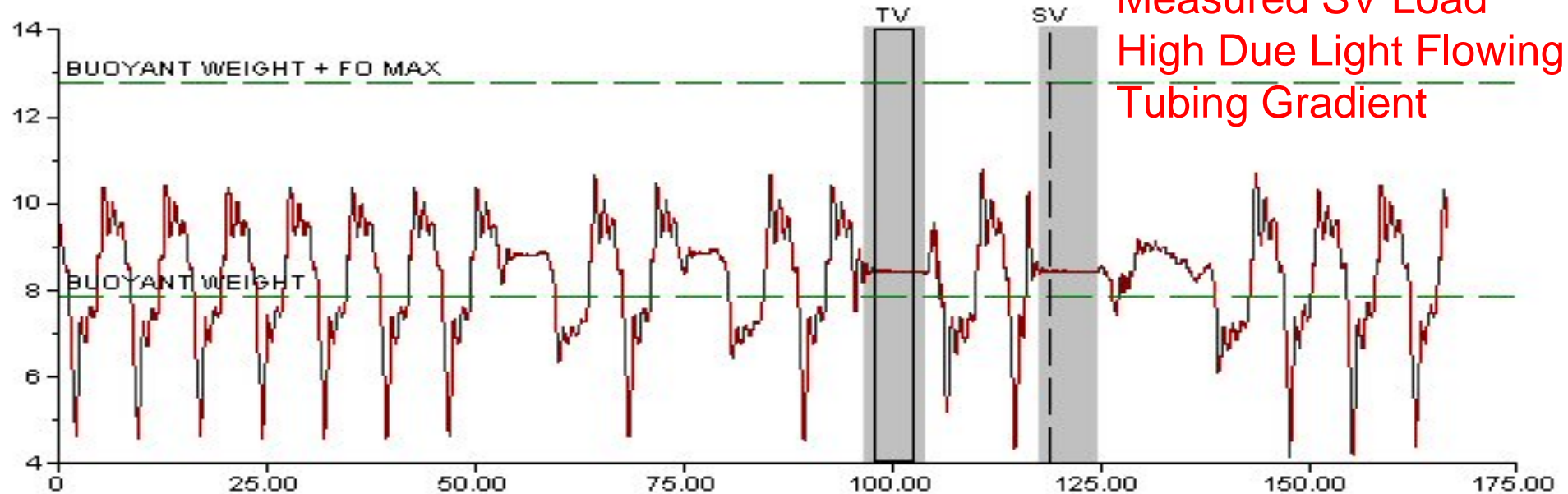
$$W_{rf} = W_{ra} - F_b$$

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

Valve Analysis

Traveling And Standing Valve Loads (K-Lbs) vs Time (sec)

HT910



Traveling Valve Analysis

Standing Valve Analysis

Calc. Buoyant Rod Wgt. + Fo Max 12781 lbf

Calc. Buoyant Rod Wgt. 7835 lbf

Leakage Interval

Measured Load 8433 lbf

Measured Load 8435 lbf

5 sec

Leakage 0.2 BBL/D

~~Intake Pressure 2856.3 psi (g)~~

--> | <-- | <-- --> |

< --- Left Right --- >

< --- Left

Right --- >

Show Acceleration Data

Calculated Fluid Load 4946 lbf

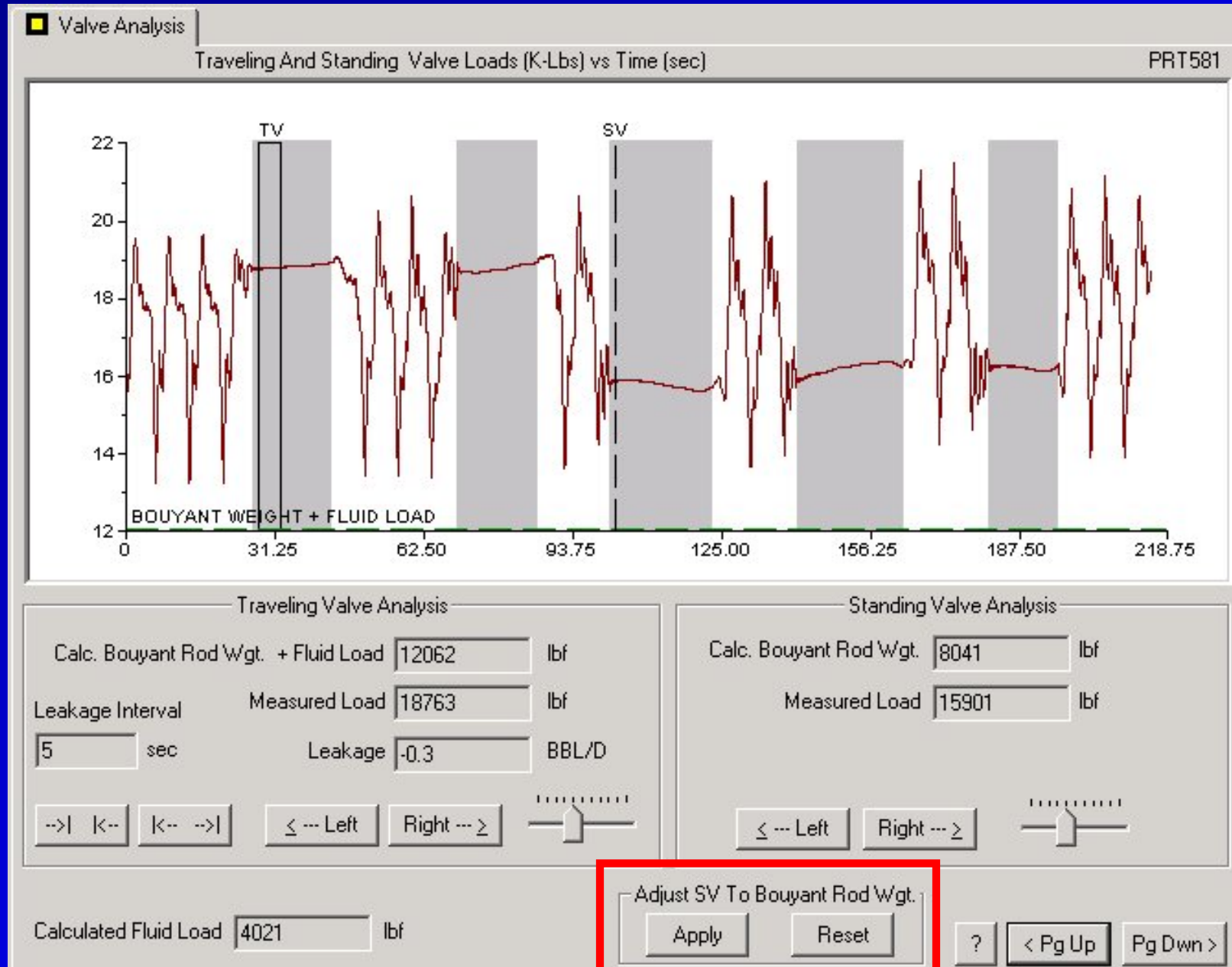
Used Normal Gradient 0.445 psi/ft

< Pg Up

Pg Dwn >

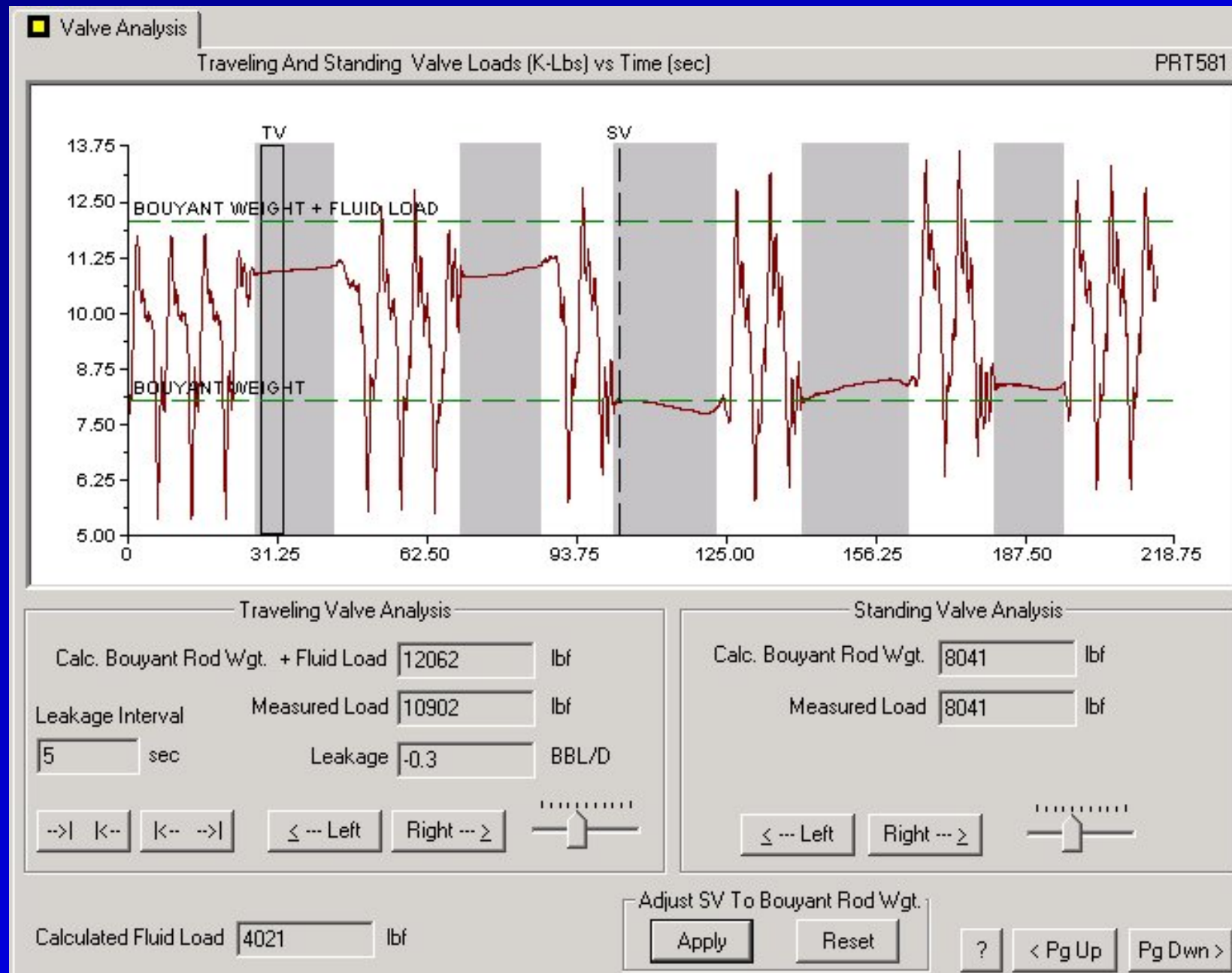
If PRT Used for Valve Checks

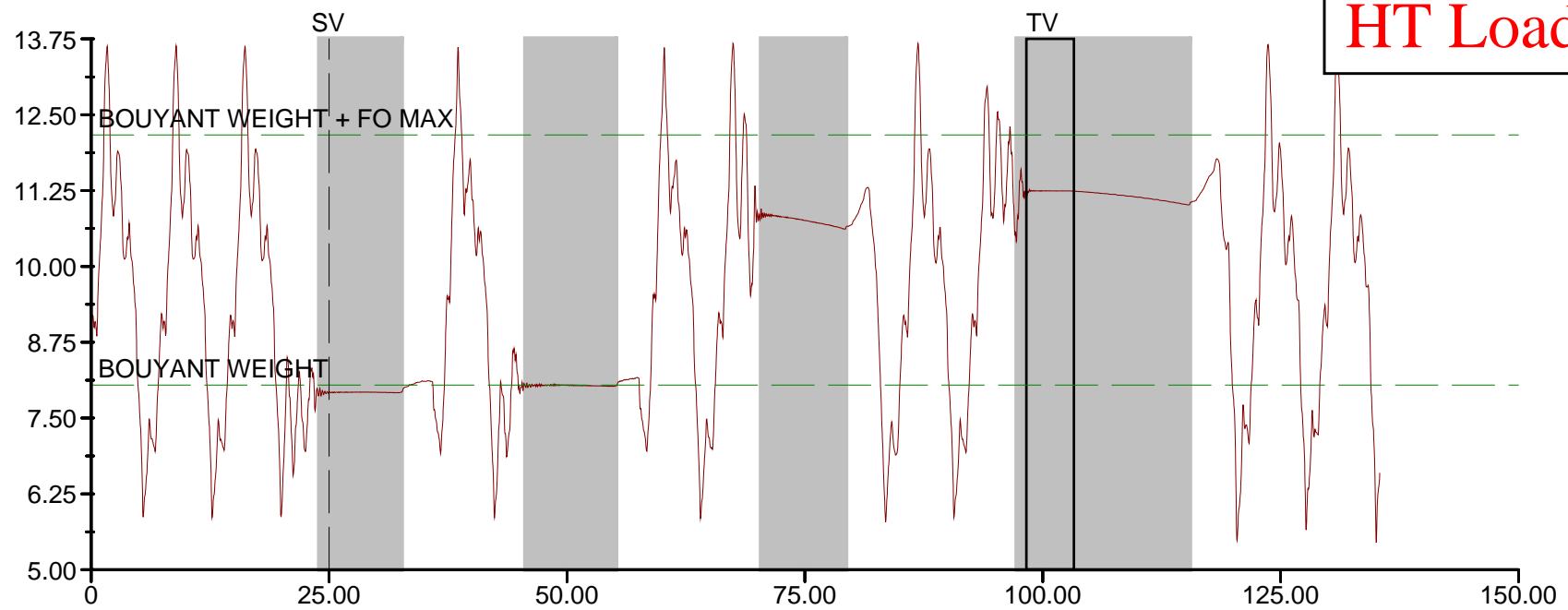
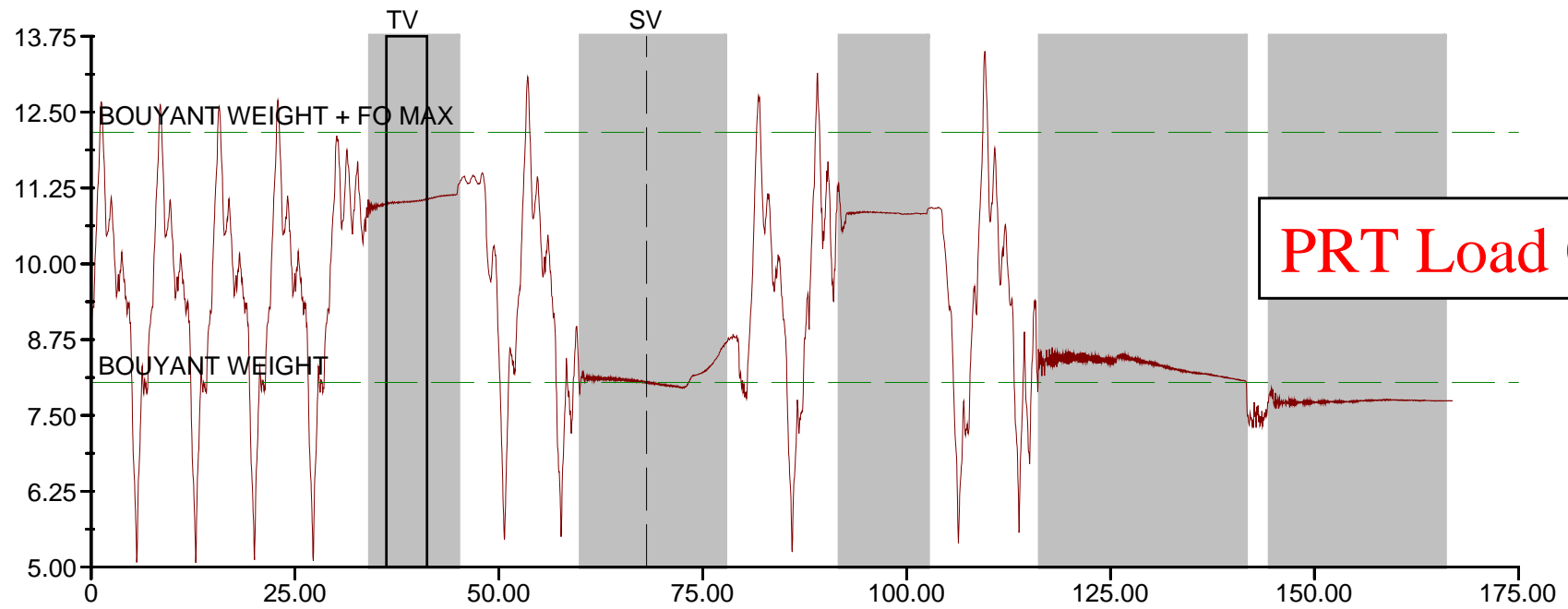
1. Verify Correct SV Check Load is Selected
2. Click **Apply** button to Adjust SV to Buoyant Rod Wgt.



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.



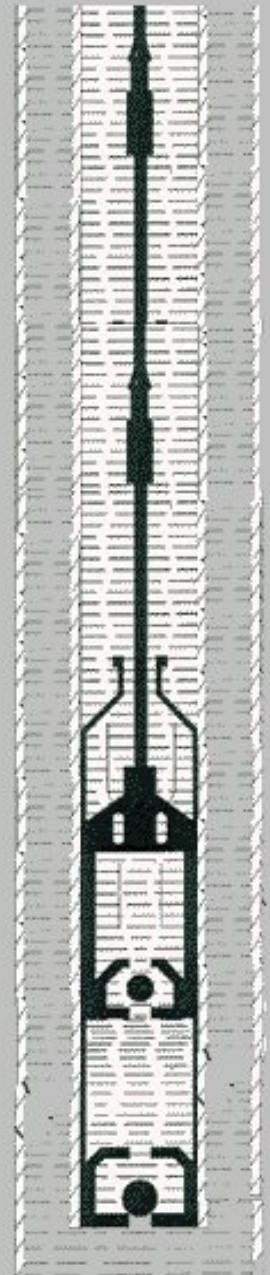


Standing Valve Check Procedure

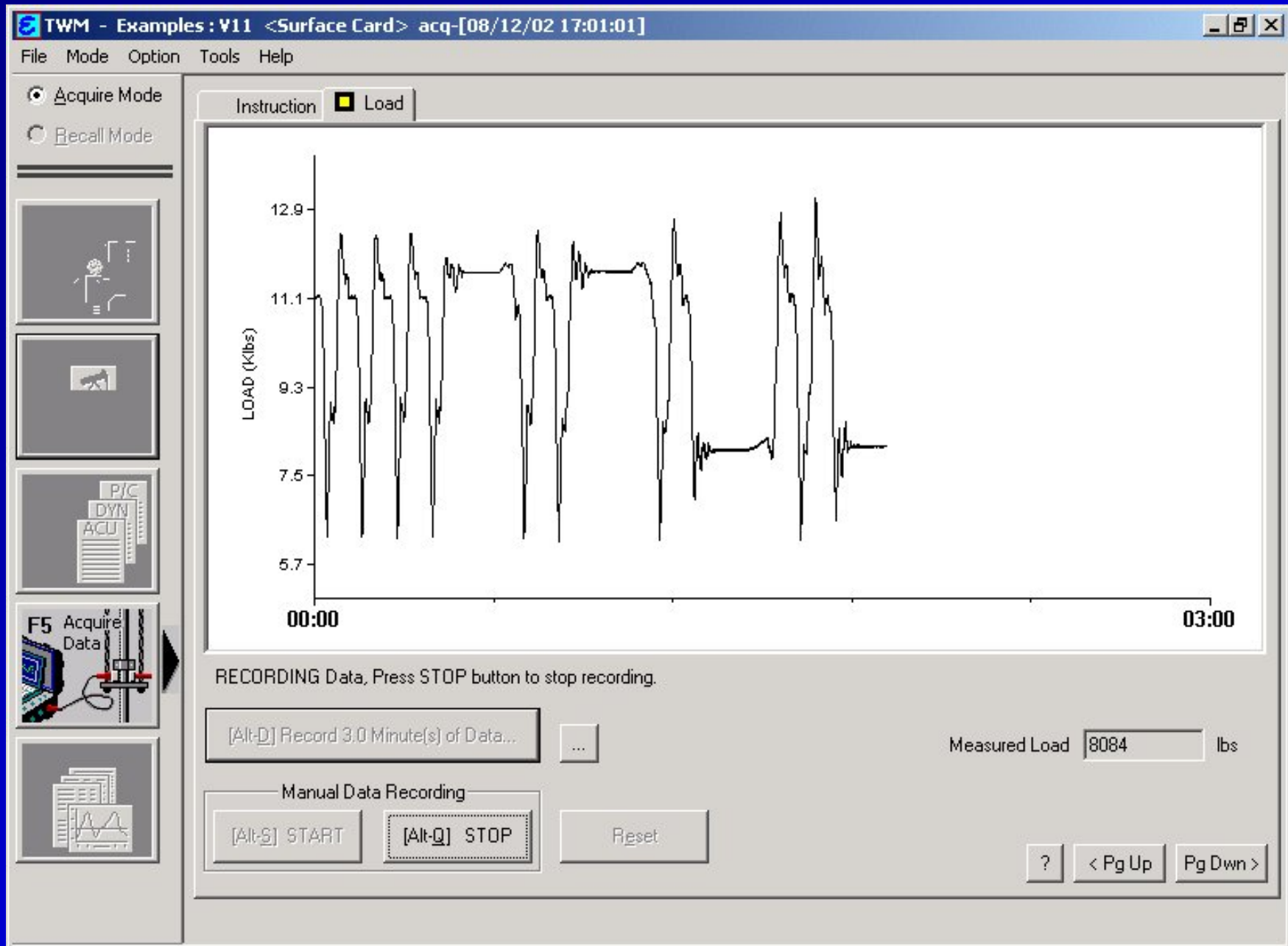
Standing valve check load is taken during the down stroke by gently using the brake to bring the pumping unit to a stop about $\frac{1}{4}$ from the bottom of the stroke.



Standing Valve
Load Check Test

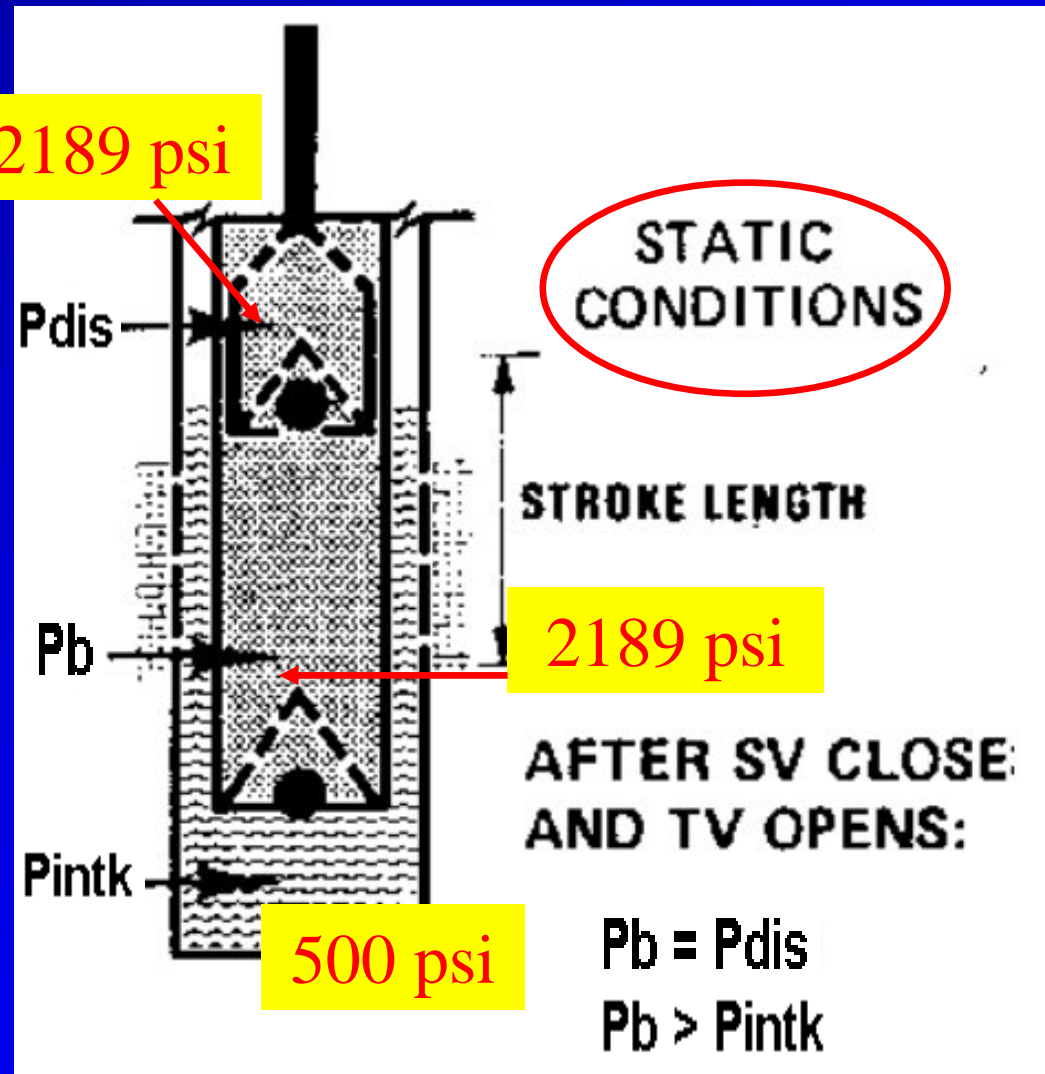


Perform Two Standing Valve Checks

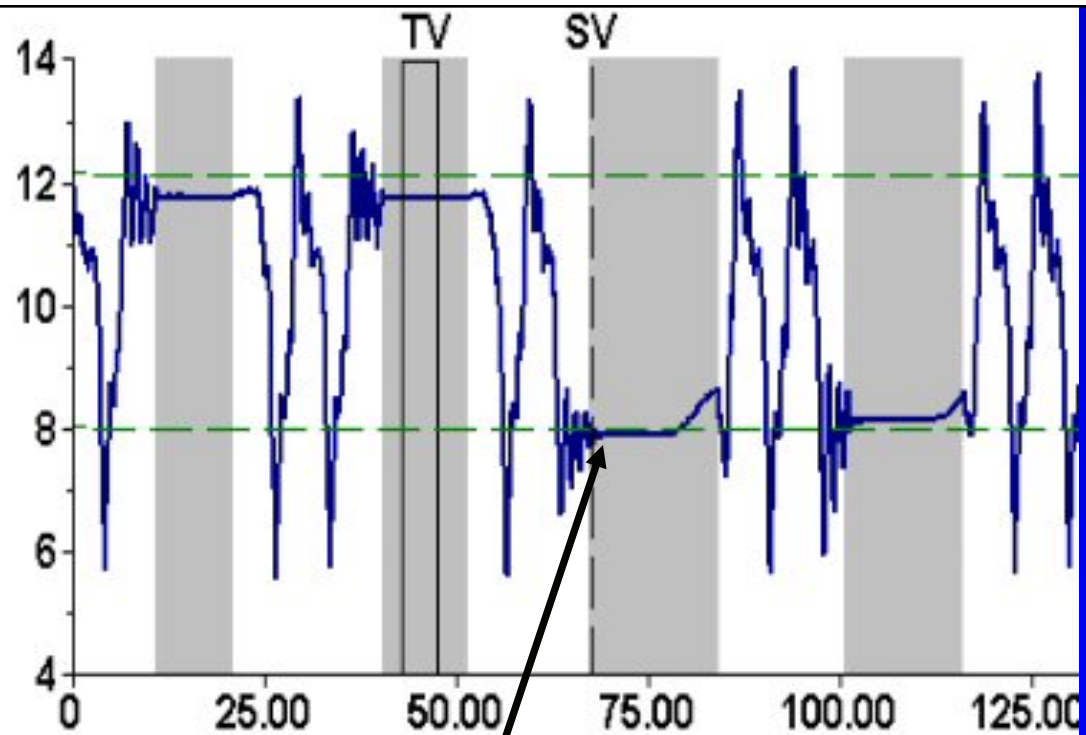
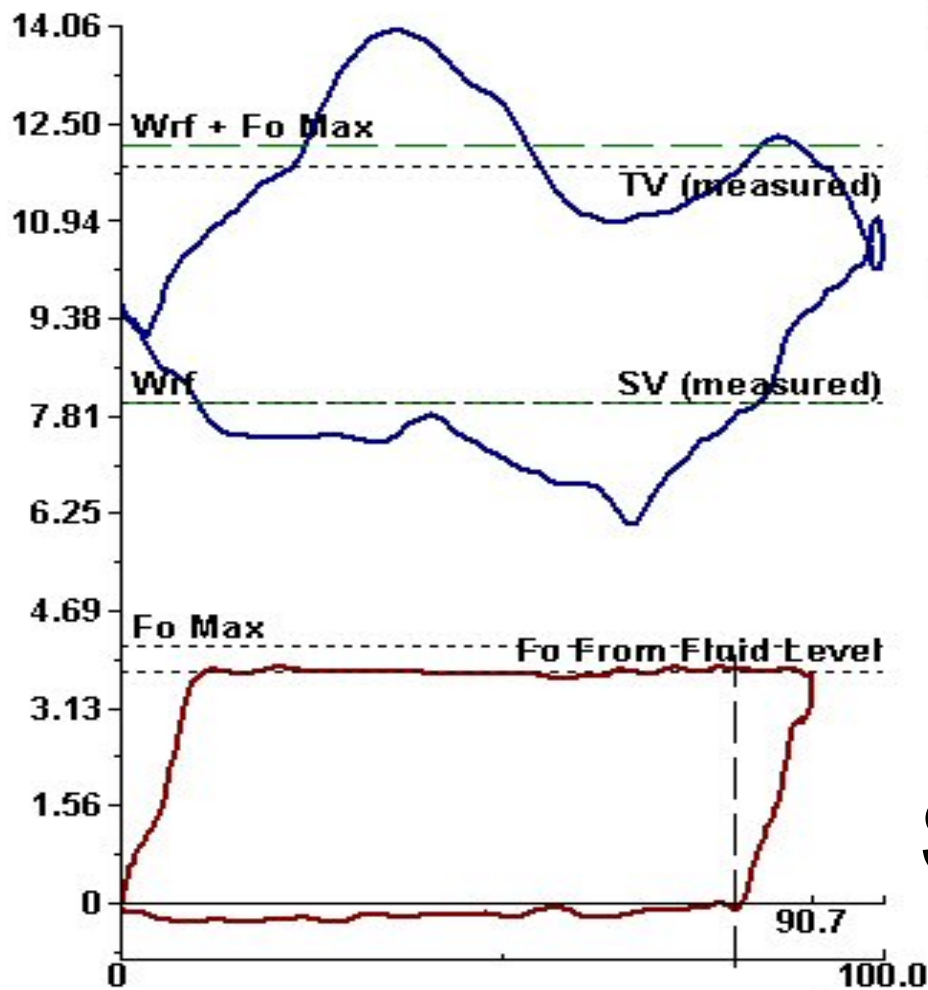


On Downstroke: Check Standing Valve Load

- 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.



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

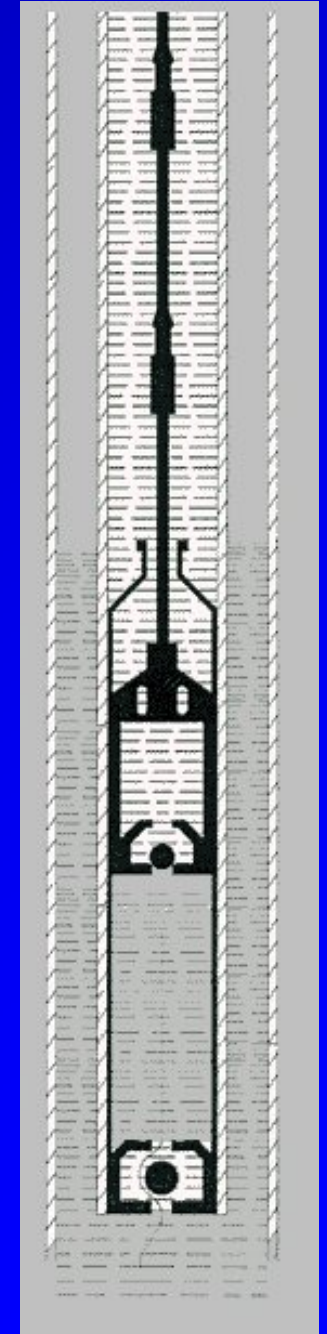


Standing Valve Test

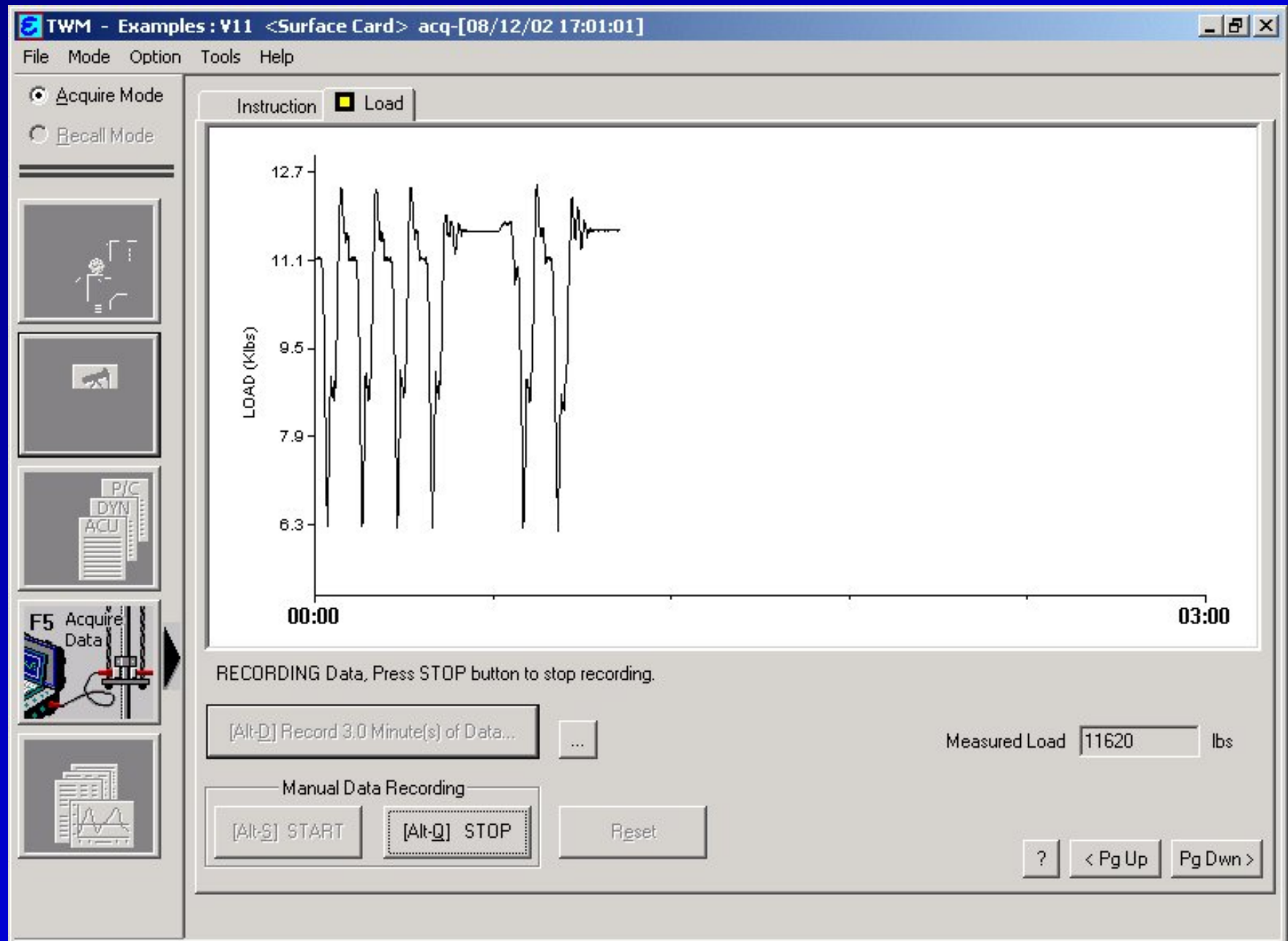
Standing Valve Load Test (above right) is a representative and correctly taken standing valve test load. The load trace is located at the standing (SV) load line and is sometimes called Wrf. The rod string load is measured, not the load on the “standing valve”. This test records the load on the sucker 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 $\frac{1}{4}$ from the top of the stroke.

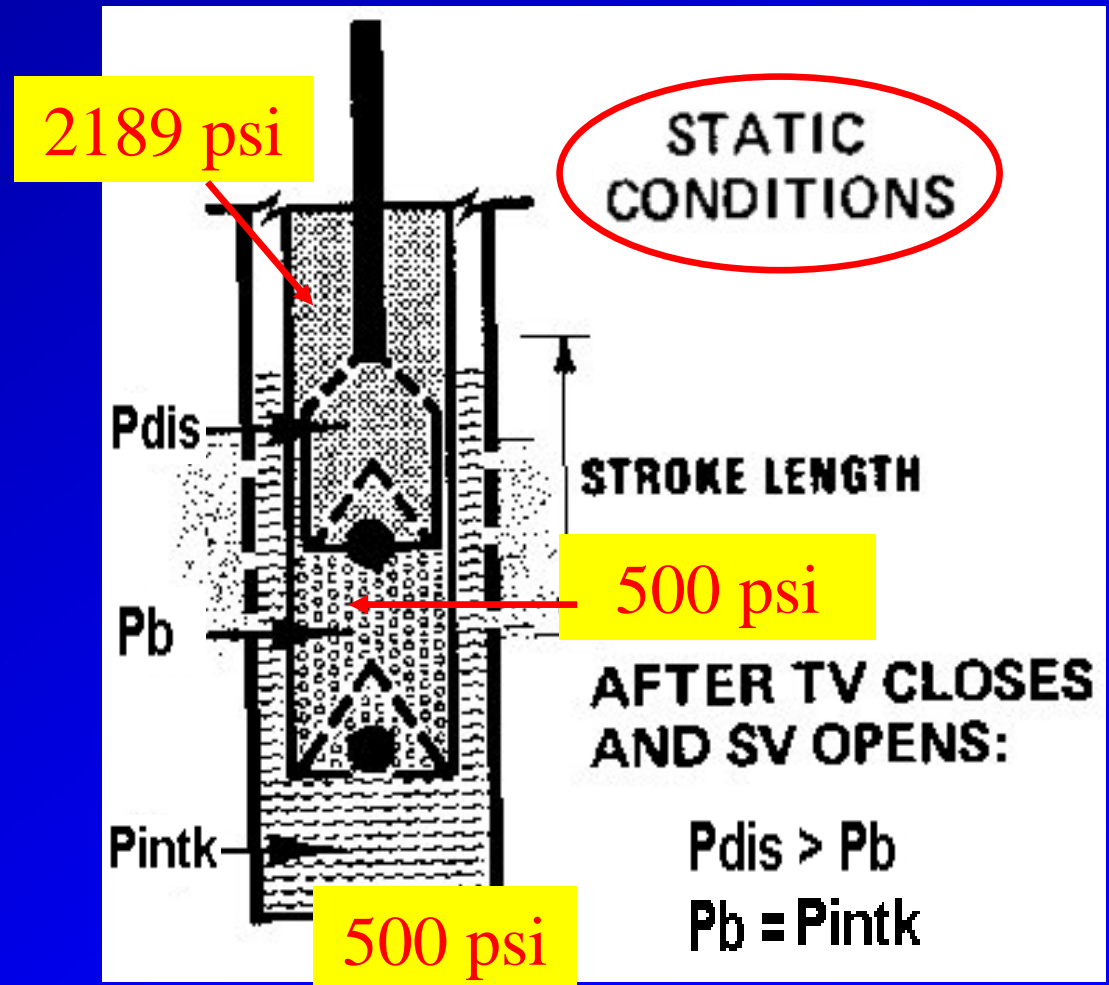


Perform Two Traveling Valve Checks



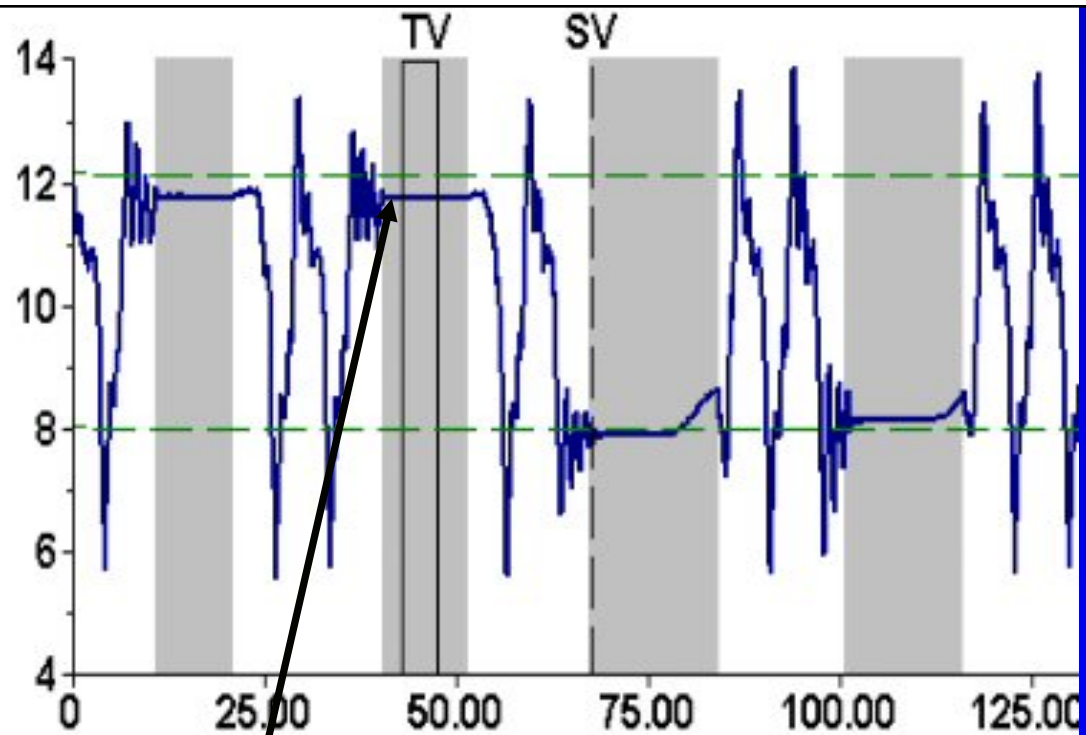
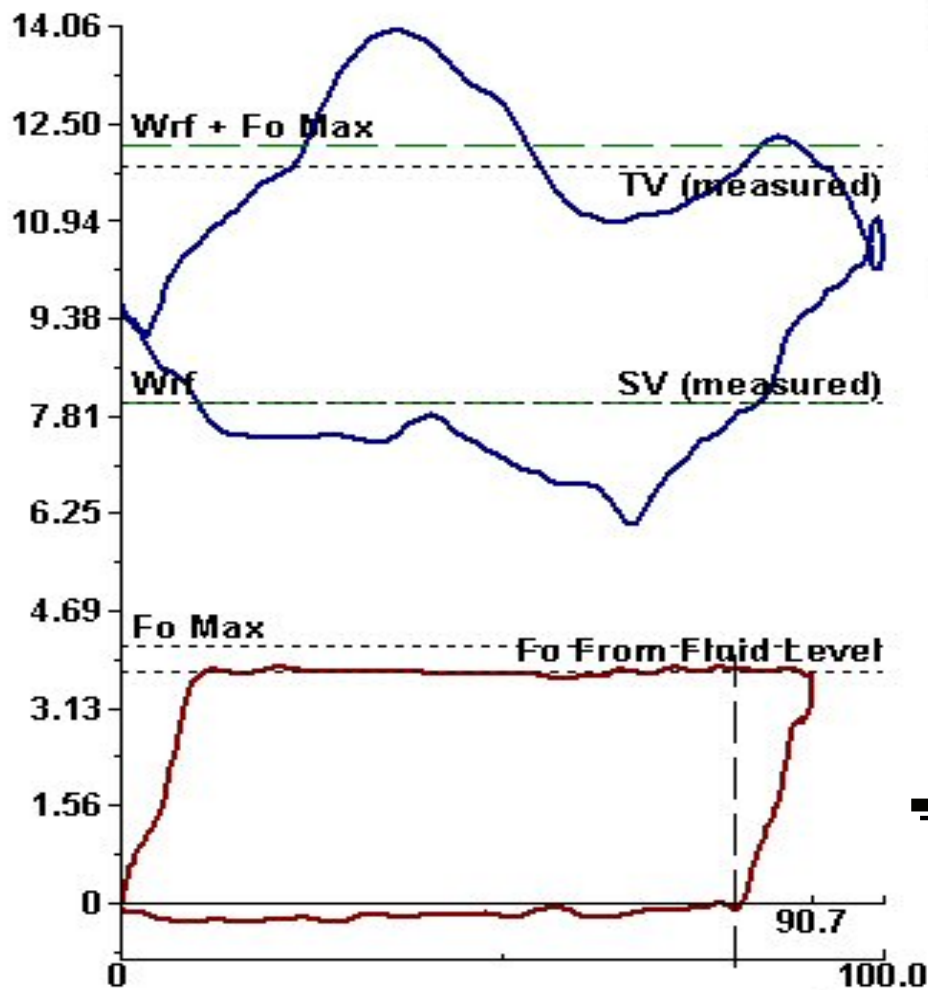
On Upstroke: Check Traveling Valve Load

- 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 = $W_{rf} + F_o$.



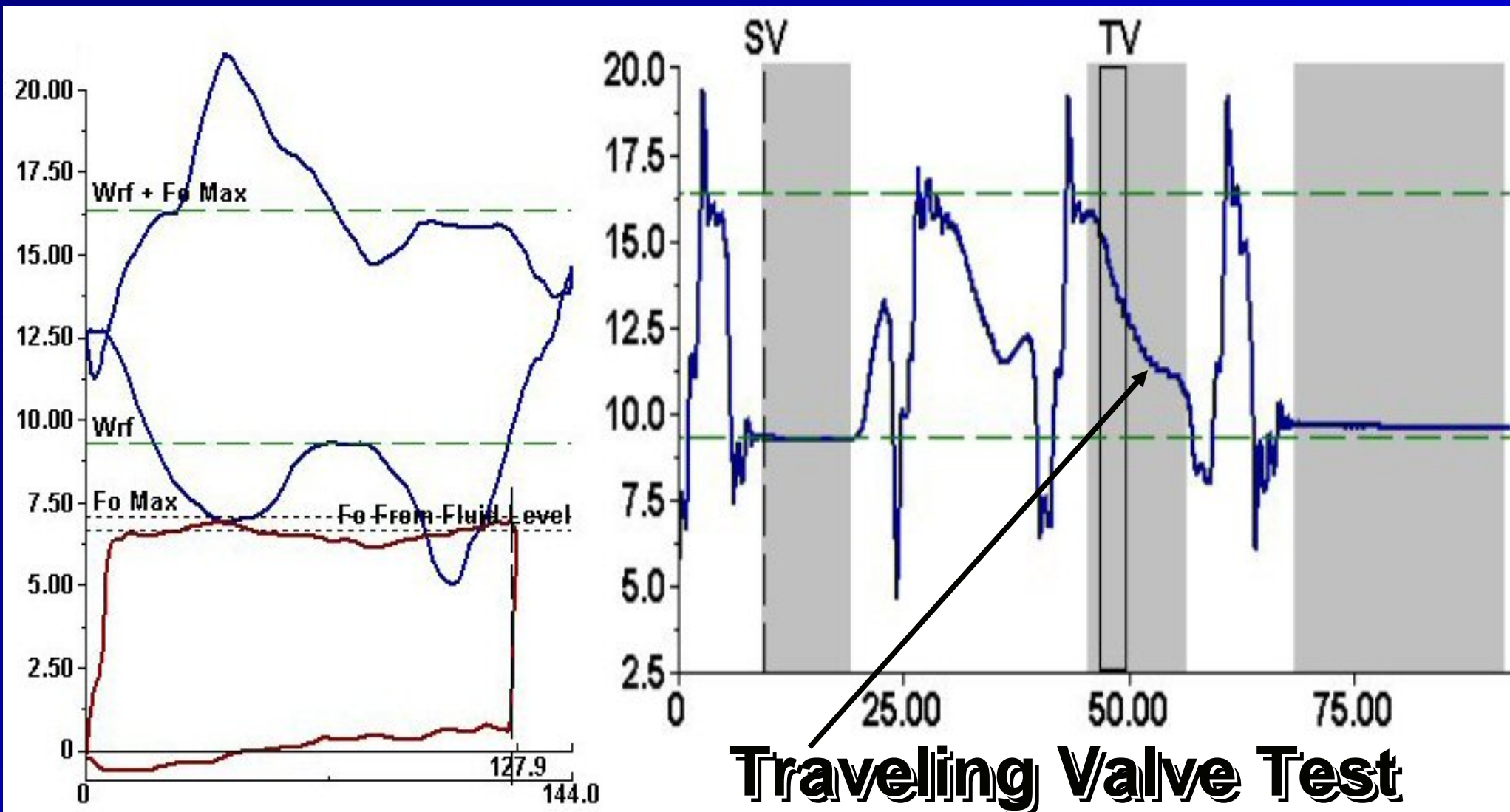
$$\Delta P_p = P_{dis} - P_{intk}$$

$$F_o = \Delta P_p * A_p$$



Traveling Valve Test

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.



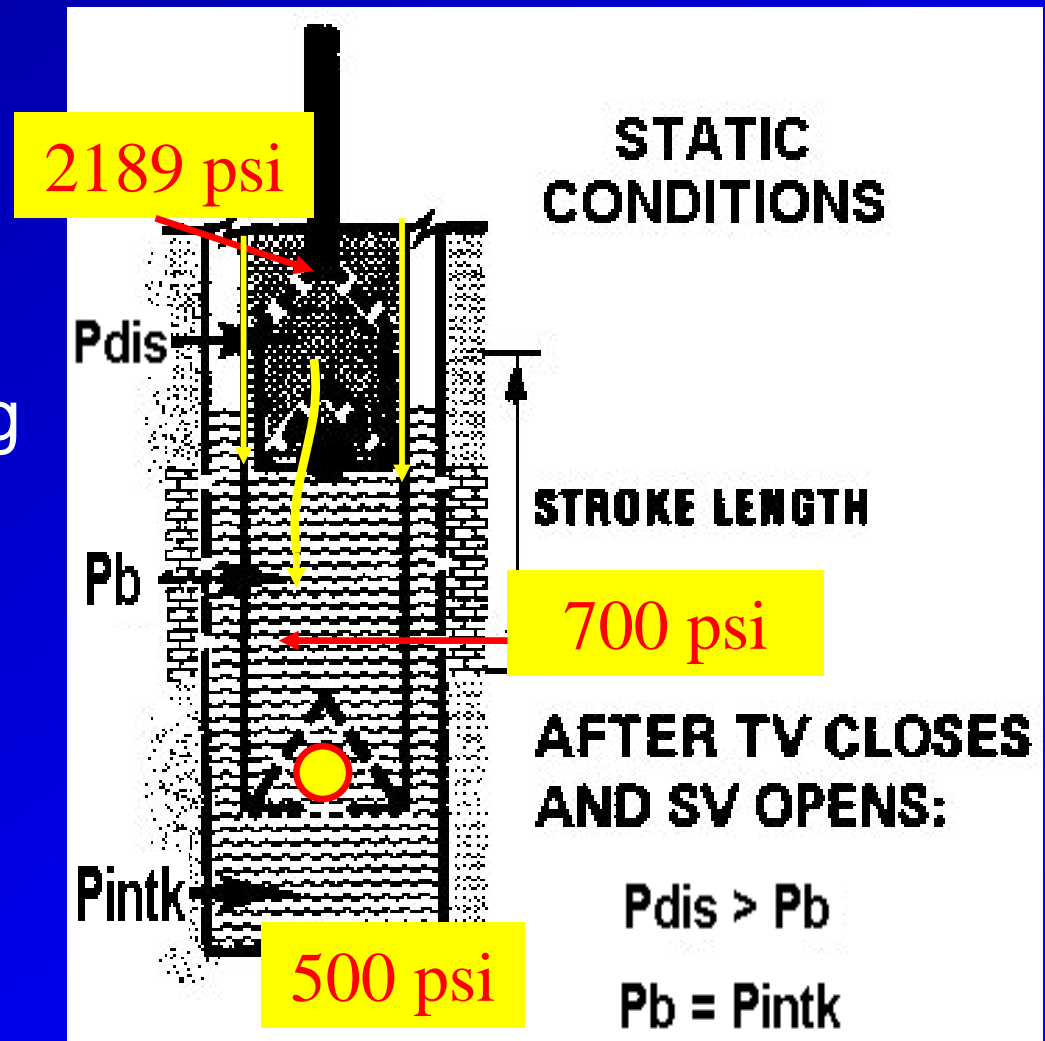
Traveling Valve Test

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**.

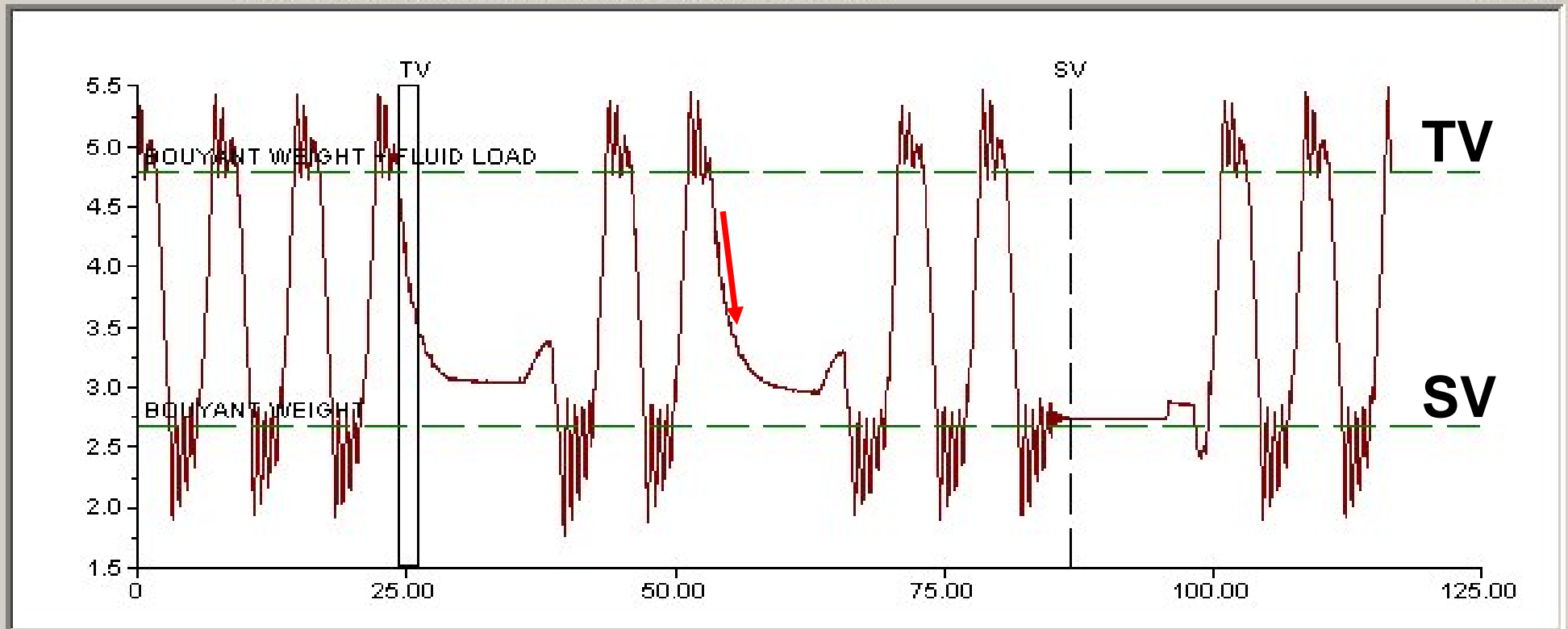


TV Check Shows Leaks

Valve Analysis

Traveling And Standing Valve Loads (K-Lbs) vs Time (sec)

HT509



Traveling Valve Analysis

Calc. Bouyant Rod Wgt. + Fluid Load lbf

Leakage Interval Measured Load lbf

sec Leakage BBL/D

Navigation buttons:

Standing Valve Analysis

Calc. Bouyant Rod Wgt. lbf

Measured Load lbf

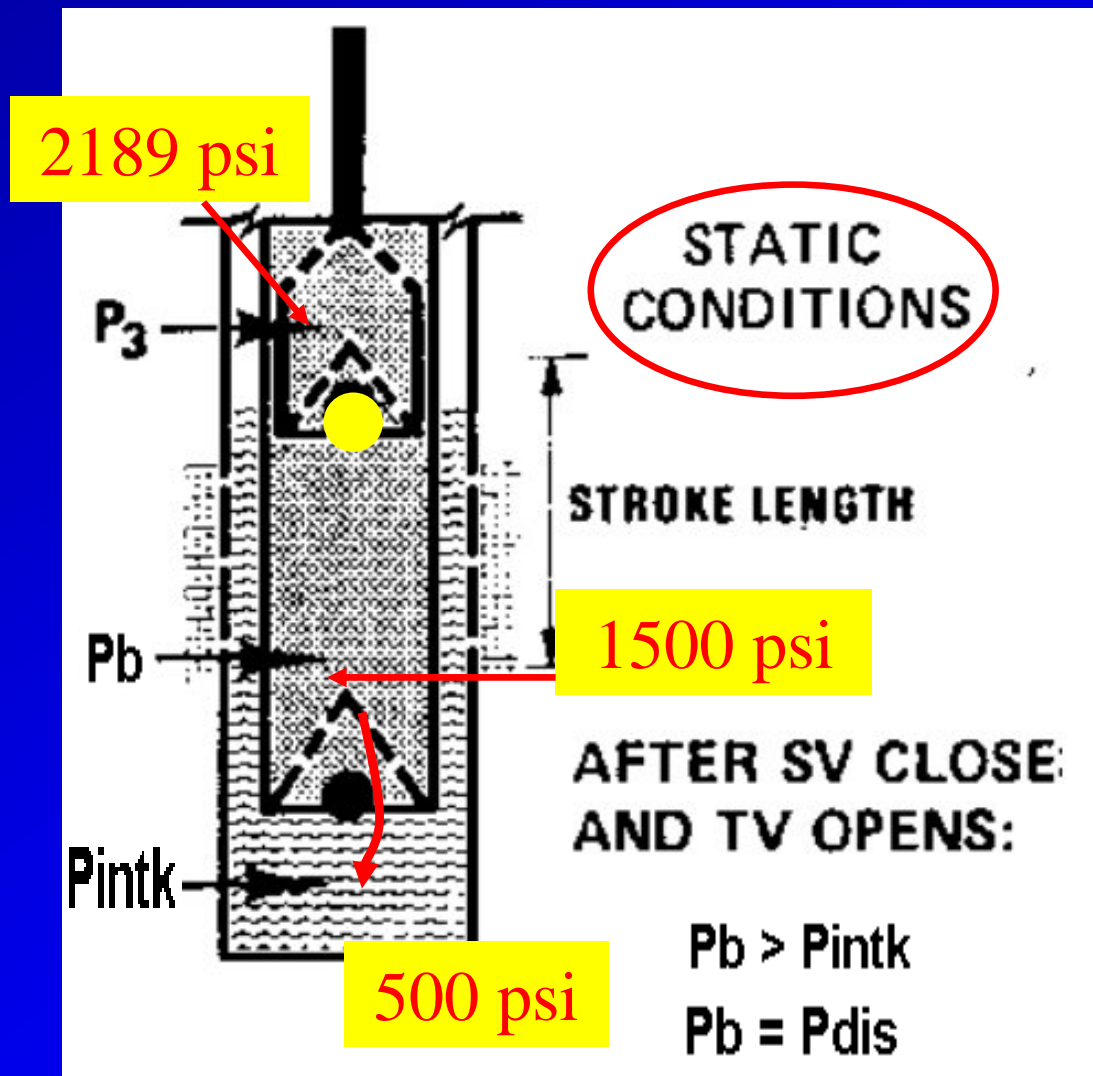
Intake Pressure psi (g)

Navigation buttons:

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.

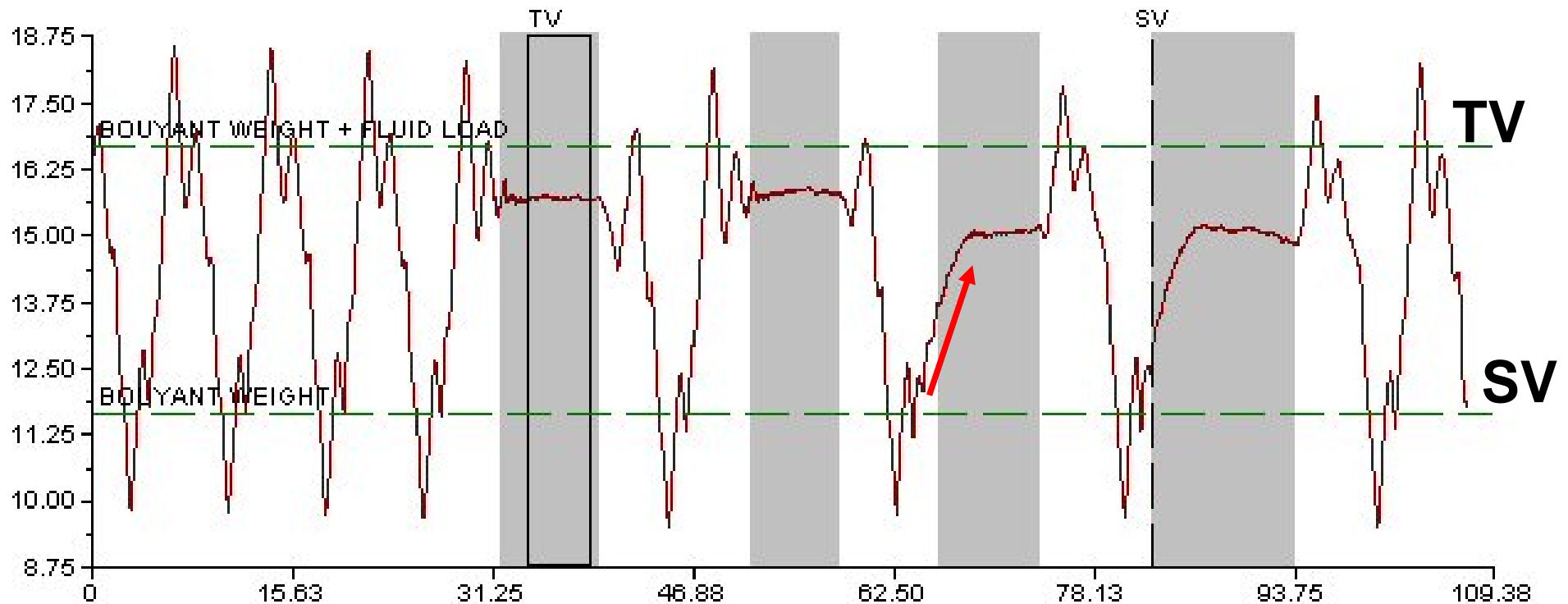


SV Check Shows Leak

Valve Analysis

Traveling And Standing Valve Loads (K-Lbs) vs Time (sec)

PRT805



Traveling Valve Analysis

Calc. Bouyant Rod Wgt. + Fluid Load lbf

Leakage Interval Measured Load lbf

sec Leakage BBL/D

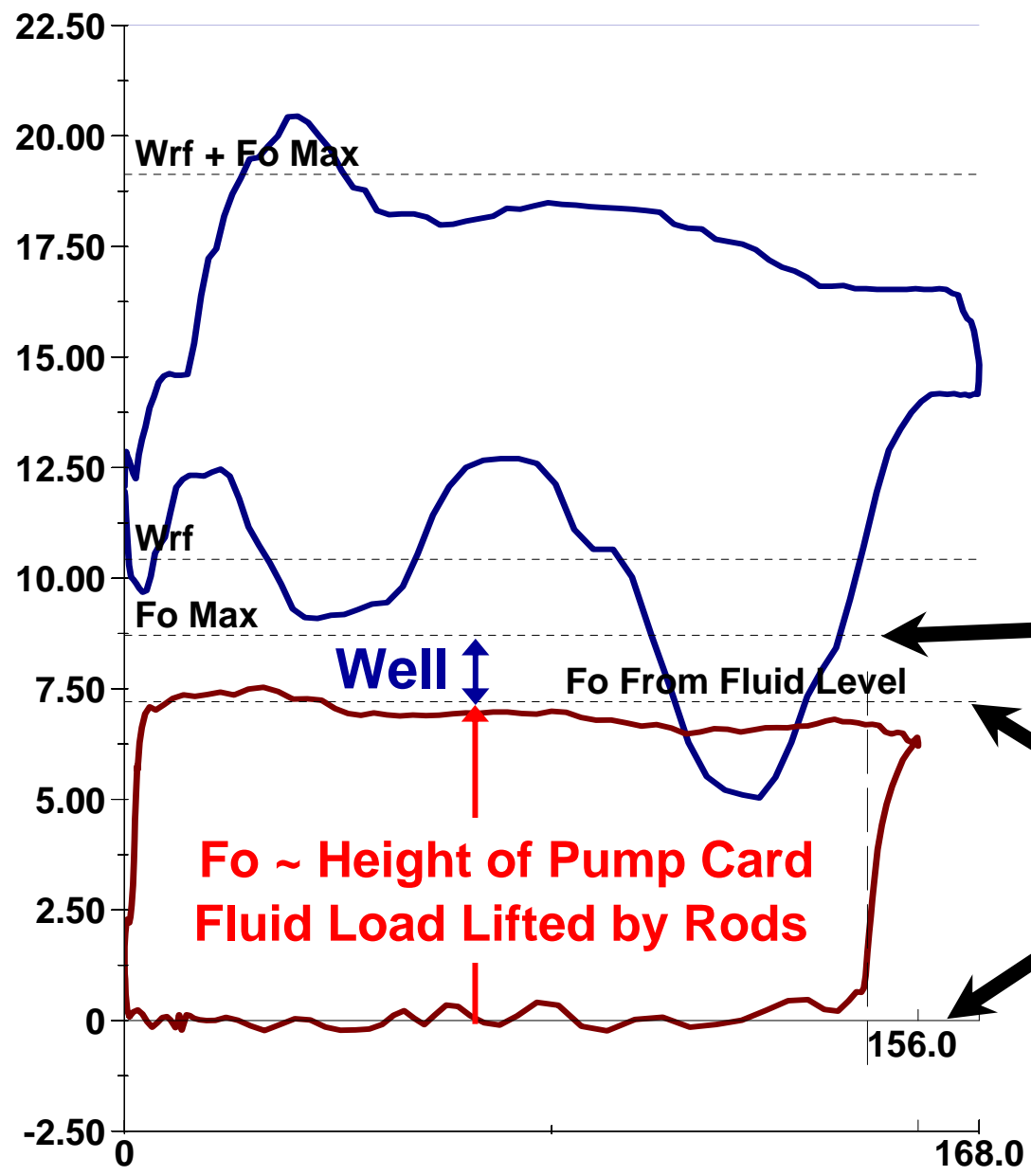
Standing Valve Analysis

Calc. Bouyant Rod Wgt. lbf

Measured Load lbf

Pump Card Reference:

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



Normal Pump Card Loads:

SV Open Upstroke:

$$Fo \text{ Max} = (P_{dis} - 0) * A_p$$

$$Fo = (P_{dis} - P_{intk}) * A_p$$

TV Open Downstroke:

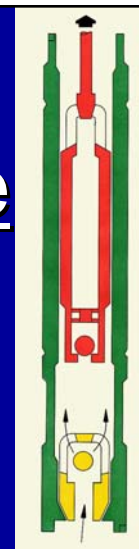
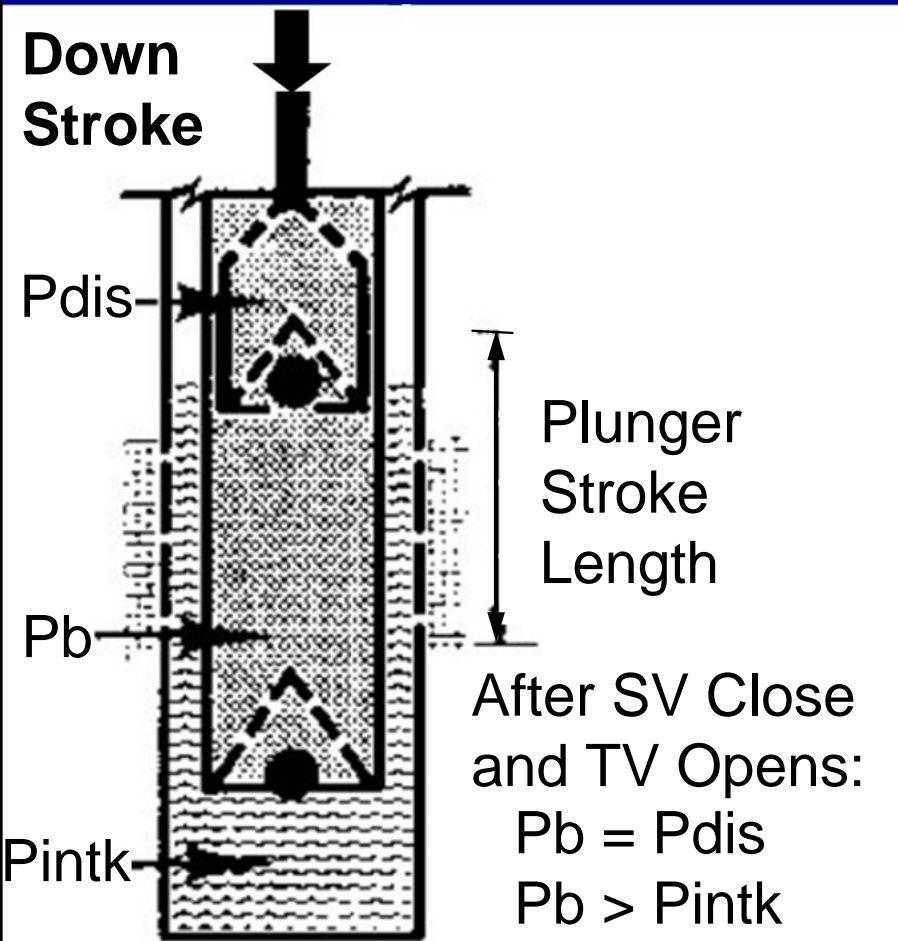
$$Fo = 0$$

Reference Lines:

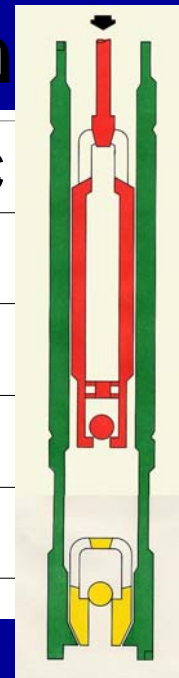
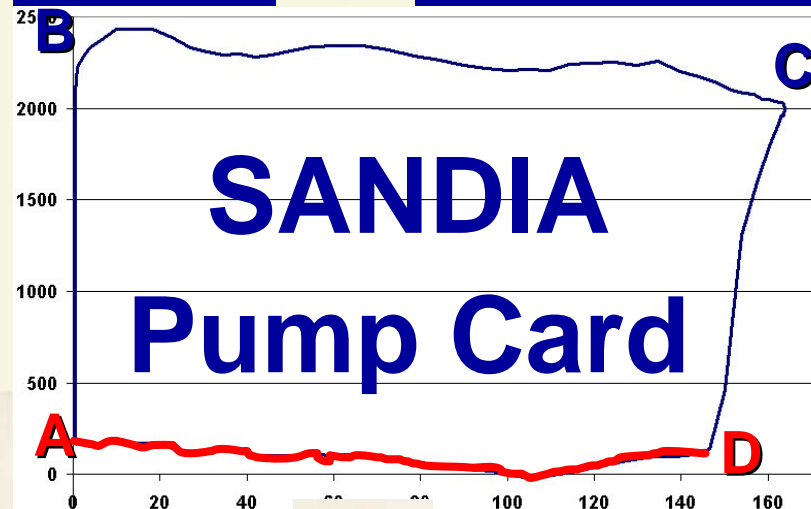
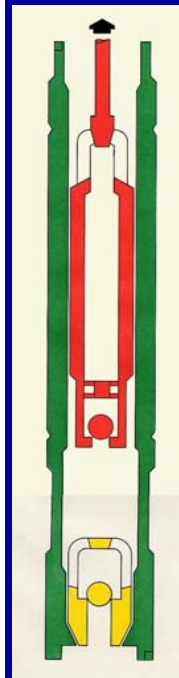
1. Fo Max - assumes pump intake pressure is zero, where well provides no help in lifting the fluid to the surface.
2. Fo From Fluid Level - assumes pump intake pressure determined from fluid level shot, where well's PIP provides help in lifting the fluid.
3. Zero Load Line - assumes pressure above and 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



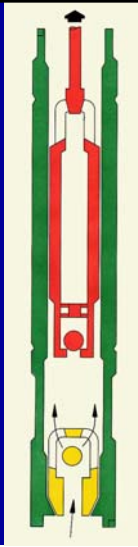
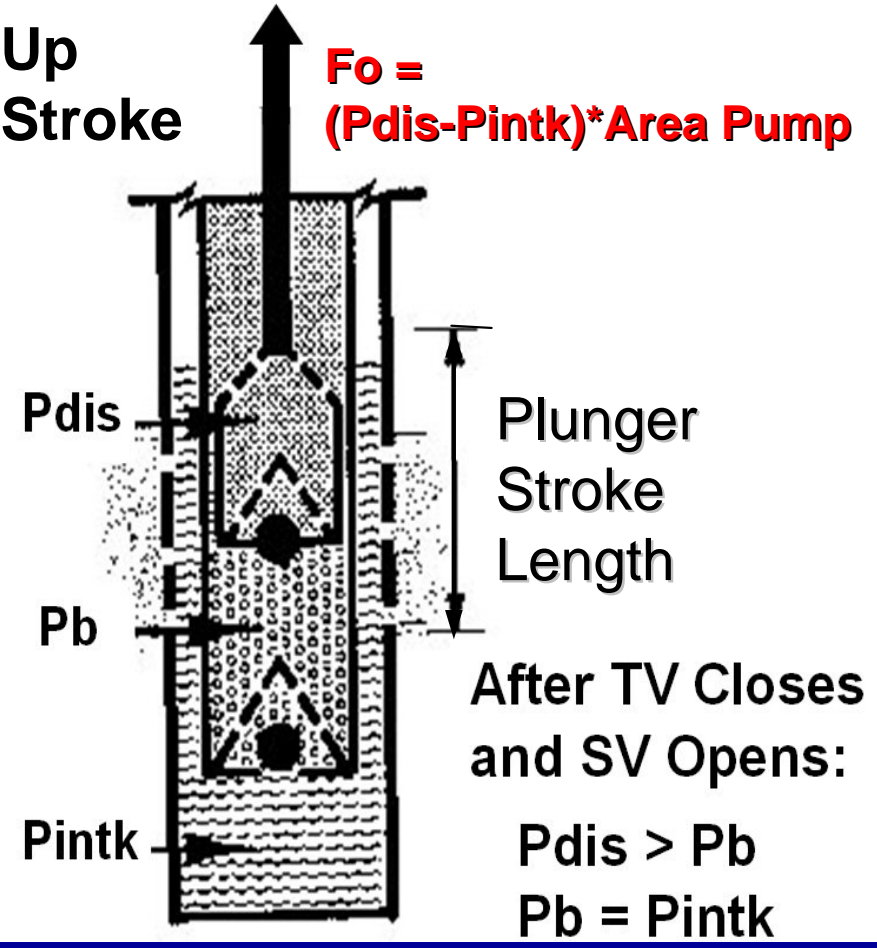
D) Pump discharge pressure (P_{dis}) equals the static tubing pressure (P_b), and the traveling valve opens. P_{dis} now carried by tubing.

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

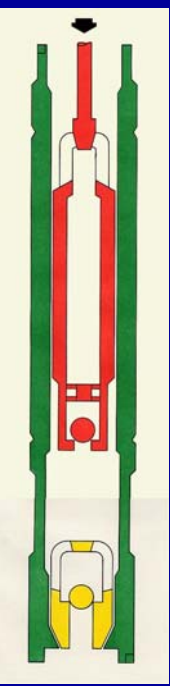
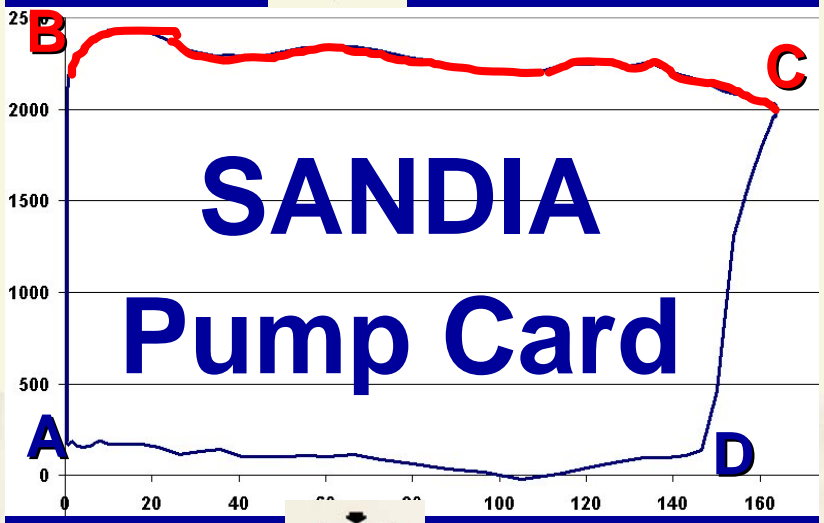
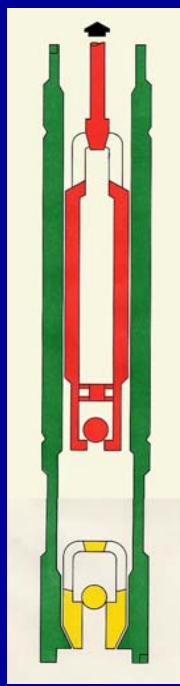


Fo From Fluid Level

Load Reference Line on Up Stroke



Steps in the Pump Operation



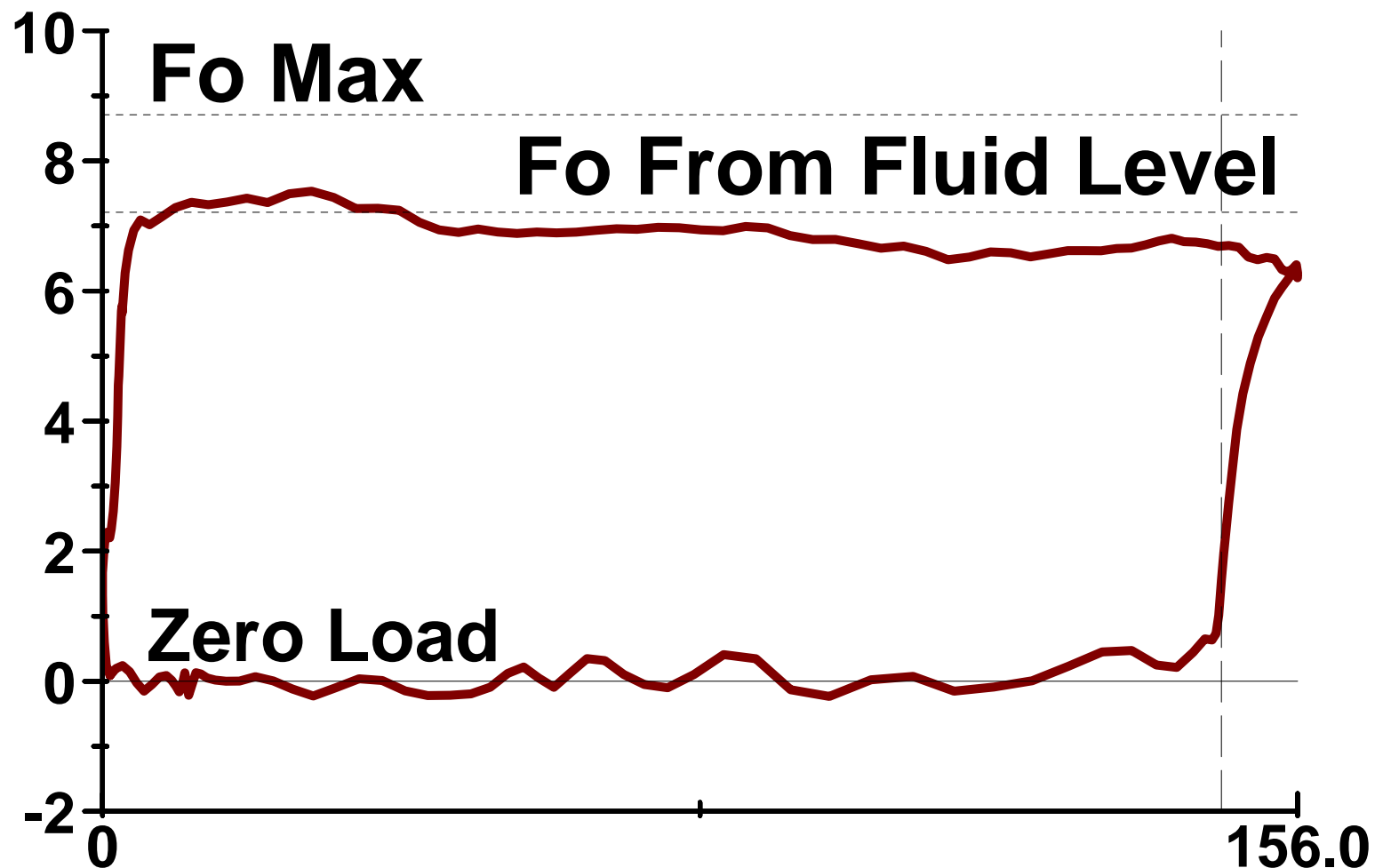
- B) Standing Valve opens, when rods stretch to pick up fluid load, F_o , from tubing.
- C) Standing valve closes.

B-C Plunger applies Fluid load, F_o , 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

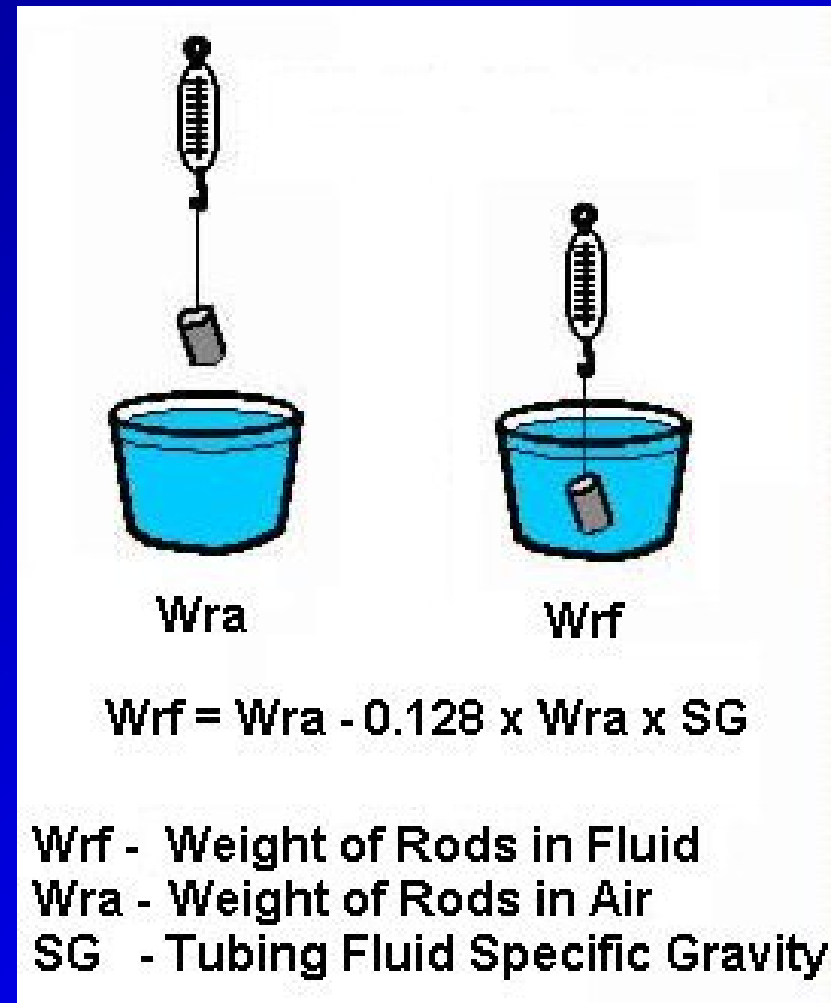
Acting on a sucker rod
was defined long ago.

Archimedes' Principle:

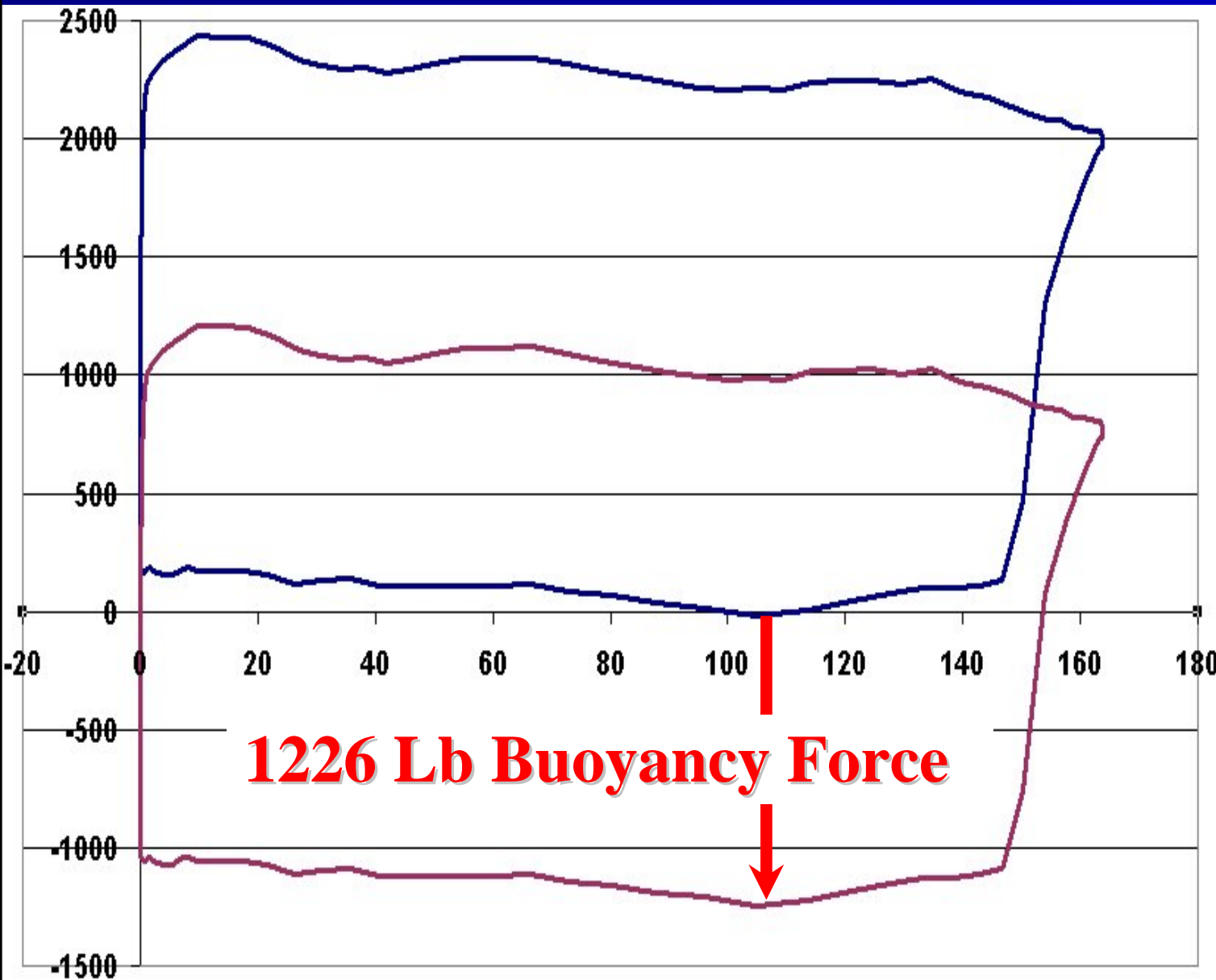
Defines the buoyancy force to be equal to the weight of the volume of fluid displaced by an object.

Impact of the buoyancy force:

- Rods suspended in a fluid appears to weigh less, W_{rf} .
- $W_{rf} = W_{ra}$, minus the buoyant force, $0.128 \times SG \times W_{ra}$.
- Buoyant force does not depend on the depth (pressure) at which the object is submerged, but the specific gravity, SG , of the fluid displaced.

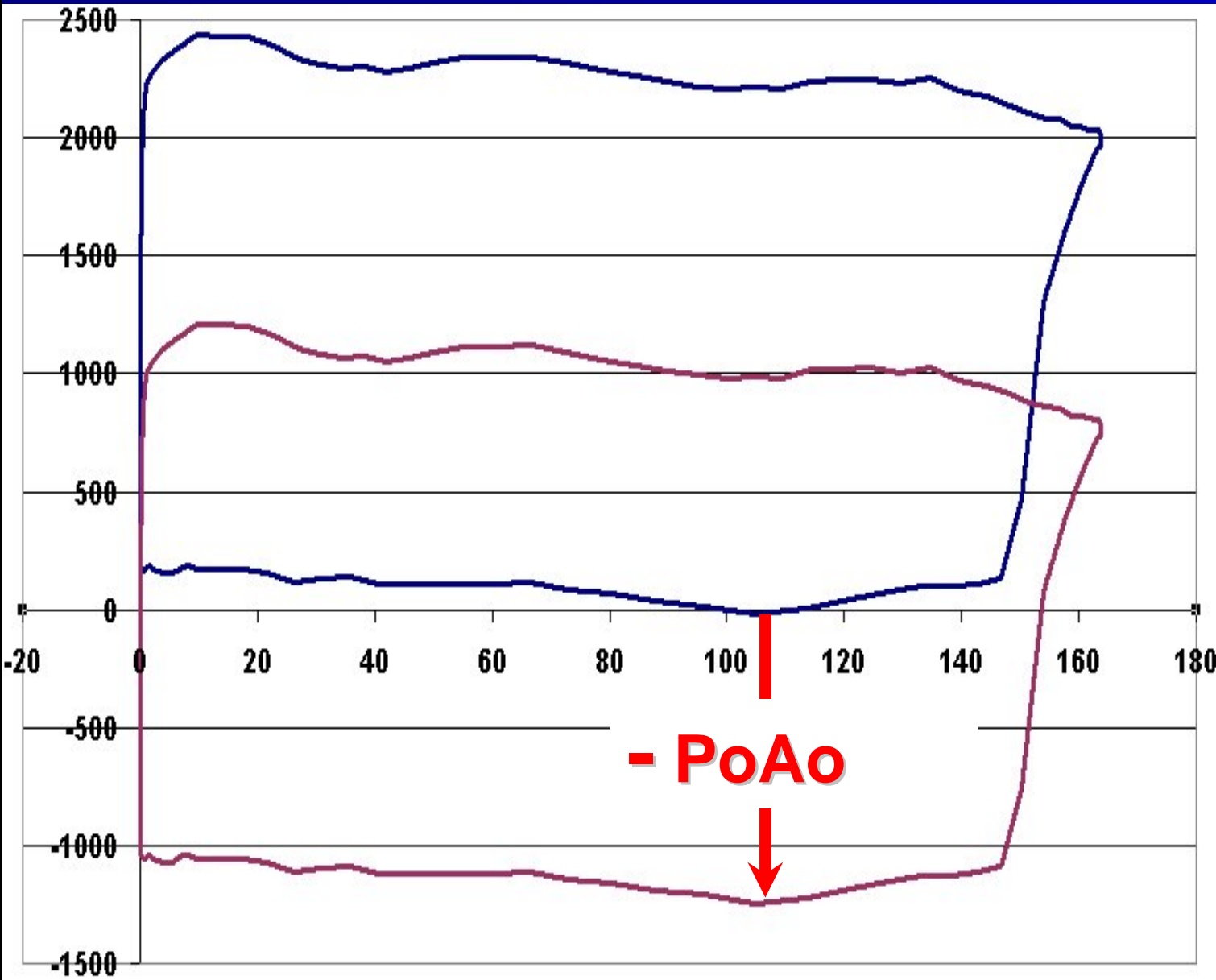


True Load = Dynamic Load - Buoyancy Force



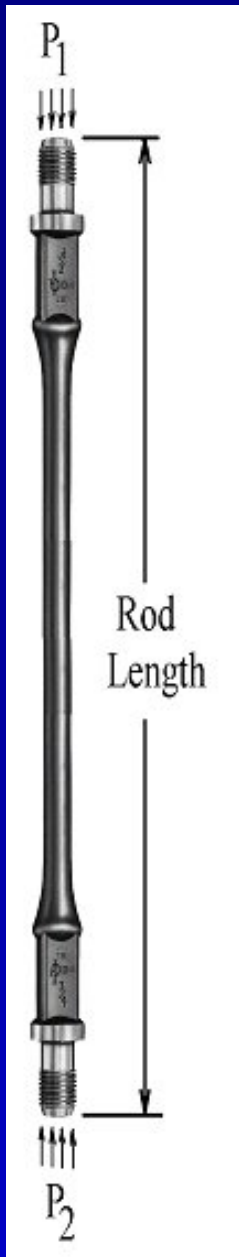
- ◆ Solved Wave Eq. without gravity term
- ◆ No Buoyancy Effective on Dynamic Pump Loads
- ◆ Pump Card loads shifted down below the zero load line.

$\text{Load}(\text{true}) = \text{Load}(\text{eff}) - P_o A_o$



1. A_o is the outside cross sectional area
2. P_o is the hydrostatic pressure @ A_o

Where does “PoAo” come from?



API RP 11L Equation for Calculating Wrf by Displaced Volume

$$Wrf = Wra - Fbuoy = Wra(1 - 0.128G)$$

$$Fbuoy = Wra * 0.128 * SG$$

$$\text{Density Ratio (Water/Steel)} = 62.4/487.5 = 0.128$$

$$\text{Volume(Rod)} = Wra/487.5$$

$$Fbuoy = \text{Volume(Rod)} * 62.4 * SG$$

$$\text{Volume} = \text{Length} * \text{Area}$$

$$Fbuoy = \text{Length} * \text{Area} * \text{Gradient}$$

Buoyancy Force calculated by Pressure Equilibrium

PoAo

P_1 = Pressure

$P_2 = P_1 + \text{Length} * \text{Gradient}$

$Fbuoy = (P_2 - P_1) * \text{Area} = (P_1 + \text{Length} * \text{Gradient} - P_1) * \text{Area}$

$Fbuoy = \text{Length} * \text{Area} * \text{Gradient}$

$$\mathbf{Wrf = Wra - AoPo}$$

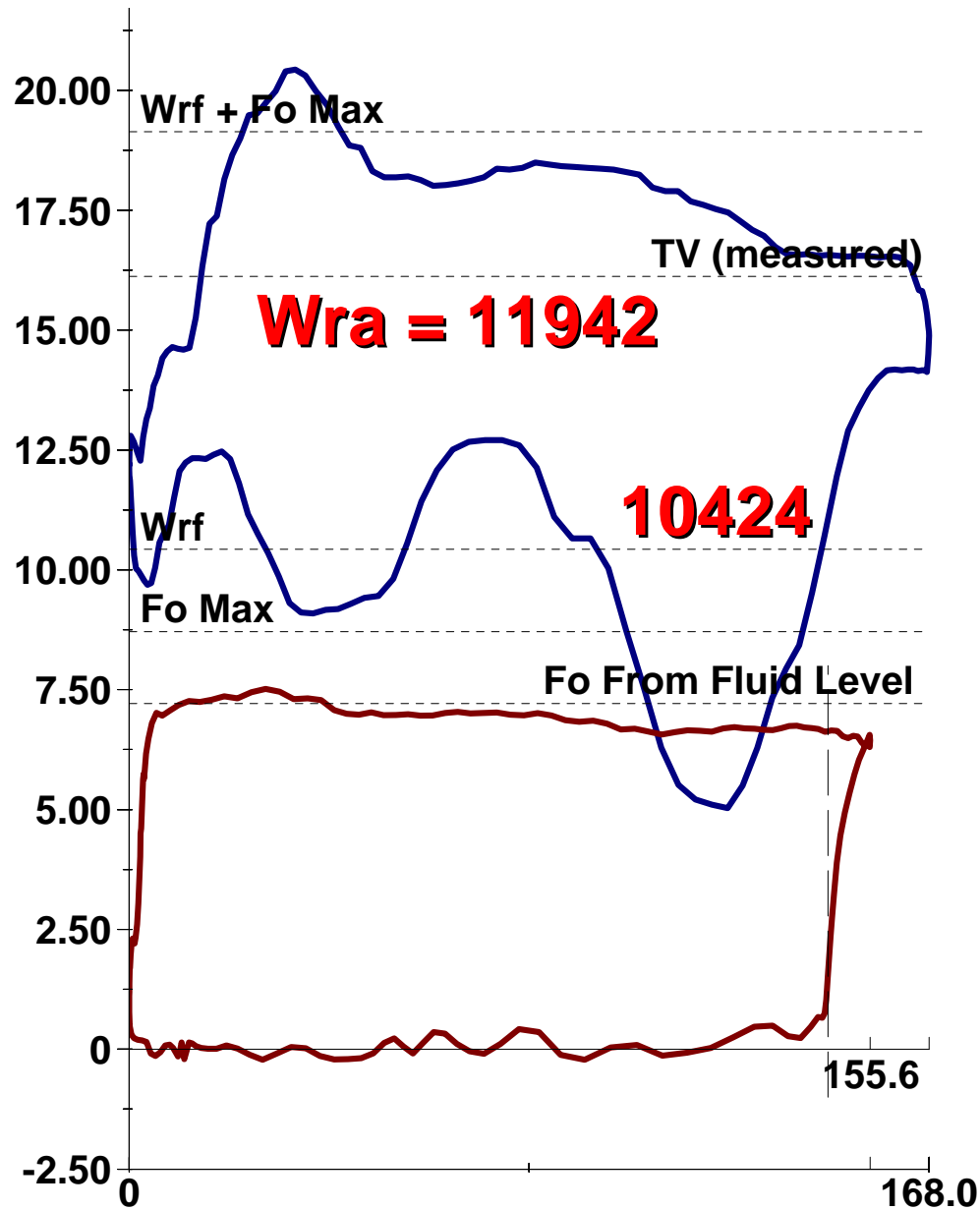
$$Ao = (\text{wt/ft}) / \text{density}$$

$$= 2.90 / 487.5 \times 144 = 0.8566 \text{ sq in}$$

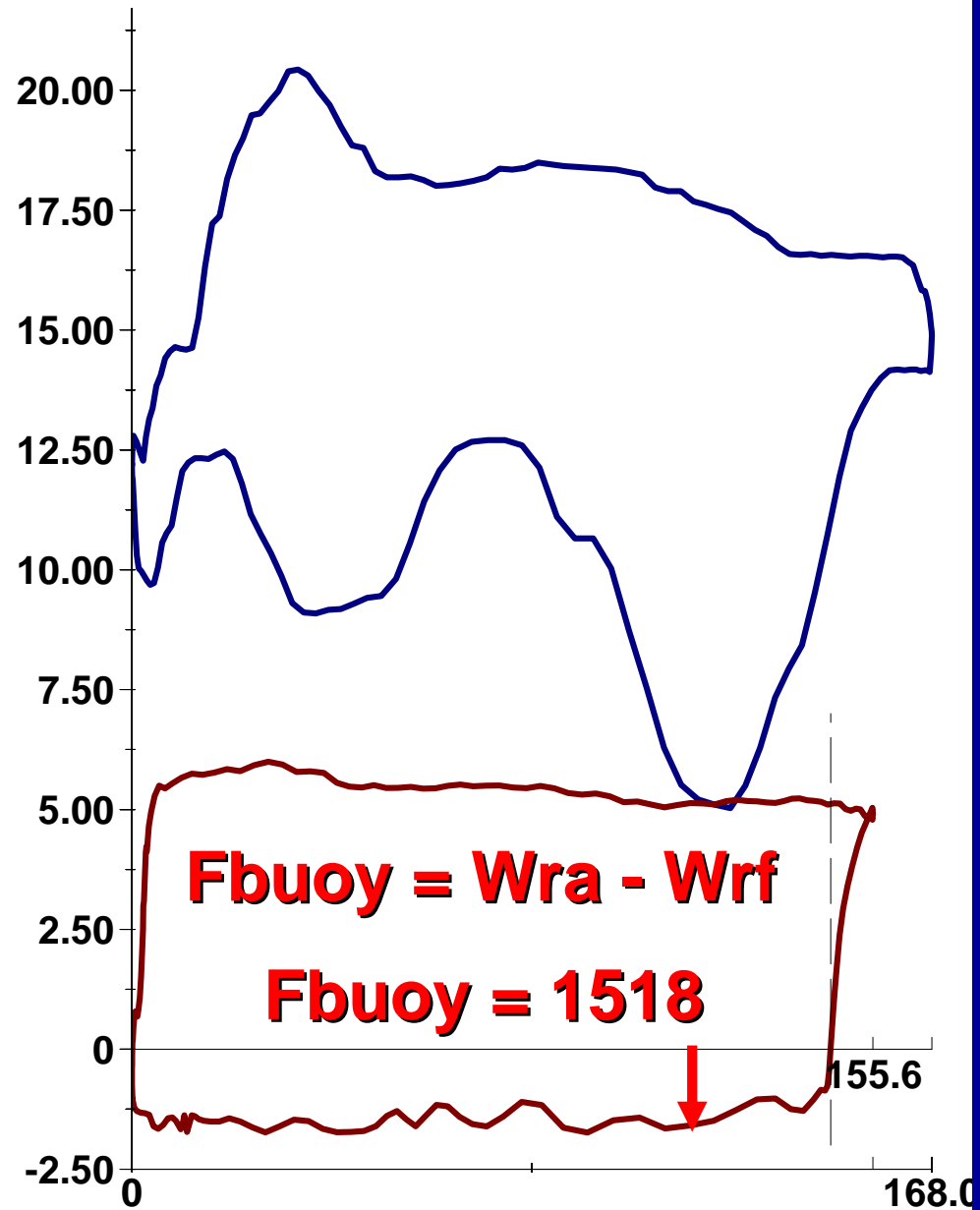
Diameter 1" Rod = 1.044" (True Diameter)

Buoyancy – Tubing Fluid Gradient

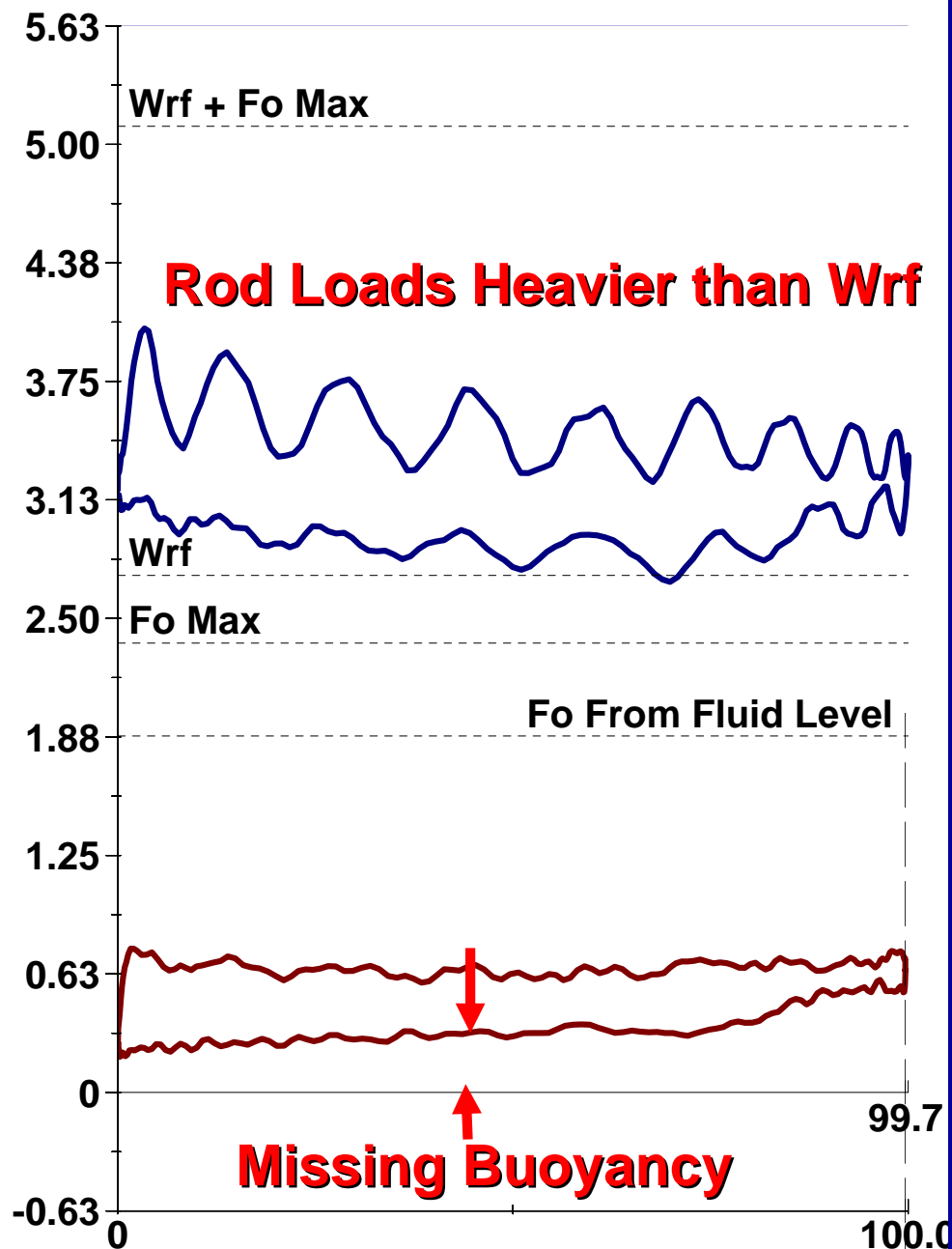
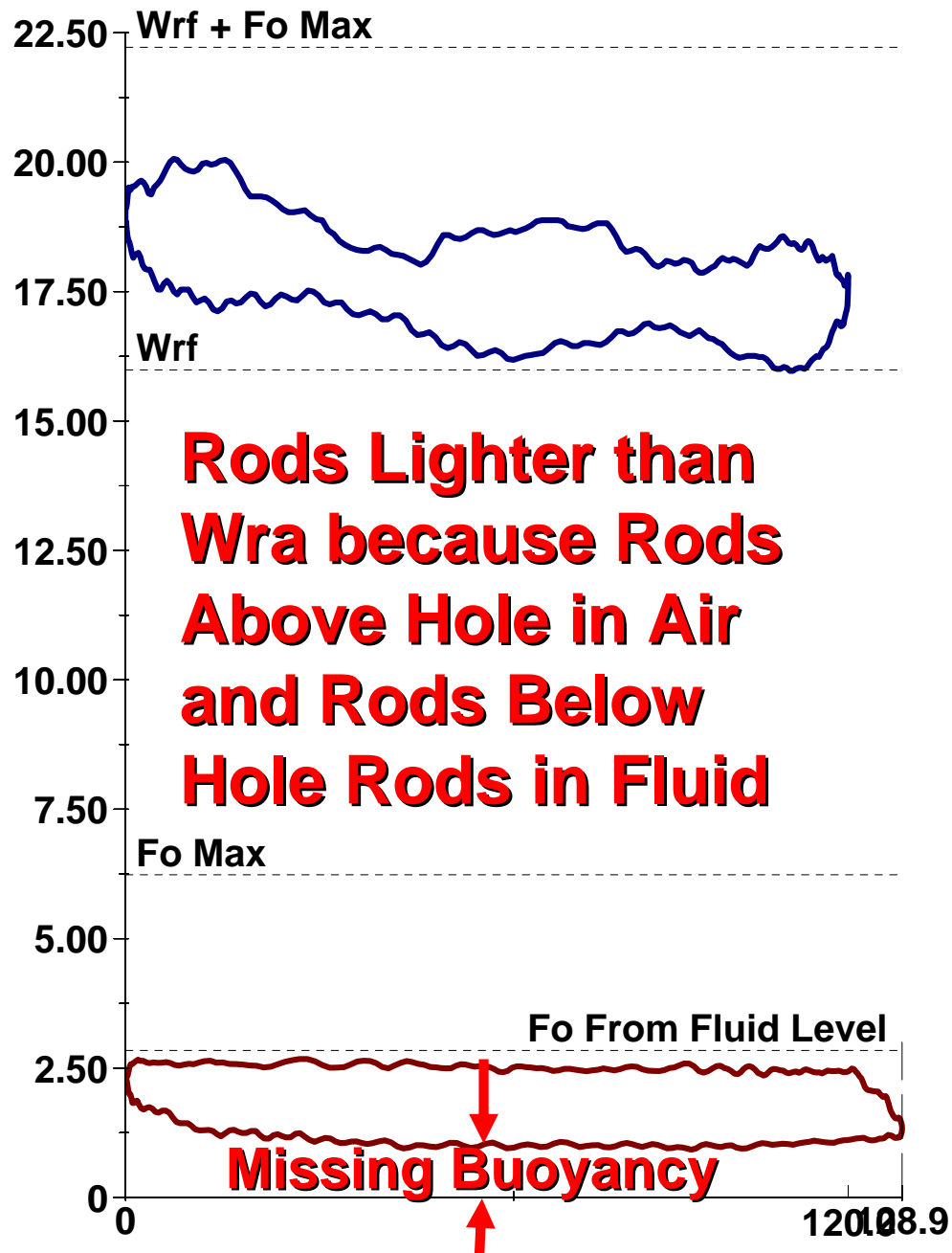
Tubing Fluid Gradient = 0.432



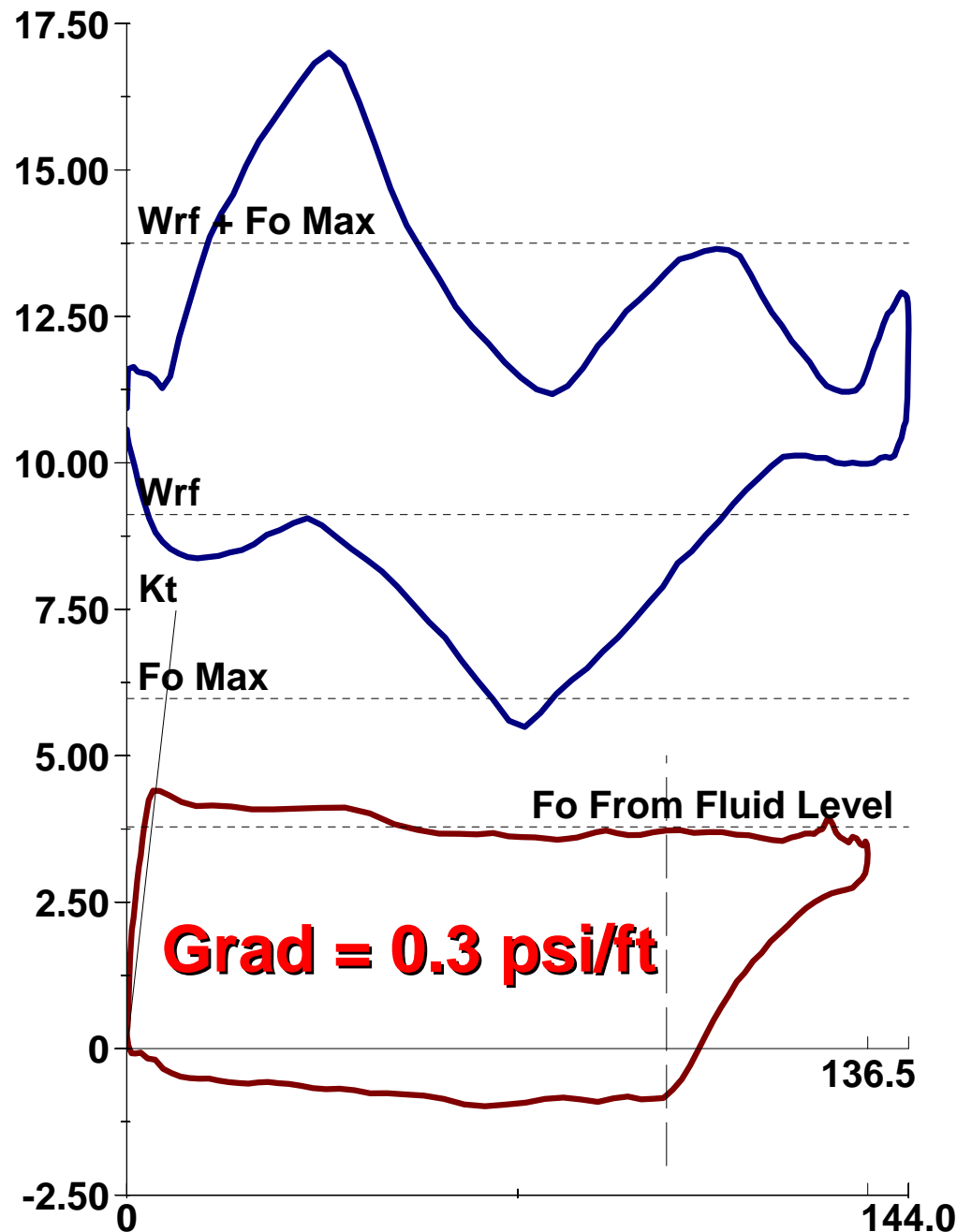
Tubing Fluid Gradient = 0.0



Missing Buoyancy – Hole in Tubing



Tubing Fluid Gradient – Wrf & Pdisp



Casing Pressure BHP Collars

Casing Pressure psi (g)

Casing Pressure Buildup psi

min

Gas/Liquid Interface Pres. psi (g)

Liquid Level Depth MD ft

Pump Intake Depth MD ft TVD

Formation Depth MD ft

Well State:

Annular Gas Flow Mscf/D

% Liquid

Liquid Below Tubing

Oil %

Water %

% Liquid Below Tubing %

Pump Intake Pressure psi (g)

PBHP psi (g)

Reservoir Pressure (SBHP) psi (g)

Questions ?

