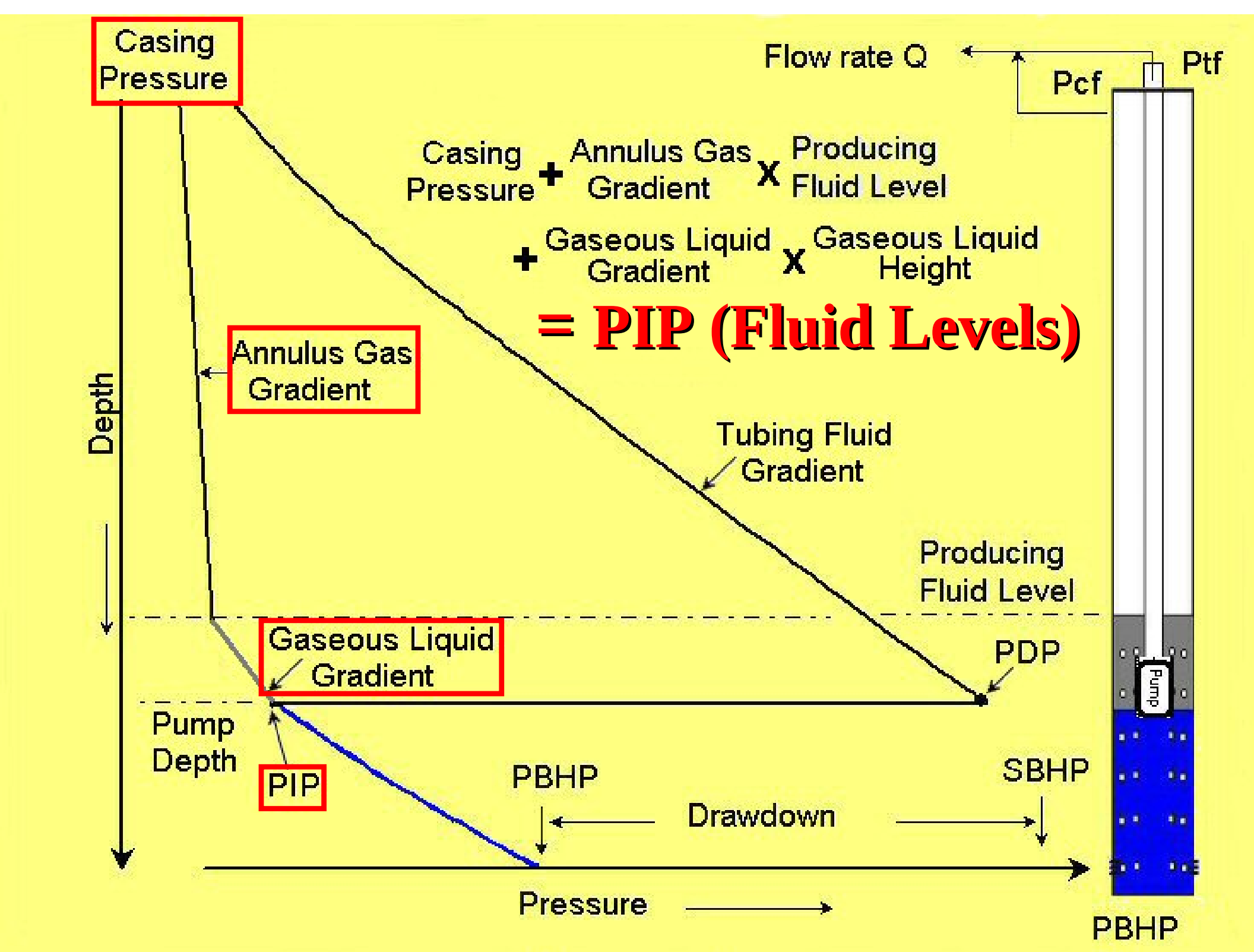
Dynamometer Analysis Advanced

Pump Intake Pressures from Dynamometer Pump Cards
Valve Check Load Tests
Fluid Levels Shots

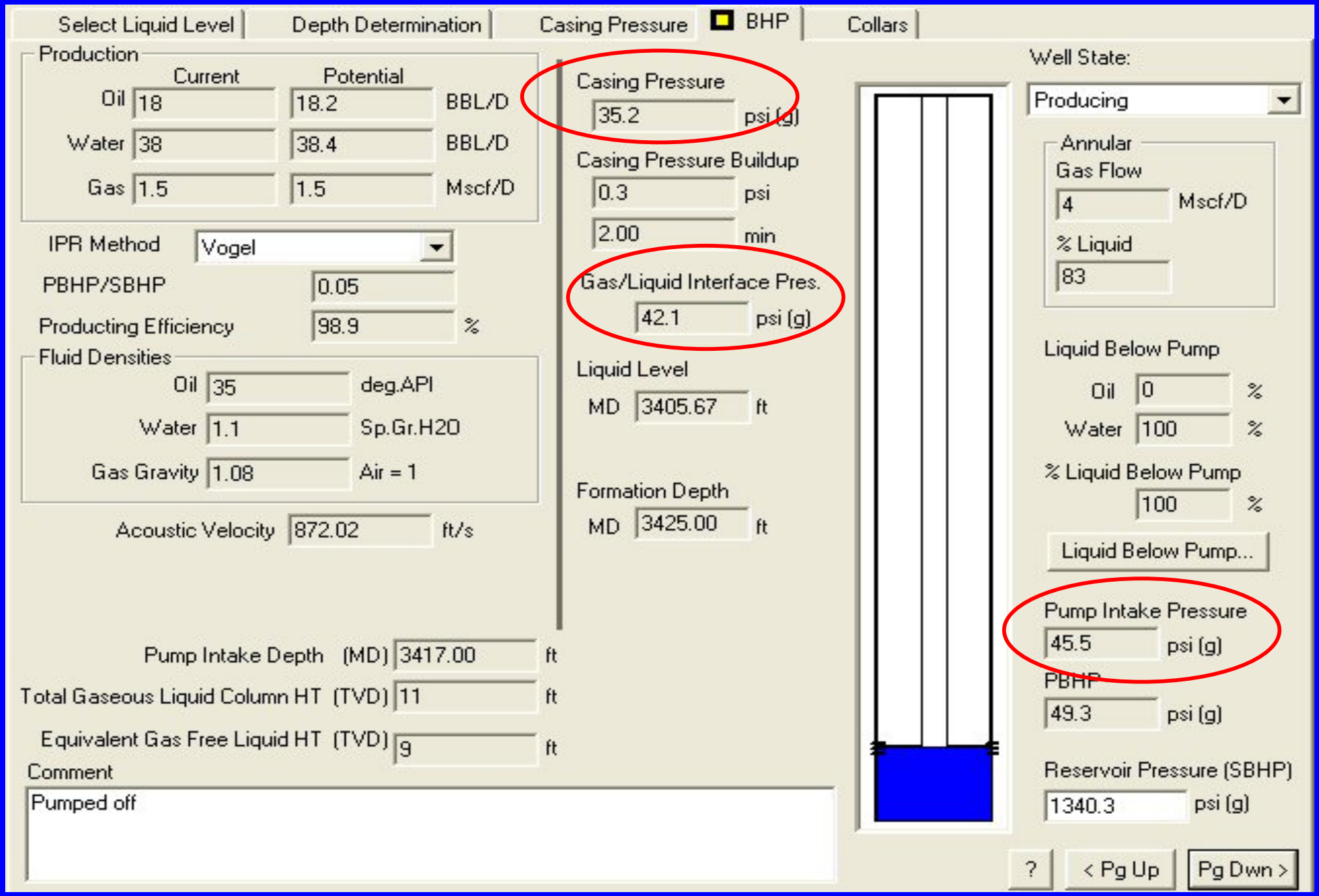
(((ECHOMETER)))

Acoustic PIP Calculation

- Requires stabilized conditions
- Determination of Liquid Level Depth
  - Avg. Joint Length, Acoustic Velocity, SG Gas ….
- Measurement of casing pressure
- Tubing, Casing Size, & Pump Depth
- Oil, water and annular gas densities
- Measurement of casing pressure buildup rate (at Producing Conditions)


Casing Pressure
Flow rate Q
Pcf
Ptf
Casing Pressure + Annulus Gas Gradient X Producing Fluid Level
+ Gaseous Liquid Gradient X Gaseous Liquid Height
= PIP (Fluid Levels)
Annulus Gas Gradient
Depth
Tubing Fluid Gradient
Producing Fluid Level
Gaseous Liquid Gradient
PDP
Pump Depth
PIP
PBHP
SBHP
Drawdown
Pressure
Pump
PBHP

Calculate Pump Intake Pressure from Fluid Level

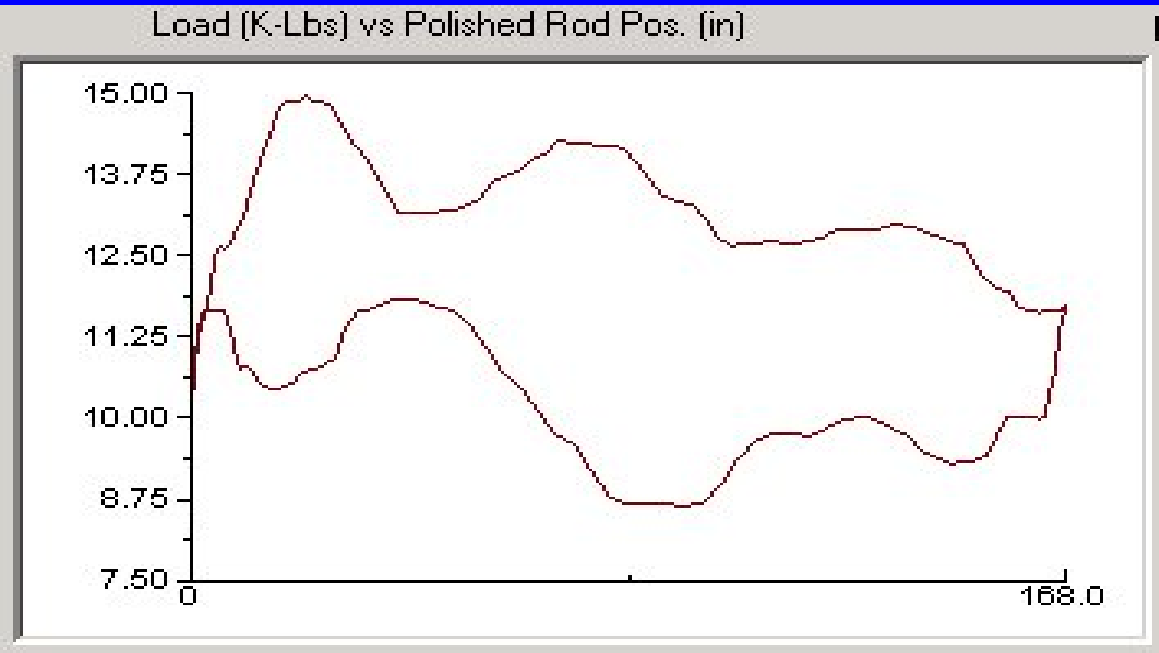


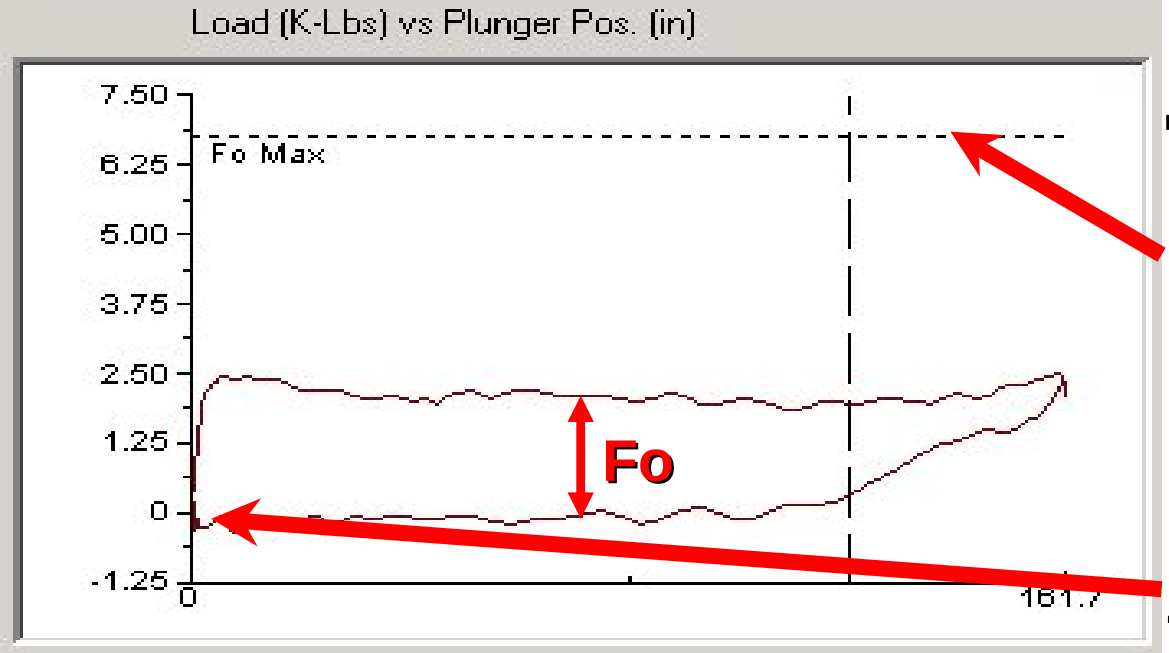
PIP = Casing Pressure + Gas Gradient * Liquid Level + Gaseous (Gradient*Height)

Dynamometer PIP Calculation

- Requires stabilized conditions
- Determination of Fluid Load
  - » Pump Card or (TV Load – SV Load)
- Measurement of tubing pressure
- Pump Diameter, Rod String & Pump Depth
- Oil, water and gas densities
- Oil, water, and gas Production Rate
- Damping Coefficients

Fluid Load, Fo, Has Two Reference Lines





Fo - Fluid Load is the load that the Pump applies to the rod string.

Fo = FoUp - FoDn

Upstroke: FoUp = (Pdis - Pintk) * Ap

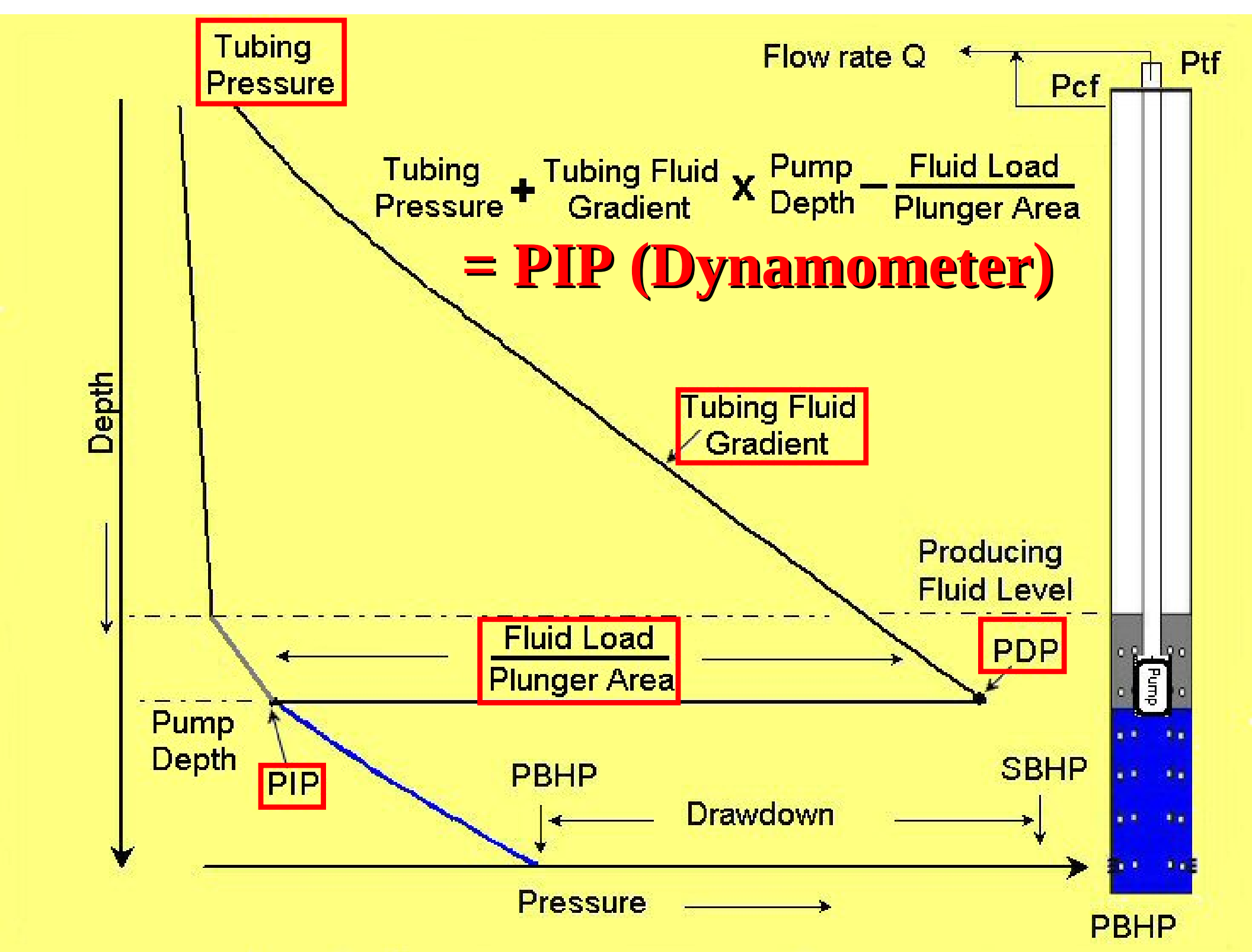
Downstroke: FoDn = 0

Two reference lines

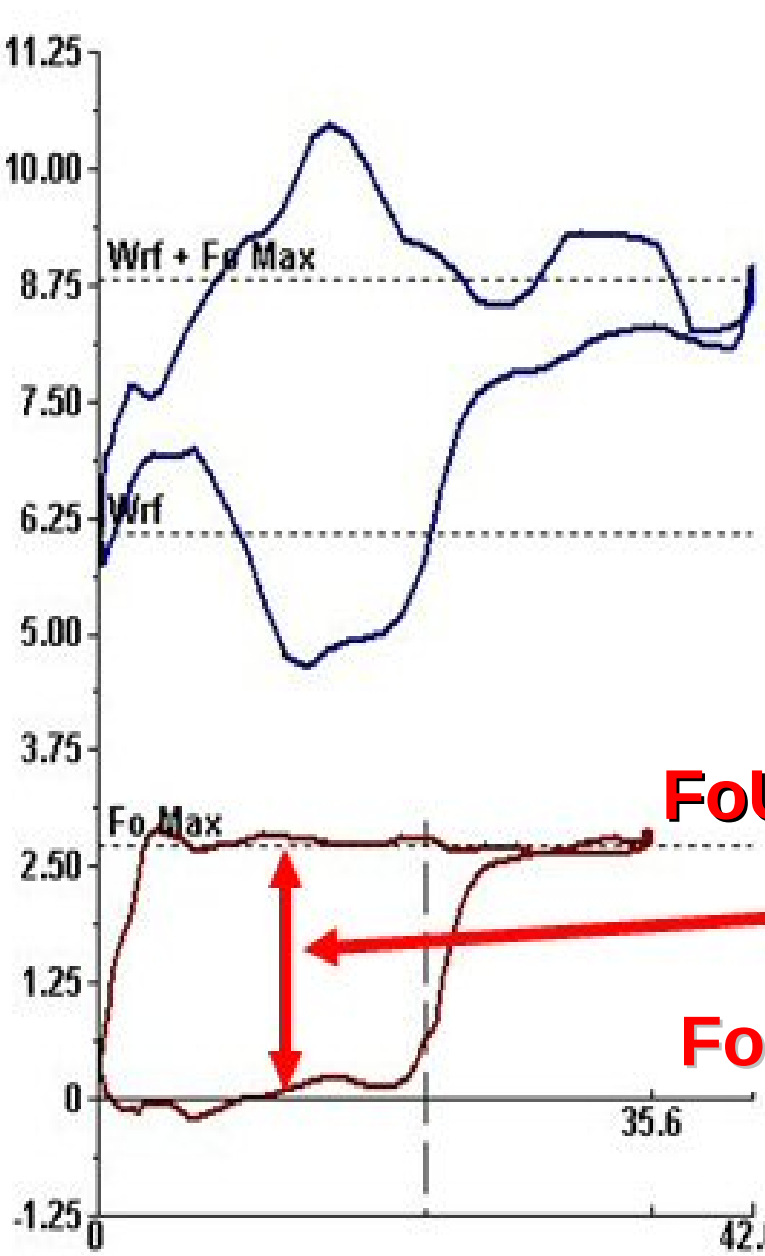
1. FoMax = Pdis * Ap

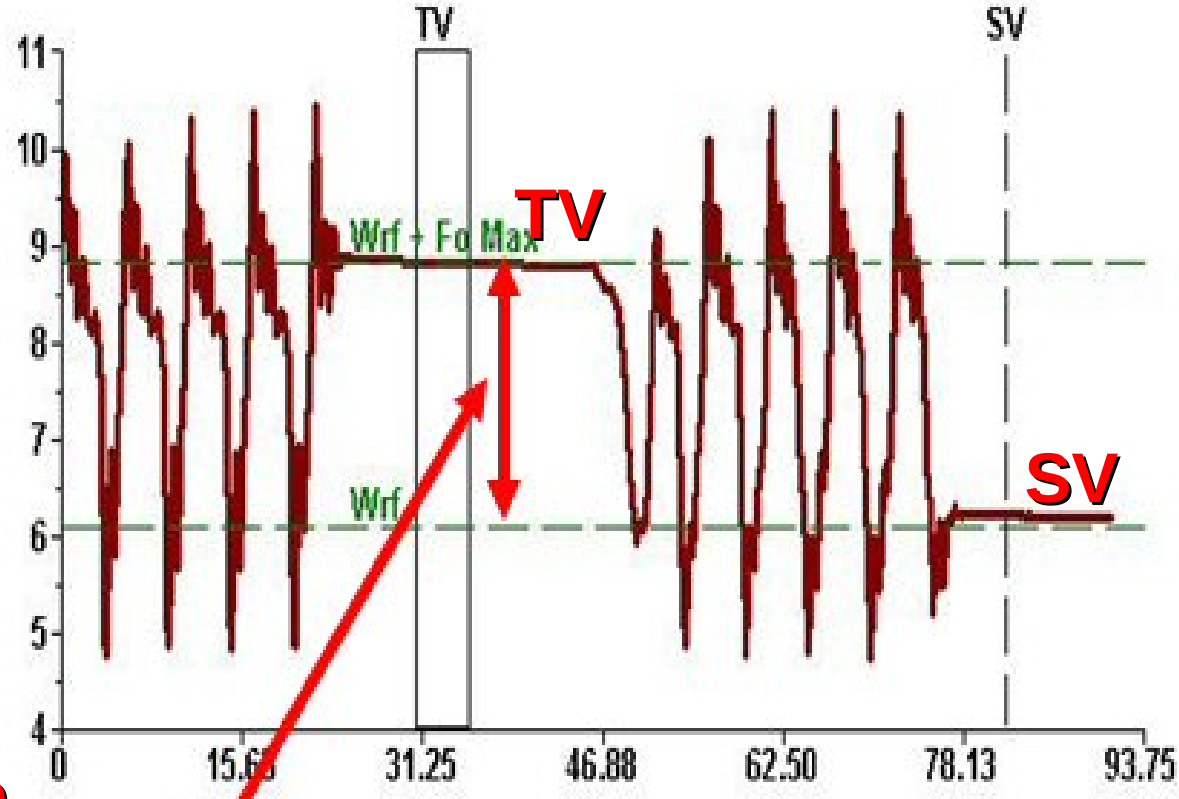
FoMax is the maximum load that the pump would apply to the rod string assuming pump intake pressure is zero. The well would provides no help in lifting the fluid to the surface.

2. Zero Load Line


Tubing Pressure
Flow rate Q
Ptf
Pcf
Tubing Pressure + Tubing Fluid Gradient x Pump Depth − Fluid Load / Plunger Area
= PIP (Dynamometer)
Depth
Tubing Fluid Gradient
Producing Fluid Level
Fluid Load / Plunger Area
PDP
Pump Depth
PIP
PBHP
SBHP
Drawdown
Pressure
Pump
PBHP

Calculate Pump Intake Pressure from Fluid Load





TV

SV

FoUp

Fo

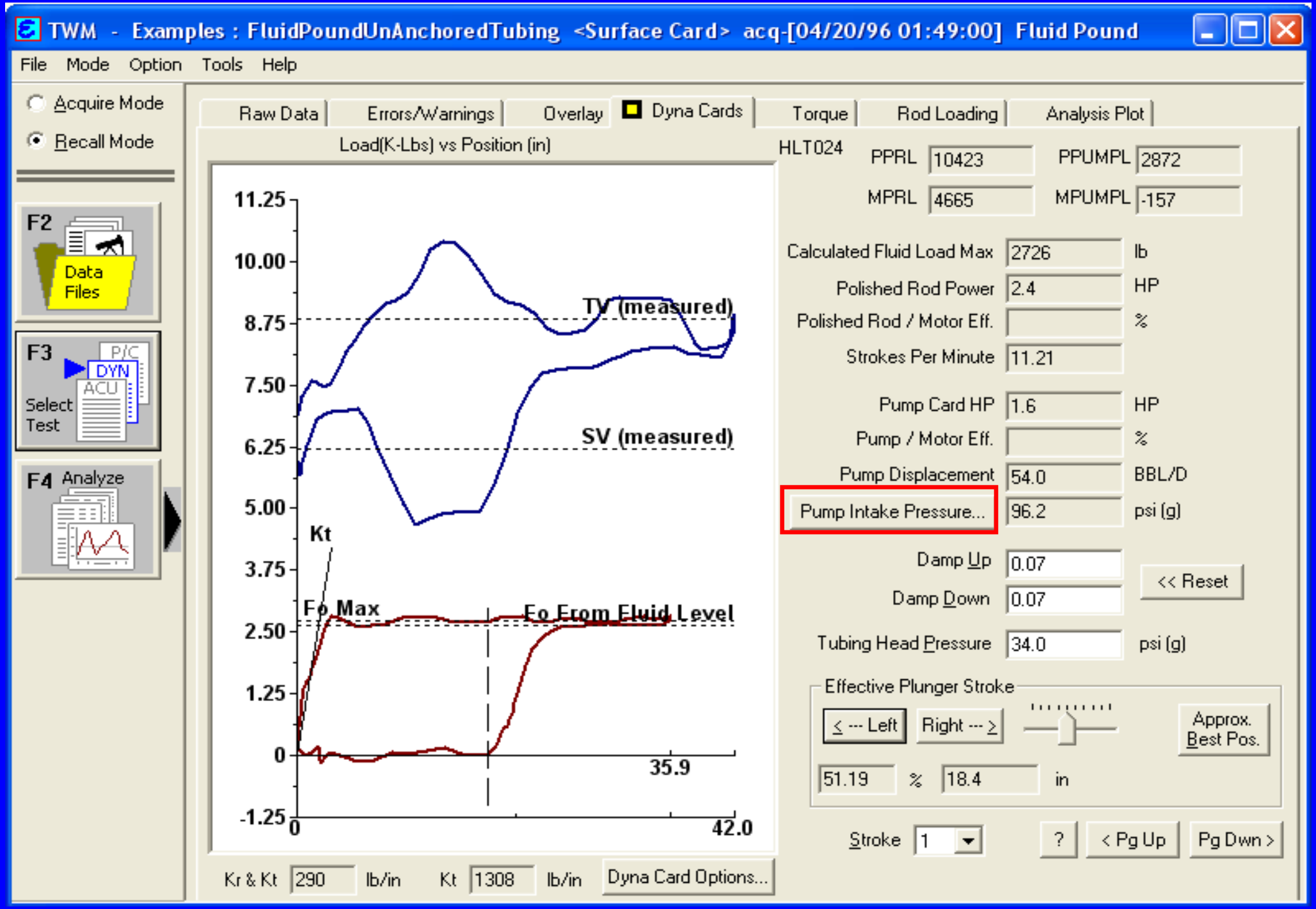
FoDn

Fo (Valve Test) = (TV – SV)

Fo (Pump Card) = (FoUp – FoDn)

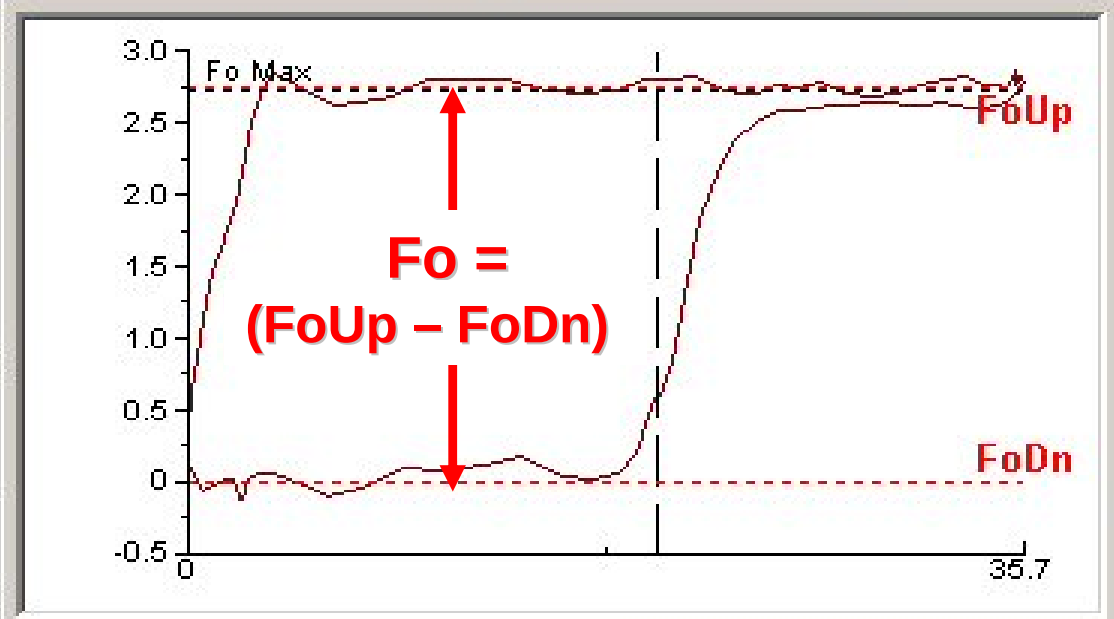
PIP = Tubing Pressure + Tubing Gradient * Pump Depth (TVD) – Fo /Plunger Area

Calculate PIP using Fo from Pump Card



Calculate PIP using Fo from Pump Card

Worksheet to Calculate Pump Intake Pressure using Fluid Load from Pump Card



Up Stroke Pump Load Options

- (•) Average of Up Stroke Loads
- ( ) Maximum Up Stroke Load (adj. by Unaccounted Friction)
- ( ) Load at Pump Fillage Line
- ( ) User Input — Up / Down

Fo Up 2744 lb

Down Stroke Pump Load Options

- (•) Zero Load Line
- ( ) Minimum Down Stroke Load (adj. by Unaccounted Friction)
- ( ) Average of Down Stroke Loads
- ( ) User Input — Up / Down

Fo Down 0 lb

Unaccounted Friction 126 lb

Calculations For Fo (Fluid Load Plunger)

- [ ] Fo Calculated From PIP of Fluid Level Analysis 2620 lb
  Fo = Plunger Area * [Tbg Pres. - PIP + Pump Depth * Fluid Gradient]
- [ ] Fo Calculated from Valve Check Analysis 2623 lb
  Fo = (TV-SV)

Fo = FoUp - FoDown

Fluid Load (Fo) 2744 lb

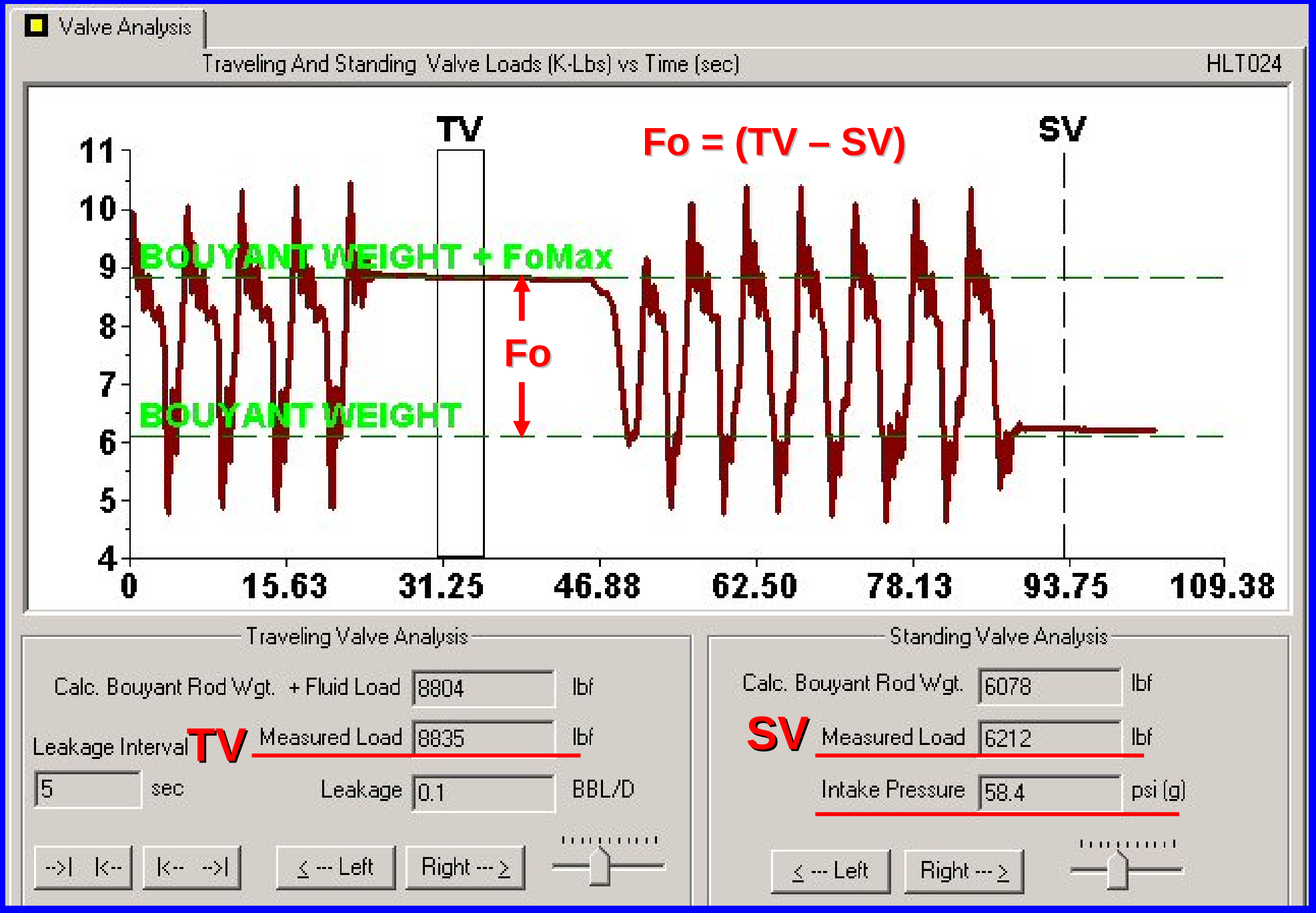
PIP = Tubing Pressure + Pump Depth(TVD) * Fluid Gradient - Fo / Plunger Area

Pump Intake Pressure 35.2 psi

[ ] Include Worksheet In Reports

OK Cancel

Calculate PIP using Fo from Valve Test



Well Data

PIP Examples

1) Pump Cards
   Valve Checks
   Fluid Levels

2) Load Measured
   a) Horseshoe
   b) PRT
   c) Modified Leutert

3) 16 selected from 38 possible files

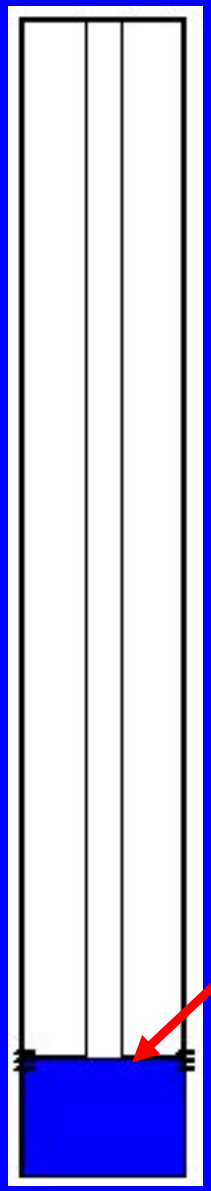
#	Example Dataset Well Name	A	D	V
1	Anchored but NOT Set	1	L 1	✓
2	Anchored With Rod Stretch	✓	HT 47	✓
3	Asphaltenes in Pump	✓	L 2	✓
4	average_well	✓	PRT 1	✓
5	Bad Tail Bearing	✓	L 2 2	✓
6	Deep_well	✓	PRT 1	✓
7	FluidPoundUnAnchoredTubing	✓	L 2 1	✓
8	Flumping	✓	✓	
9	Gas Interference	✓	L 1	✓
10	GearboxBalance	✓	HT 1	✓
11	Gunk in Pump	✓	✓	
12	Leak Hole In Pump Barrel	✓	HT 1	✓
13	Leak Standing Valve	✓	PRT 1	✓
14	Leak Tubing Hole	✓	✓	✓
15	Leak TV Unanchored		✓	✓
16	Need Gas Separator	✓	HT 1	✓
17	PFL_Anomaly	✓	✓	
18	PFL_DHM_CasingWtChange	✓	HT 1	✓
19	PFL_DHM_CoalBedPerfs	✓	✓	
20	PFL_Gaseous_noisy	✓		
21	PFL_Gaslift	✓		
22	PFL_High	✓		
23	PFL_High_liquid_low_gas	✓		
24	PFL_Imp_Exp	✓		
25	PFL_Liner	✓	✓	
26	PFL_Lot of Gas2	✓	✓	
27	PFL_SBHP	✓		
28	PFL_Tubing_anchor	✓		
29	RodPart_5365		✓	
30	RodPart_NoPlunger		✓	✓
31	Tagging Down Hard	✓	PRT 1 26	✓
32	Tagging Fiberglass Rods on Downstrok	✓	HT 2 1	✓
33	Tagging Unanchored	✓	L 1	✓
34	Trash Sticks SV Open	✓	PRT 1 17	✓
35	Trash Sticks TV Open	✓	HT 1 12	✓
36	TV Action Erratic	✓	L 1	✓
37	Unaccounted Wellbore Friction	✓	HT 1	✓
38	V11	✓	HT 3 1	✓

Pump Intake Pressure from 16 Wells

1) Average Error (PIP – Avg) = 436.4 Psig
2) (Meas – Avg) / Avg = 7.7% – 123.4% Avg 64%
3) Pump Cards (3) Fluid Levels (5) Valve Check (8)

#	Example Dataset Well Name	DYNO Data	Pump Intake Pressure Psig			Average	Error % (Meas - Avg)/Avg			Abs Max Error	Abs Max Error
		D	A	D	V	Psig	A	D	V	%	Psig
38	V11	HT 3 1	62	66.2	42.7	57.0	8.8	16.2	-25.0	25.0	14.3
7	FluidPoundUnAnchoredTubing	L 2 1	45.4	109.9	58.4	71.2	-36.3	54.3	-18.0	54.3	38.7
9	Gas Interference	L 1	722.3	734.6	647.1	701.3	3.0	4.7	-7.7	7.7	54.2
33	Tagging Unanchored	L 1	62.9	53.6	187	101.2	-37.8	-47.0	84.8	84.8	85.8
16	Need Gas Separator	HT 1	228.4	117.3	271.9	205.9	10.9	-43.0	32.1	43.0	88.6
18	PFL_DHM_CasingWtChange	HT 1	286.5	386.3	550.4	407.7	-29.7	-5.3	35.0	35.0	142.7
32	Tagging Fiberglass Rods on Downstroke	HT 2 1	338.6	58.1	58.1	151.6	123.4	-61.7	-61.7	123.4	187.0
1	Anchored but NOT Set	L 1	400.3	65.3	165.3	210.3	90.3	-68.9	-21.4	90.3	190.0
5	Bad Tail Bearing	L 2 1	568.4	955	731.9	751.8	-24.4	27.0	-2.6	27.0	203.2
37	Unaccounted Wellbore Friction	HT 1	340.5	329.8	18	229.4	48.4	43.7	-92.2	92.2	211.4
2	Anchored With Rod Stretch	HT 47	176	118.3	542.7	279.0	-36.9	-57.6	94.5	94.5	263.7
10	GearboxBalance	HT 1	827.3	810.2	1649.4	1095.6	-24.5	-26.1	50.5	50.5	553.8
35	Trash Sticks TV Open	HT 1 12	305.1	364.7	1228	632.6	-51.8	-42.3	94.1	94.1	595.4
3	Asphaltenes in Pump	L 2	527	1545	1523	1198.3	-56.0	28.9	27.1	56.0	671.3
36	TV Action Erratic	L 1	622.7	2318.3	2303	1748.0	-64.4	32.6	31.8	64.4	1125.3
12	Leak Hole In Pump Barrel	HT 1	405.1	3989.8	4492.1	2962.3	-86.3	34.7	51.6	86.3	2557.2
			5	3	8						
								Average =		64.3	436.4
								Maximum =		123.4	2557.2
								Minimum =		7.7	14.3

7 – Fluid Pound Unanchored Tbg



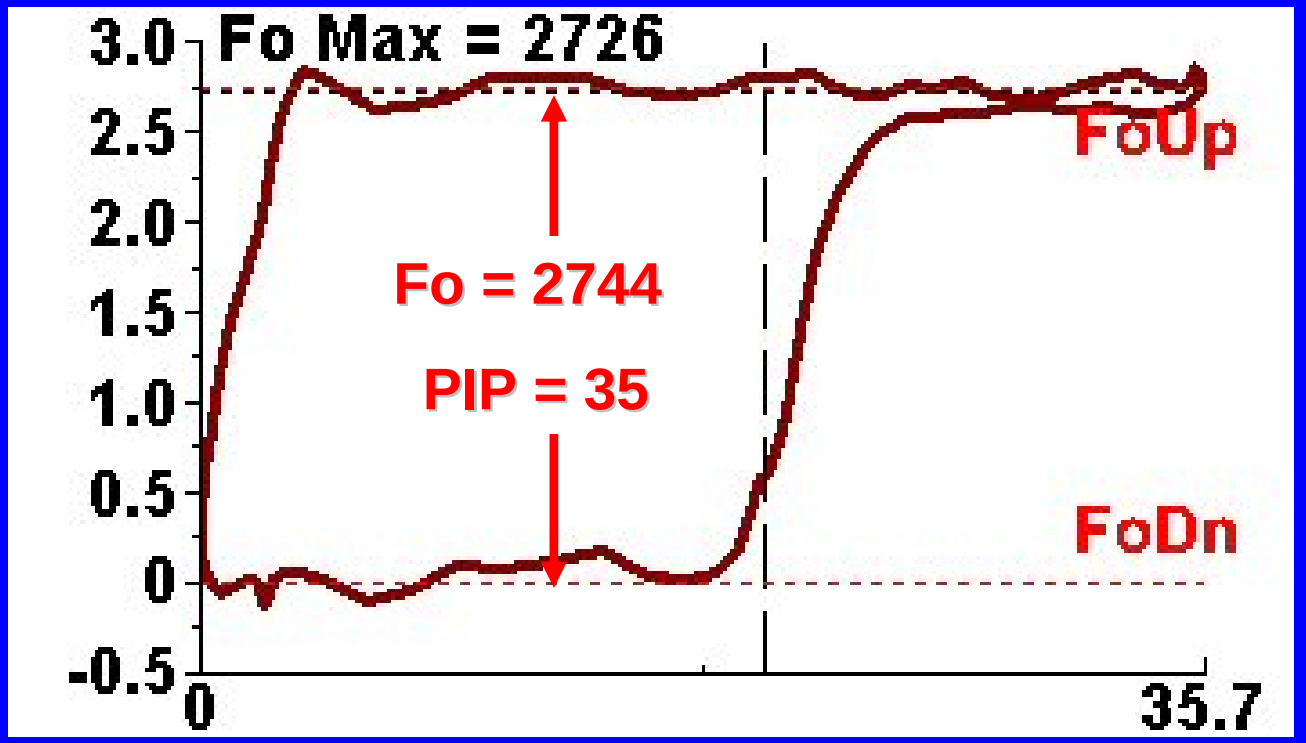
1.5” = 1.78 in^2

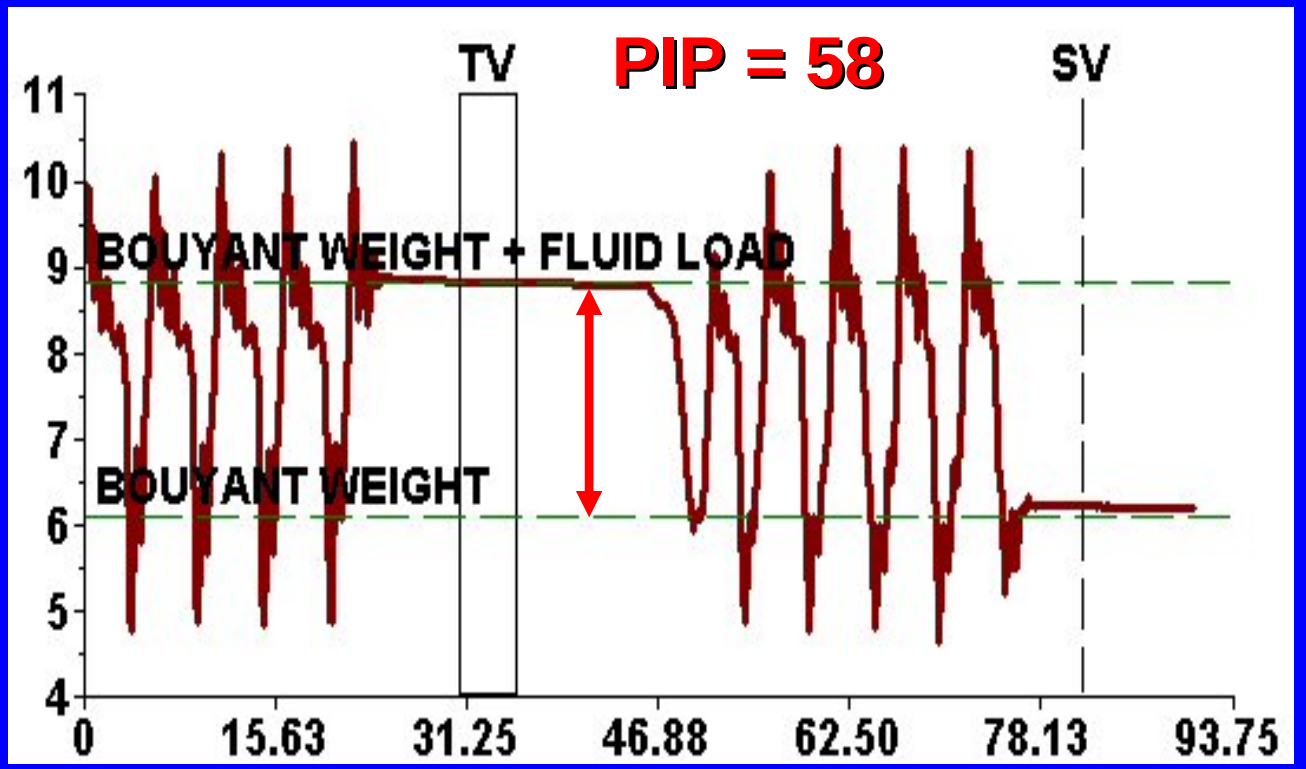
Fo(fl) = 2620

Fo(pc) = 2744

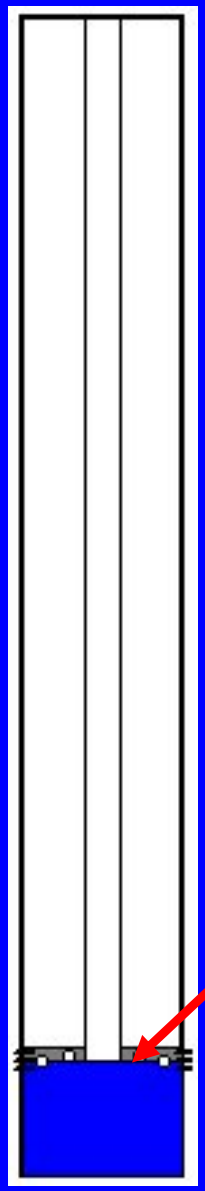
Fo(vc) = 2623

PIP = 45





38 – V11 Normal Pumped Off Well



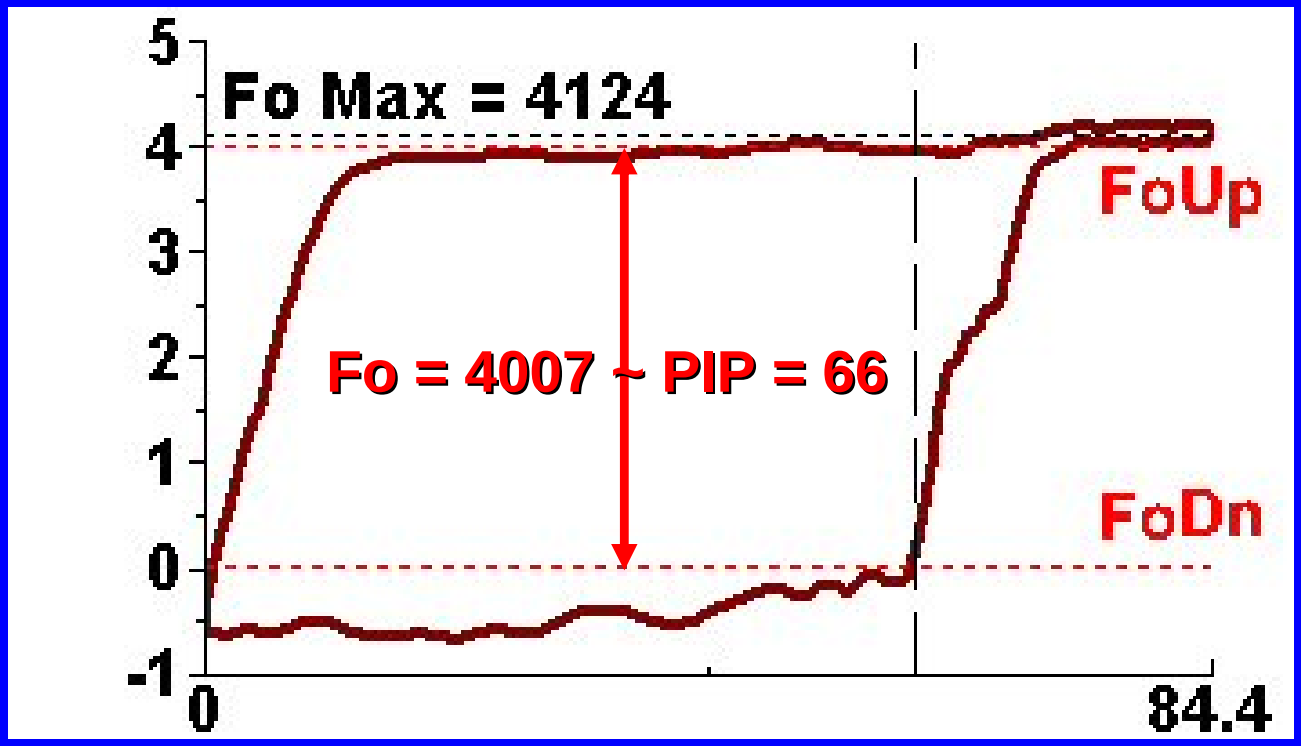
1.5” = 1.78 in²

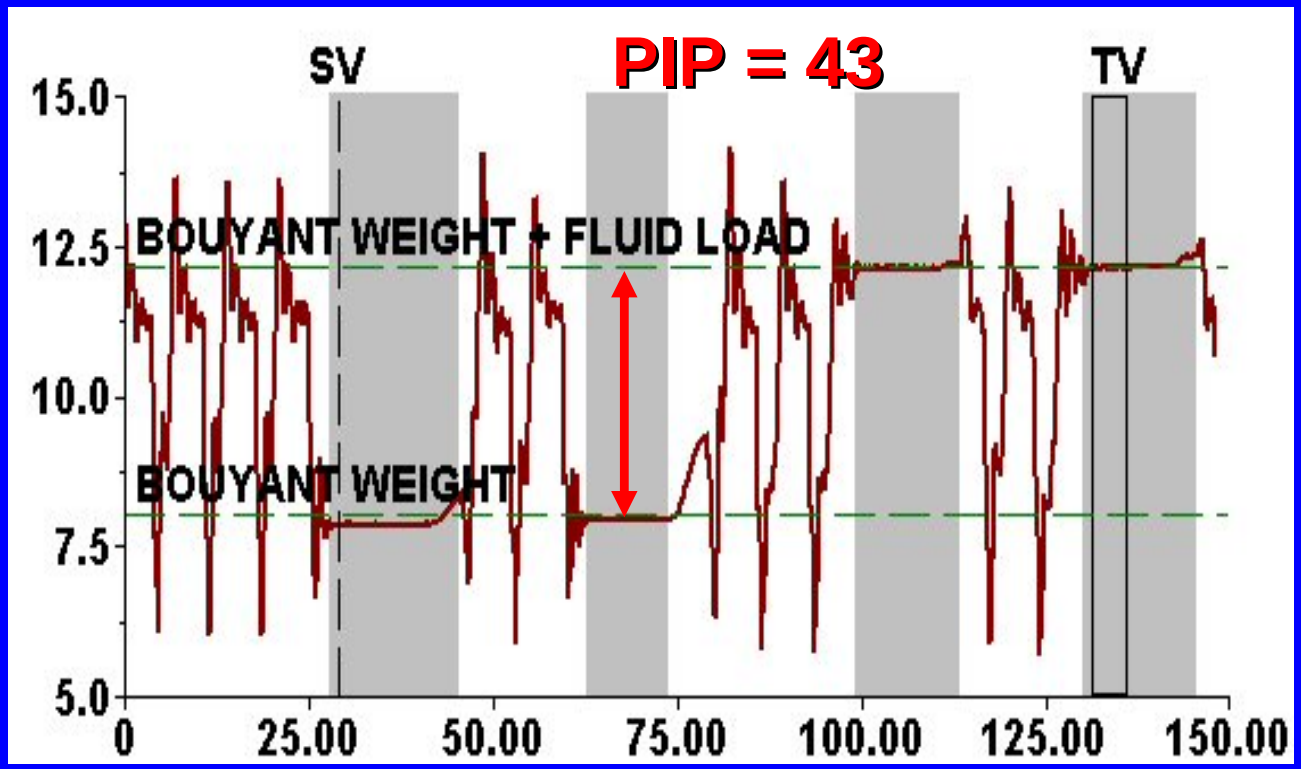
Fo(fl) = 3977

Fo(pc) = 4007

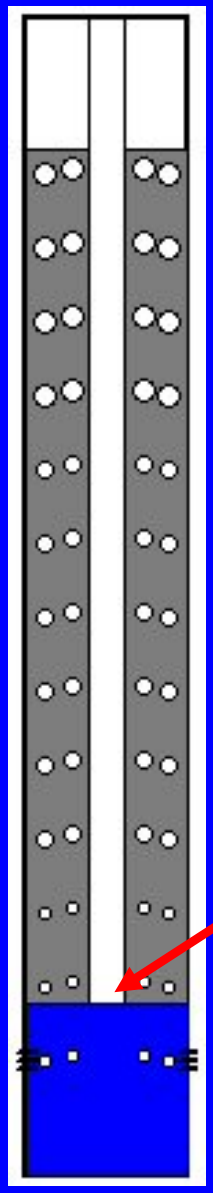
Fo(vc) = 4278

PIP = 62





9 – Gas Interference



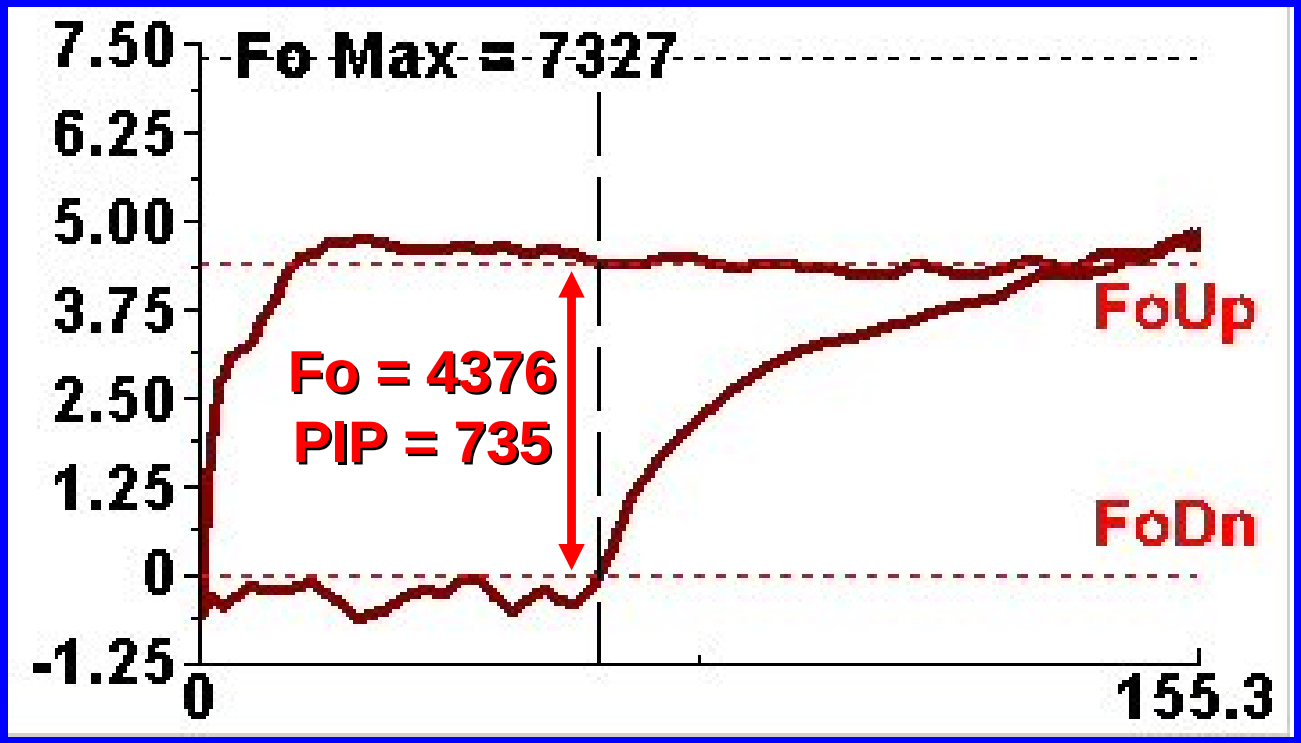
2.25” = 3.98 in²

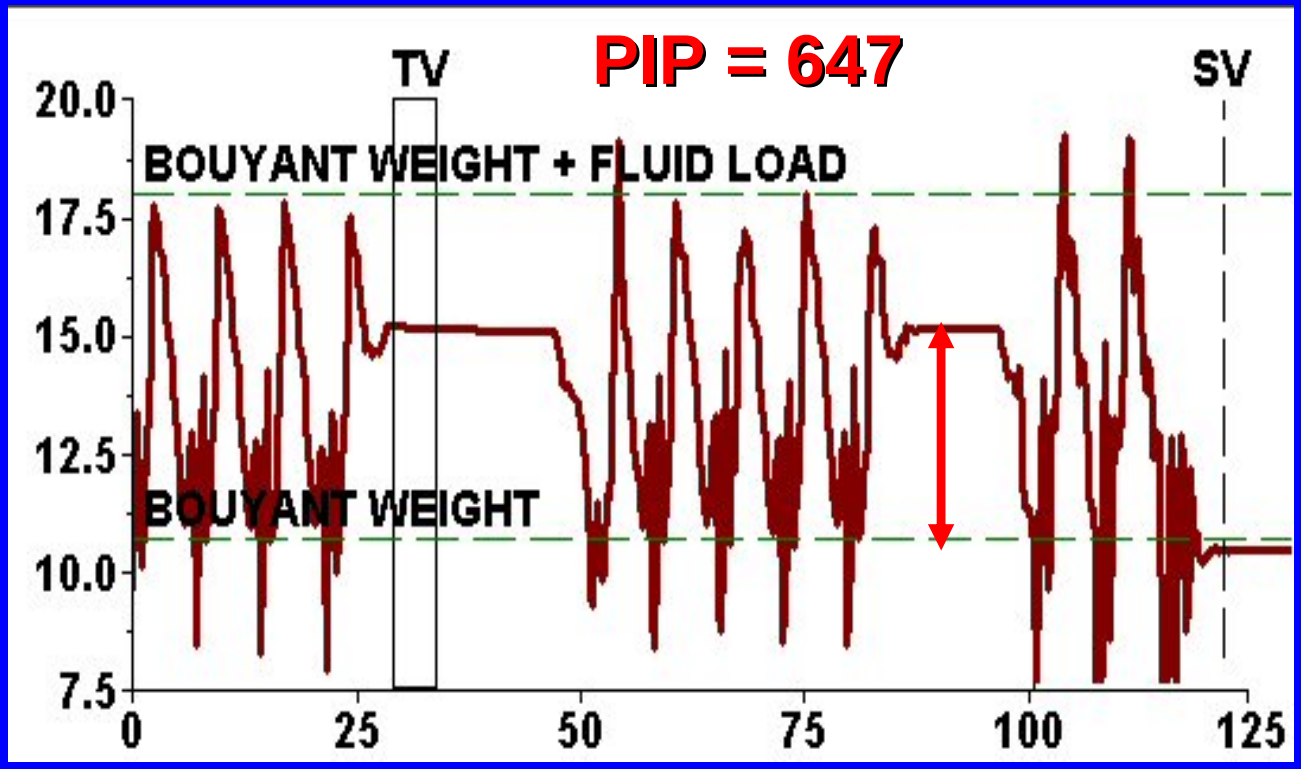
Fo(fl) = 4399

Fo(pc) = 4376

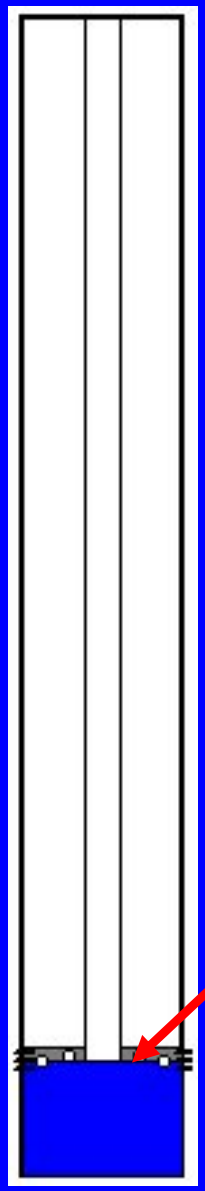
Fo(vc) = 5045

PIP = 722





35 – Trash Sticks TV Open



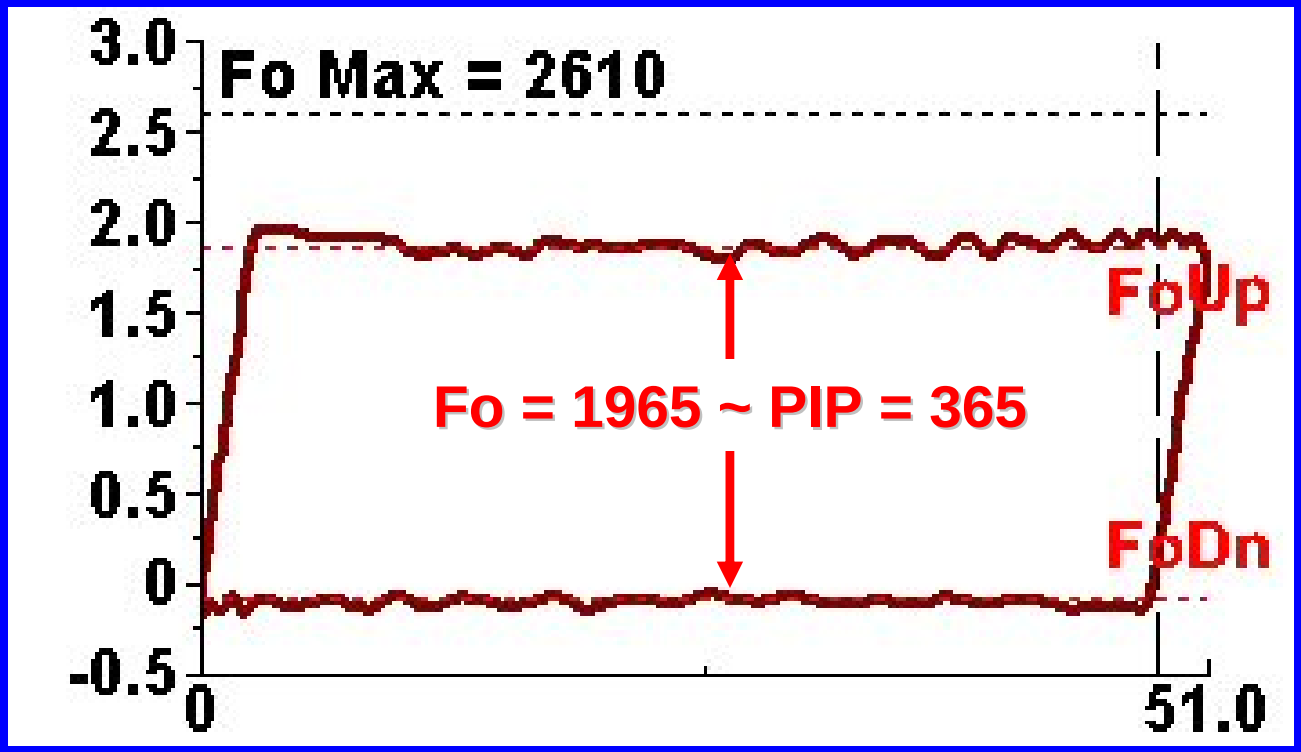
1.5” = 1.78 in²

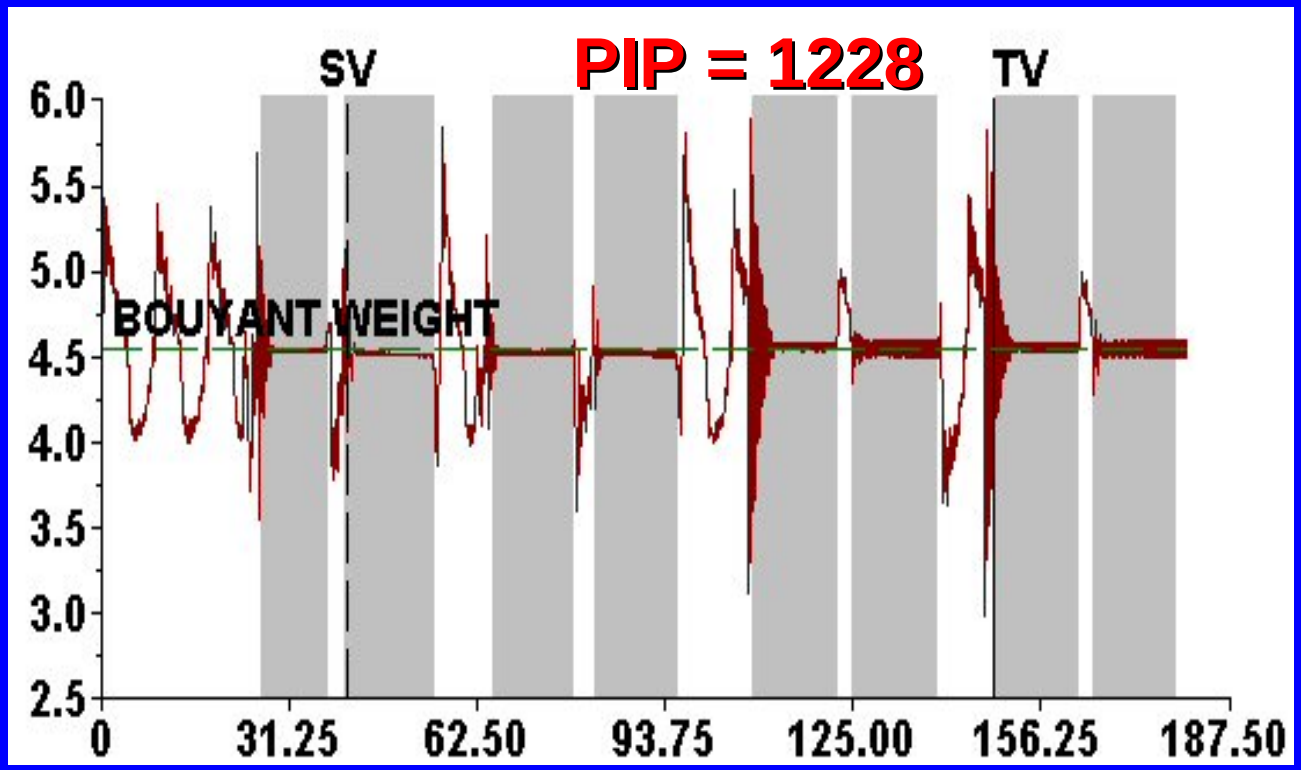
Fo(fl) = 1962

Fo(pc) = 1965

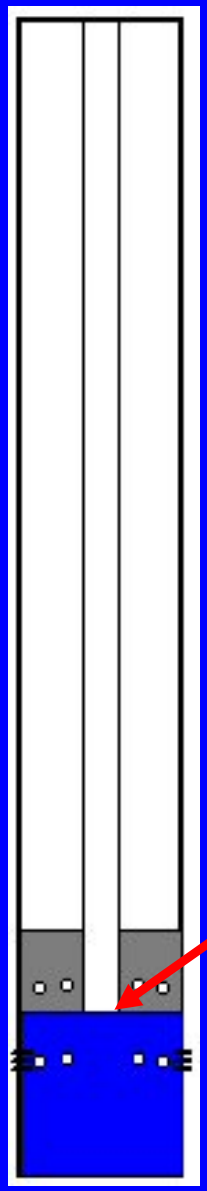
Fo(vc) = 449

PIP = 352





18 - PFL DHM Casing Weight Change

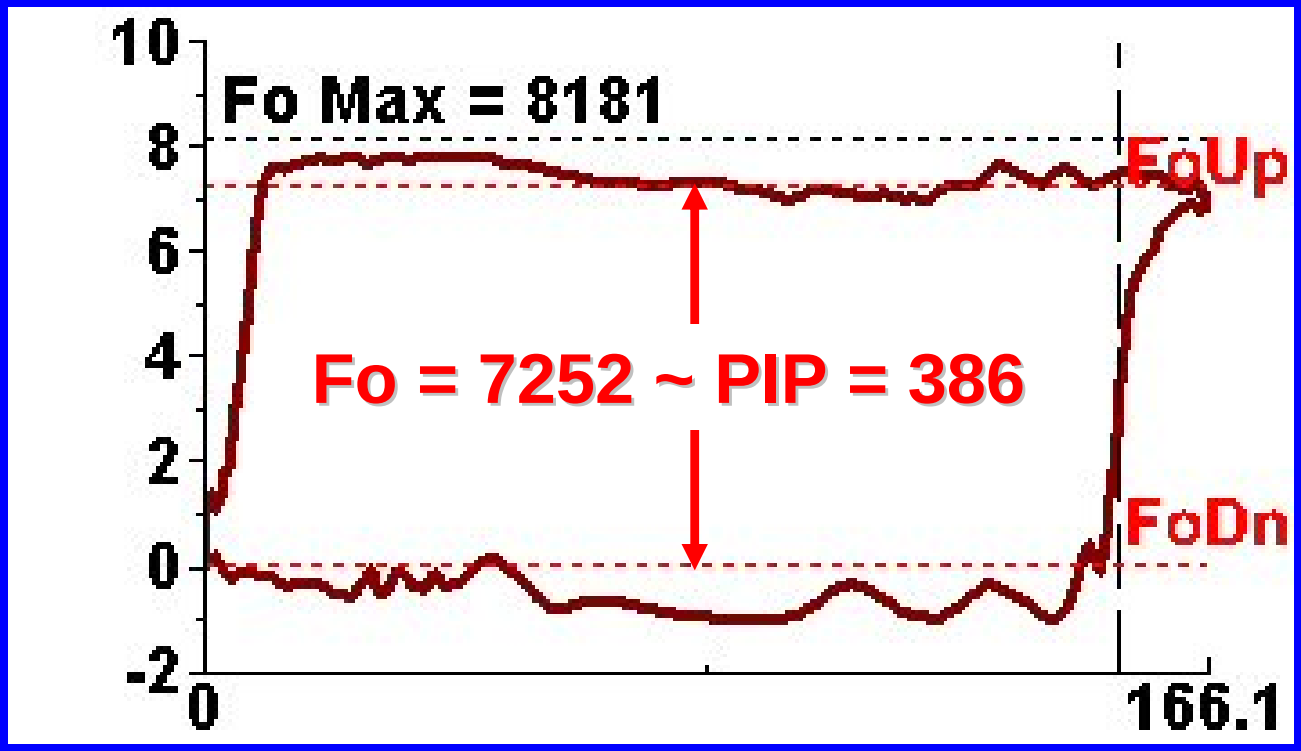


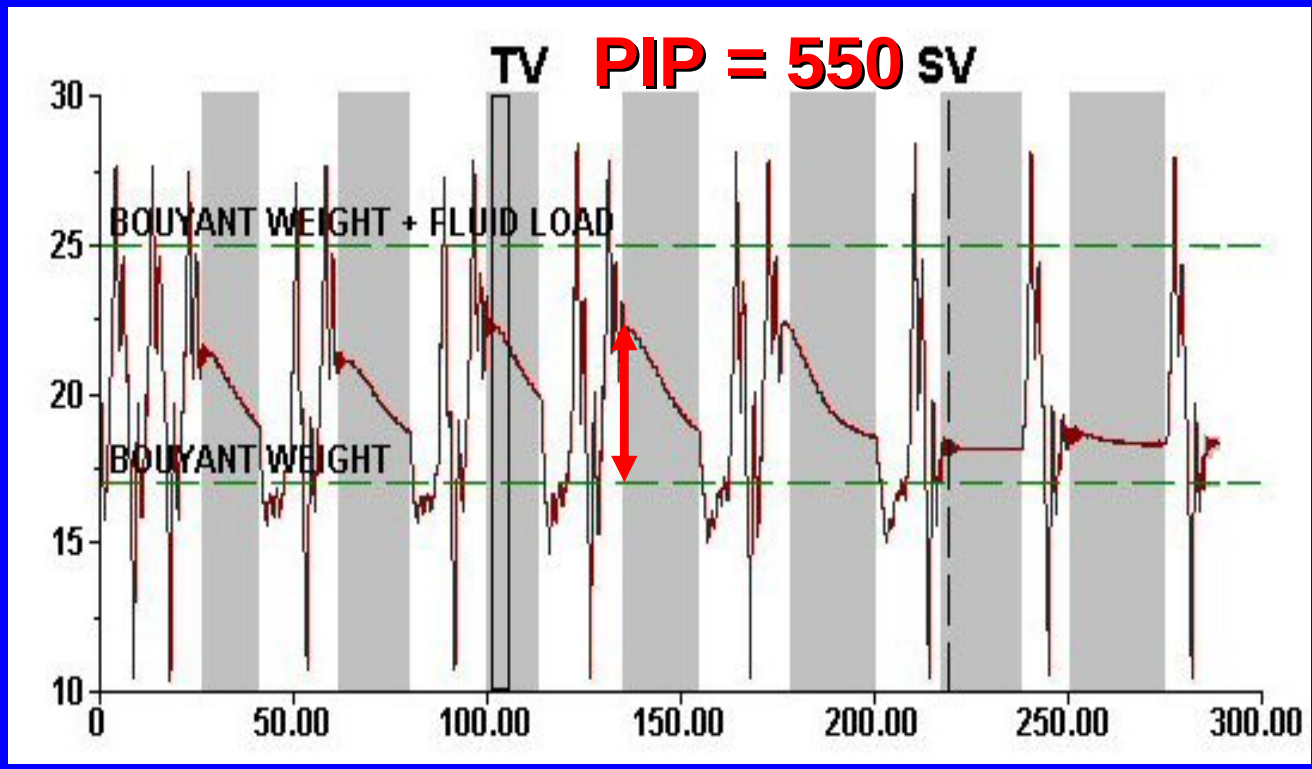
Fo(fl) = 7457

Fo(pc) = 7252

Fo(vc) = 6857

PIP = 287





Pump Intake Pressure (Exclude Valve Check PIPs)

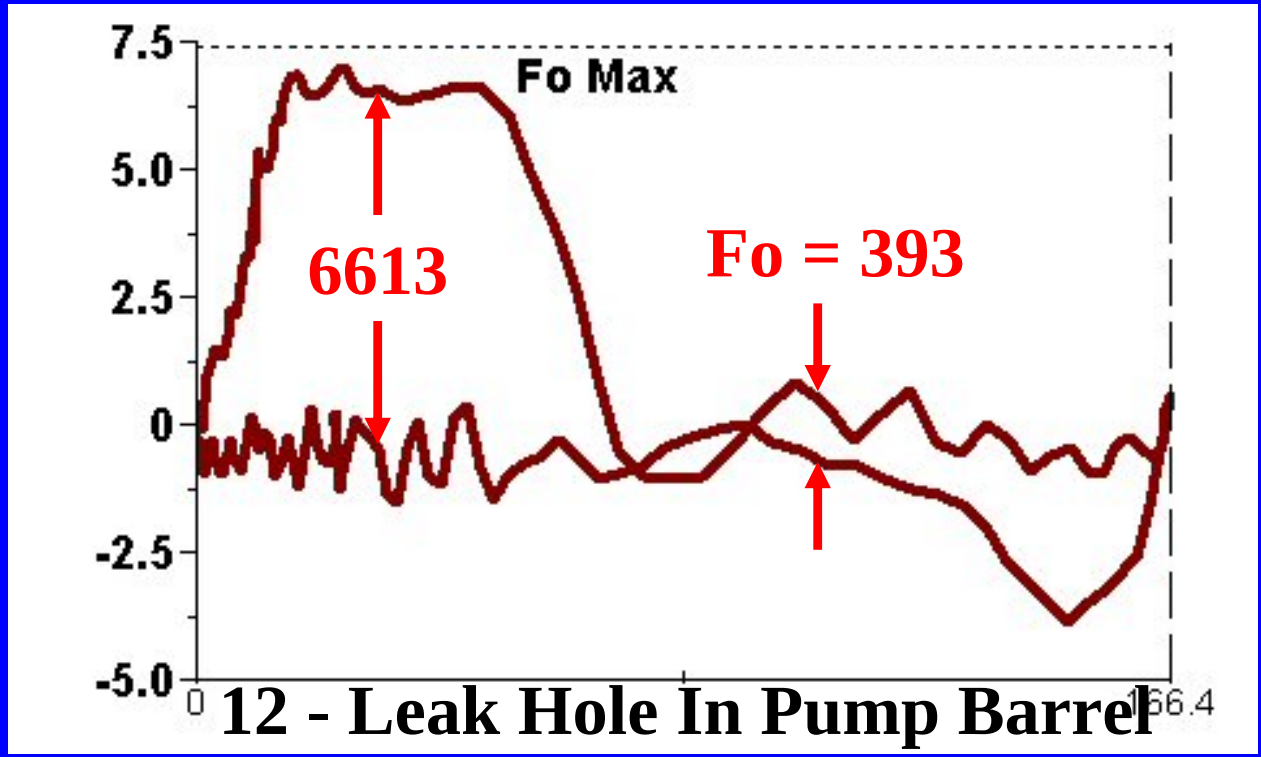
1) Average Error (PIP – Avg) = 242 Psig
2) (Meas – Avg) / Avg = 0.8% – 81.6% Avg 30.5%
3) Improved Average Error from 436 Psig

#	Example Dataset Well Name	DYNO Data	Pump Intake Pressure Psig			Average PIP Psig	Abs Max Error %	Abs Max Error Psig
		D	A	D	V			
38	V11	HT 3 1	62	66	43	64	3.3	2.1
33	Tagging Unanchored	L 1	63	54	187	58	8.0	4.7
37	Unaccounted Wellbore Friction	HT 1	341	330	18	335	1.6	5.4
9	Gas Interference	L 1	722	735	647	728	0.8	6.2
10	GearboxBalance	HT 1	827	810	1649	819	1.0	8.5
2	Anchored With Rod Stretch	HT 47	176	118	543	147	19.6	28.9
35	Trash Sticks TV Open	HT 1 12	305	365	1228	335	8.9	29.8
7	FluidPoundUnAnchoredTubing	L 2 1	45	110	58	78	41.5	32.3
18	PFL_DHM_CasingWtChange	HT 1	287	386	550	336	14.8	49.9
16	Need Gas Separator	HT 1	228	117	272	173	32.1	55.6
32	Tagging Fiberglass Rods on Downstroke	HT 2 1	339	58	58	198	70.7	140.3
1	Anchored but NOT Set	L 1	400	65	165	233	72.0	167.5
5	Bad Tail Bearing	L 2 1	568	955	732	762	25.4	193.3
3	Asphaltenes in Pump	L 2	527	1545	1523	1036	49.1	509.0
36	TV Action Erratic	L 1	623	2318	2303	1471	57.7	847.8
12	Leak Hole In Pump Barrel	HT 1	405	3990	4492	2197	81.6	1792.4

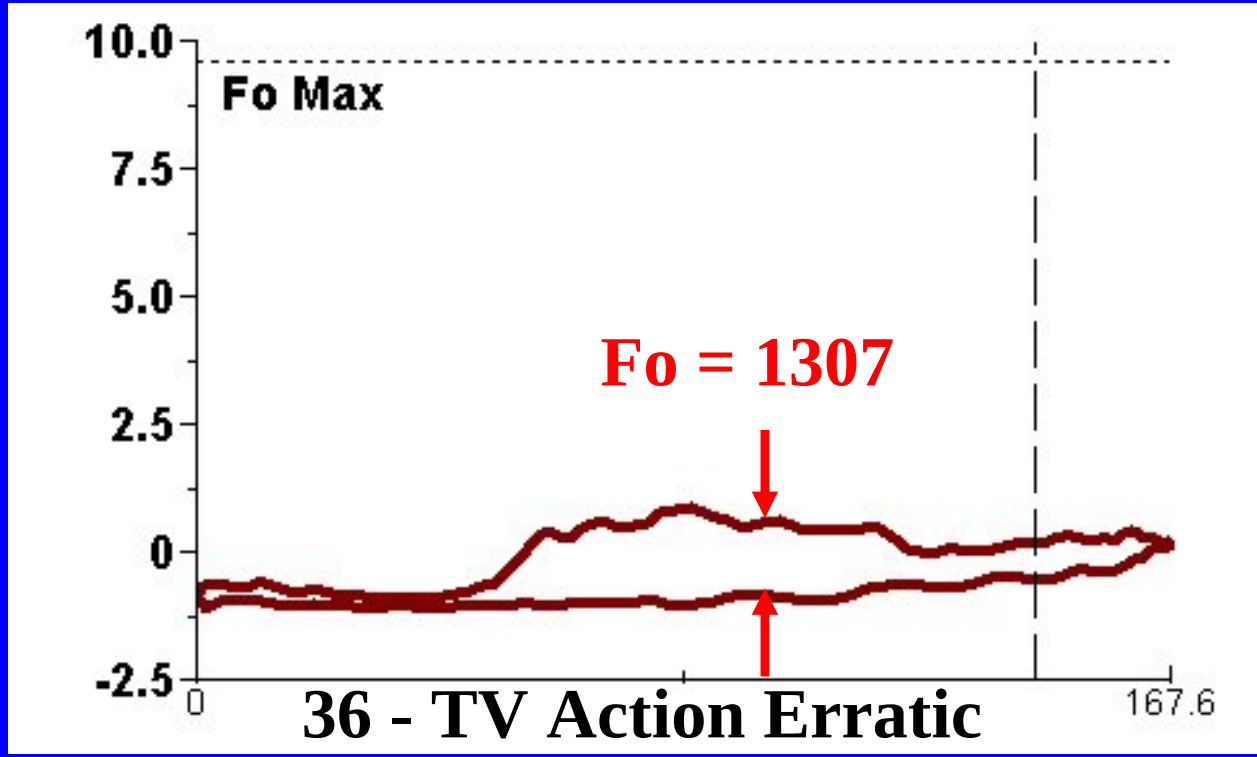
Improved Calc Intake Pressures by Excluding:

Problems Due to:
Asphaltenes in Pump
TV Action Erratic
Hole In Pump Barrel

Result in:
1) High Fluid Level
2) Erratic Pump Loads
3) Not Representative



12 - Leak Hole In Pump Barrel



36 - TV Action Erratic

Pump Intake Pressure (Exclude Dyno w/ Problems)

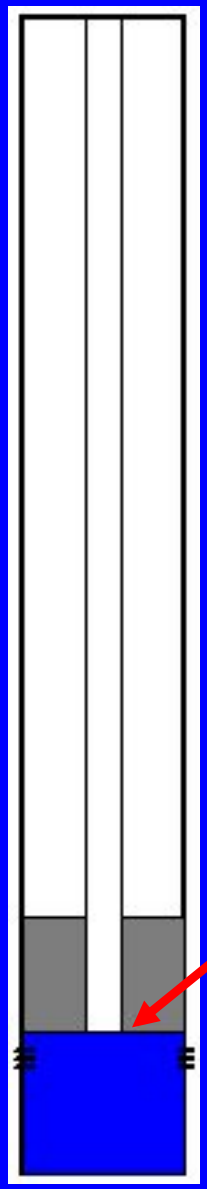
1) Average Error (PIP – Avg) = 55.7 Psig
2) (Meas – Avg) / Avg = 0.8% – 72% Avg 23.1%
3) Best Match at Lower Pump Intake Pressures

#	Example Dataset Well Name	DYNO Data	Pump Intake Pressure Psig			Average PIP Psig	Abs Max Error %	Abs Max Error Psig
		D	A	D	V			
38	V11	HT 3 1	62	66	43	64	3.3	2.1
33	Tagging Unanchored	L 1	63	54	187	58	8.0	4.7
37	Unaccounted Wellbore Friction	HT 1	341	330	18	335	1.6	5.4
9	Gas Interference	L 1	722	735	647	728	0.8	6.2
10	GearboxBalance	HT 1	827	810	1649	819	1.0	8.5
2	Anchored With Rod Stretch	HT 47	176	118	543	147	19.6	28.9
35	Trash Sticks TV Open	HT 1 12	305	365	1228	335	8.9	29.8
7	FluidPoundUnAnchoredTubing	L 2 1	45	110	58	78	41.5	32.3
18	PFL_DHM_CasingWtChange	HT 1	287	386	550	336	14.8	49.9
16	Need Gas Separator	HT 1	228	117	272	173	32.1	55.6
32	Tagging Fiberglass Rods on Downstroke	HT 2 1	339	58	58	198	70.7	140.3
1	Anchored but NOT Set	L 1	400	65	165	233	72.0	167.5
5	Bad Tail Bearing	L 2 1	568	955	732	762	25.4	193.3
3	Asphaltenes in Pump	L 2	527	1545	1523	1036		
36	TV Action Erratic	L 1	623	2318	2303	1471		
12	Leak Hole In Pump Barrel	HT 1	405	3990	4492	2197		

Calculated Intake Pressures Improved by:

38 -	V11 ……	Normal Well, OK
33 -	Tagging Unanchored ……	Pumped Off, Fluid Level at Pump
37 -	Unaccounted Wellbore Friction ..	Adjusted Pump Card, Fo
9 -	Gas Interference ……..	Adjusted Tubing Fluid Gradient
10 –	Gearbox Balance ……	Normal Well, OK
2 -	Anchored With Rod Stretch ……	Manually selected collar interval
35 -	Trash Sticks TV Open ……	dPdT not correct, changed(0.7 to 0.3)
7 –	FluidPoundUnAnchoredTubing .	Use defaults for FoUp and FoDn
16 -	Need Gas Separator ……..	User selected FoUp Load
18 -	PFL_DHM_CasingWtChange ..	User selected FoUp Load
32 -	Tagging Fiberglass Rods on … Downstroke	Average Joint Length incorrect, too high of PFL (Exclude Data)
1 -	Anchored but NOT Set ……..	User selected FoUp and FoDn
5 -	Bad Tail Bearing ……	Avg of Downstroke Loads, change tubing gradient from 0.412 to 0.38

37 - Unaccounted Wellbore Friction



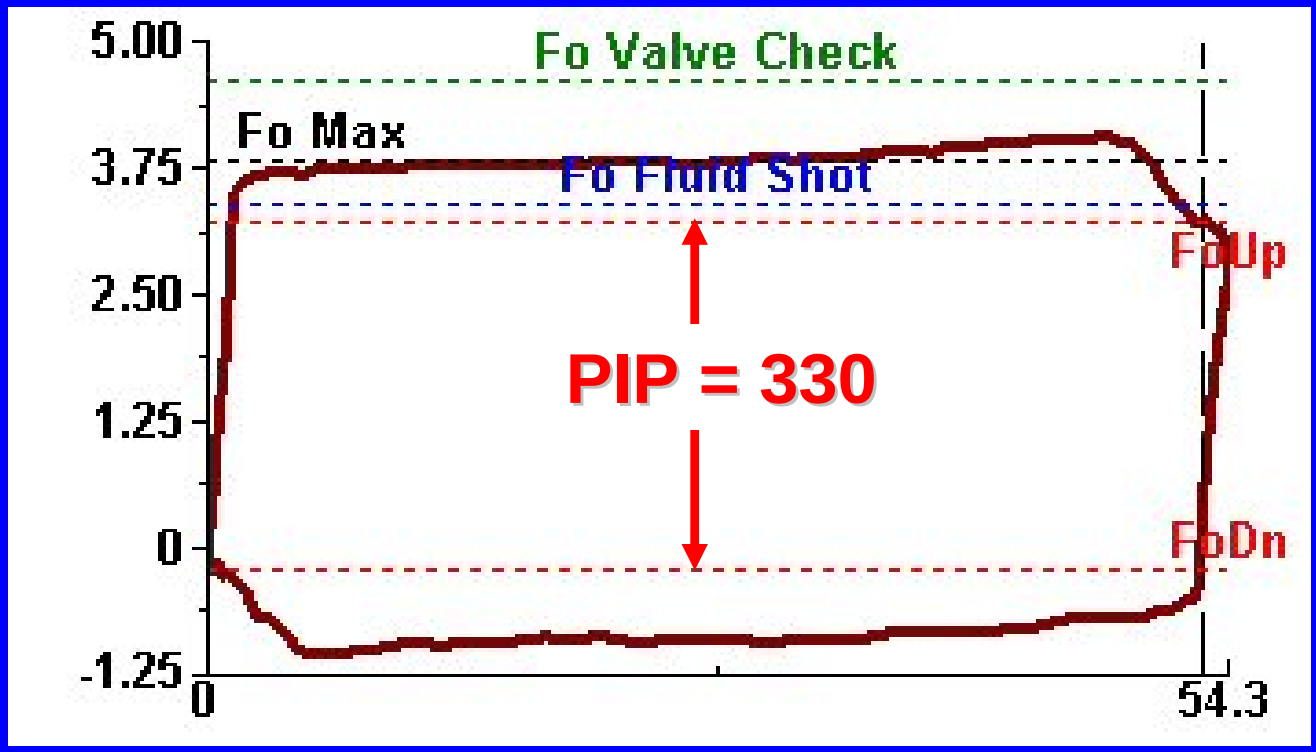
2.25” = 3.98 in²

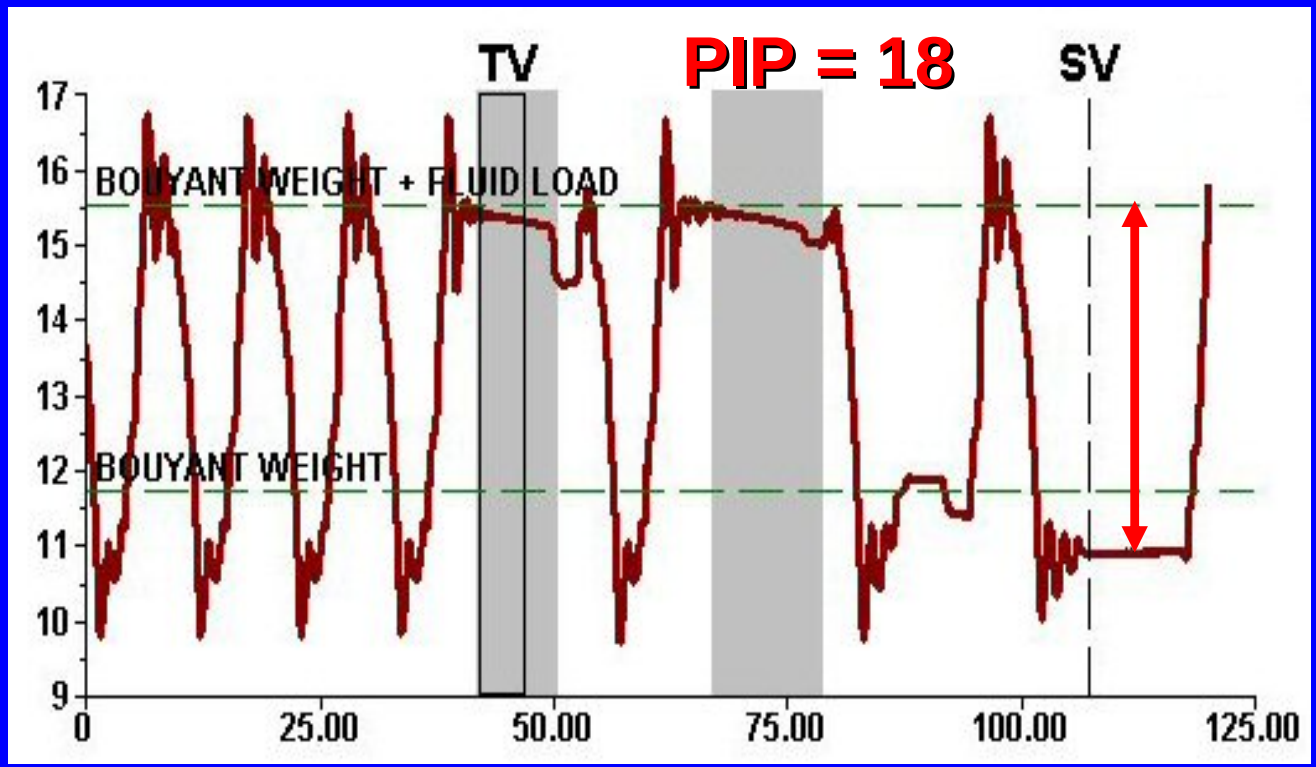
Fo(fl) = 7457

Fo(pc) = 7252

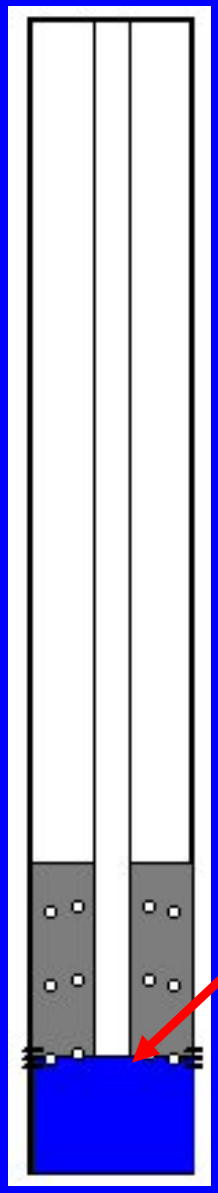
Fo(vc) = 6857

PIP = 341





16 – Need Gas Separator



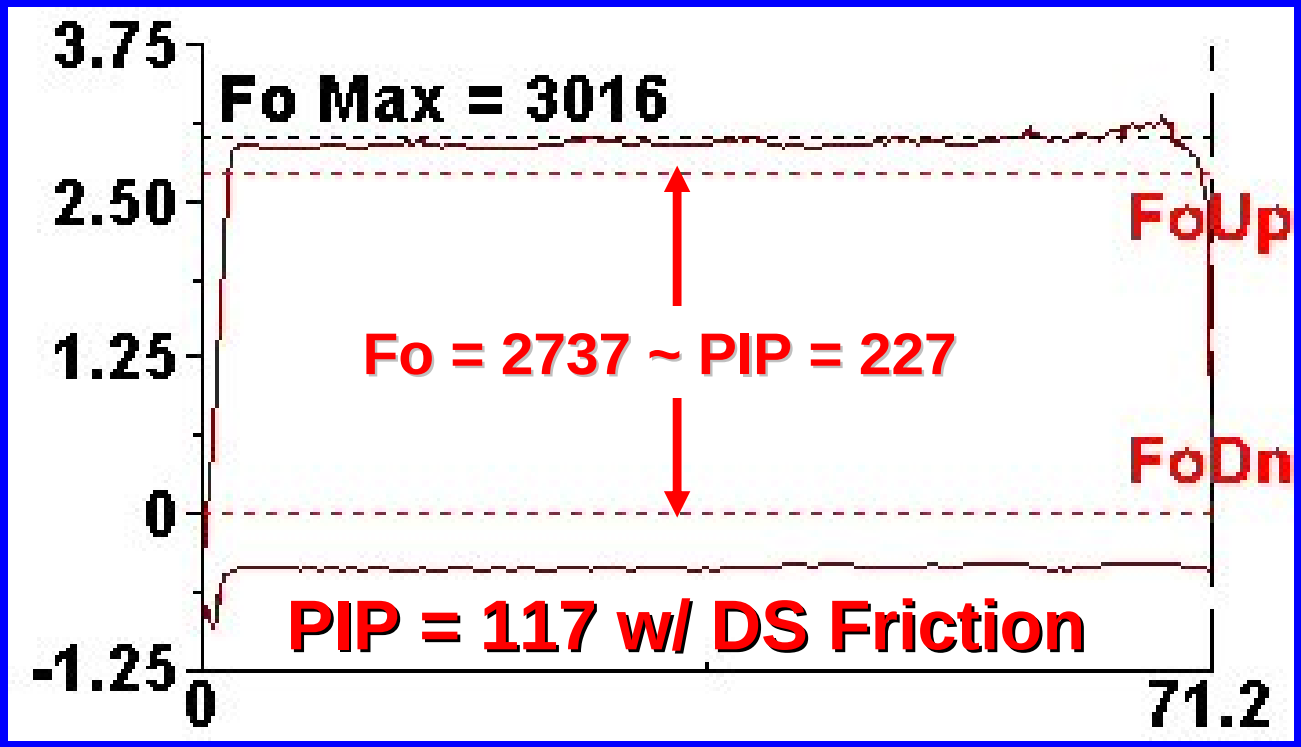
1.25” =1.22 in²

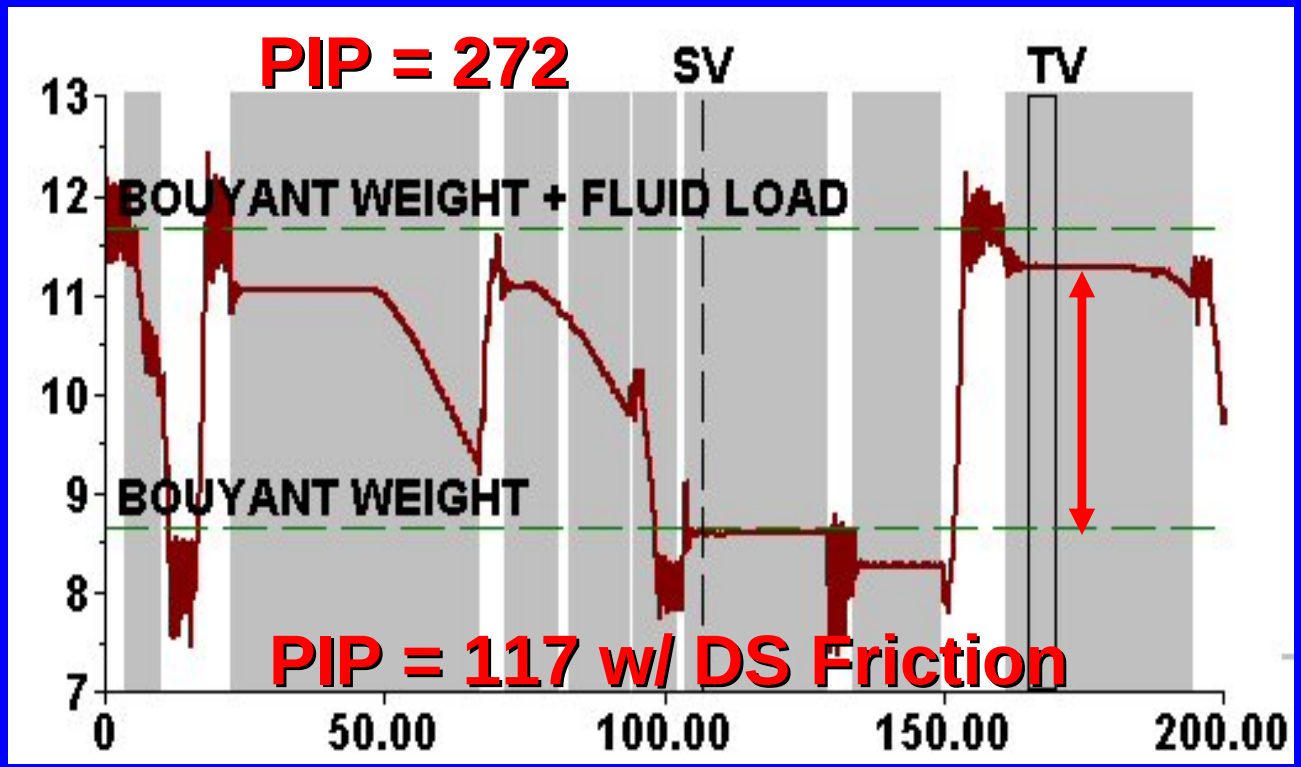
Fo(fl) = 2718

Fo(pc) = 2737

Fo(vc) = 2682

PIP = 228





Corrected Calculation of Pump Intake Pressures

1) Average Error (PIP – Avg) = 4.5 Psig
2) (Meas – Avg) / Avg = 0.1% – 12% Avg 3.0%
3) Improved Average Error from 436 Psig

#	Example Dataset Well Name	DYNO Data	Pump Intake Pressure Psig			Average PIP Psig	Abs Max Error %	Abs Max Error Psig
		D	A	D	V			
38	V11	HT 3 1	62	66	43	64	3.3	2.1
33	Tagging Unanchored	L 1	63	54	187	58	8.0	4.7
37	Unaccounted Wellbore Friction	HT 1	341	330	18	335	1.6	5.4
9	Gas Interference	L 1	722	735	647	728	0.8	6.2
10	GearboxBalance	HT 1	827	810	1649	819	1.0	8.5
2	Anchored With Rod Stretch	HT 47	127	118	543	123	3.5	4.3
35	Trash Sticks TV Open	HT 1 12	352	365	1228	358	1.8	6.4
7	FluidPoundUnAnchoredTubing	L 2 1	45	35	58	40	12.7	5.1
16	Need Gas Separator	HT 1	228	227	272	228	0.3	0.7
18	PFL_DHM_CasingWtChange	HT 1	287	301	550	294	2.5	7.3
32	Tagging Fiberglass Rods on Downstroke	HT 2 1	339	58	58	198		
1	Anchored but NOT Set	L 1	400	401	165	401	0.1	0.4
5	Bad Tail Bearing	L 2 1	568	562	564	565	0.6	3.4
3	Asphaltenes in Pump	L 2	527	1545	1523	1036		
36	TV Action Erratic	L 1	623	2318	2303	1471		
12	Leak Hole In Pump Barrel	HT 1	405	3990	4492	2197		

Accuracy of PIP from Dynamometer Measured Loads Depends On

1) Load cell damaged
2) Calibration of the load cell
   - Zero Offset and Hysteresis
   - Not centrally loaded
3) Pump card shifted off the zero load line
4) Specifying a tubing fluid gradient, difficult in wells that flow or have lots of gas.
5) Unaccounted friction: deviated wells, tight stuffing boxes, bottled up pumps, or paraffin
6) Bad/Missing Input Data

15000 lbs x 1% x 1.50” Plunger = 85 psi

Accuracy of PIP from Fluid Levels Depends On

1) Can't shoot Fluid level when Pumping Below Packer
2) User Frequently does not Verify Input Data
   - Default Avg. Joint Length
   - Other Missing Data
3) Gaseous Liquid ? for very high Fluid Levels, CO2 and Viscous Crude
4) Operator does not review and verify analysis done automatically by software

Fluid Level off by 1 joint = 11 psi

Conclusions

1) Should not accept default analysis for PIP
   - Initial Average PIP Error was 436 psi
   - Initial Maximum Error was 2556 psi
2) Error impacts PIP differently
   - Fluid Level Off by 1 Tubing Joint ~ 11 Psi
   - 1% Error in Dyno Load ~ 85 psi Error
3) PIP from Valve Checks most Error
4) PIP from Pump Card in the Middle
5) PIP from Fluid Level has Least Error

6) Proper Analysis Results in Accurate PIP