Introduction – Basic Loads

- Recording load and position data on sucker rod lifted wells with a dynamometer transducer has been performed in the oil field for many years.

- Early Dynamometer Examples:
  - 1950's the popular Johnson-Fagg dynamometer .
  - Leutert dynamometer .

- Current portable dynamometer technology :
  - High performance digital data acquisition systems
  - Quick, accurate data, safe and easy to use .

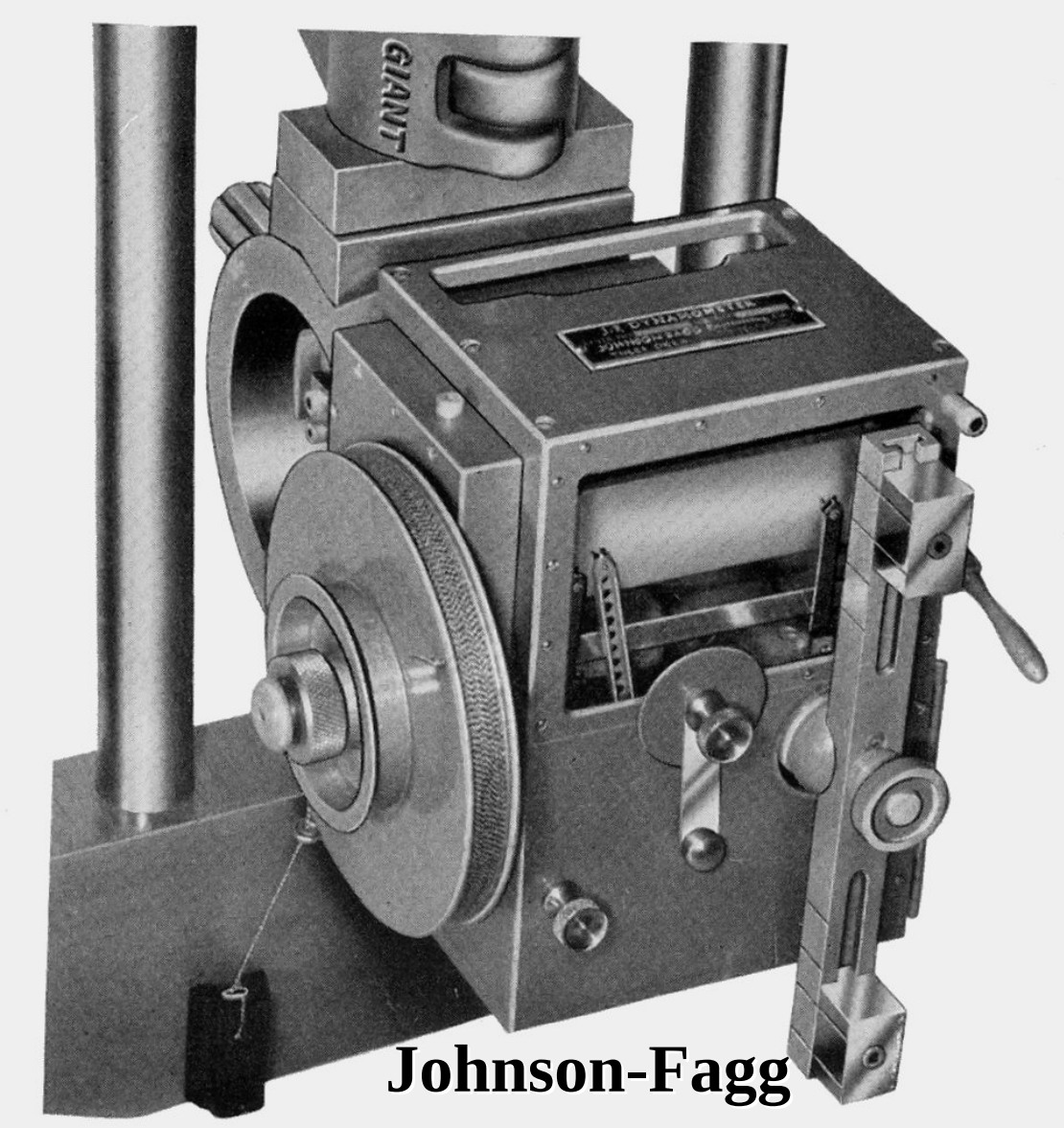
What is Force or Load?

1. Weight of the rods in fluid, **Wrf**, is a force.
2. Rods have weight due to gravity.
3. Rod Load is the amount of force that the Earth gravity exerts on the rod's mass.
4. ***Gravity*** pulls the rods down toward the center of the Earth.

   When you step on a **bathroom scale**, you exert a force on the scale. The force you apply to the scale compresses a spring, which moves the needle.

Dynamometers are used to determine the Rod Load, PRL, during a Stroke?

Popular 1950's Portable Dynamometer



Johnson-Fagg

Disadvantages:

1) Recorded position was distorted

2) Installation of this dynamometer between the polished rod clamp and carrier bar was difficult and time consuming

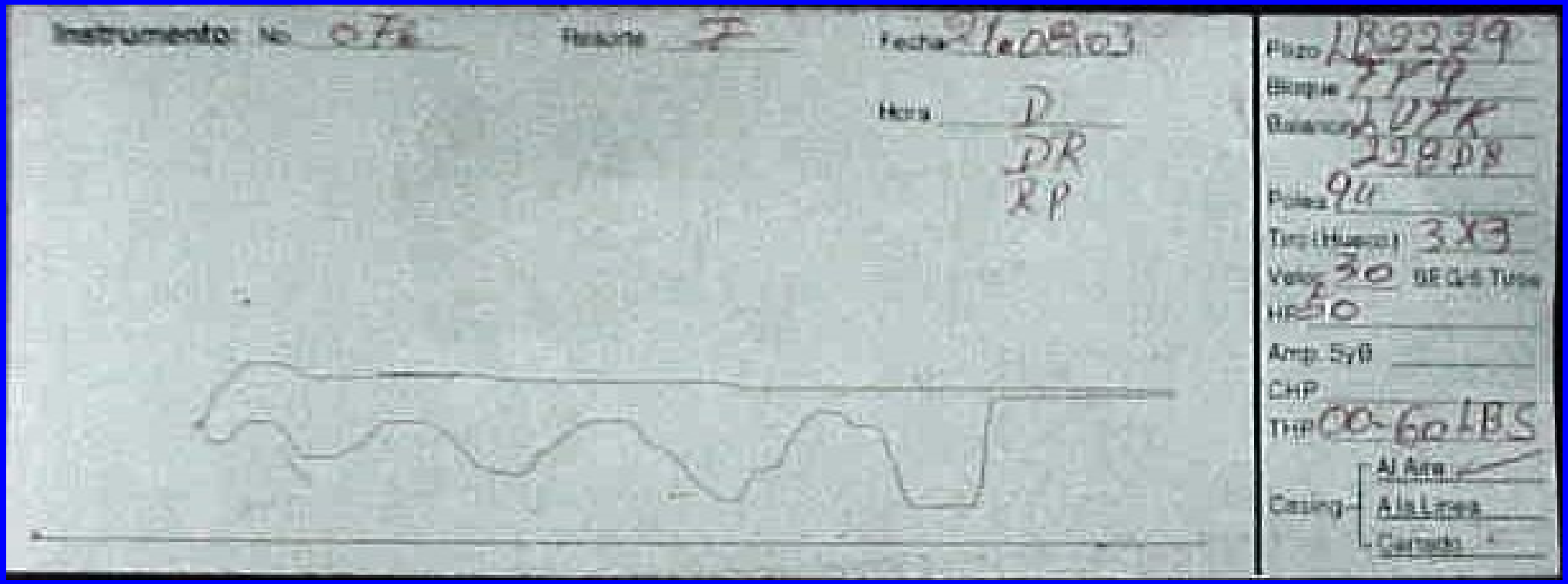
Polished Rod Load Compressed Steel Rings

Popular 1950's Portable Dynamometer

1. Integral Hydraulic pump extends two pistons supporting the load using hydraulic pressure
2. Calibrated springs in the registration unit convert the hydraulic pressure into load
3. String attached to the wellhead turns the registration unit in proportion to the polished rod position

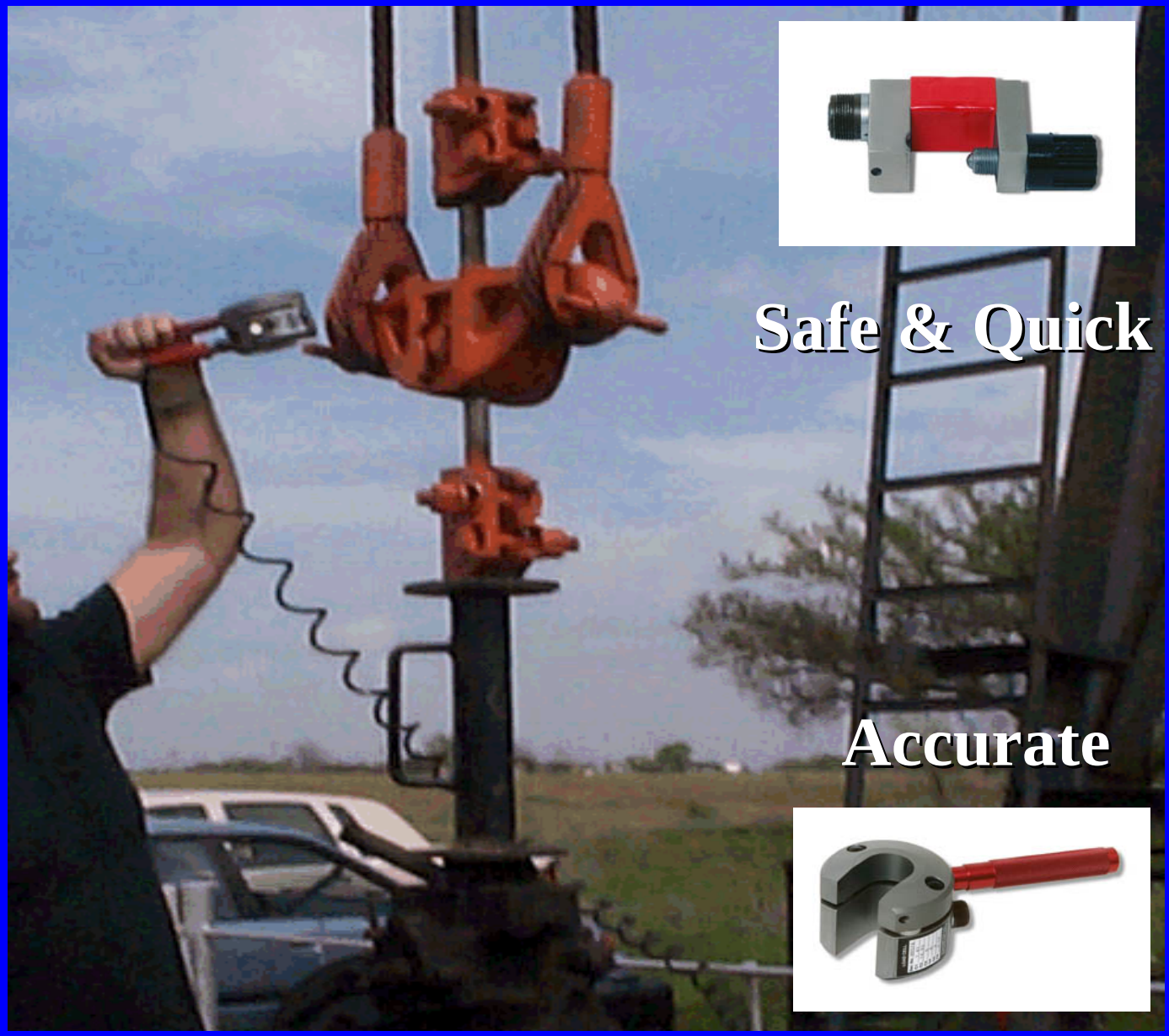
Inaccurate load measurement of up to 40% is a documented problem when using the Leutert

Example Leutert Dynamometer Card



1. Scribed load and position onto the wax dynamometer card for each stroke
2. Disadvantage of wax dynamometer card systems is that the load and position traces have to be tediously digitized by hand, before any detailed analysis can be performed

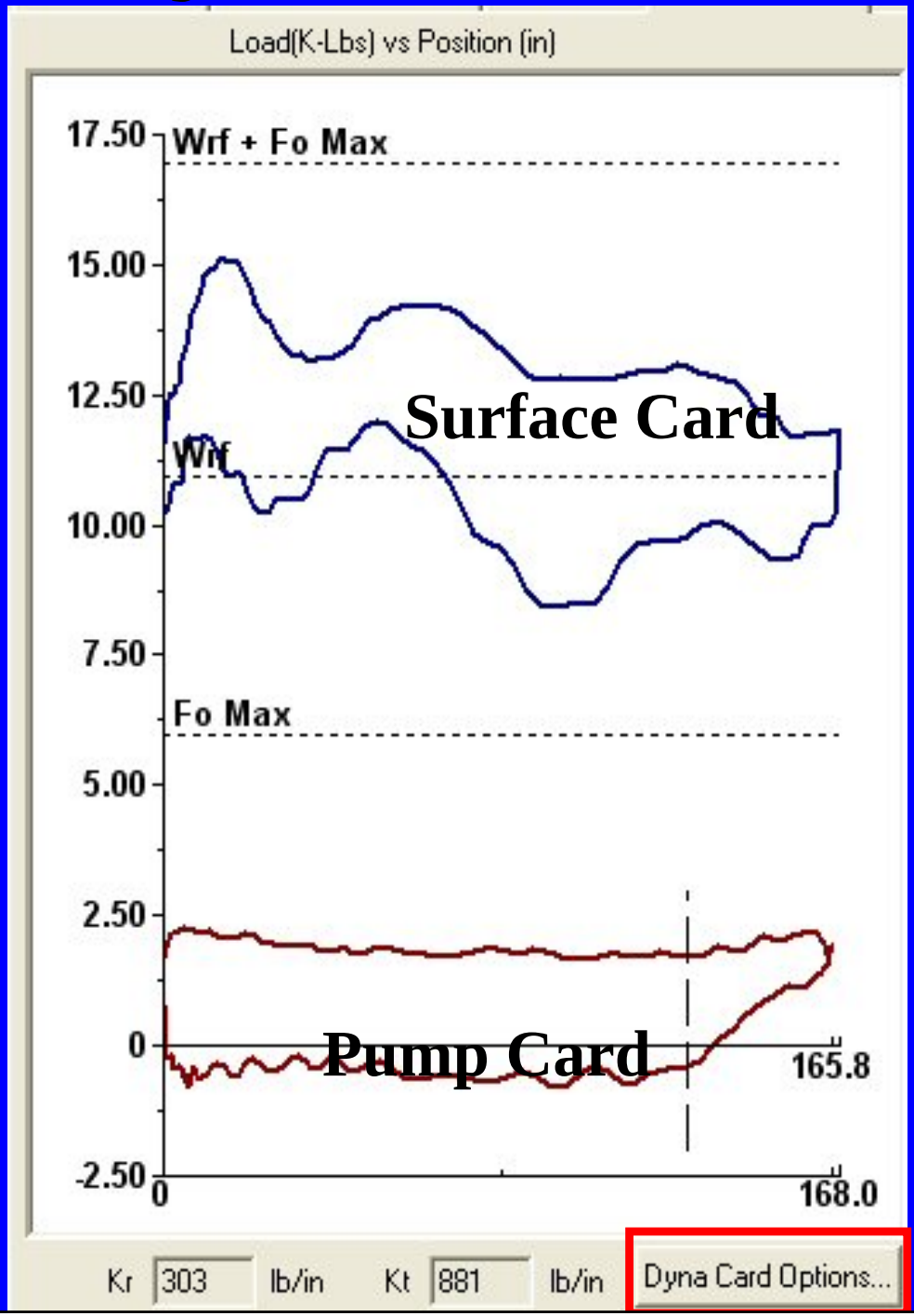
Use Any of these Dynamometer Transducers to Perform a Dynamometer Survey



Safe & Quick

Accurate

Dynamometer Card Definition

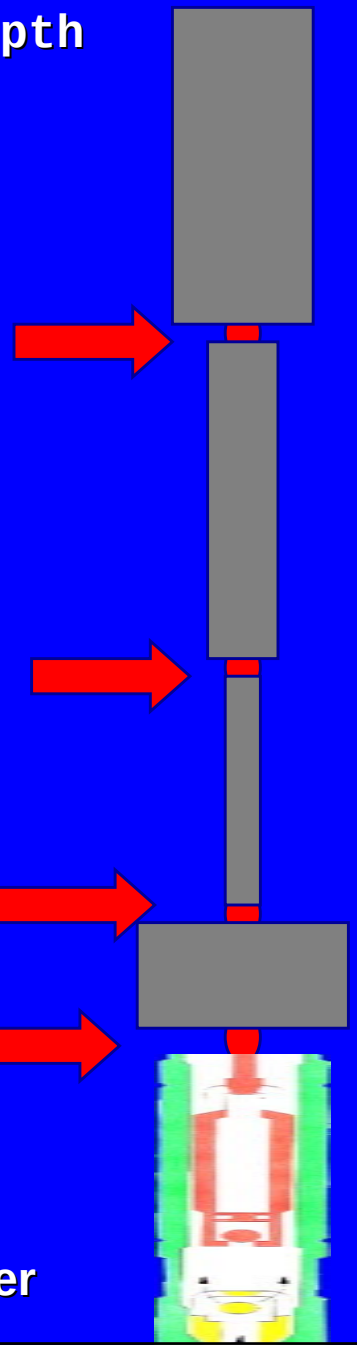


1) Surface dynamometer card is the plot of the measured rod loads at the various positions throughout a complete stroke; the load is usually displayed in pounds of force and the position is usually displayed in inches.

2) Pump dynamometer card is a plot of the calculated loads at various positions of pump stroke and represents the fluid load the pump applies to the bottom of the rod string.

1986 Glen Albert Developed an Electronic Downhole Dynamometer – Used by SANDIA

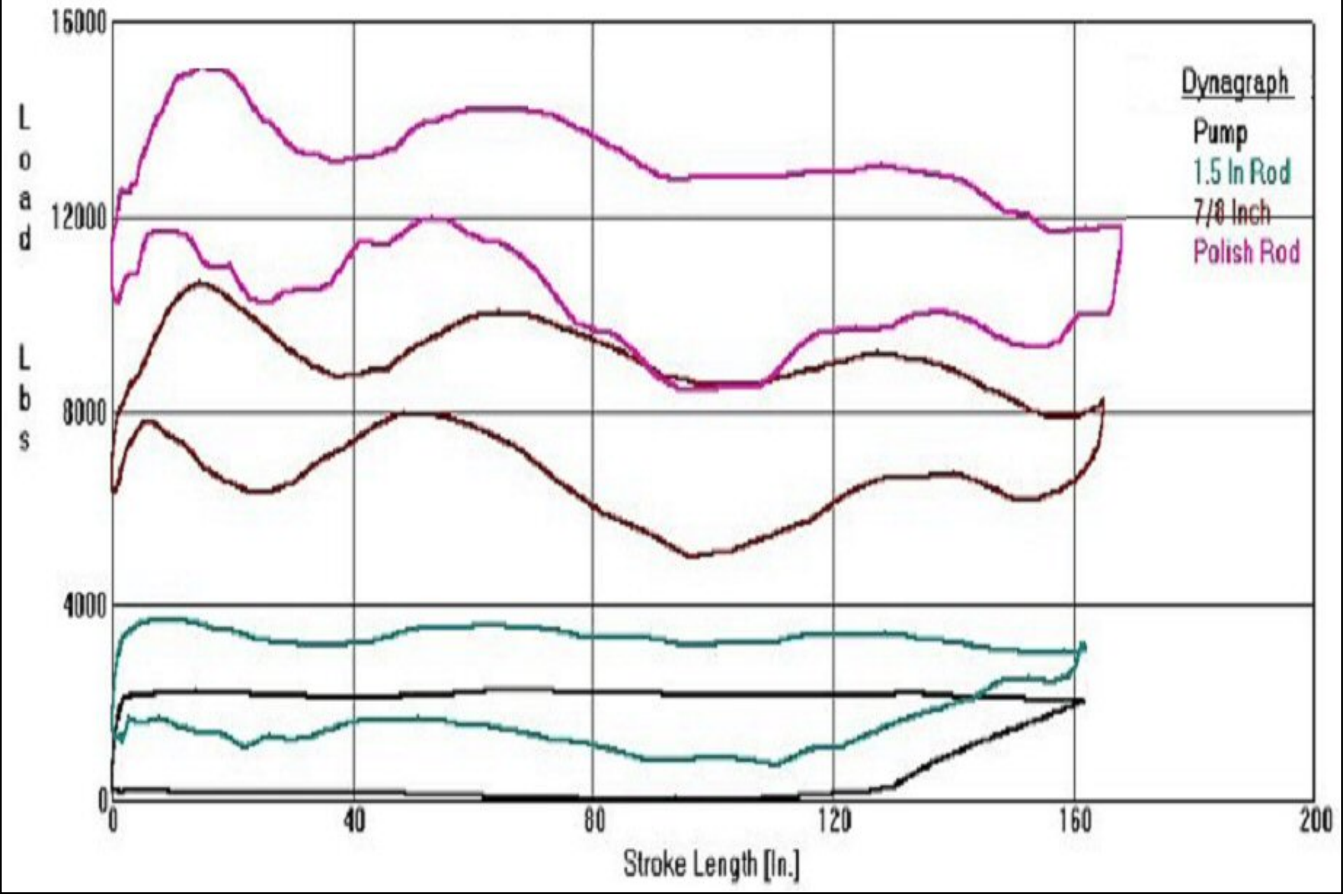
-Size-	-Description-	Length	Ea.-	-Number-	-Cum.Depth
1.5"	Polished Rod	30'		1	0'
1.0"	API Grade 'D' Steel	4'		1	4'
1.0"	API Grade 'D' Steel	2'		1	6'
1.0"	API Grade 'D' Steel	6'		1	10'
1.0"	API Grade 'D' Steel	25'		60	1510'
	DHLC Tool #5	2'		1	1512'
0.875"	API Grade 'D' Steel	25'		64	3112'
	DHLC Tool #4	2'		1	3114'
0.75"	API Grade 'D' Steel	25'		65	4739'
	DHLC Tool #3	2'		1	4741'
1.5"	Sinkerbars	25'		10	4991'
	DHLC Tool #2	2'		1	4993'
	Flexbar Stabilizer	4'		1	4997'
	2” Pump	24'			5060'



Well Depth: 5278' w/ Casing of 5.5" to 5090'
Tubing: 2.875" to 5060', seating nipple – 5060'
, tubing anchor - 4970'

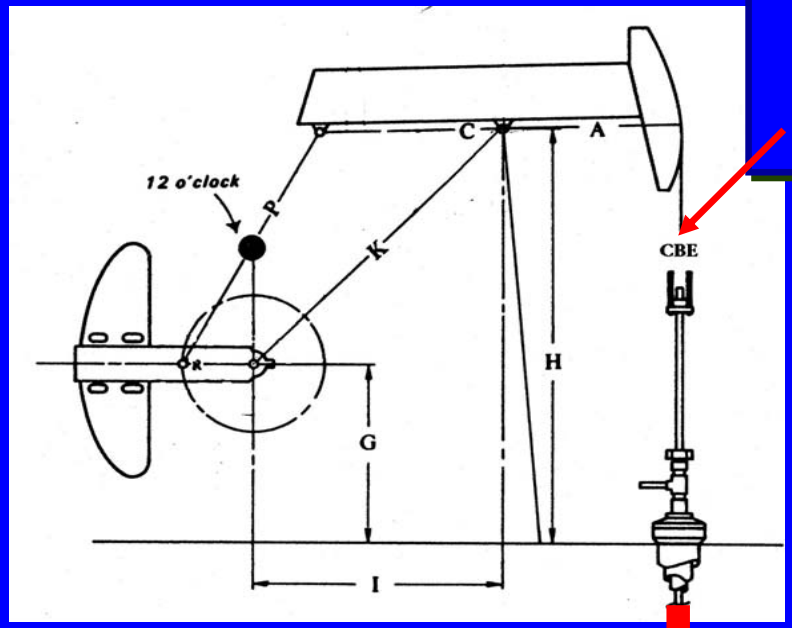
1936 W.E. Gilbert of Shell developed a mechanical downhole dynamometer

SANDIA Downhole Dynamometer

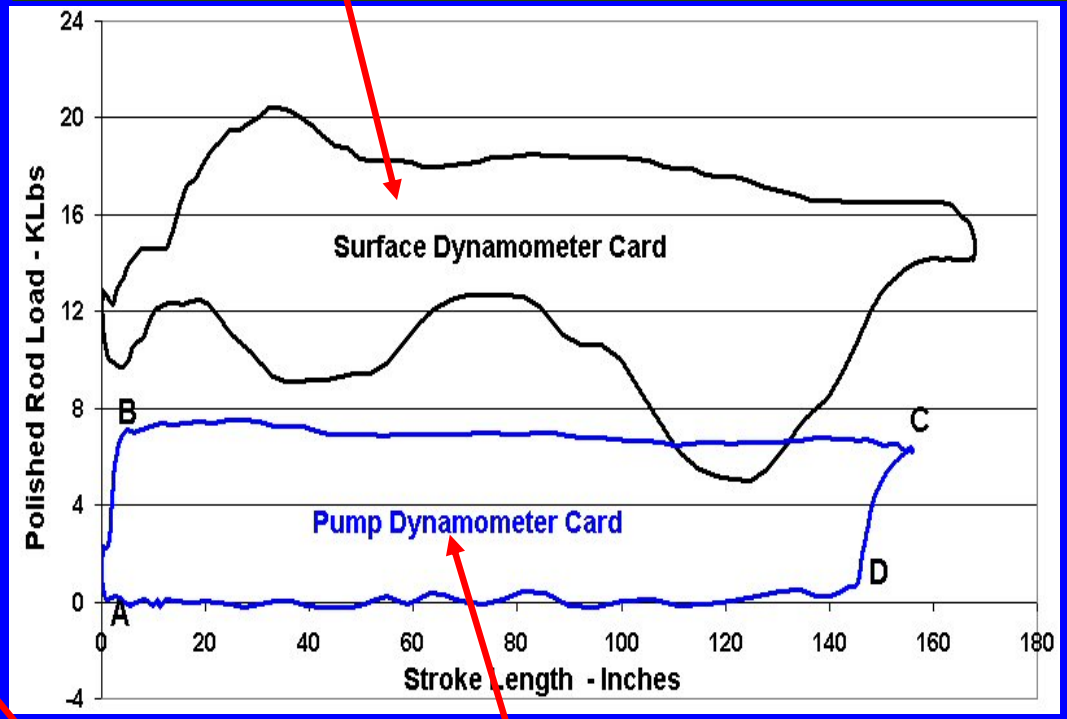


Surface Load
14,820 Lbs at
Top of Stroke

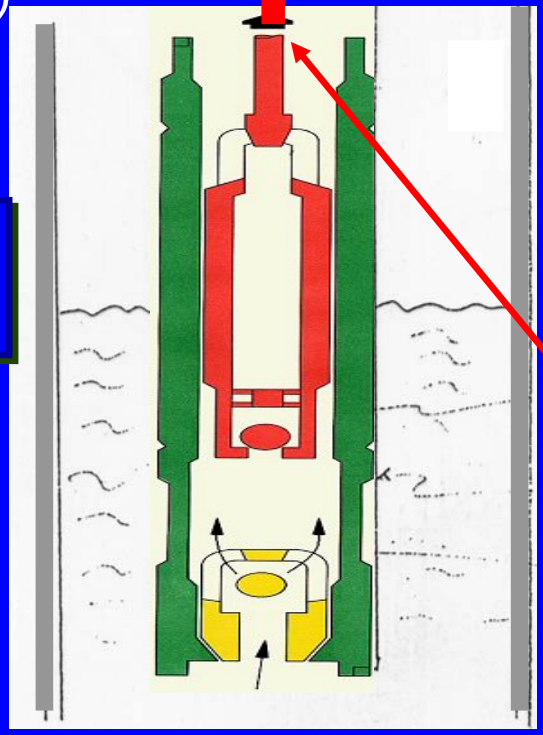
1960s, S.G. Gibbs
Mathematically "Wave Down"



Surface Dynamometer Card: Load vs. Polished Rod Position



Sucker Rods:
10,434 Lbs (Wrf)

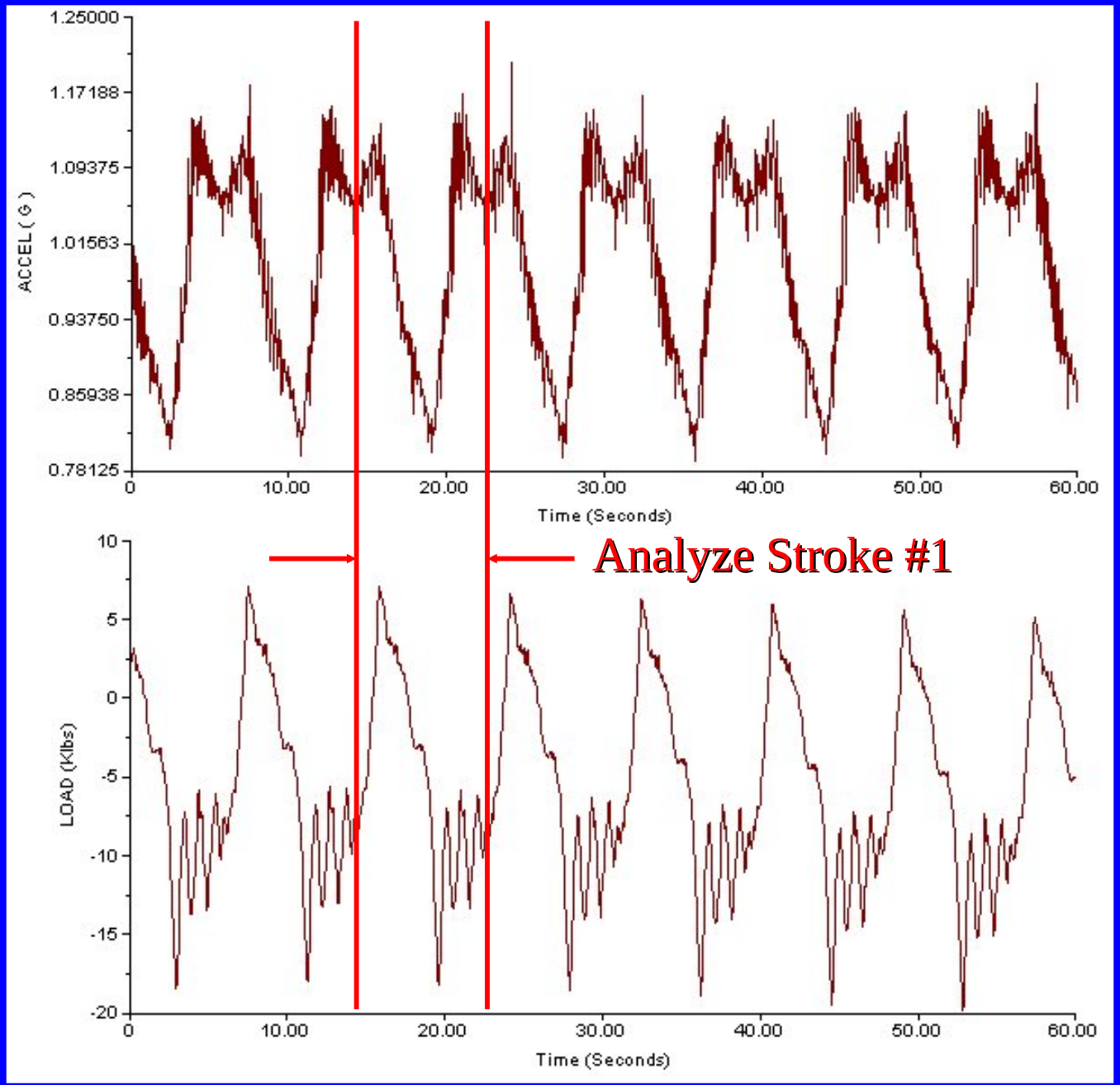


Fluid Load 6,280
Lbs at point C

Fluid Load 0
Lbs at point D

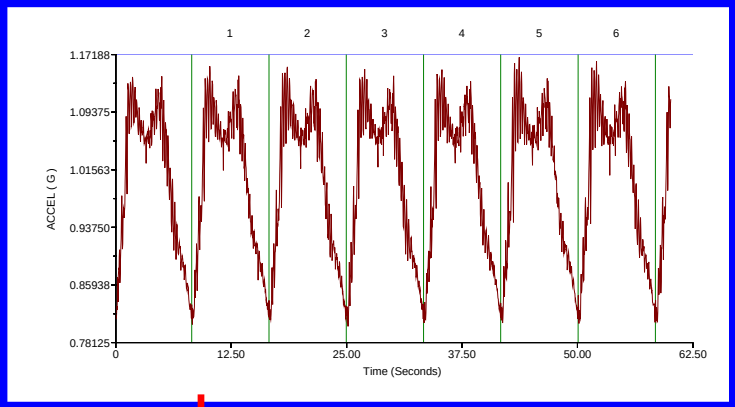
Pump Dynamometer Card: Load vs. Pump Rod Position

Acquire Load & Acceleration Versus Time

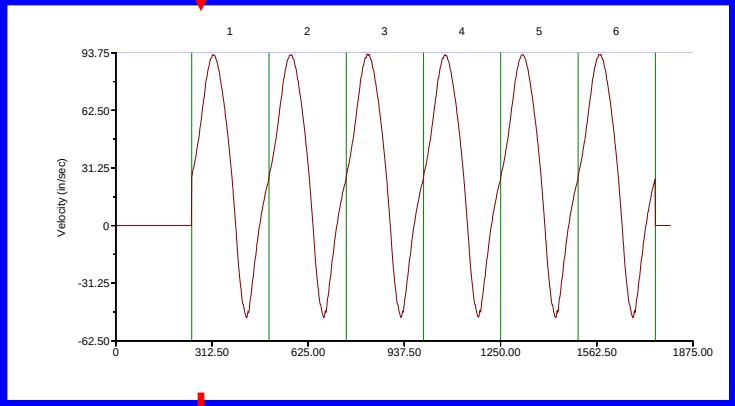


Identify individual strokes and process acceleration data to get velocity and position

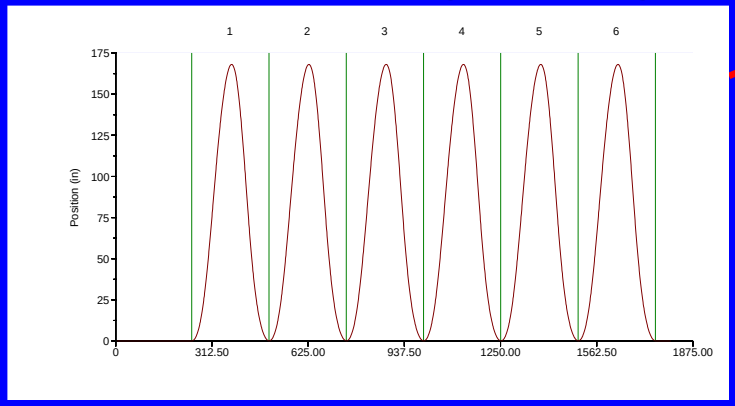
Acceleration



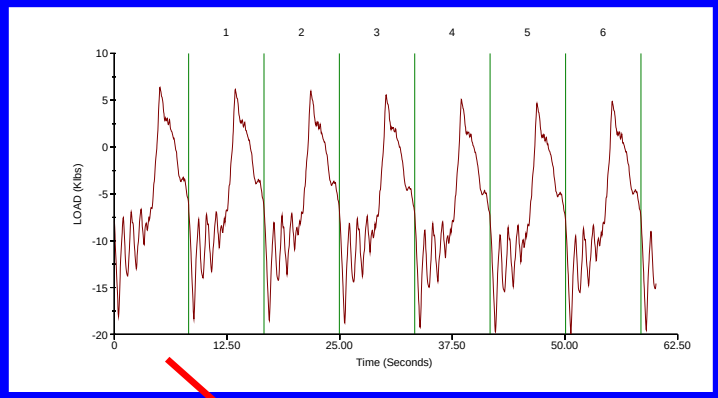
Integrate once

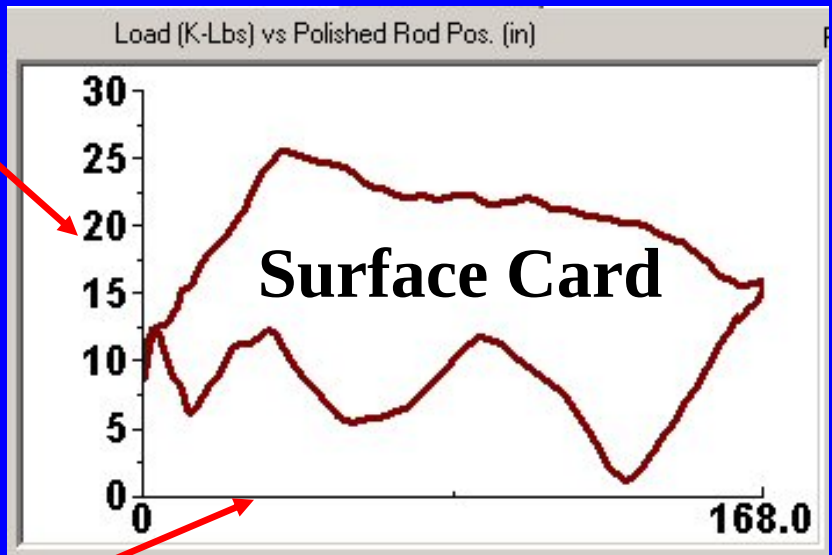


Integrate again

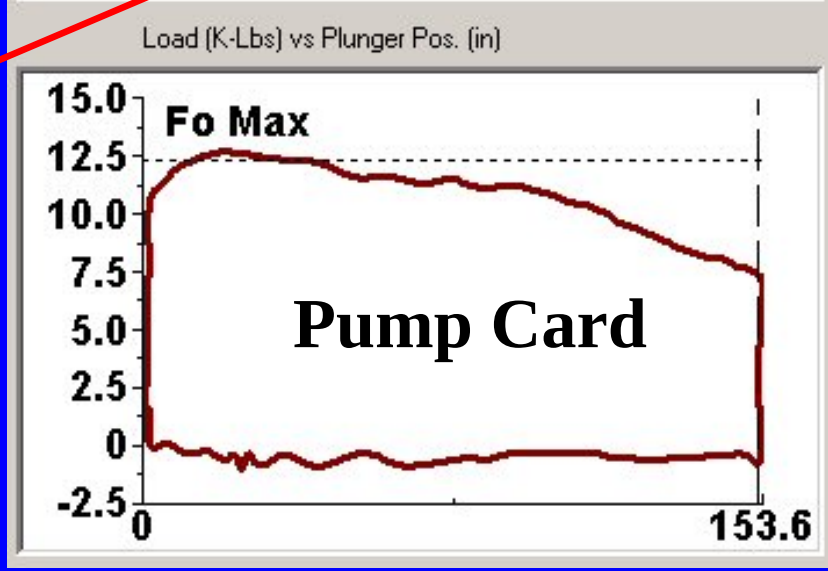


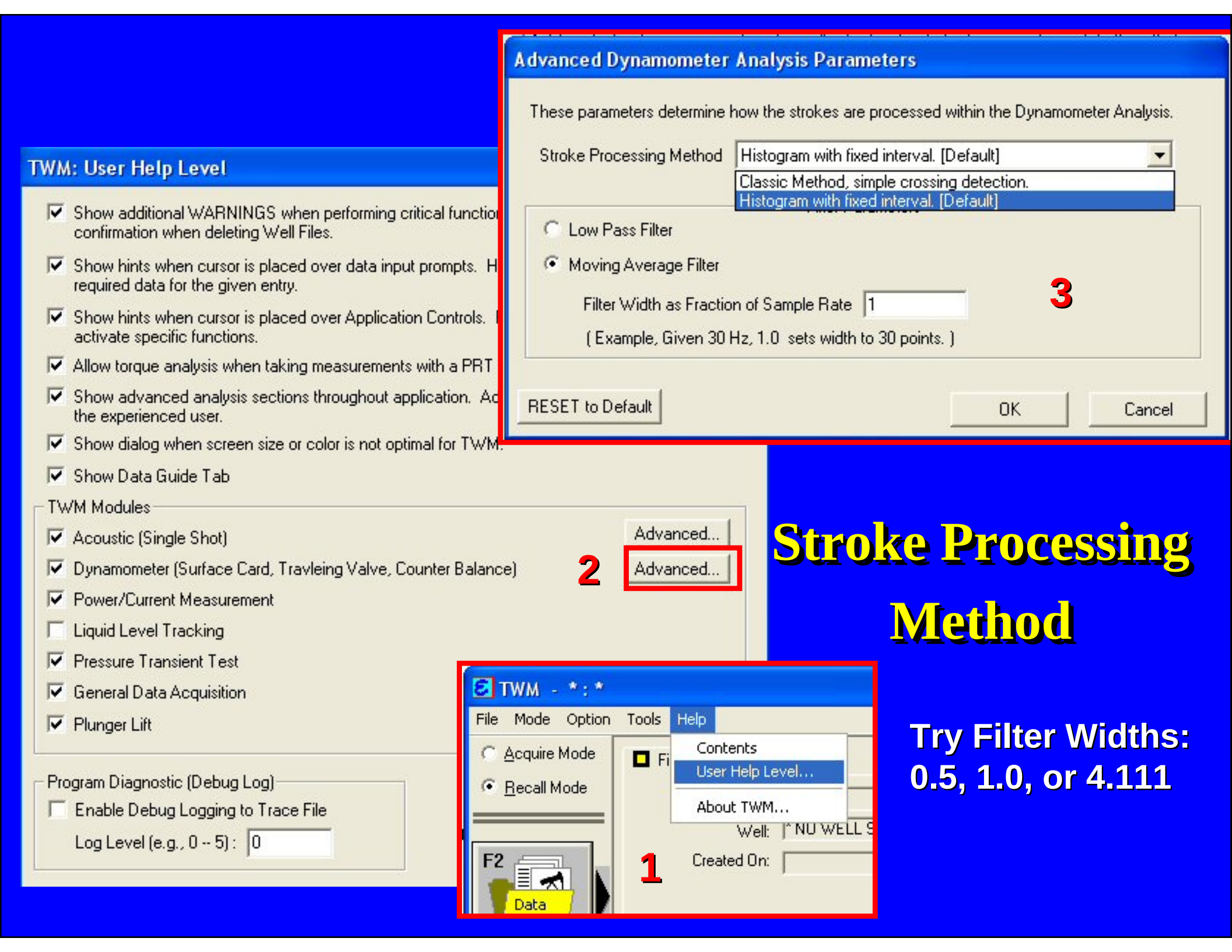
Load



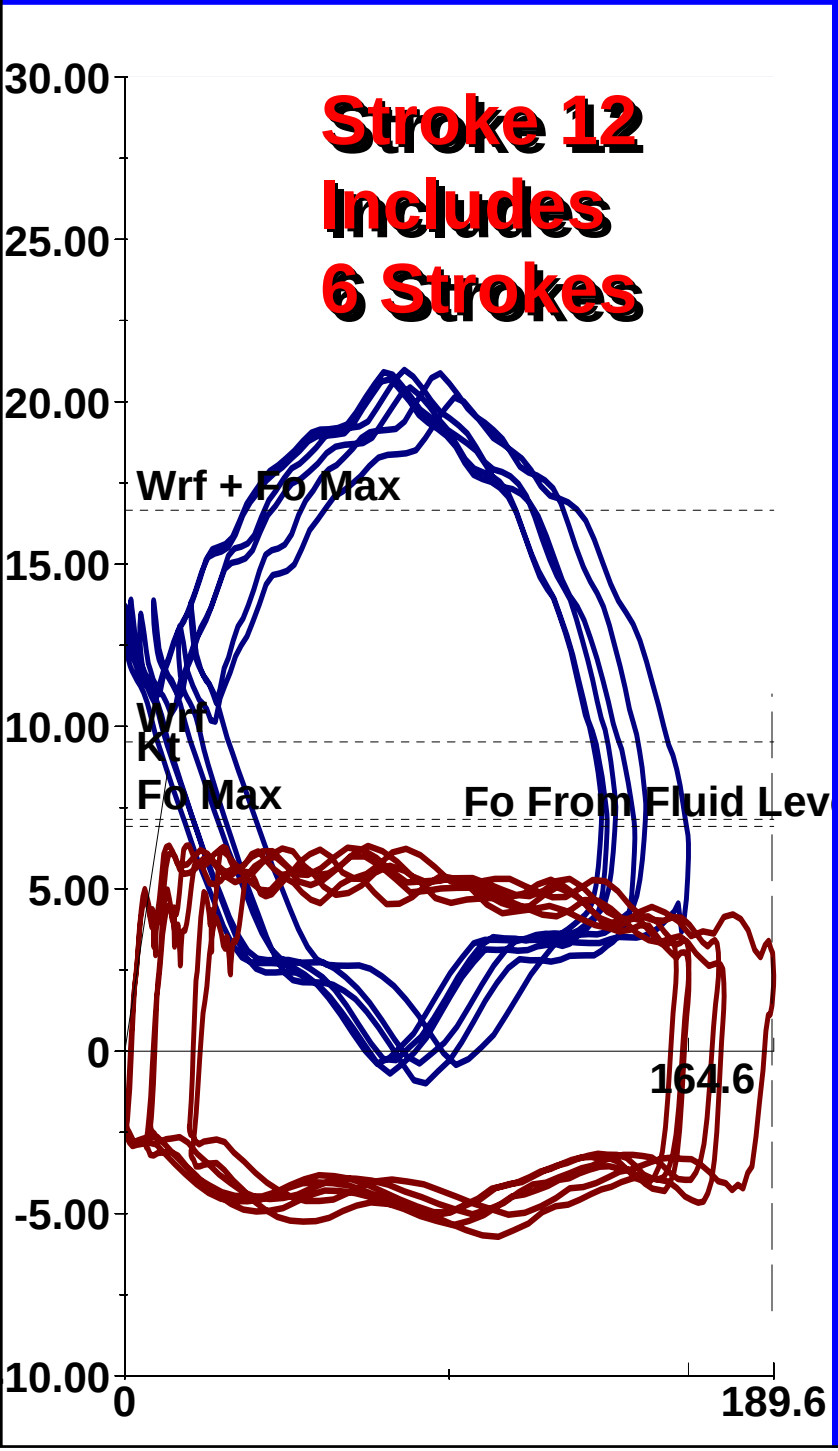


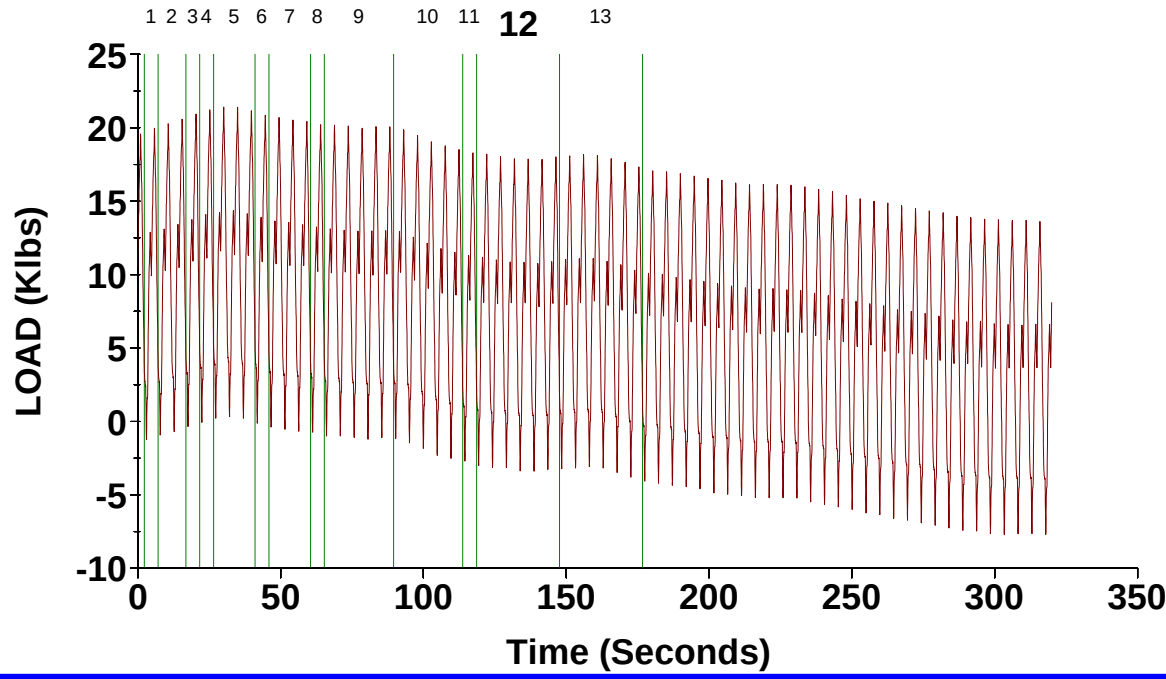
Wave Down To Pump

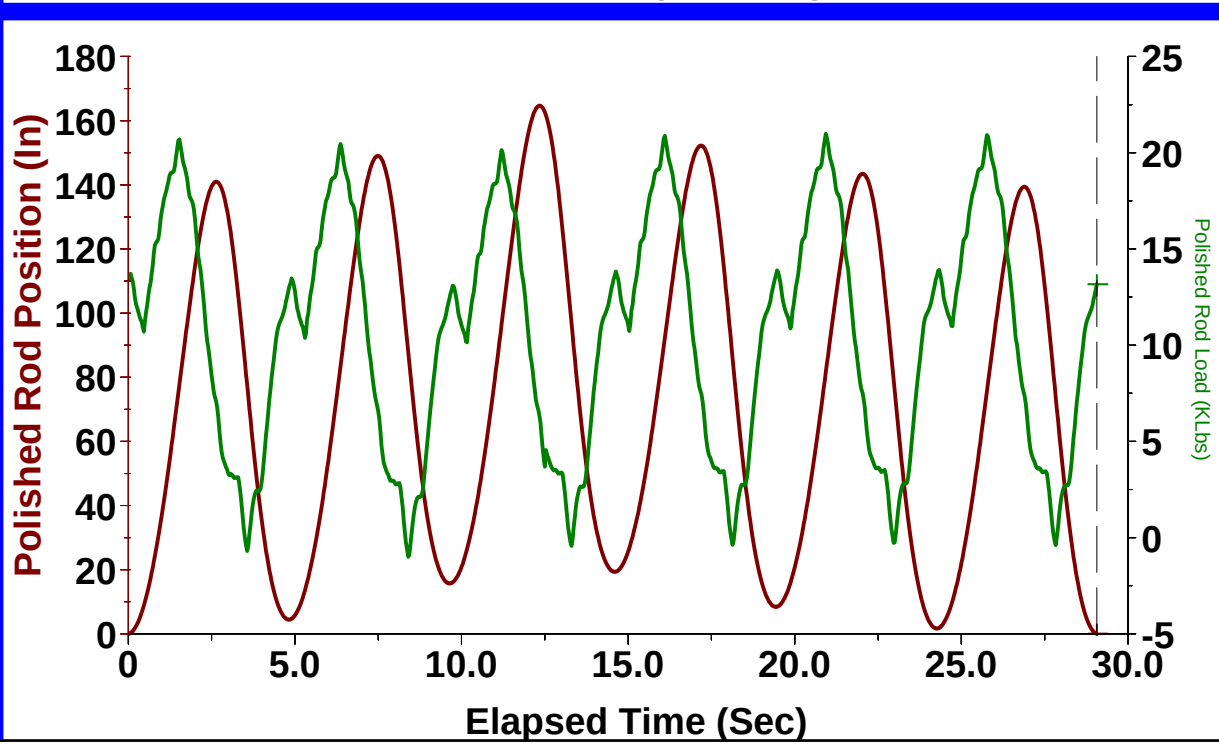



Advanced Dynamometer Analysis Parameters
These parameters determine how the strokes are processed within the Dynamometer Analysis.
Stroke Processing Method
Histogram with fixed interval. [Default]
Classic Method, simple crossing detection.
Histogram with fixed interval. [Default]
Low Pass Filter
Moving Average Filter
Filter Width as Fraction of Sample Rate
1
(Example, Given 30 Hz, 1.0 sets width to 30 points.)
3
RESET to Default
OK
Cancel
TWM: User Help Level
Show additional WARNINGS when performing critical functio
confirmation when deleting Well Files.
Show hints when cursor is placed over data input prompts. H
required data for the given entry.
Show hints when cursor is placed over Application Controls.
activate specific functions.
Allow torque analysis when taking measurements with a PRT
Show advanced analysis sections throughout application. Ac
the experienced user.
Show dialog when screen size or color is not optimal for TWM.
Show Data Guide Tab
TWM Modules
Acoustic (Single Shot)
Dynamometer (Surface Card, Travleing Valve, Counter Balance)
Power/Current Measurement
Liquid Level Tracking
Pressure Transient Test
General Data Acquisition
Plunger Lift
Advanced...
Advanced...
2
Program Diagnostic (Debug Log)
Enable Debug Logging to Trace File
Log Level (e.g., 0 -- 5) :
0
TWM - *:*
File
Mode
Option
Tools
Help
Acquire Mode
Recall Mode
Contents
User Help Level...
About TWM...
Well:
Created On:
F2
Data
1
Stroke Processing Method
Try Filter Widths:
0.5, 1.0, or 4.111

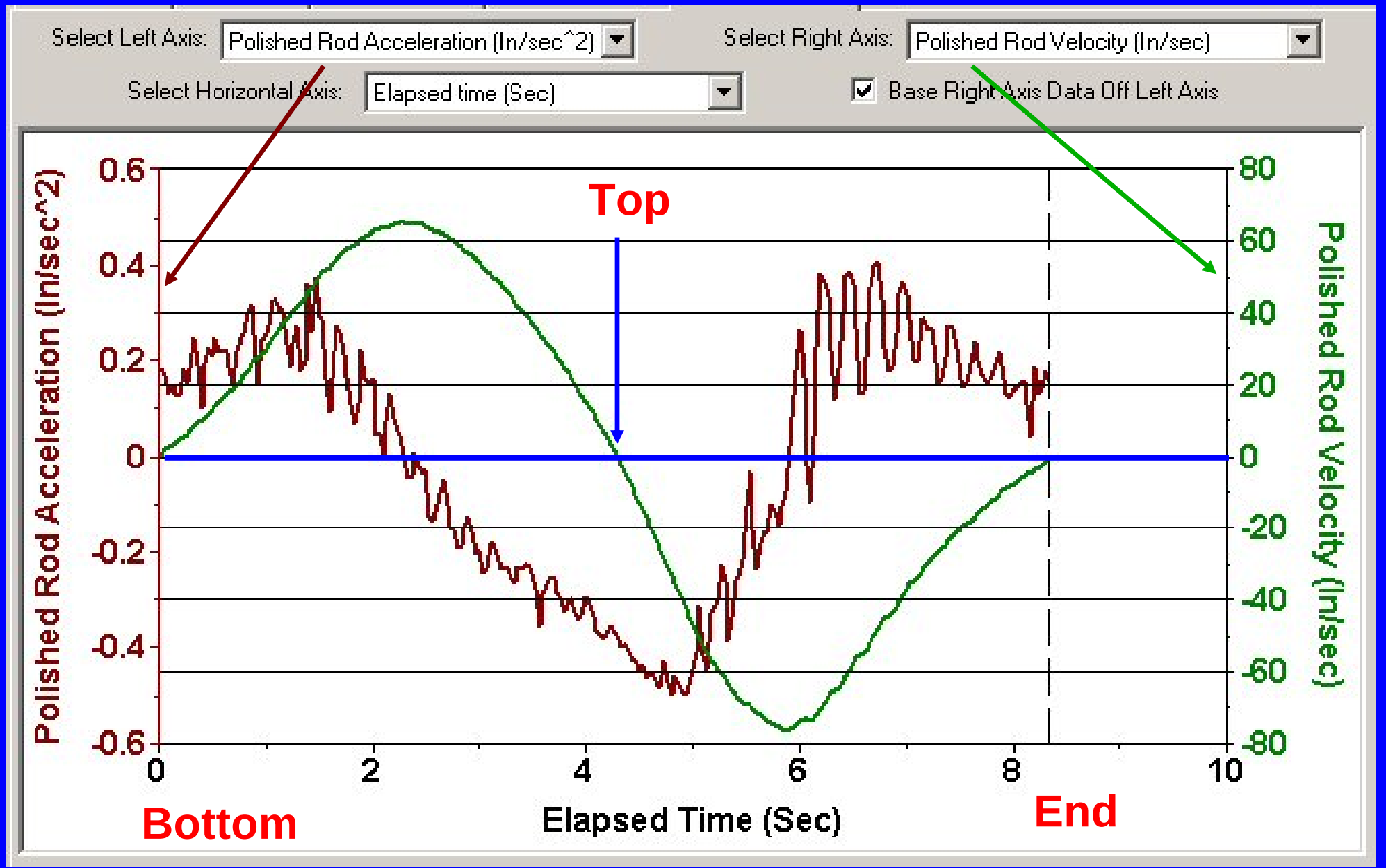
Classic Stroke Processing Method



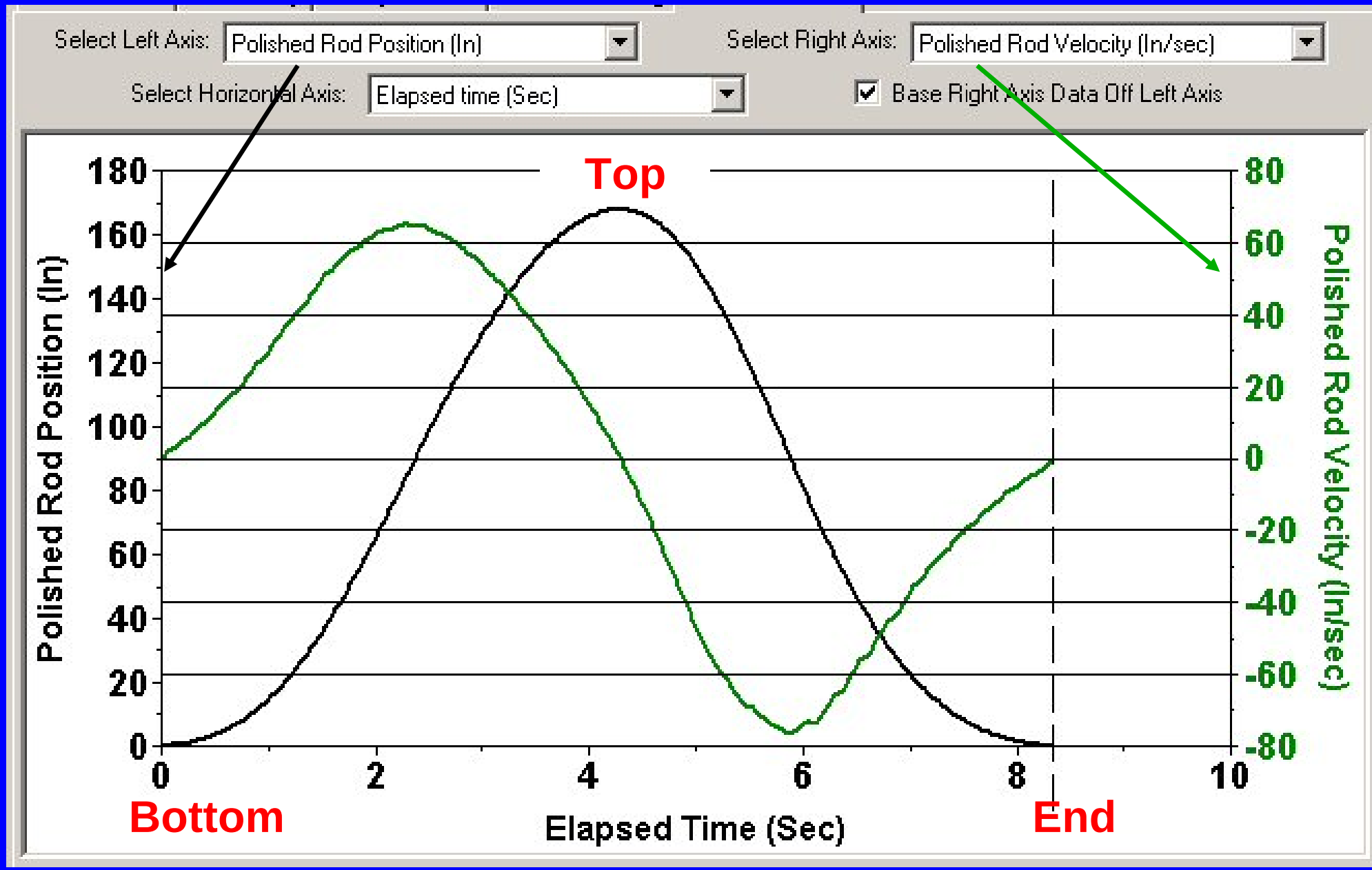




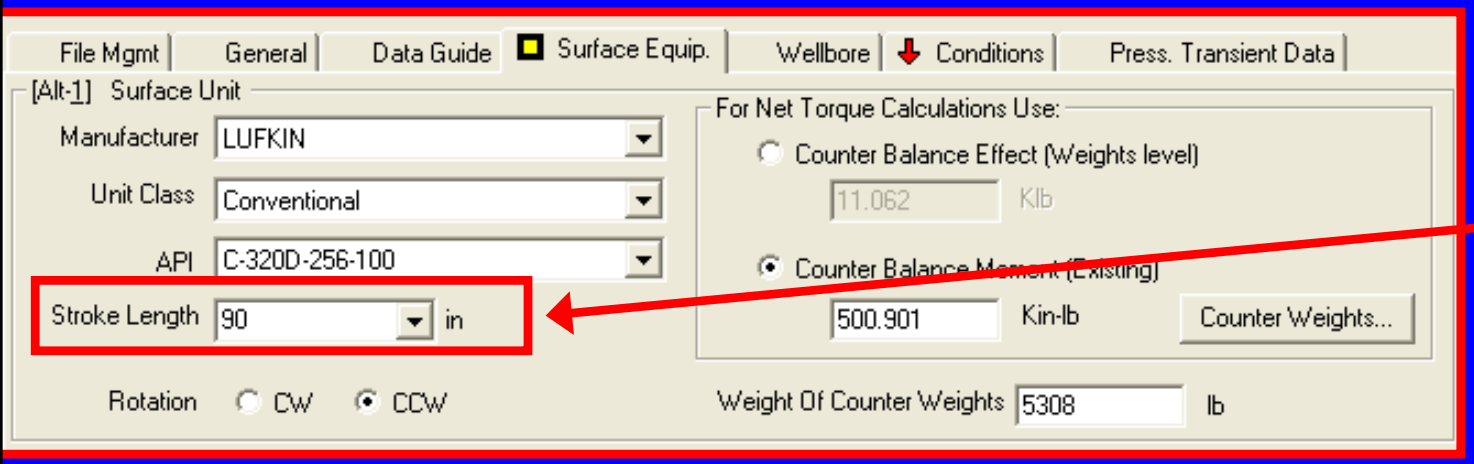
One Stroke of Polished Rod Acceleration Integrated to Determine Polished Rod Velocity



Polished Rod Velocity Integrated to Determine Polished Rod Position



Stroke Length 100.255” Calculated from Integration of Accelerometer Data

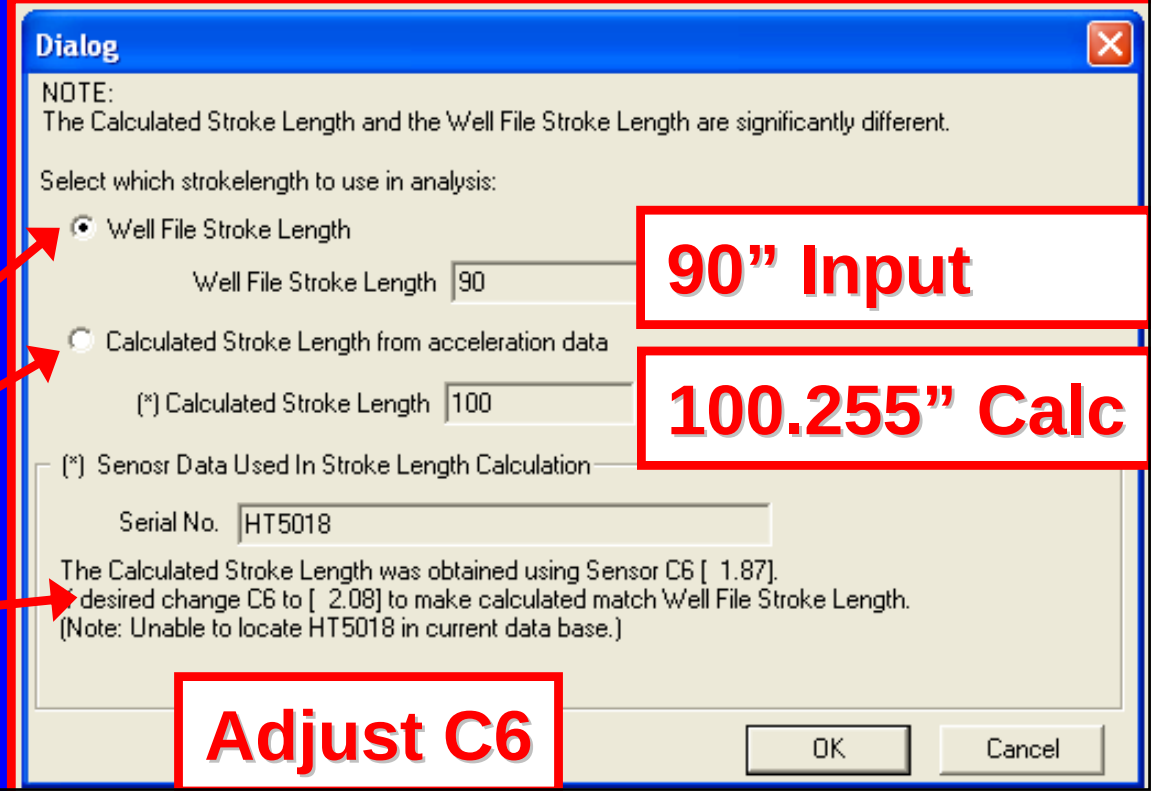


Leave the Stroke Length Blank and Stroke Length for Unit Calculated

Warning Displayed

If ERROR > 10% Between Well File and Calculated Stroke Length

3 Choices?



Surface Unit Not Selected and Stroke Length Left Blank

Left Stroke Blank so TWM Would Calculate

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

[Alt-1] Surface Unit

Manufacturer: (None)

Unit Class:

API:

Stroke Length: in

Rotation: CW CCW

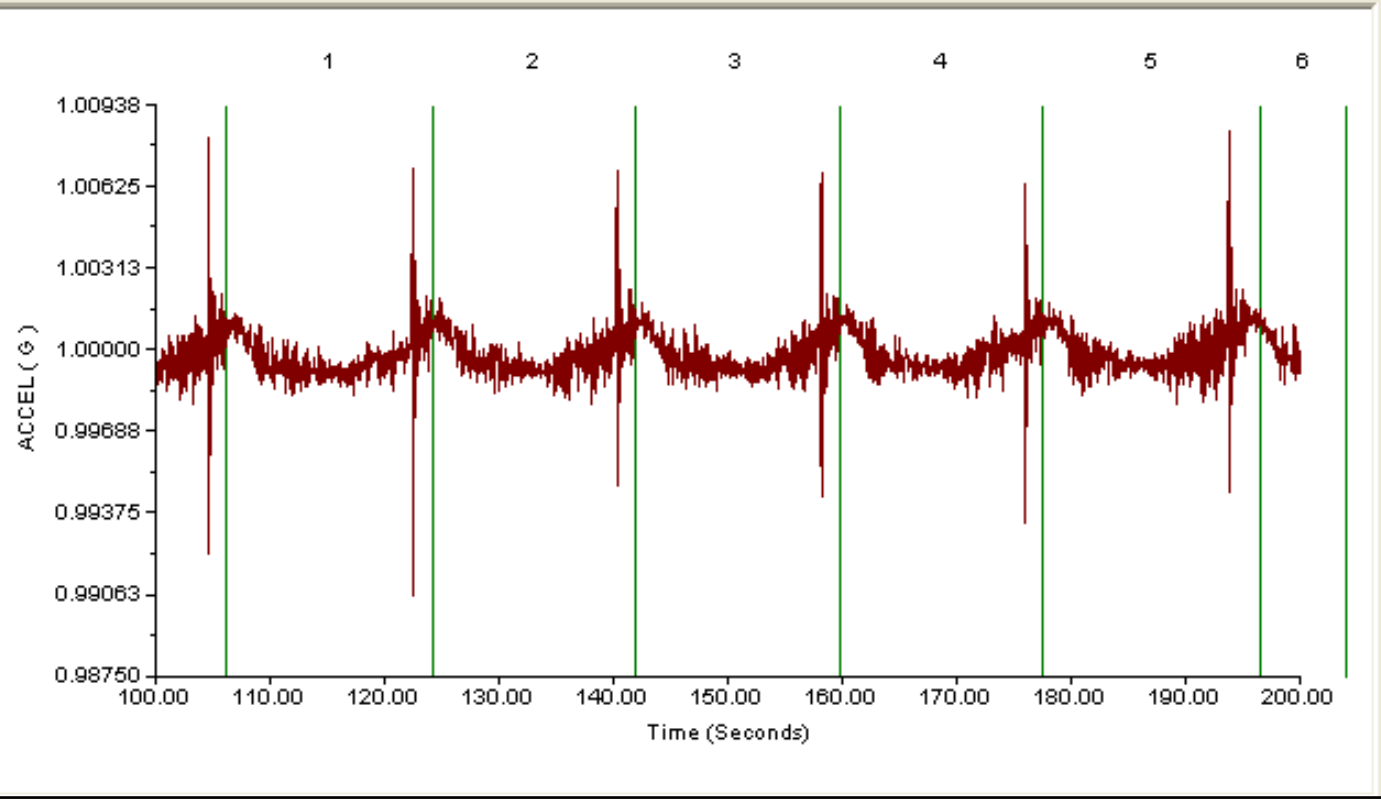
For Net Torque Calculations Use:

Counter Balance Effect (Weights level) Klb

Counter Balance Moment (Existing) Kin-lb Counter Weights...

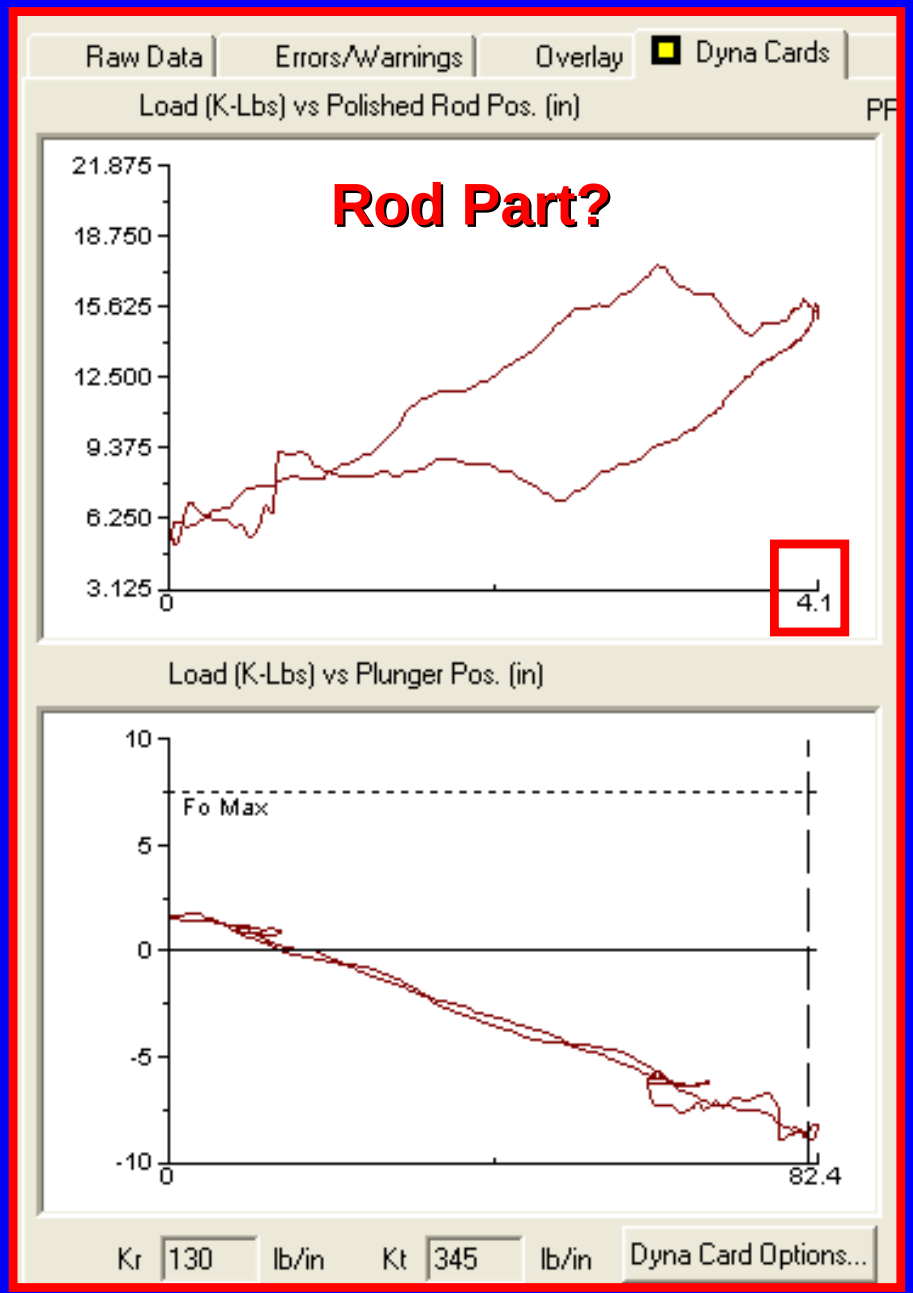
Raw Data | Errors/Warnings | Overlay | Dyna Cards | Rod Loading | Analysis Plot

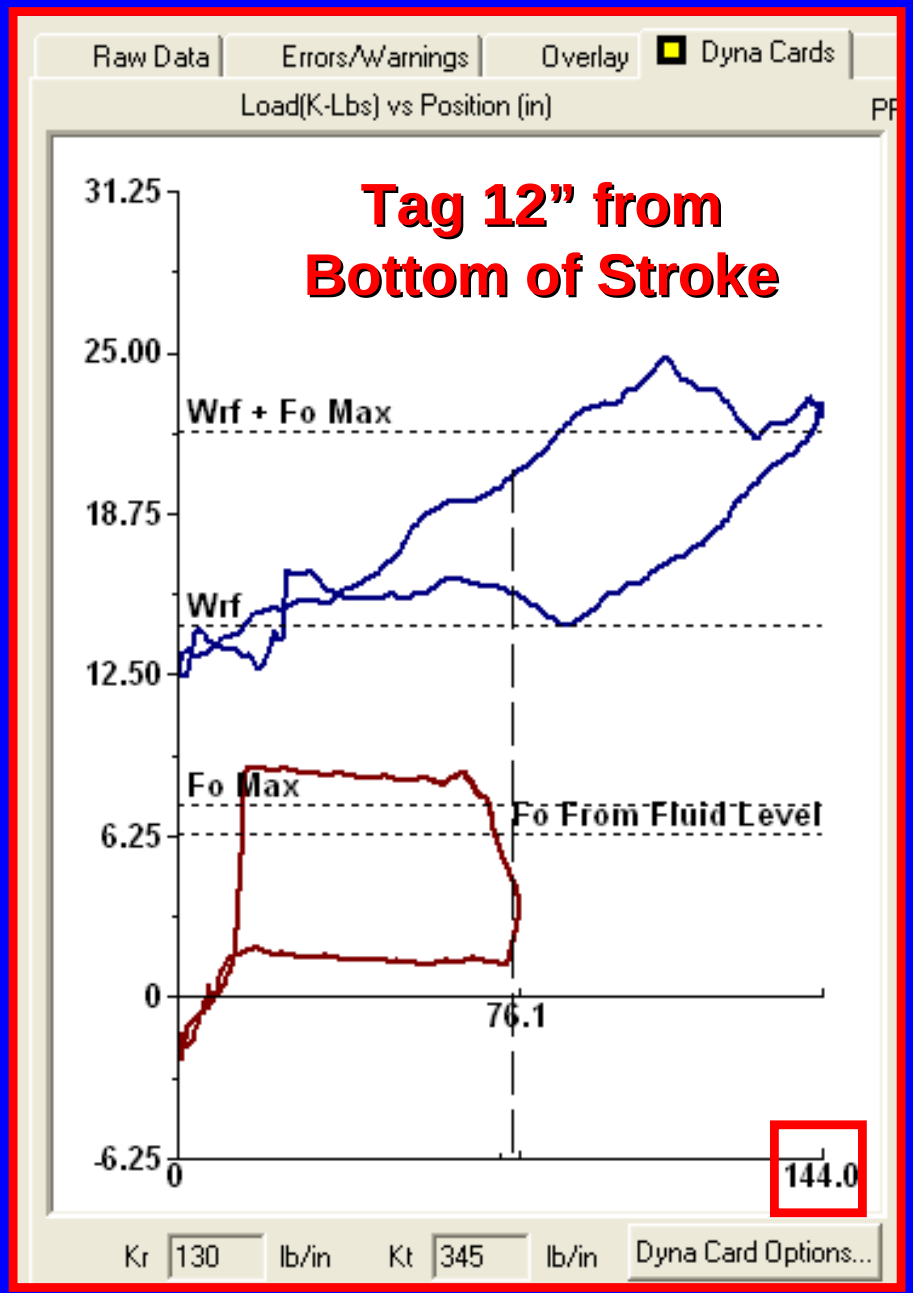
Select Graph: Acceleration



Hard Tag Near Bottom of Stroke Results in TWM Calculated Surface Stroke of 4.1”

What is Wrong with My Well?

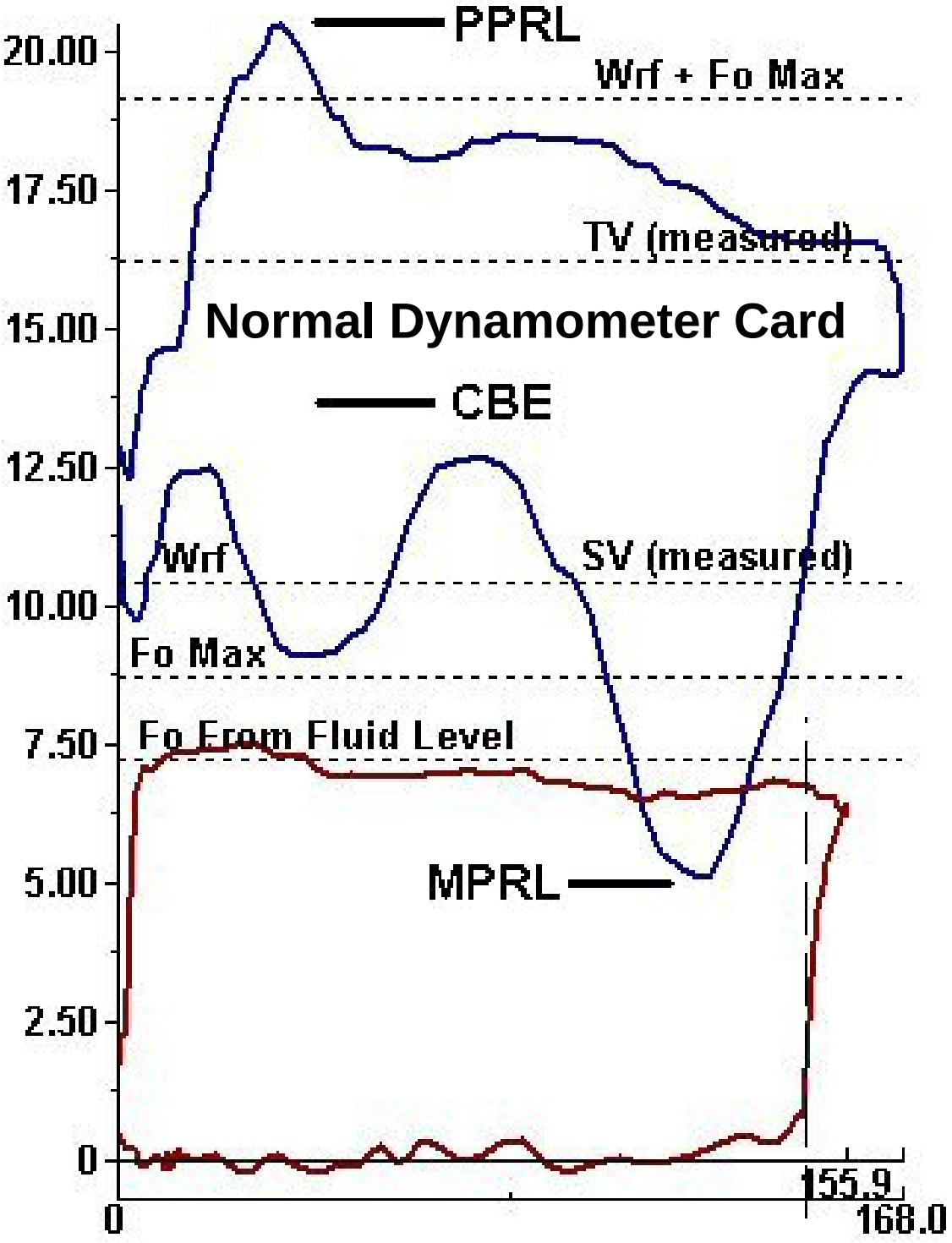




Sucker Rod Loads

Understanding six(6) basic loads are critical to analyzing the sucker rod pumping cycle:

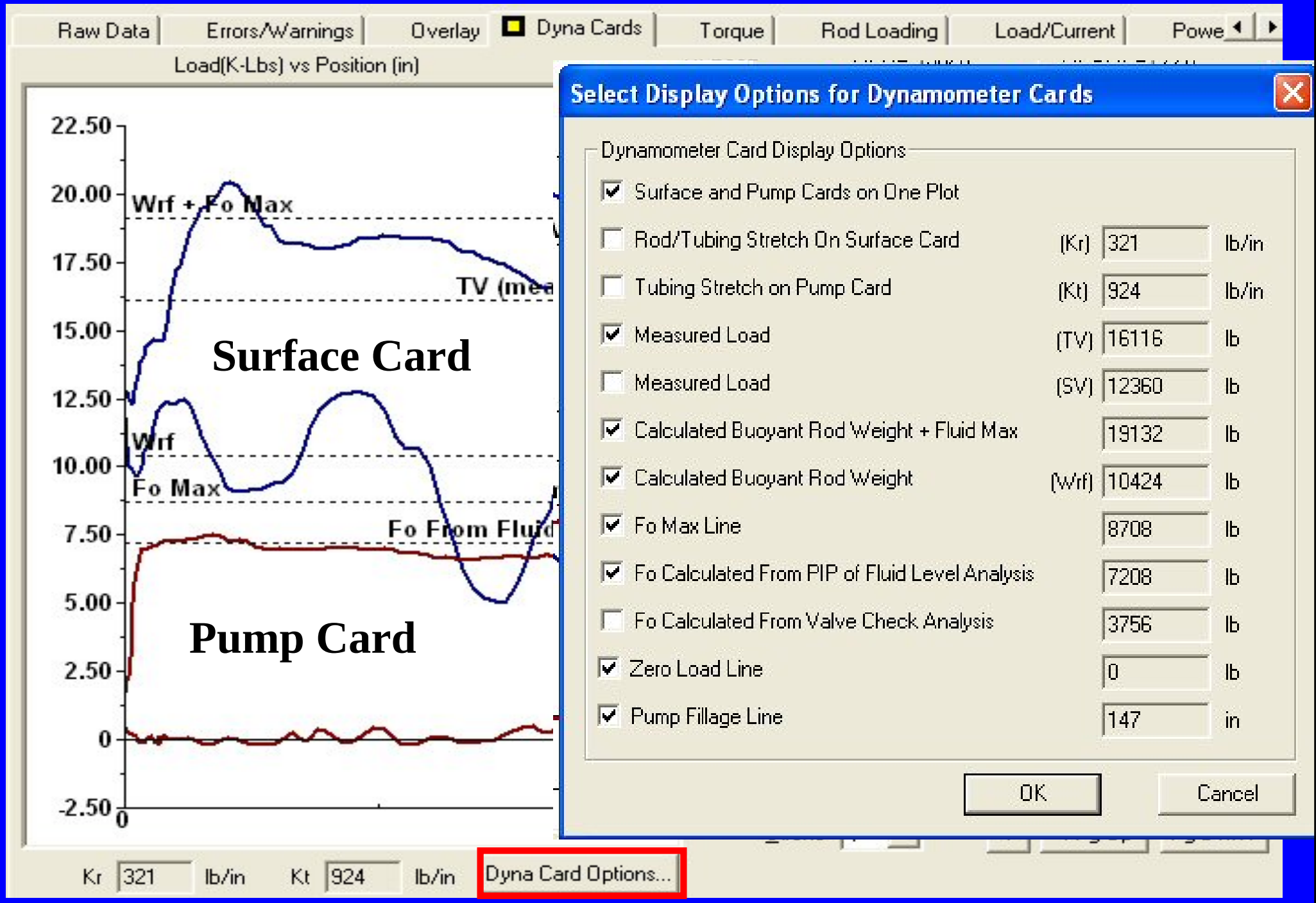
- Zero Load [0],
- Peak Polished Rod Load [PPRL],
- Minimum Polished Rod Load [MPRL],
- Counterbalance Effect [CBE],
- Standing Valve Load [SV], and the
- Traveling Valve Load [TV].



PPRL Peak Polished Rod Load experienced during a stroke.
Wrf + Fo Max (TV) Weight of Rods in Fluid plus the fluid load applied to the rods by the pump
CBE load at the polished rod due to the effect of the cranks and weights when horizontal.
Wrf (SV) Weight of Rods in Fluid, TV open and plunger is applying no load to the rods.
MPRL Minimum Polished Rod Load experienced during the pumping cycle.

LOAD RANGE (PPRL – MPRL) used in calculating % rod loading based on max and min sucker rod stresses and API Modified Goodman Guide

Dynamometer Survey Analysis



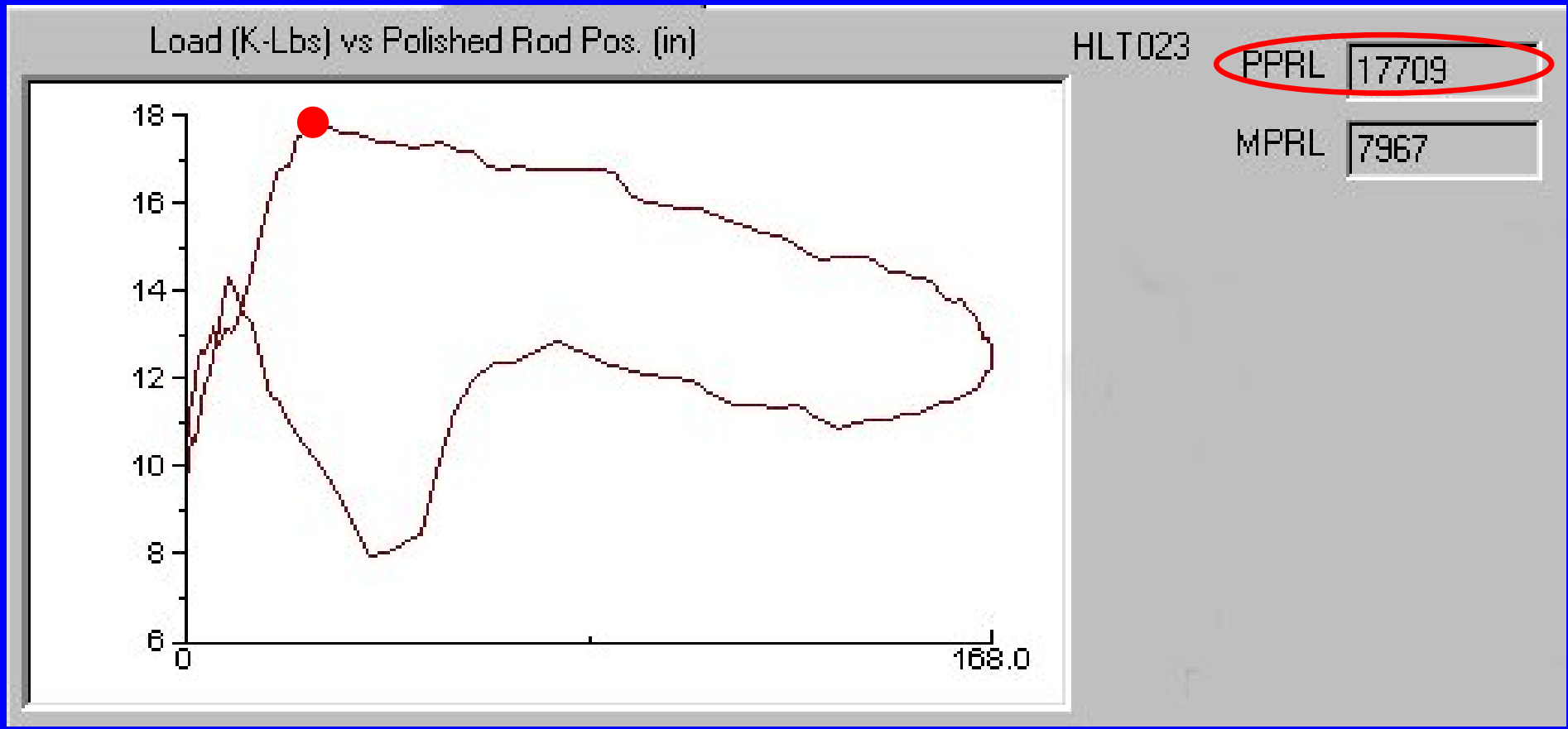
Zero Load Line

1) The zero load is the starting point.

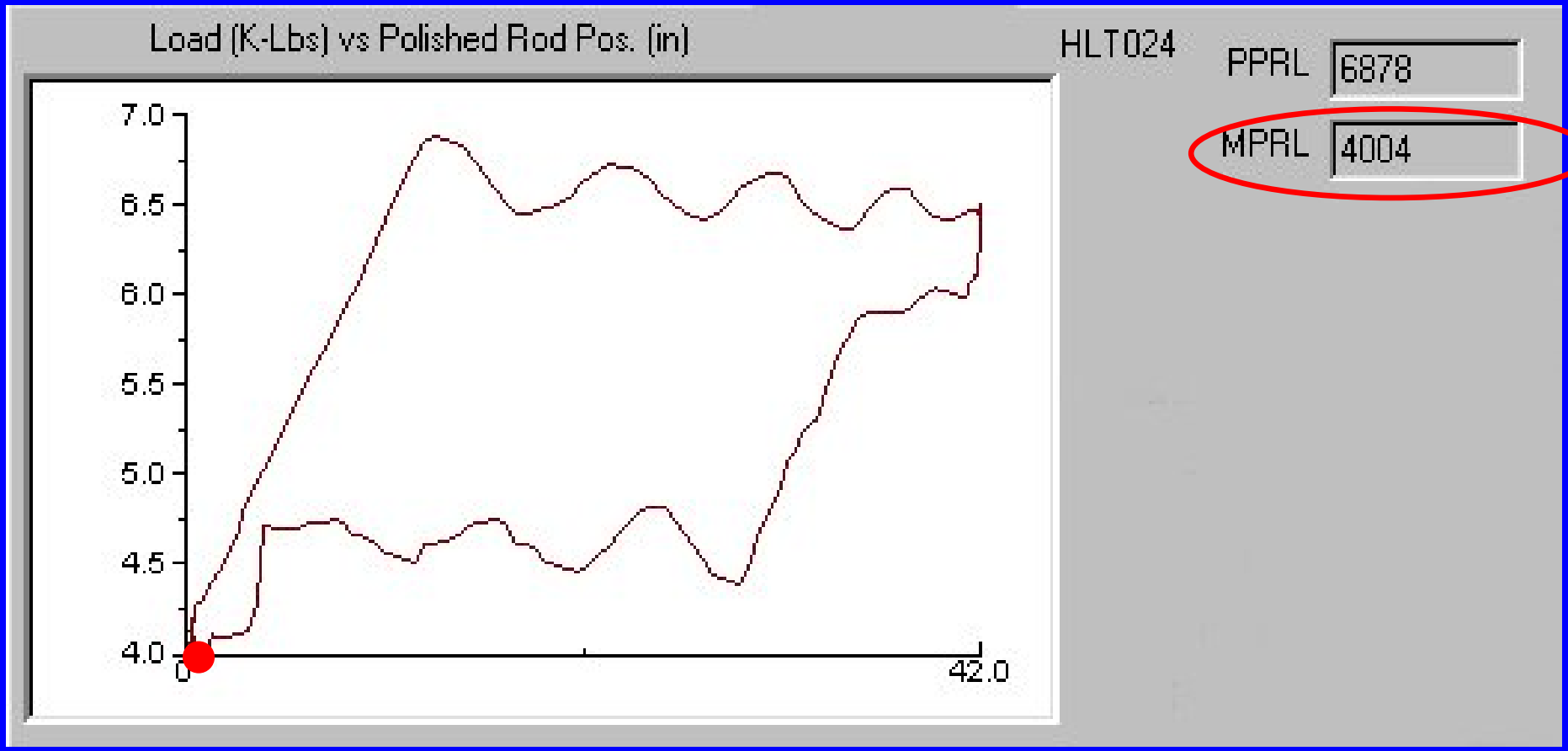
2) Set the Zero offset during calibration process for no-load conditions on the load cell.

Peak Polished Rod Load, [PPRL]

Peak polished rod load is the maximum load experienced during the pumping cycle.

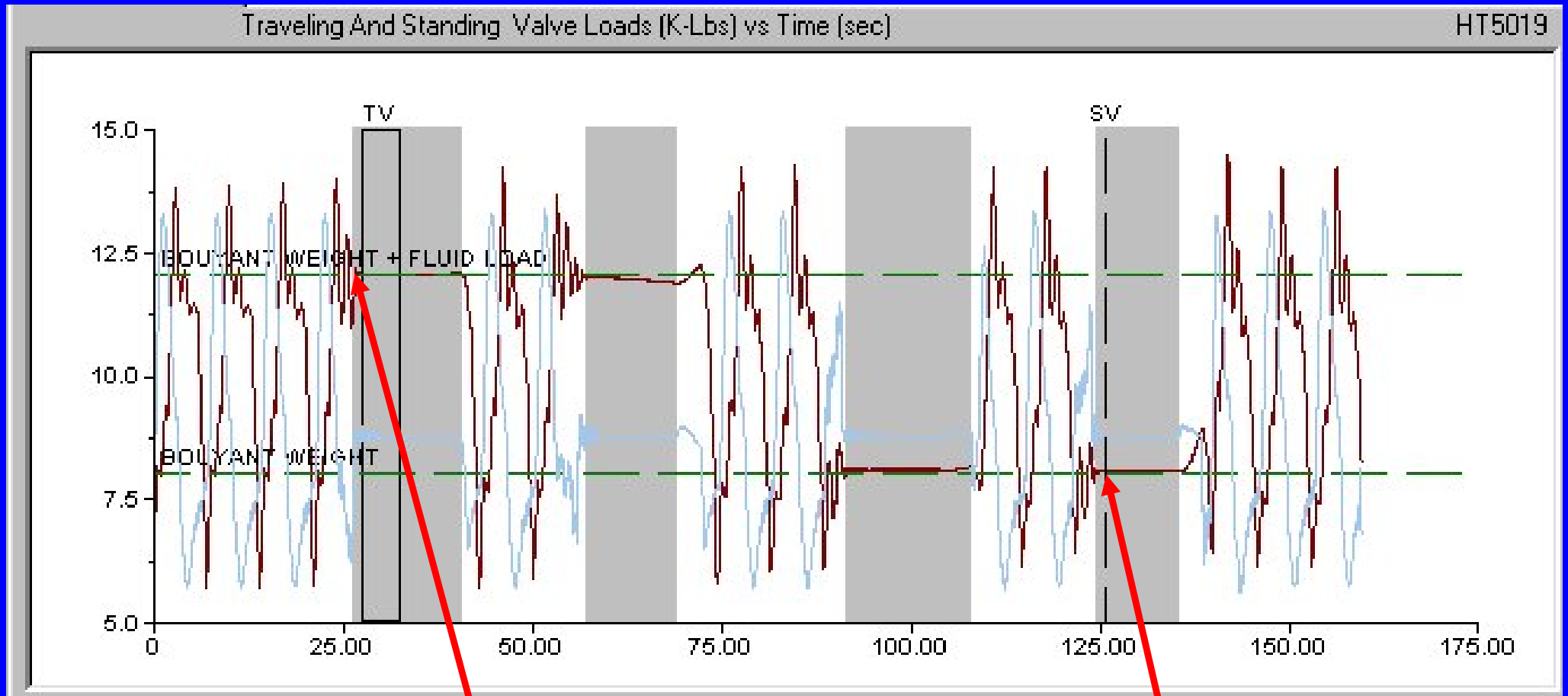


Minimum Polished Rod Load, MPRL



Minimum polished rod load is the minimum load experienced during the pumping cycle.

Measured and Computed Valve Loads



Traveling Valve Analysis

Calc. Bouyant Rod Wgt. + Fluid Load	12062	lbf
Measured Load	12057	lbf
Leakage Interval		
5 sec	Leakage	-0.0 BBL/D

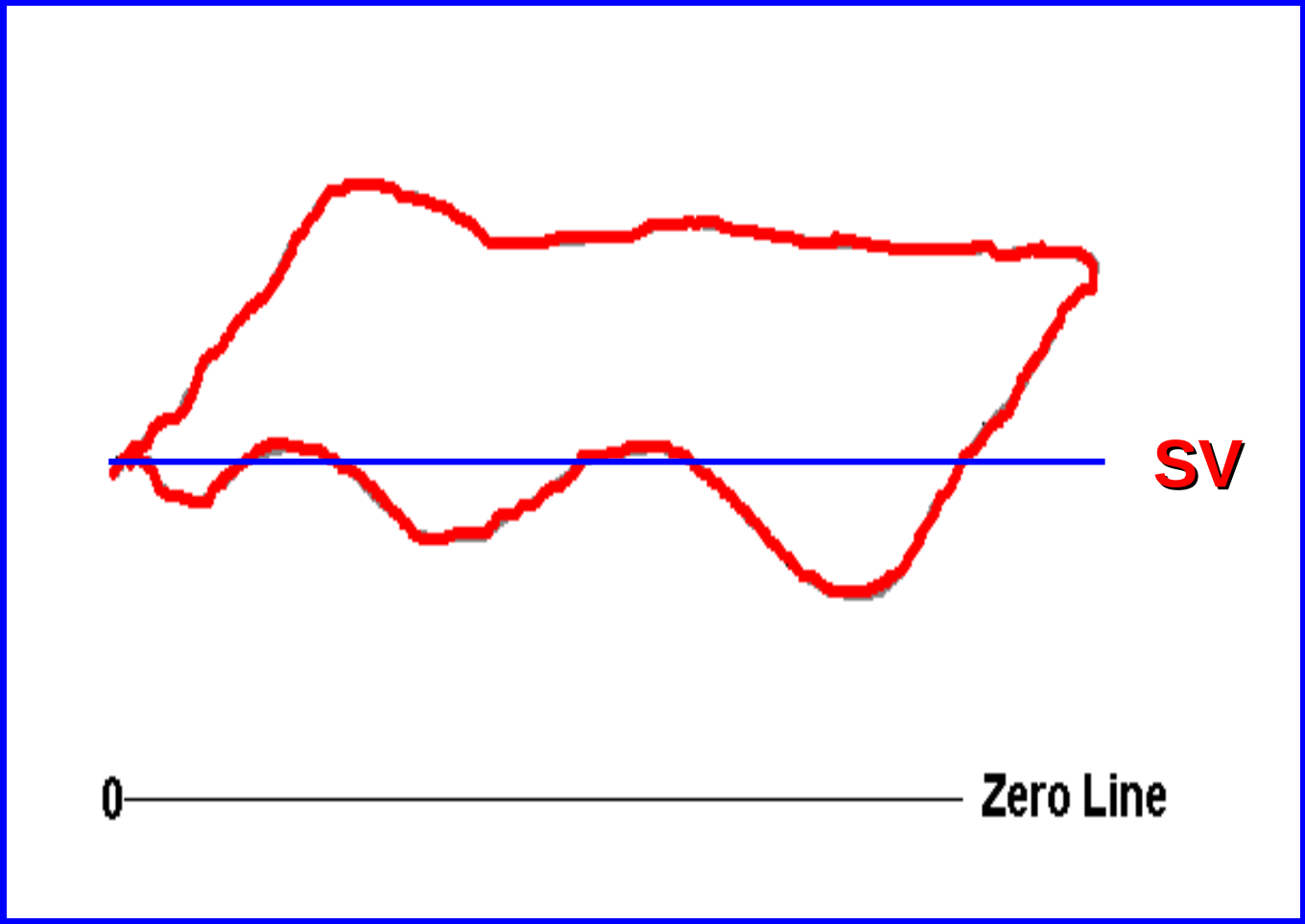
Standing Valve Analysis

Calc. Bouyant Rod Wgt.	8041	lbf
Measured Load	8089	lbf
Intake Pressure	88.0	psi (g)

Standing Valve Load Line

SV Test Measures:

Weight of the Rods Buoyed in Fluid (Wrf)



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

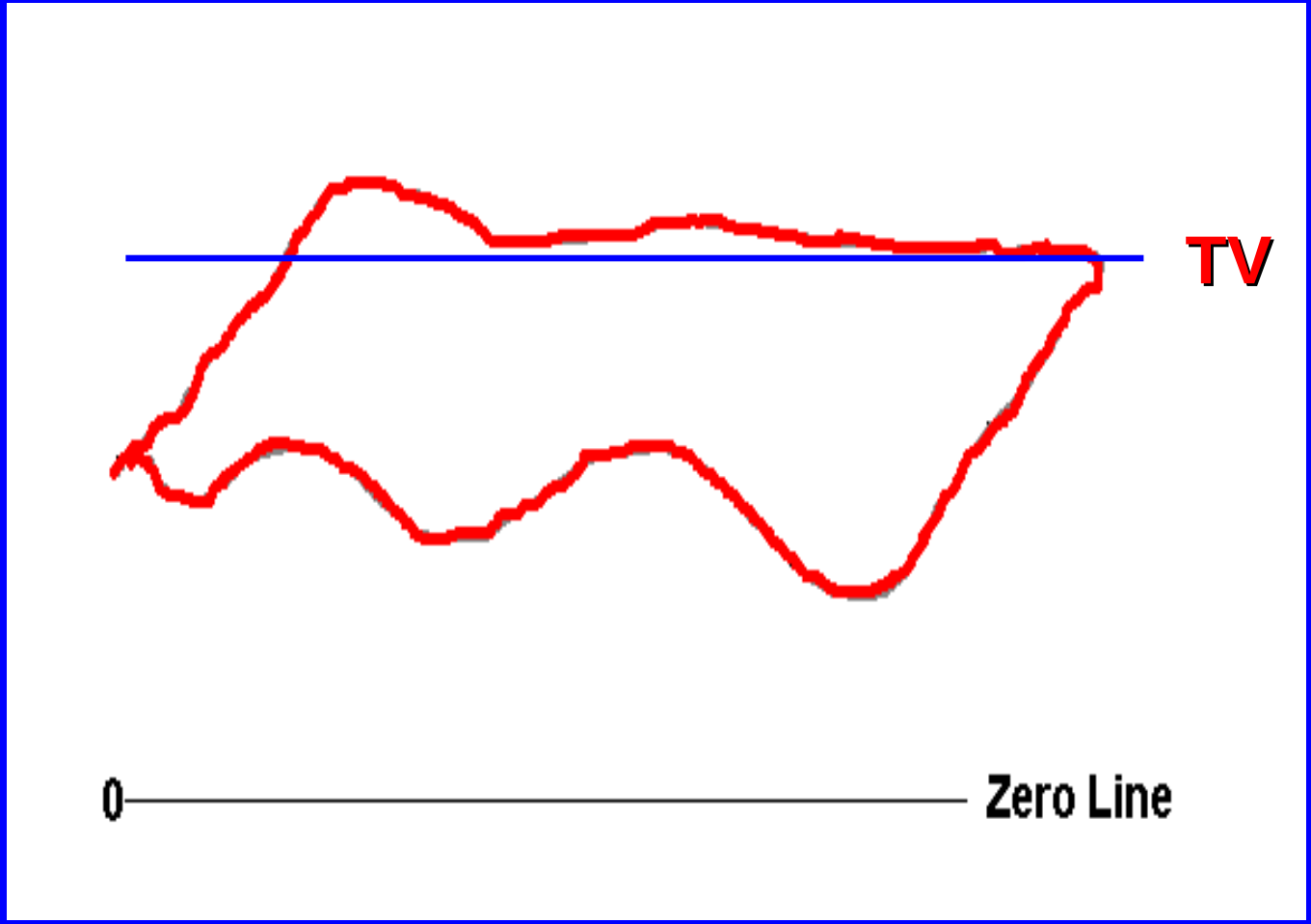
Traveling Valve Load Line

TV Test Measures:

Weight of the Rods Buoyed in Fluid (Wrf)

plus

Fluid Load (Fo)

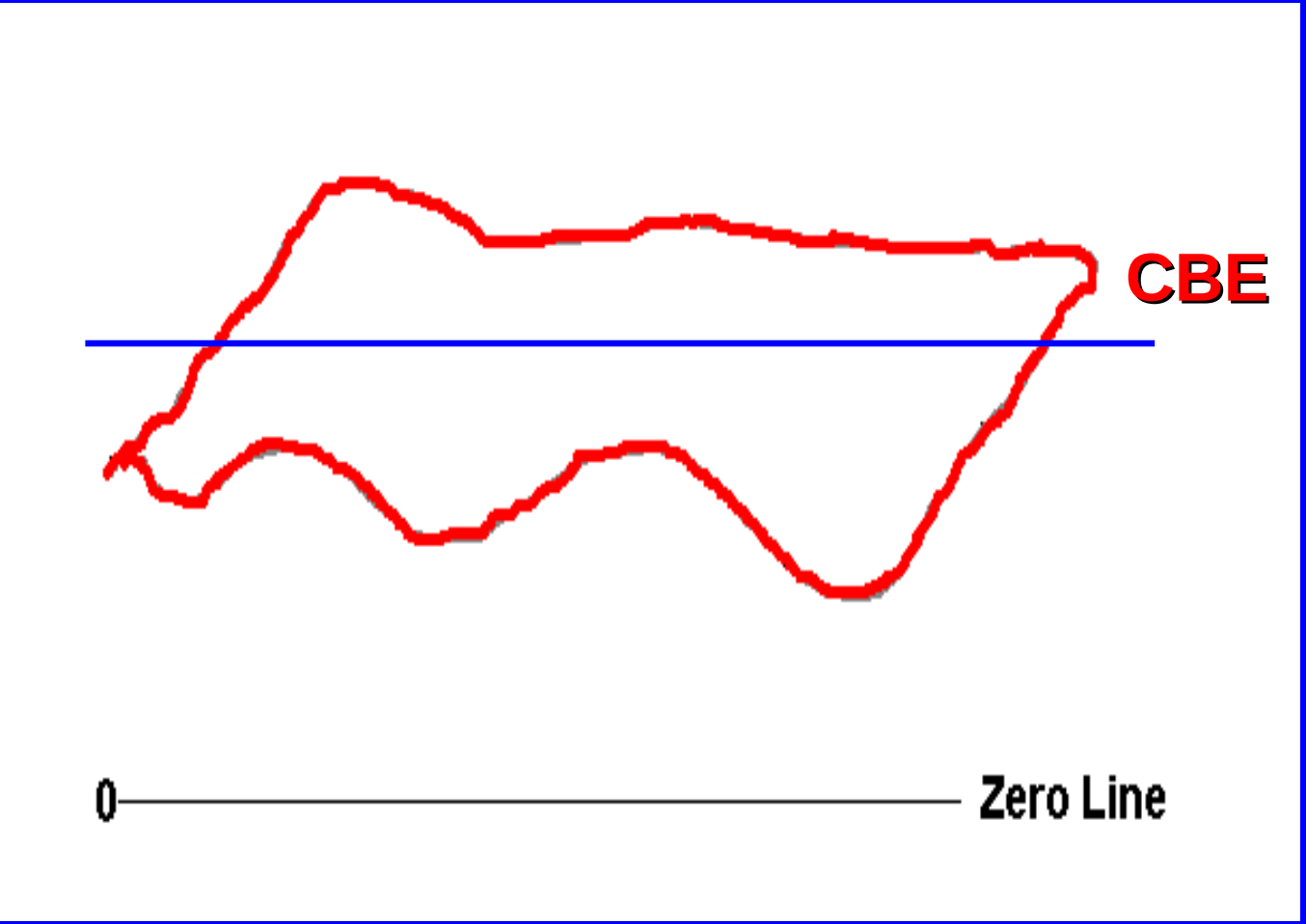


$$TV = W_{ra} - W_{ra} * 0.128 * SG_{tbg} + \Delta P * A_p$$

Counterbalance Effect Load Line

Counterbalance Effect Line (CBE):

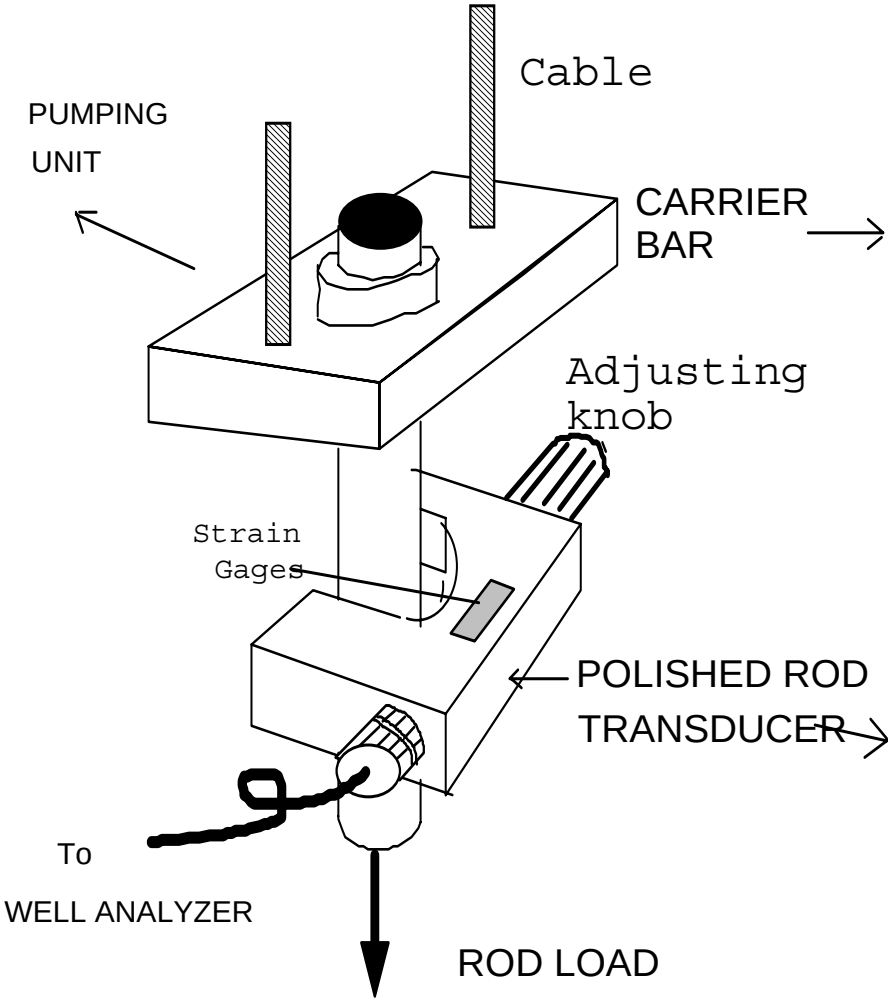
Weight at the polished rod that balances the counterweights on the upstroke with cranks level.



$$CBE = 1.06 * \left(W_{rf} + \frac{F_o}{2} \right)$$

POLISHED ROD TRANSDUCER

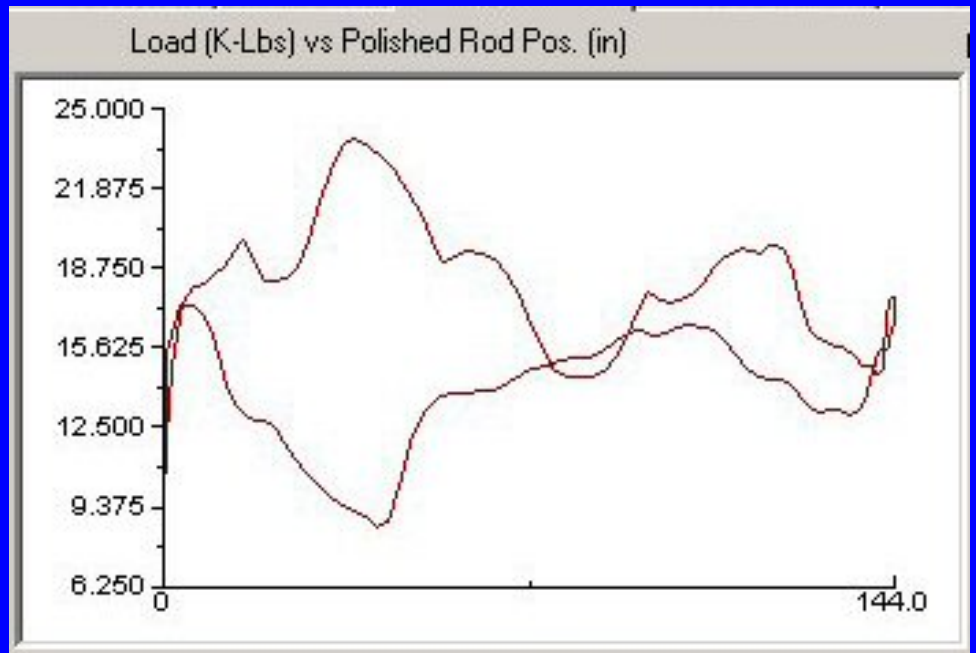
ACCELEROMETER FOR POSITION

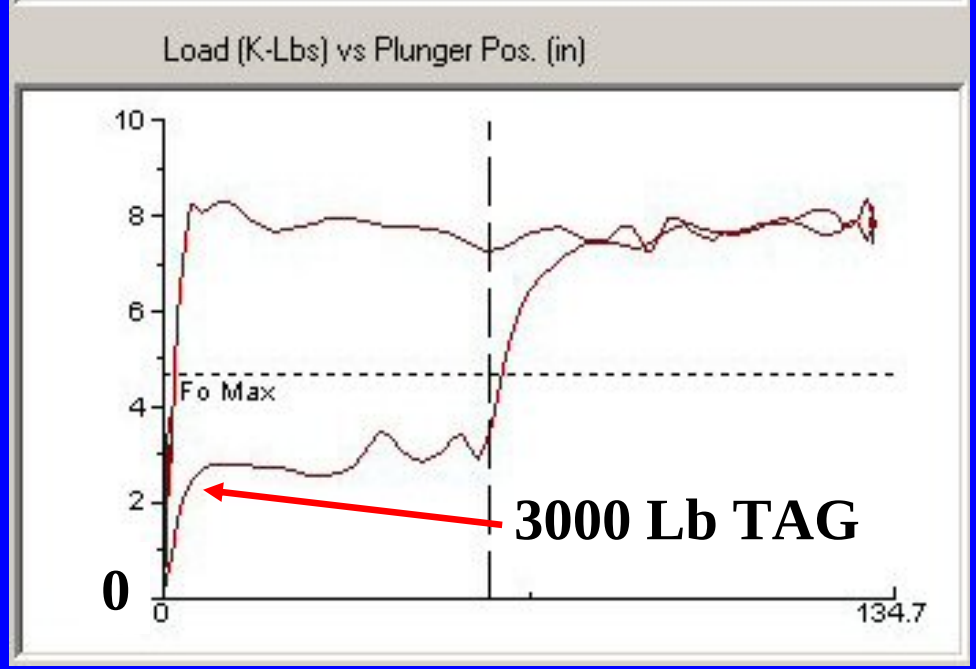


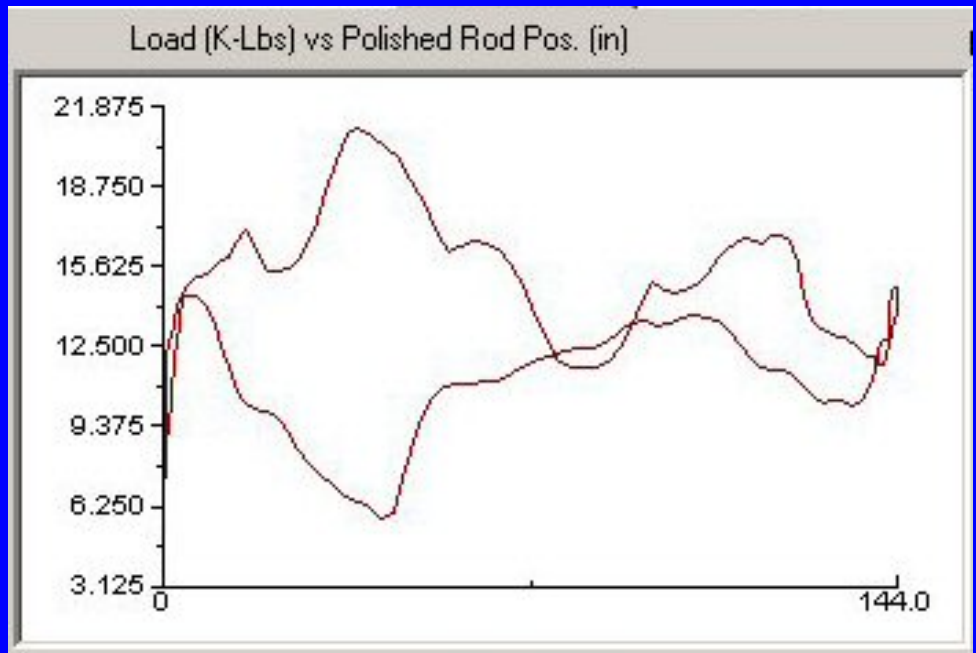
FAST, CONVENIENT, REASONABLY ACCURATE

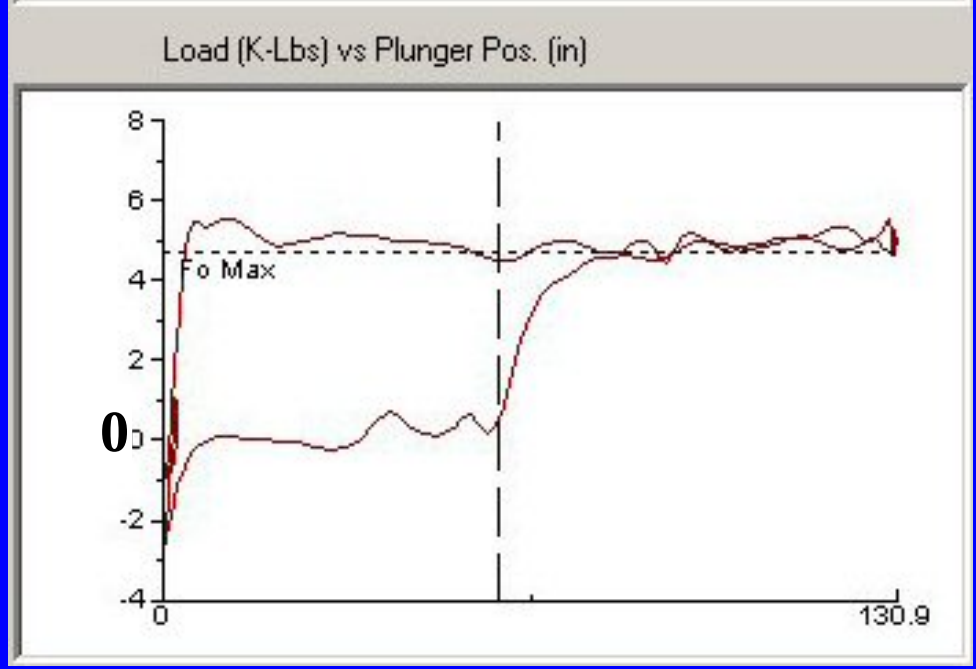
LOAD AND POSITION DATA.

Min. Pump Card Load Sets on Zero Load Line









Load Shifted by Tag

CORRECTED

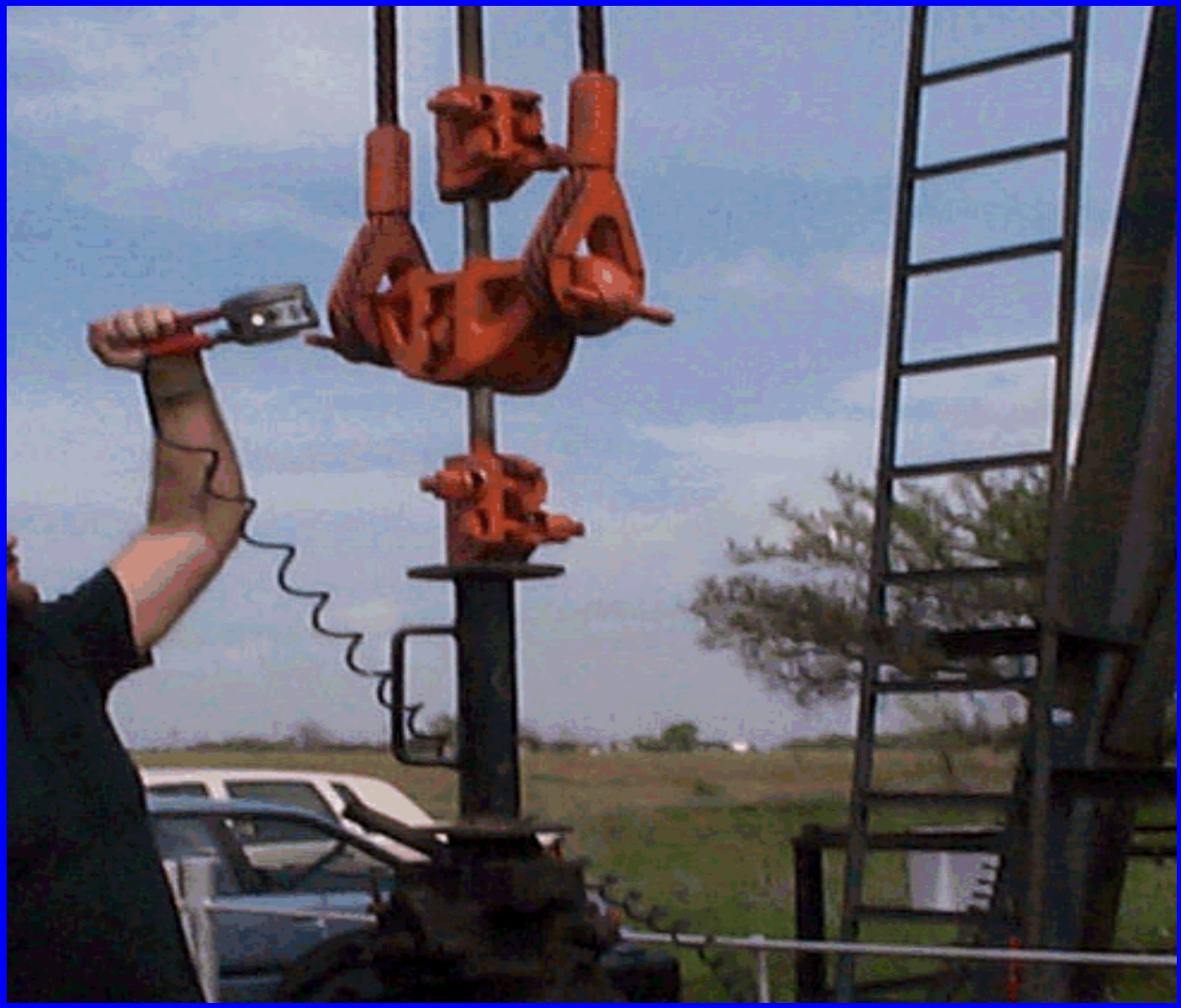
30k HORSESHOE TRANSDUCER

POSITION FROM ACCELEROMETER

1. Highly accurate transducer
2. Provide a precise load value.
3. Load cell placed on polished rod between the permanent polished rod clamp and the carrier bar.
4. Sensor acquires the acceleration of the polished rod.
5. Software calculates velocity and position of the polished rod by integration of the acceleration signal vs. time.

Place 30k HT on Carrier Bar Below Polished Rod Clamp.

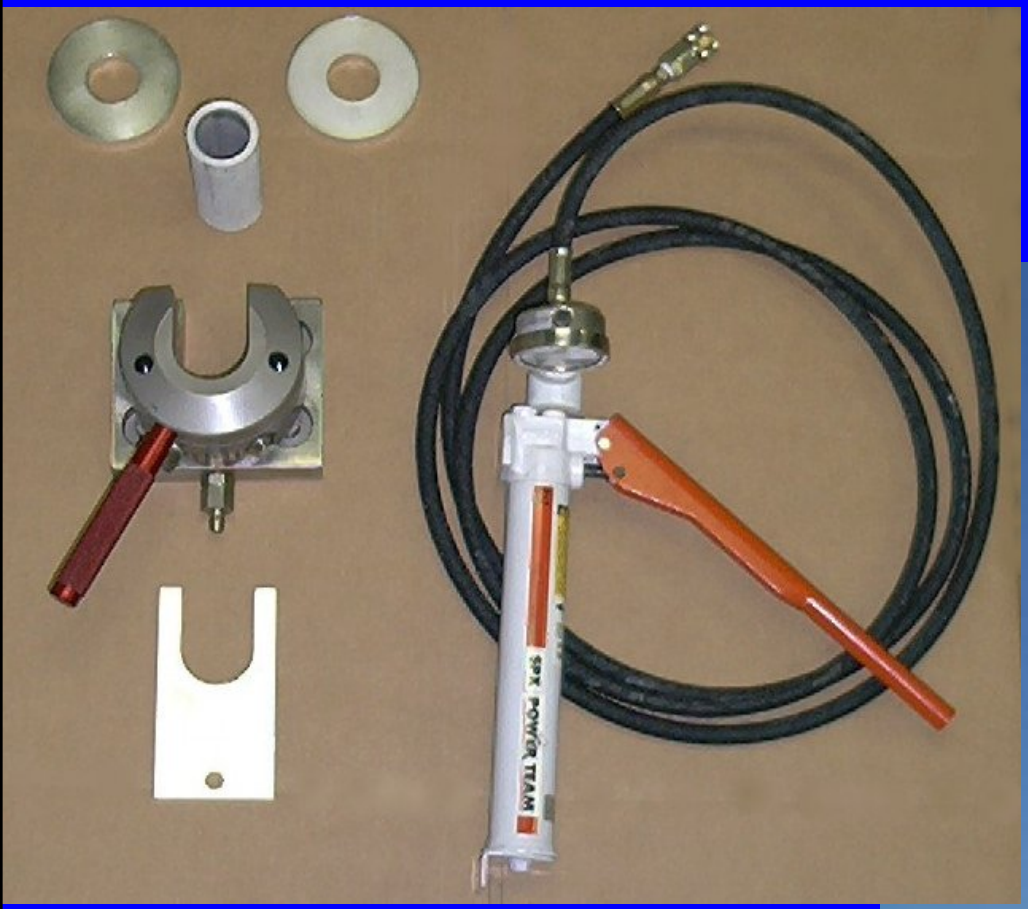
The brake or clamps could slip and for safety reasons **NEVER** place hand between carrier bar and polished rod clamp.



50k HORSESHOE TRANSDUCER

INCLUDES ACCELEROMETER

SAFE, FAST, CONVENIENT, ACCURATE LOAD & POSITION



Spool & Washers Mounted on Well

1. Permanently Install Spool Assembly on the Well.

2. Spool fits over the polished rod between the carrier bar and the permanent polished clamp.

3. Spool assembly consists of upper washer, lower washer and 5" long (2" OD) steel tube; separate the two washers.

Use Existing Load Cell with Special Accelerometer

1. Operator has Load Cells mounted on many wells.
2. Replace external string box or position transducer is used to determine position
3. Special accelerometer transducer determines position, similar in size to the PRT but containing only the accelerometer function.
4. Can be be used with ***any*** type of load cell.

Quickly installed onto the polished rod below the carrier bar.

Questions?