Ask Echometer 21 Online Seminar – October 14, 2020

Over Travel Occurs on Up and Down Stroke

Benefits of High Speed and High Resolution Data Acquisition

TOTAL ASSET MONITOR (TAM)

http://www.echometer.com/Software/Total-Asset-Monitor

"OVER-TRAVEL CAN OCCUR ON BOTH THE UPSTROKE AND DOWN STROKE", Rowlan, Taylor, Craig, SWPSC 2017

"REVIEW OF NON-DIMENSIONAL PUMPING PARAMETERS AND USE IN SUCKER ROD STRING DESIGN", Rowlan, Hein, SWPSC 2018

"The Use of Polished Rod Velocity and MPRL/PPRL Ratio as an Indicator of Failure Frequency". SWPSC 2018

"Reference Load Lines Aid in Analysis of the Downhole Dynamometer Pump Card" Rowlan, McCoy, Podio, SWPSC 2009

Presenters: O. Lynn Rowlan and Carrie-Anne Taylor

Q & A: Gustavo Fernandez and Echometer Engineering and Support

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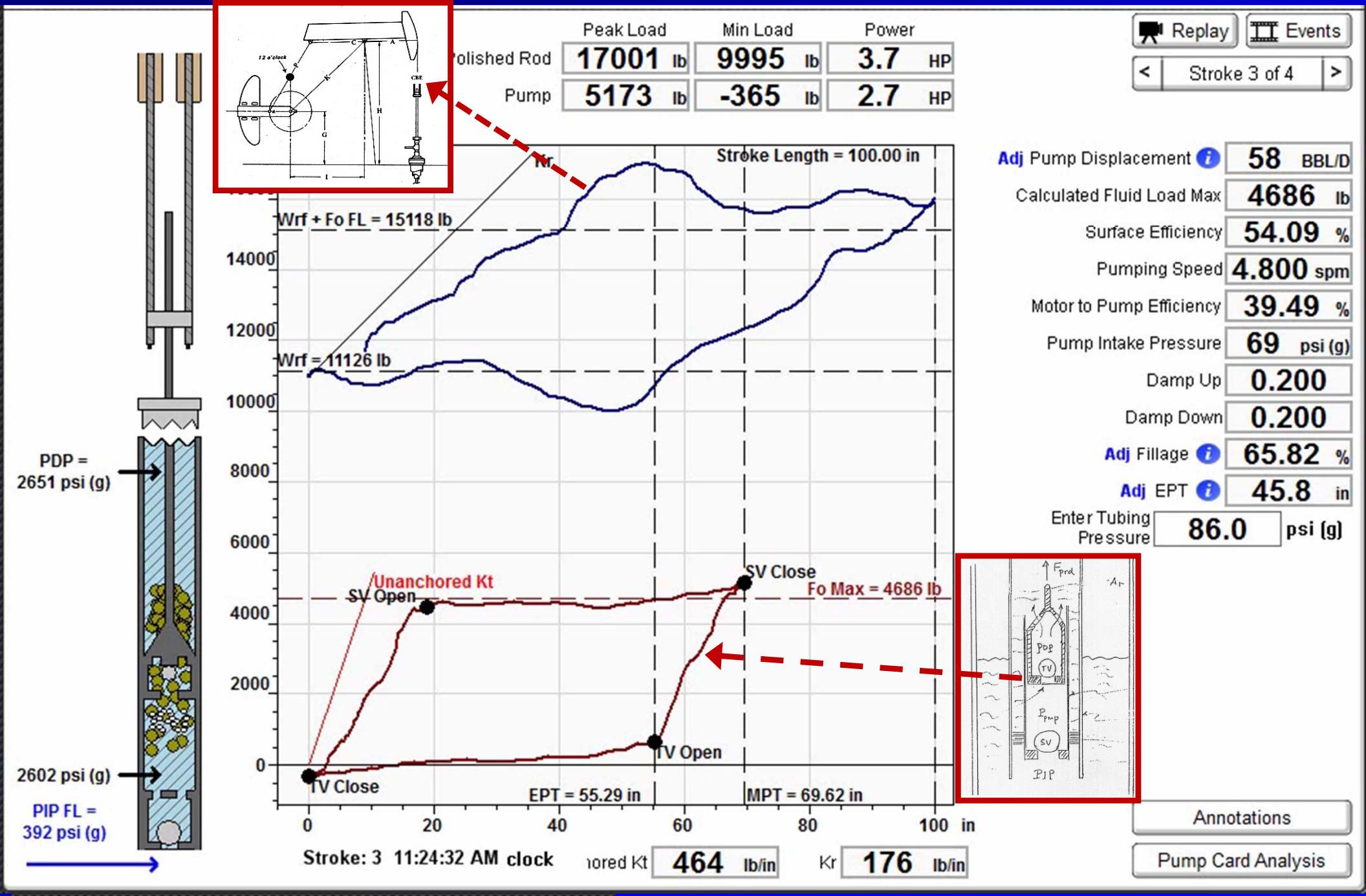
Download the Session 21 PDF Bundle and TAM Example Data from

https://echometer.com/Support/AskEchometer

Introduction

- Pump Stroke Will Increase, when the Dynamic Motion of the Beam Pump System Adds Momentum to the Rod String
- Pump Stroke Will Shorten, when the Rods Stretch to Pick Up the Pump Fluid Load and to overcome Coulomb Friction
- Surface Dynamometer Card Sloping Up or Down from Left to Right Defines:
  - Up to Right an "Over Travel Card Shape“
  - Down to Right an “Under Travel Card Shape”
- Rod Stretch Creates Under Travel Cards.
- Pumping Fast or High Plunger Velocities Created by the Sudden Release of Pump Load Creates Over Travel Dynamometer Cards.

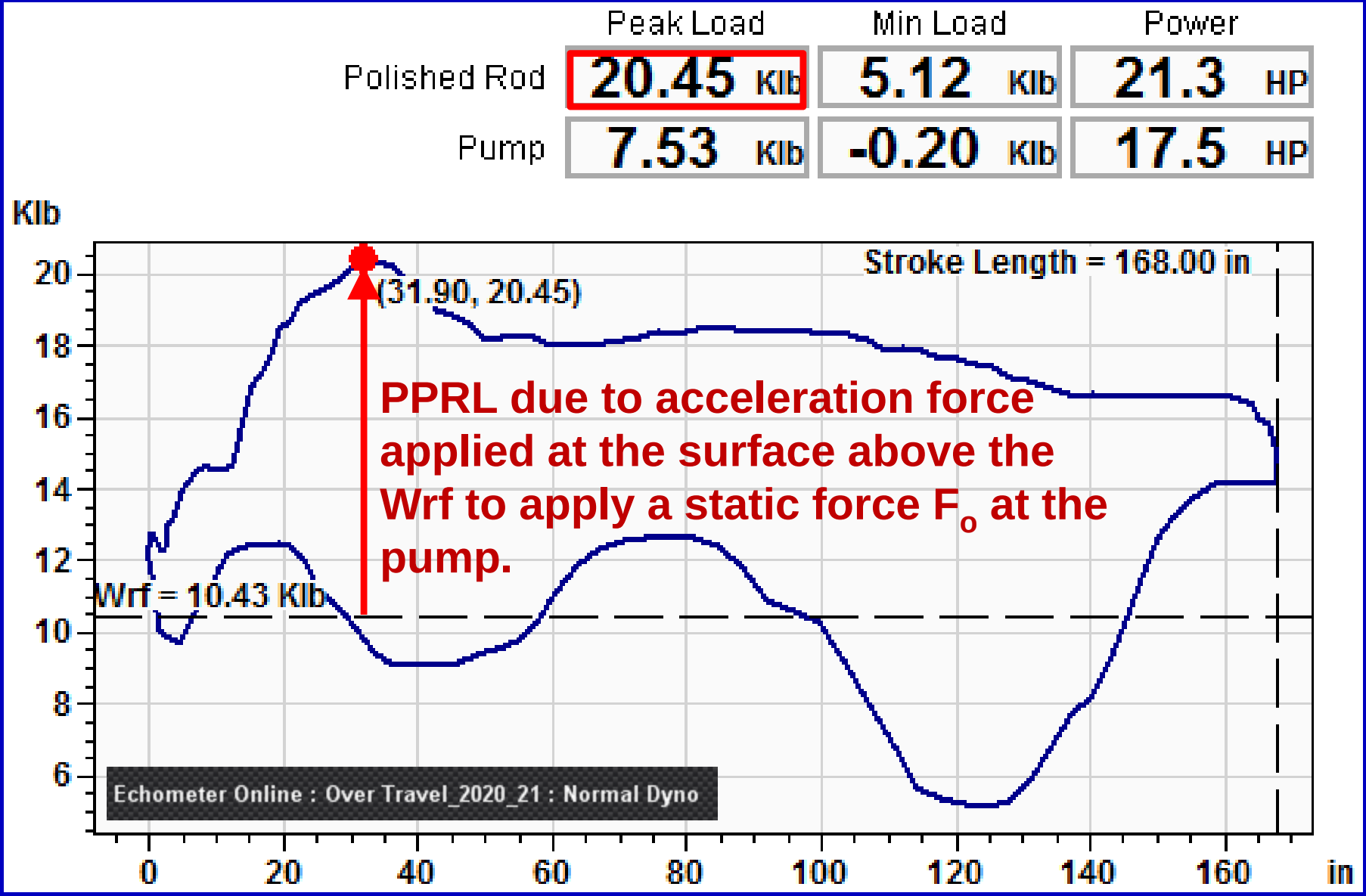
Dynamometer Displays SR Pumping System Performance



Recommendations For Producing Sucker Rod Lifted Wells

- Recommended practices include properly installing equipment in the well, providing proper chemical treatments, preventing rod on tubing wear, identifying cause of well failures, and periodic surveillance of the well.
- Dynamometer and fluid level surveys are used to identify when the well is properly operating and when there are operating problems.
- Use predicted and measured dynamometer data as cross-check; calculate what is measured
- Rod Parts are often caused by wear
  - Rods-on-Tubing Contact
  - Pump fillage (fluid pound or gas interference)
  - Avoid Sudden impact loads (tagging) on upstroke or down stroke

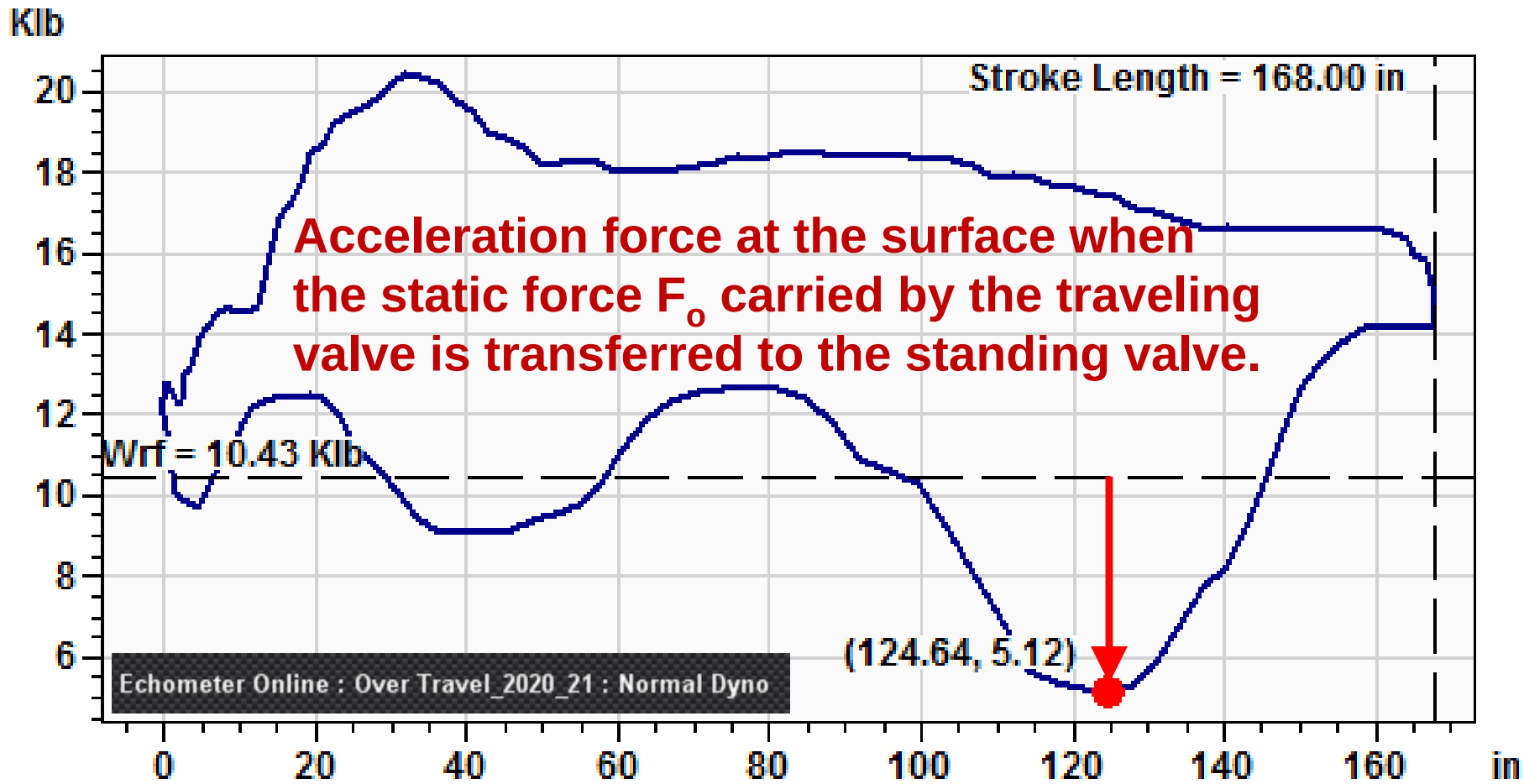
Peak Polished Rod Load



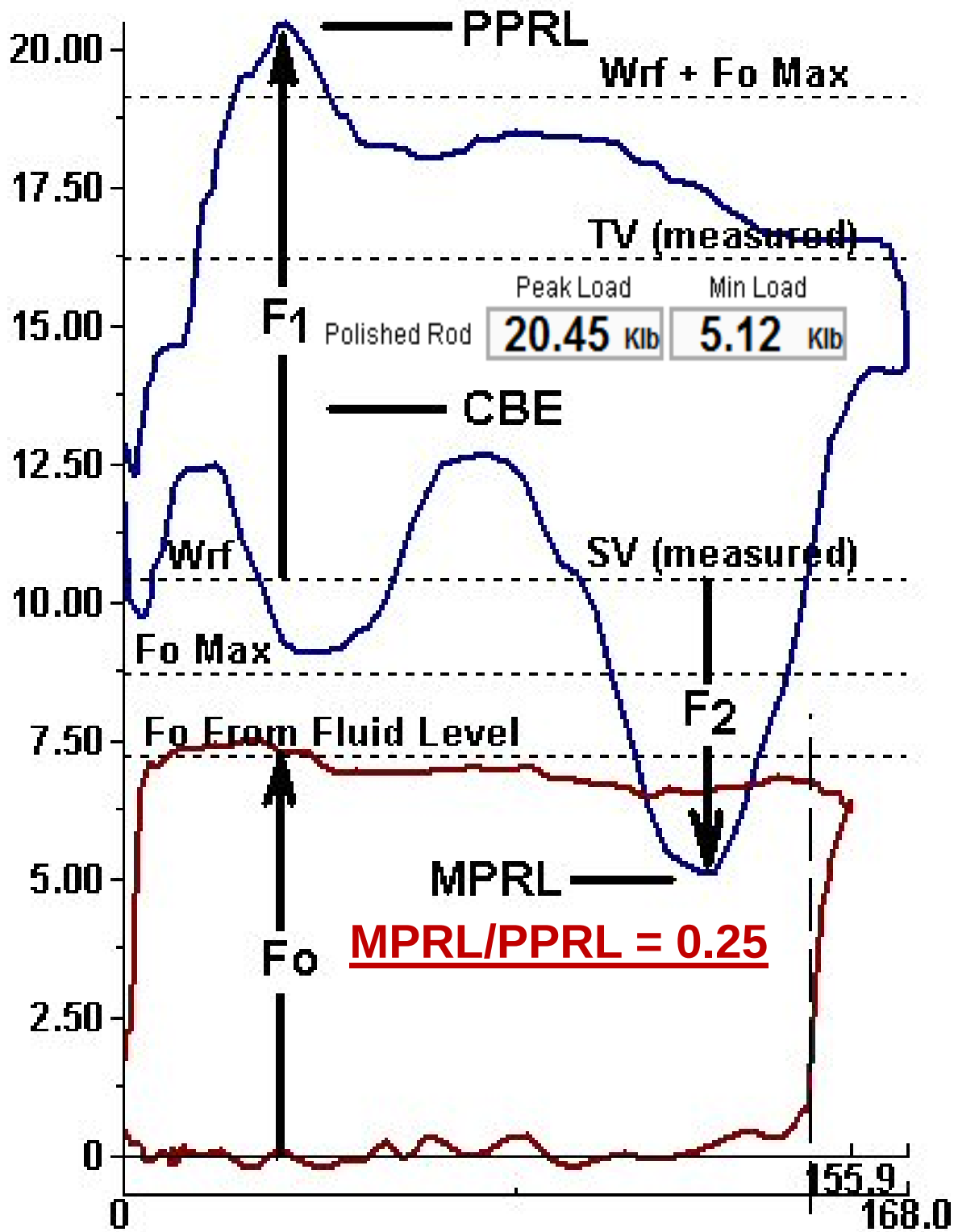
PPRL experienced during the pumping cycle depends on pumping speed, faster SPM then more acceleration and higher peak load.

Minimum Polished Rod Load

	Peak Load	Min Load	Power
Polished Rod	20.45 Klb	5.12 Klb	21.3 HP
Pump	7.53 Klb	-0.20 Klb	17.5 HP



Minimum polished experienced during the pumping cycle is a function of pump speed.



Echometer Online : Over Travel_2020_21 : Normal Dyno

MPRL/PPRL > 0.1 per each 2500'/pump depth

TV Weight of Rods in Fluid, Wrf, plus the Fluid Load, Fo, plunger is applying to the rods.

Wr fluid = Wr air - Buoyancy

Fo fluid load the pump applies to the rod string.

F1 dynamic force required at the surface to apply a static force Fo at the pump..

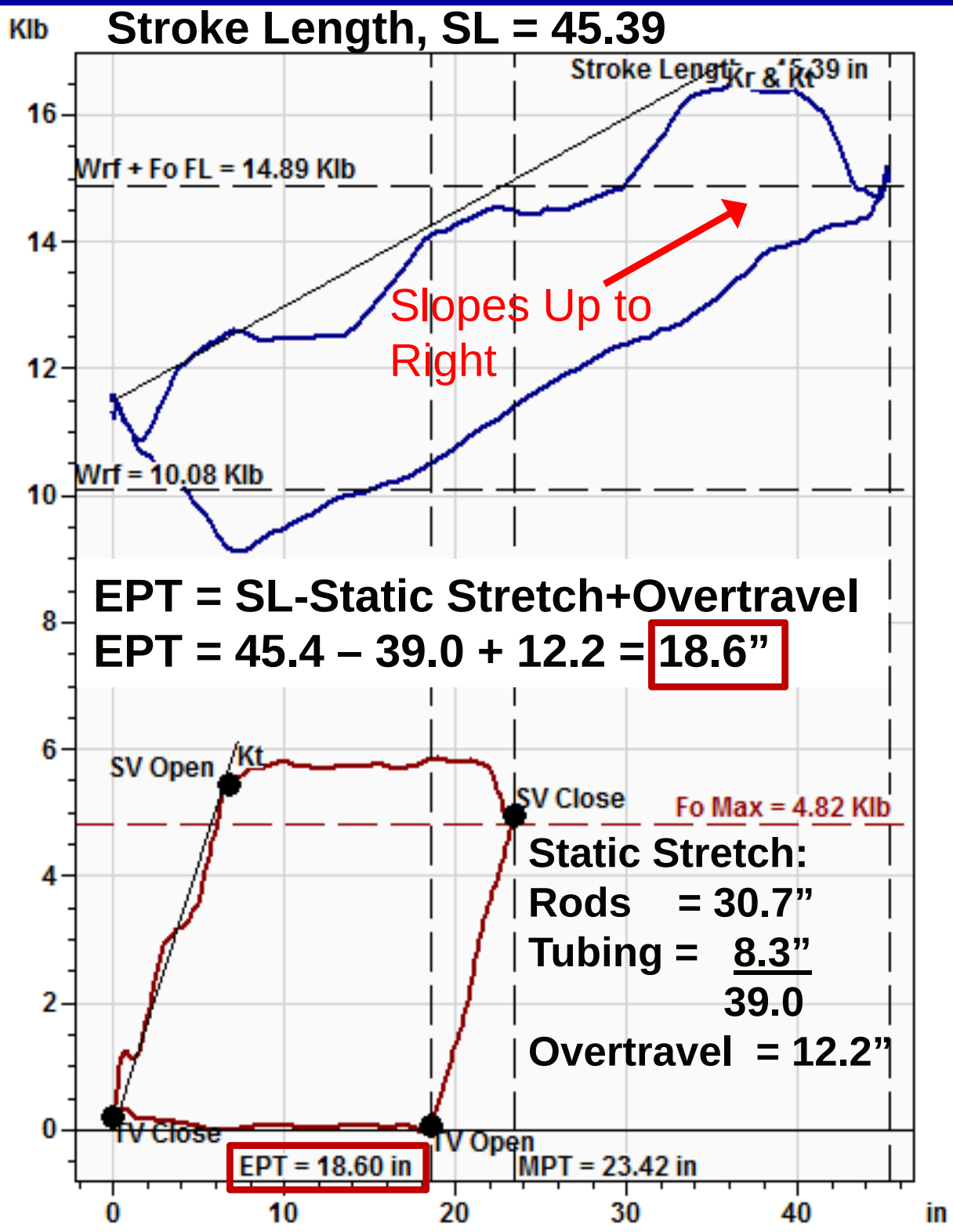
F2 dynamic surface force due to transferring the Fo carried by the traveling valve to the standing valve.

Pump Depth = 4836

MPRL/PPRL Limit = 1.9

OK 0.25 > 0.19

Under Travel

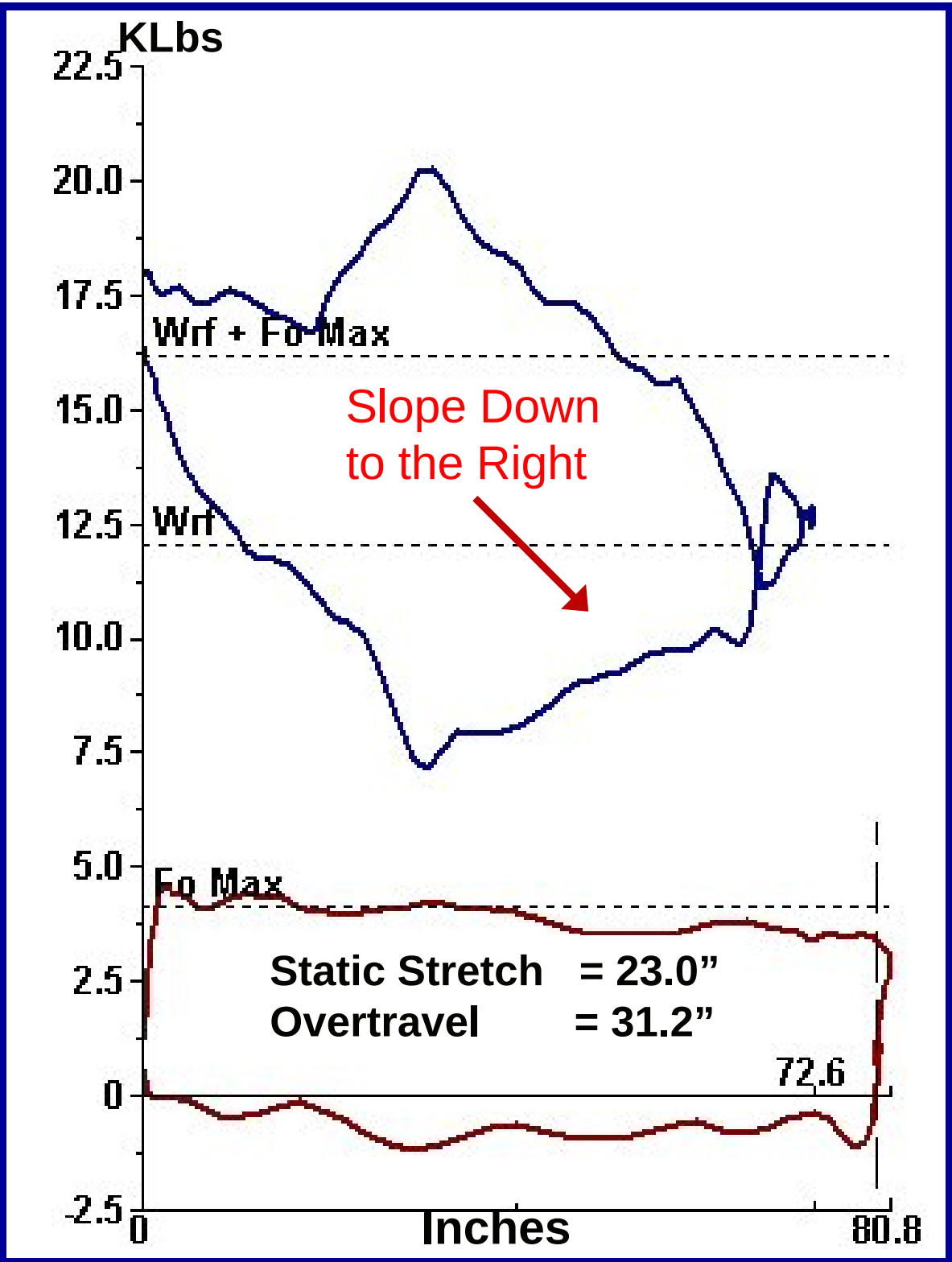


Under Travel Surface card slopes upward from left to right.

Pump plunger moves ***less*** than the polished rod stroke.

Under Travel is due to rod stretch from fluid load, downhole friction or other reasons.

Under Travel cards include: stuck pumps, ***plunger is too large for the rod string***, sand or scale problems, too tight stuffing box and/or paraffin.



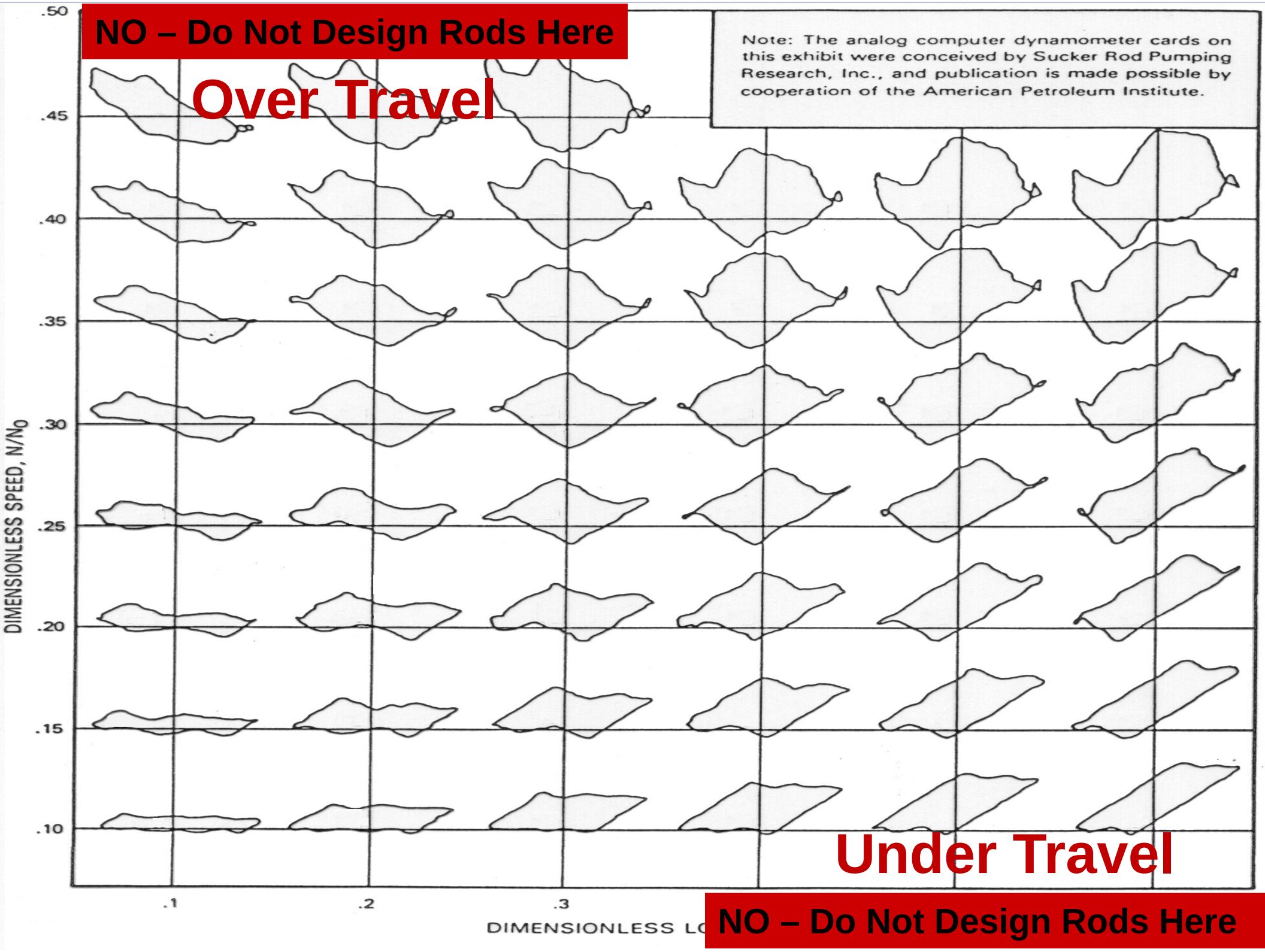
Over Travel

<u>Over Travel</u> Plunger stroke increases due to pumping speed.

Surface card slopes downward from left to right.

The 13.74 SPM adds momentum to the rods increasing stroke by 31.2” inches.

Over Travel cards include: parted rods, TV stuck open, hole in pump barrel, flowing wells, unseated pumps, gas locks, worn pumps, fiberglass rod strings or pumping at a very fast SPM.

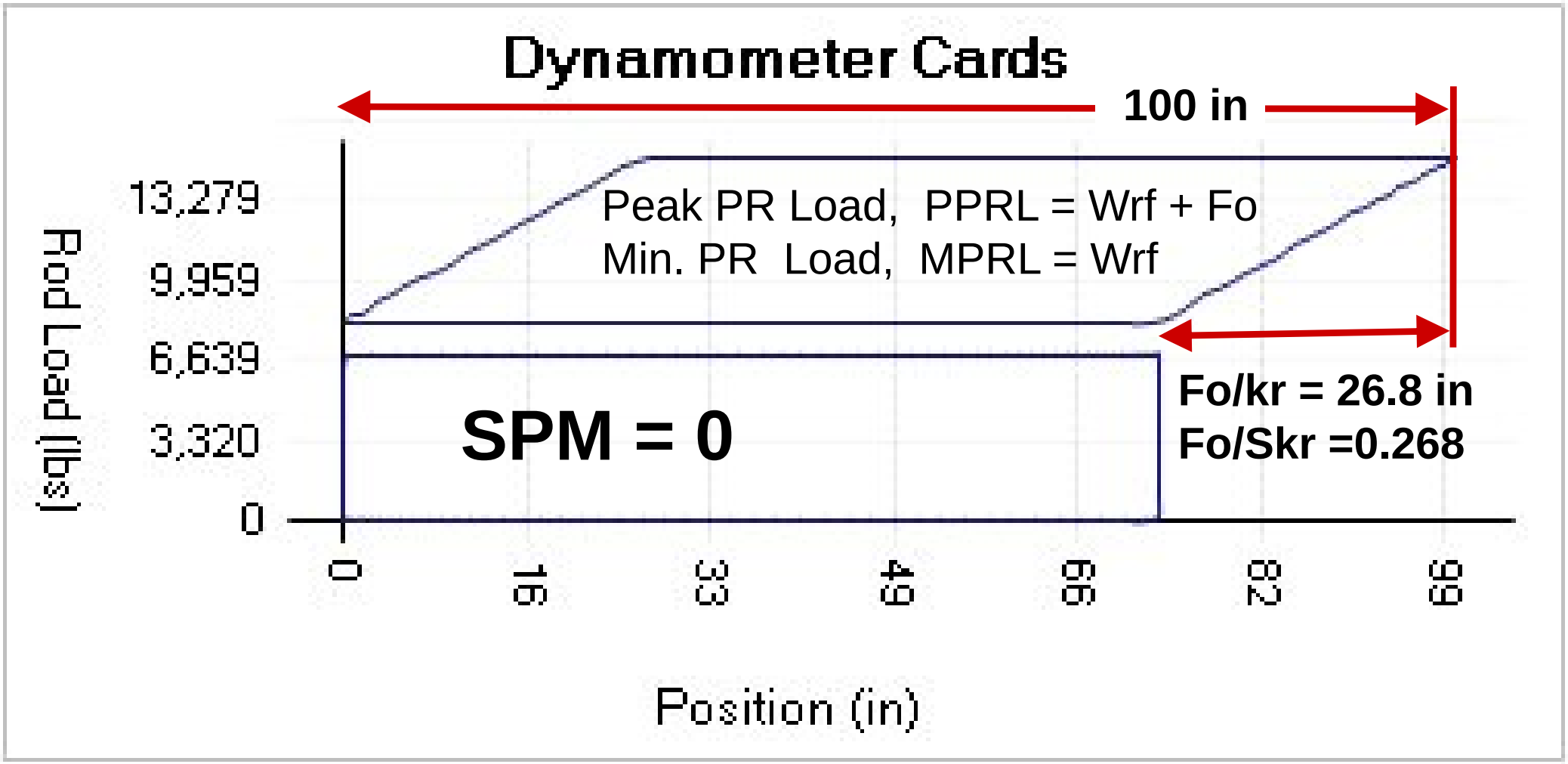

NO – Do Not Design Rods Here
Over Travel
Note: The analog computer dynamometer cards on this exhibit were conceived by Sucker Rod Pumping Research, Inc., and publication is made possible by cooperation of the American Petroleum Institute.
.50
.45
.40
.35
.30
.25
.20
.15
.10
DIMENSIONLESS SPEED, N/N0
.1
.2
.3
DIMENSIONLESS LO
Under Travel
NO – Do Not Design Rods Here

Example Well

1. 5000 ft pump depth, 100 in surface stroke (s), 50 psi tubing and pump intake pressure
2. 2 inch diameter plunger with anchored tubing
   a) Fluid Load 6802 lbs
3. Tubing Fluid Gradient 0.433 psi/ft
4. 76 API Designation rod string
   a) 41.2% - 7/8” and 58.8% - 3/4” rods
   b) Weight Rods in Fluid – 8,288 Lbs
   c) Kr = 254 lb/in & SKr = 25400 lb
   d) Fo/SKr =0.268 with 26.8 in of Stroke lost to Stretch

Pump Stroke Less by Static Stretch

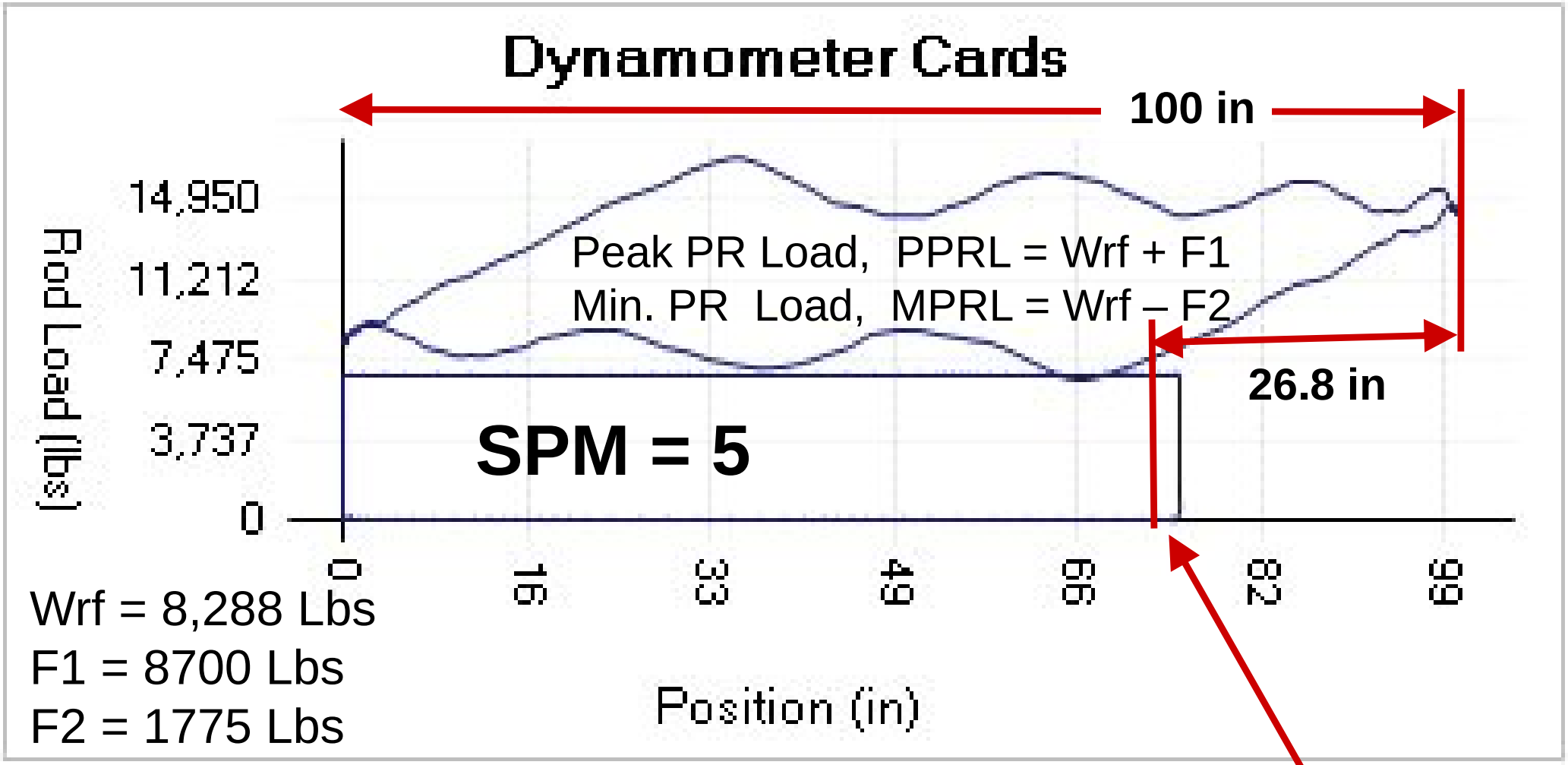
Dynamometer Cards at Pumping Speed of approximately 0 SPM



PPRL 15,089 lbs	MPRL 8,288 lbs	Fo 6,802 lbs
Pump Stroke 73.2 in	Static Stretch 26.8 in	Overtravel 0.0 in
Fo/Skr 0.268	Kr 254 lb/in	Kt 894 lb/in

Pumping Speed at 5 SPM

Pump Stroke 1.7 inches longer due to Over-travel from SPM>0

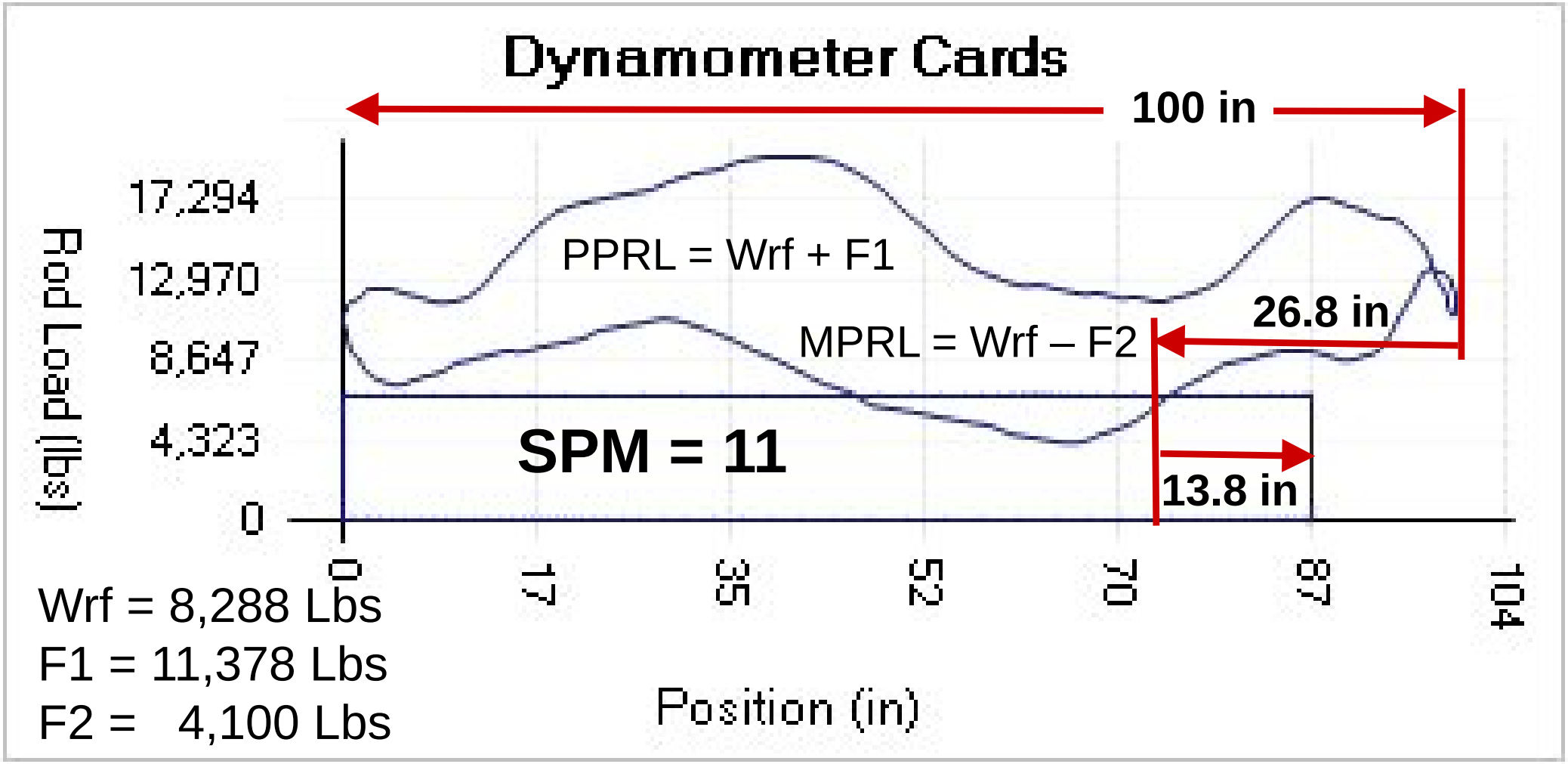


PPRL 16,988 lbs
Pump Stroke 75.0 in
Fo/Skr 0.268

MPRL 6,513 lbs
Static Stretch 26.8 in
Kr 254 lb/in

Fo 6,802 lbs
Overtravel 1.7 in
Kt 894 lb/in

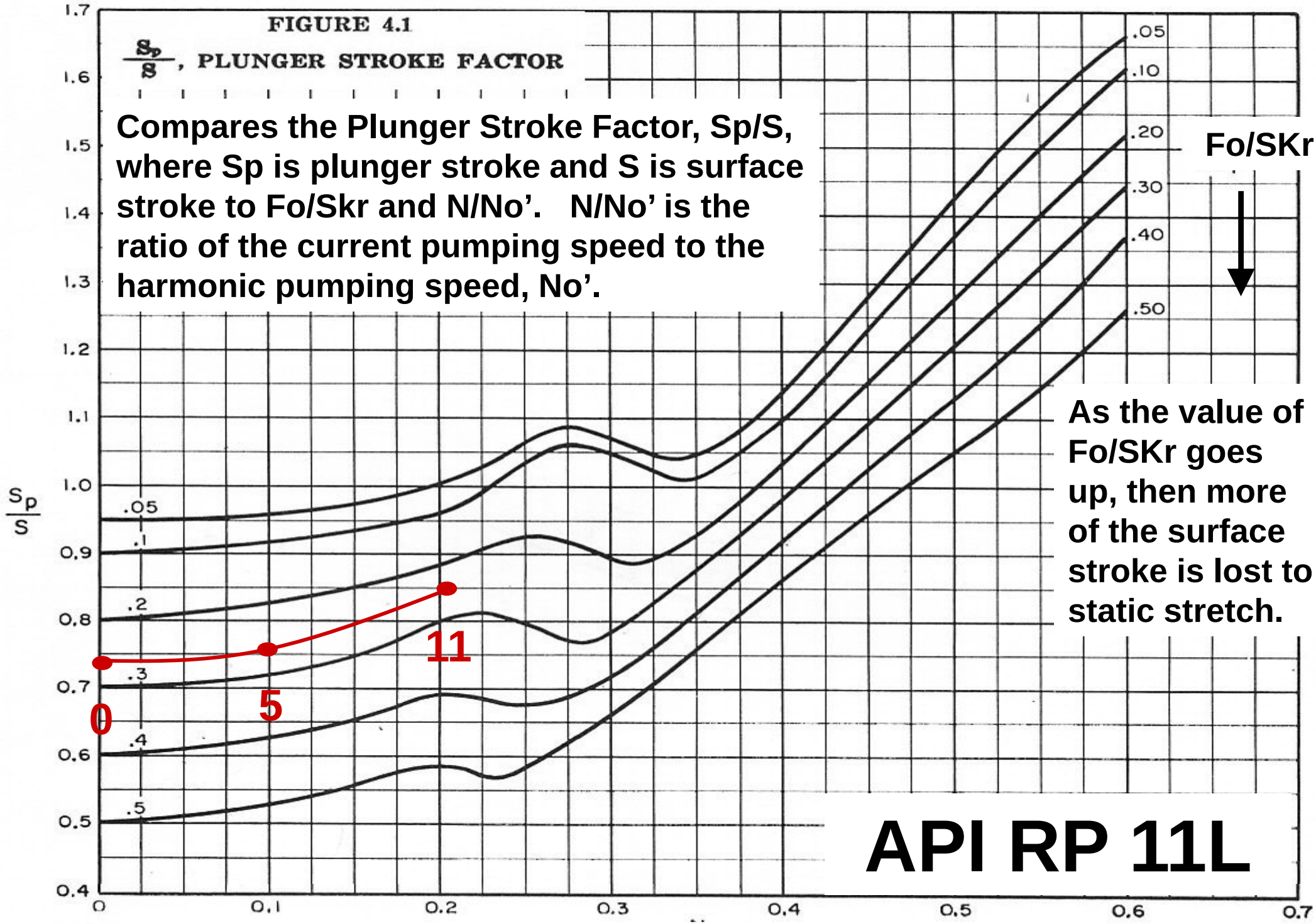
Rod String 76 Design loaded to 100% of the Allowable Modified Goodman Stress



PPRL 19,666 lbs
Pump Stroke 87.1 in
Fo/Skr 0.268

MPRL 4,188 lbs
Static Stretch 26.8 in
Kr 254 lb/in

Fo 6,802 lbs
Overtravel 13.8 in
Kt 894 lb/in



As N/No' increases, then more Over Travel occurs

Problems Associated with Pumping Off more than 2% of Time

Constant Pump Off causes vibration throughout the whole system. This causes:

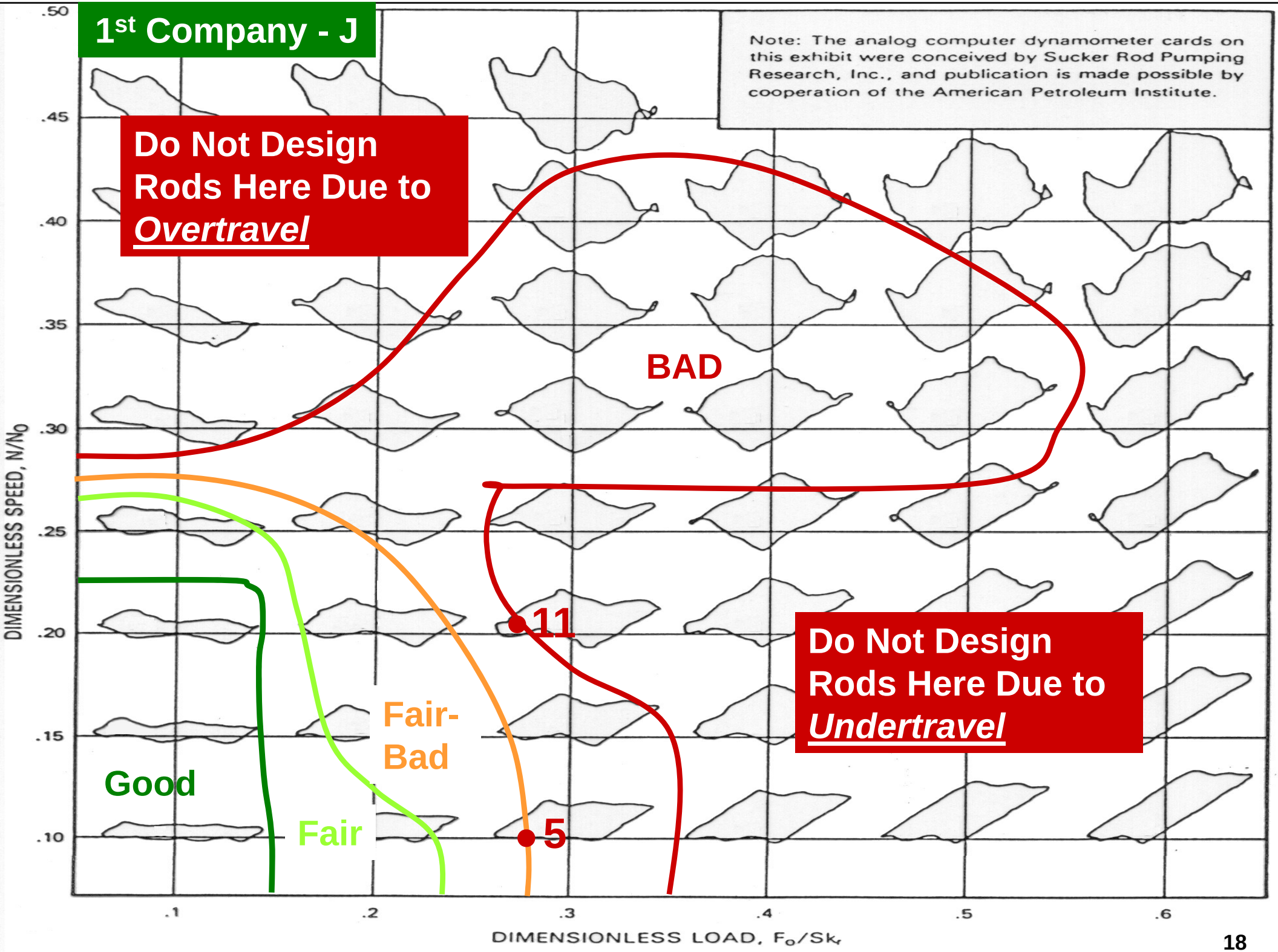
- Rod buckling
- Pump wear
- Rod on Tubing wear
- Vibration stresses
- Severe rod loading changes
- Pumping unit vibration

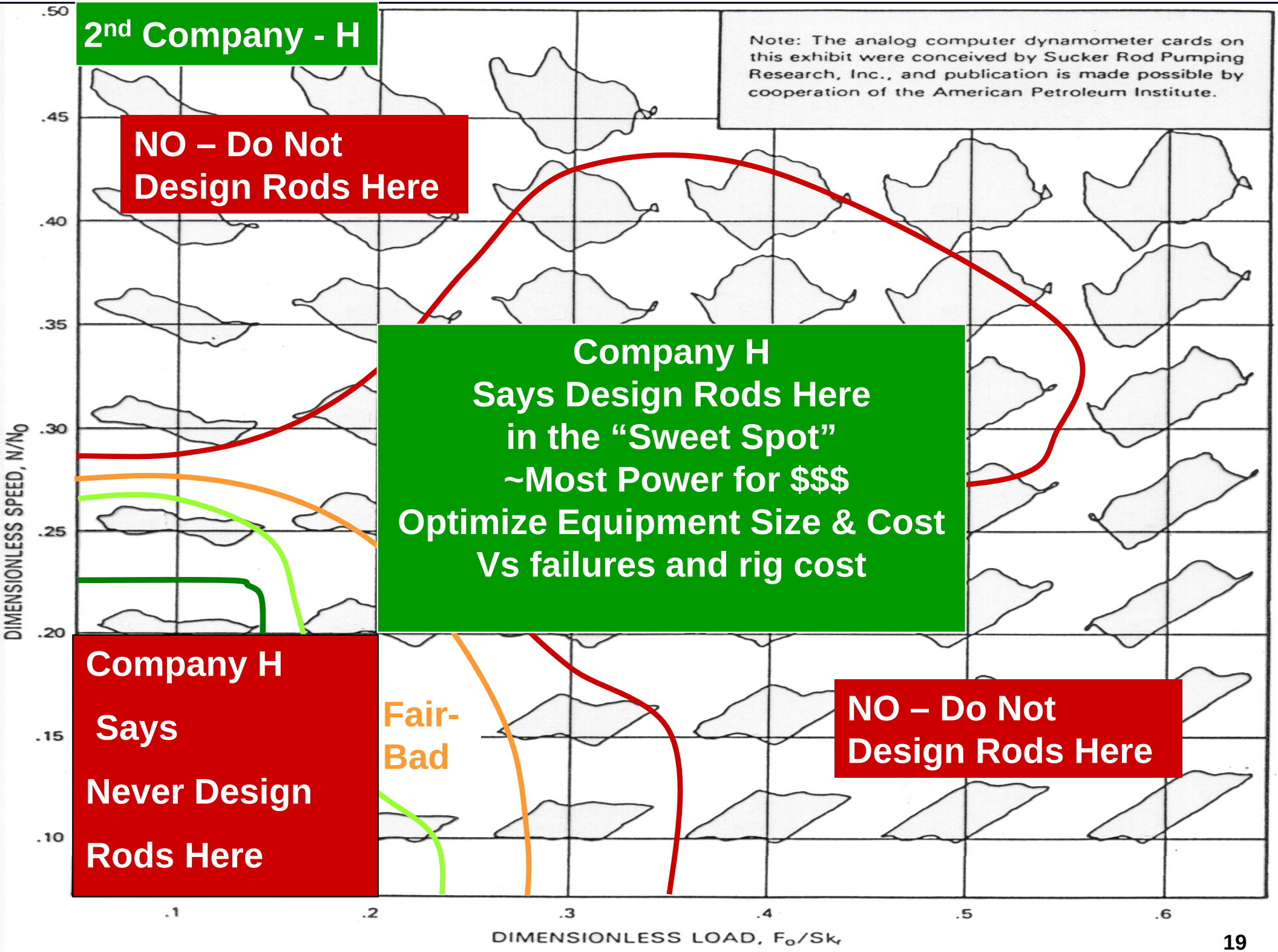
Fo/Skr & N/No' Rod Design Practice

1st company's rod design practice where:
Fo/SKr<0.2 and N/No'<0.2 Maximum
LONG AND SLOW IS THE WAY TO GO

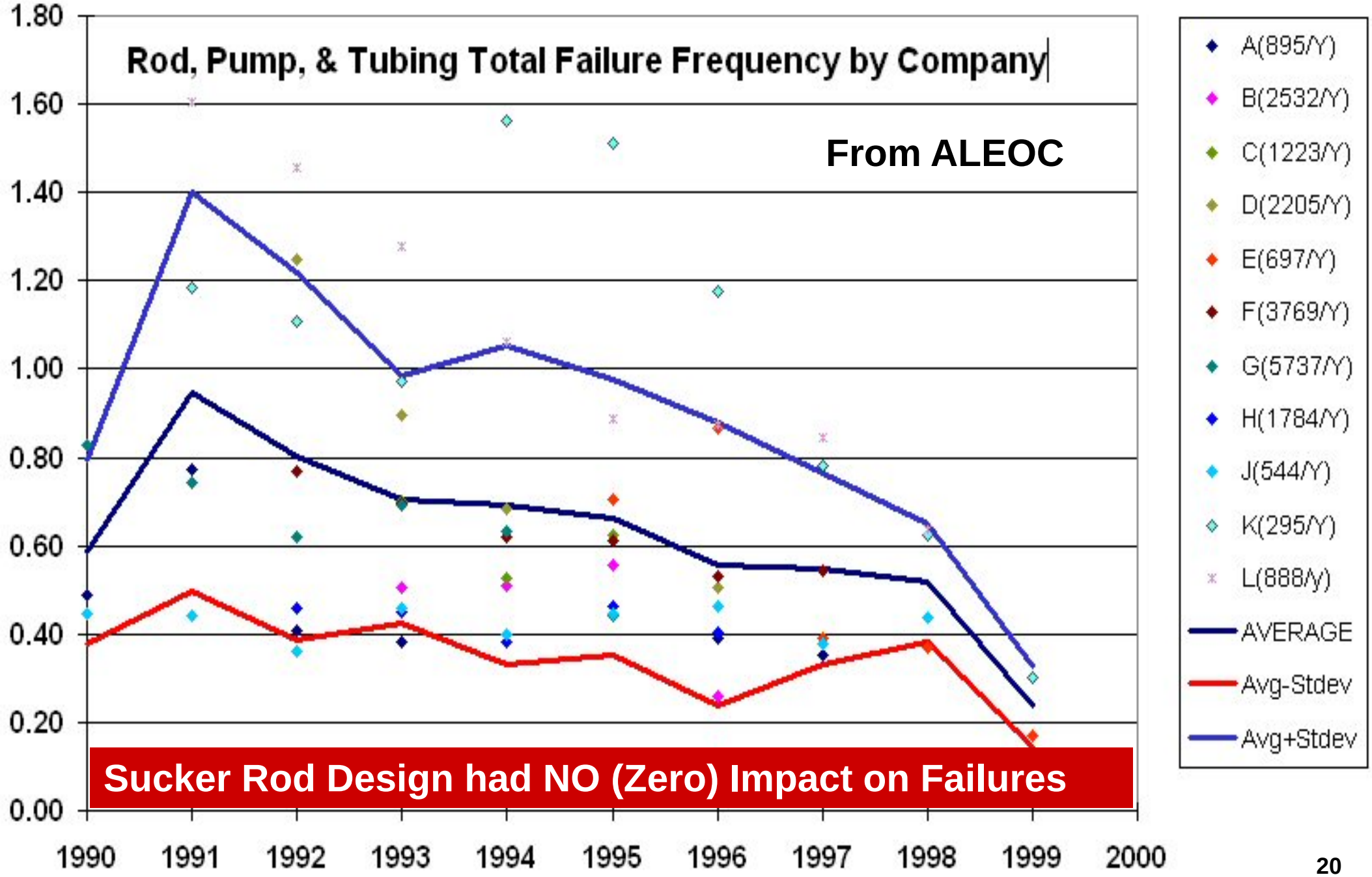
2nd company designed rod strings where:
Fo/SKr>0.2 and N/No'>0.2 Minimum
SHORT AND FAST IS LOWEST COST

Did design practice impact failure Rates?


1st Company - J
Note: The analog computer dynamometer cards on this exhibit were conceived by Sucker Rod Pumping Research, Inc., and publication is made possible by cooperation of the American Petroleum Institute.
Do Not Design Rods Here Due to Overtravel
BAD
Do Not Design Rods Here Due to Undertravel
11
5
Fair-Bad
Good
Fair
DIMENSIONLESS SPEED, N/N0
DIMENSIONLESS LOAD, F0/Skr
.50
.45
.40
.35
.30
.25
.20
.15
.10
.1
.2
.3
.4
.5
.6


2nd Company - H
Note: The analog computer dynamometer cards on this exhibit were conceived by Sucker Rod Pumping Research, Inc., and publication is made possible by cooperation of the American Petroleum Institute.
NO – Do Not Design Rods Here
Company H Says Design Rods Here in the "Sweet Spot" ~Most Power for $$$ Optimize Equipment Size & Cost Vs failures and rig cost
Company H Says Never Design Rods Here
Fair-Bad
NO – Do Not Design Rods Here
DIMENSIONLESS SPEED, N/N0
.50
.45
.40
.35
.30
.25
.20
.15
.10
.1
.2
.3
.4
.5
.6
DIMENSIONLESS LOAD, F0/Skr

Both had 0.4 Failure Frequency



What did Companies J and H have in Common?

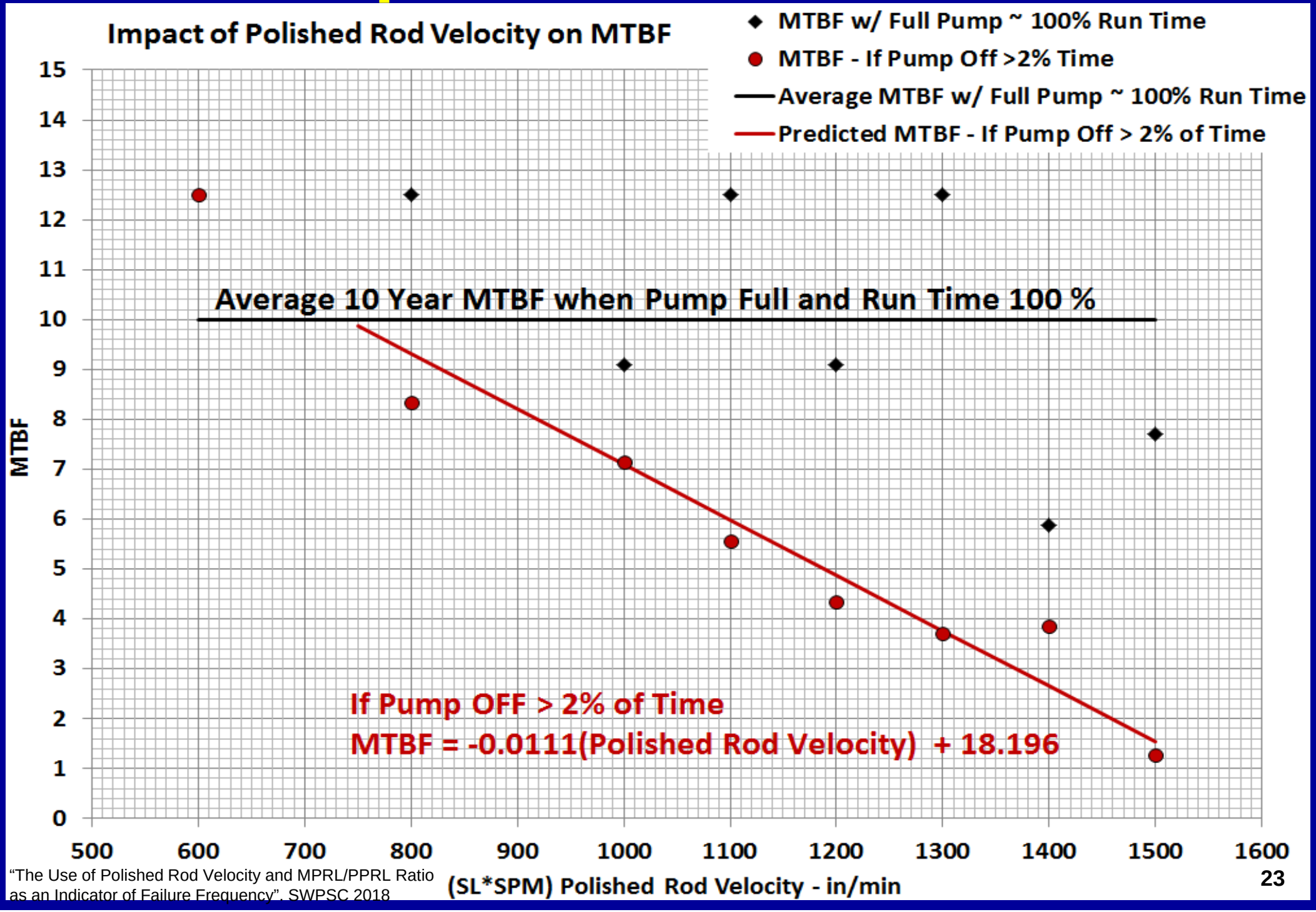
1. ***Practice of Operating Pumps Filled with Liquid***
2. **Active Program where Technicians:**
   a) **Acquired Data**
   b) **Analyzed Problems**
   c) **Followed-up Recommendations**
3. **Practiced a "Company" Methodology to Analyze, Optimize, and Trouble Shoot Wells**
4. **Tracked Cause and Condition of Failed Downhole Equipment in a Failure Data Base**
5. **Determined to investigate Root Cause of Failure and Correct the Problem.**

Data from more than 6000 sucker rod lifted wells shows impact of incomplete pump fillage on run life

- When the pump is filled with liquid then the pump load transfer occurs at/near the bottom and top of the pump stroke.
- This field collected dynamometer data is from 6000 different SR wells
- There is a significant increase in failure rate when NOT transferring pump load at bottom and top of the pump stroke

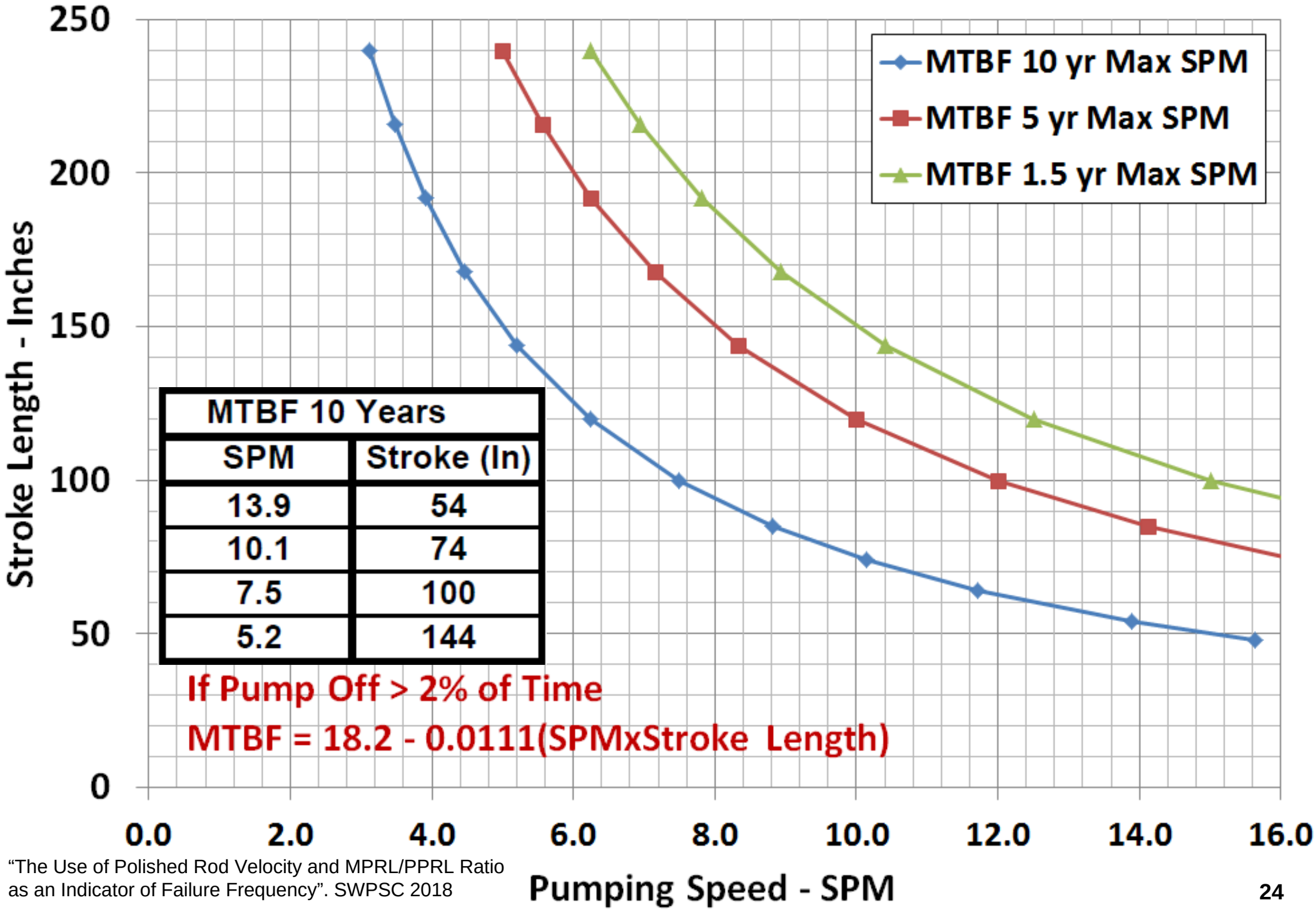
"The Use of Polished Rod Velocity and MPRL/PPRL Ratio as an Indicator of Failure Frequency". SWPSC 2018

Full Pump MTBF for SPM x Stroke



"The Use of Polished Rod Velocity and MPRL/PPRL Ratio as an Indicator of Failure Frequency", SWPSC 2018

MTBF vs SPM x Stroke, If Pump Off > 2% of Time



MTBF 10 Years	
SPM	Stroke (In)
13.9	54
10.1	74
7.5	100
5.2	144

"The Use of Polished Rod Velocity and MPRL/PPRL Ratio as an Indicator of Failure Frequency". SWPSC 2018

“Long and Slow” VS “Short and Fast”

1. “**Long and Slow**” OR “**Short and Fast**” is **NOT** the way to go.
2. Maintain high pump volumetric efficiency:
   - Match pump displacement with wellbore inflow.
   - Pump a Full Stroke of liquid by controlling run time with a POC or Timer or VSD or ….
   - Eliminate Gas interference.
3. Gas Interference requires an efficient downhole gas separation with capacity exceeding the net pump displacement
4. Full pump fillage requires controlling the run time to match the pump displacement to the well inflow rate

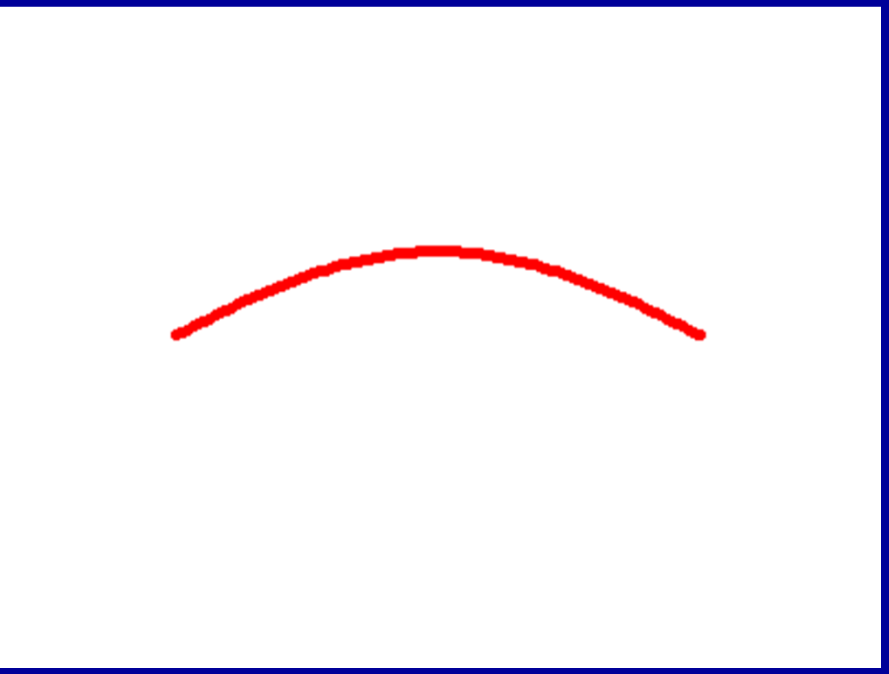
Focus on Operating Sucker Rod Lifted Wells with Pump Full of Liquid

- **"The Way to Go" is to produce wells with complete liquid pump fillage.**
- **Less problems, more efficient operations and lower failure rate will result, if wells are operated with a pump filled with liquid.**
- **Incomplete pump fillage is a significant factor causing problems to the operation of the well.**

- ***Be <u>determined</u> to operate your pump filled with liquid, plus do not forget to apply other recommended practices.***

No - Undamped Natural Frequency

Synchronous Speed of Straight Uniform Sucker Rod String



$$No = 15\ v_s / L$$

No = 15 x 16300 / 5000 = 48.9

No – Undamped natural frequency , SPM

v_s – Velocity of Sound in Steel, ft/sec

v_s = 16,300 ft/sec

L – Length of Rod String, Ft

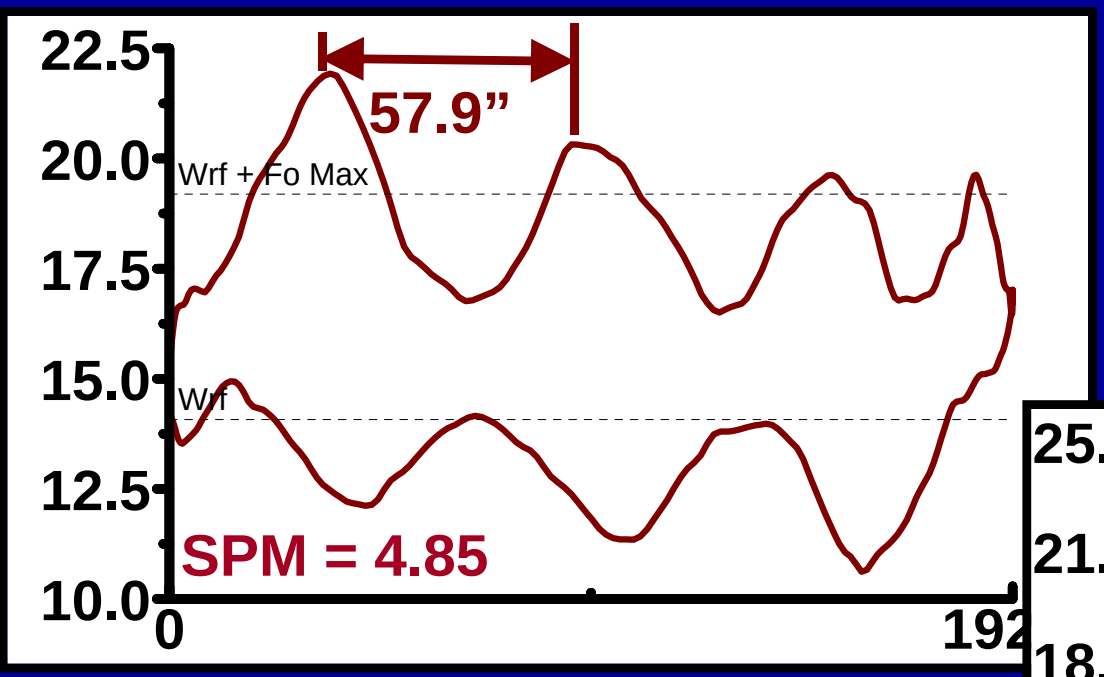
N – Current Pumping Speed, SPM

No' – Natural Frequency adjusted for Taper – Fc x No

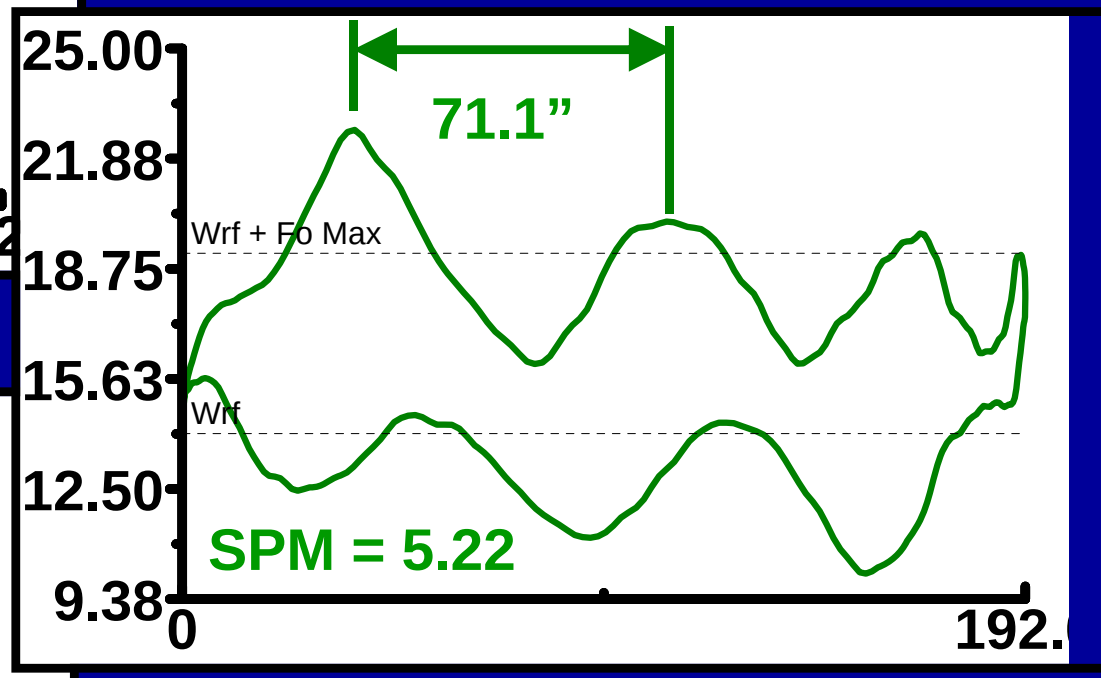
Fc = 1.093 No' = 1.093 x 48.9 = 53.4

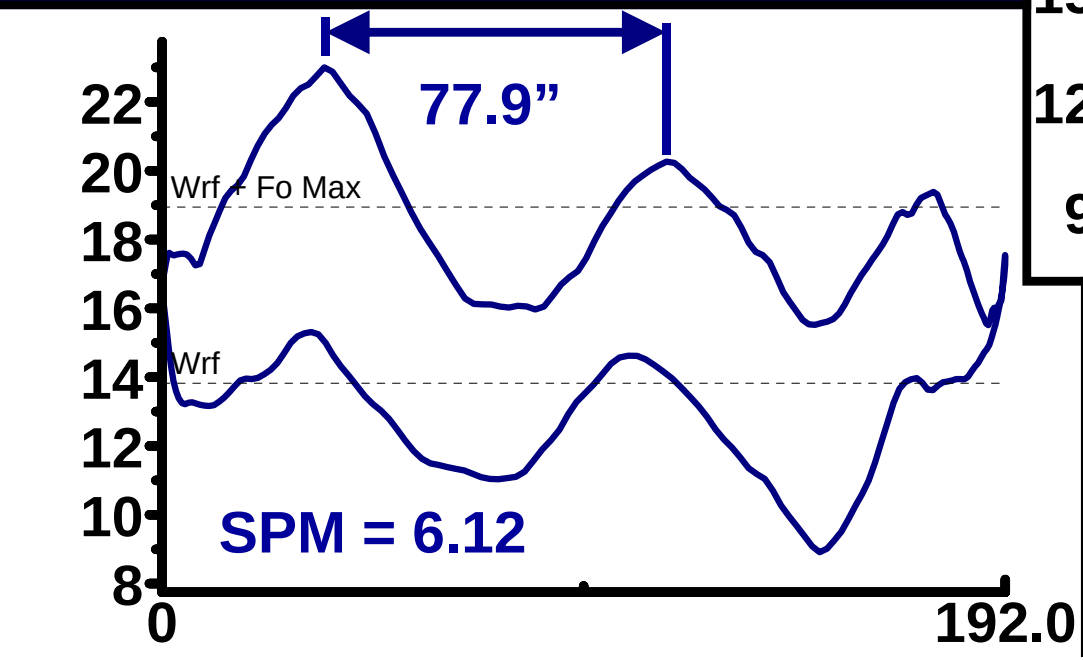
N/No' - Dimensionless Speed Ratio

Peak-to-Peak Load Echo Moves Further Apart as SPM: 4.85=>6.12



Natural Frequency adjusted for Taper = 45.88 SPM

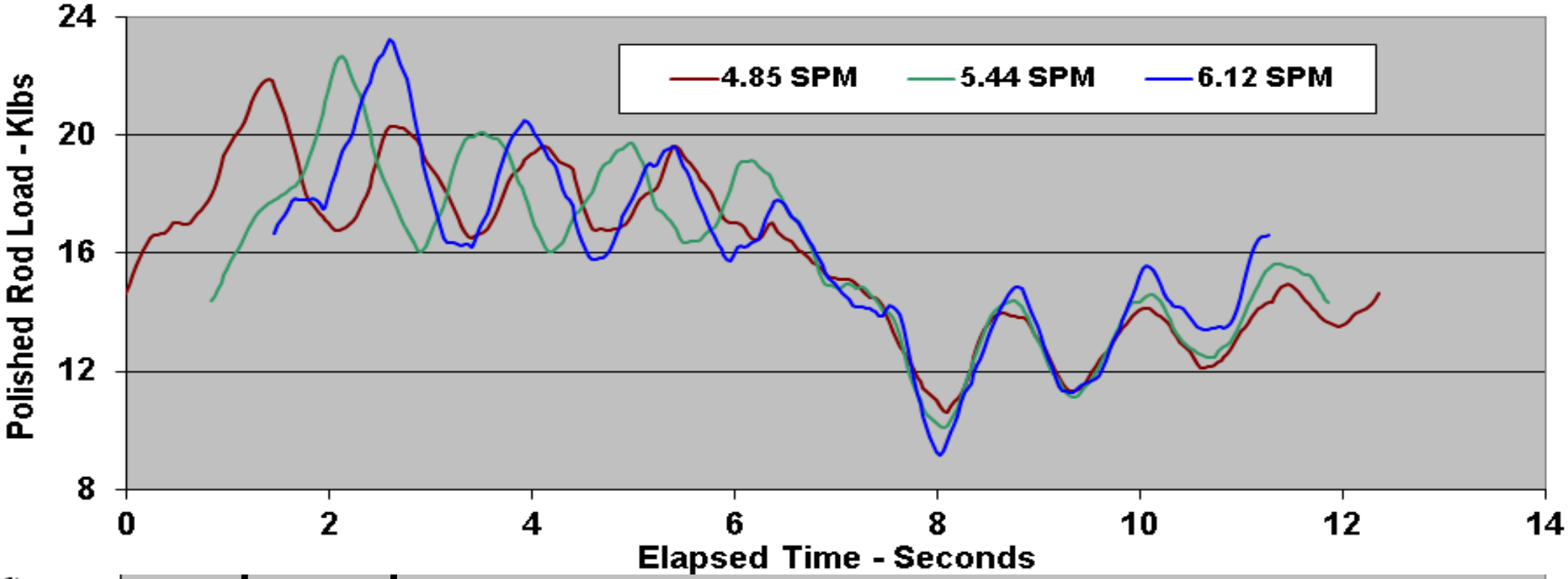


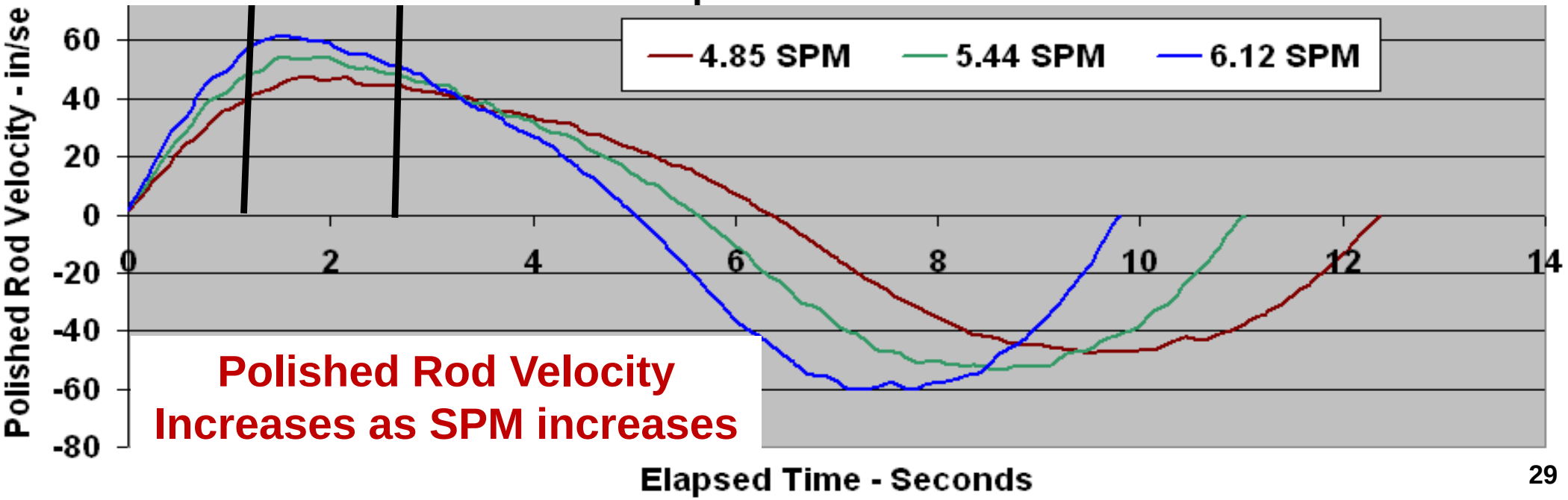


Elapsed Time Between Repeating Load Peaks = 1.31 Seconds

Echometer Online : Over Travel_2020_21 : DynoChangeSPM

Loads Echo Peak-to-Peak at Rod Frequency

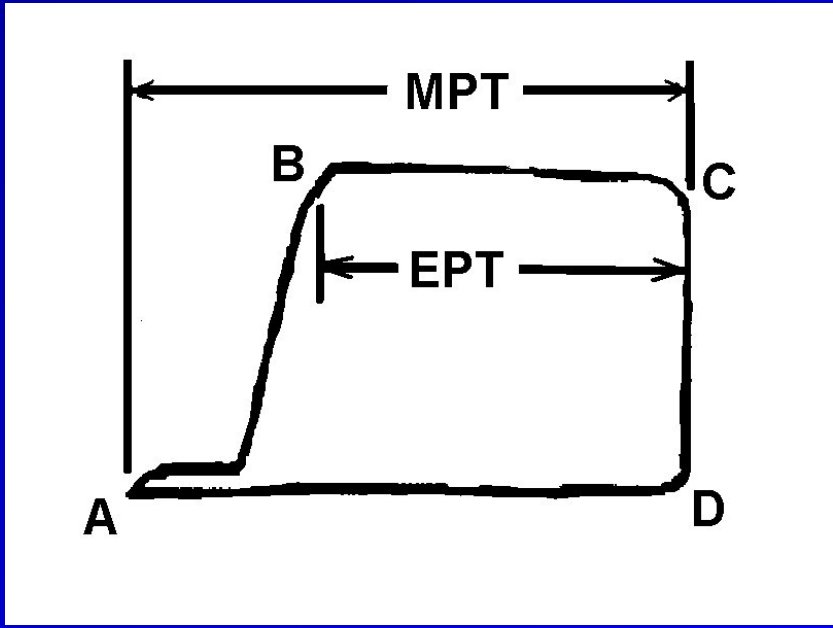




Polished Rod Velocity Increases as SPM increases

Upstroke Fluid Pound
Delayed Closing of TV on Up Stroke

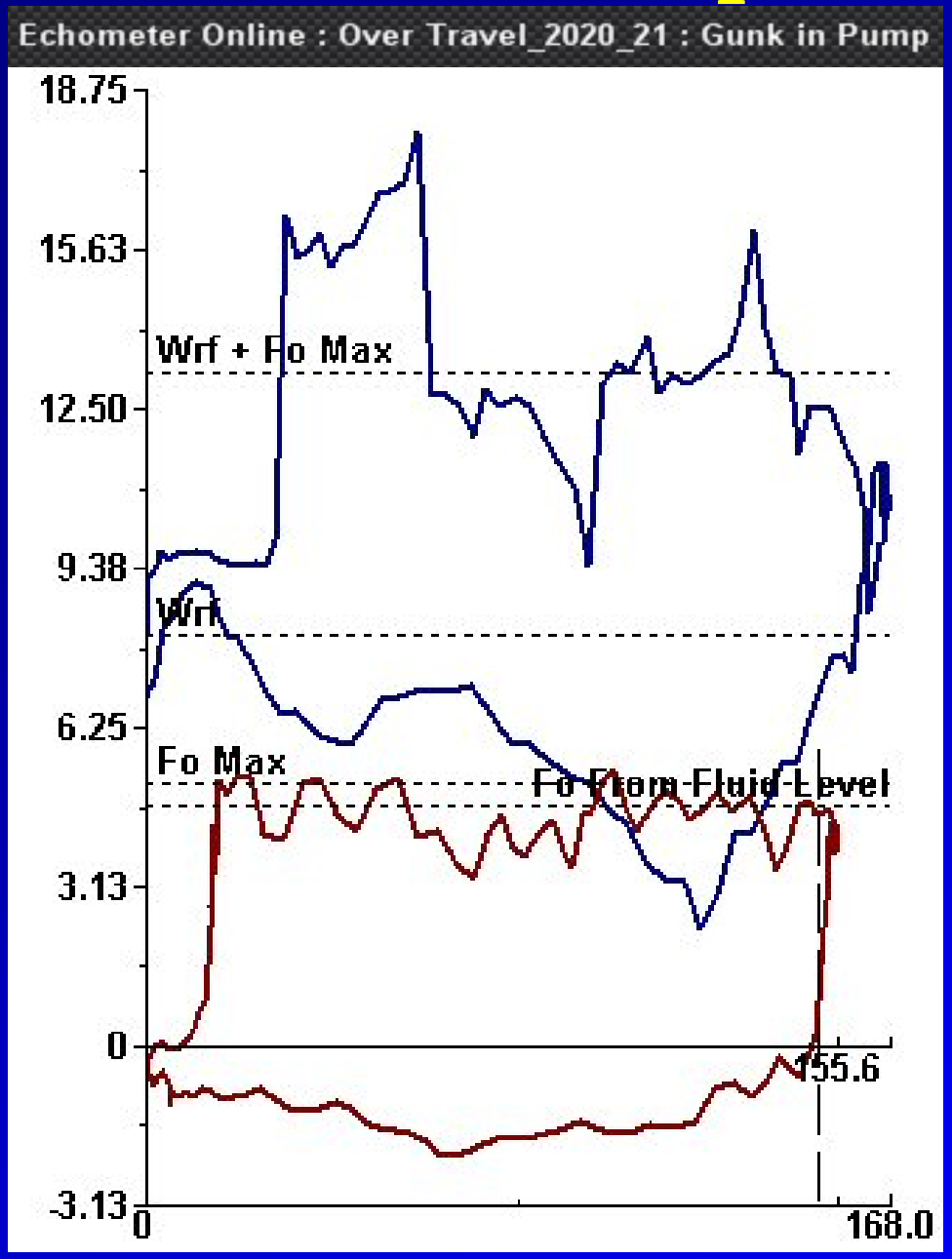
Tubing anchored or unanchored



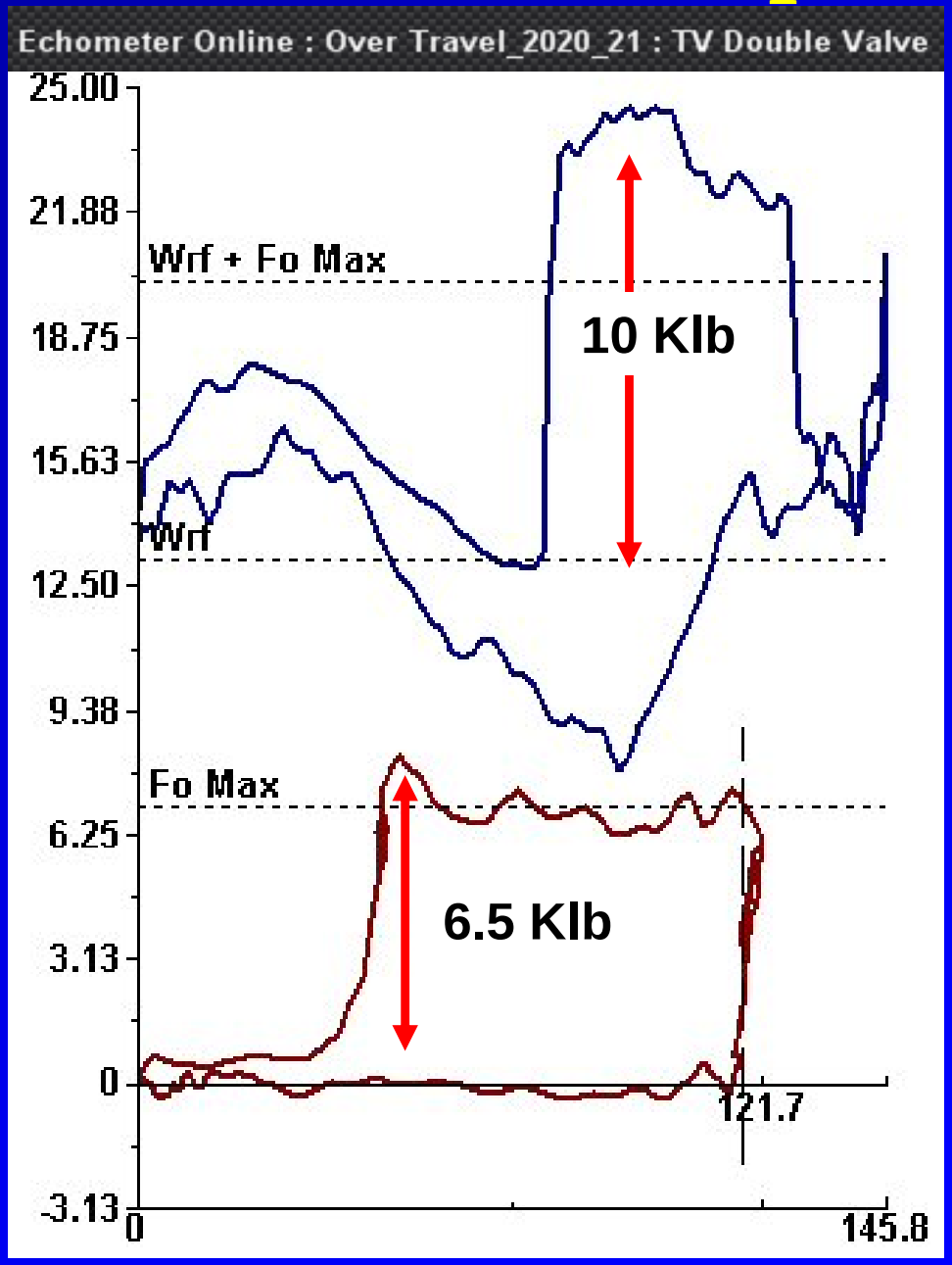
Traveling Valve Ball/Seat not closing properly at beginning of upstroke: Flow restricted by very viscous fluid in pump OR TV ball prevented from going on seat OR flow area smaller than plunger above pump to small OR damaged/pitted TV ball.

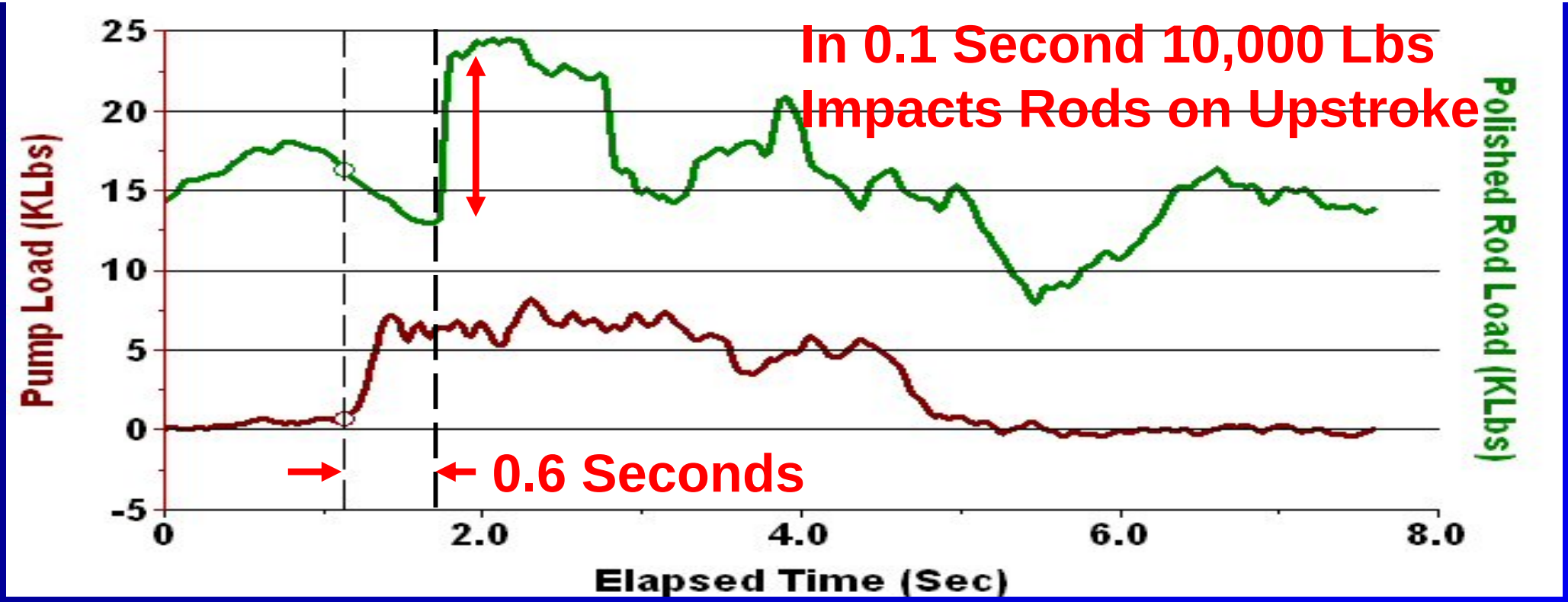
Shock Loads Increase Rod Failures

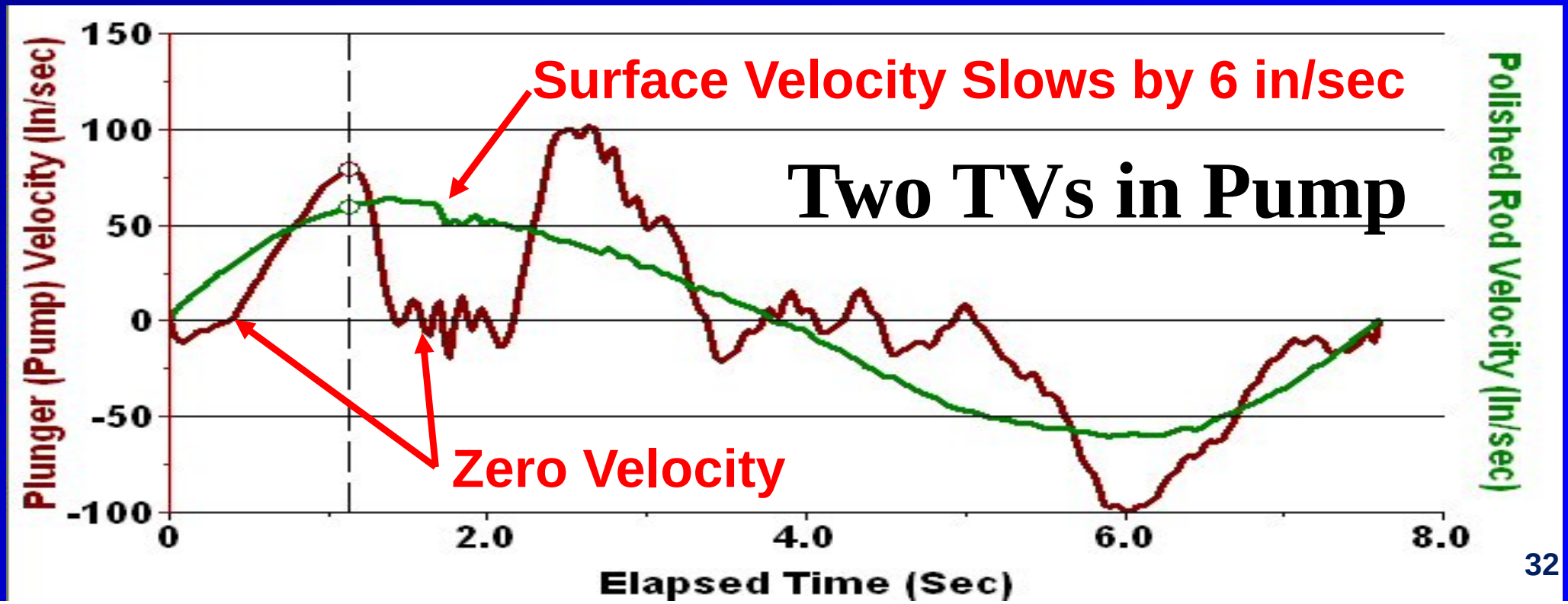
Gunk in Pump



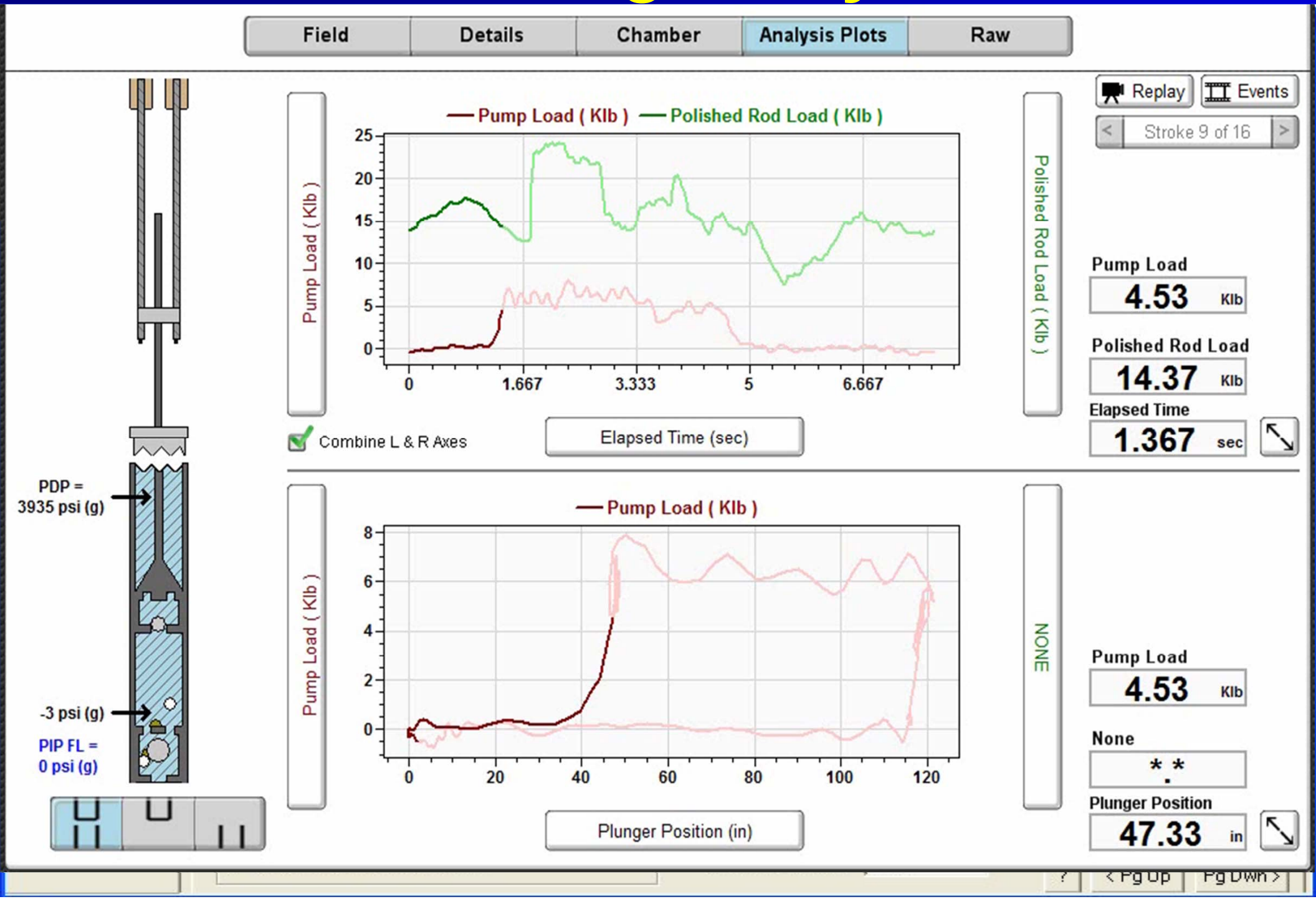
Two TVs in Pump



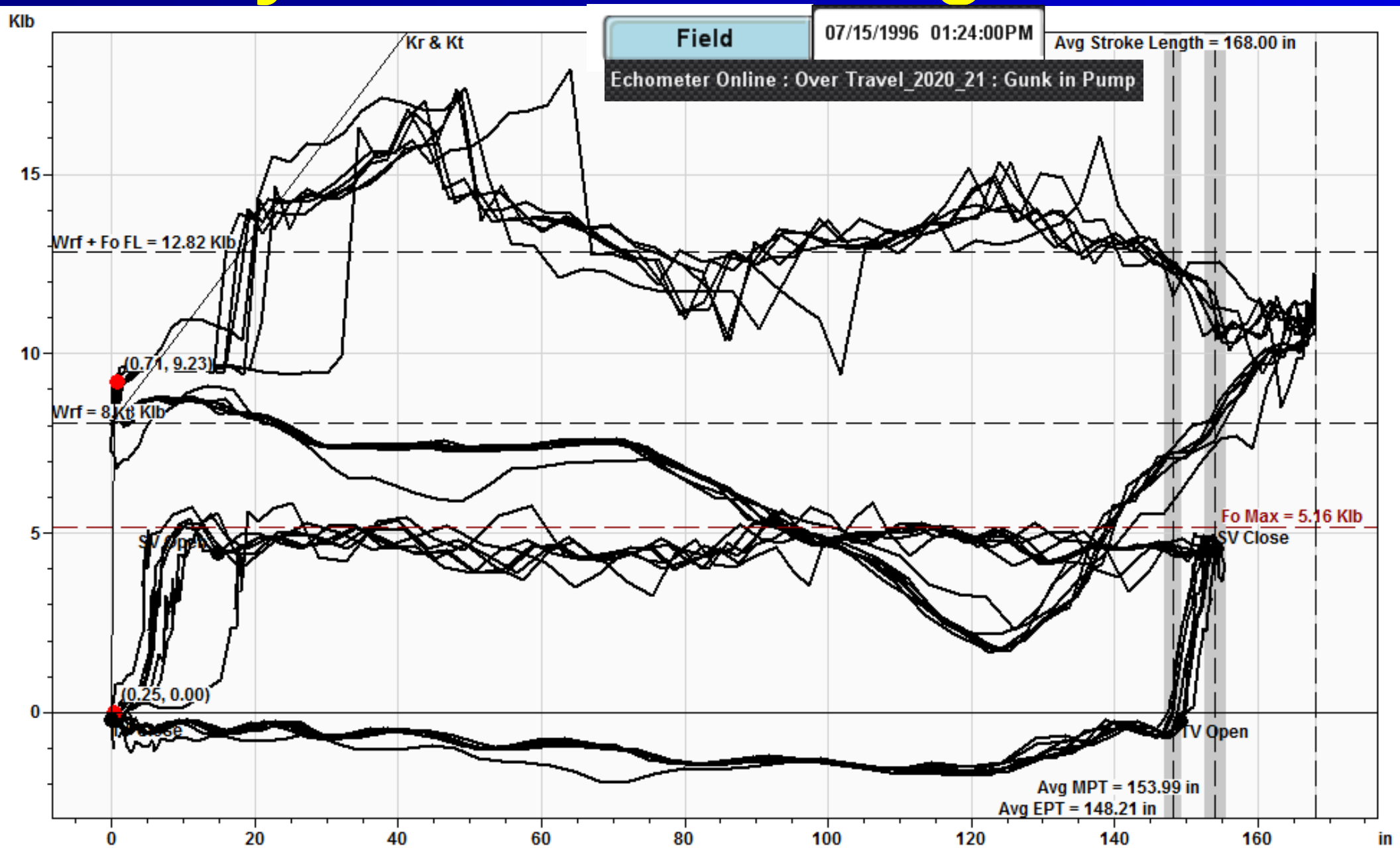

In 0.1 Second 10,000 Lbs
Impacts Rods on Upstroke
0.6 Seconds
Pump Load (KLbs)
Polished Rod Load (KLbs)
Elapsed Time (Sec)
25
20
15
10
5
0
-5
0
2.0
4.0
6.0
8.0


Surface Velocity Slows by 6 in/sec
Two TVs in Pump
Zero Velocity
Plunger (Pump) Velocity (In/sec)
Polished Rod Velocity (In/sec)
Elapsed Time (Sec)
150
100
50
0
-50
-100
0
2.0
4.0
6.0
8.0

Visualize Using Analysis Plots

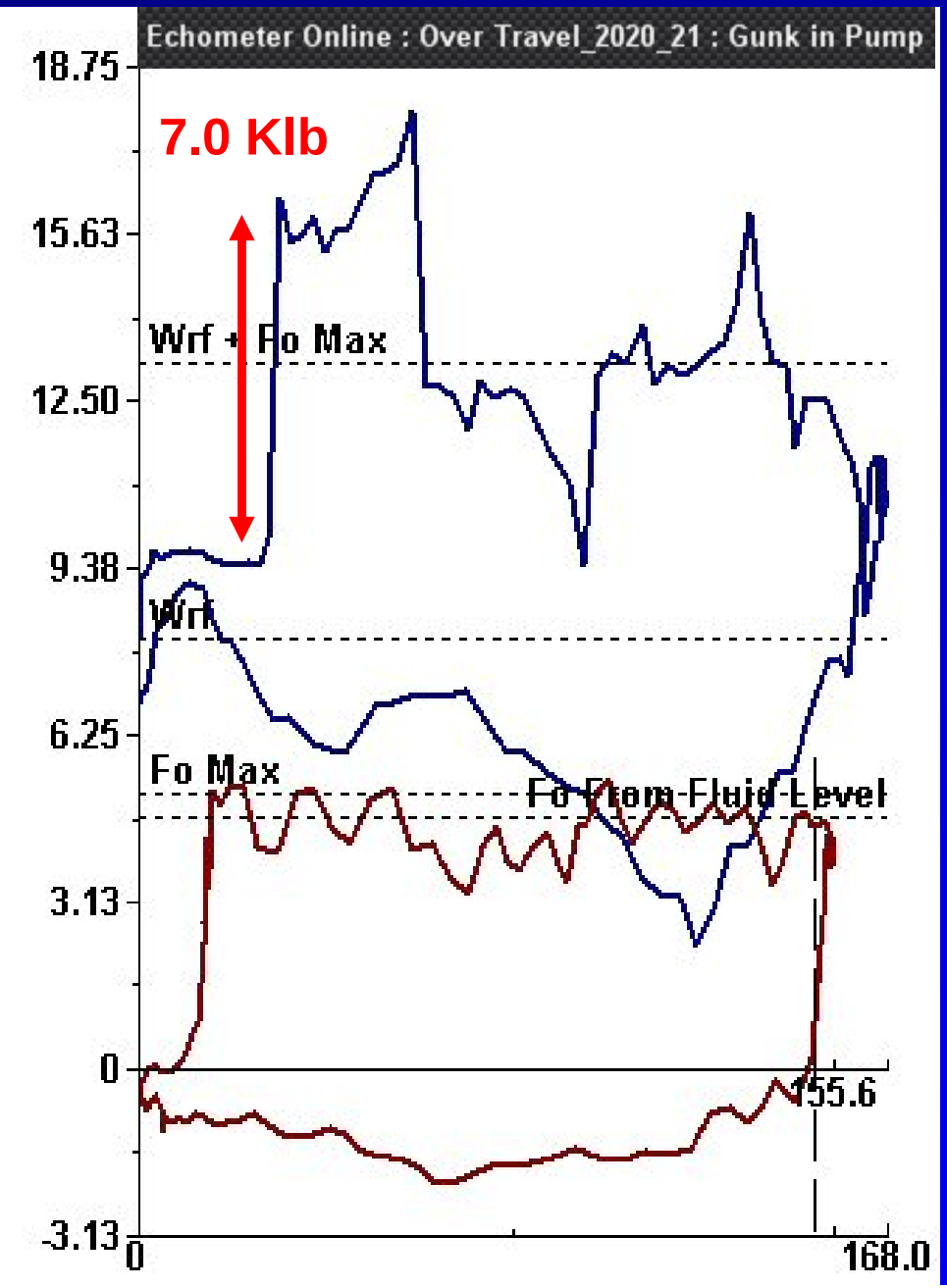


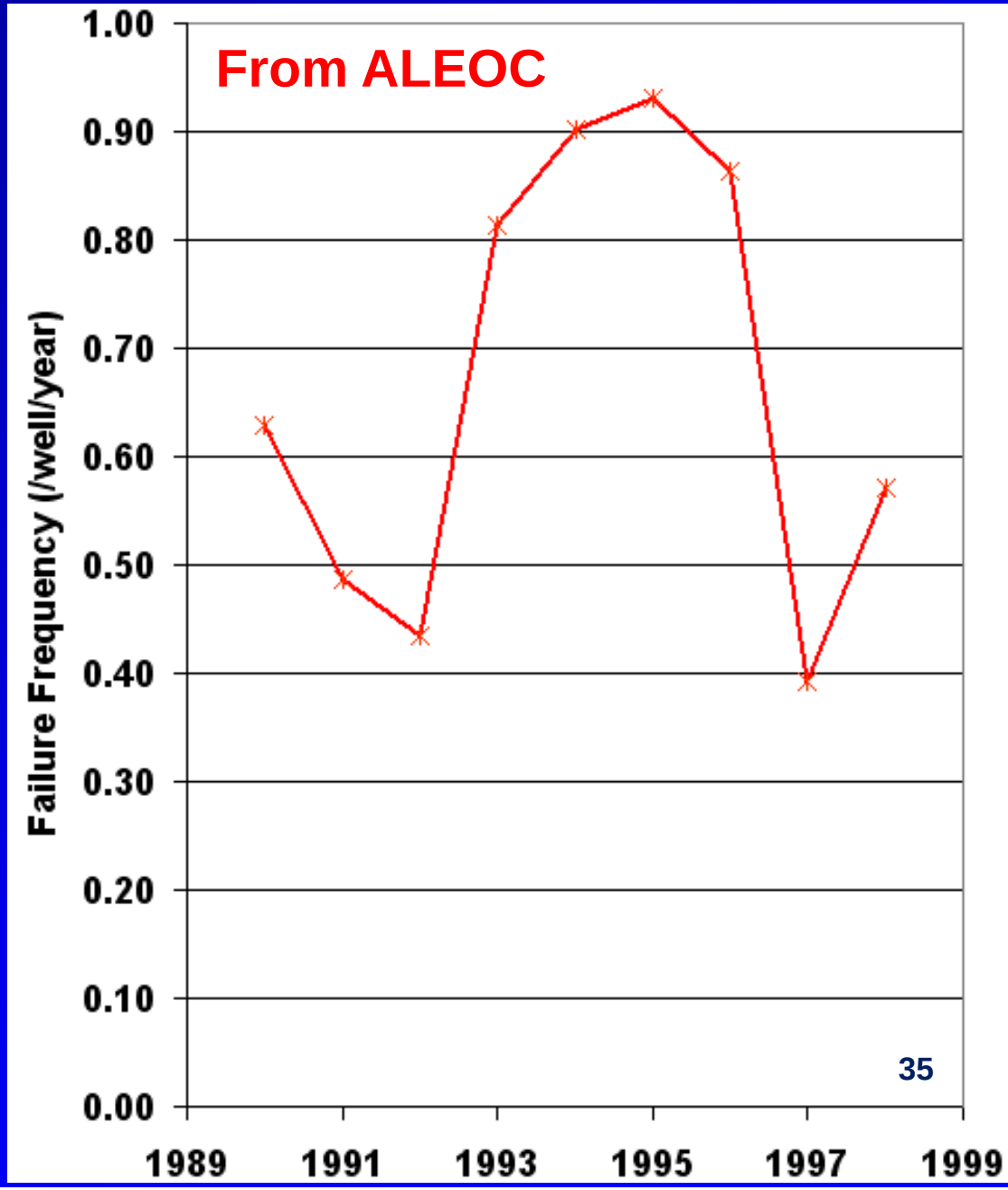
Erratic Behavior Due to Delay in TV Ball Going on Seat

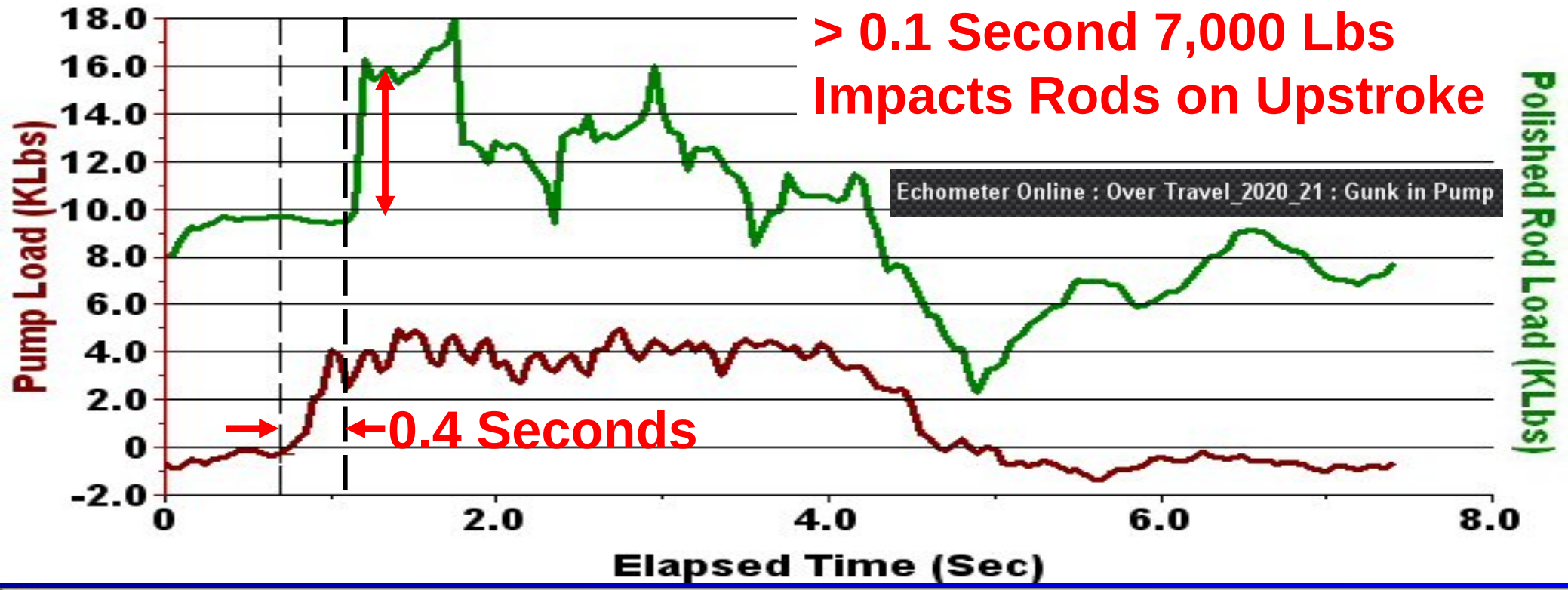


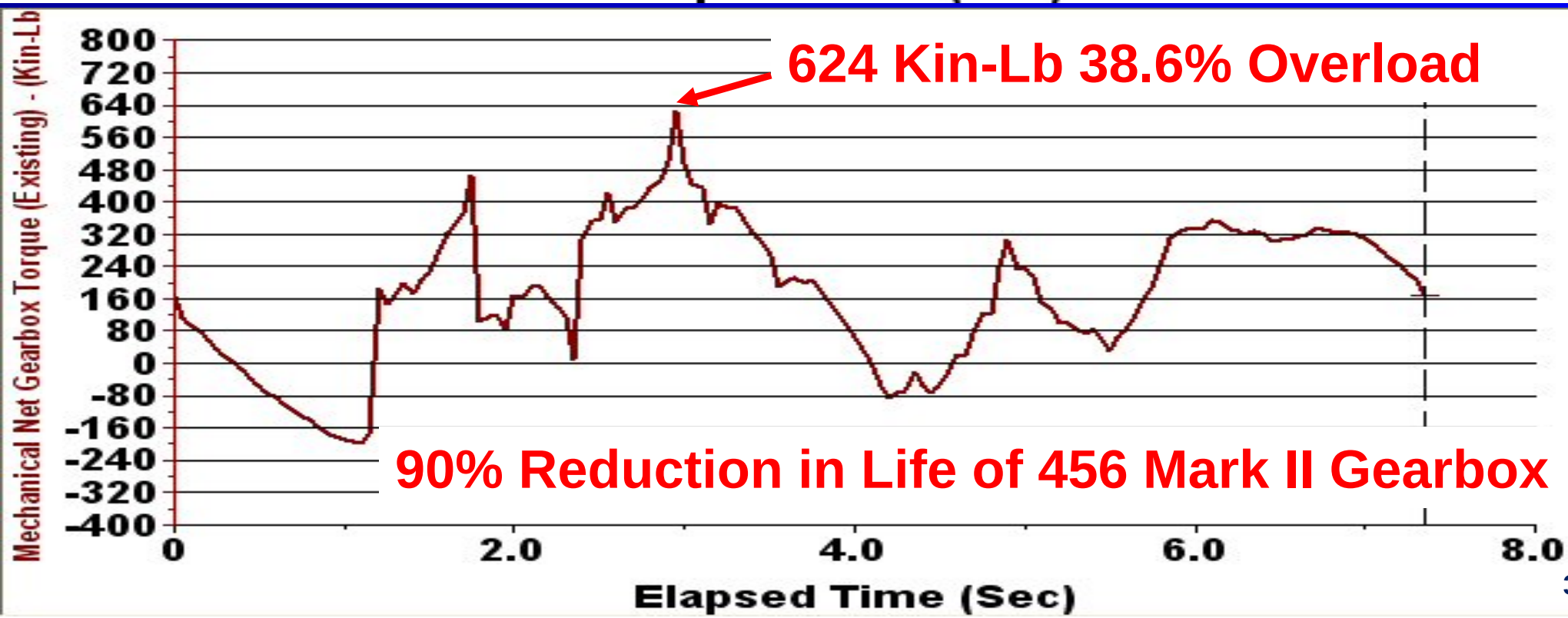
Shock Loads Increase Rod Failures

Gunk in Pump

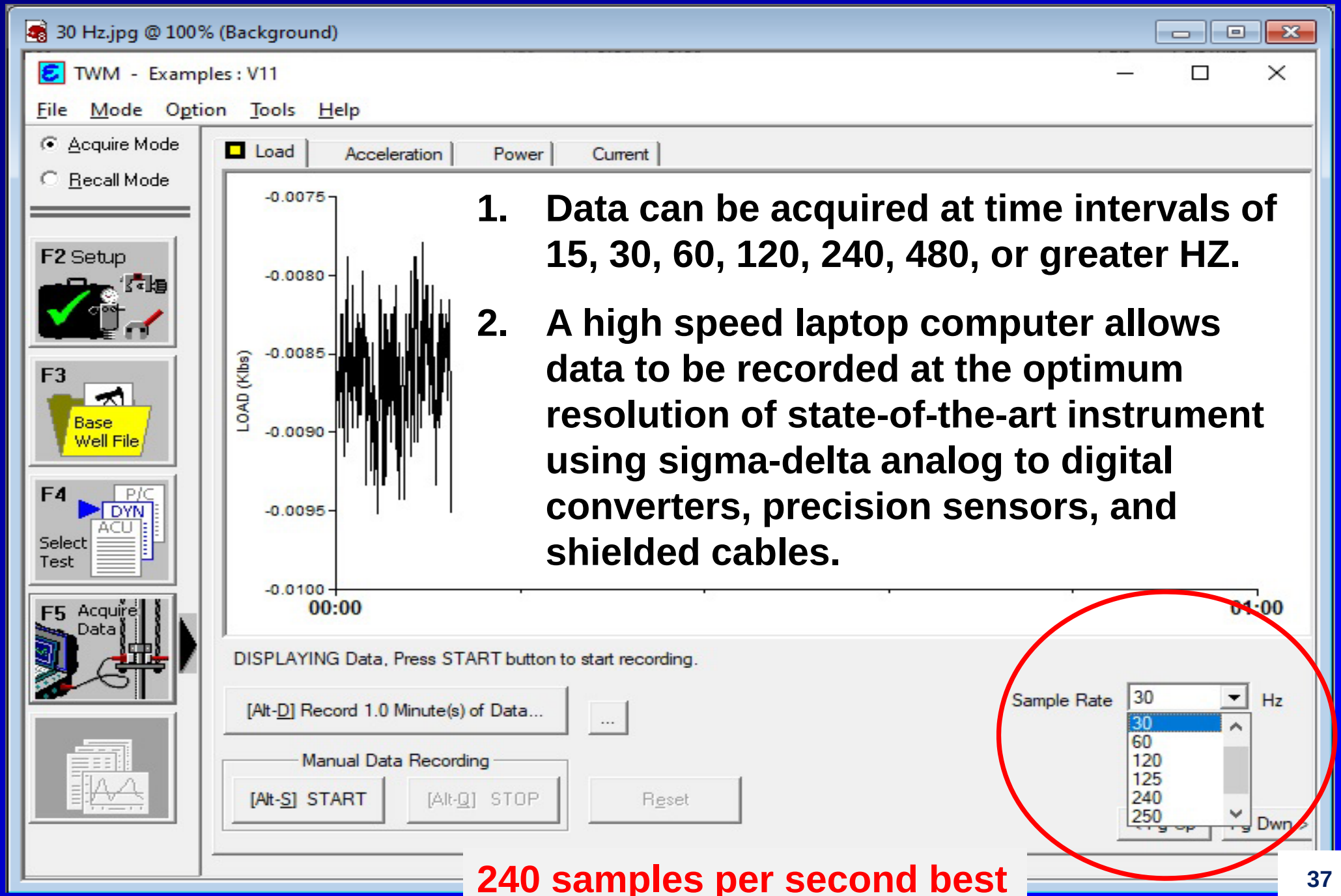





> 0.1 Second 7,000 Lbs
Impacts Rods on Upstroke
Echometer Online : Over Travel_2020_21 : Gunk in Pump
0.4 Seconds
Pump Load (KLbs)
Polished Rod Load (KLbs)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
0
2.0
4.0
6.0
8.0
Elapsed Time (Sec)


624 Kin-Lb 38.6% Overload
90% Reduction in Life of 456 Mark II Gearbox
Mechanical Net Gearbox Torque (Existing) - (Kin-Lb
800
720
640
560
480
400
320
240
160
80
0
-80
-160
-240
-320
-400
0
2.0
4.0
6.0
8.0
Elapsed Time (Sec)

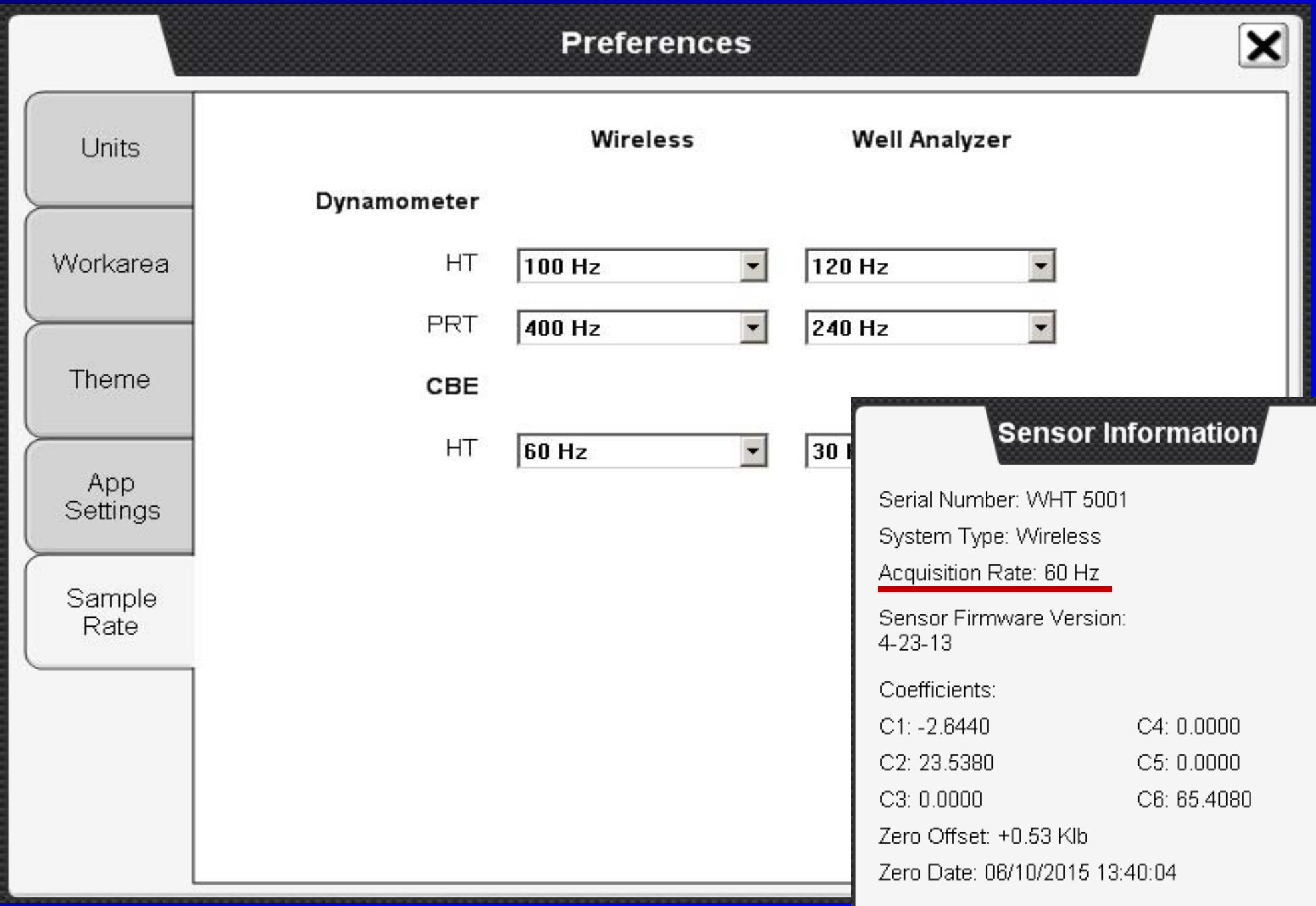
High Speed Acquisition - TWM

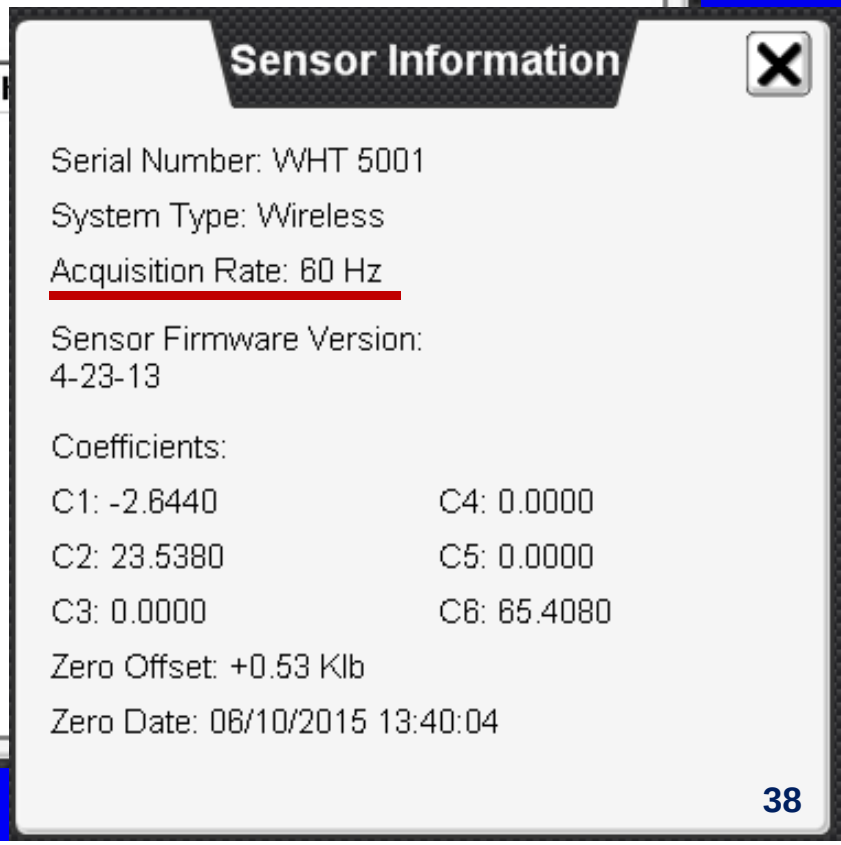


1. Data can be acquired at time intervals of 15, 30, 60, 120, 240, 480, or greater HZ.
2. A high speed laptop computer allows data to be recorded at the optimum resolution of state-of-the-art instrument using sigma-delta analog to digital converters, precision sensors, and shielded cables.

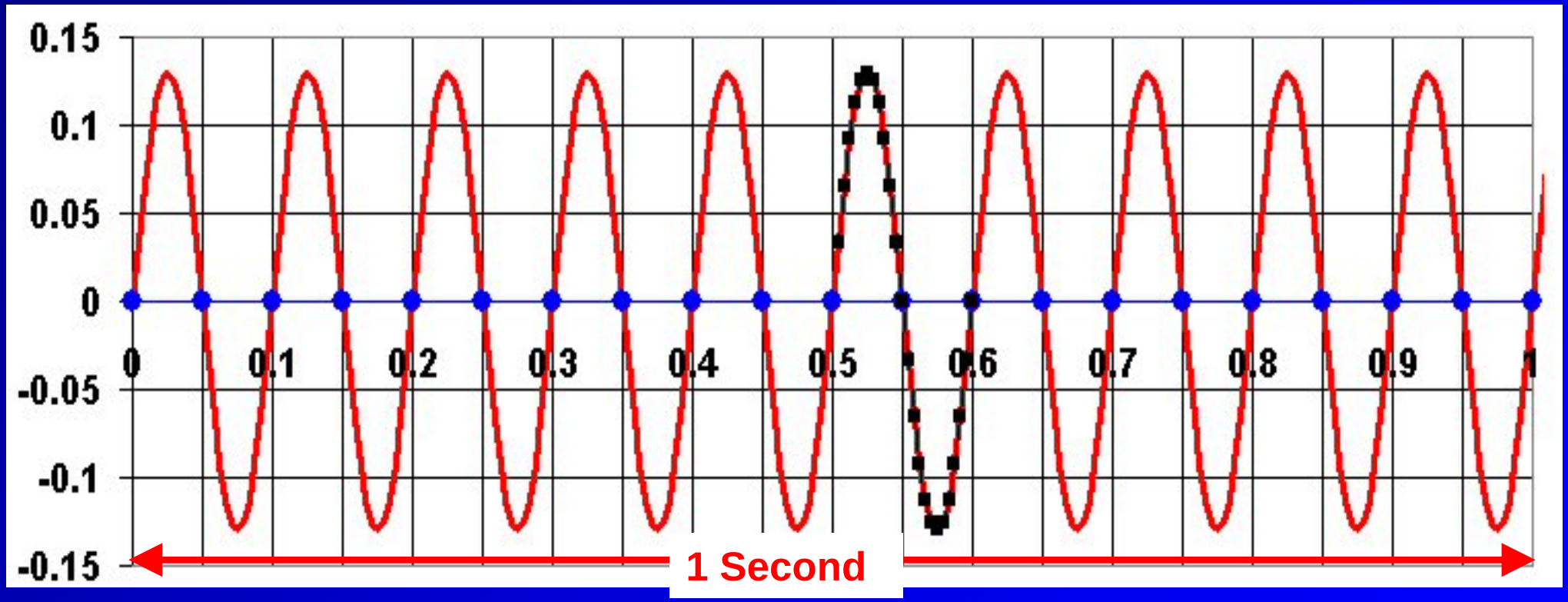
240 samples per second best

High Speed Data Acquisition - TAM



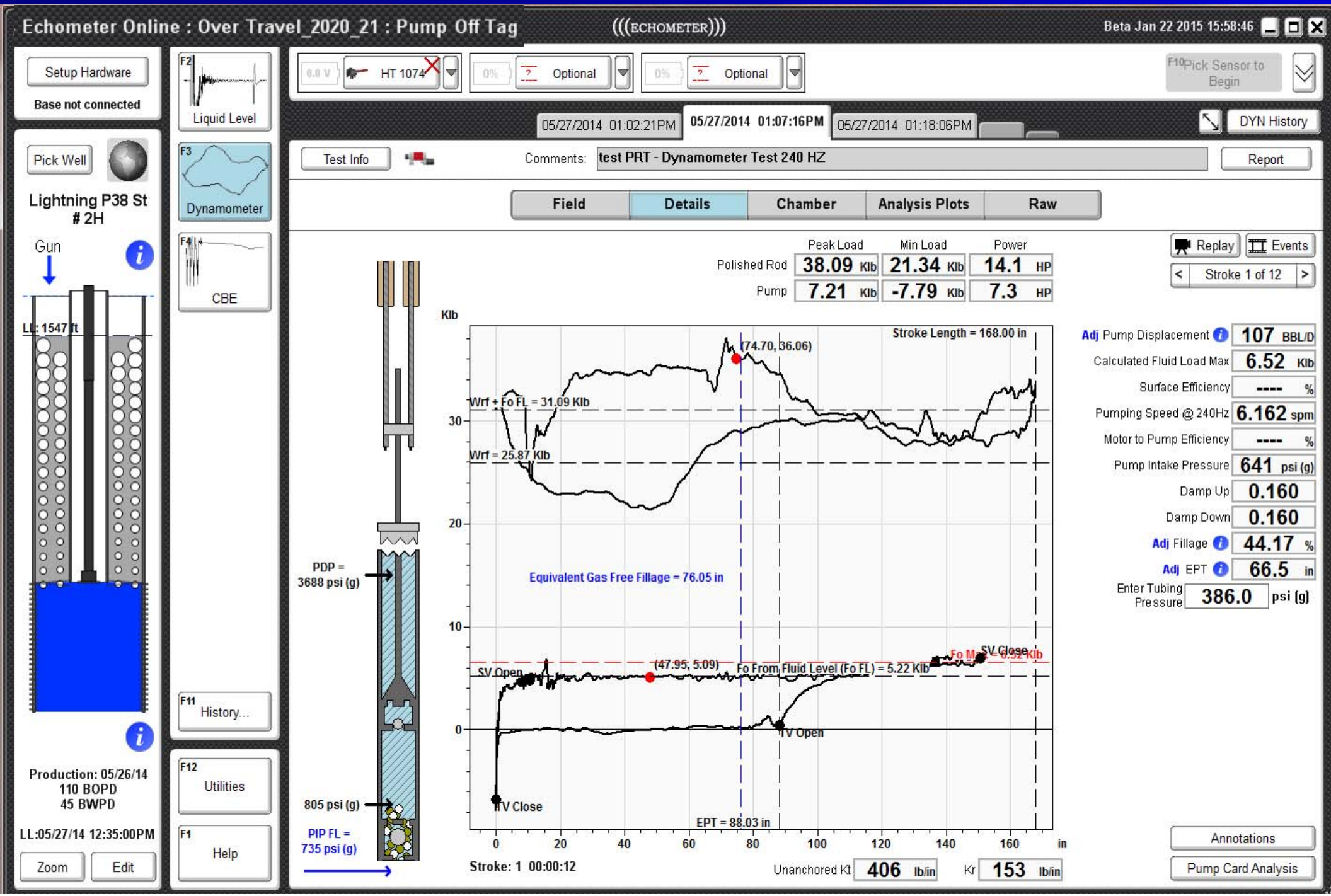


Sampling Rate Important for 1/10 Sec Duration High Speed Event



1. Blue - 20 Samples per Second results in 2 data values acquired during event.
2. Black - 240 Samples per Second results in 24 data values acquired during event
3. Sampling to slow can completely miss occurrence an Event

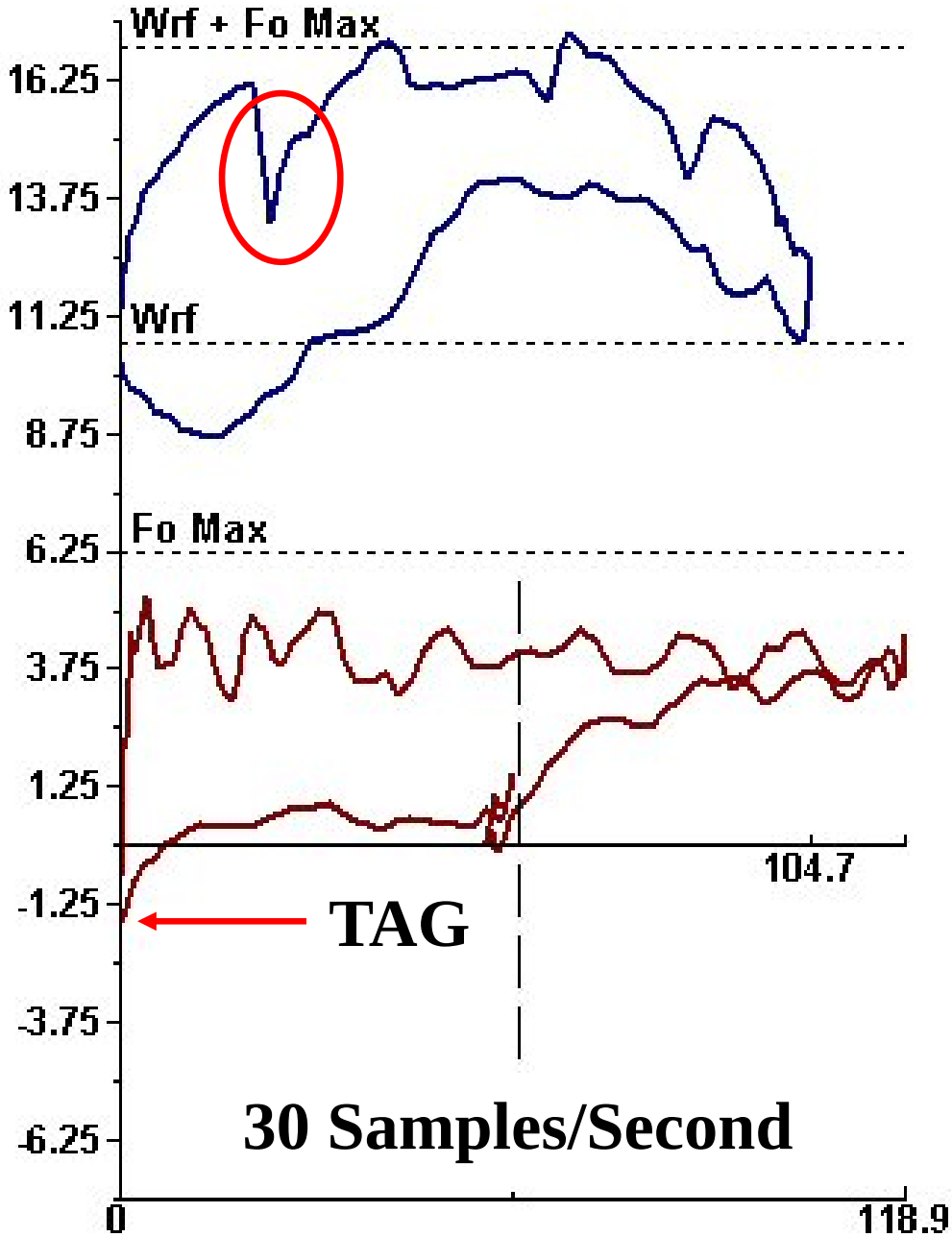
240 HZ Instability in Wave Eq ~ Fixed

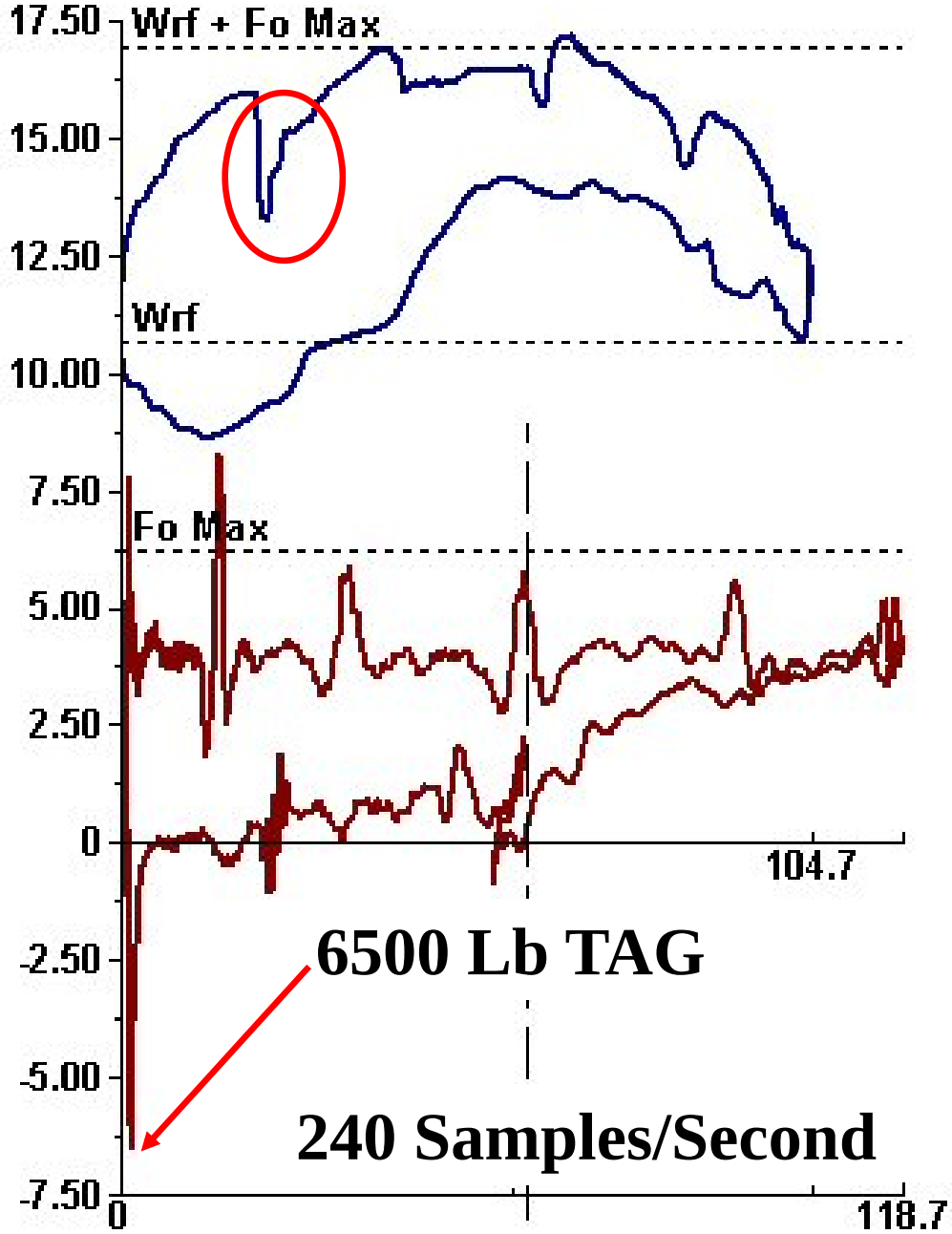


High Speed and High Resolution Data Acquisition

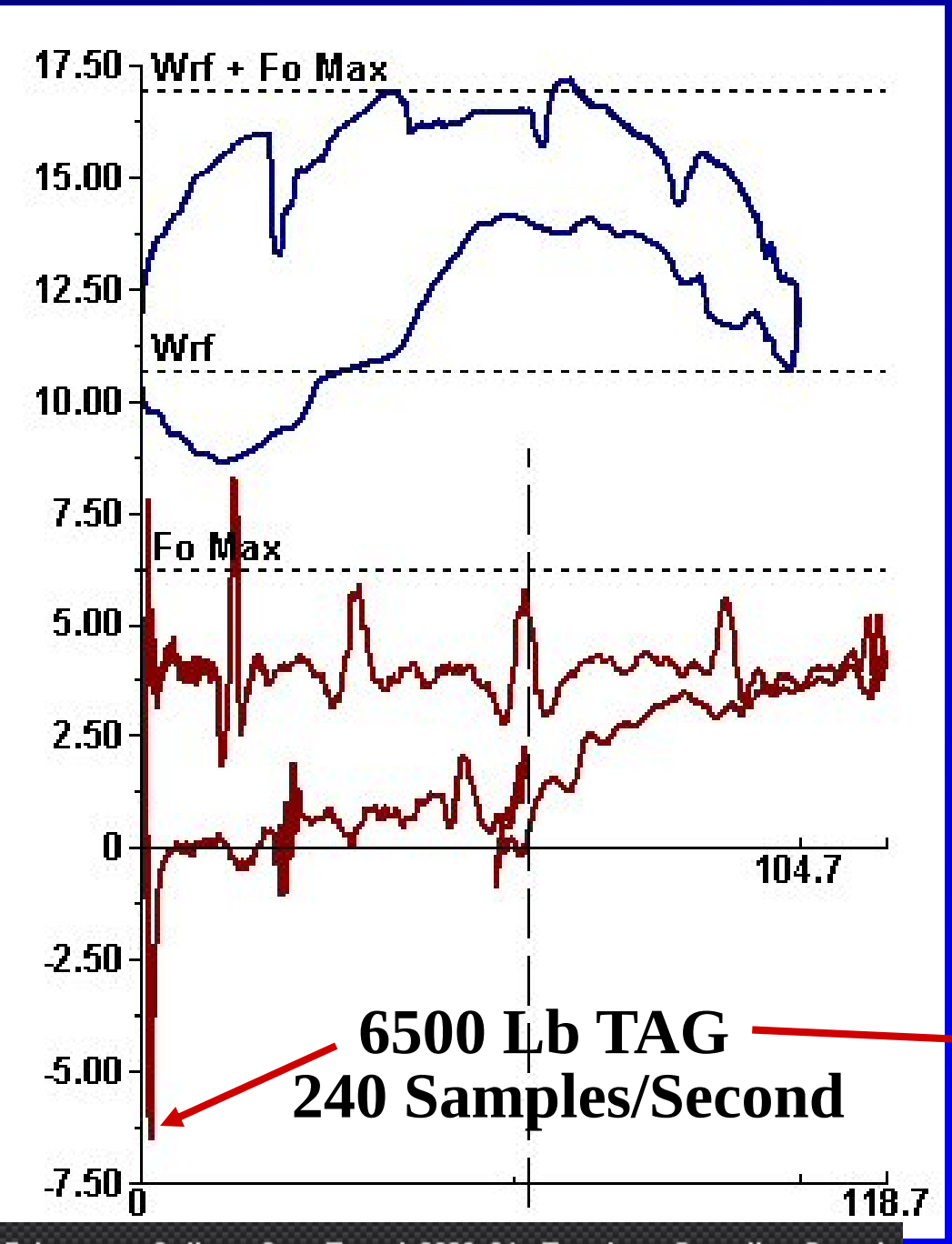
1. Noisy or poor quality data requires special processing/smoothing to prevent false load spikes.
2. High speed/high resolution data required to see character of sudden impact loads.
3. High speed/high resolution data is used to clearly analyze the severity of sudden impact loads.

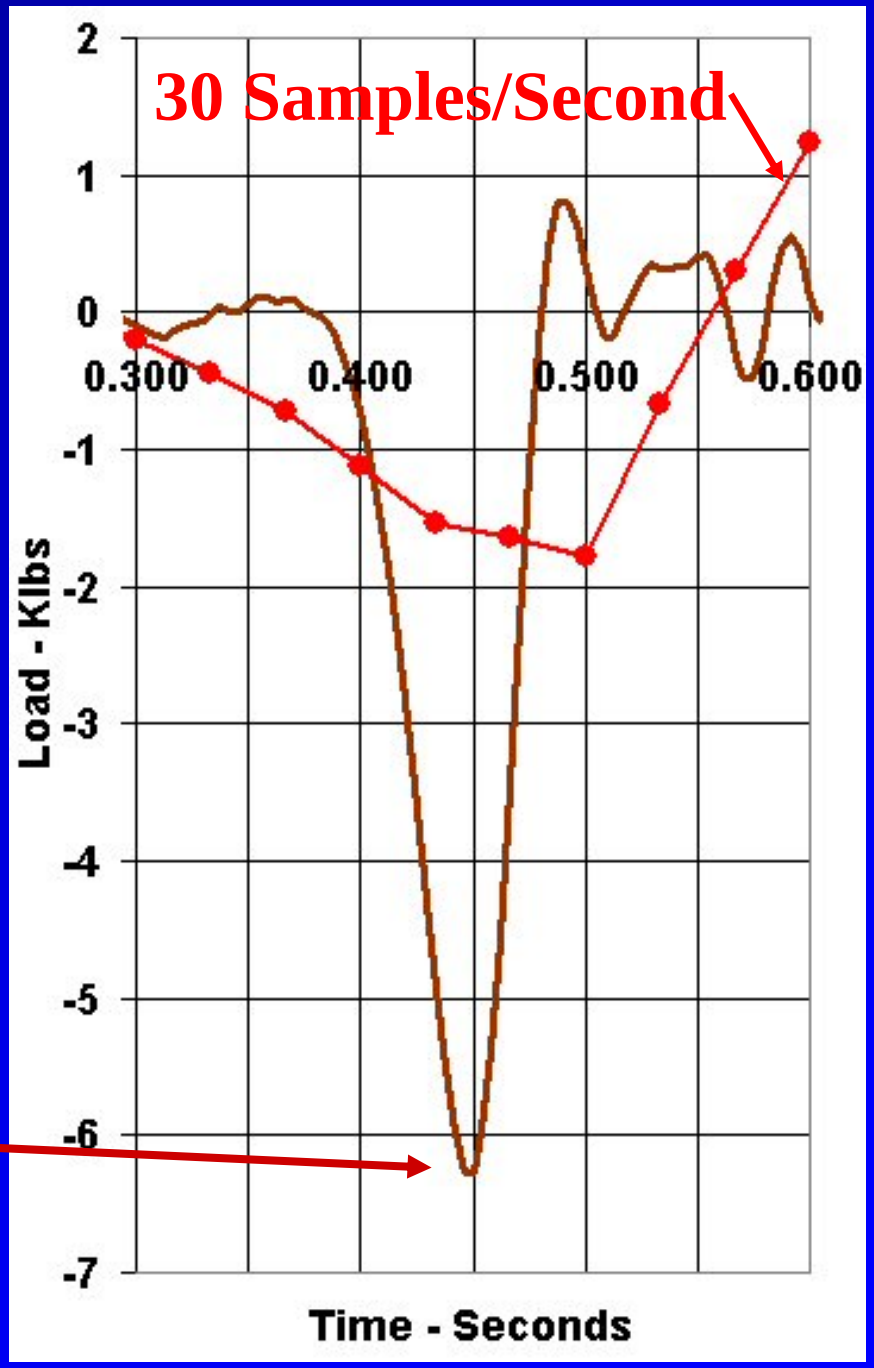
High Speed Sampling Shows Correct Tag Force



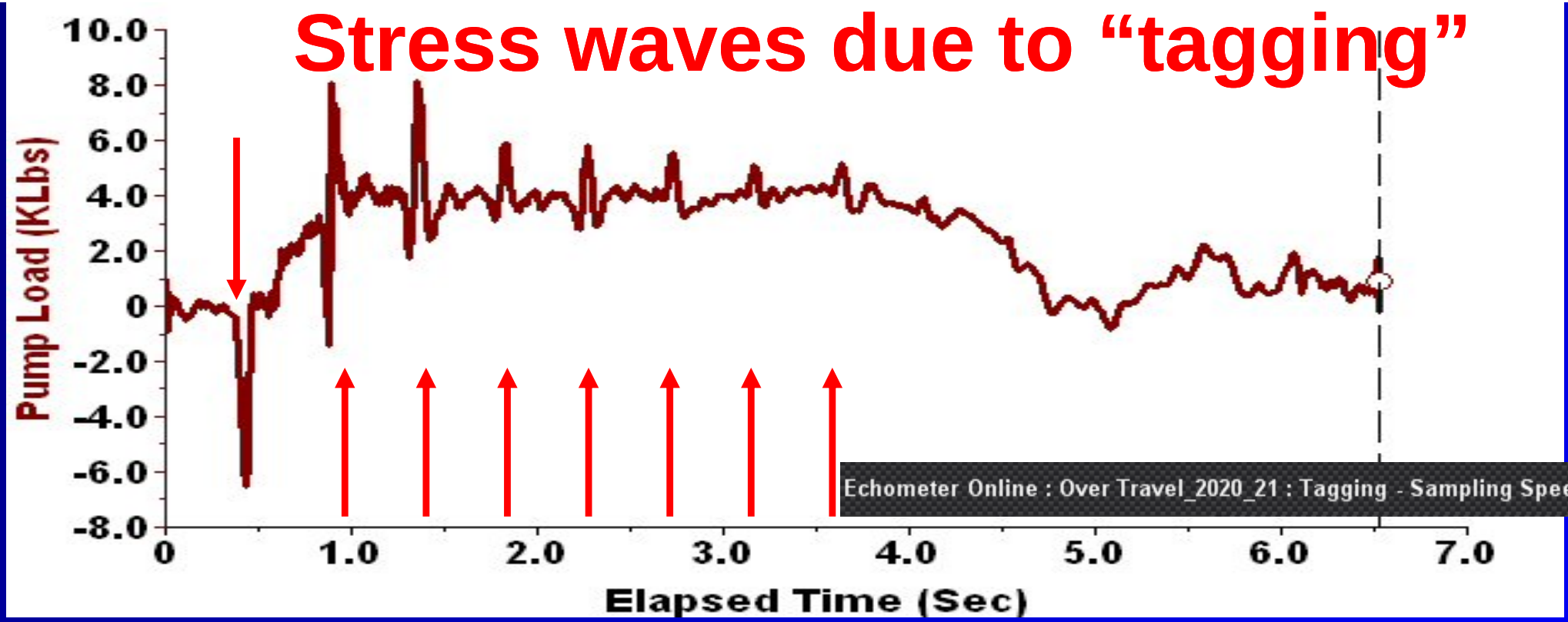


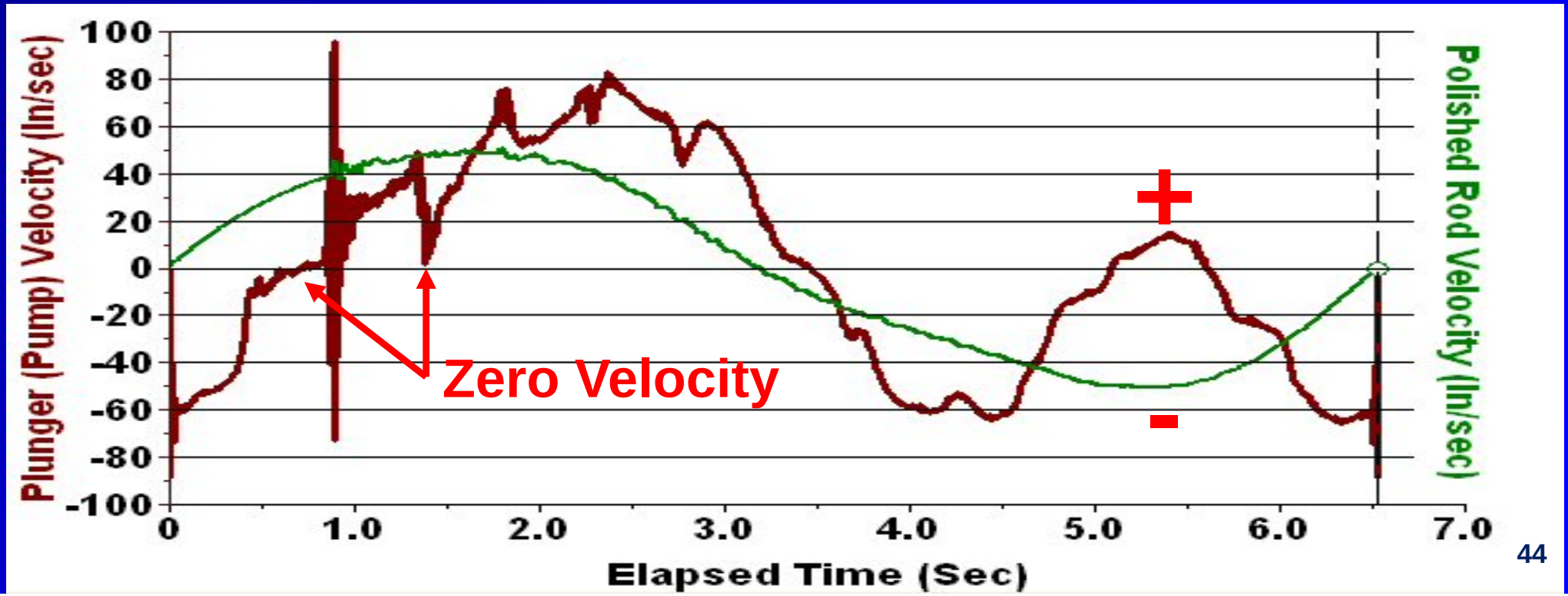
Compare Tag Force of 30 & 240 Hz



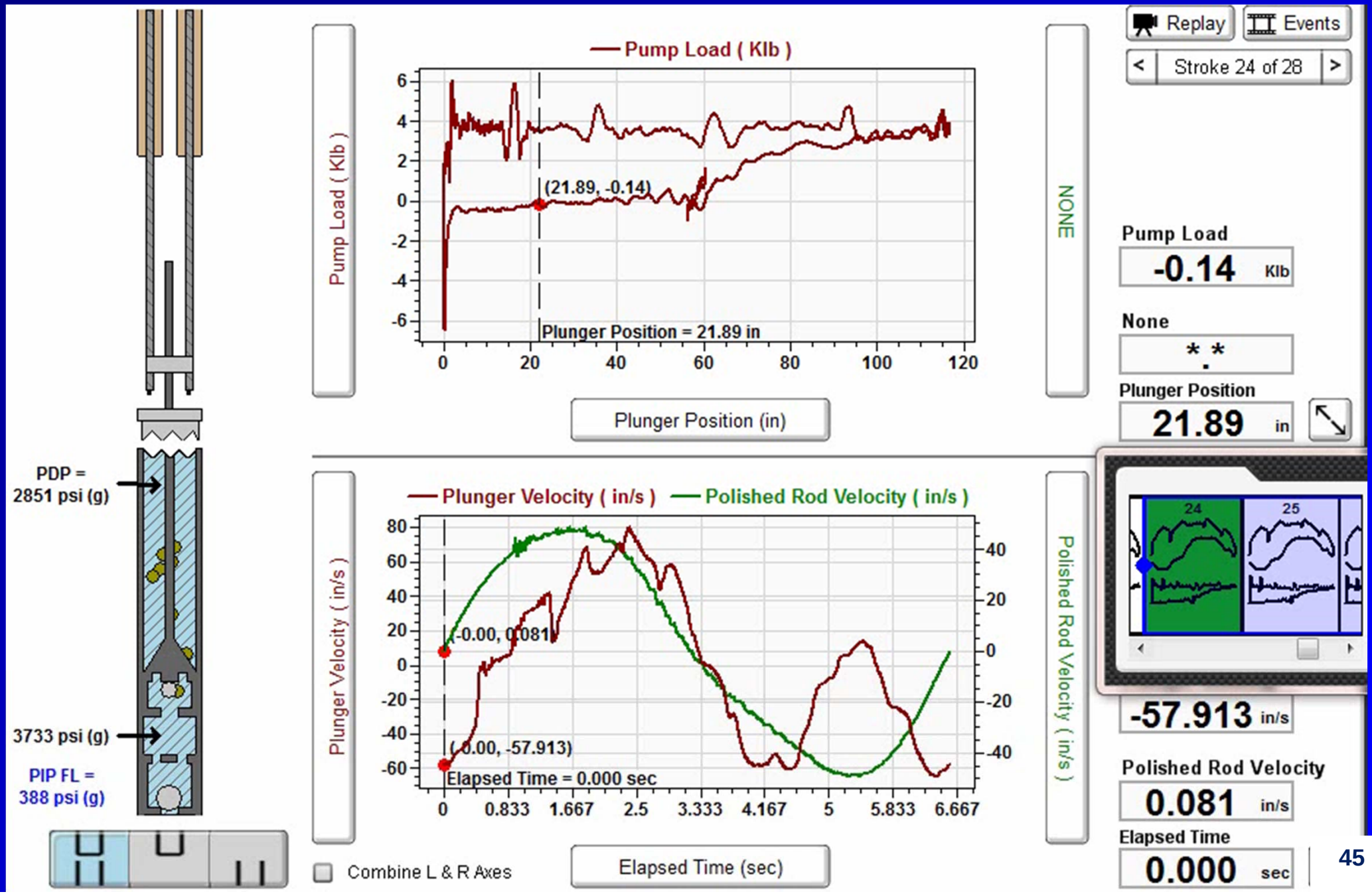


Stress waves due to "tagging"

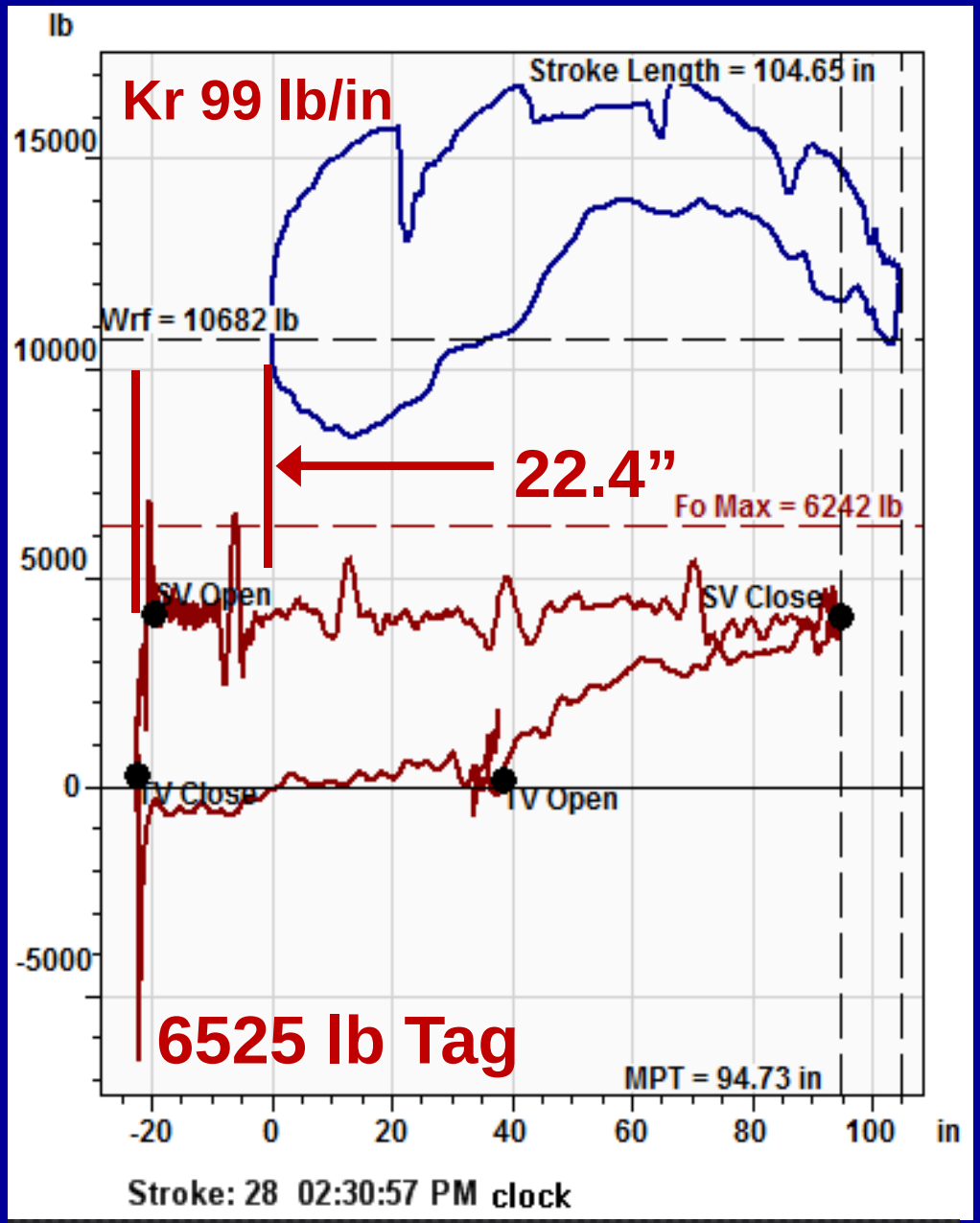


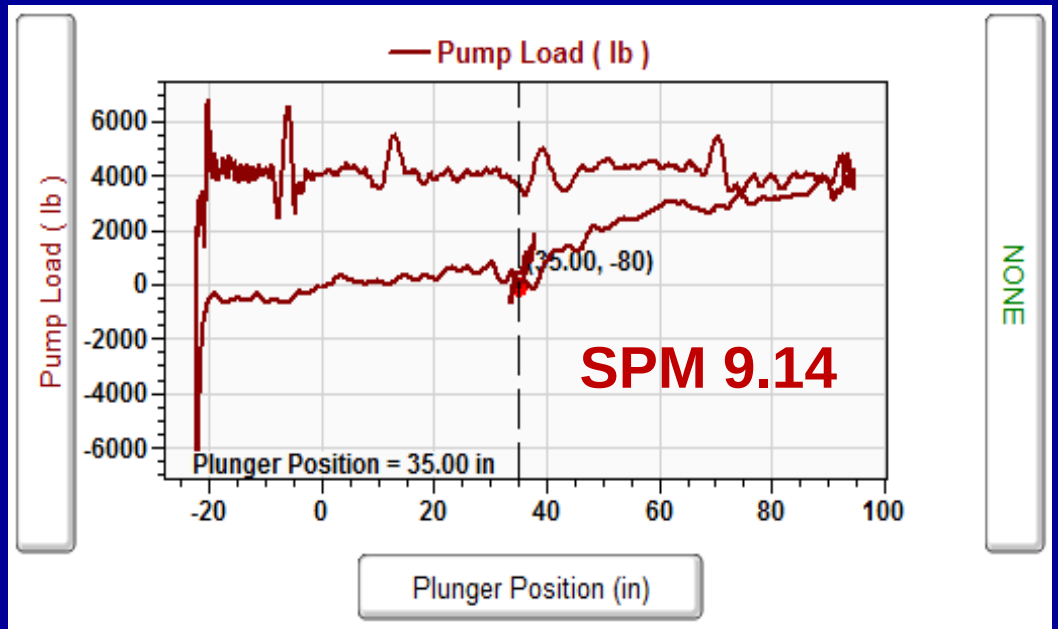


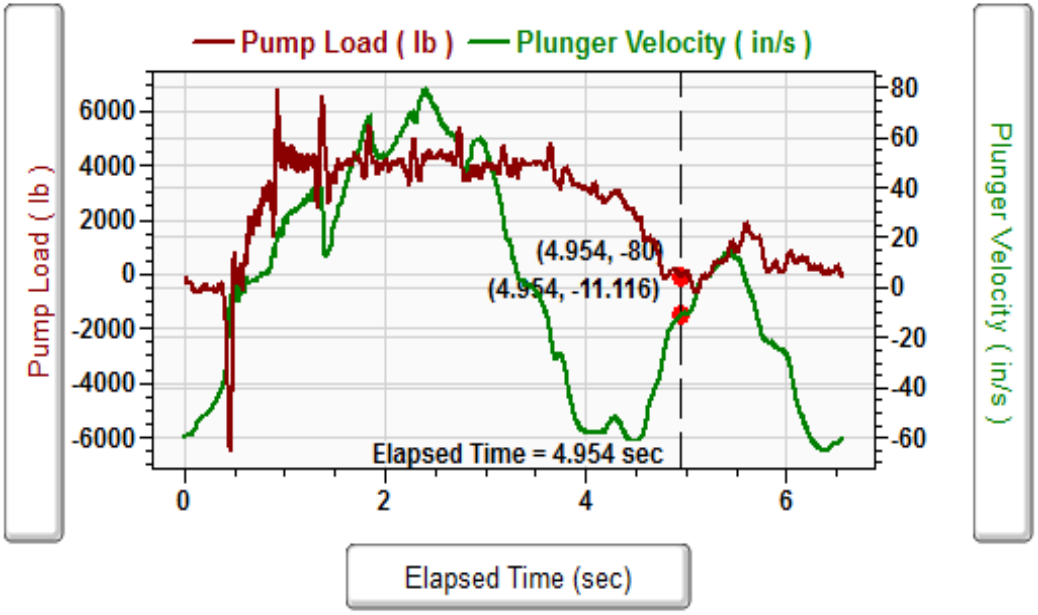
Notice Gas Compression TV Open Reflection Plunger Moves Up on Down Stroke



Over Travels 22” Deeper into the Barrel Tags Due to Velocity Profile and Momentum





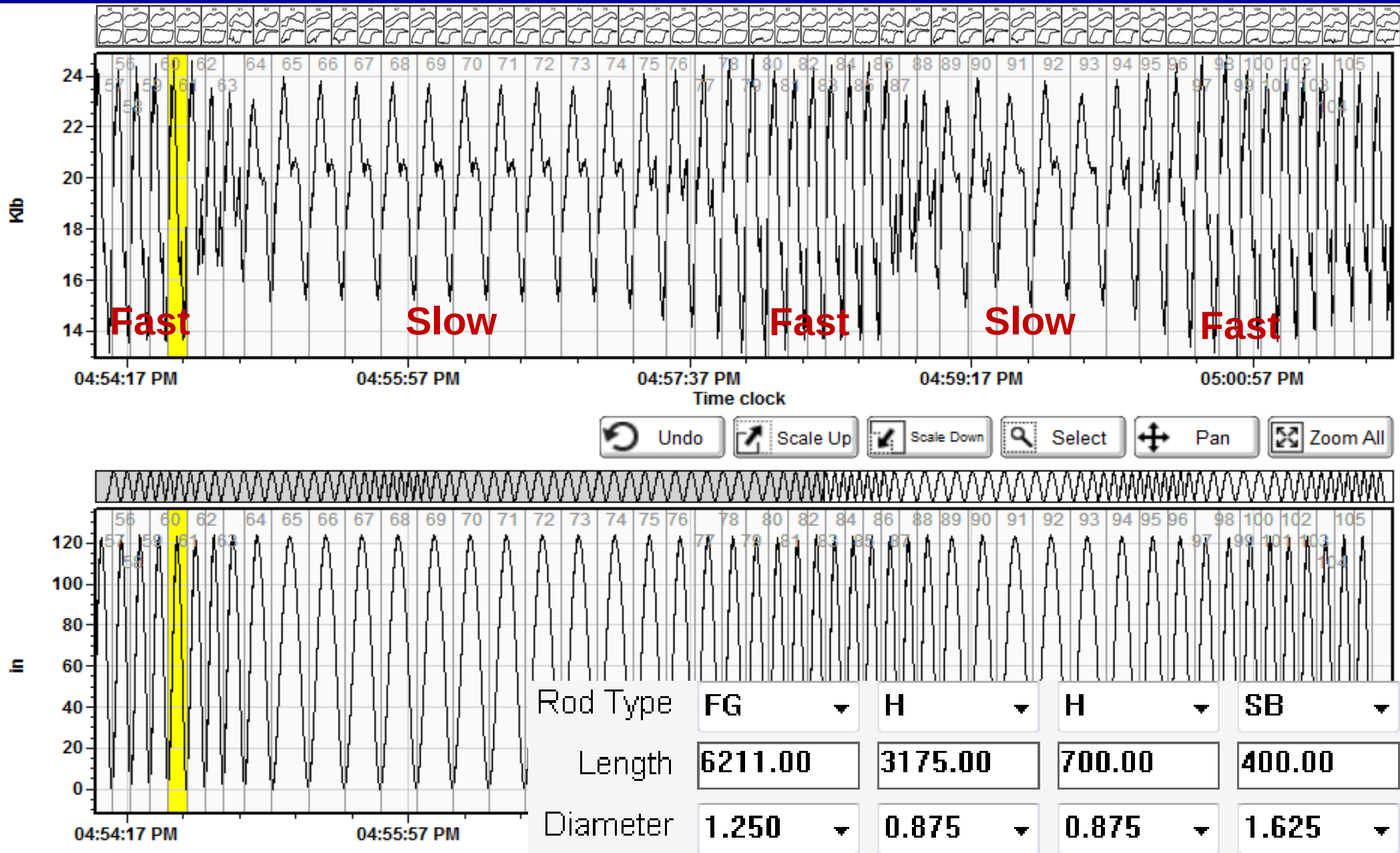


Echometer Online : Over Travel_2020_21 : Tagging - Sampling Speed

Incomplete Pump Fillage

- Pump load on the up stroke is the same when a pump is filled with liquid or not filled (pumped off) and the rod weight is the same.
- During incomplete pump fillage portion of the down stroke the loads applied by the pump to the rods is higher thereby causing the pump stroke to be longer than when pump is full.
- If the pump position during the stroke were plotted relative to the tubing, then bottom of stroke can be farther down when the pump is not full.
- A fluid pound Pump-OFF tag can occur, because:
    1. Plunger over travels on the down stroke
    2. Plunger moves deeper into the barrel
    3. Tagging due to pump spacing,
    4. Higher load on down stroke and higher downward inertia is created by higher downward velocity.

VSD Quickly Changing from SPM 4.5 to 9.7 SPM For POC

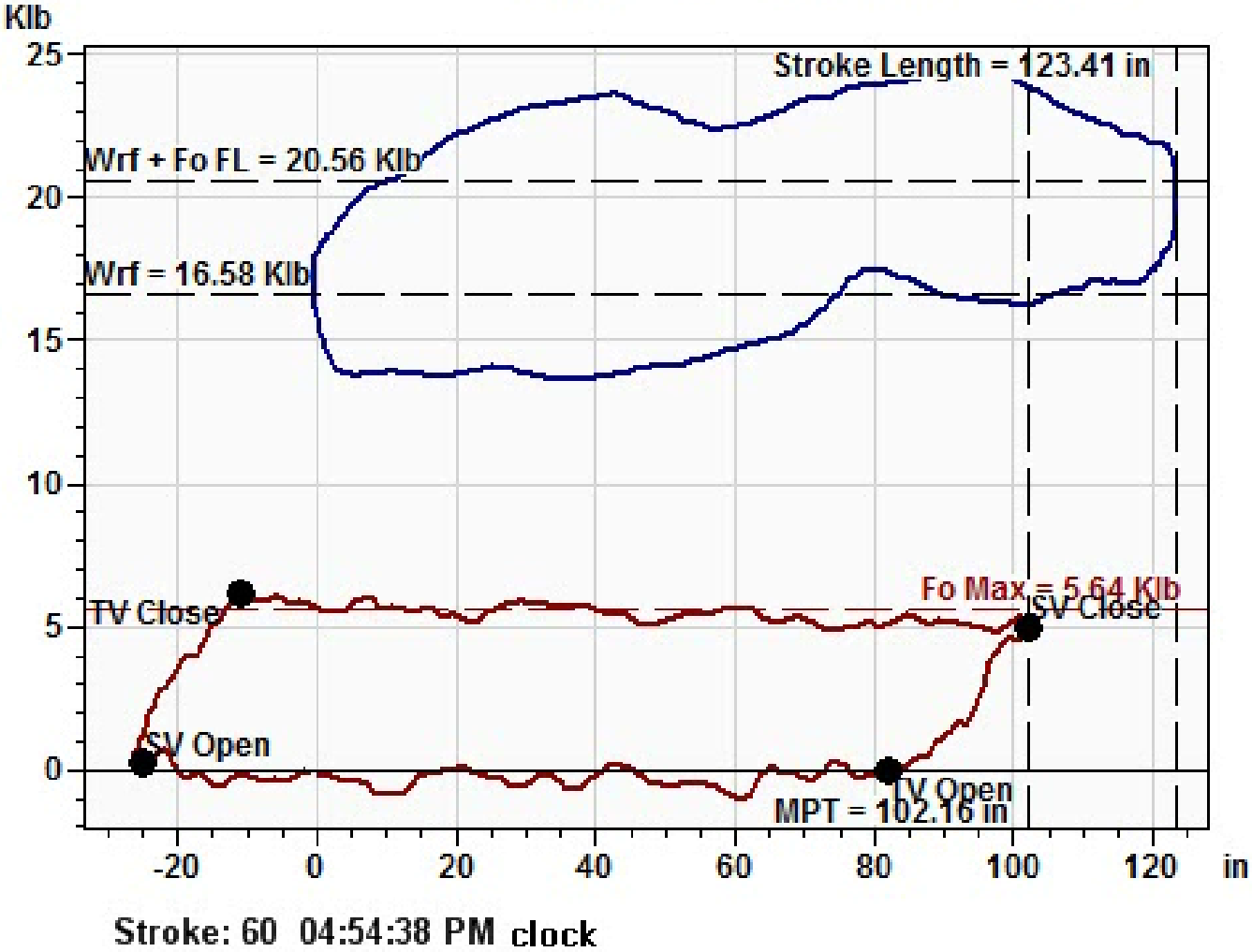


Video Shows VSD Changing from SPM 4.5 to 9.7 SPM

	Peak Load	Min Load	Power
Polished Rod	24.57 Klb	13.64 Klb	21.3 HP
Pump	6.18 Klb	-1.02 Klb	15.3 HP

Replay | Events

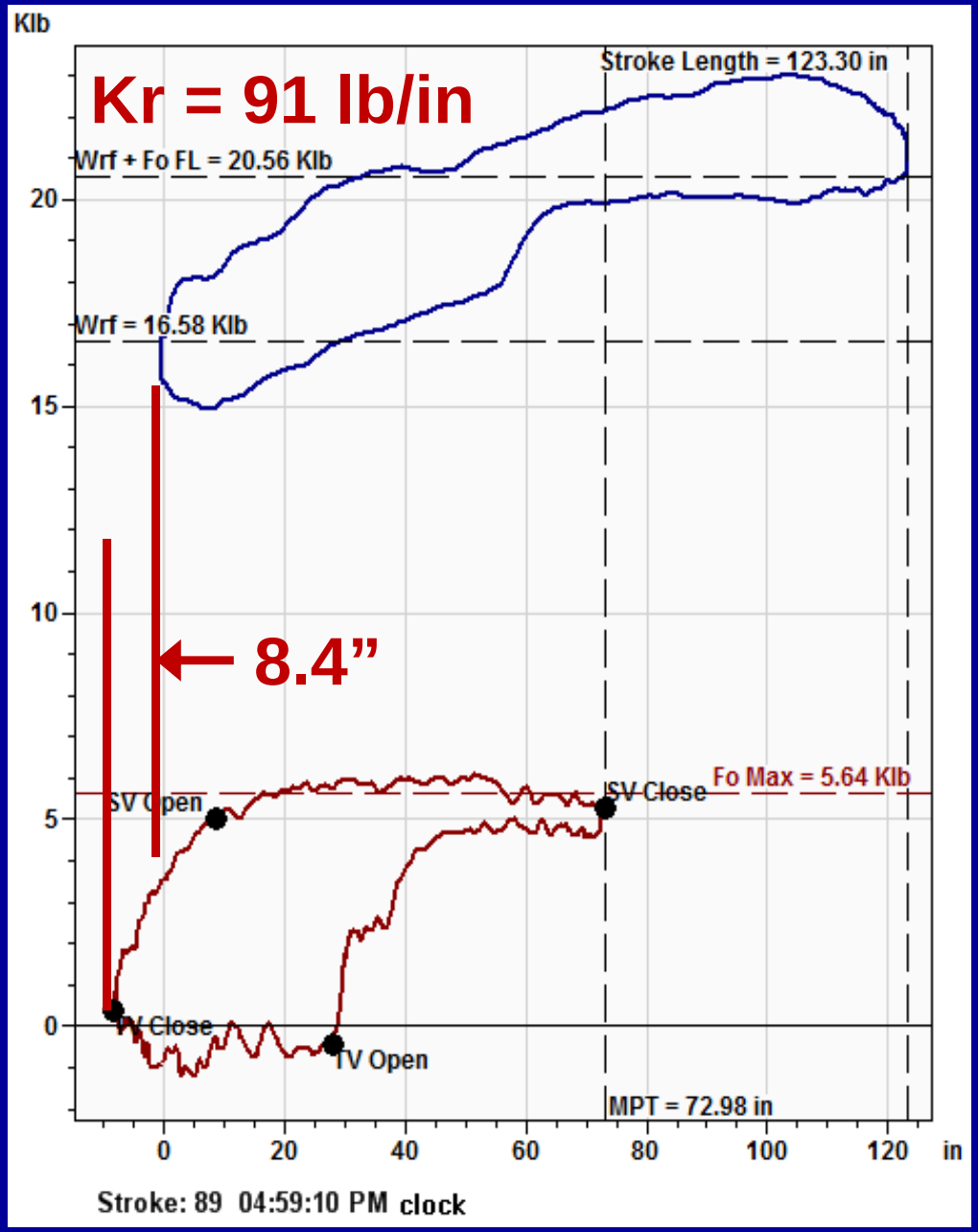
< Stroke 60 of 105 >

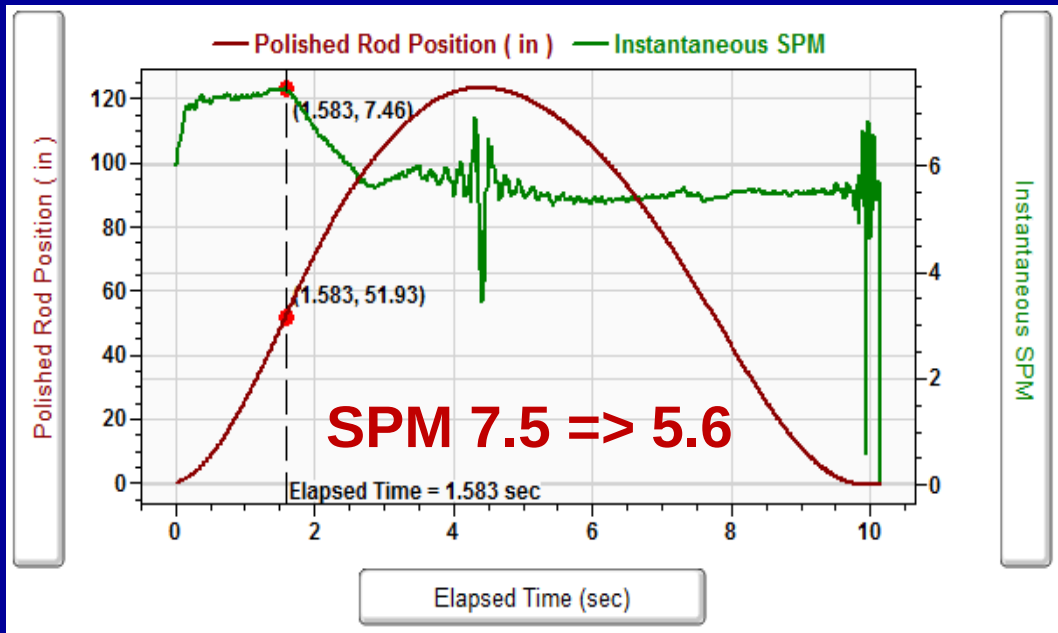


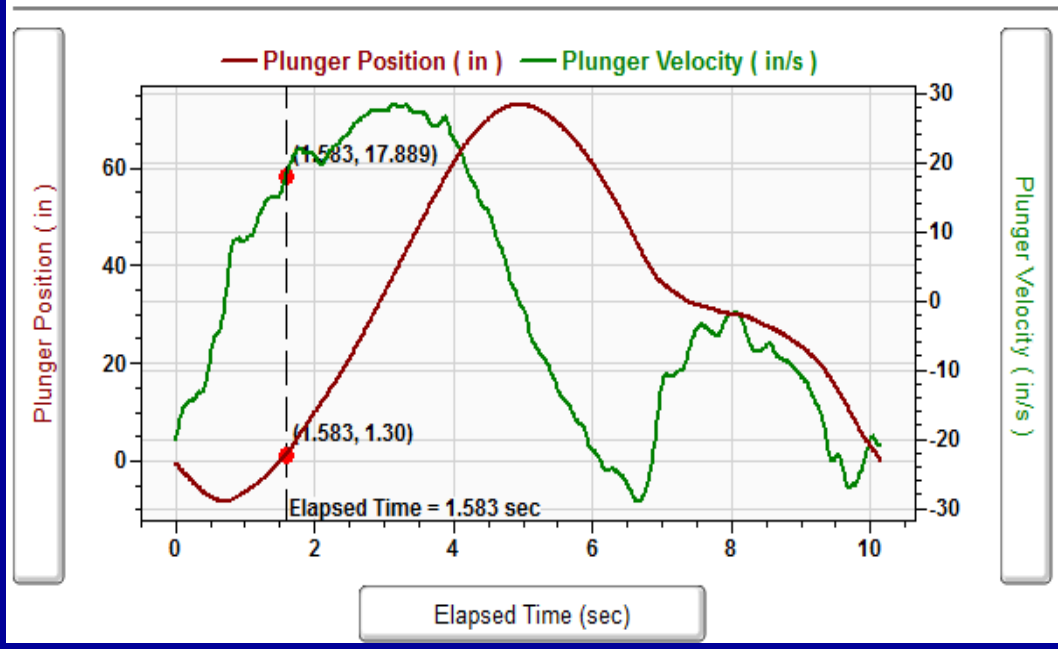
Adj Pump Displacement	191 BBL/D
Calculated Fluid Load Max	5.64 Klb
Surface Efficiency	94.77 %
Pumping Speed	9.160 spm
Motor to Pump Efficiency	68.06 %
Pump Intake Pressure	180 psi (g)
Damp Up	0.160
Damp Down	0.250
Adj Fillage	77.64 %
Adj EPT	79.3 in
Enter Tubing Pressure	250.0 psi (g)

Annotations

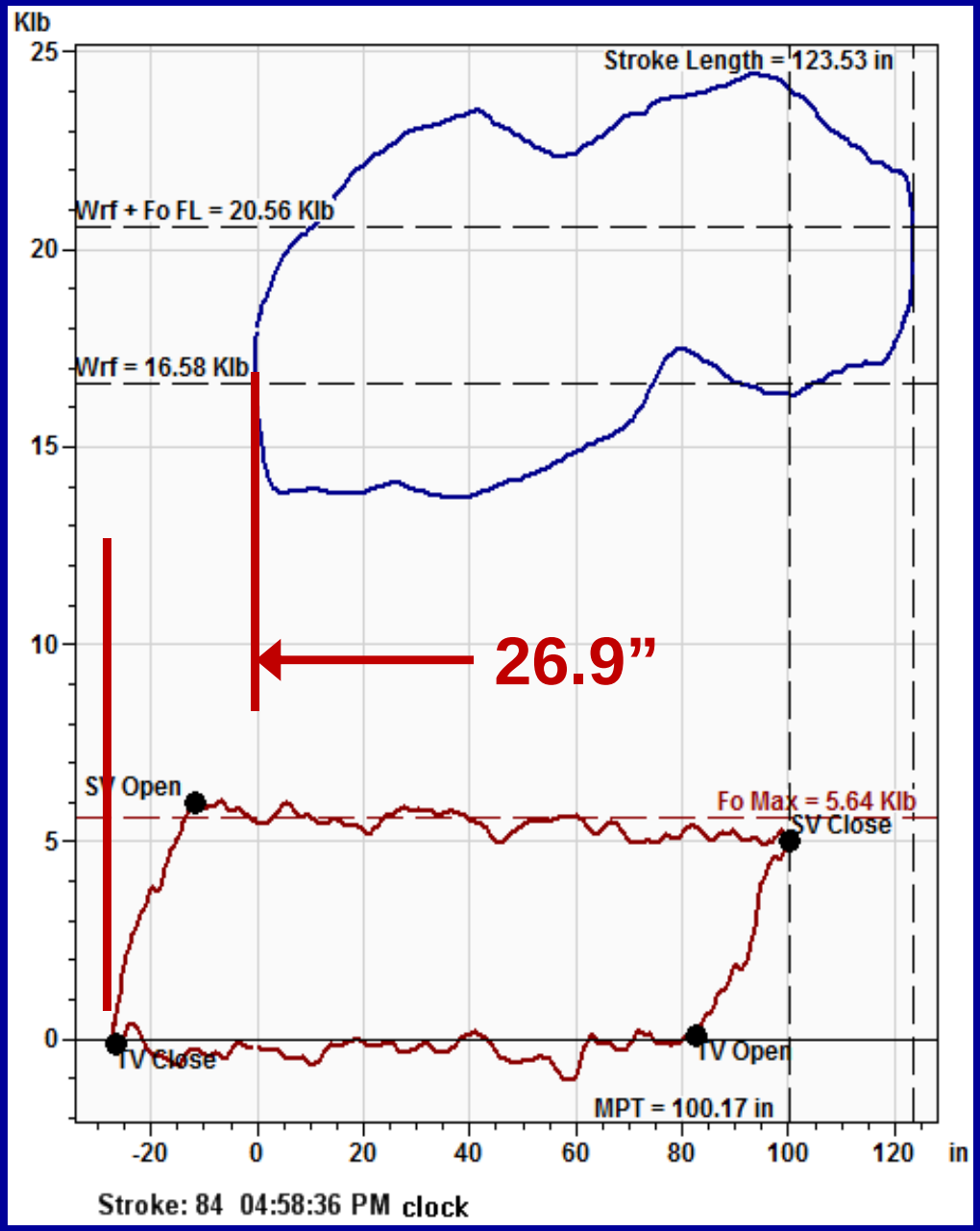
Gas Interference Seen in Pump When SPM is Slowest

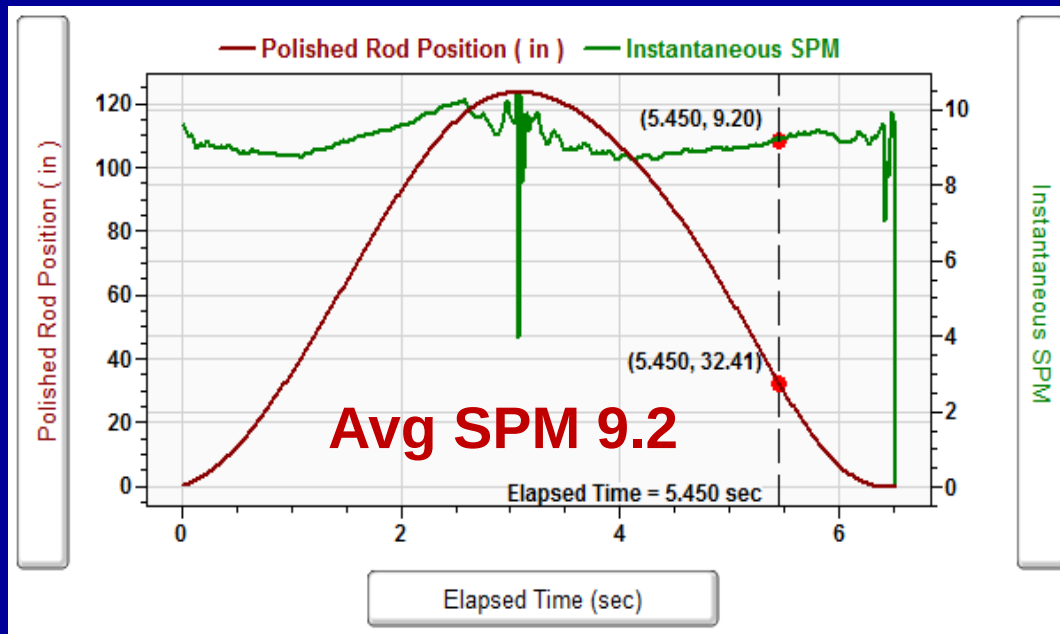


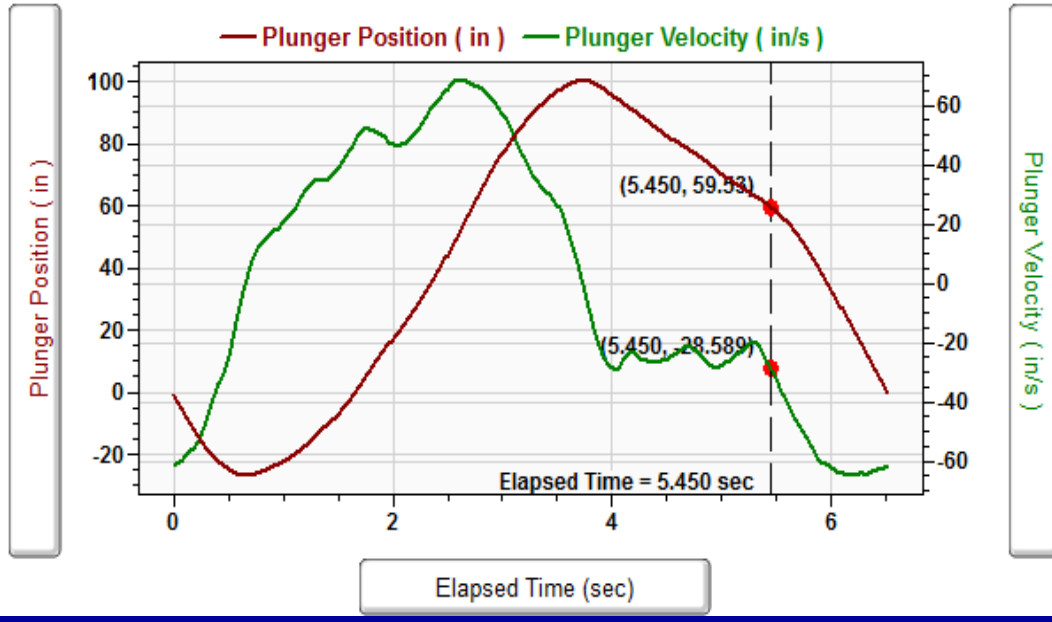




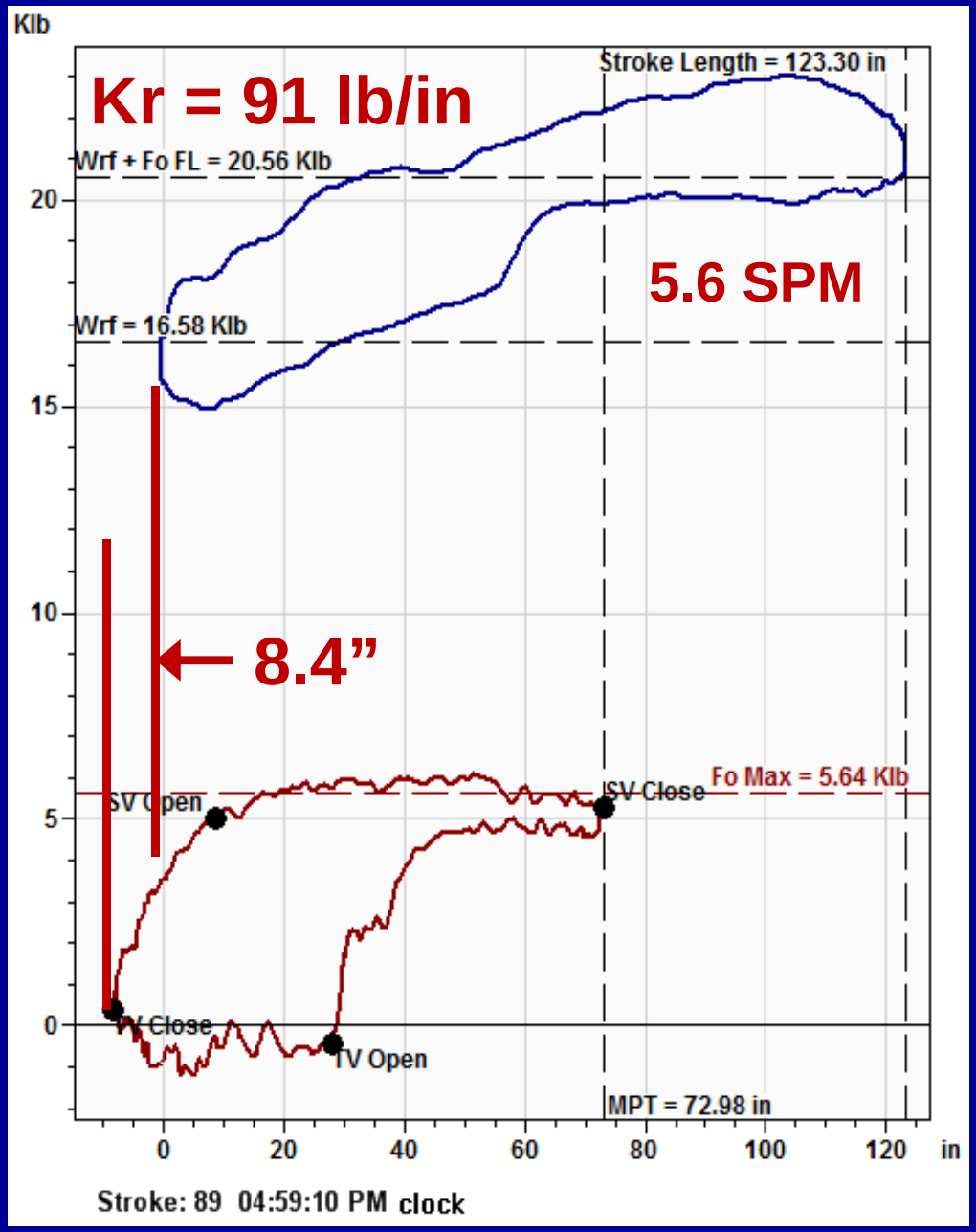
NO Gas Interference When SPM is Fastest
Pumping Fast Exceeds Gas Separator Capacity

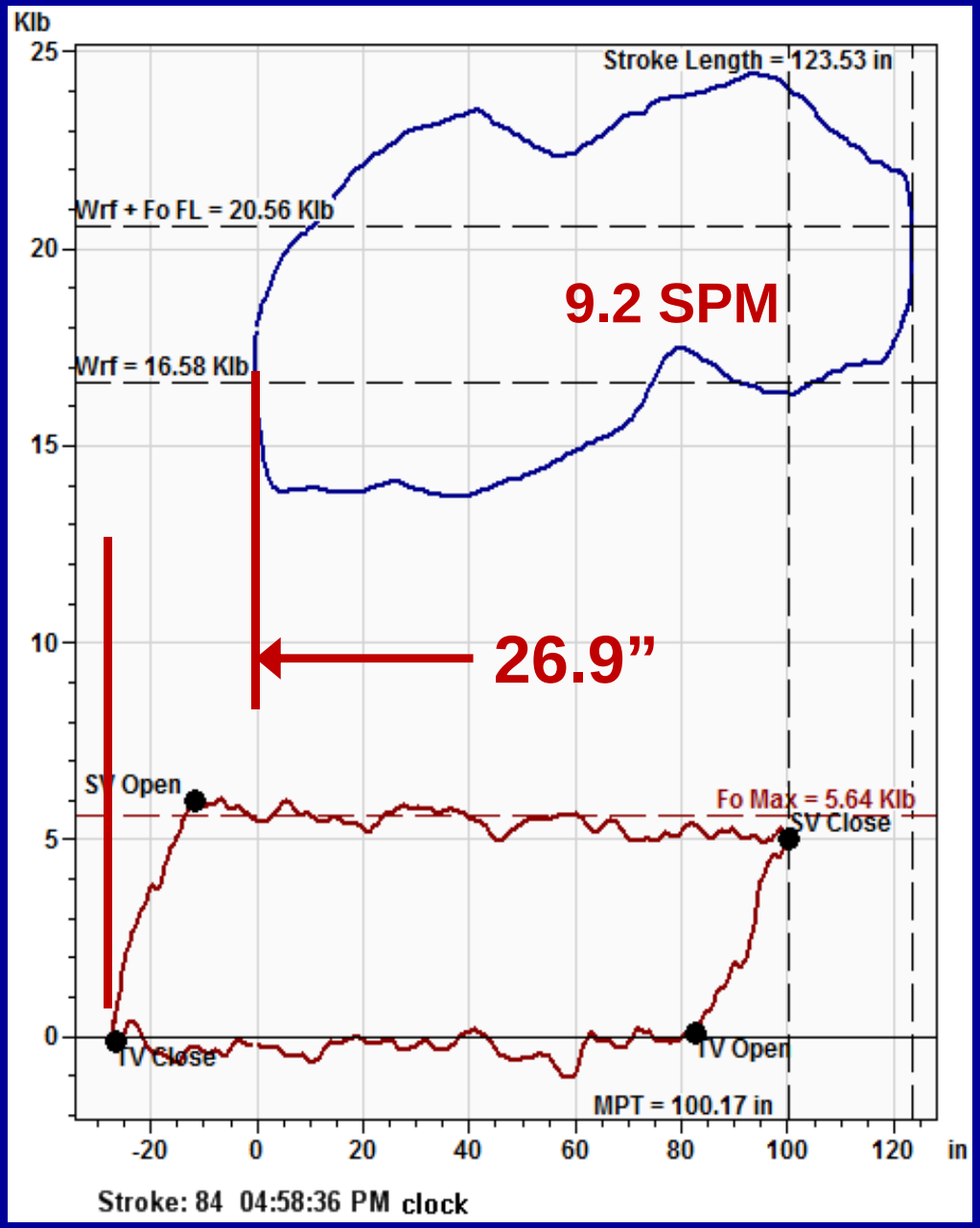




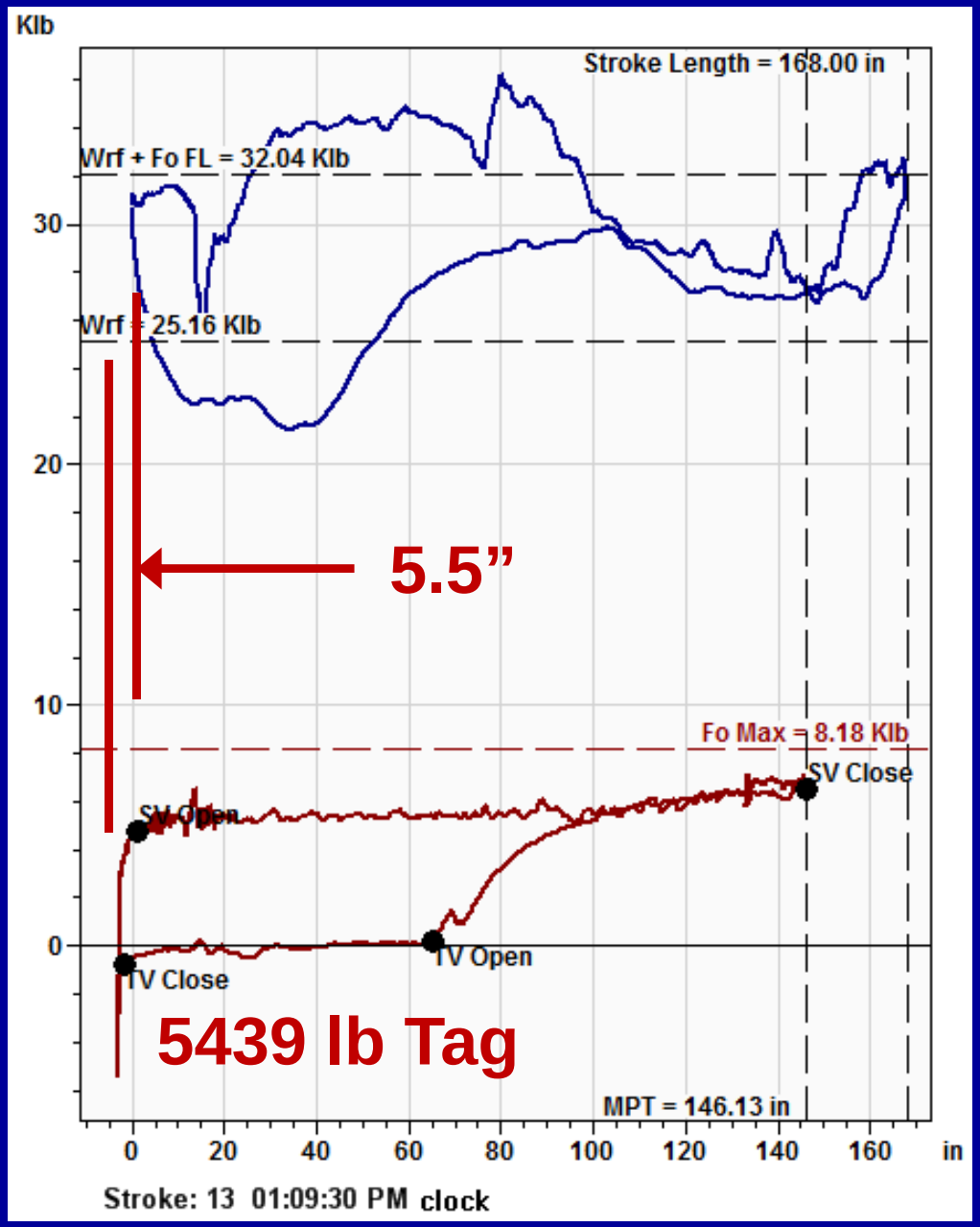


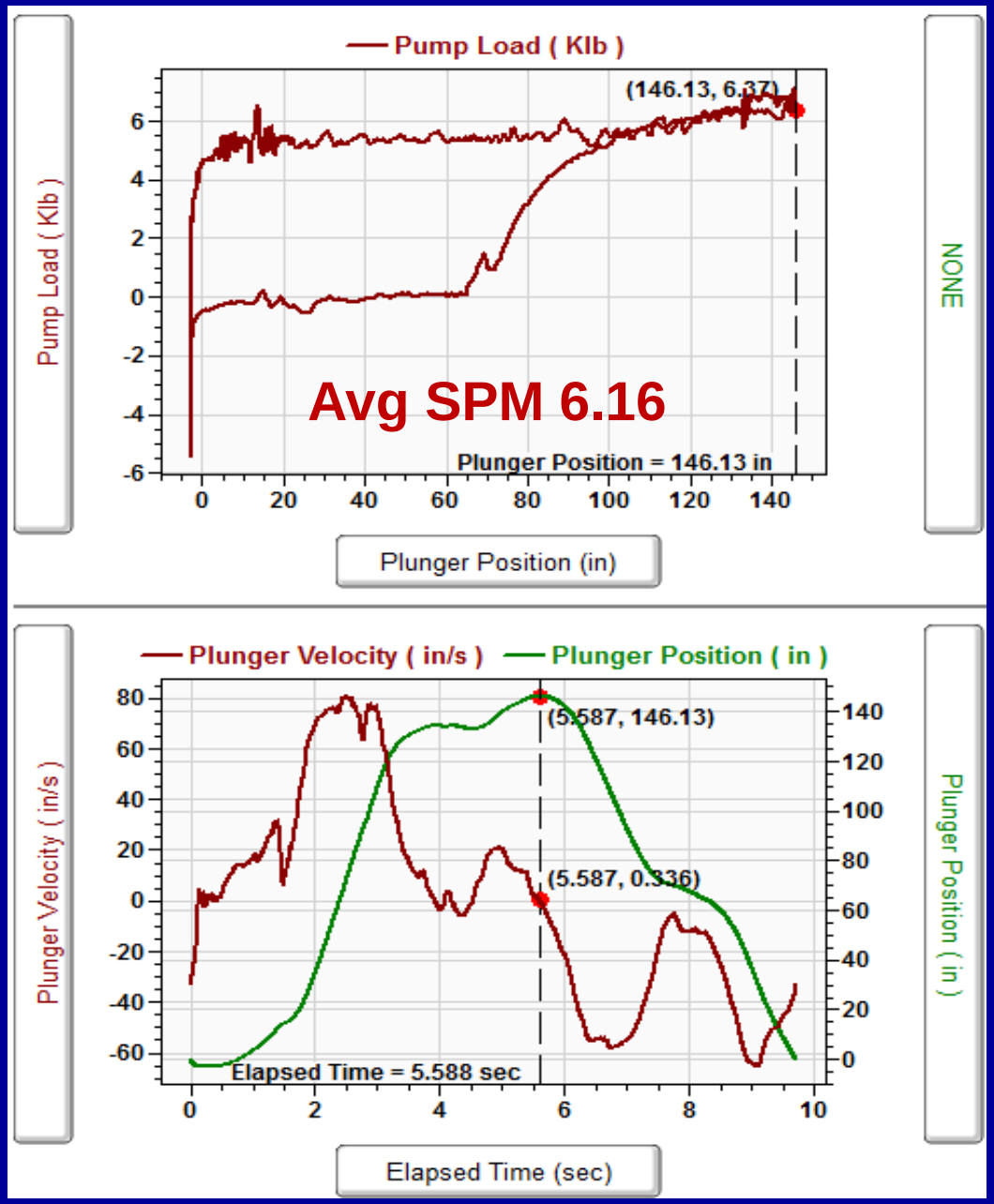
Compare SPM Slowest to Fastest





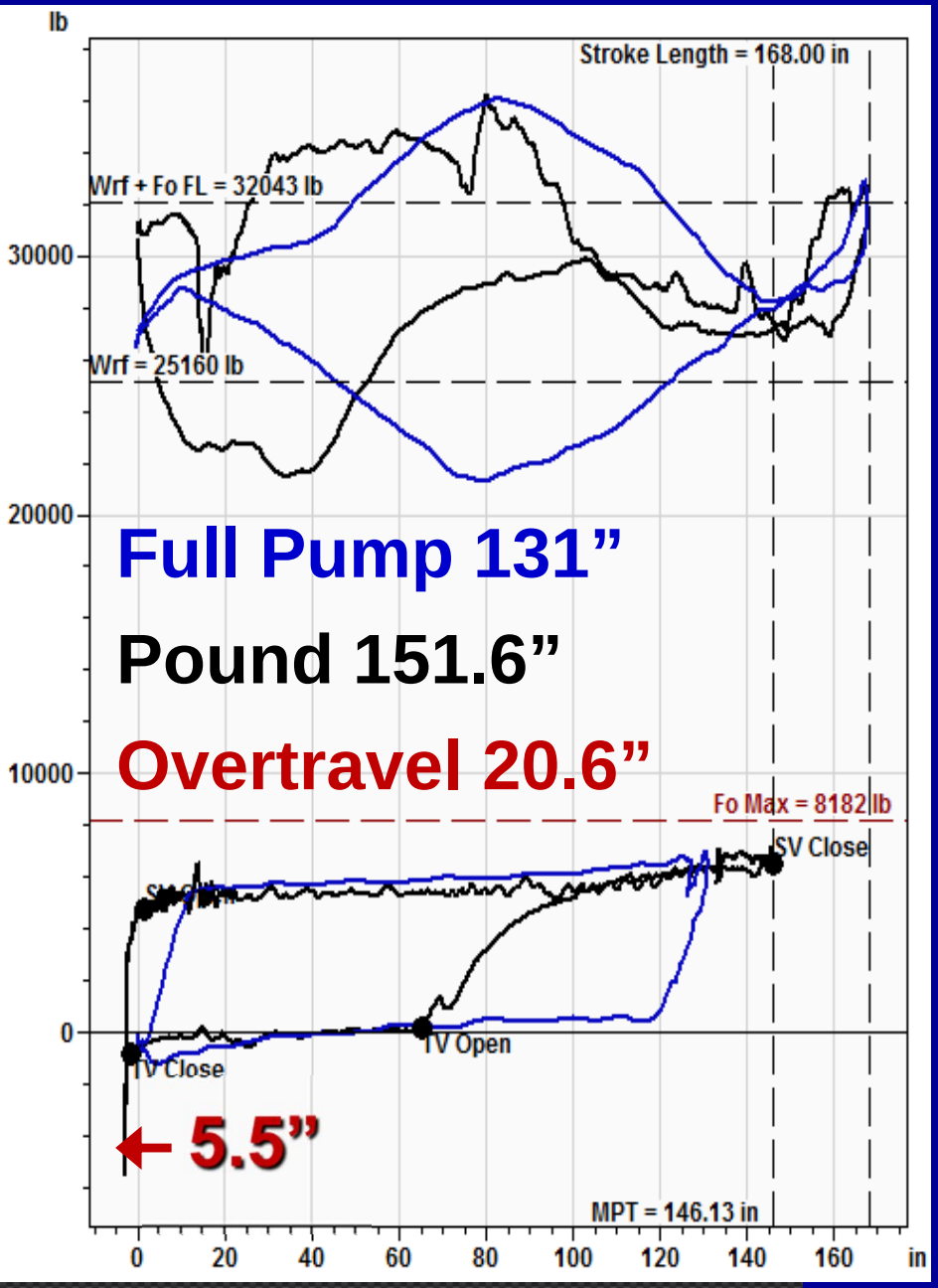
Plunger Moves 5.5” Further Down and Tags Due to Velocity Profile and Momentum

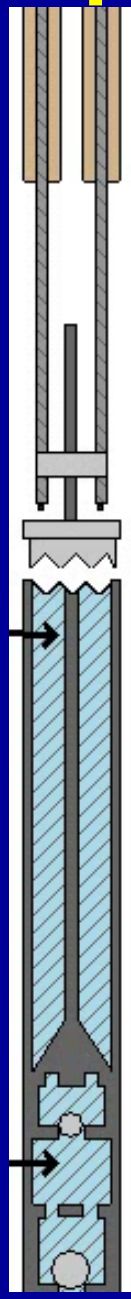


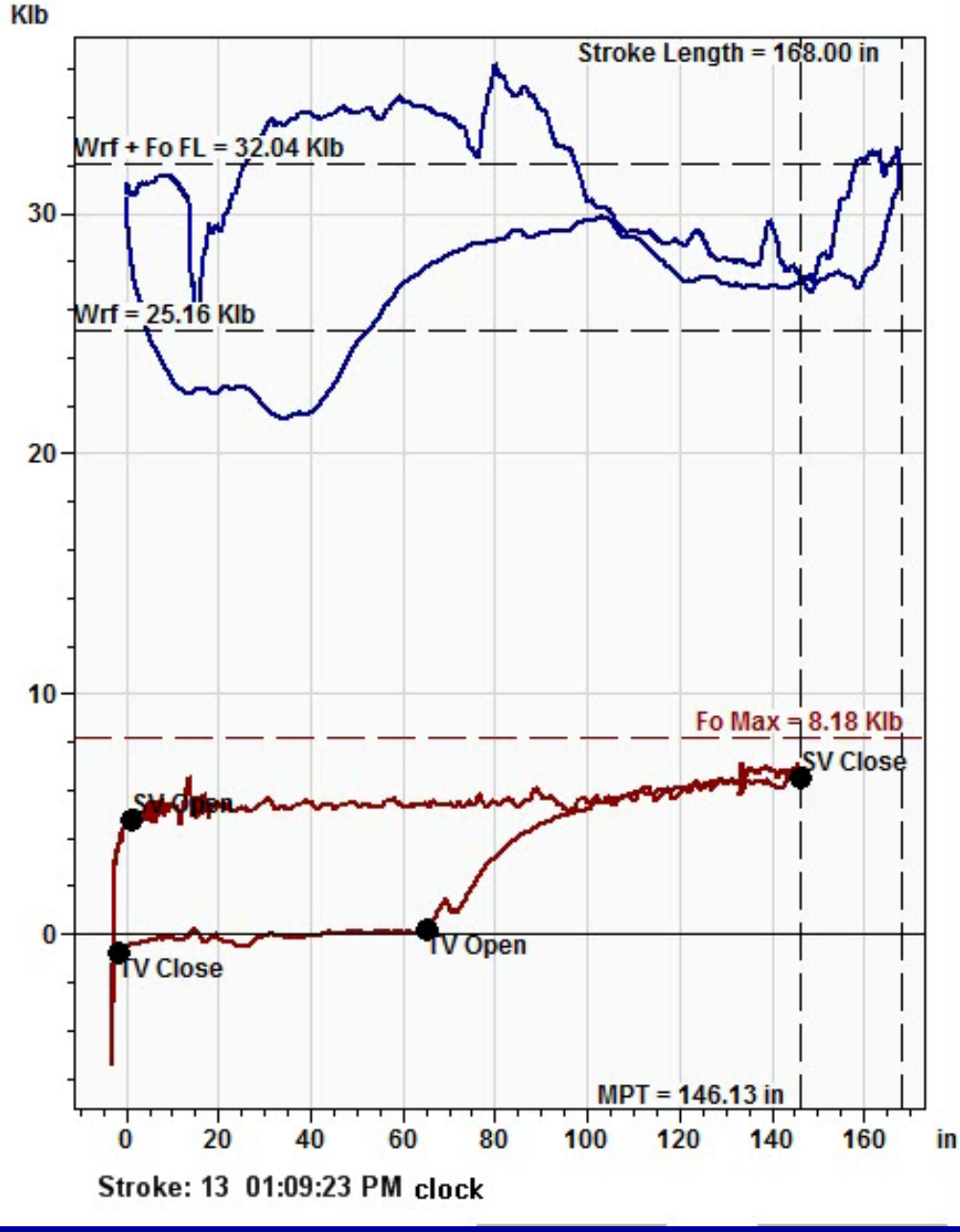


Echometer Online : Over Travel_2020_21 : Pump Off Tag

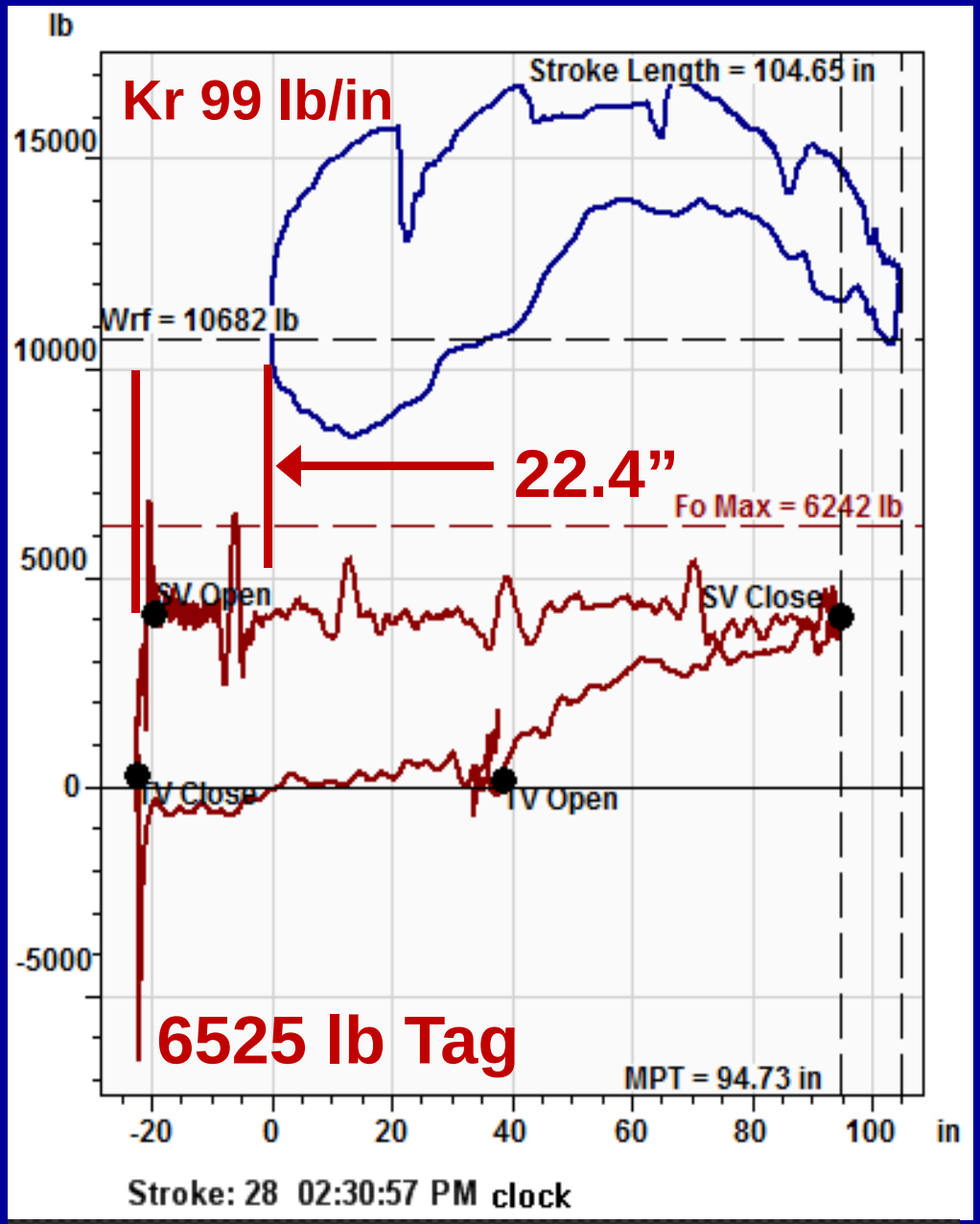
Plunger Suddenly Slows to Open TV
Over Travels on Up and Down Stroke

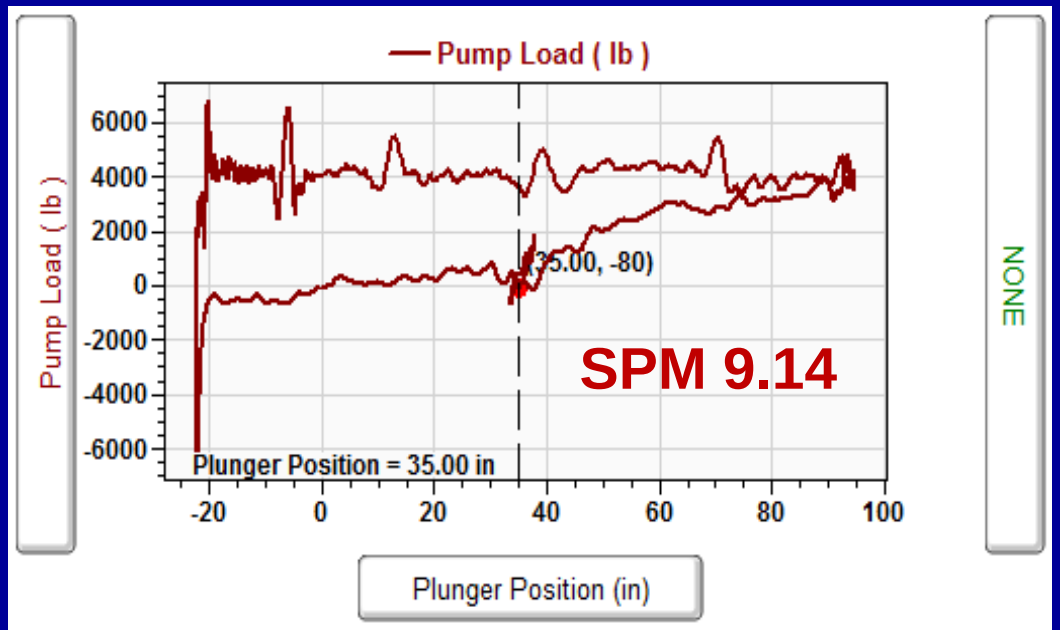


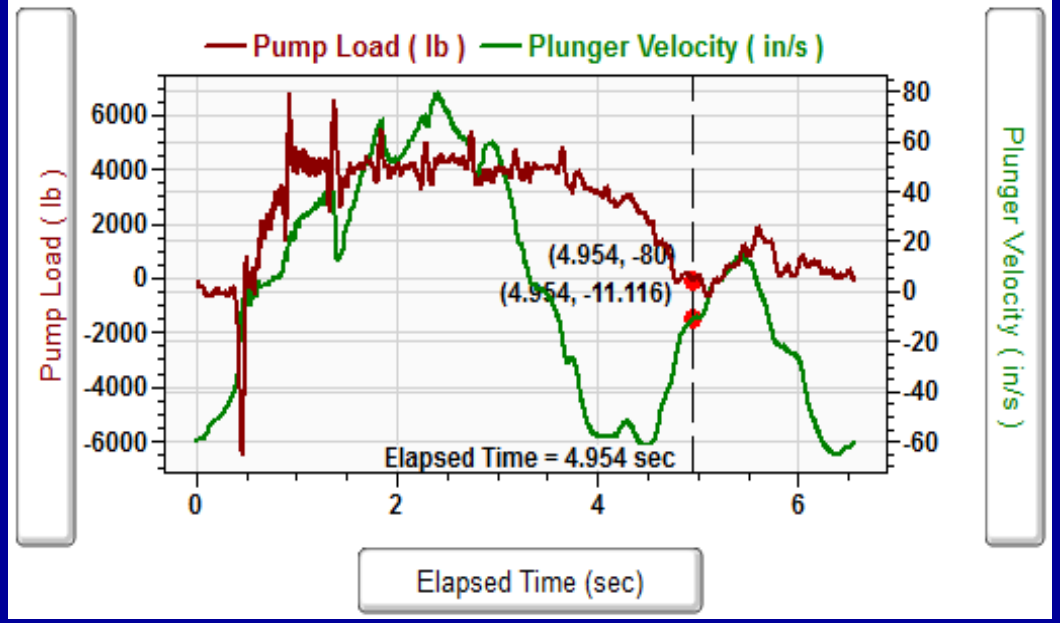




Plunger Overtravels 22” Deeper into the Barrel Tags Due to Velocity Profile and Momentum

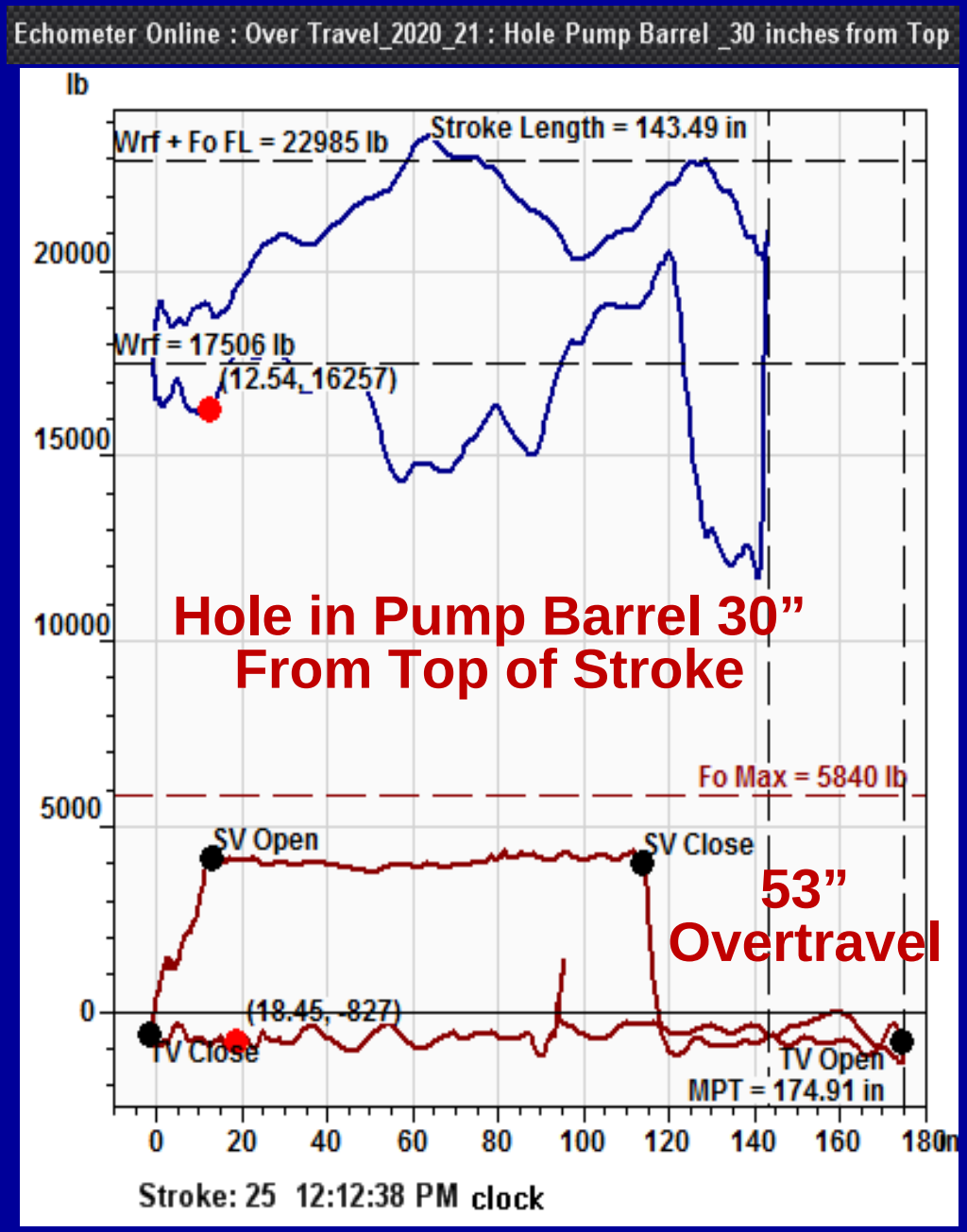


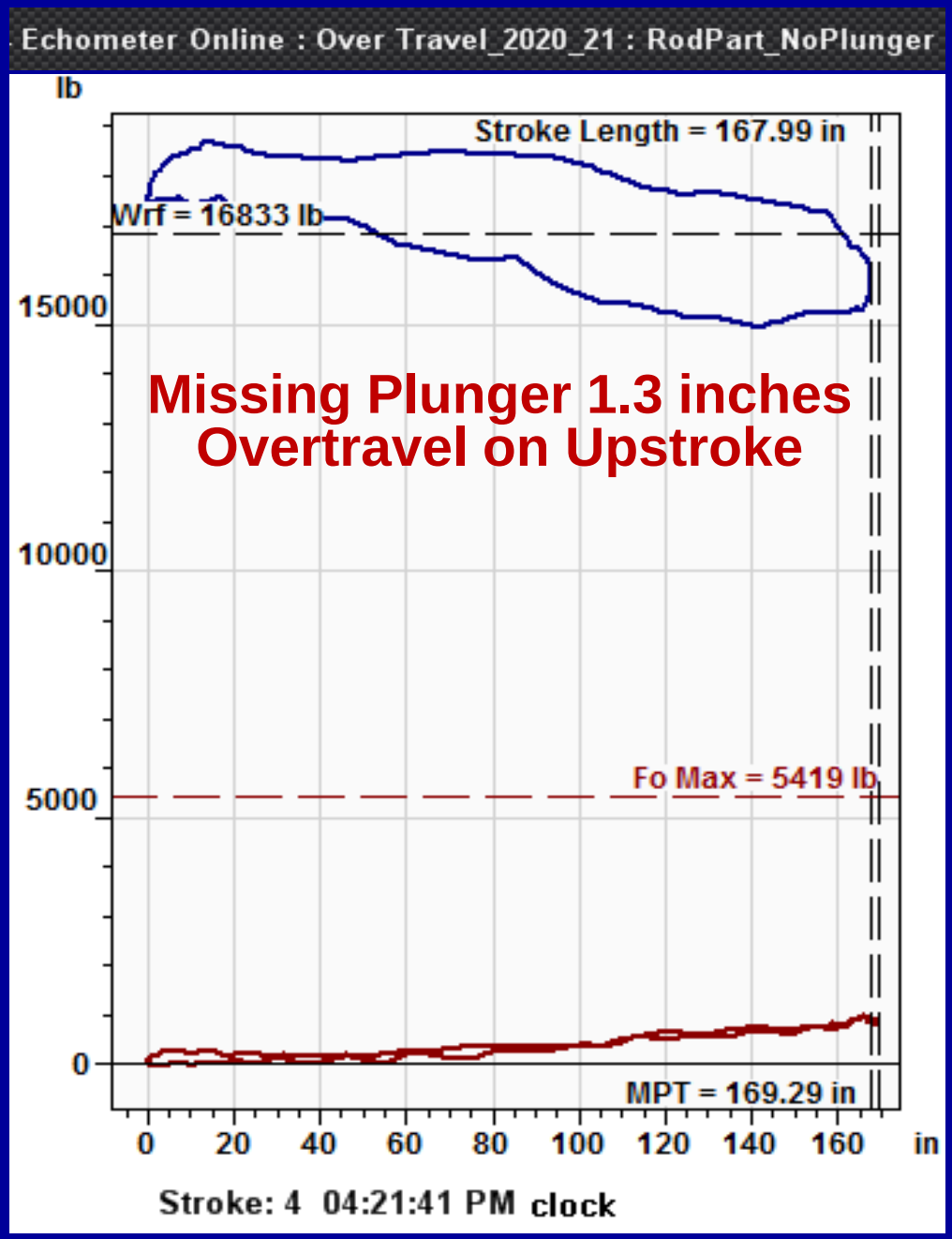




Echometer Online : Over Travel_2020_21 : Tagging - Sampling Speed

Over Travel on Upstroke





Is Over Travel Good or Bad?

1. ***Good*** **because Pump Displacement Increases with Increase in SPM**
2. ***Bad*** **because Failures "tend" to increase with increased SPM**
3. **Operating within a pumping speed 5-10 SPM range is common practice and failures rates should not increase when pumping within this speed range.**

Conclusion

- Pumping speed creates dynamic forces that impact the elongation of the rod string. These forces may cause over and under travel of the pump plunger.
- Sudden release/application of pump load results in plunger position changing relative to the pump barrel.
- Zero position for the plots of surface and pump card is typically the same for most diagnostic wave equation since about 1984.
- Plotting surface and downhole cards with a common zero position is useful to compare the magnitude of the surface and plunger travel
- Plotting the pump card position relative to the pump barrel is useful to compare plunger position of a pump filled with liquid versus a pump that is not filled.