



Surface and Downhole Dynamometer Card Interpretation



Table of Contents

The Rod Pumping Analysis Tool Chest.....	9
Producing Well Test Values	9
Gas-Free Fluid Levels	9
Dynamometer Surveys	9
Surface Dynamometer Cards.....	10
Load Input Devices	12
Position Input Devices	14
Surface Dynamometer Card Shape.....	17
Downhole Pump Cycle.....	21
Effects of 'Net Lift'	22
Surface Dynamometer Card Library	23
Downhole Dynamometer Card History	41
Wave Equation Explanation.....	44
The "Gibbs" Method	45
The "Everitt-Jennings" Method.....	45
The Modified "Everitt-Jennings" Method	47
Damping Factor Determination.....	47
Damping Factor Determination.....	48



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

'Buoyant Load' / 'Effective Load' Definitions.....	50
The Calculated Downhole Pump Card	52
DH Cards – 'Full Pump Fillage' / No 'Tubing Movement'.....	55
DH Cards – True 'Fluid Pound'.....	61
True 'Fluid Pound' Card Examples.....	61
Incomplete Fillage / Low Pressure Gas Compression ('Pump Off' / 'Fluid Pound' Card) Examples.....	66
DH Cards –	73
'Gas Compression' / 'Gas Interference' or 'Gas Pound'	74
'Pumped Off' vs. 'Gassy' Determination	83
DH Cards – 'Full Pump Fillage' / 'Tubing Movement'	87
DH Cards – 'Full Pump Fillage' / Malfunctioning 'Tubing Anchor'.....	94
Possible Effects of 'Fluid Pound'/'Pump Off'/'Gas Pound' / 'Tubing Movement'	96
DH Cards – 'Upstroke Pump Wear'	99
DH Cards – Downstroke Pump Wear (SV)	107
DH Cards – 'Worn Out Pump'	111
DH Cards – 'Tagging' (Hitting Up and Down)	112
DH Cards – 'Tight Spot' in Barrel/Plunger Travel	121
DH Cards – 'Hole in the Pump Barrel' / 'Split Barrel'	128
DH Cards – 'Fluid Inertia' / 'Fluid Acceleration'.....	133
DH Cards – 'Downhole Friction'	136
DH Cards – 'Fiberglass' Rod String	143
When Downhole Cards are 'Flat Lines'	146
'Fouled TV' / 'Fouled SV' Examples.....	147
Severe 'Fluid Pound' – 'Restricted Pump Intake' (Fluid Level High)	161
'Delayed TV Closure'	164
DH Cards – 'Undertravel' and 'Overtravel'	166
DH Cards – Slanted?.....	173
Incorrect 'Stroke Length'	173
Incorrect 'SPM'	173
Bent Polished Rod (Strain Gauge)	174
Use 'Fluid Load' Lines – If Available.....	175
'Fluid Load' Line Examples	176
DH Cards – Example Library.....	180
'Hole in the Tubing'?	189
'Rod Par't Examples	192
'Gas Lock' Examples.....	195
'No Load Signal' Example	200
Downhole 'Friction' / 'Set-down Packer' / 'Buckled Tubing'.....	202
'Top of Stroke' Problems	204



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

'Fluid Acceleration' / 'Deceleration'	210
'Stuffing Box Friction'	211
'Rod Guides' and Downhole Cards	215
'Stuck Pump Plunger'	216
Effects of 'Tubing Pressure'	218
Lufkin 'Mark II' Pumping Unit Dyno Card Characteristics	221
Things That Affect Calculated Downhole Cards	222
'Damping Factor' Effects on Downhole Cards	226

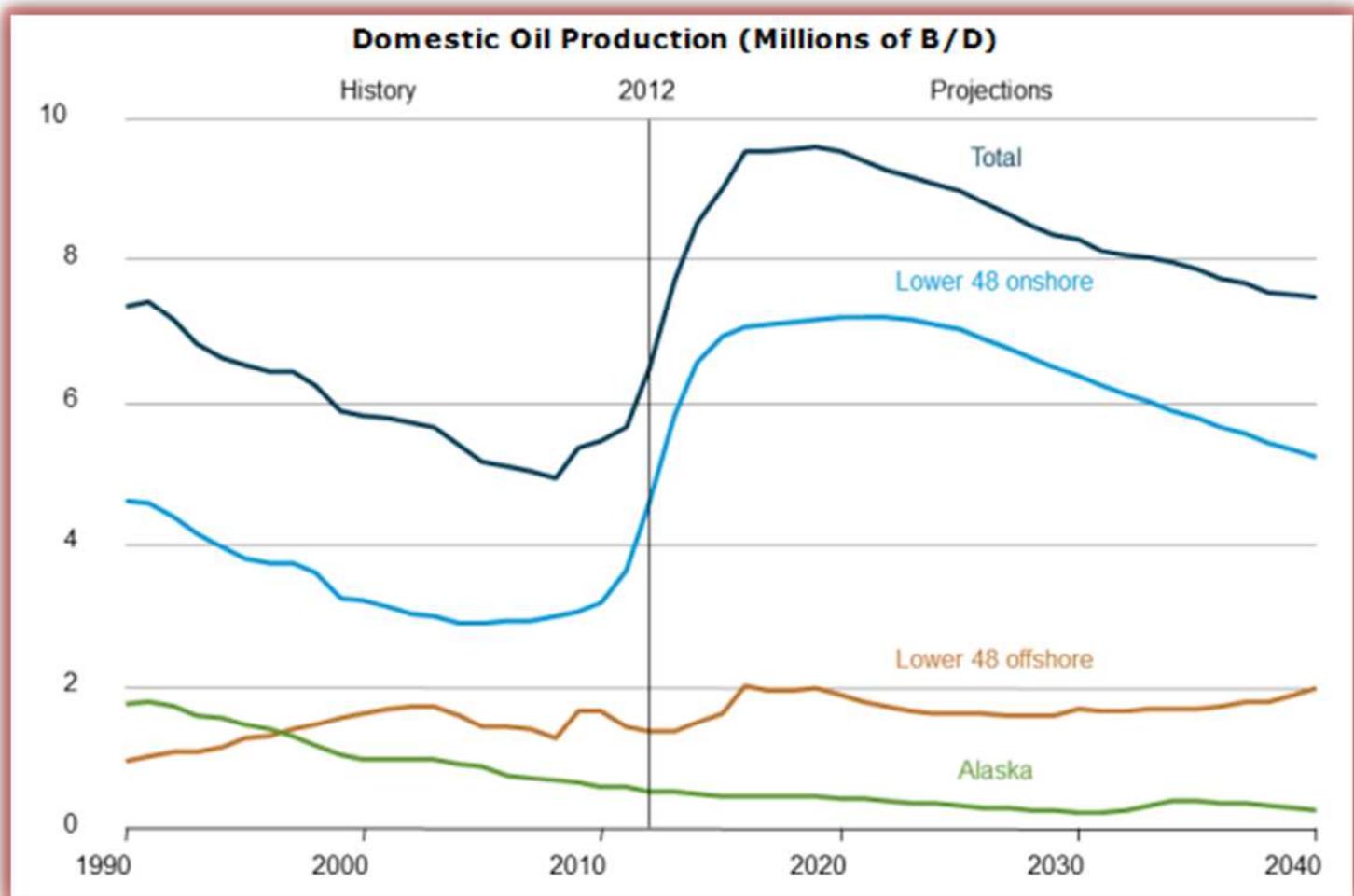


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

**Why Do We Need to Understand Dynamometer Cards?
Lots of oil in the world!**

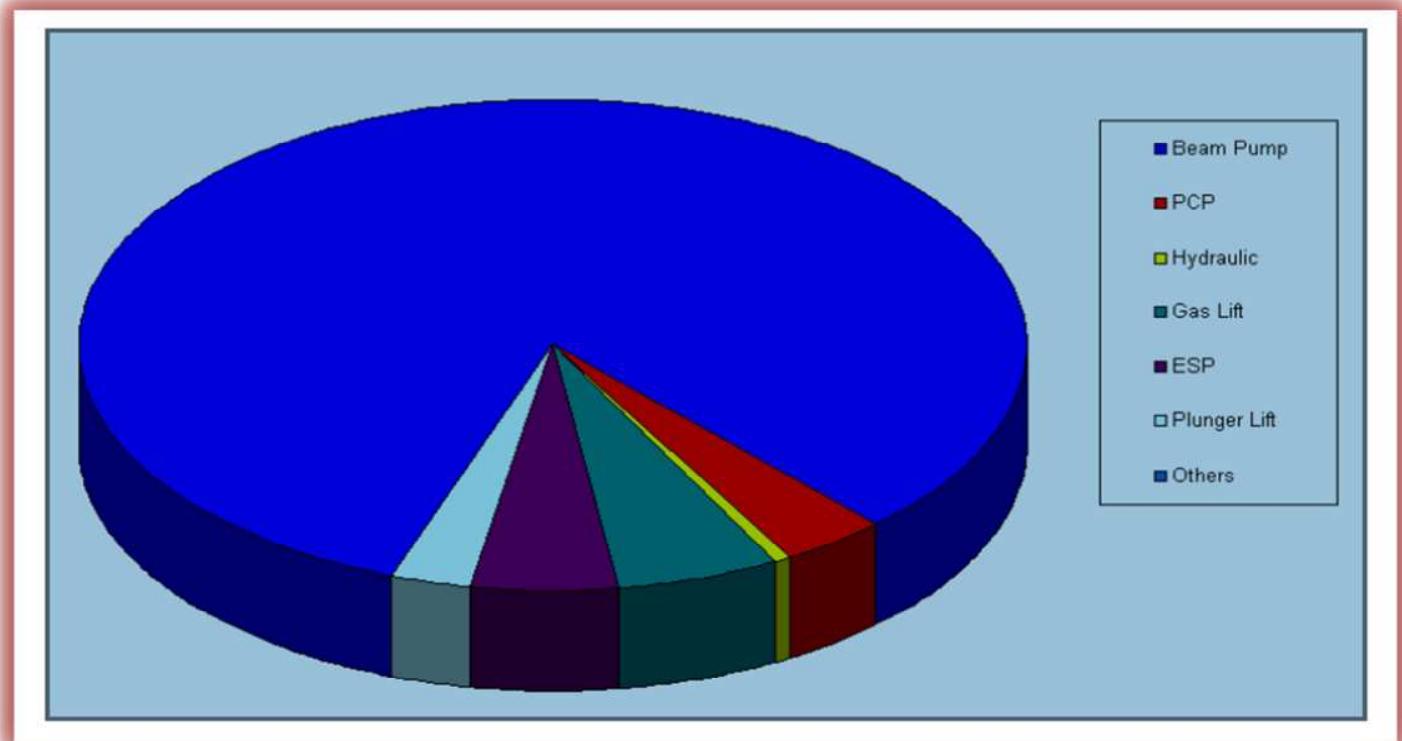


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

And How Do We Get All of This Oil Out of the Ground?



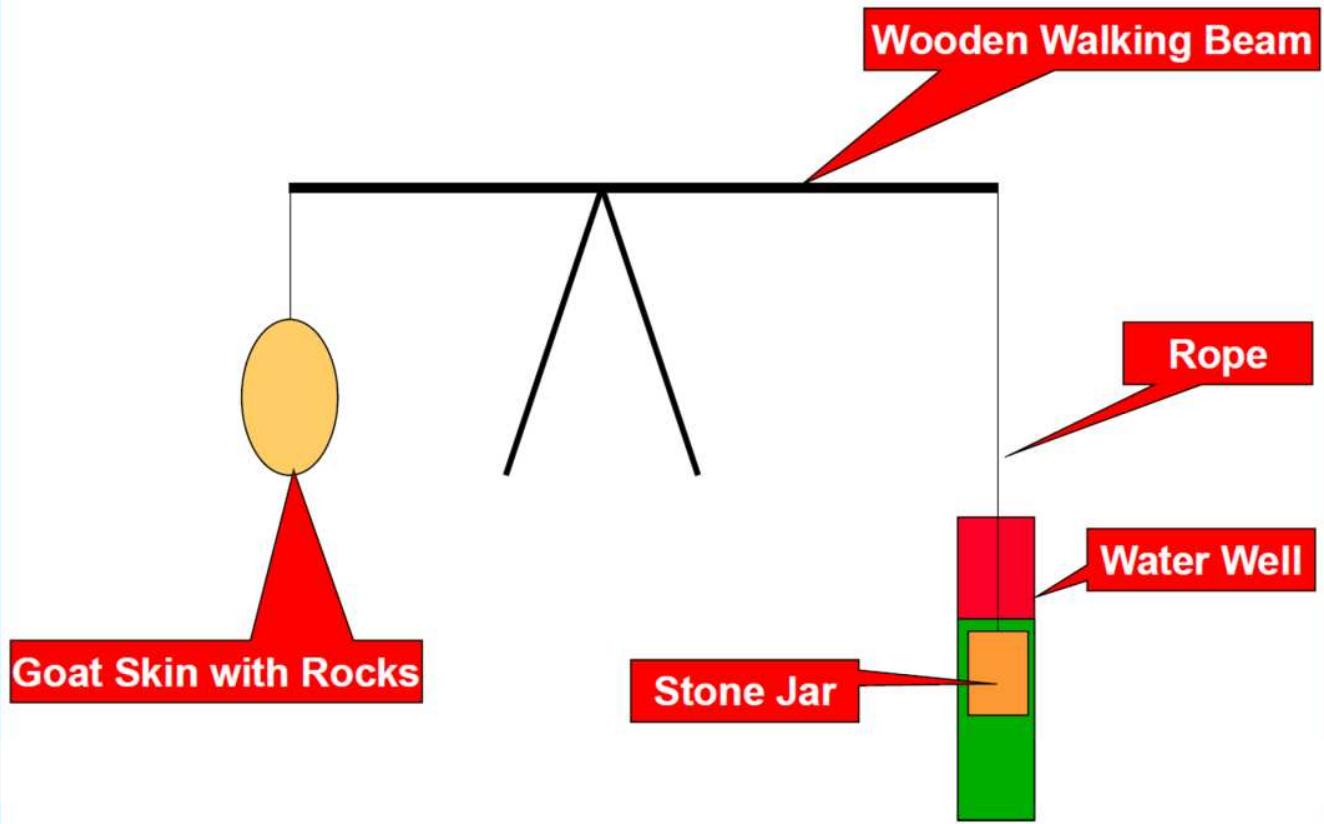
Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Pumping Liquids to the Surface Began Here

Egyptian Sucker Rod Pump 476 AD



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

And Has Progressed ...



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation And Has Progressed ...



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

The Rod Pumping Analysis Tool Chest

Producing Well Test Values

Gas-Free Fluid Levels

Dynamometer Surveys

- The most important tool is access to surface and downhole dynamometer cards.**



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Surface Dynamometer Cards

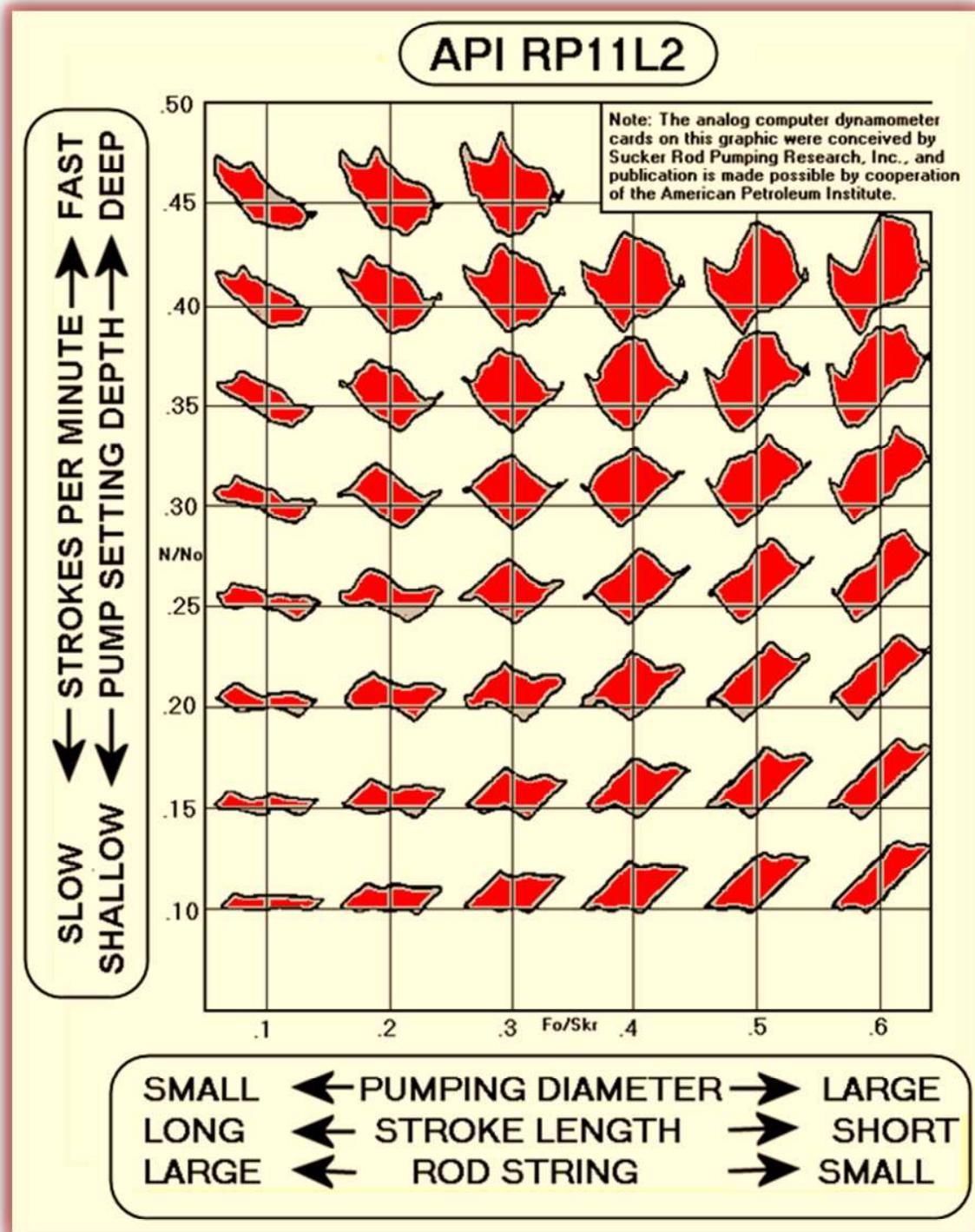
- Webster defines a “dynamometer” as an instrument used to measure force. In terms of its use in the “oil patch”, a dynamometer records polished rod load in relation to polished rod position. The result is a plot of “load versus position” – commonly called the surface “dynamometer card” that measures the amount of work being done by the rod pumping system. Dynamometer systems allow the user to record the necessary information to generate a “surface card” – i.e., load and position data. This data can then be analyzed by any “wave equation” driven diagnostic program. Analysis results include downhole cards, load/stress calculations, counterbalance information, pump displacement, calculated fluid levels, estimated electrical costs, etc. Through the years, the polished rod dynamometer has been the principal tool for analyzing the operation of rod pumped wells. The shape of the surface dynamometer card is determined by changing downhole conditions.
- A dynamometer system gathers polished rod load and displacement “points” and plots the resulting “curve” - which is commonly known as the “surface dynamometer card”. Ideally, changing downhole conditions would be apparent from the surface card by visual interpretation. However, because of the complex behavior of the rod string and the great diversity of card shapes, visual diagnosis is not always possible. Though much information can be gained from visual interpretation of surface cards, success is directly linked to the skill and experience of the analyst – and even the most experienced analysts are often misled into an incorrect diagnosis. The graphic shown below illustrate how “surface cards” relate to the motion of the polished rod and the actions of the downhole pump.
- Surface card shapes are dependent on SPM, pump size, pump depth, stroke length, and rod taper design.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Load Input Devices

Today's Load Input Devices



Horseshoe Load Cell



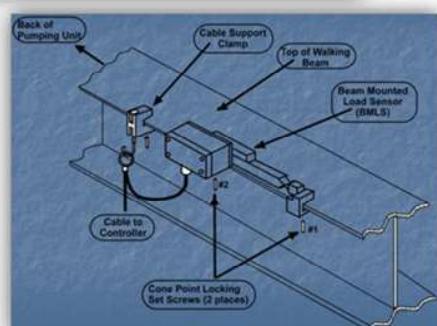
'Clamp-on' Strain Gauge



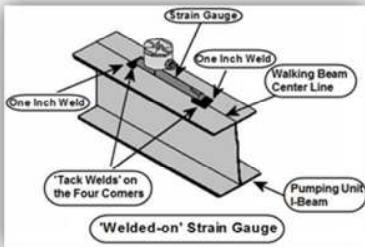
Polished Rod Load Transducer



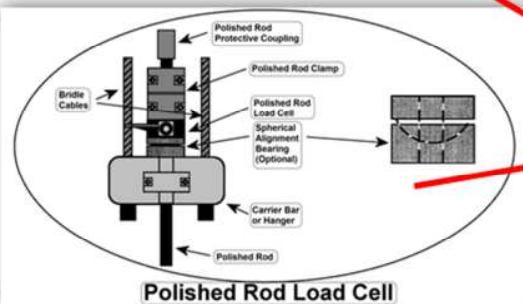
'Doughnut' Calibrated Load Cell



Beam Mounted Load Sensor (BMLS)



'Welded-on' Strain Gauge



Polished Rod Load Cell





Weatherford



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Wireless Load Cell

- ▶ Drop-in replacement for wired load cell installation
- ▶ Rotaflex, VSH2, and improved geometry/conventional units with high cable failure rates
- ▶ ~9 month battery life



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Position Input Devices



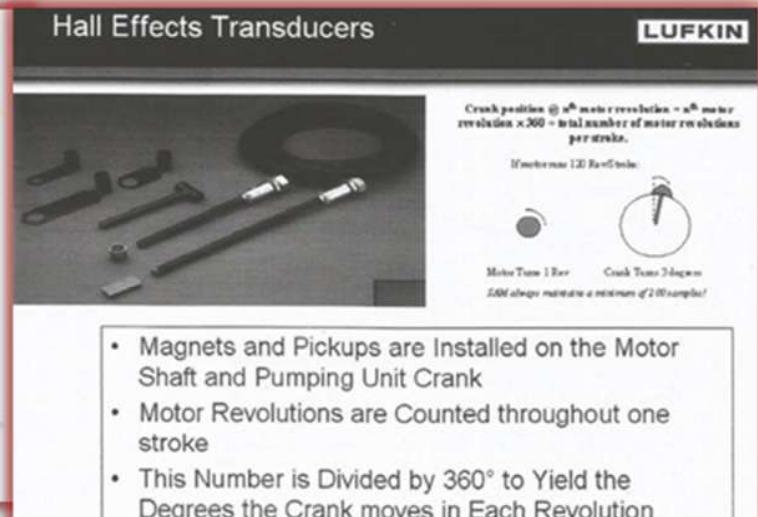
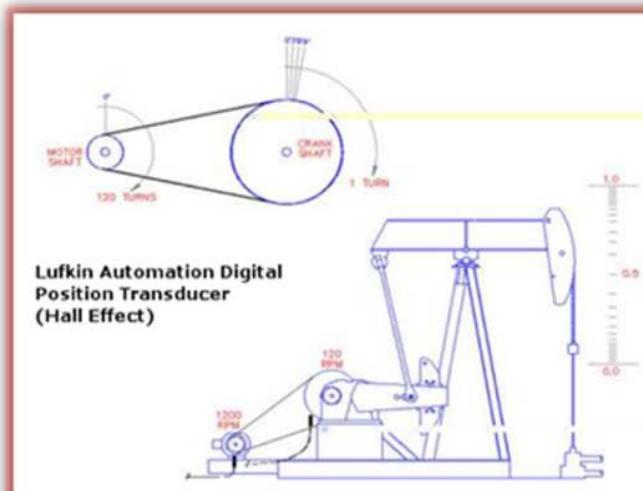
Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Real Position

Lufkin Automation (General Electric) utilizes two digital position transducers that provide a relationship between the speed and loading of the motor and the position of the pumping unit. The GE Well Manager RPC utilizes the geometry data from the specific model of the installed pumping unit and then calculates the relationship between the motor RPM and the slow speed gearbox shaft, and thus accurately plots the exact position of the polish rod throughout the period of each stroke.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Card Data Report 05-29-15 06:58 AM	
Current card for Dunaway #11 collected: 08-09-06 09:40	
Number of Load/Position Pairs = 137	
Position Load	
=====	=====
0.00,	8688
0.00,	8848
0.20,	8928
0.50,	9584
1.00,	9728
1.60,	10224
2.30,	10288
3.10,	10656
4.00,	10832
5.10,	11232
6.30,	11872
7.60,	12368
9.00,	12800
10.60,	13280
12.20,	13520
13.90,	13216
15.80,	12800
17.70,	12448
19.80,	12080
21.90,	12000
24.10,	12240
26.40,	12640
28.70,	12880
31.10,	13104
33.60,	13168
36.20,	12944
38.80,	12672
41.40,	12480
44.10,	12368
46.80,	12304
49.60,	12480
52.40,	12736
55.20,	12800
58.00,	12912
60.80,	12944
63.60,	12816
66.50,	12608
69.20,	12544
72.00,	12432
74.80,	12432
77.60,	12544
80.30,	12704
82.90,	12800
85.60,	12816
88.10,	12816
90.70,	12704

Position values begin at zero and increase to the maximum stroke length value.

Card Data Report 05-29-15 06:58 AM	
Current card for Dunaway #11 collected: 08-09-06 09:40	
Number of Load/Position Pairs = 137	
Position Load	
=====	=====
106.30,	12768
108.20,	12848
110.00,	12848
111.70,	12768
113.30,	12672
114.70,	12640
116.10,	12544
117.30,	12608
118.50,	12672
119.50,	12816
120.40,	12816
121.10,	12848
121.80,	12800
122.30,	12544
122.70,	11904
122.90,	11360
123.10,	9920
123.10,	9184
122.90,	9584
122.70,	10768
122.30,	11760
121.80,	12432
121.10,	12432
120.40,	12000
119.50,	10864
118.50,	10256
117.30,	10096
116.10,	10224
114.70,	10720
113.30,	11760
111.70,	11968
110.00,	11840
108.20,	11536
106.30,	11168
104.30,	10320
102.20,	10288
100.00,	10592
97.80,	10832
95.50,	11168
93.10,	11696
90.70,	11600
88.10,	11296
85.60,	11072
82.90,	10896
80.30,	10560

Maximum Stroke Length

Position values return to zero

Raw Load and Position Values

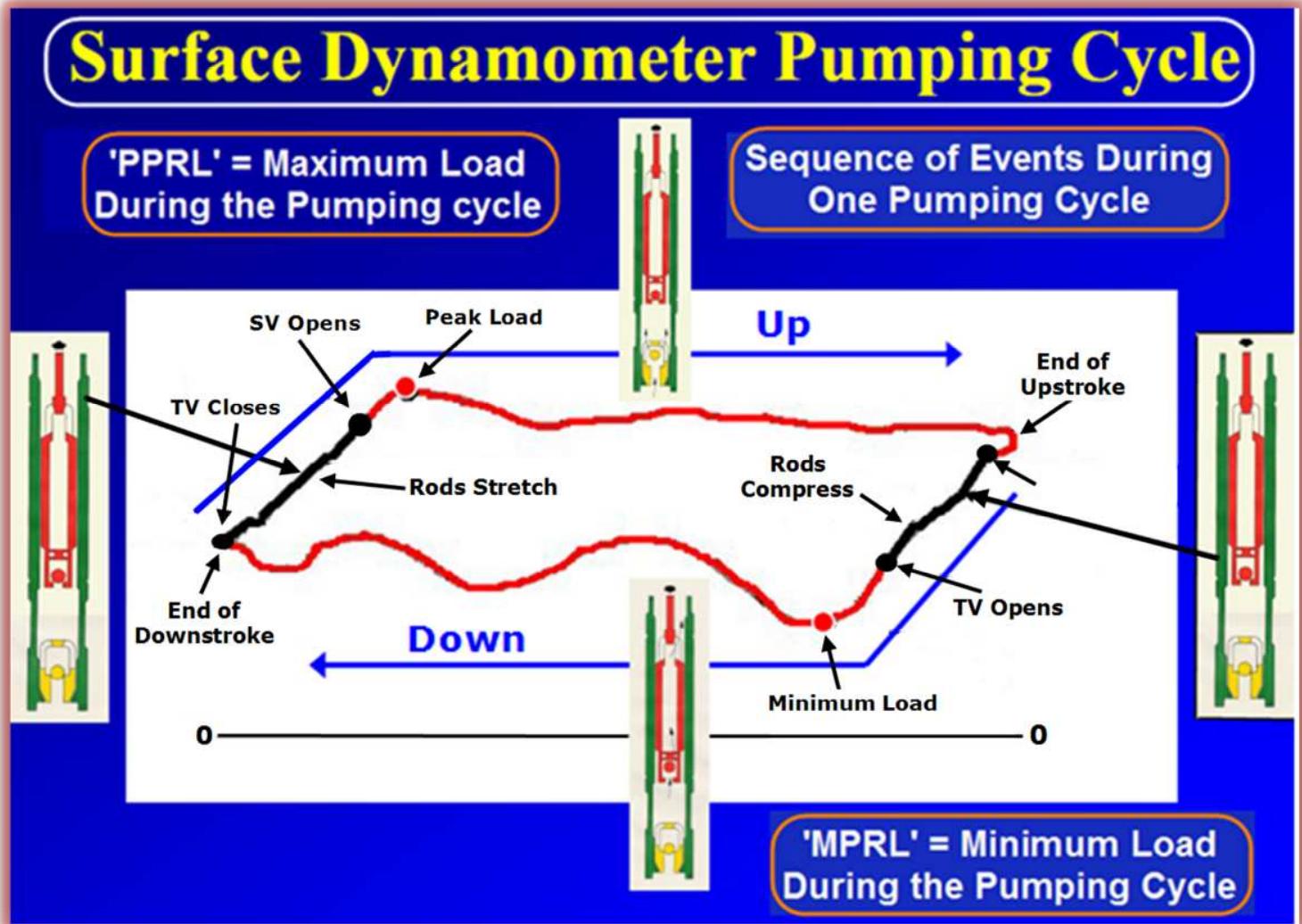


Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Surface Dynamometer Card Shape



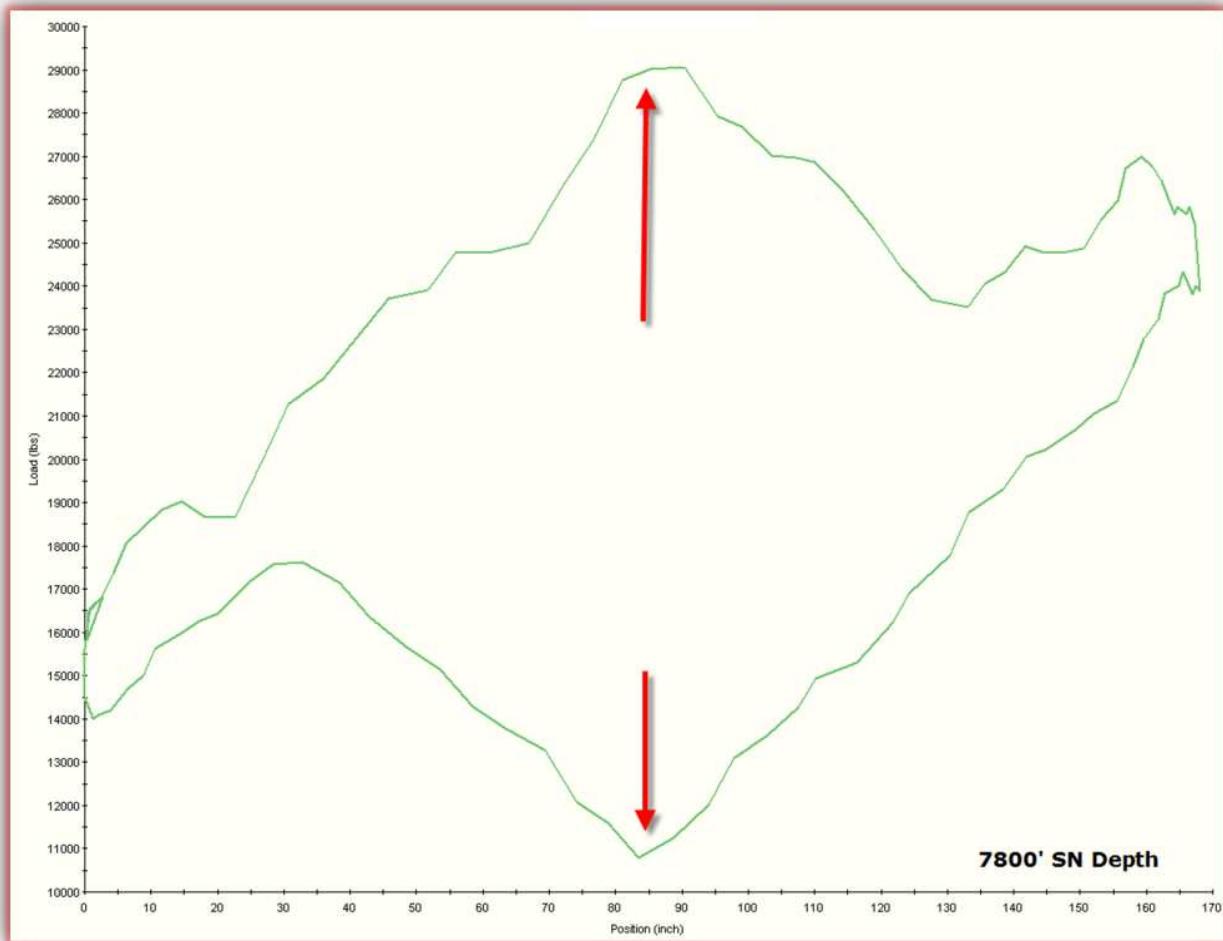
((ECHOMETER)))



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



The Surface Dynamometer Card -- Deep Well --

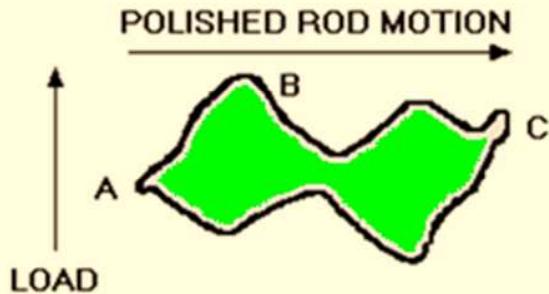
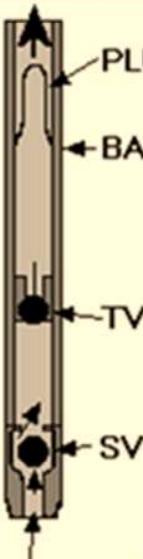
**Note the 'Diamond shaped' surface card
as compared to the shallow well surface
card on the previous page.**



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com

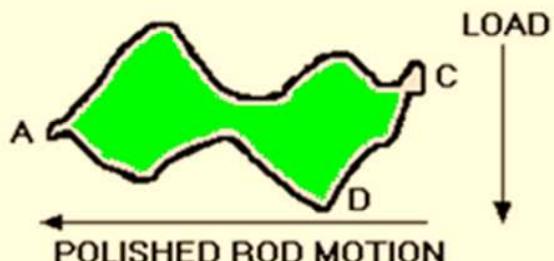
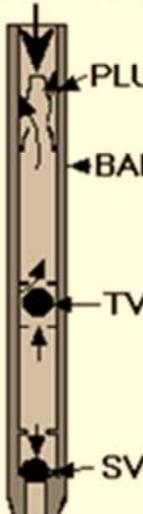


Surface and Downhole Dynamometer Card Interpretation



- A. Beginning of the upstroke. Plunger reversal causes the traveling valve to close.
 A to B. The rods stretch, the plunger is stationary.
 B to C. The plunger travels to the top of the upstroke, allowing the standing valve to open.
 C. Top of the upstroke.

SURFACE DYNAMOMETER (UPSTROKE)



- C. Beginning of the downstroke. Plunger reversal causes the standing valve to close and the traveling valve to open. The load is transferred to the tubing.
 C to D. The rods begin to contract, the plunger is stationary.
 D. Minimum load is reached, the rods have contracted.
 D to A. The plunger travels to the bottom of the downstroke.
 A. Bottom of the downstroke.
 C. Top of the upstroke.

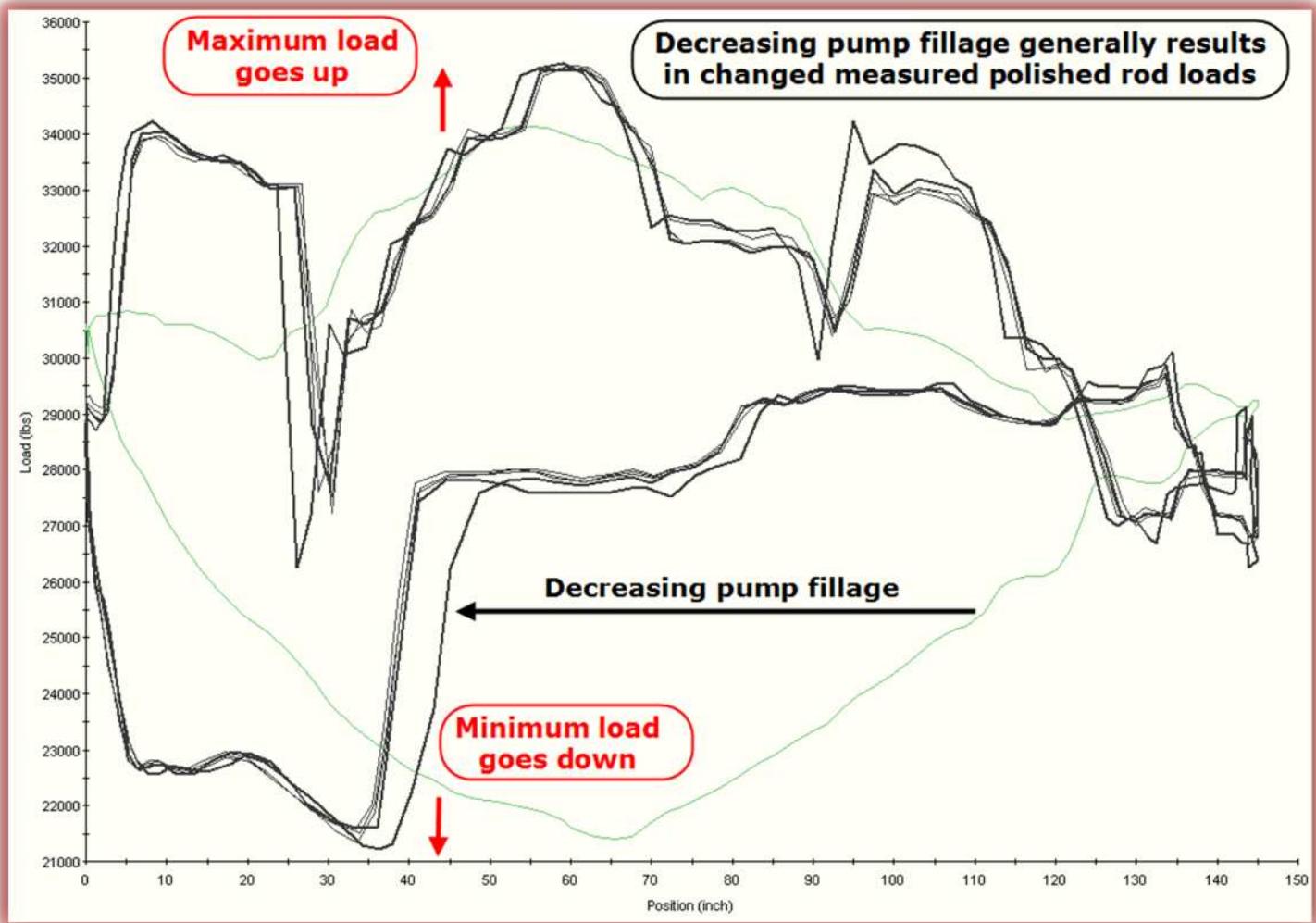
SURFACE DYNAMOMETER (DOWNSTROKE)



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



- ▶ Note that both the maximum and the minimum load values move further apart as pump fillage decreases – or that the ‘load range’ increases.

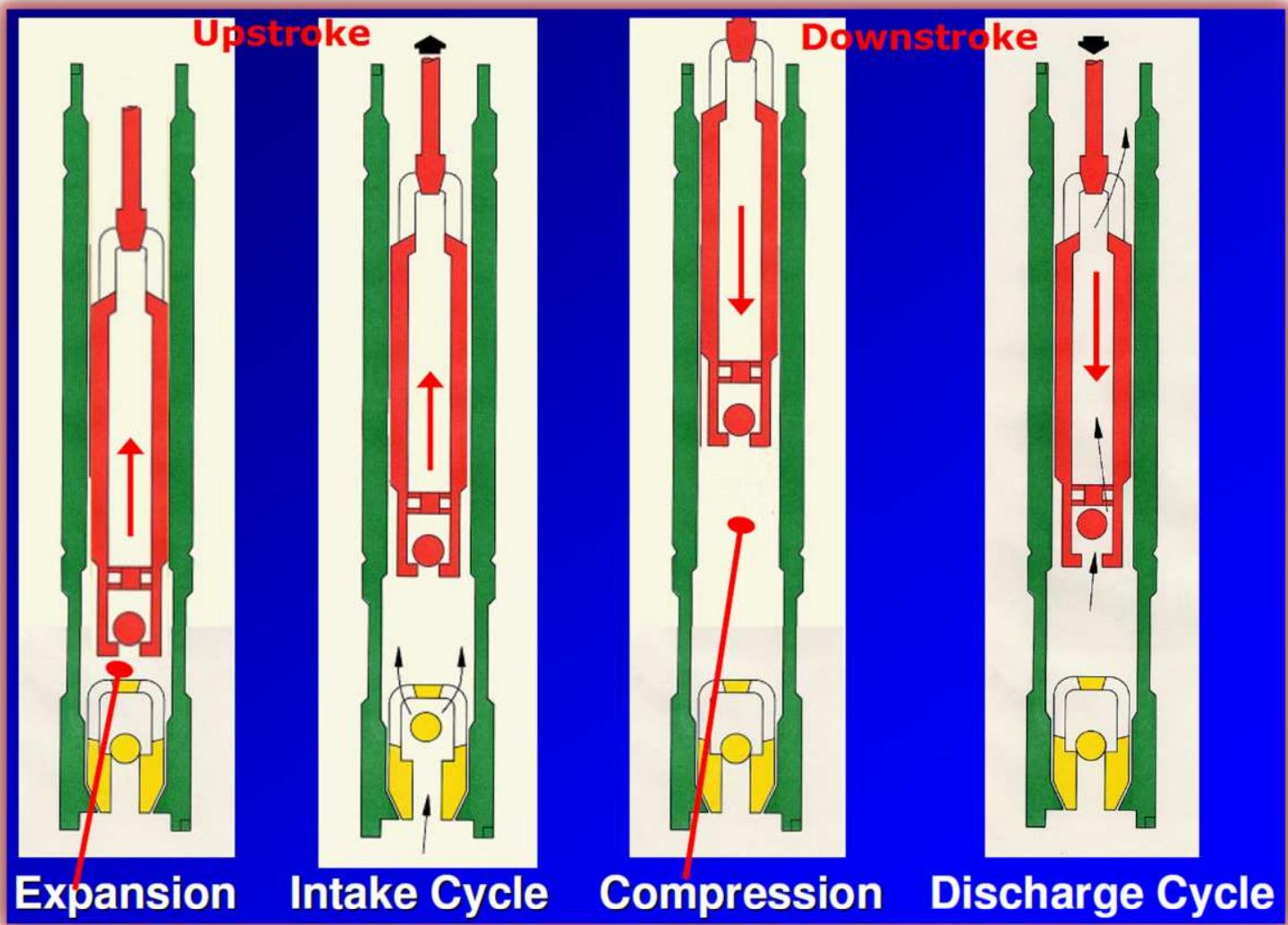


Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Downhole Pump Cycle



((((ECHOMETER))))

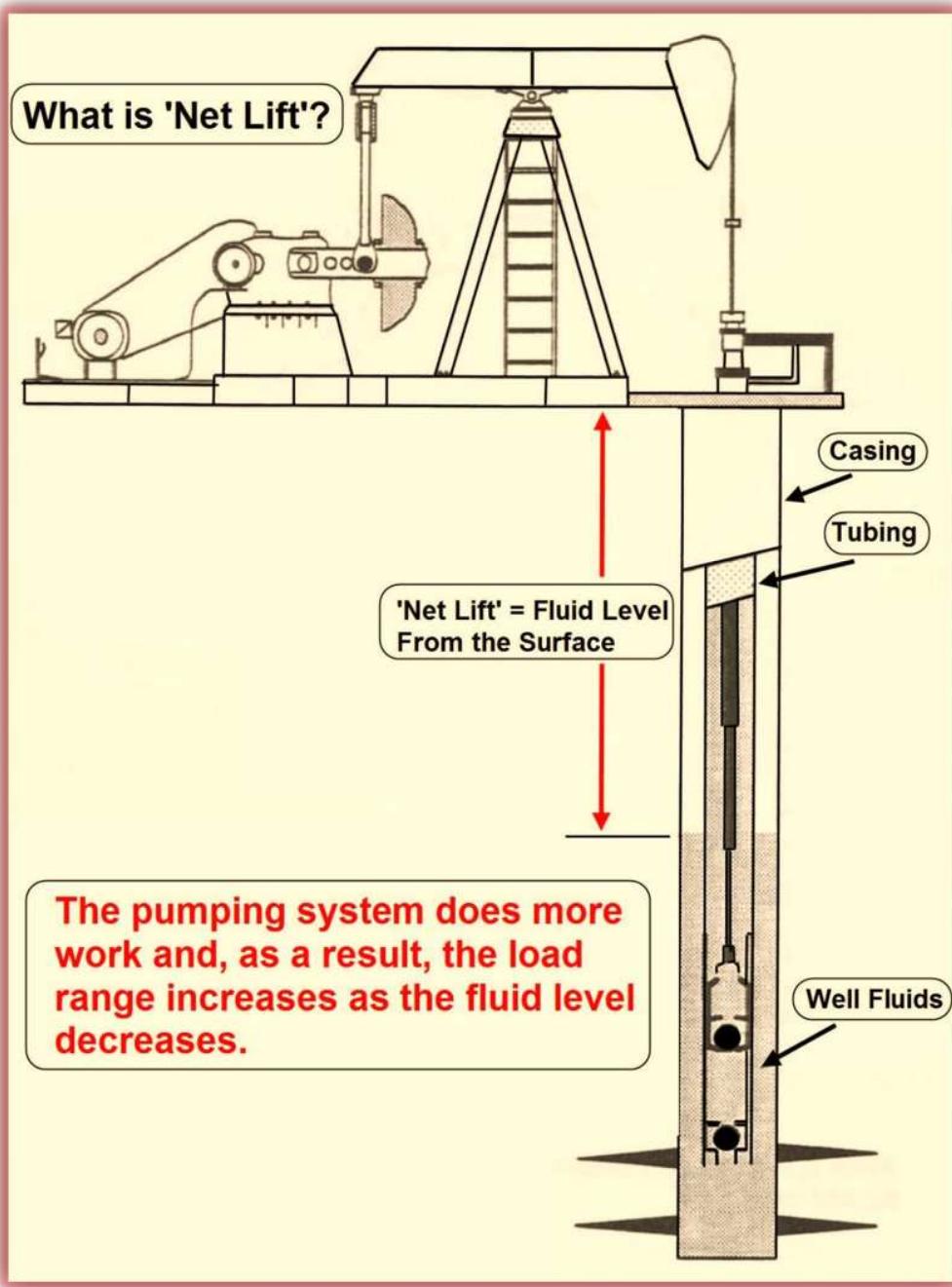


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Effects of 'Net Lift'



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com

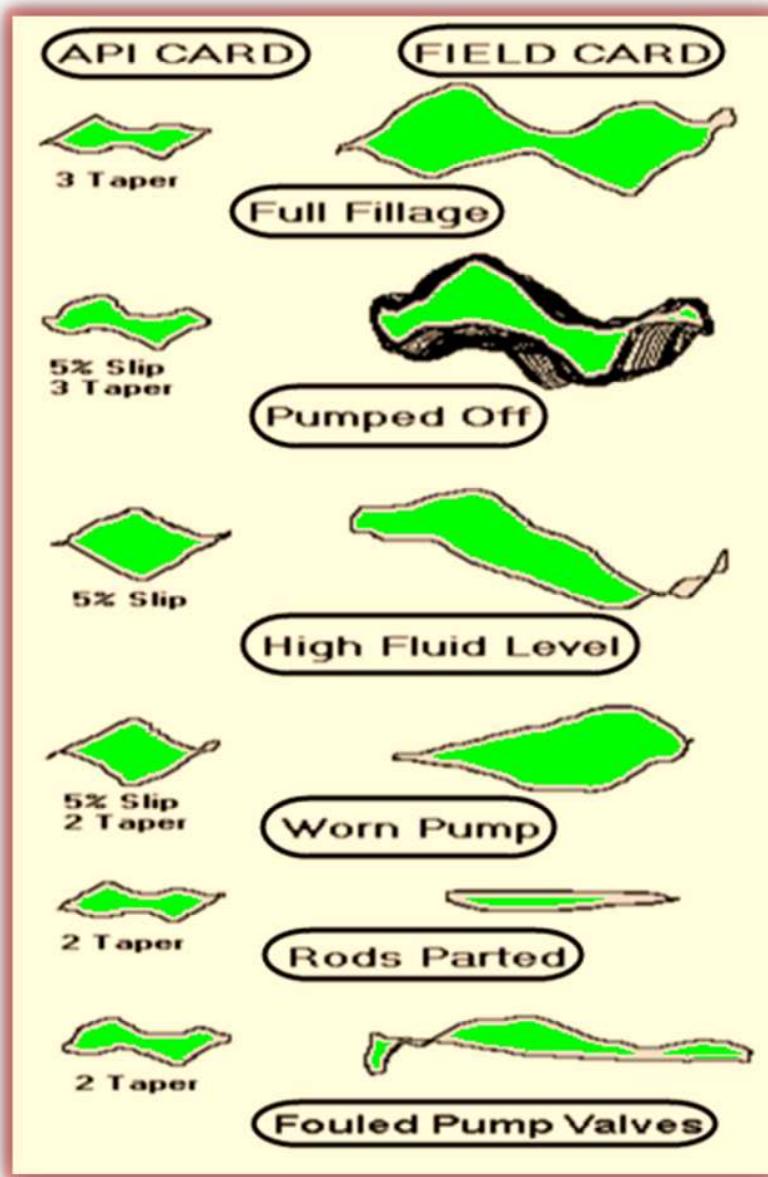


Surface and Downhole Dynamometer Card Interpretation

Surface Dynamometer Card Library

Card Area

 The following graphics are a library of "API 11L2" generated surface cards and "actual" cards gathered in the field.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com

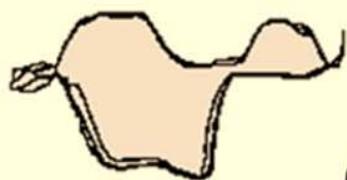


Surface and Downhole Dynamometer Card Interpretation



API Card (BUL 11L2)

Pumped Off - Fluid Pound

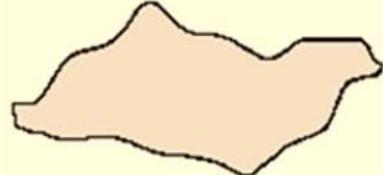


Field Card

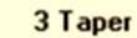
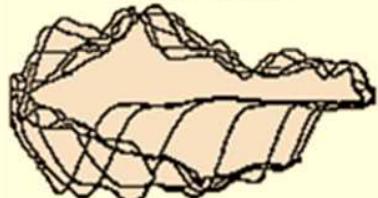
The pump is not filling. The traveling valve does not open and transfer the load to the standing valve until fluid is contacted.



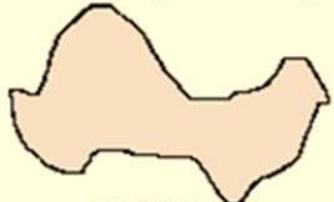
API Card (BUL 11L2)



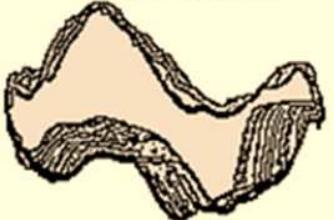
Field Cards



API Card (BUL 11L2)



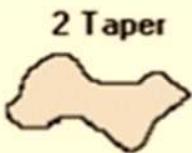
Field Cards



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com

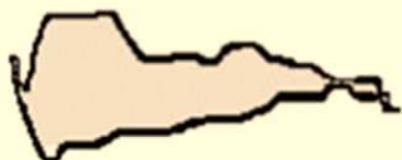


Surface and Downhole Dynamometer Card Interpretation



Gas Interference

API Card (BUL 11L2)



Field Card

Gas is being compressed.
Traveling valve does not open
and transfer the load to the
standing valve until late in the
downstroke.



API Card (BUL 11L2)



API Card (BUL 11L2)



Field Card



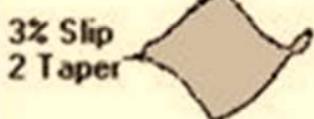
Field Card



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com

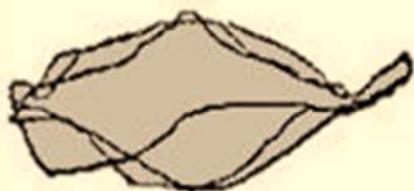


Surface and Downhole Dynamometer Card Interpretation



Irregular Pump Fillage
Fouled Pump Valves

API Card (BUL 11L2)

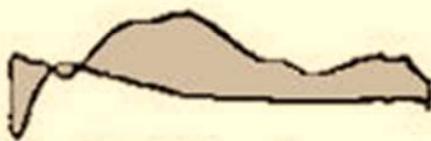


Pumping condition not stable.
Pump volume varies from
stroke to stroke.

Field Card



API Card (BUL 11L2)



Fouled TV or SV

Field Card



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

API Card (Bul 11L2)

5% Slip
2 Taper

API Card (Bul 11L2)

"Not Pumping" to "Pumping"

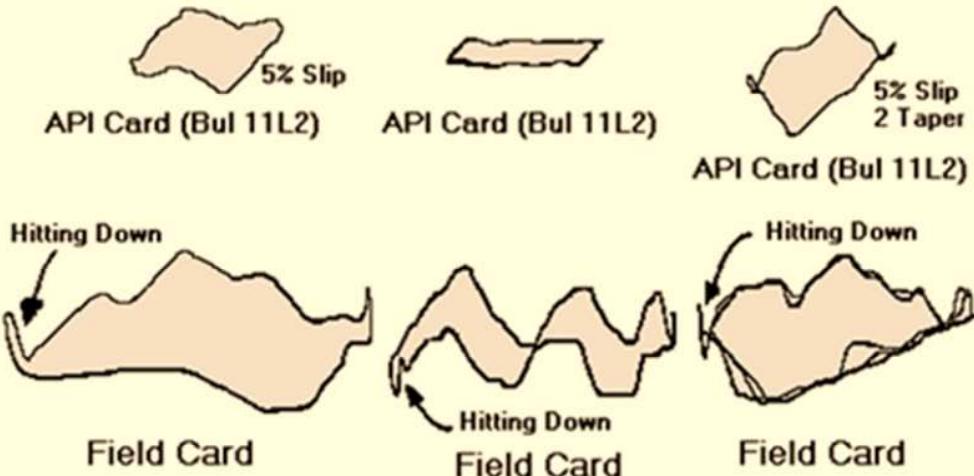


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



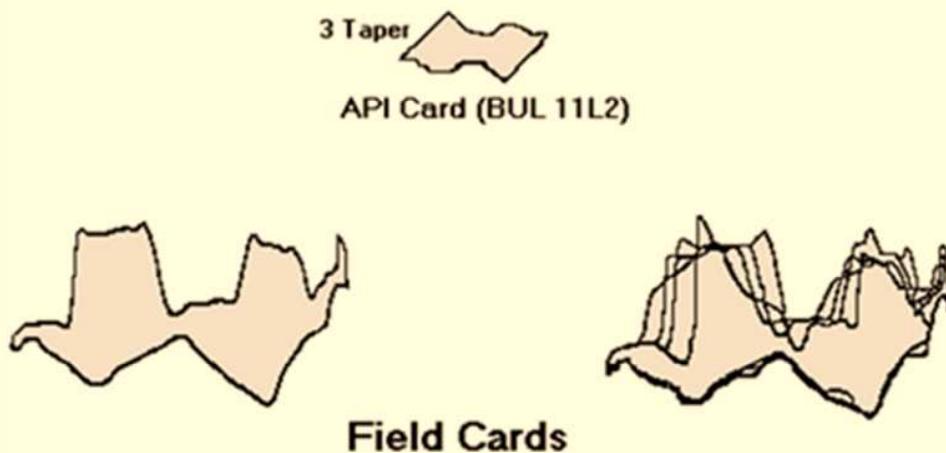
Surface and Downhole Dynamometer Card Interpretation

"Hitting Down" or "Bumping Bottom"



Rods go into compression as the pump "hits down". Stress reversals occur as the rods recoil - causing abnormal loading.

Delayed Traveling Valve Seating

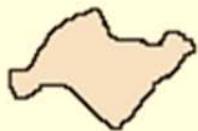


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



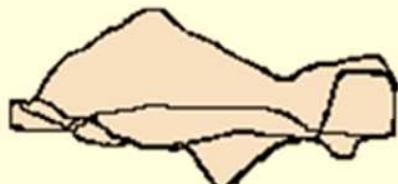
Surface and Downhole Dynamometer Card Interpretation

5% Slip
3 Taper



Pump Valves Not Seating

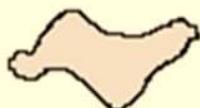
API Card (BUL 11L2)



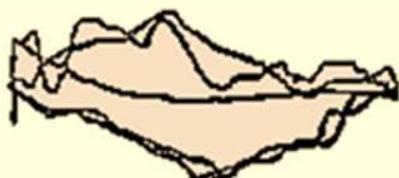
Field Card

Traveling valve does not close to allow the transfer of the fluid load from the tubing to the rods on the upstroke. The fluid load remains on the tubing.

5% Slip
2 Taper



API Card (BUL 11L2)



Field Card

Standing valve does not close to allow the transfer of the fluid load from the rods to the tubing on the downstroke. The fluid load remains on the tubing.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

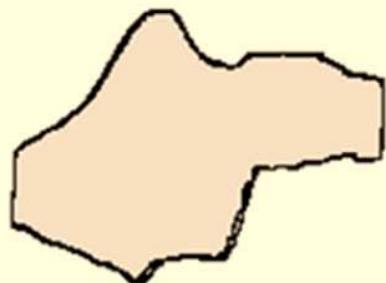
Downhole Friction

Mechanical friction causes rod string damping and reduces the effects of rod dynamics. Damping indicates the presence of downhole friction---buckled tubing, crooked hole or paraffin. Damping the downstroke tends to smooth and thicken the dynamometer card shape.

5% Slip



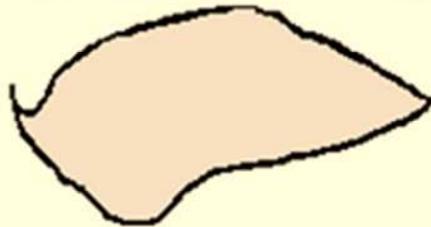
API Card (BUL 11L2)



Field Cards

5% Slip
3 Taper

API Card (BUL 11L2)



Field Cards



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

API Card (BUL 11L2)

Flowing Well

Well is flowing - with little work performed by the pump. Fluid is rising faster than the plunger and holding the traveling valve open.

Field Card

API Card (BUL 11L2)

API Card (BUL 11L2)

Field Card

Field Card

Field Card

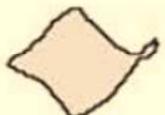


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



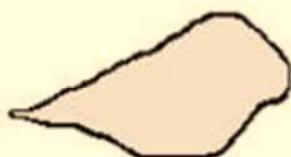
Surface and Downhole Dynamometer Card Interpretation

5% Slip
2 Taper



Upstroke Pump Wear

API Card (BUL 11L2)



Field Card

There is a problem with the TV or the barrel/plunger fit. The peak polished rod load, which should occur at mid-stroke (see the API card), is not reached until near the top of the stroke. Fluid slippage on the upstroke is almost greater than the displacement rate of the pump.

2 Taper



API Card (BUL 11L2)

5% Slip



API Card (BUL 11L2)

Field Card

Field Card



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com

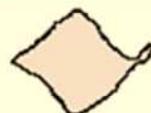


Surface and Downhole Dynamometer Card Interpretation

2 Taper



5% Slip
2 Taper

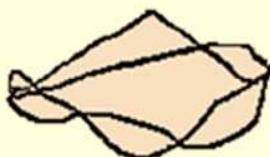


Worn Pump - Traveling Valve Leak

Field Card
Ball Pitted



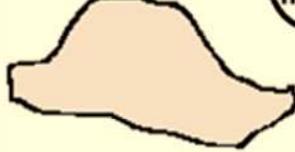
Field Card
Ball Out of Round



Balls pitted and out of round. With this condition, loading can vary from stroke to stroke - depending on the area of the ball that makes contact with the valve seat. When contact between ball and seat provides a seal, pump loading will be normal. When the worn or pitted area of the ball contacts the seat, no seal is provided and slippage occurs.

Worn Pump - Standing Valve leak

5% Slip



Standing valve leaks are characterized by cards showing an absence of a defined minimum load during the downstroke. Depending on the rate of slippage, the load may not transfer from traveling valve to standing valve, or once transferred, it prematurely transfers back from tubing to rods.

2 Taper



Field Card

Field Card



Louis Ray – Optimization Specialist / Senior Trainer

Weatherford Production Optimization

22001 North Park Drive, Houston, TX 77339

Main: 281 348-1000 Mobile: 903-647-6777

E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Worn Traveling and Standing Valves



API Card (BUL 11L2)

Erratic loading on both the upstroke and downstroke. Both balls and seats are beaten out.



Field Card

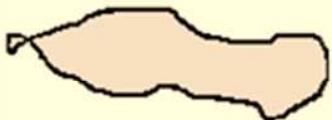


API Card (BUL 11L2)

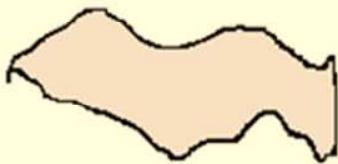
Worn Barrels



API Card (BUL 11L2)



Field Card



Field Card

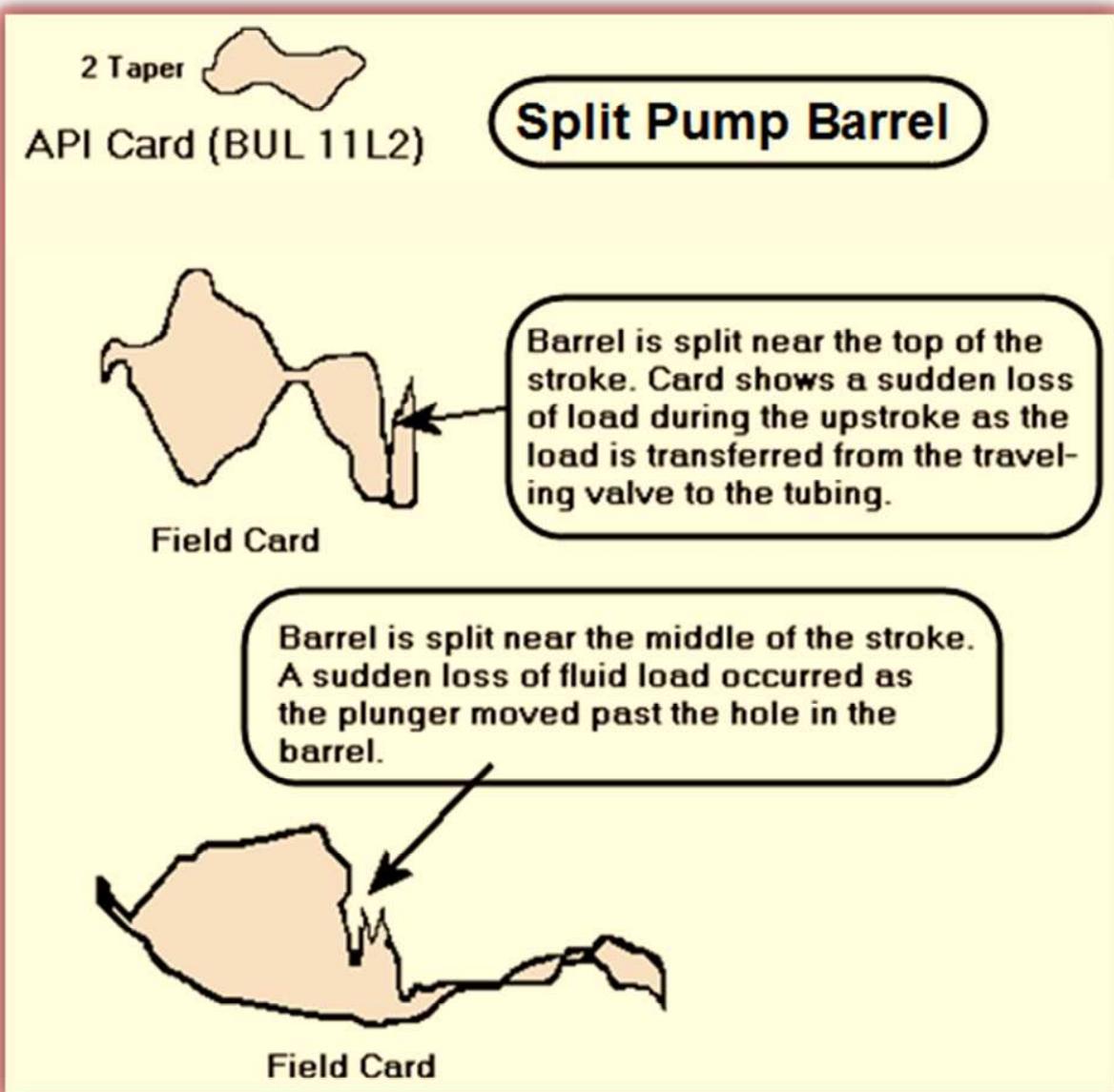
- The card on the left above shows that the pump was leaking fluid throughout the upstroke, indicating that wear had occurred in the lower portion of the barrel. Loss of load becomes more apparent at the top of the stroke (characterized by the "blunt" end of the card) because the plunger is moving upward at a very slow rate of speed (plunger is almost stationary) and slippage exceeds the displacement rate of the pump.
- The card on the right above shows that wear was confined to the top of the barrel. The field card compares favorably with the API card until the top of the stroke is reached, at which point slippage becomes apparent (characterized by the square end of the card) as the plunger comes in contact with the worn portion of the barrel.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



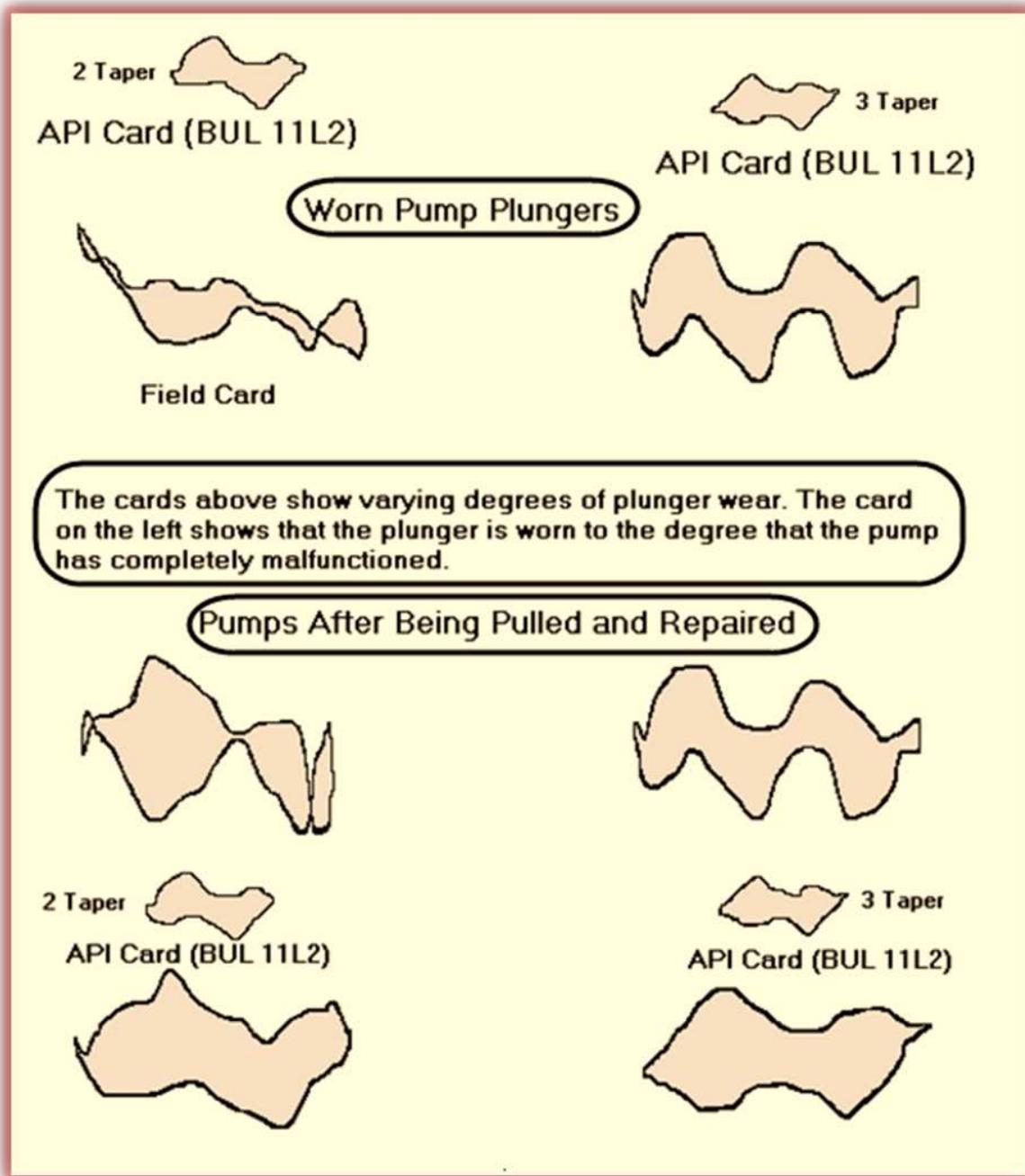
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



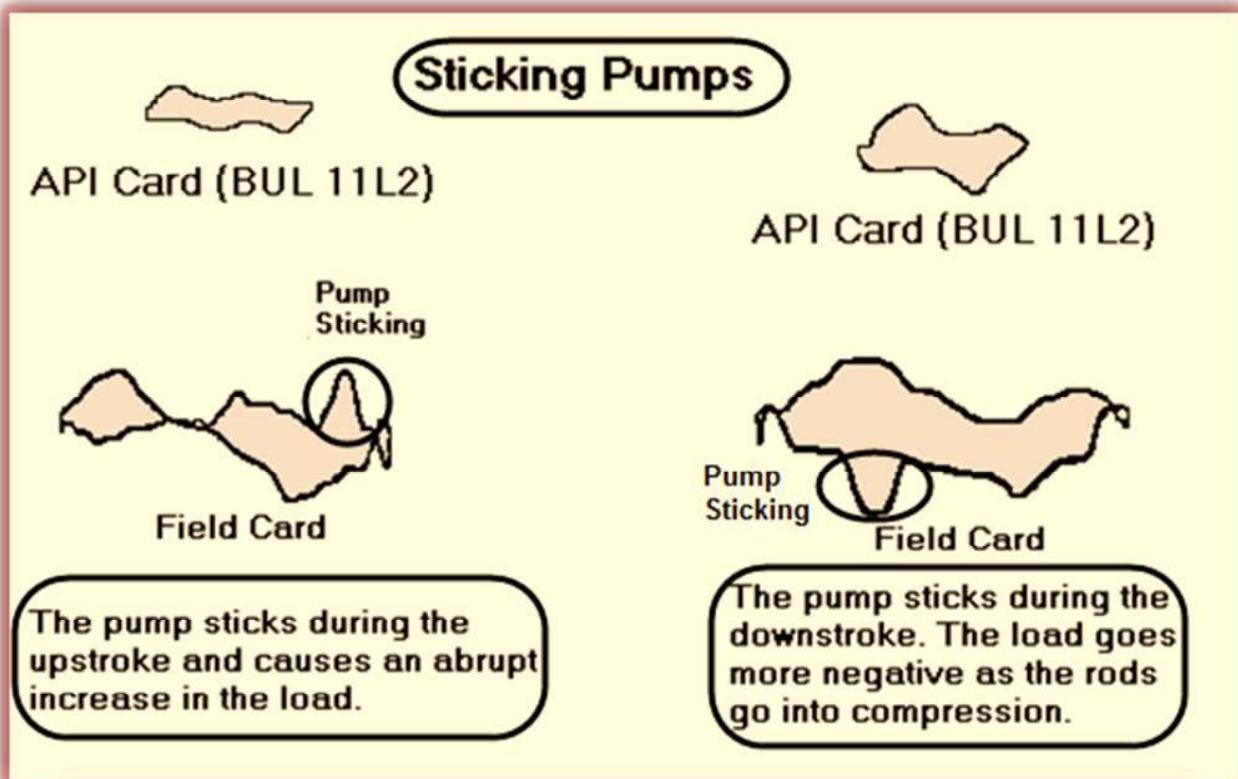
- The “before and after” cards shown above dramatize clearly that when differences in the shape of calculated and field cards are apparent, there are downhole problems --- conditions are abnormal.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com

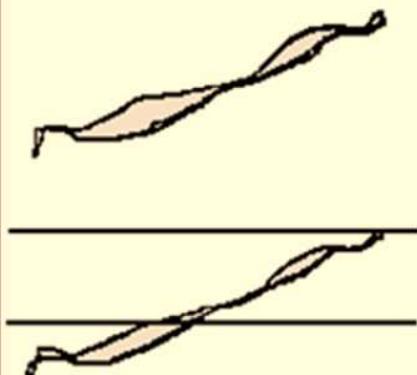


Surface and Downhole Dynamometer Card Interpretation

Excessive Undertravel - Pump Stuck



API Card (BUL 11L2)



Field Cards

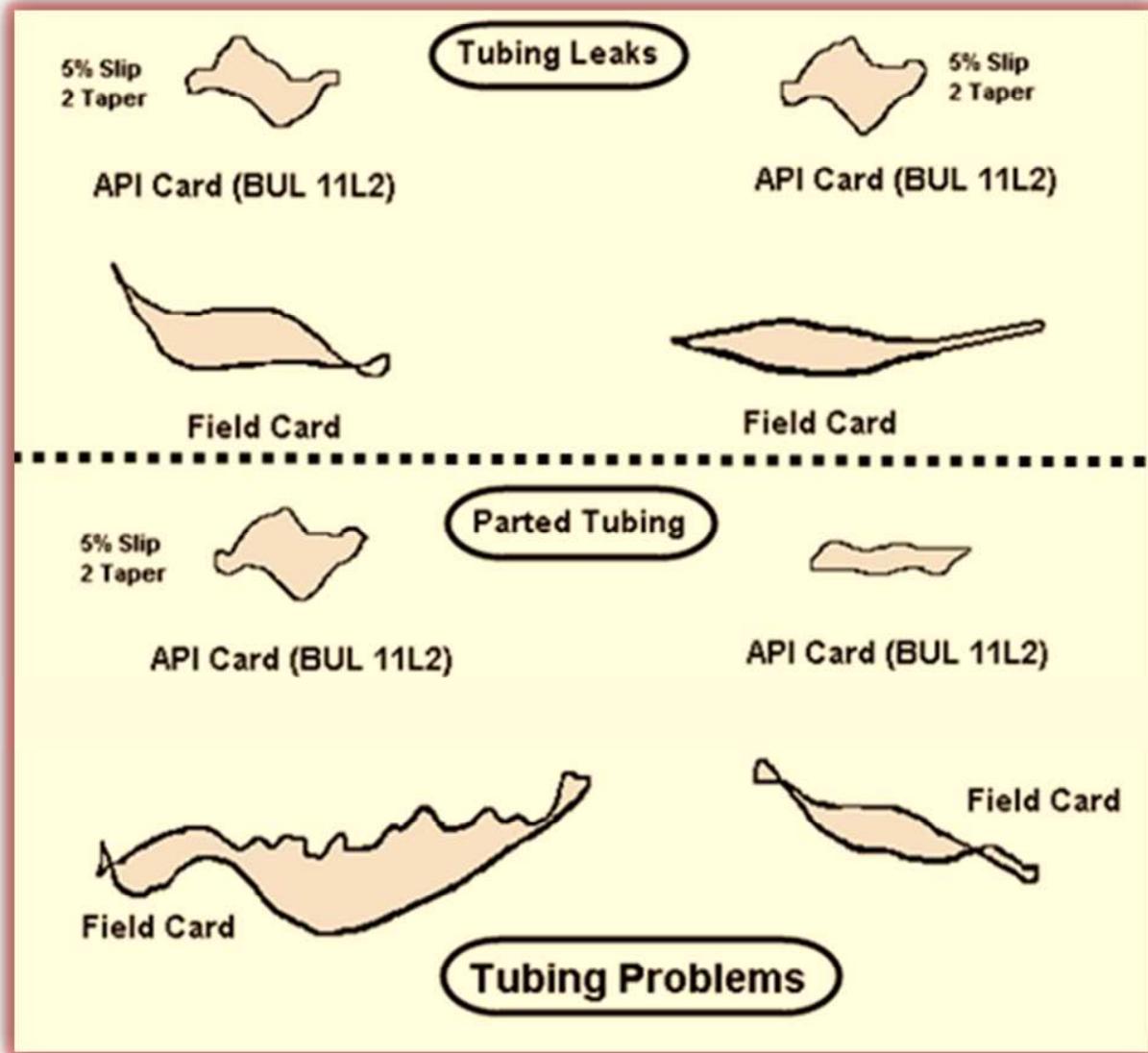
No pump action — the plunger is stuck. The card and the valve checks are abnormal because the peak load and the traveling valve check are the same. The load differential between the traveling valve and the standing valve is the result of rod stretch only. This same condition can also be caused by not enough rods in the hole.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

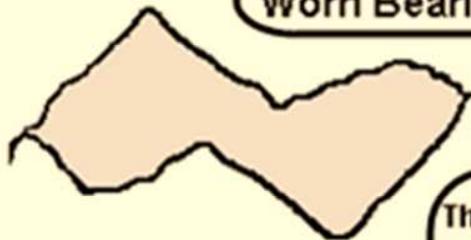
2 Taper



Pumping Unit Problems

API Card (BUL 11L2)

Worn Bearings



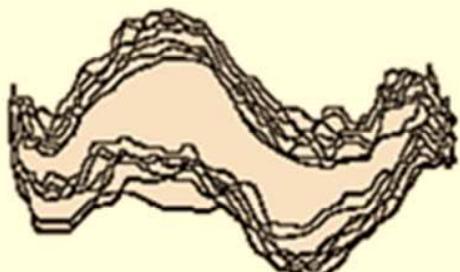
Field Card

The "rippling" effect occurred during both the upstroke and downstroke - caused by a worn tail bearing.

2 Taper



API Card (BUL 11L2)



Field Card

Defective Gearbox

Teeth were broken in the reduction gear, causing a backlash in the gears and erratic polished rod loading.



Louis Ray – Optimization Specialist / Senior Trainer

Weatherford Production Optimization

22001 North Park Drive, Houston, TX 77339

Main: 281 348-1000 Mobile: 903-647-6777

E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



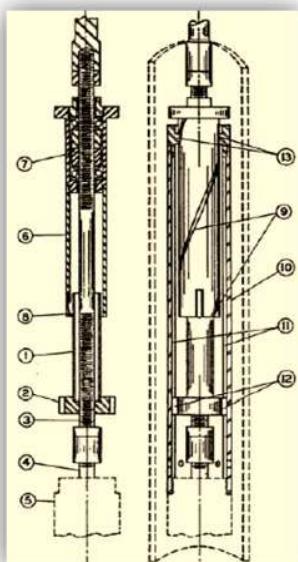
Surface and Downhole Dynamometer Card Interpretation

Downhole Dynamometer Card History

From studies of surface dynamometer cards, it is understood that one of the primary things that affect the shape of the actual dynamometer card is the load condition at the bottom of the hole. Therefore, downhole conditions such as a crooked hole, paraffin, scale, sand, and solids all affect the maximum and minimum loads and the shape of the card. In an effort to find out exactly what was happening at the bottom of the hole, W. E. Gilbert (Shell) and others designed a bottomhole dynagraph that measured loads and displacement at the bottom of the hole. His work, and a number of bottomhole dynagraphs, was published in 1936. In 1967, Sam Gibbs – a Shell Oil Co. engineer – received a patent on a mathematical method for simulating the sucker rod pumping system. His work and the work of others made it possible to use a surface dynamometer card as a basis for a simulated bottom hole card. In 1986 G. Albert designed an electronic bottomhole analyzer which measured the downhole conditions electronically in the same manner that W. E. Gilbert had measured them mechanically. This tool confirmed that the mathematical simulation from surface dynamometer cards does indeed give accurate downhole loads and displacement.



Gilbert's Downhole Dynagraph

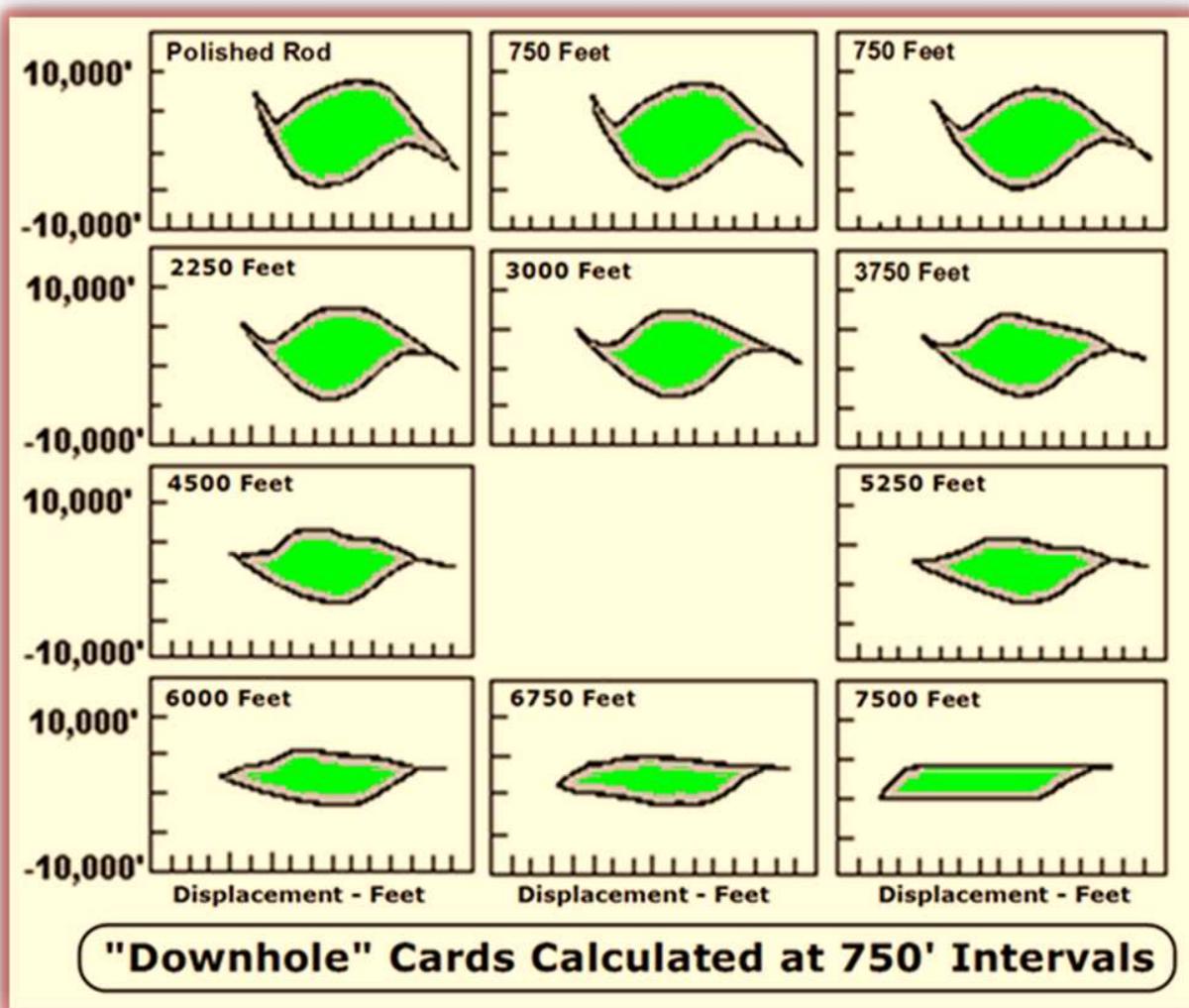


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

- To bridge the gap that arises from knowing that visual interpretation of the surface card is often inconclusive - and when good "quantitative" downhole data is needed, today's diagnostic programs make use of a mathematical solution based on a model of the rod pumping system, known throughout the industry as the "wave equation". The resulting subsurface or downhole card removes personal judgment and experience from the diagnosis of downhole conditions. The "wave equation" solution can be used to calculate a "downhole" card at any depth – see the example below.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

- The following several pages show example calculated downhole pump cards and detailed explanations that are the result of the "wave equation" diagnostic solution.

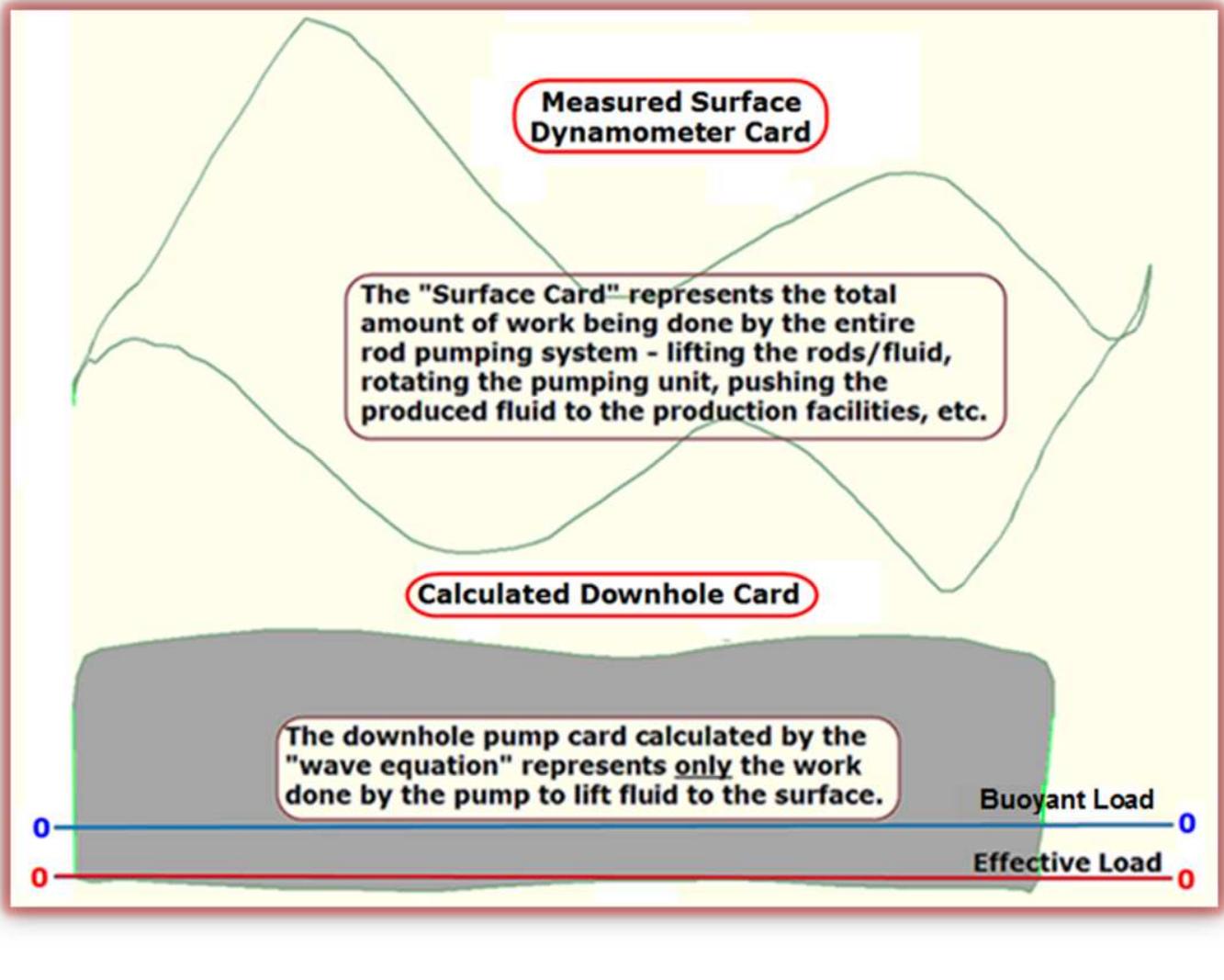


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Wave Equation Explanation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

The “Gibbs” Method

- ▶ The original and historically the most commonly used method of calculating downhole cards.
- ▶ Uses the classical method of separation of variables, which involves the splitting of the original partial differential wave equation into two “ordinary differential equations”.
- ▶ Each ‘ODE’ is solved and a product solution is formed that satisfies the wave equation.
- ▶ The polished-rod load and displacement vs. time functions are approximated

The “Everitt-Jennings” Method

- ▶ T. A. Everitt & J. W. Jennings --

“An Improved Finite-Difference Calculation of Downhole Dynamometer Cards for Sucker-Rod Pumps”, SPE, Feb 1992



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

An Improved Finite-Difference Calculation of Downhole Dynamometer Cards for Sucker-Rod Pumps

T.A. Everitt,* SPE, Chevron Oil Field Research Co., and J.W. Jennings,** SPE, Texas A&M U.

Summary. This paper presents a finite-difference representation of the wave equation developed for diagnostic analyses of sucker-rod pumping systems. A consistent method of computing the viscous damping term associated with the damped-wave equation is also presented.

Introduction

Sucker-rod pumping is the most widely used means of artificial lift. About 85% to 90% of all producing wells in the U.S. are rod-pumped. Thus, a reliable method of analyzing these pumping systems is a necessity.

For many years, the surface dynamometer has been used to analyze sucker-rod systems. Interpretation of actual pump conditions from surface dynamometer cards is often difficult, if not impossible. Results obtained from surface cards are strictly qualitative and are dependent on the analyzer's expertise.

The ideal analysis procedure would be to measure the actual pump conditions with a downhole dynamometer. However, this situation is not economically feasible. Therefore, an accurate method of calculating downhole pump cards from measured surface cards is needed. This paper presents a method for calculating these downhole cards that uses a finite-difference representation of the wave equation. First, a brief description of previous calculation techniques is given.

Previous Methods. Past work involving the analysis of sucker-rod pumping systems can be divided into two categories. One category involves predicting the performance of new sucker-rod installations by calculating surface load from known surface position and pump load. The other category deals with the diagnosis of existing pumping installations by determining actual pump conditions from measured surface conditions. This paper focuses on the latter category.

Snyder¹ was the first to develop a method for calculating downhole forces and displacements. His technique incorporates the method of characteristics to solve the undamped-wave equation. Snyder assumed that the tension in the rod is the result of two force waves, *f* (downward wave) and *g* (upward wave). The values of *f* and *g*, calculated from the surface dynamometer card, would be constant over the entire rod string for the undamped solution. Snyder corrected for damping using a concentrated damping force to advance the values of *f* and *g* down the rod string. These two force waves are then used to compute the downhole pump card. Snyder's method is rigorously valid only for a uniform sucker-rod string.

Gibbs and Neely² developed an analytical technique in 1966 for obtaining subsurface conditions. The method uses truncated Fourier series approximations of the 1D, damped-wave equation to determine load and displacement. The relative smoothness of the load/time and displacement/time curves is important in a Fourier analysis; however, the load function approaches a square wave at the pump. The Fourier series solution oscillates at the discontinuities of this square wave, restricting the number of terms that can be taken in the series solution and still preserve accuracy. In turn, the smaller number of terms in the series causes the solution to be less accurate. Gibbs and Neely's analytical method has become the primary means of calculating downhole dynamometer cards.

Knapp³ was the first to present a method for computing downhole dynamometer cards using finite differences. His formulation does not account for variable rod diameter or rod material. Knapp's theory was used in the development of the model presented here.

Model Development

The behavior of the sucker-rod pumping system is complex. This study entails modeling a portion of this system, namely the sucker-rod string from the surface to the pump. The wave equation is ideal for this purpose because the problem at hand involves the propagation of waves in a continuous medium.

Wave Equation. The 1D wave equation is a linear hyperbolic differential equation that describes the longitudinal vibrations of a long, slender rod. Using this equation with viscous damping, we can approximate the motion of the sucker-rod string. In its simplified form, the wave equation is given by

$$v^2 \frac{\partial^2 u}{\partial x^2} = \frac{\partial^2 u}{\partial t^2} + c \frac{\partial u}{\partial t}, \quad (1)$$

where $v = \sqrt{144Eg_c/\rho}$.

Eq. 1 is for the simplified case of a constant rod diameter. Multiplying through by $(\rho A/144g_c)$ modifies Eq. 1 to account for variable rod diameter:

$$EA \frac{\partial^2 u}{\partial x^2} = \frac{\rho A}{144g_c} \frac{\partial^2 u}{\partial t^2} + c \frac{\rho A}{144g_c} \frac{\partial u}{\partial t}, \quad (2)$$

which is the form of the wave equation used to develop the finite-difference model. Several researchers⁴⁻⁶ gave a detailed derivation of the wave equation, beginning with a force balance on an element of the sucker-rod string.

Generally, solving the wave equation would require two boundary conditions and two initial conditions because the equation contains second-order derivatives in both time and space. However, the problem solved here does not require initial conditions because only periodic (steady-state) solutions are desired. Because the effects of the initial conditions have faded in periodic solutions, only two boundary conditions are required.

The two required boundary conditions are time histories of polished-rod load and displacement. These conditions can be obtained directly from a surface dynamometer point plot, a graph of polished-rod load vs. displacement recorded at evenly spaced increments of time. Surface cards are typically recorded as continuous plots, however, and not as point plots at equal time increments. In this case, pumping-unit kinematics must be used to attain a relationship between time and polished-rod displacement. Svinos⁷ developed a versatile method for performing the kinematic analysis of pumping units. His method was used in this study to obtain surface position at evenly spaced time increments. Constant speed was assumed for the prime mover, and inertia effects were neglected.

*Now at Shell Offshore Inc.

**Now retired.

Copyright 1992 Society of Petroleum Engineers

SPE Production Engineering, February 1992



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

The Modified "Everitt-Jennings" Method

- ▶ Weatherford has 'modified' the EJ method for efficiency and specific functionality.
- ▶ The EJ method uses the finite difference method to solve directly the wave equation.
- ▶ Each rod taper is segmented to a number of finite difference elements (8).
- ▶ Rod stress is calculated on based on each segment. And may be determined on any rod in a rod string.
- ▶ Calculations progress from the surface to the downhole location along the above number of finite difference elements.
- ▶ Provides iteration on the net stroke and the damping factor to ensure the best downhole card.
- ▶ Computes 'effective load' for downhole data.
- ▶ The displacement vs. time function is approximated by Fourier series.
- ▶ The load vs. time function is approximated by least squares and cubic spline methods.
- ▶ Increasingly used by well analysts

Damping Factor Determination

- ▶ "Damping" refers to the irreversible energy loss which occurs along the rod string assumed to be of viscous nature only.
- ▶ "Gibbs" Damping Factor –
 - ▶ Damping factor values are *defaulted* based on tubing/rod size or may be manually adjusted as desired.
 - ▶ Modified "Everitt-Jennings" Damping Factor –
 - ▶ *Calculated* - Iteration on the value is done based on the "net stroke" and "damping factor" using a fluid level calculation.
 - ▶ First, iterate on "net stroke" until the result is within tolerance.
 - ▶ Next, iterate on the "damping coefficient" based on hydraulic horsepower and pump horsepower.
 - ▶ Point: "Gibbs" damping factors are defaulted / manually determined. 'EJ' damping is calculated.



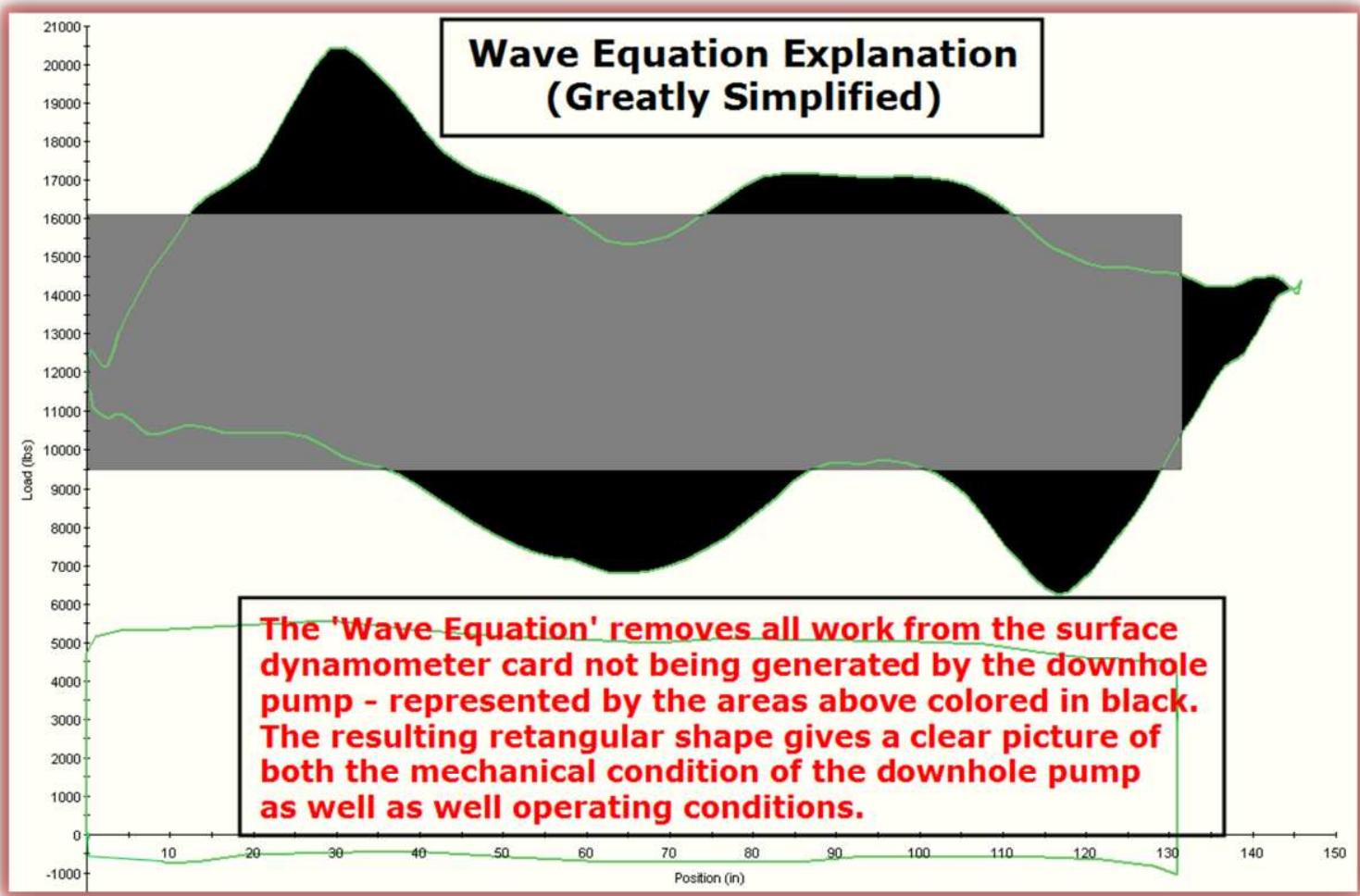
Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Damping Factor Determination

- Downhole fillage calculation is comprised of four algorithms that use only downhole data to compute the pump fillage for a given pumping unit stroke.
- Improved fluid level calculations.
- More frequent calculation of stress level throughout the rod string and is capable of stress calculation on any individual rod in the string.

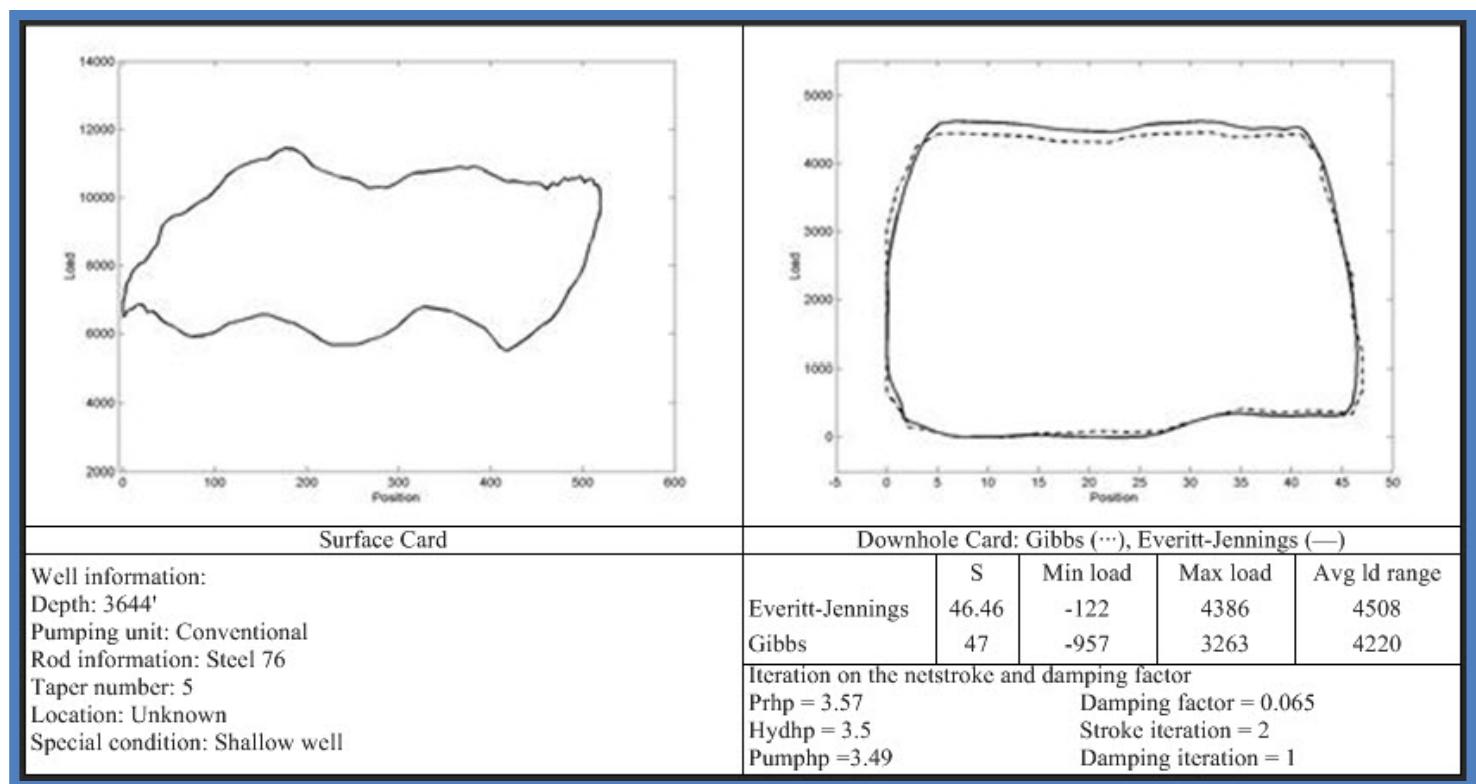


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

SANDIA Labs "Measured "Gibbs Test Data
Presented in 1997 at the SWPSC – Lubbock, TX
vs.
"Calculated" Everitt-Jennings Data



Note that the 'measured Gibbs' downhole card is displayed on zero load.



weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

'Buoyant Load' / 'Effective Load' Definitions

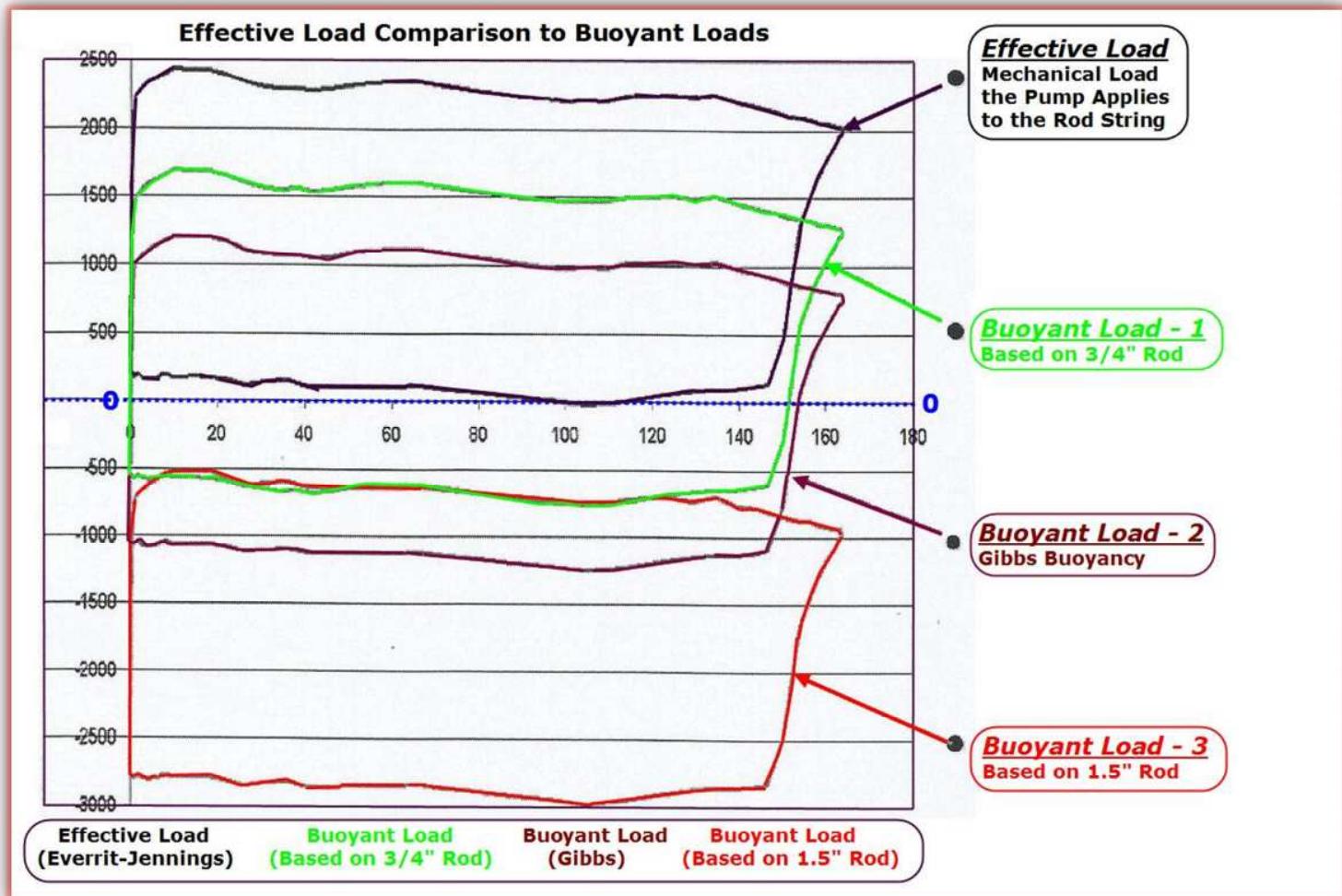
- The examples of calculated downhole card shapes displayed and described in this document are shown in terms of "Buoyant Load" and "Effective Load".
- ☺ "Buoyant Load" – Downhole cards are calculated and displayed including buoyancy, in other words, the minimum value of the fluid load will be negative. "Gibbs" downhole cards will always display using "Buoyant Load" as the default presentation method.
- ☞ The Weatherford LOWIS analysis software allows the user to optionally display the "Gibbs" downhole card using "Effective Load" as defined below.
- ☺ "Effective Load" – Downhole cards are calculated and displayed not including buoyancy, in other words, the minimum value of the fluid load will be zero.
- "Everitt-Jennings" downhole cards will always be displayed using the "Effective Load" presentation.
- Echometer 'onsite' dynamometer systems will always display downhole cards using "Effective Load".



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



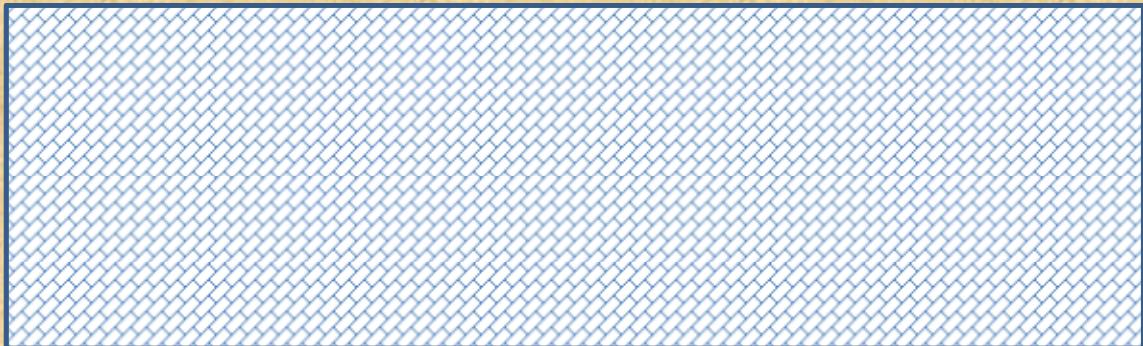
Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

The Calculated Downhole Pump Card

The 'Perfect' Calculated Downhole Pump Card



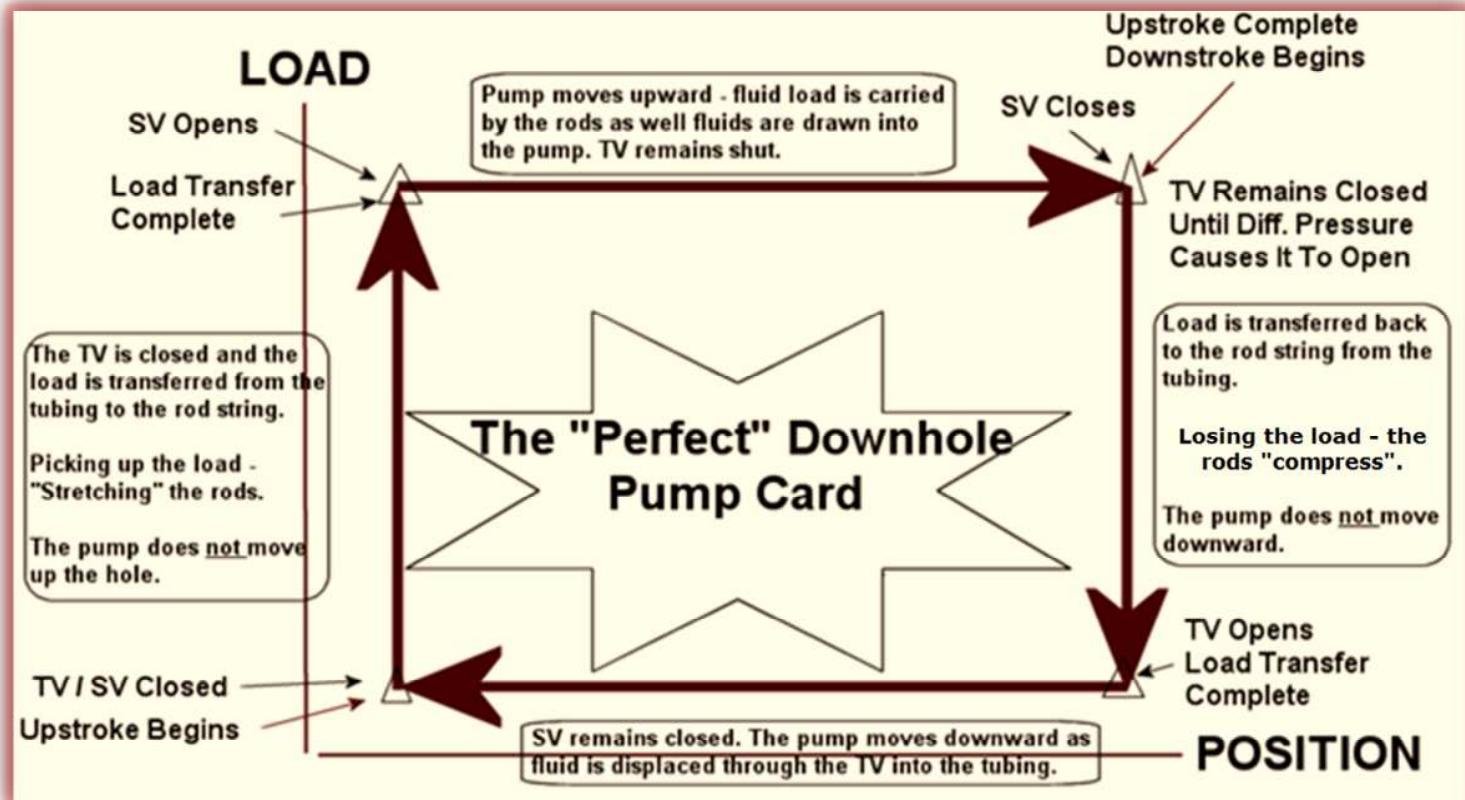
Why Does It Have a Rectangular or Parallelogram Shape?



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

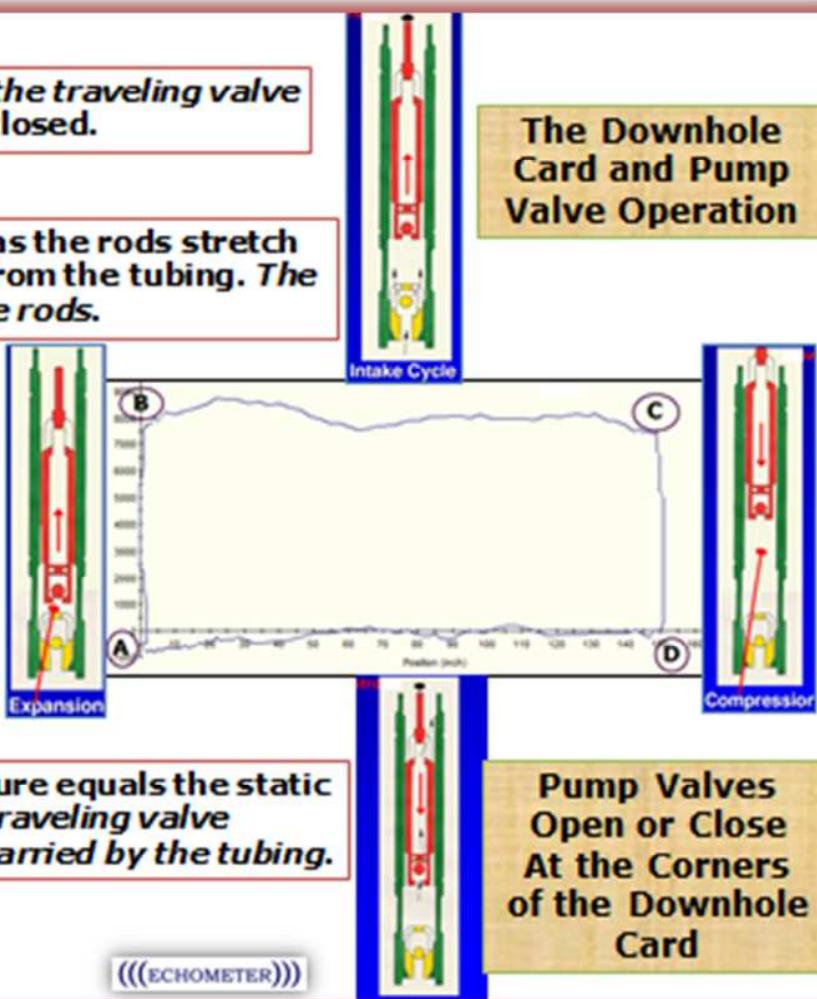
A) Start of the upstroke, *the traveling valve closes* – both valves are closed.

B) *Standing valve opens as the rods stretch to pick up the fluid load from the tubing. The fluid load is carried by the rods.*

C) *Standing valve closes and the traveling valve remains closed until the pressure inside the pump is slightly greater than the pump discharge pressure.*

D) *Pump discharge pressure equals the static tubing pressure and the traveling valve opens. The fluid load is carried by the tubing.*

The Downhole Card and Pump Valve Operation



Pump Valves Open or Close At the Corners of the Downhole Card

Weatherford

((ECHOMETER)))

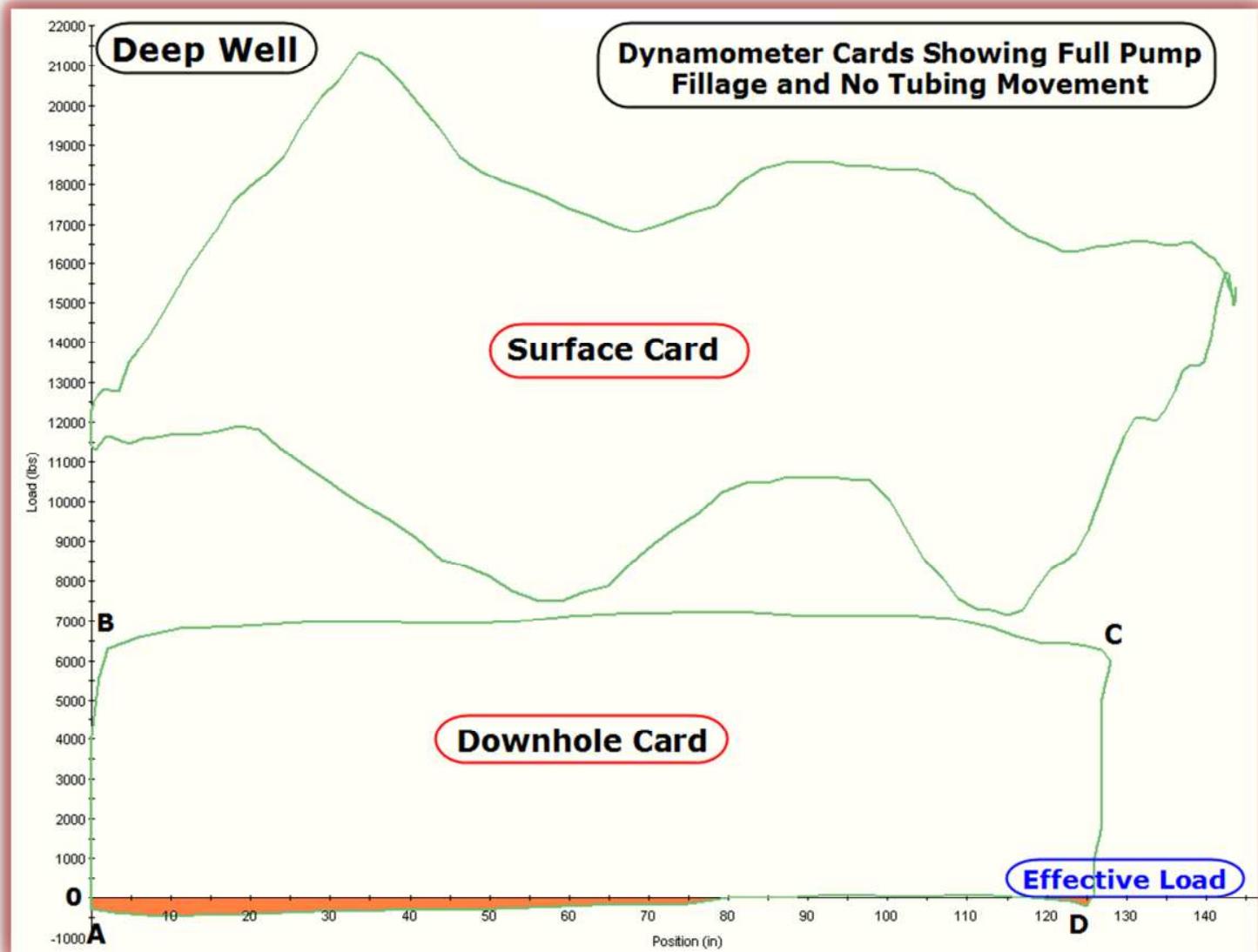


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

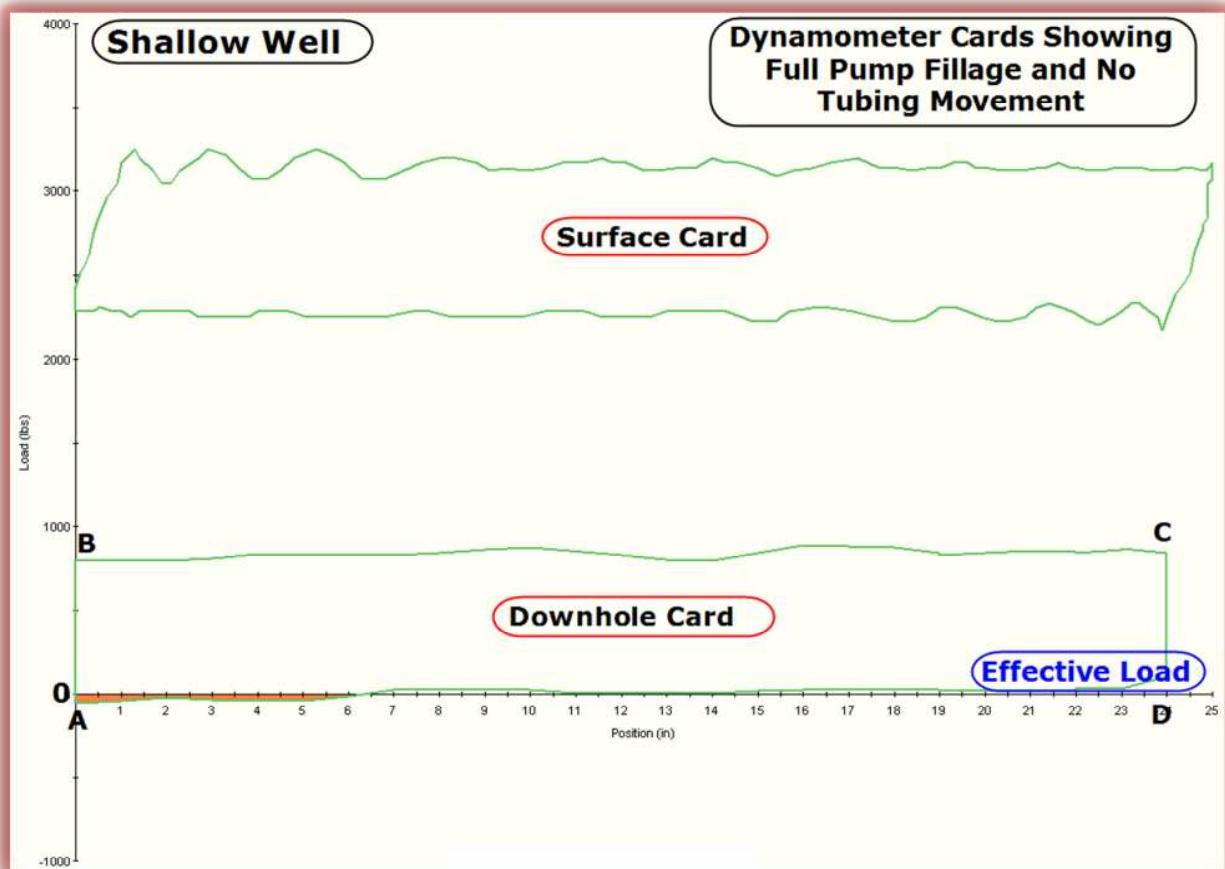
DH Cards – ‘Full Pump Fillage’ / No ‘Tubing Movement’



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



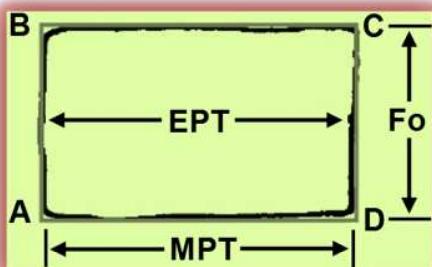
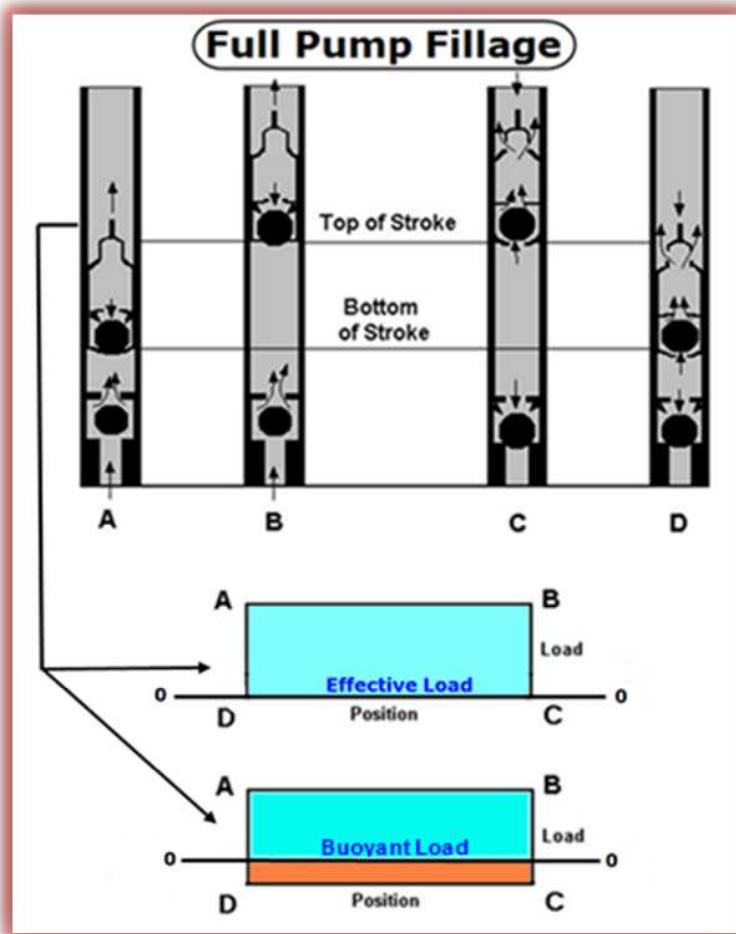
The shape of a downhole card showing full liquid fillage (with anchored tubing) is approximately rectangular – see examples above.



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Tubing Anchored - Effective Pump Travel = Maximum Pump Travel
Fo = Fluid Load



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Detailed Description



1. At point "A", the traveling valve closes and the load begins to be transferred from the tubing to the rods.
2. Between points "A" and "B", tension in the pull rod is increasing as the rods are picking up the fluid.
3. At point "B", the entire fluid load is borne by the rods and the standing valve opens.
4. Between points "B" and "C", fluid is being lifted toward the surface. At the same time, the pump chamber below the traveling valve is filling completely with liquid through the open standing valve.
5. At point "C", the top of the stroke has been reached and the downward tendency of the pump motion causes the standing valve to close.
6. Between points "C" and "D", the fluid load is being transferred back to the tubing. Because the pump chamber has filled completely with liquid (nearly incompressible) the pump cannot move downward until the entire fluid load has been released. This is one of the reasons for the rectangular card shape. The pump remains stationary (if the tubing is anchored) while the load is being transferred back to the tubing from the rods.
7. At point "D", the traveling valve opens and the pump begins to descend.
8. Between points "D" and "A", the pump descends with the traveling valve open (standing valve closed) through the fluid that entered the pump chamber during the upstroke.
9. At point "A", the traveling valve is closed by the tendency of the pump to move upward. This action begins another pumping cycle.



Important Conclusion

- In a pump that fills completely with liquid (with anchored tubing), traveling and standing valve actuation occurs at the top and bottom of the stroke with little movement of the pump. This gives the downhole card a characteristic rectangular appearance.

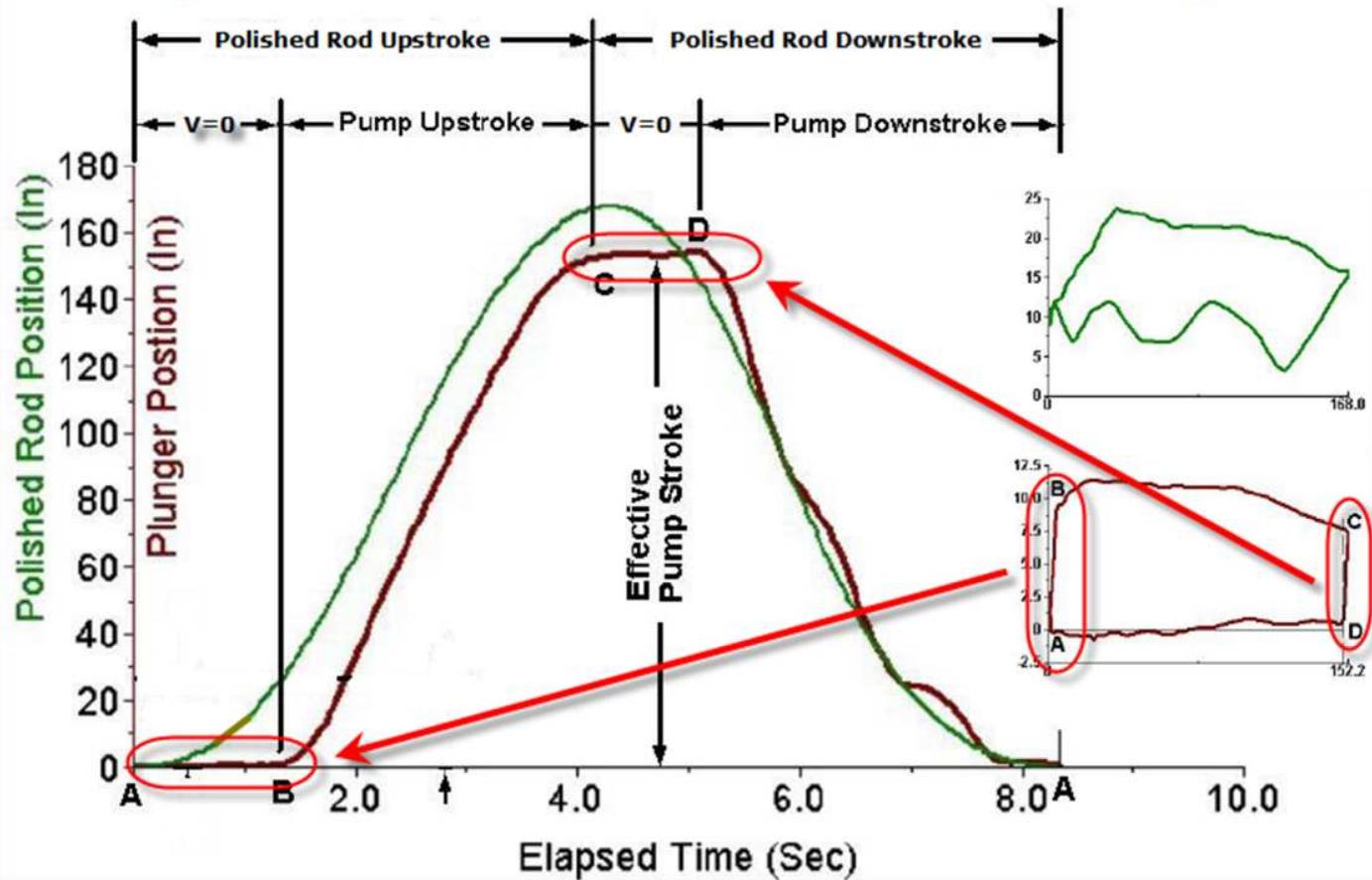


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Compare Polished Rod Position to Pump Plunger Position - Anchored Tubing



((ECHOMETER)))



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

- Incomplete Pump Fillage Cards Descriptive Definitions --- *Otherwise Known as a 'Moving Target'!*
 - **Incomplete pump fillage** is most often a case of limited or 'low pressure gas interference'. If there is any gas present in the barrel, the plunger never really encounters incompressible liquid. The traveling valve opens when sufficient pressure is built up by compressing the gas present in the barrel. This load transfer may be commonly referred to as 'pump off' or 'fluid pound' or 'incomplete pump fillage'.
 - True 'fluid pound' occurs when pump intake pressure is very low and the incompletely filled (with liquid) pump contains almost incompressible fluid with no gas present. The load release when the TV opens thus takes place more abruptly than the gradual load transfer that occurs with gas compression.
 - High pressure gas present in the pump barrel results in the terminology 'gas compression' / 'gas interference' / 'gas pound'.
- ☞ No matter what we call it, the important thing to remember what is likely to happen as a result of these rod pumping system conditions.**



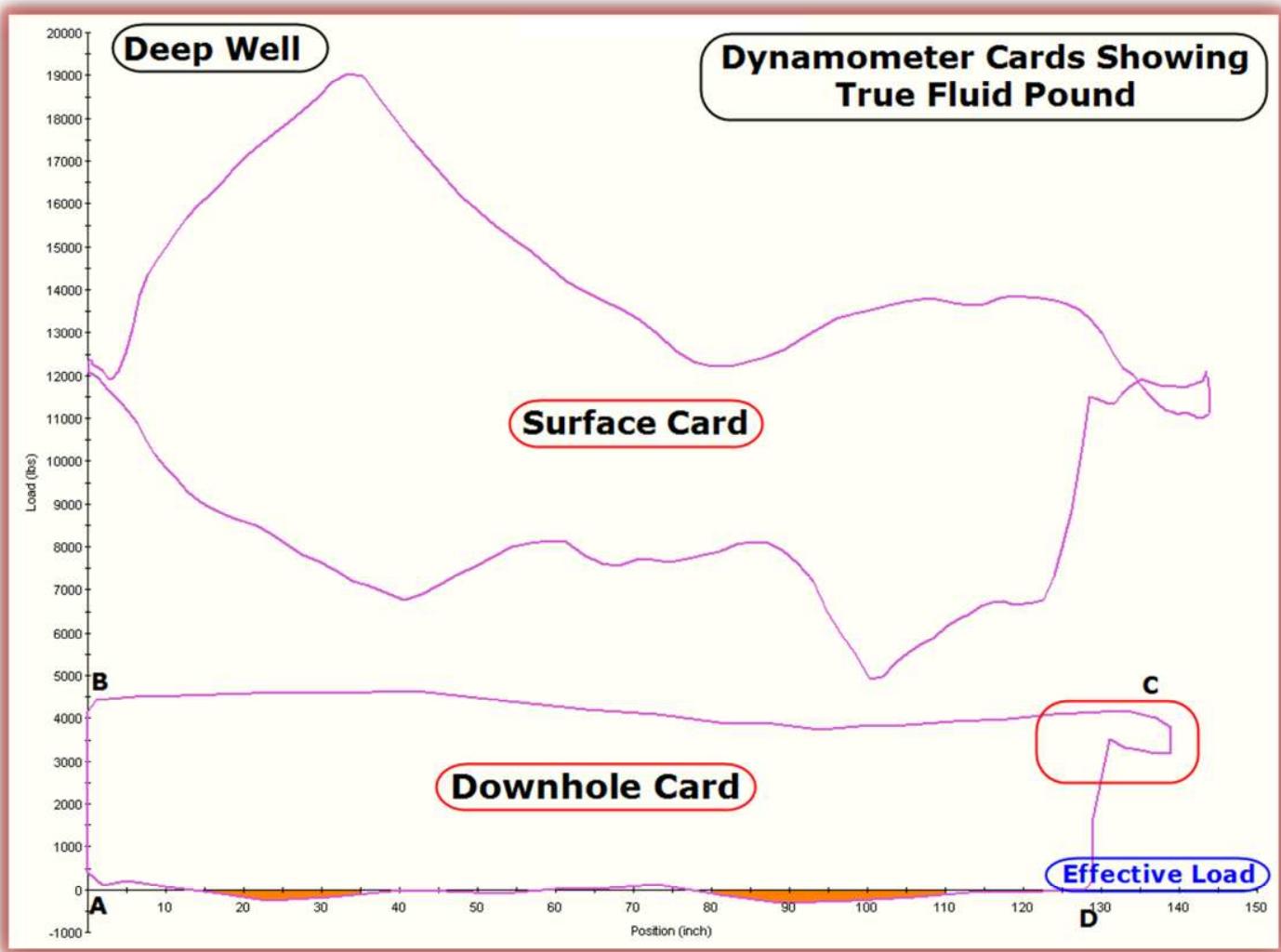
Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

DH Cards – True ‘Fluid Pound’

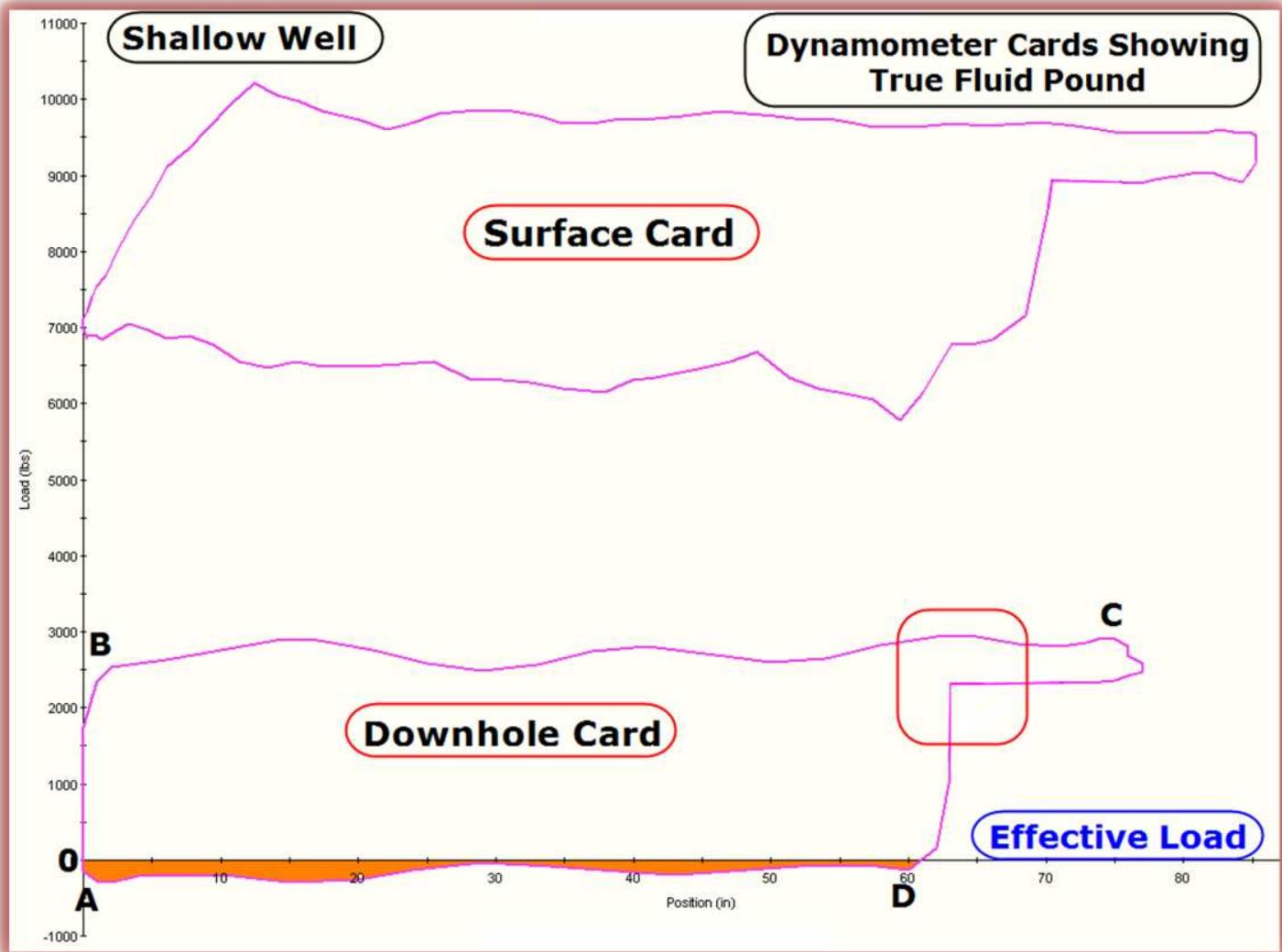
True ‘Fluid Pound’ Card Examples



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



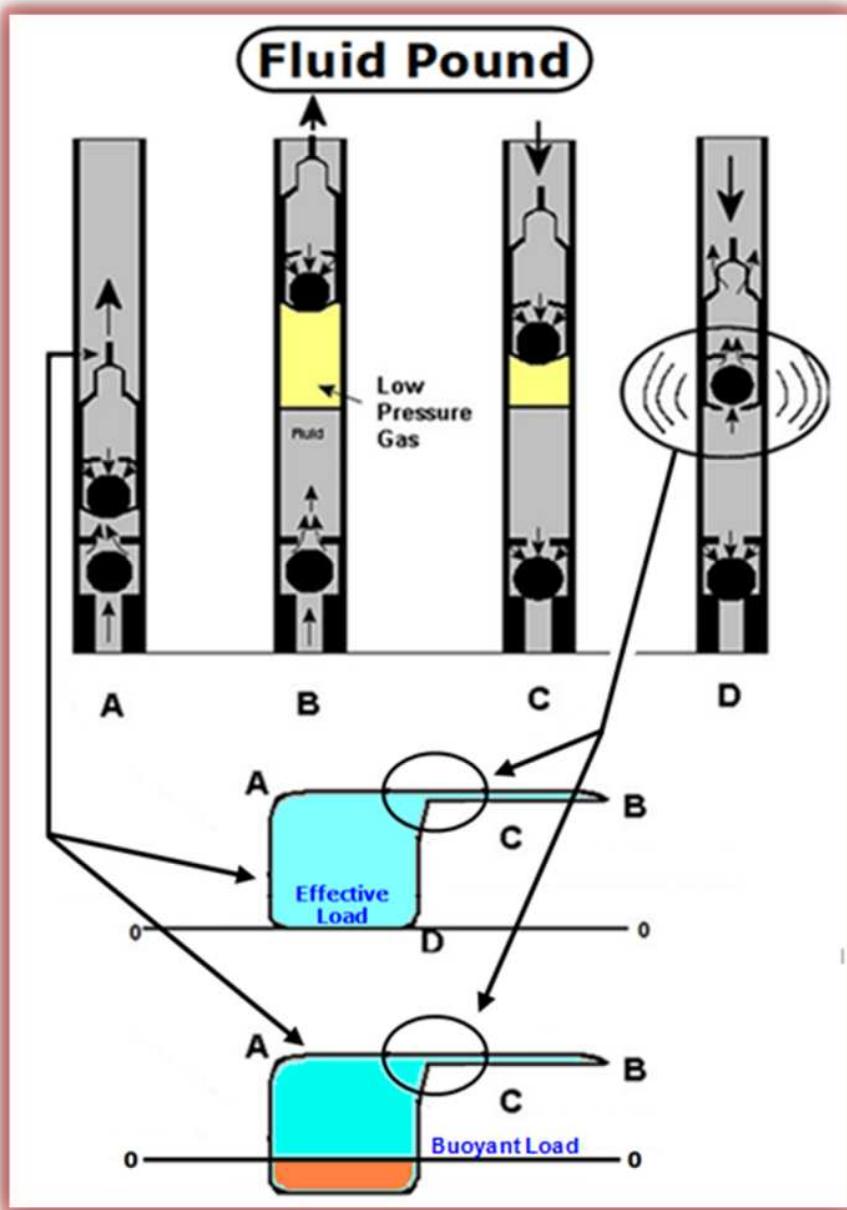
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



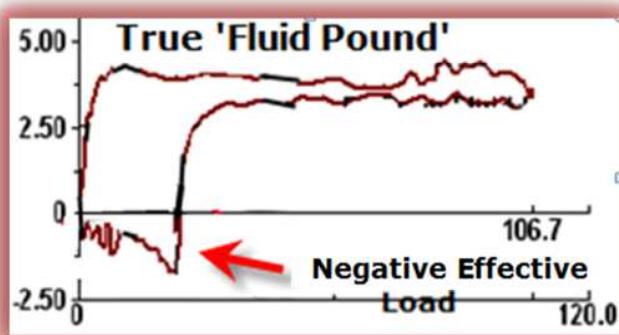
Surface and Downhole Dynamometer Card Interpretation



Tubing Anchored - Effective Pump Travel Less Than Maximum Pump Travel

Tubing Not Anchored - Effective Pump Travel Less Than Maximum Pump Travel

- 'Pump off' is usually a case of limiting case of 'gas interference'. If there is gas present in the barrel, the plunger never really encounters incompressible liquid. The traveling valve opens when sufficient pressure is built up by compressing the gas present in the barrel.
- 'Fluid pound' occurs when pump intake pressure is low and the incompletely filled (with liquid) pump contains almost incompressible fluid. The load release thus takes place more abruptly than the gradual transfer that occurs with 'gas compression'.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

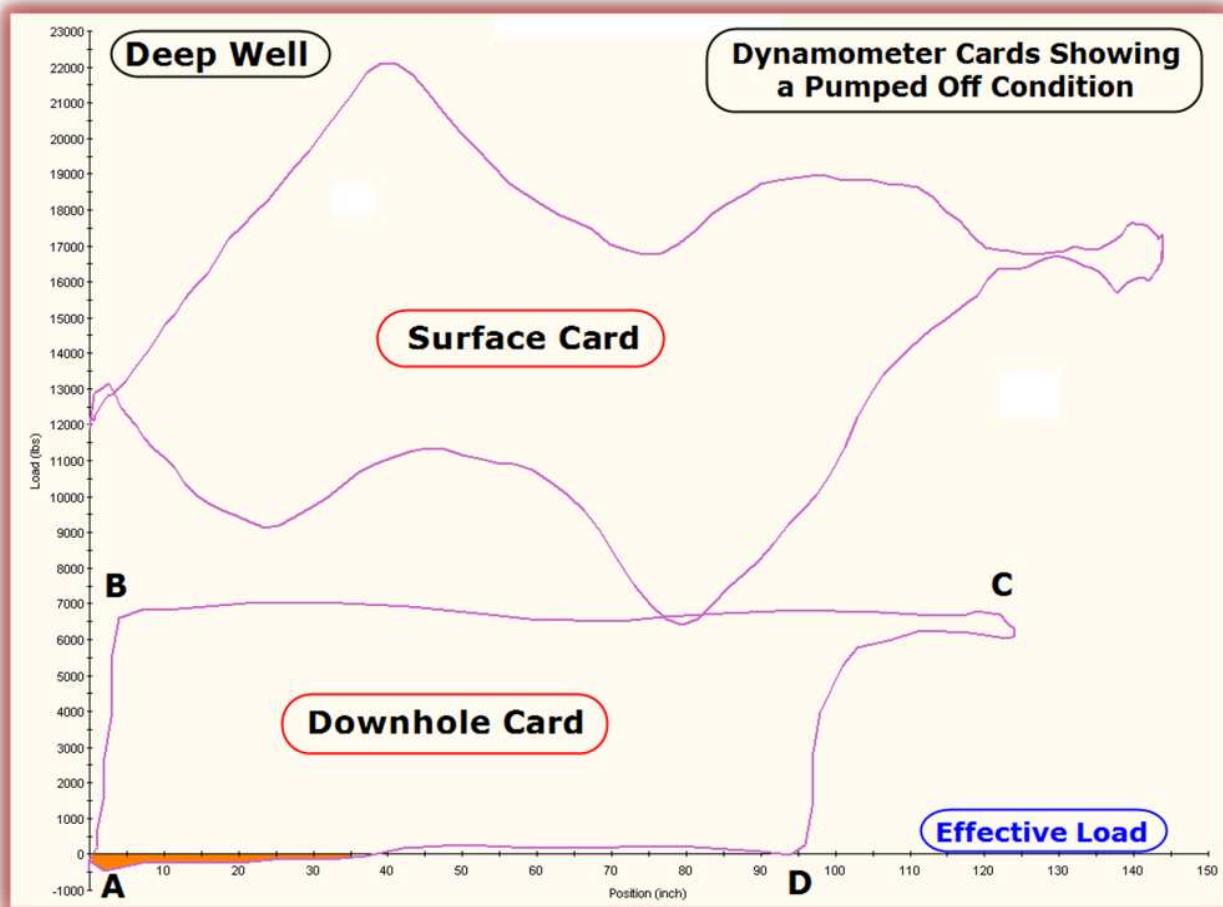


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

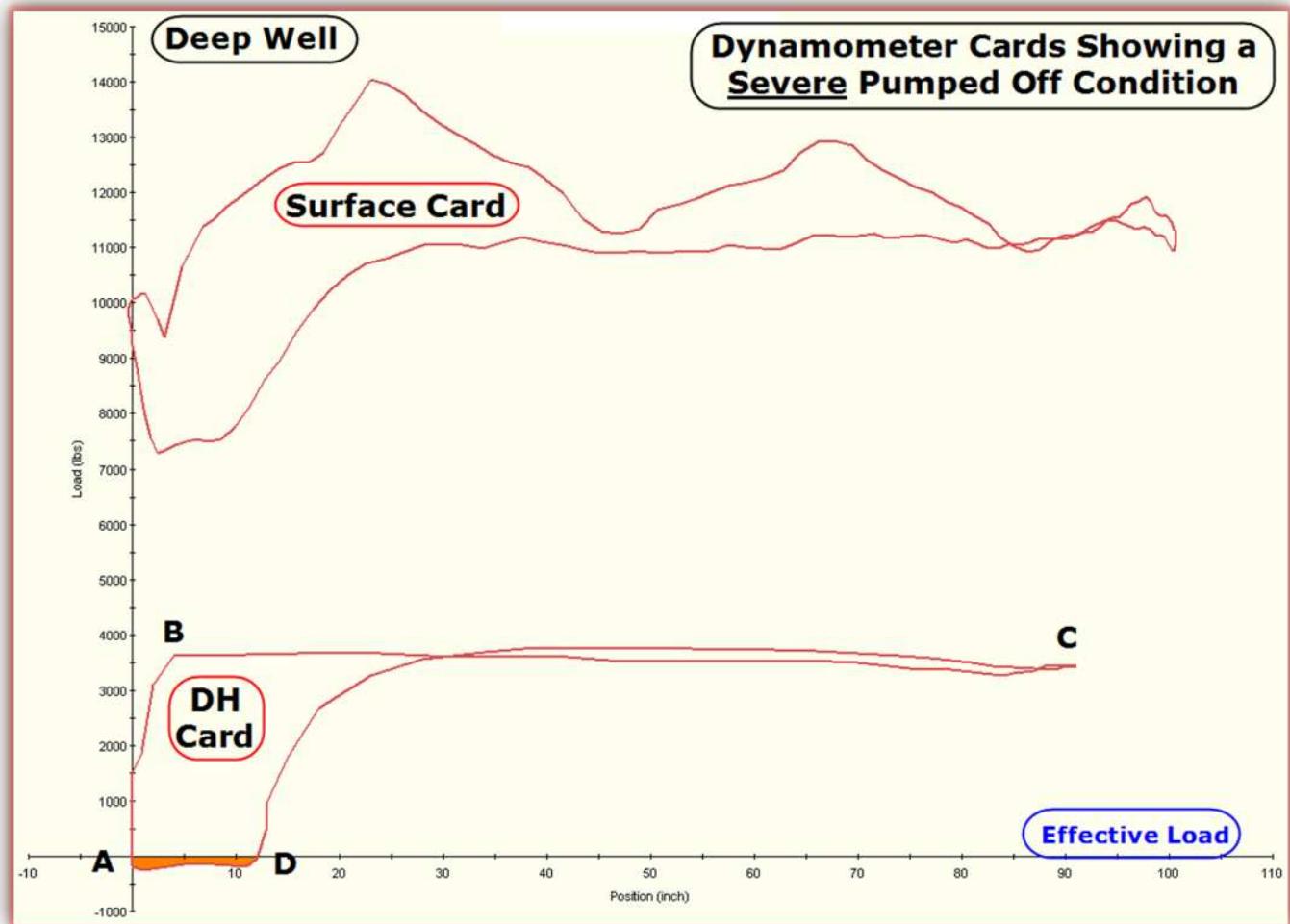
Incomplete Fillage / Low Pressure Gas Compression ('Pump Off' / 'Fluid Pound' Card) Examples



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



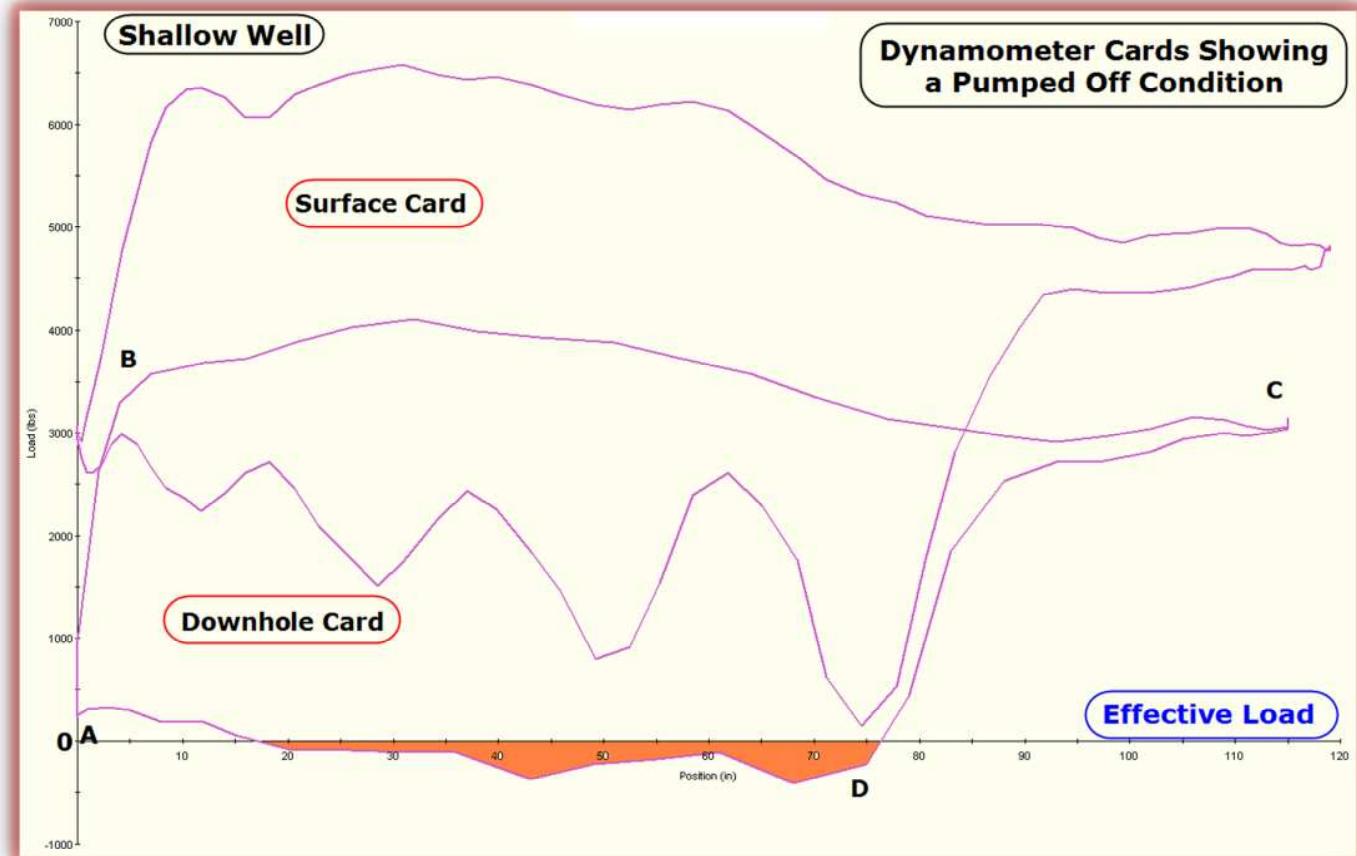
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



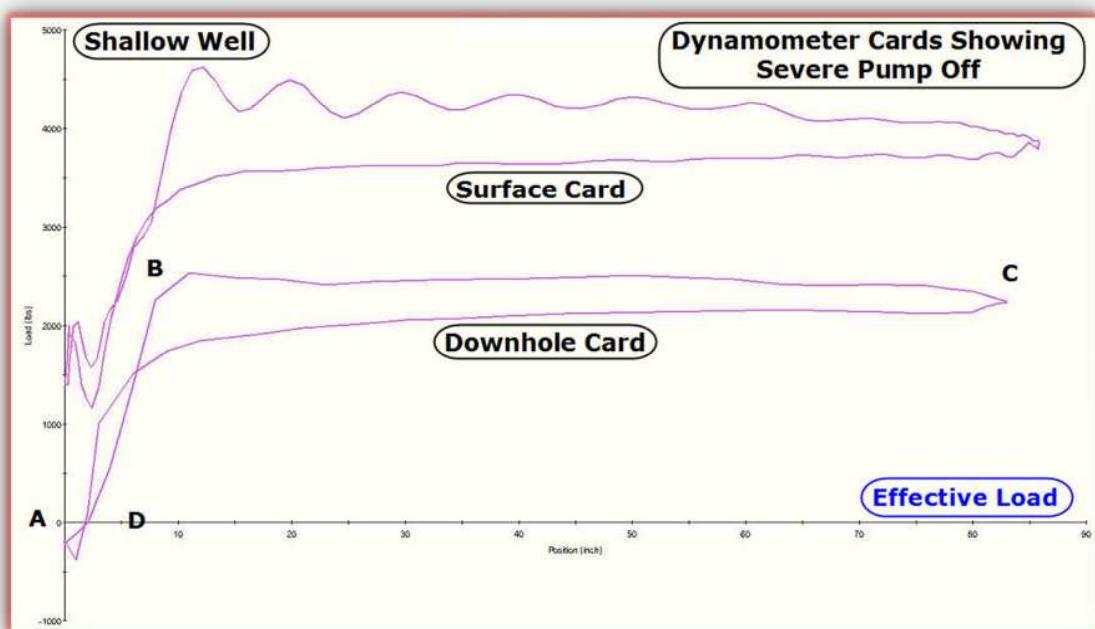
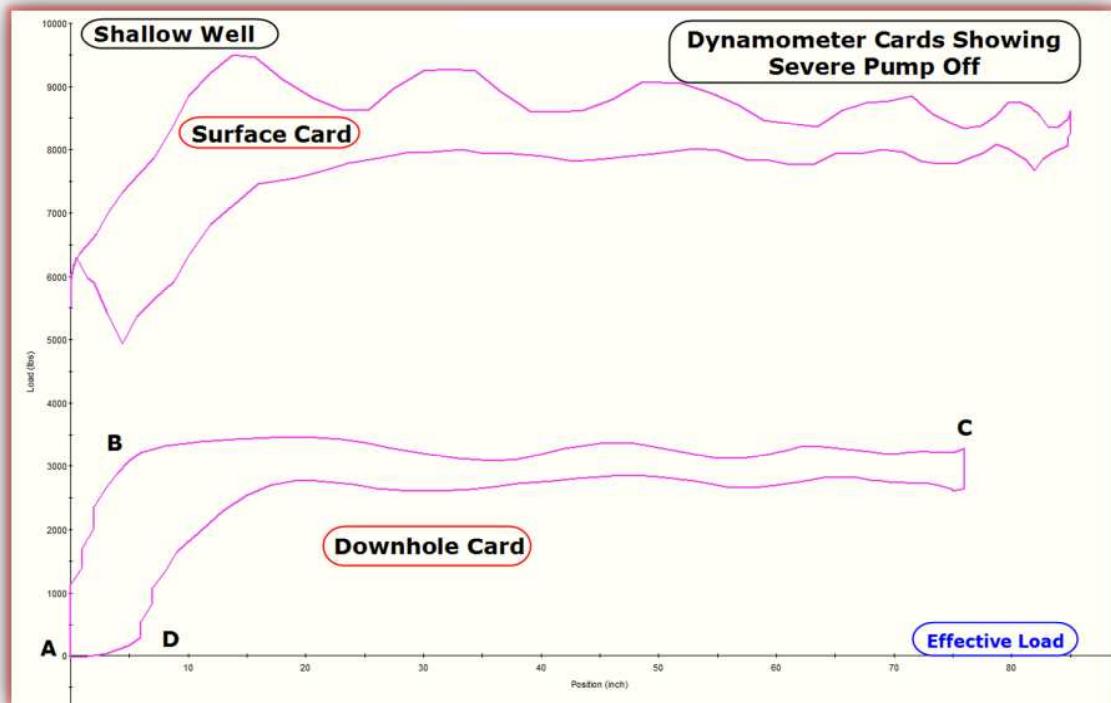
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



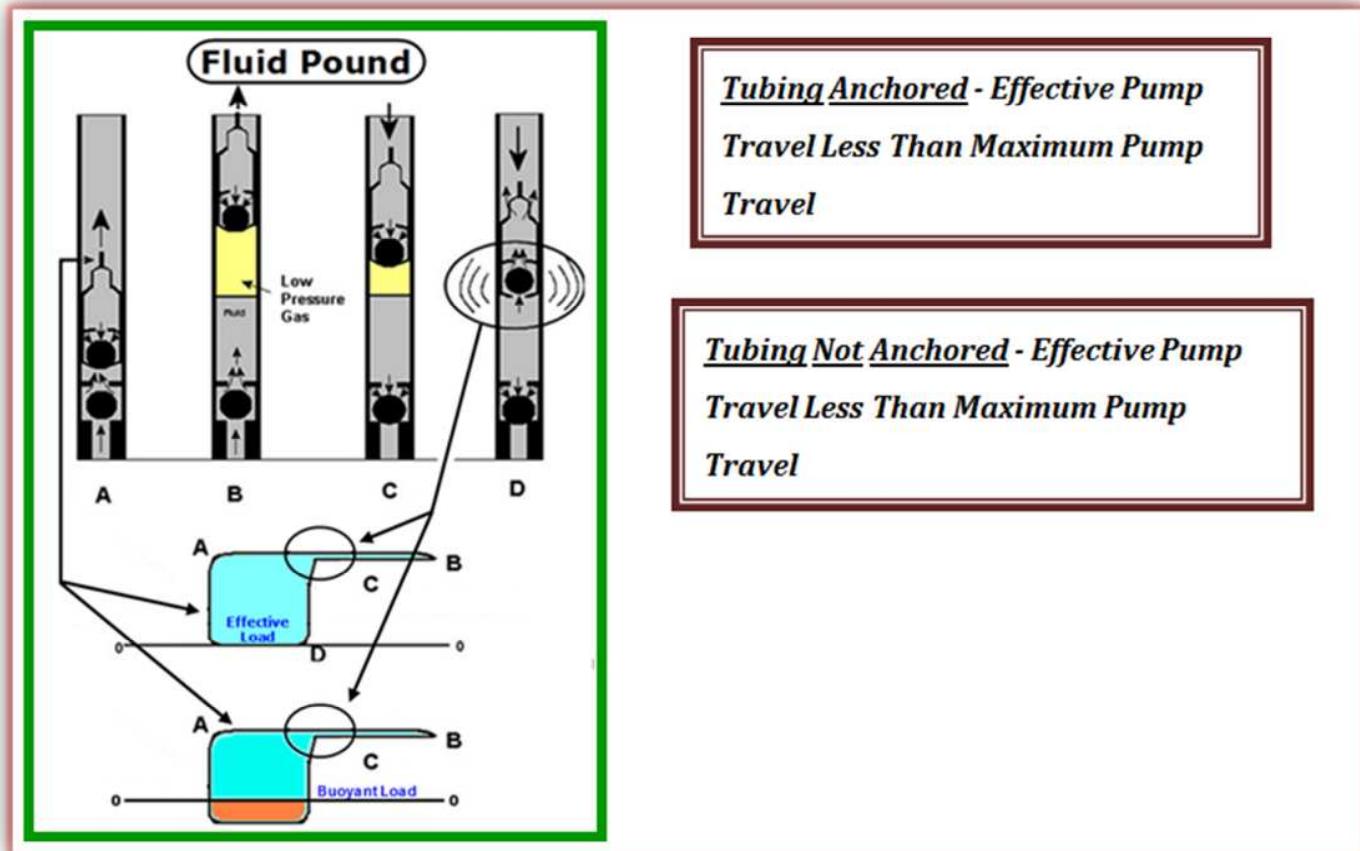
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Detailed Description

H

1. At point "A", the traveling valve closes and the load begins to be transferred from the tubing to the rods.
2. Between points "A" and "B", tension in the pull rod is increasing as the rods are picking up the fluid.
3. At point "B", the entire fluid load is borne by the rods and the standing valve opens.
4. Between points "B" and "C", fluid is being lifted to the surface. At the same time, the pump chamber below the traveling valve is filling with a mixture of liquid and low-pressure gas. Liquid fillage can be much less than the volume of the pump chamber.
5. At point "C", the top of the stroke has been reached and the downward tendency of the pump causes the standing valve to close.
6. Between points "C" and "D", the fluid load is being transferred from the rods to the tubing.

 **If there is NO gas present in the pump barrel, eventually the plunger encounters nearly incompressible liquid in the incompletely filled (with liquid) pump chamber. At this point, the load is rapidly released from the rods and the pump is said to "pound fluid".**

 **If there is gas present in the barrel, the plunger never really encounters incompressible liquid. The traveling valve opens when sufficient pressure is built up by compressing the gas present in the barrel - and the well is said to be "pumped off".**

7. The traveling valve opens at point "D" and the pump continues to descend.
 8. Between points "D" and "A", the pump descends with the traveling valve open (standing valve closed) through the fluid that entered the pump chamber during the upstroke.
 9. At point "A", the traveling valve is closed by the tendency of the pump to move upward. This action begins another pumping cycle.
-

H

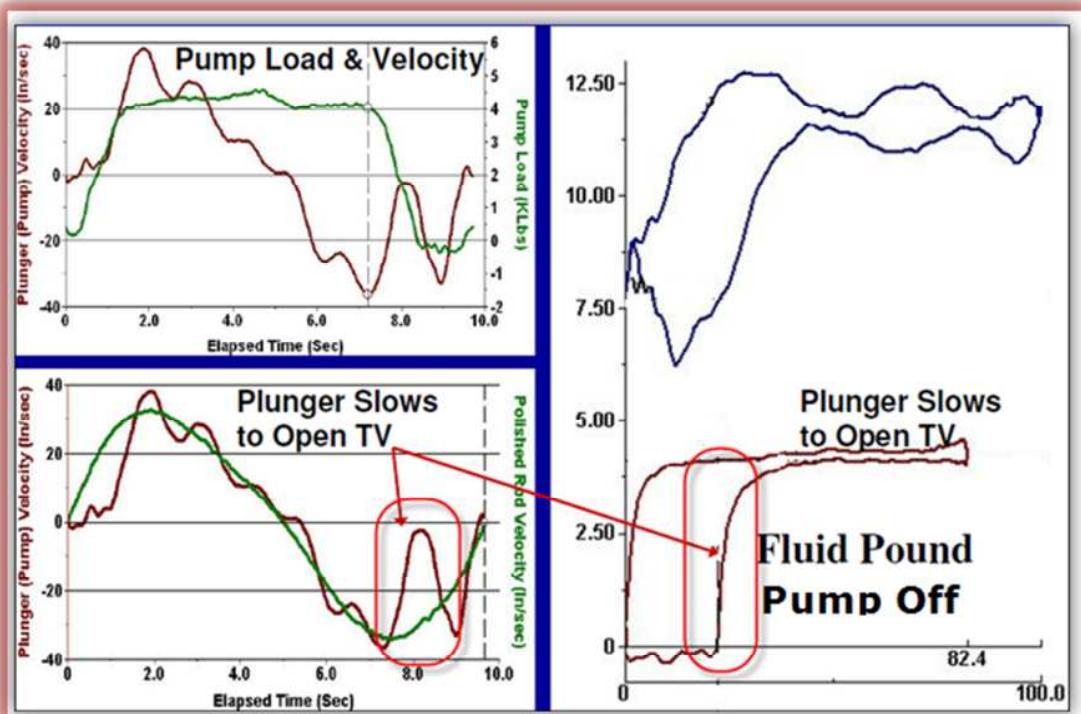


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Effects of 'Pump Off' / 'Fluid Pound' (Low Pressure 'Gas Compression')



((((ECHOMETER))))



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

DH Cards –

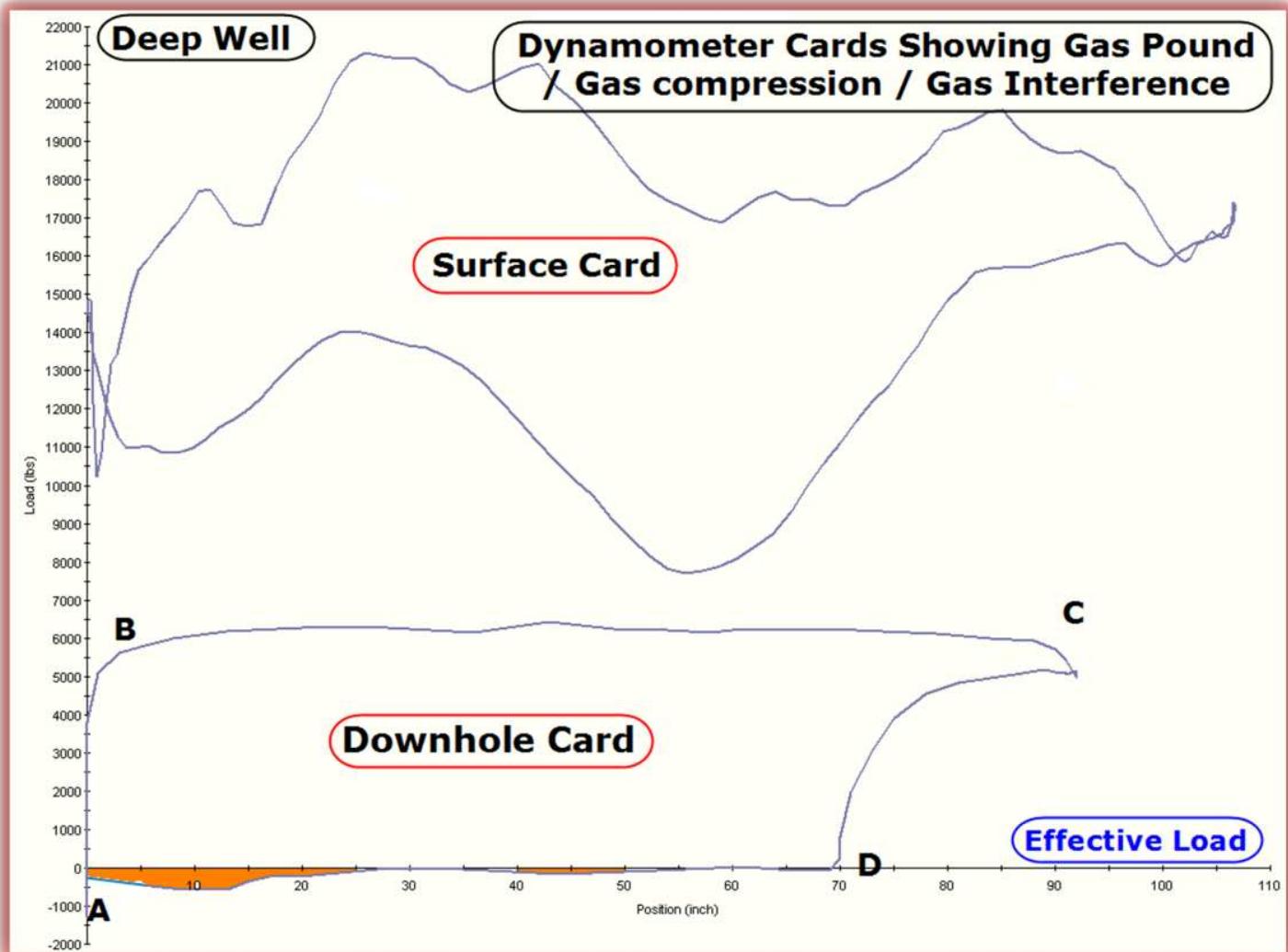


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

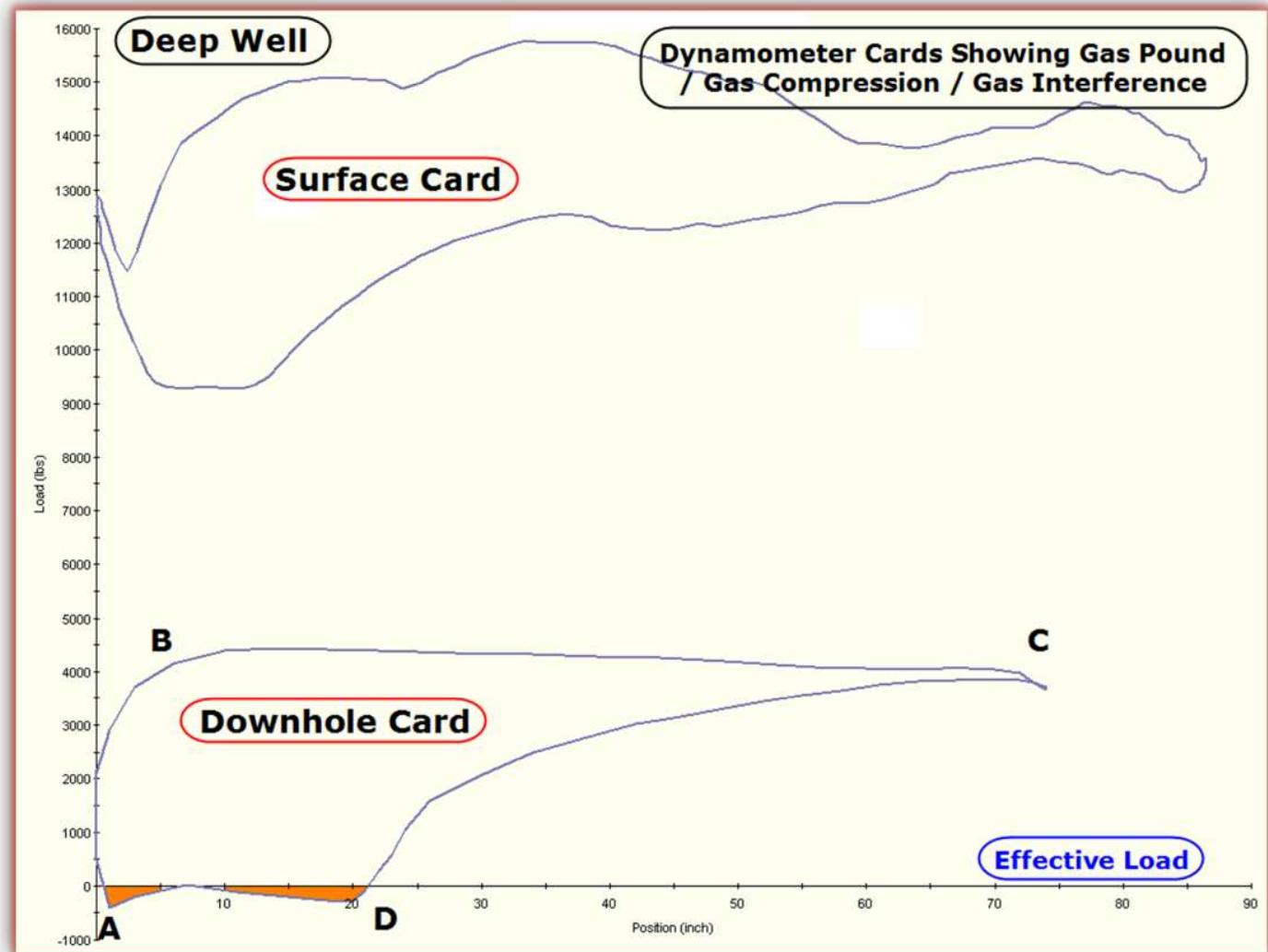
'Gas Compression' / 'Gas Interference' or 'Gas Pound'



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



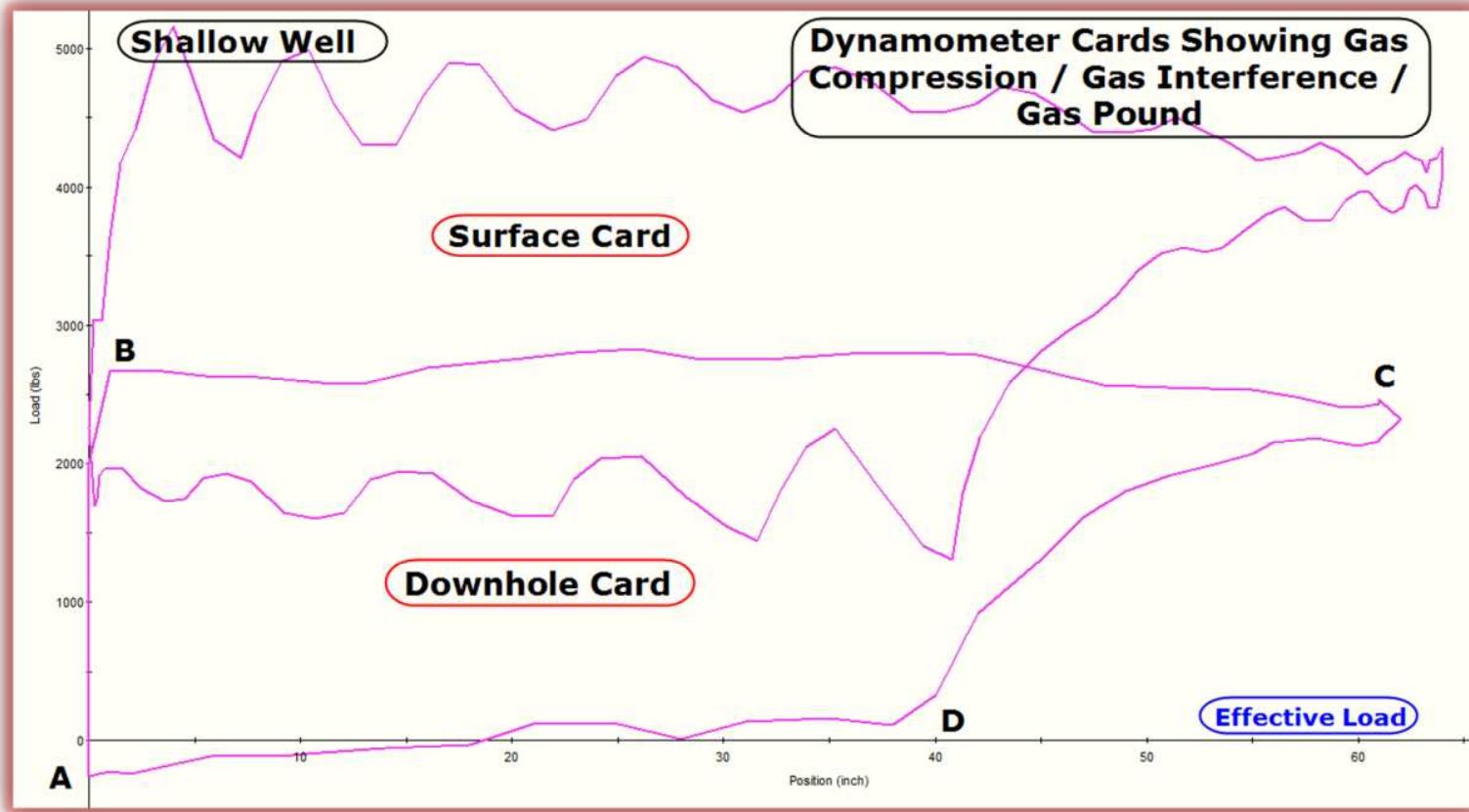
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



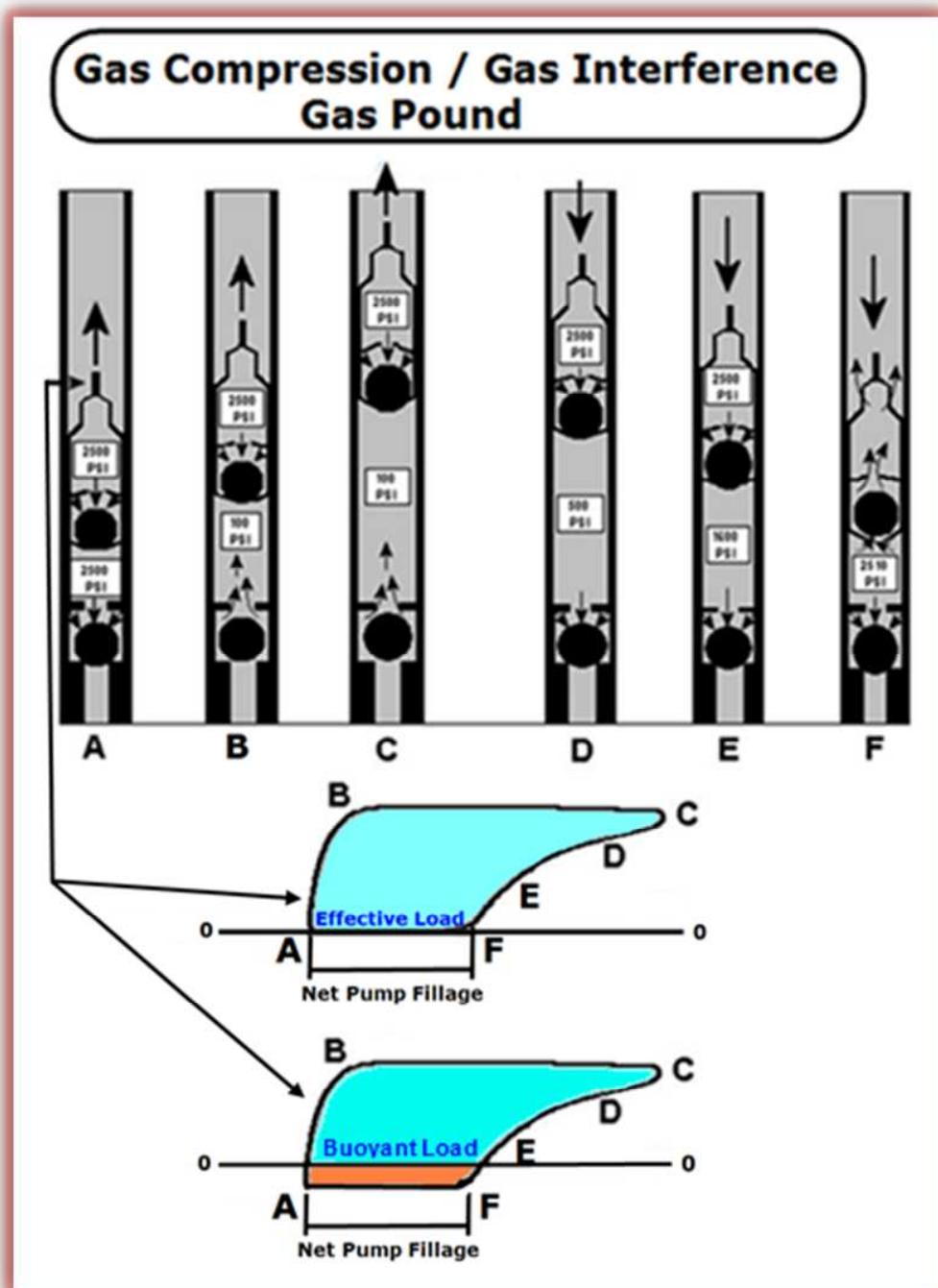
The shape of a downhole card with 'gas interference' shows a compression curve in the upper portion of the downstroke (points "C" - "D").



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



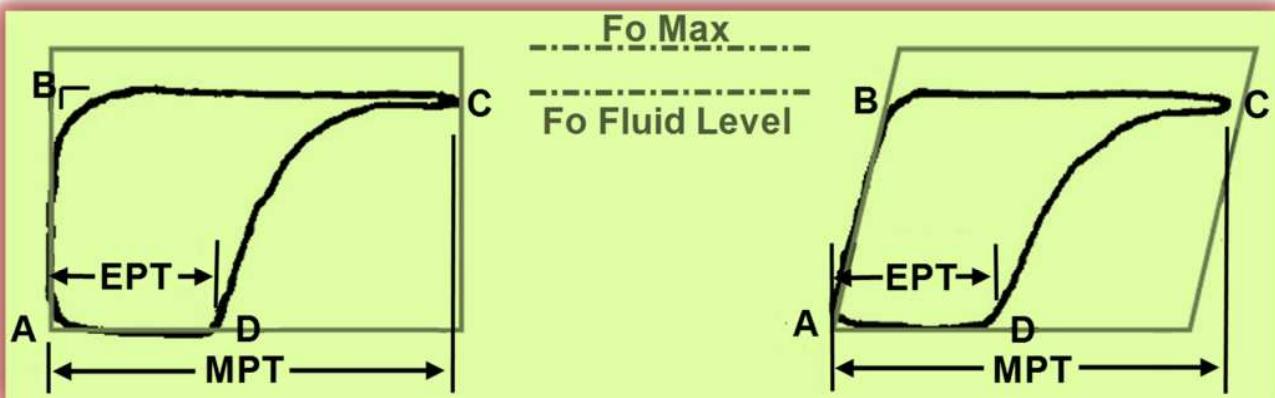
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Tubing Anchored - Effective Pump

Travel Less Than Maximum Pump

Travel

Tubing Anchored - Effective Pump

Travel Less Than Maximum Pump

Travel

Detailed Description

H

1. At point "A", the traveling valve closes and the load begins to be transferred from the tubing to the rods.
2. Between points "A" and "B", tension in the pull rod is increasing as the rods are picking up the fluid. If the fluid in the lower portion of the pump chamber is compressible (very gassy), a slight upward movement of the pump may occur during the load pick-up.
3. At point "B", the entire fluid load is borne by the rods and the standing valve opens.
4. Between points "B" and "C", fluid is being lifted to the surface. At the same time, the pump chamber below the traveling valve is filling with a mixture of liquid and high-pressure gas through the open standing valve.
5. At point "C", the top of the stroke has been reached and the downward tendency of the pump causes the standing valve to close.
6. Between points "C" and "D", the fluid load is being transferred back to the tubing. Because of the compressible gas that entered the pump during the charging cycle, the load transfer takes place along a "compression curve". The pump moves downward during load transfer – which



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

compresses the gas in the chamber below the closed traveling valve. As the pressure in the gas below the traveling valve increases, the load is removed from the rods.

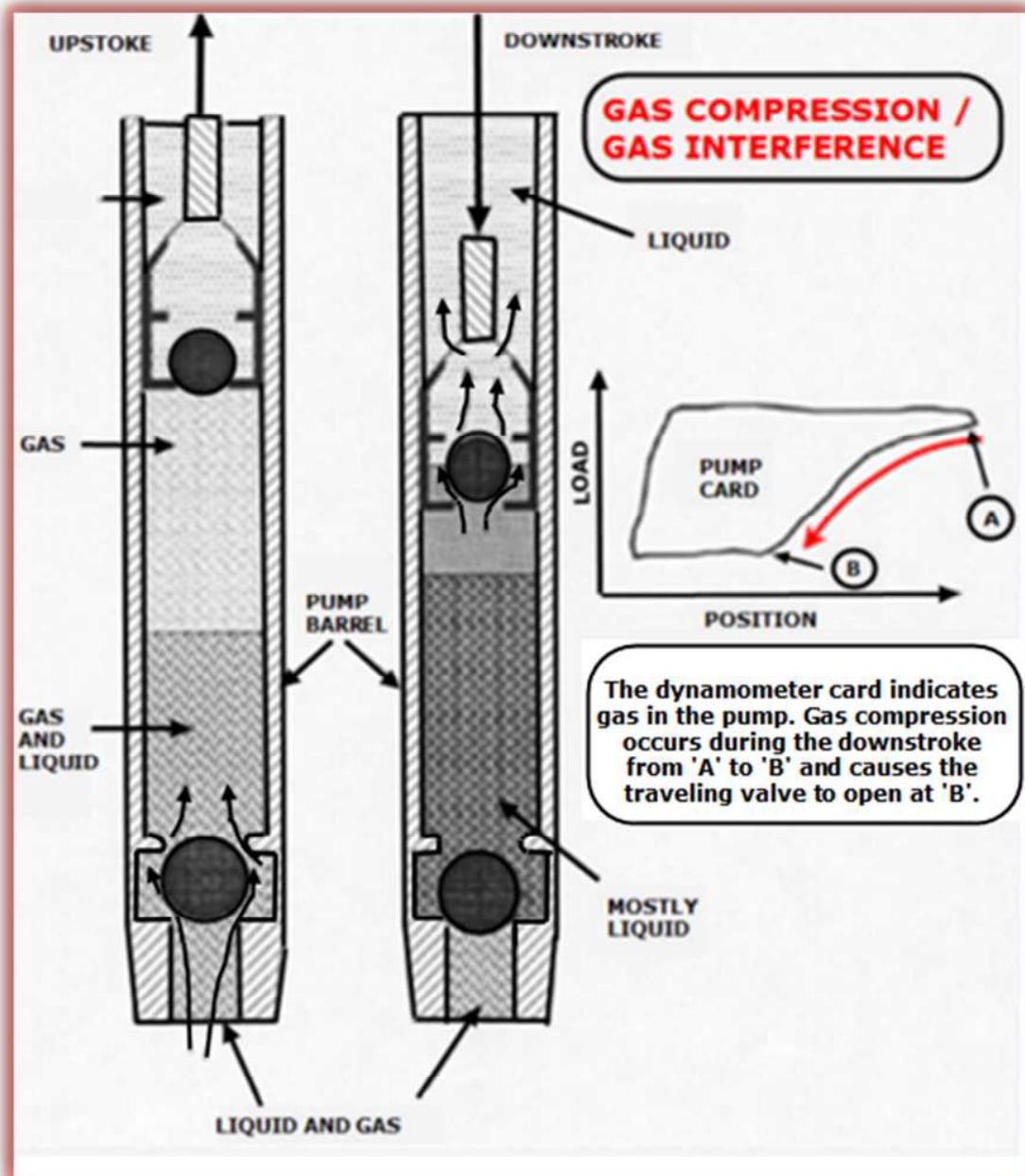
7. At point "D", the pressure in the compressed gas in the pump chamber is high enough to offset the pressure in the tubing at which point the traveling valve opens. The pump continues to descend.
 8. Between points "D" and "A", the pump descends with the traveling valve open (standing valve closed) through the fluid that entered the pump chamber during the upstroke.
 9. At point "A", the traveling valve is closed by the tendency of the pump to move upward. This action begins another pumping cycle.
-



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



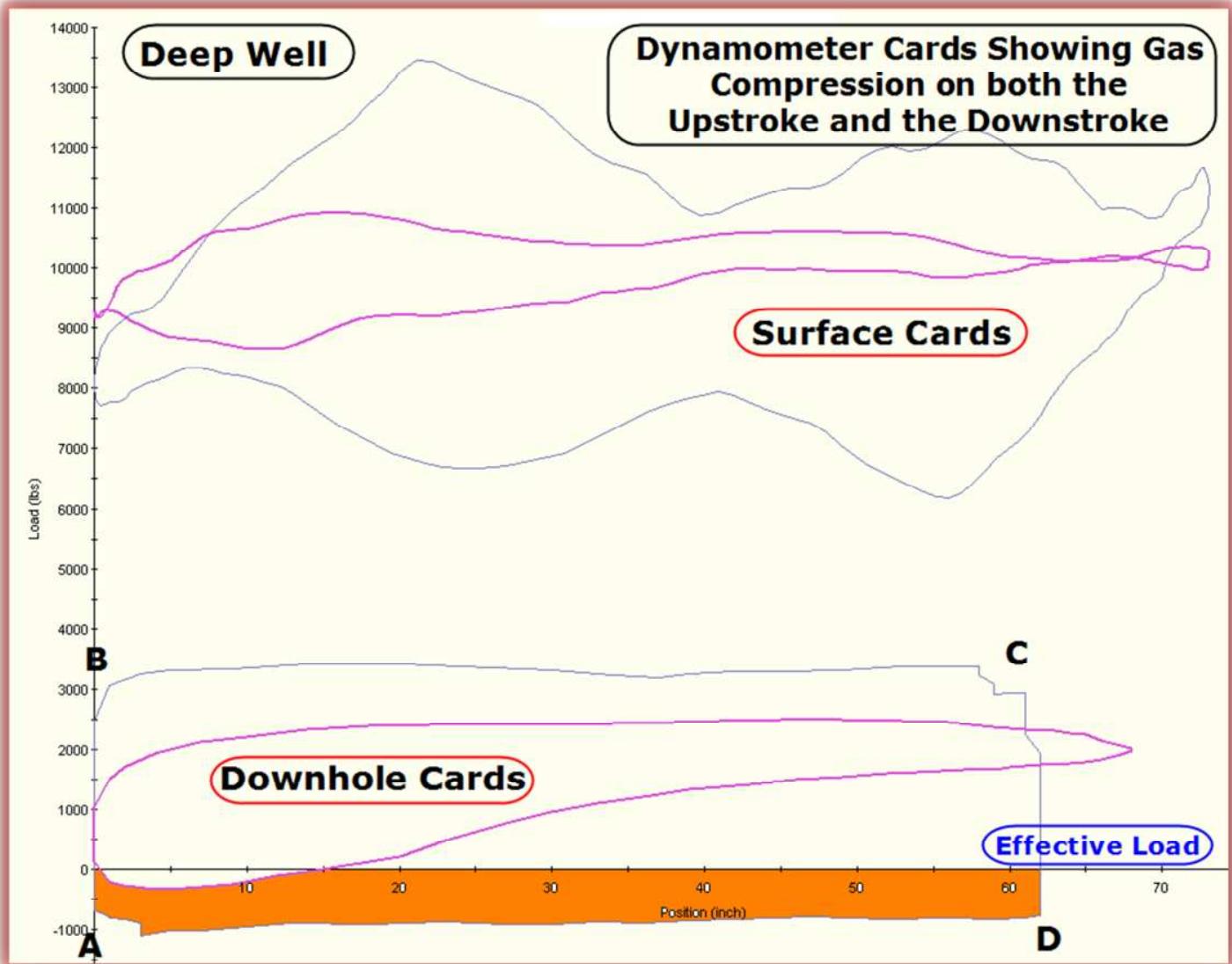
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

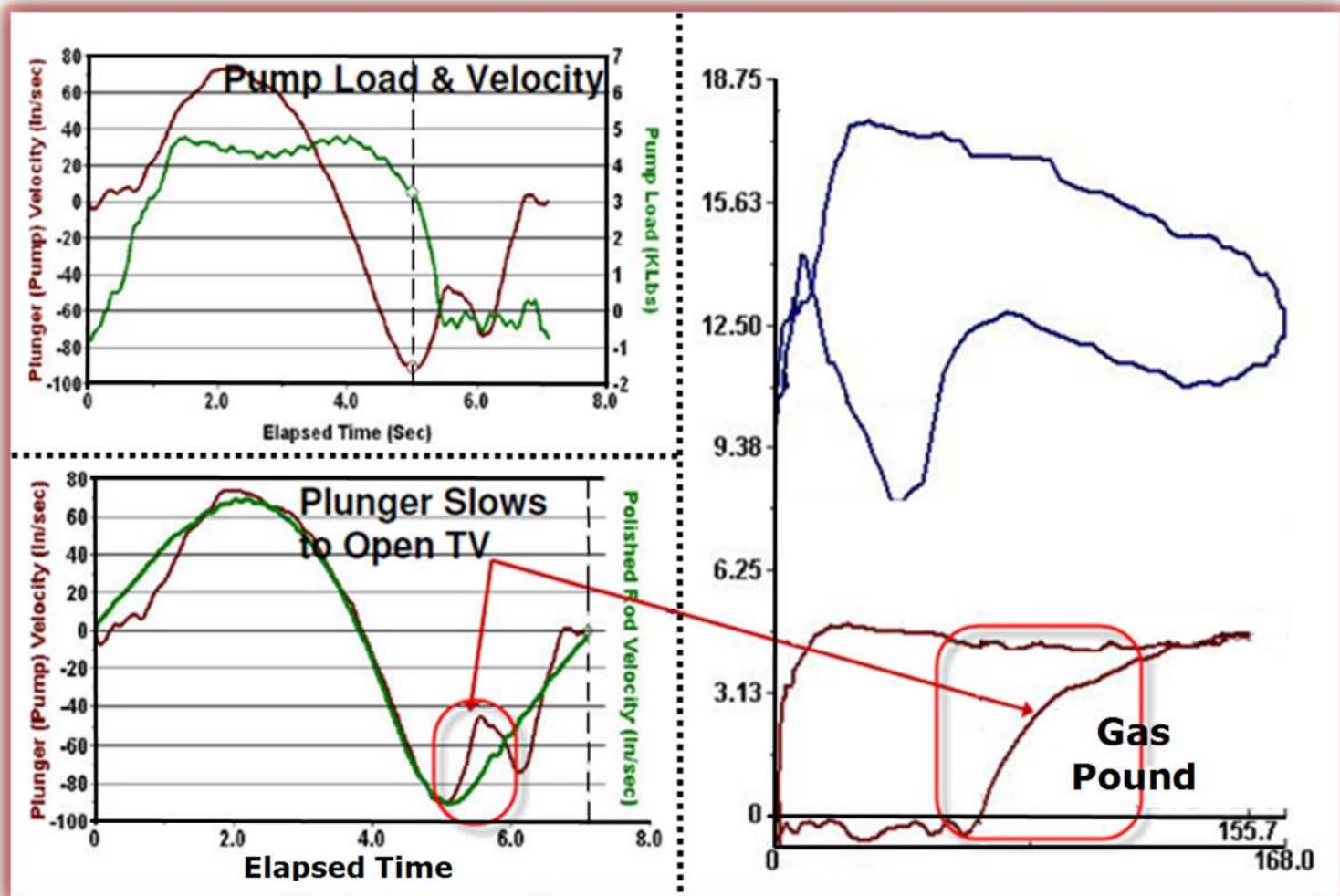


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Effects of 'Gas Compression' / 'Gas Interference' / 'Gas Pound'



((((ECHOMETER))))



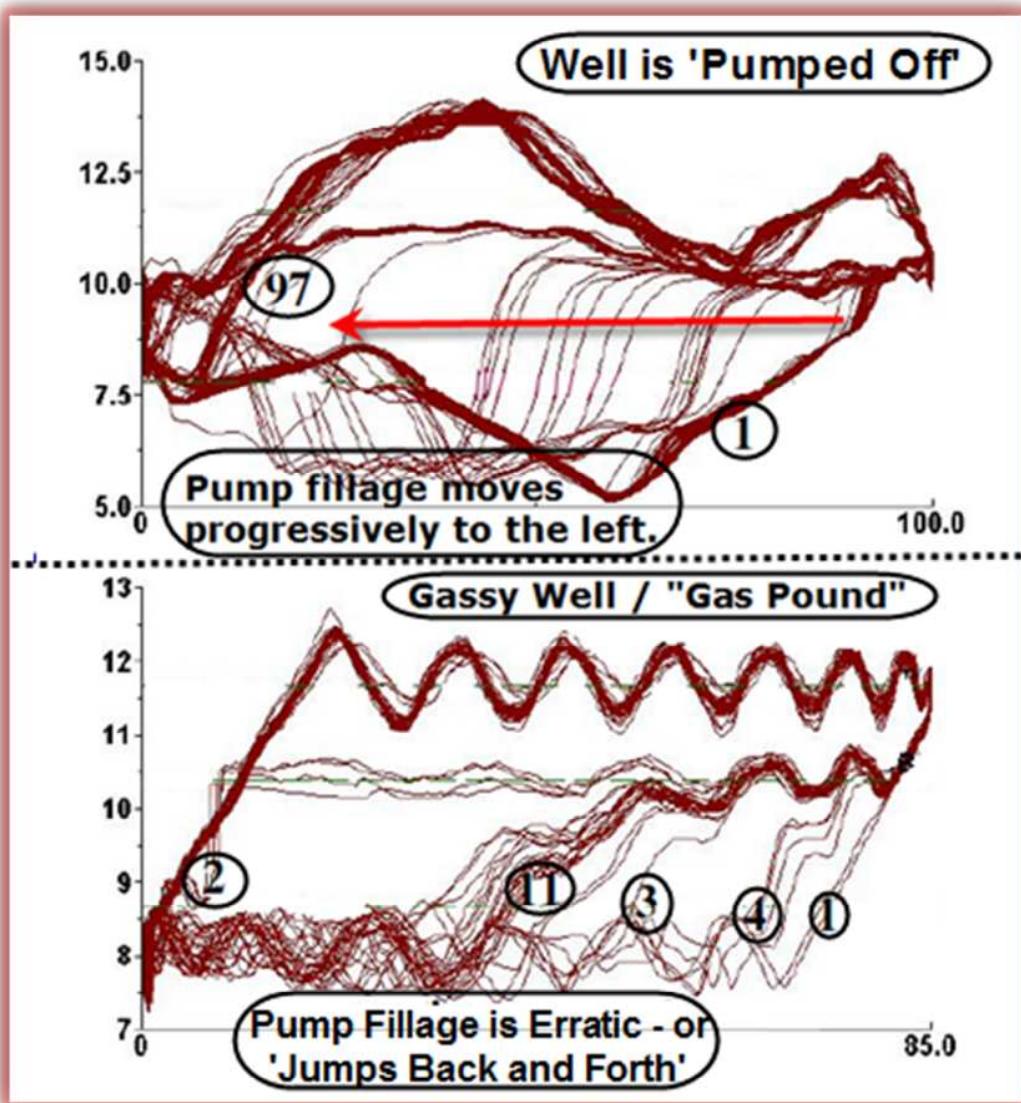
Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

'Pumped Off' vs. 'Gassy' Determination

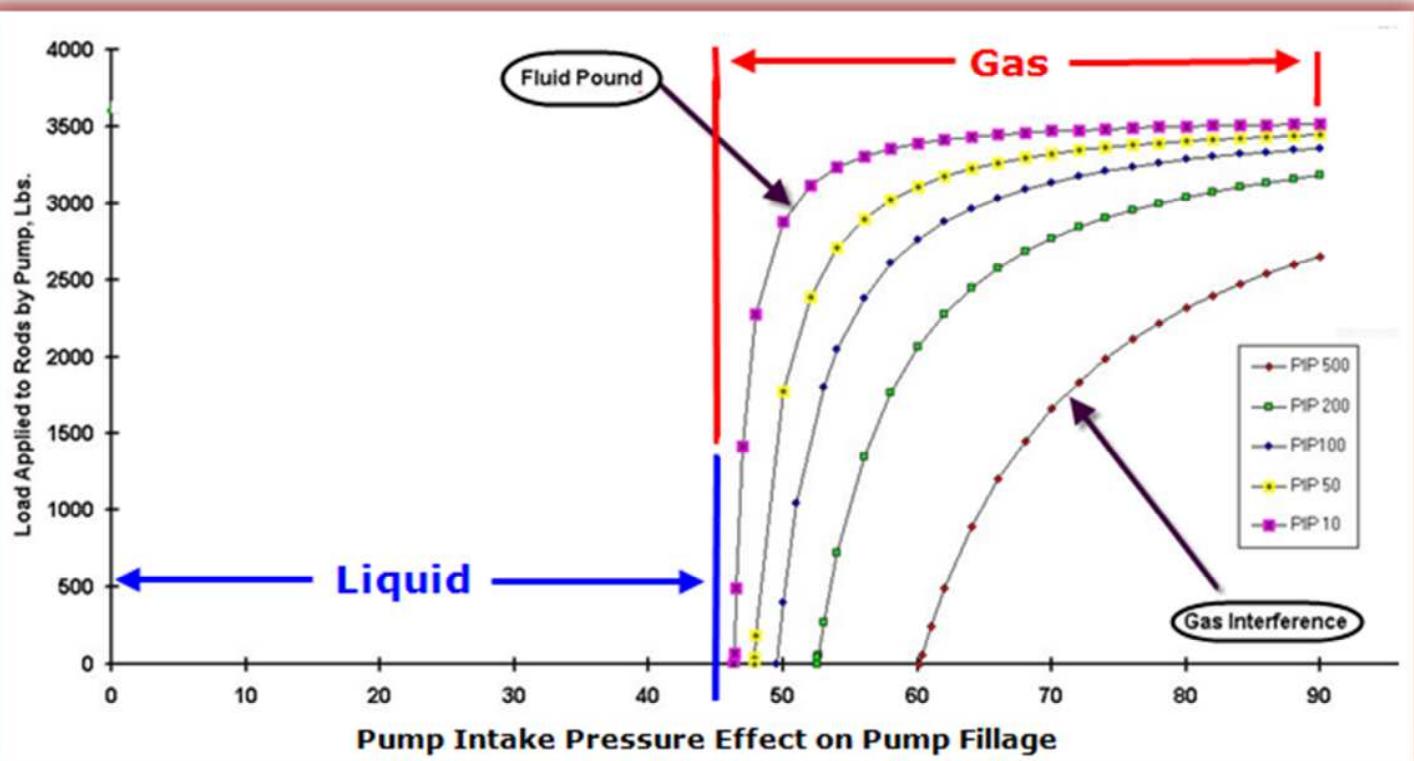
- These surface dyno cards show that pump fillage related to a 'gassy' condition does not move progressively to right-to-left. It moves back and forth or jumps around on the downstroke as more or less gas enters the pump and changes the position where the pump valves close and open during the downstroke portion of the pumping cycle.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Pump Intake Pressure Effect on Pump Fillage

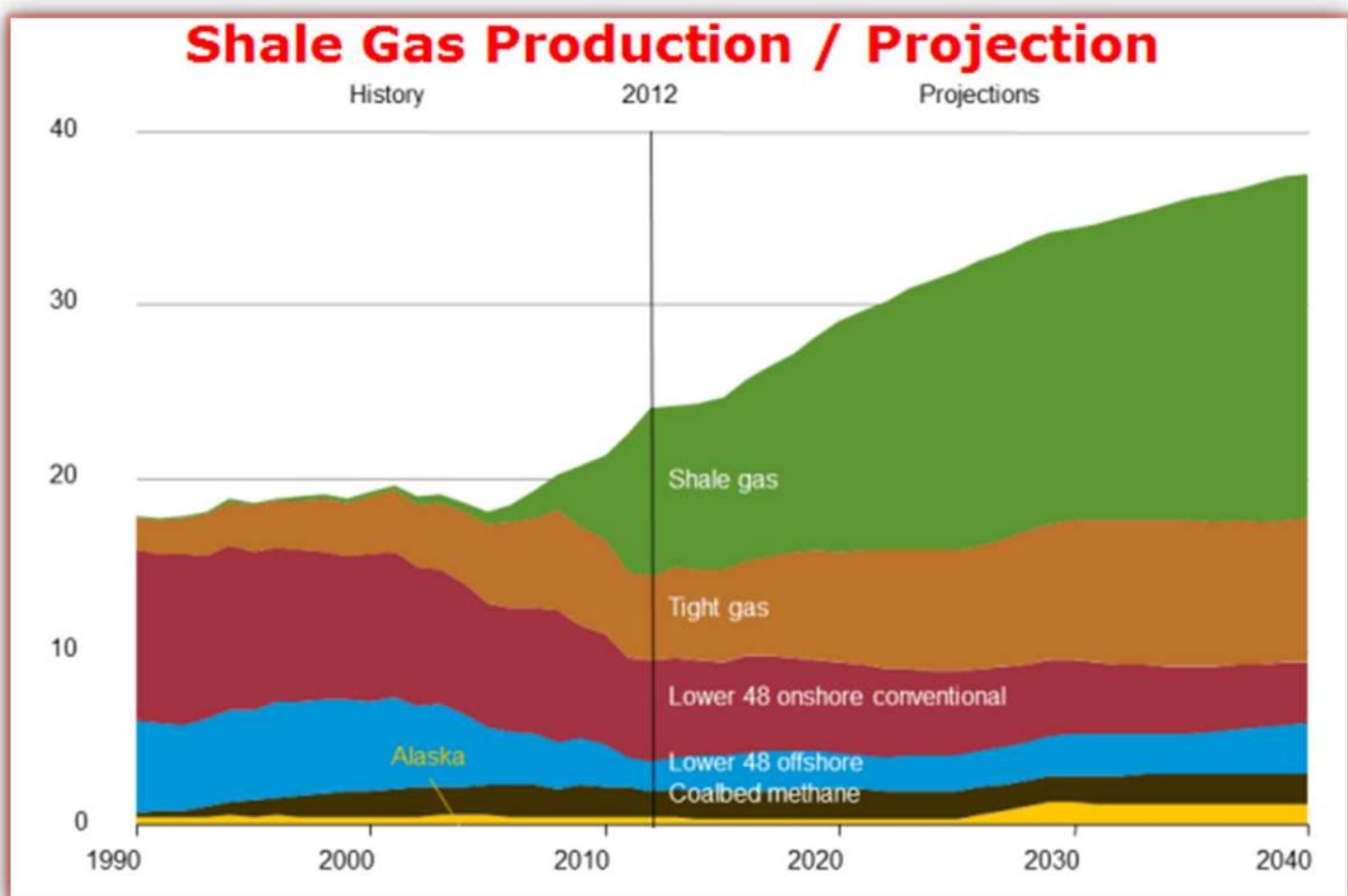


Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

- ▶ Why are 'gas compression' / 'gas interference' & 'gas pound' increasing as an issue in rod pumping?



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



- ➡ 'Pump Off' / 'Fluid Pound' / 'Gas Pound' all result in a decrease in plunger velocity.
- 💥 Polished rod velocity does not change which causes a '**train wreck**' effect above the pump.
- 😢 This is why incomplete pump fillage is always a concern when rod pumping a well.

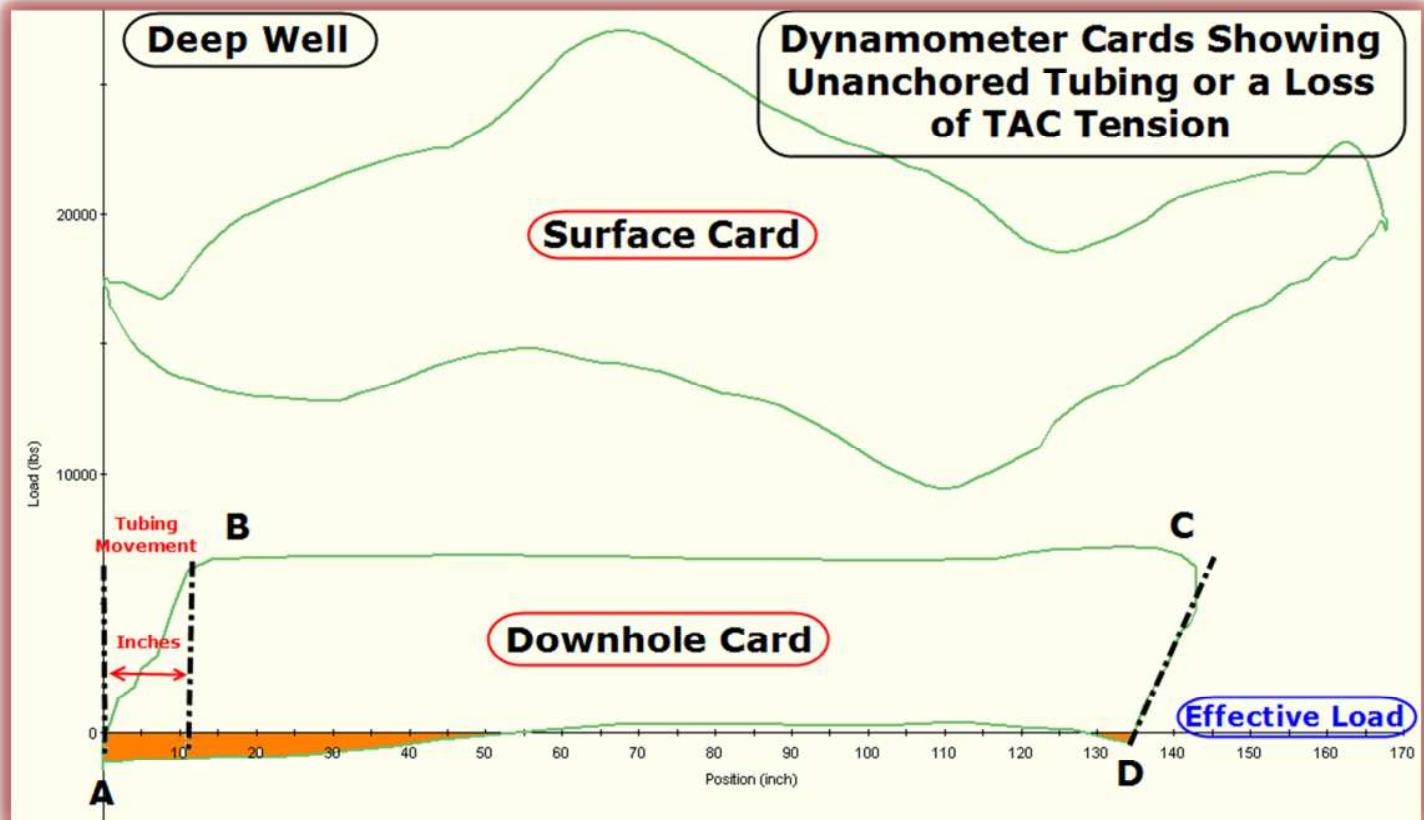


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

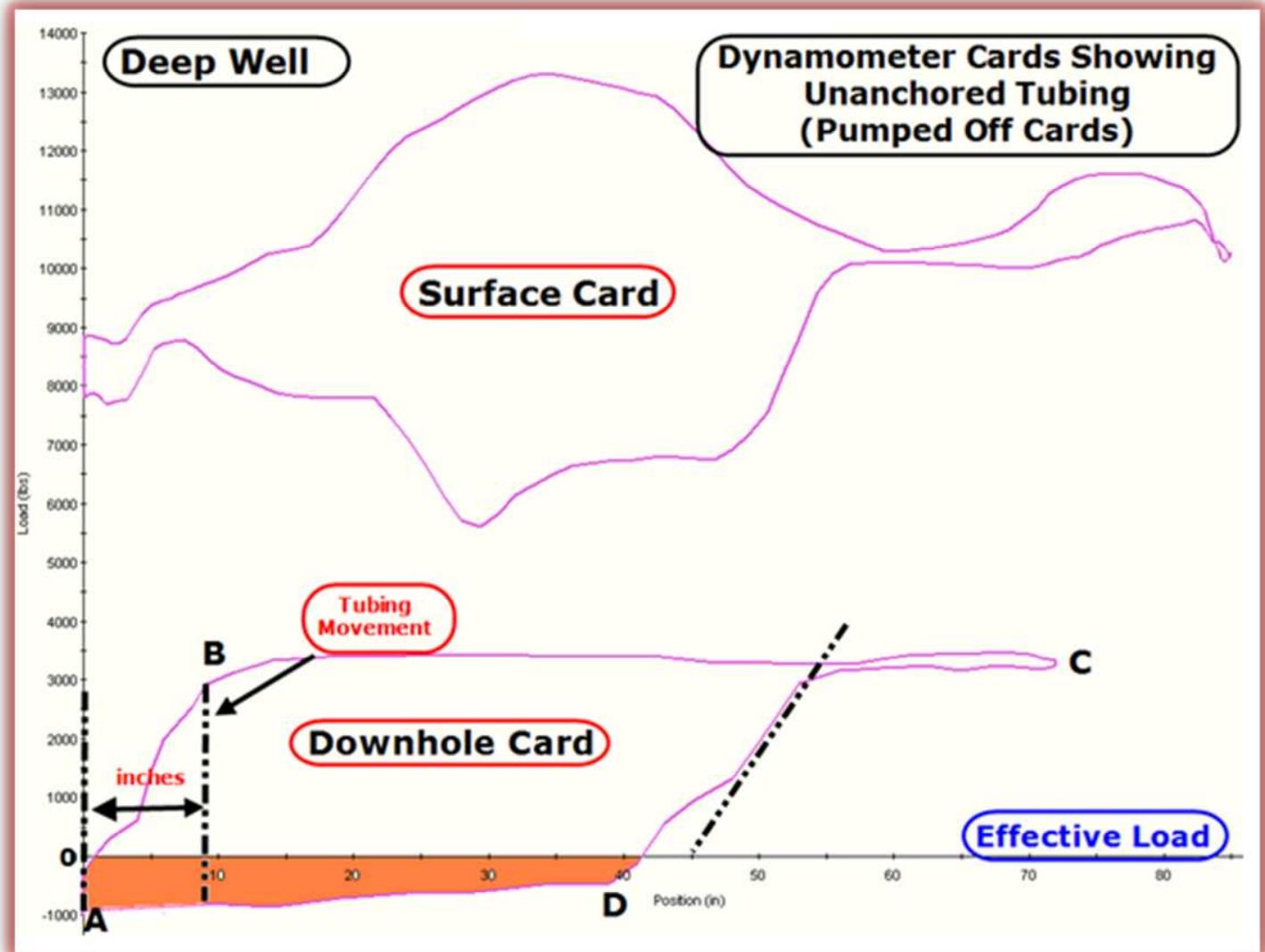
DH Cards – ‘Full Pump Fillage’ / ‘Tubing Movement’



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

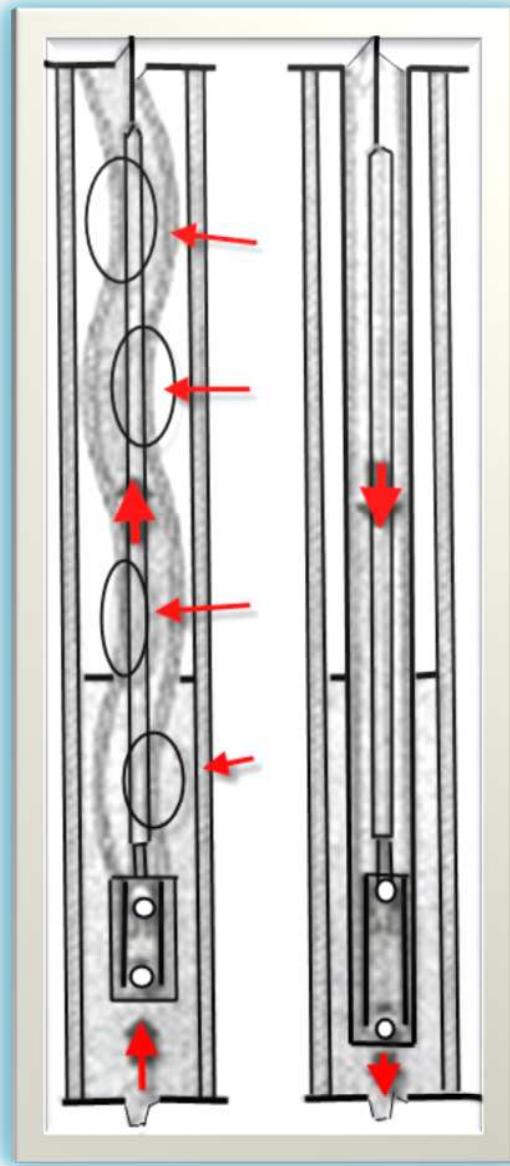


Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

- ➡ What happens when tubing 'breathes'?



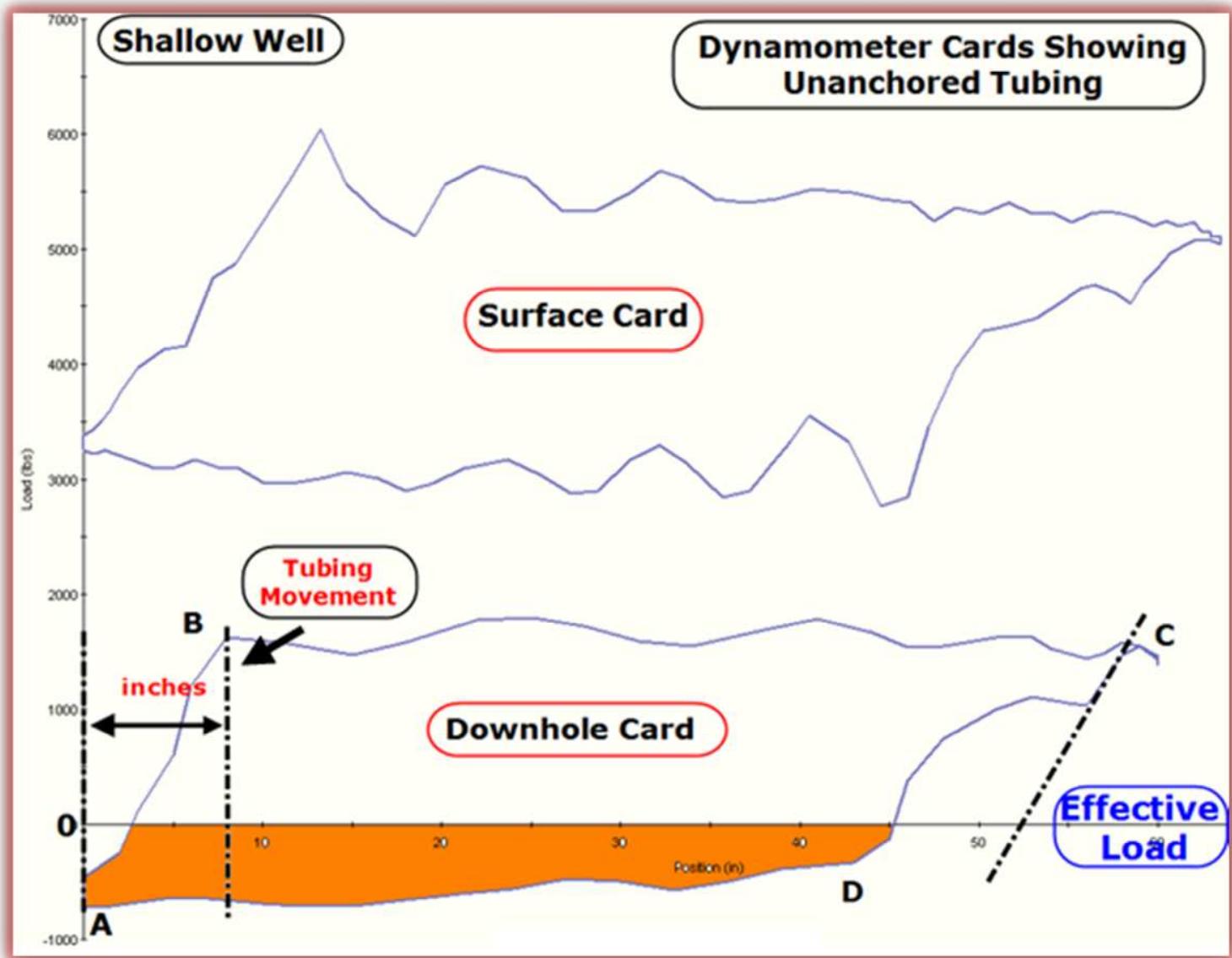
- ⌚ Unanchored or improperly anchored tubing allows the tubing to move relative to the rod string, which can result in helical buckling low in the string during the upstroke – leading to rod/tubing contact = 'rod coupling/body wear' and/or 'rod-cut tubing'.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



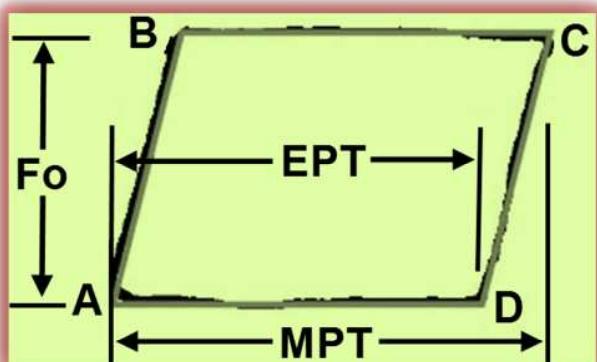
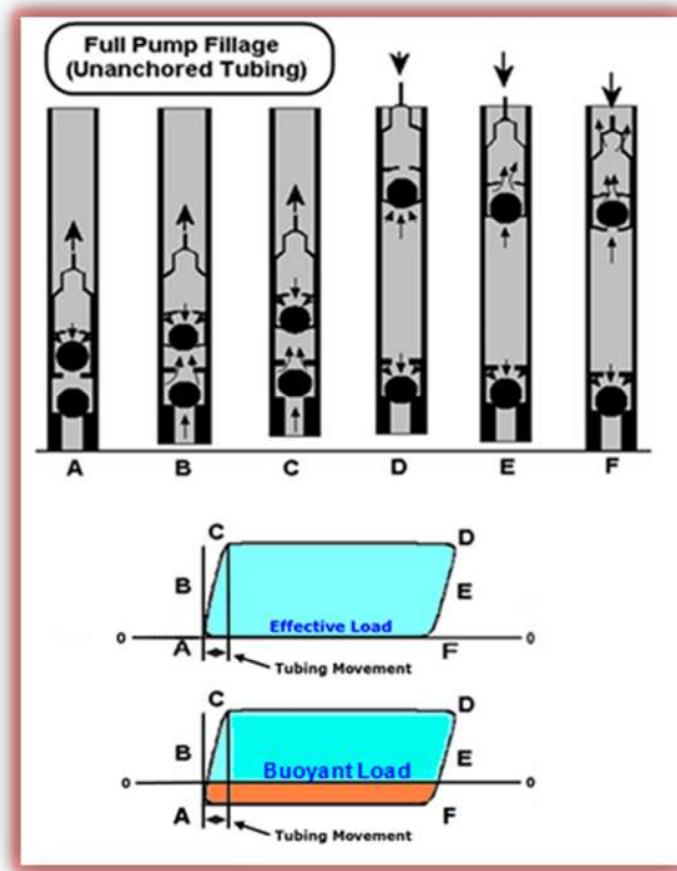
👉 A downhole card with unanchored tubing (full liquid fillage) has a parallelogram shape. The amount of tubing movement (in inches) can be scaled off from the downhole card to determine the amount of pump displacement being lost to unanchored tubing.



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Tubing Not Anchored - Effective Pump Travel Less Than Maximum Pump Travel

F_O = Fluid Load



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Detailed Description

H

1. At point "A", the traveling valve closes and the load begins to be transferred from the tubing to the rods.
 2. Between points "A" and "B", tension in the pull rod is increasing as the rods are picking up the fluid. The pump is moving relative to the casing as the fluid load is being picked up. The pump is stationary relative to the tubing. Since the tubing is not anchored, the tubing shortens as the load is removed from it. Because the pump is riding along with the tubing, the pump moves relative to the casing. This movement can be detected with the use of the "wave equation" diagnostic solution. The horizontal distance between points "A" and "B" is the amount of tubing "stretch" in inches.
 3. At point "B", the entire fluid load is borne by the rods and the standing valve opens.
 4. Between points "B" and "C", fluid is being lifted toward the surface. At the same time, the pump chamber below the traveling valve is filling completely with liquid through the open standing valve.
 5. At point "C", the top of the stroke has been reached and the downward tendency of the pump motion causes the standing valve to close.
 6. Between points "C" and "D", the pump load is transferred from the rods to the tubing. As the load shifts to the tubing, the tubing stretches downward relative to the casing. Thus, pump movement relative to the casing can be detected by the "wave equation" diagnostic solution.
 7. At point "C", the traveling valve opens and the pump begins to descend.
 8. Between points "D" and "A", the pump descends with the traveling valve open (standing valve closed) through the fluid that entered the pump chamber during the upstroke.
 9. At point "A", the traveling valve is closed by the tendency of the pump to move upward. This action begins another pumping cycle.
-

H

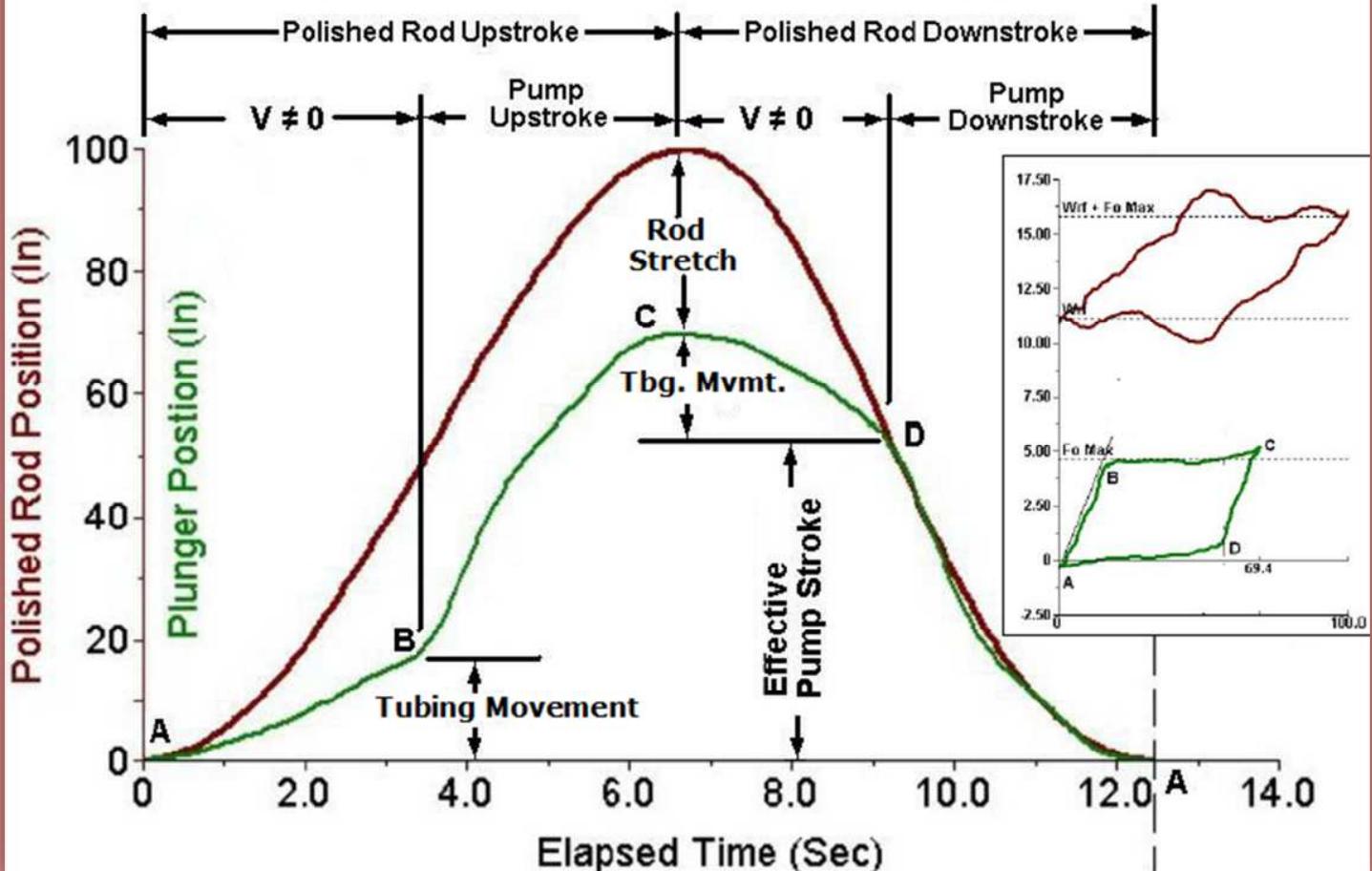


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Compare Polished Rod to Pump Plunger Position (Un-anchored Tubing)



((((ECHOMETER))))

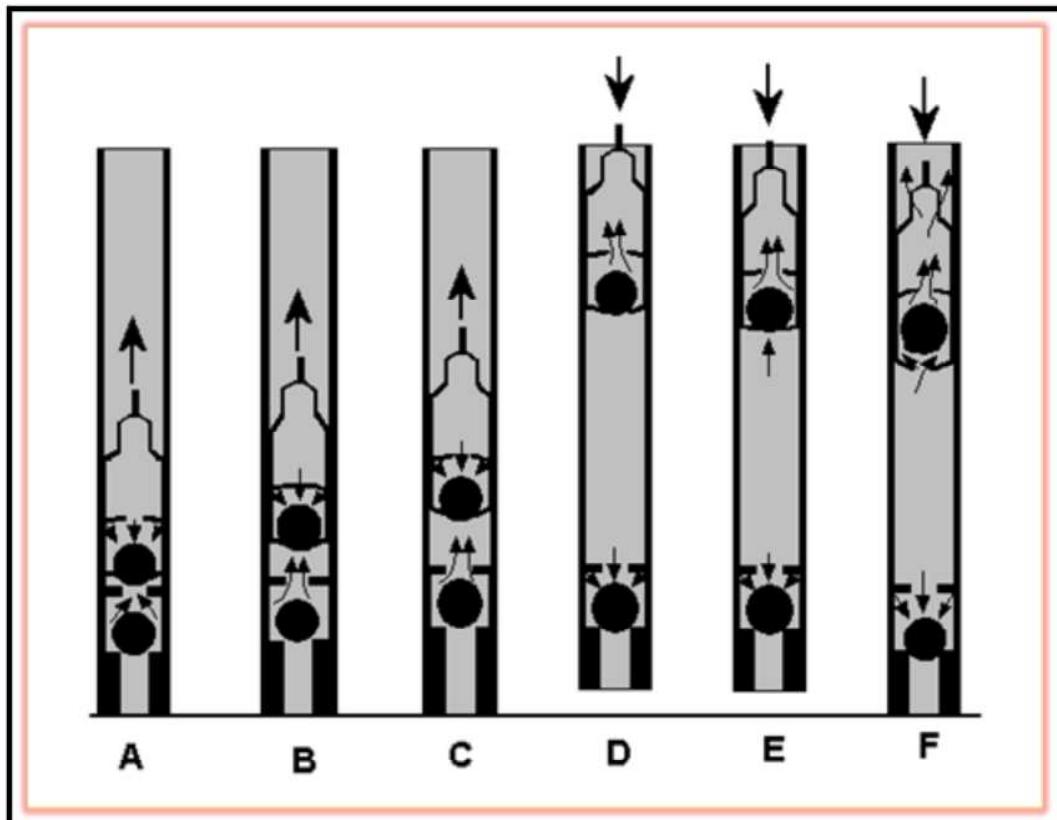
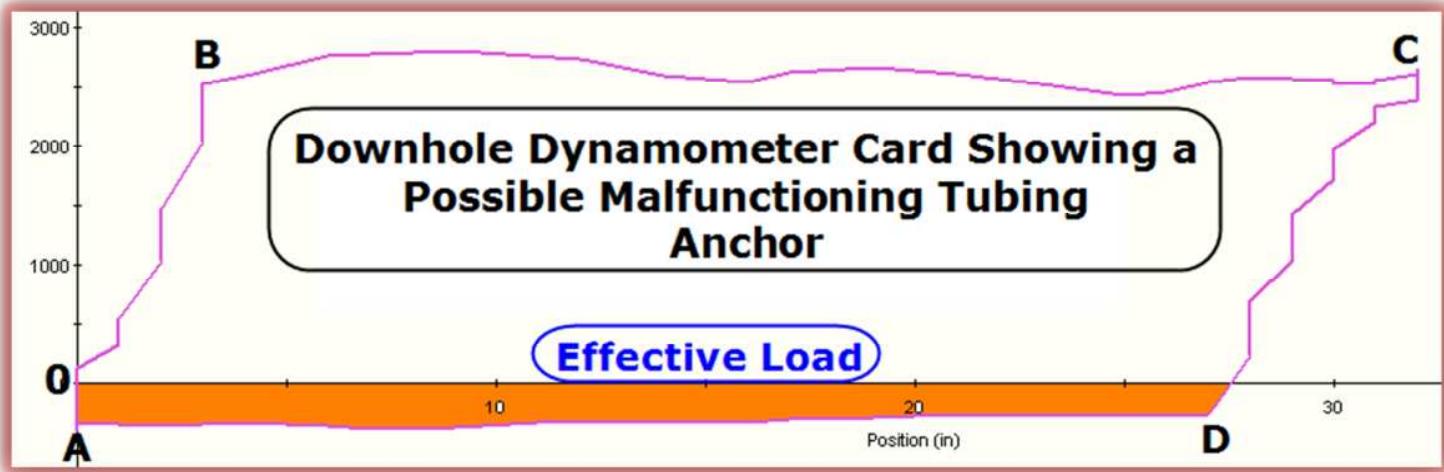


Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

DH Cards – ‘Full Pump Fillage’ / Malfunctioning ‘Tubing Anchor’



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Mechanical Tubing Anchor Catcher

Prevents movement of the tubing by two sets of teeth on each slip – one facing up and one facing down. The double gripping action allows the tool to be set for both anchoring and catching at the time of the initial installation.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

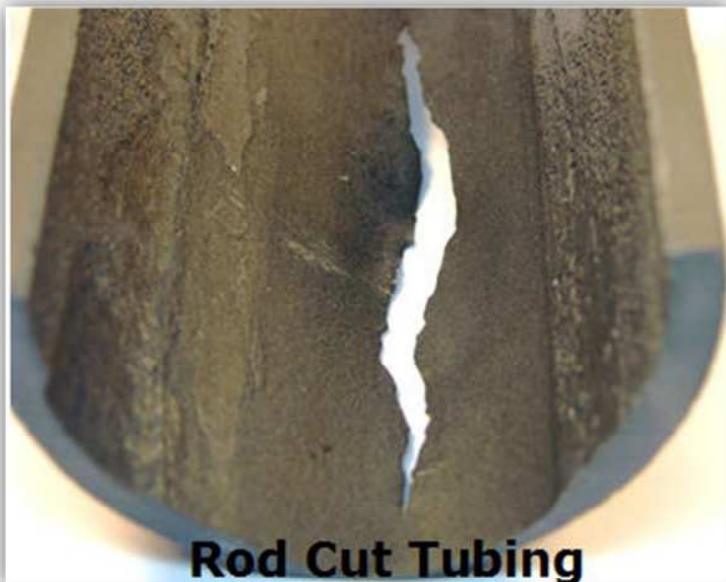
Possible Effects of 'Fluid Pound'/'Pump Off'/'Gas Pound'/ 'Tubing Movement'



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Rod Cut Tubing



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



- ➡ 'Incomplete pump fillage' or 'low pressure gas compression' – often called 'pump off' or 'fluid pound' - and 'gas pound' all result in a decrease in plunger velocity. Polished rod velocity does not change = which causes a 'train wreck' effect above the pump. This is why incomplete pump fillage is always a concern when rod pumping a well.
- ➡ 'Tubing movement' can cause rod/tubing contact leading to rod-cut tubing and/or worn rod couplings.

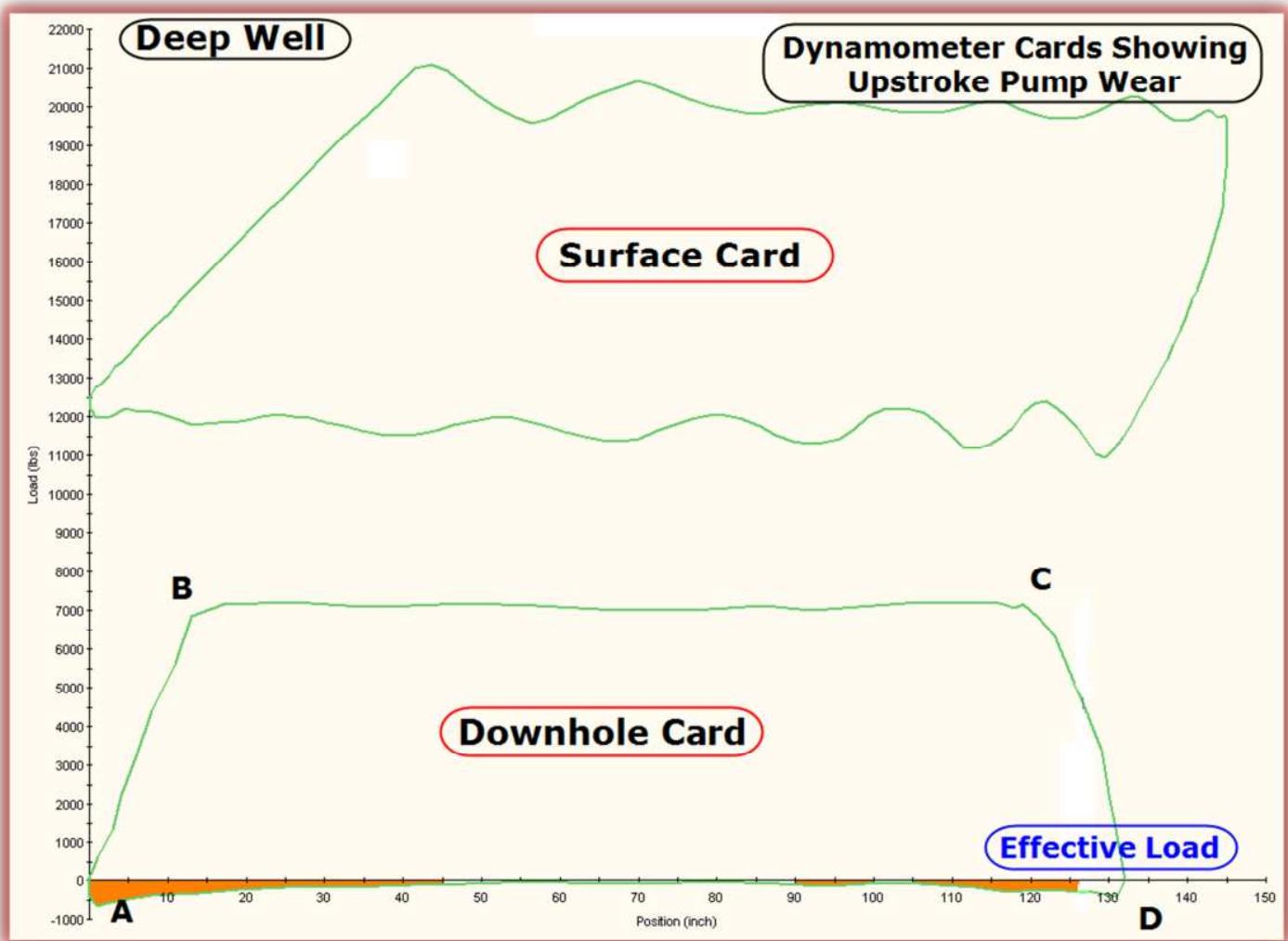


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

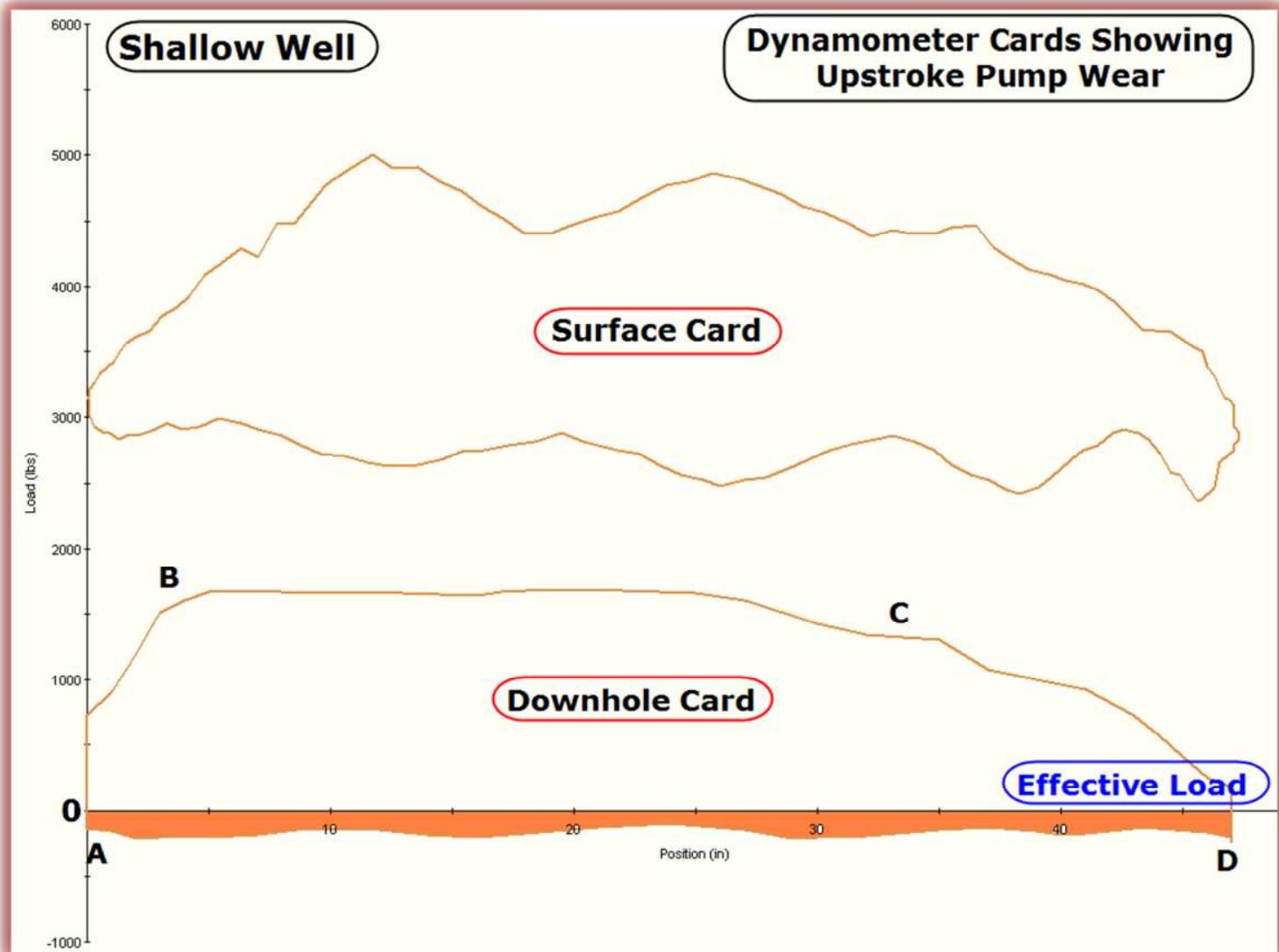
DH Cards – ‘Upstroke Pump Wear’



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



- 👉 A worn traveling valve or plunger causes the pump to pick up the fluid load slowly at the bottom of the stroke and to release it prematurely at the top of the stroke.
- 👉 Is it a TV problem or the barrel / plunger fit?



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

- ▶ TV problem will usually result in card shape changing over many strokes – often from stroke to stroke.
 - ▶ Barrel / plunger problem will usually show little change in card shape over many strokes.
- 👉 Always keep in mind that downhole card shapes that show apparent upstroke pump wear could be the result of the installed barrel/plunger fit – ('loose fit' to better handle solids, etc.) or the use of pump barrel extensions.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Upstroke Wear



Plunger Velocity?

Plunger velocity? Well depth and rod string and SPM combine to cause the pump to almost stop at the point circled in blue, then the plunger moves back up and pump load increases. We call this situation?

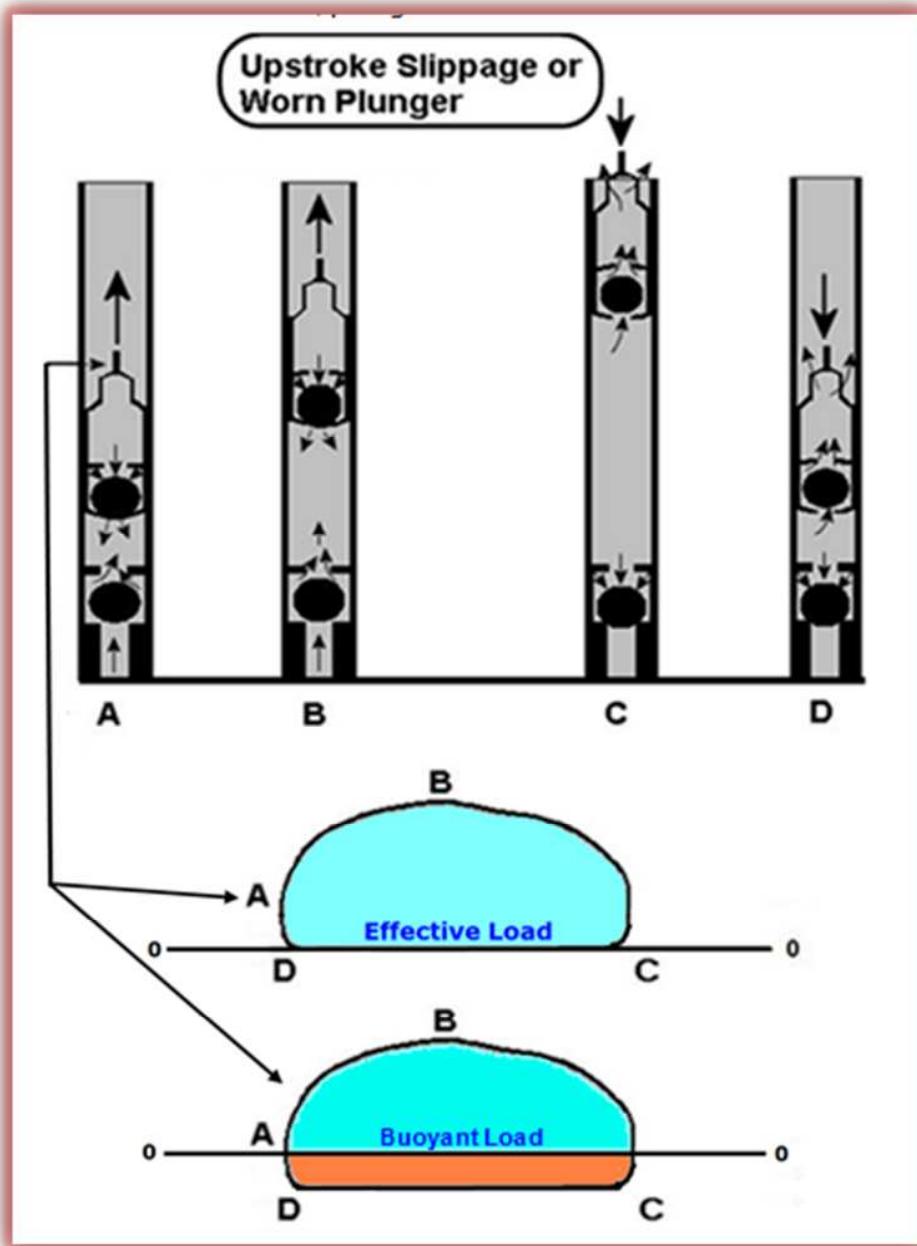
This is likely a 'rod frequency' condition. Plunger pauses, moves up faster to pick up some load, then continues to slow down and pump load leaks off.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



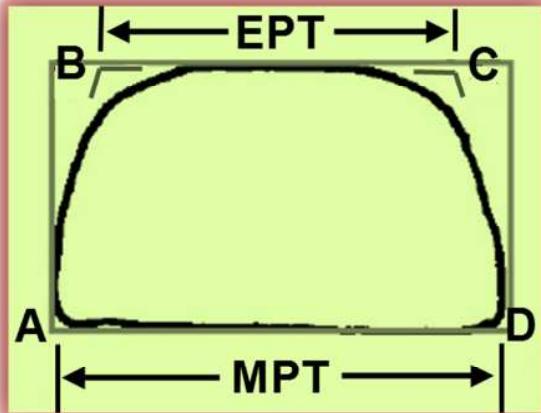
Surface and Downhole Dynamometer Card Interpretation



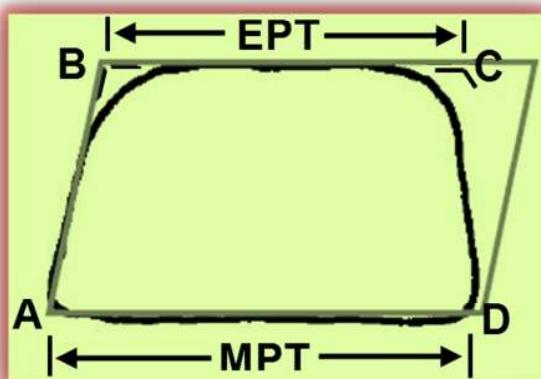
Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Tubing Anchored - Effective Pump Travel Less Than Maximum Pump Travel



Tubing Not Anchored - Effective Pump Travel Less Than Maximum Pump Travel

Detailed Description



1. At point "A", the traveling valve closes and the load begins to be transferred from the tubing to the rods.
2. Between points "A" and "B", tension in the pull rod is increasing as the rods are picking up the fluid. The pump is moving slowly during this part of the cycle – thus its displacement rate is low. The pump slippage rate is a sizeable portion of the displacement rate. This causes the fluid load pick-up to be more gradual than usual.
3. At point "B", the entire fluid load is borne by the rods and the standing valve opens.
4. Between points "B" and "C", fluid is being lifted toward the surface. At the same time, the pump chamber below the traveling valve is filling completely with liquid through the open standing valve. In addition to this, fluids are slipping back around the worn traveling valve or plunger



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

into the chamber below. This subtracts from the volume available for entry of new fluids from the reservoir.

5. At point "C", the pump speed has again slowed down enough so that the slippage rate exceeds the displacement rate of the pump. This closes the standing valve. In a worn pump of this type, the load release begins prematurely near the top of the stroke.
 6. Between points "C" and "D", the fluid load is being transferred from the rods to the tubing. If there is NO gas present in the pump barrel, eventually the plunger encounters nearly incompressible liquid in the incompletely filled (with liquid) pump chamber. At this point, the load is rapidly released from the rods and the pump is said to "pound fluid". If there is gas present in the barrel, the plunger never really encounters incompressible liquid. The traveling valve opens when sufficient pressure is built up by compressing the gas present in the barrel.
 7. At point "D", the traveling valve opens and the pump begins to descend.
 8. Between points "D" and "A", the pump descends with the traveling valve open (standing valve closed) through the fluid that entered the pump chamber during the upstroke.
 9. At point "A", the traveling valve is closed by the tendency of the pump to move upward. This action begins another pumping cycle.
-



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



**'Upstroke Pump Wear'
Sand-cut Plunger**

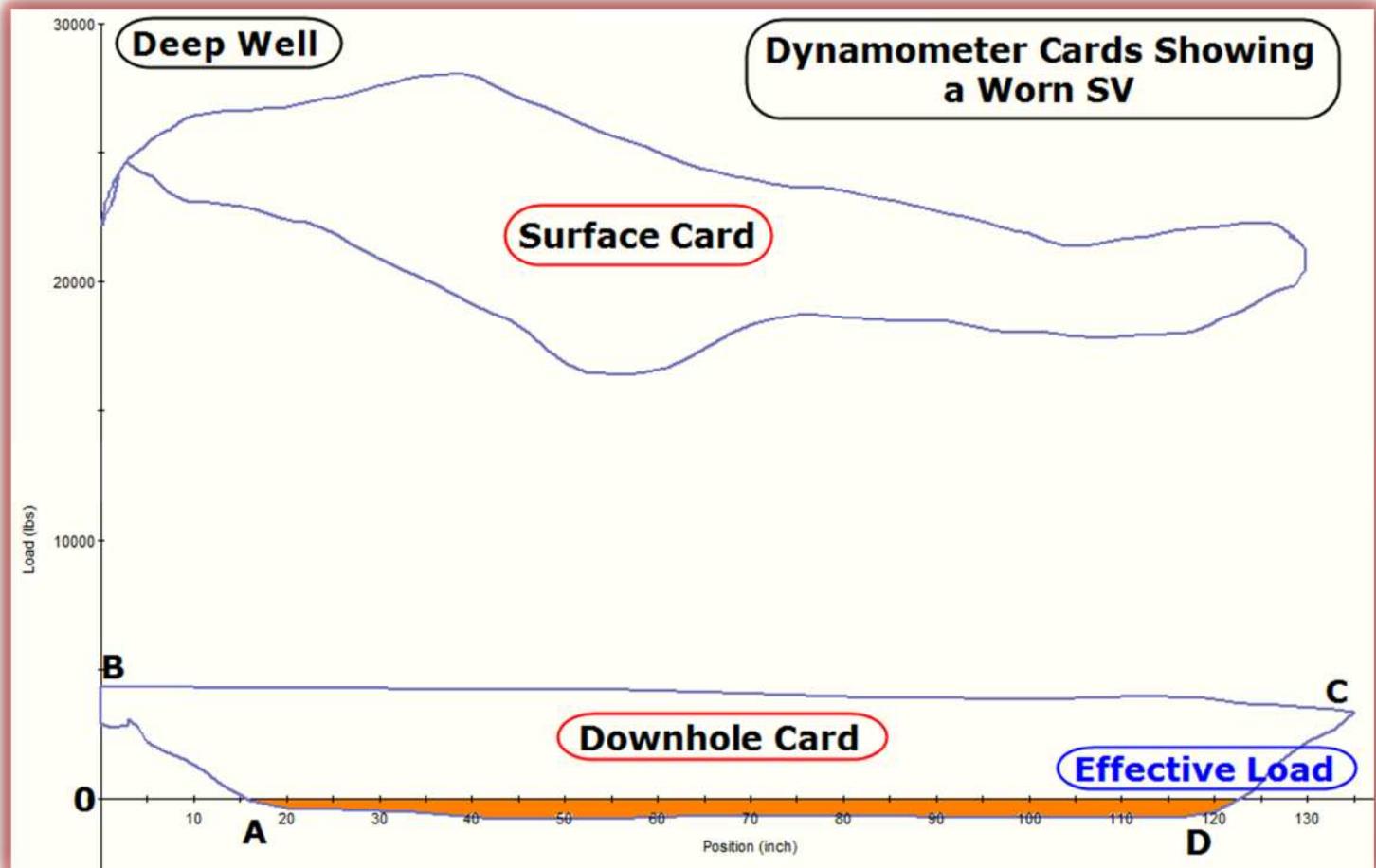


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

DH Cards – Downstroke Pump Wear (SV)



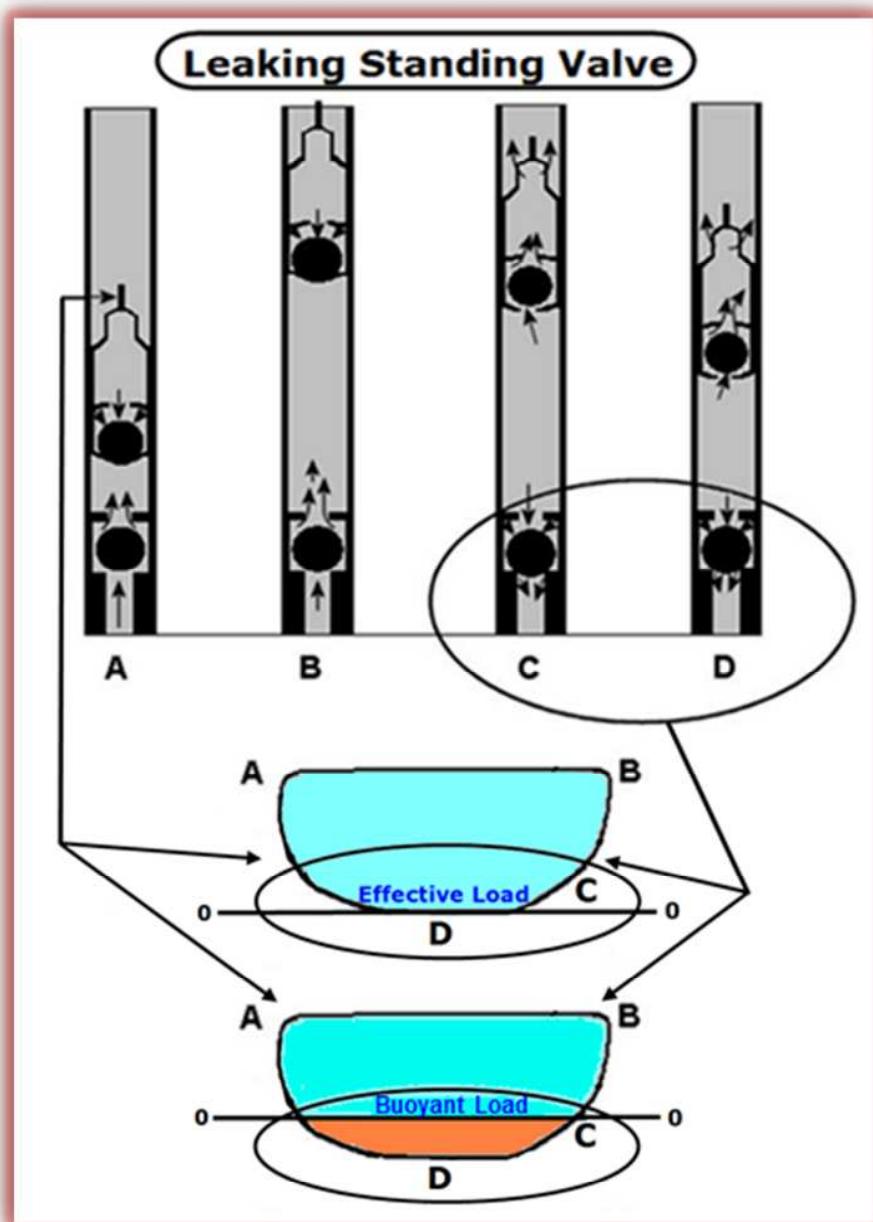
A worn standing valve causes the pump to prematurely pick-up load near the bottom of the stroke. It also causes a delayed release near the top of the stroke.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



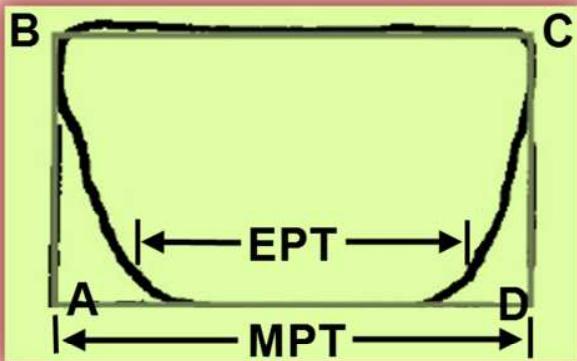
Surface and Downhole Dynamometer Card Interpretation



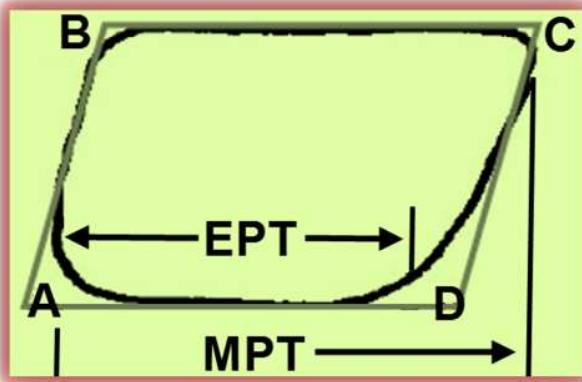
Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Tubing Anchored - Effective Pump Travel Less Than Maximum Pump Travel



Tubing Not Anchored - Effective Pump Travel Less Than Maximum Pump Travel

Detailed Description



- At point "A", the traveling valve closes and the load begins to be transferred from the tubing to the rods. The load transfer begins with the pump still on the downstroke. This happens because the slippage rate past the standing valve exceeds the displacement rate of the slowly moving pump as it approaches the bottom of the stroke. This closes the traveling valve while the pump is still moving downward.
- Between points "A" and "B", tension in the pull rod is increasing as the rods are picking up the fluid.
- At point "B", the entire fluid load is borne by the rods and the standing valve opens. When the standing valve opens, slippage ceases.
- Between points "B" and "C", fluid is being lifted toward the surface.
- At point "C", the top of the stroke has been reached and the downward tendency of the pump causes the standing valve to close.



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

6. Between points "C" and "D", the fluid load is being transferred back to the tubing. The load can be released with the pump moving down – even with complete liquid fillage. This can happen because slippage past the standing valve exceeds the displacement rate of the slowly moving pump.
 7. At point "D", the displacement rate of the pump exceeds the slippage rate of the standing valve and the traveling valve opens. The pump continues downward.
 8. Between points "D" and "A", the pump descends with the traveling valve open (standing valve closed) through the fluid that entered the pump chamber during the upstroke. Slippage past the standing valve is occurring – which decreases volumetric efficiency.
 9. At point "A", the pump has slowed down enough so that the slippage rate past the standing valve exceeds the displacement rate of the pump. This closes the traveling valve and a new pump cycle begins.
-

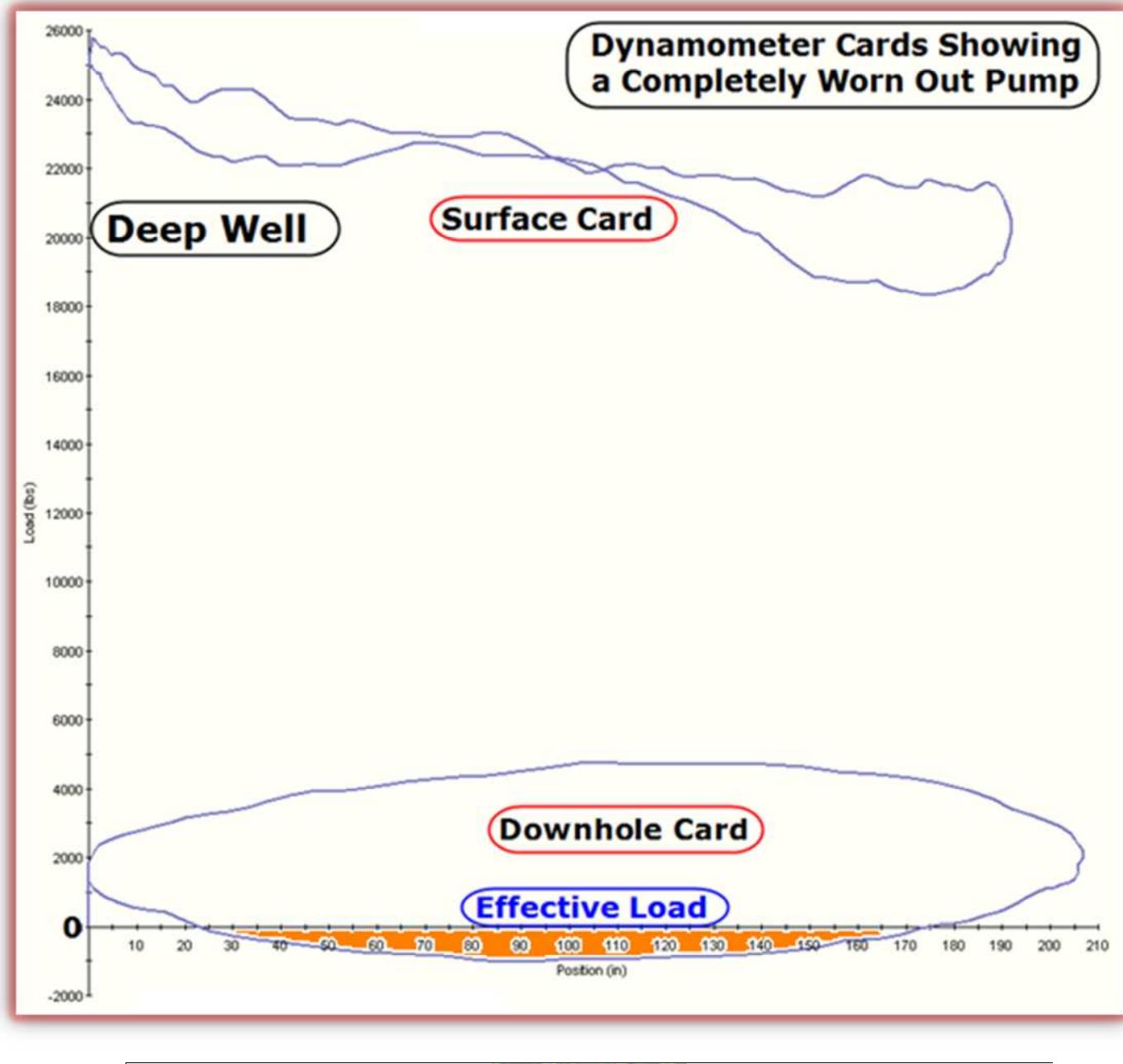


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

DH Cards – ‘Worn Out Pump’

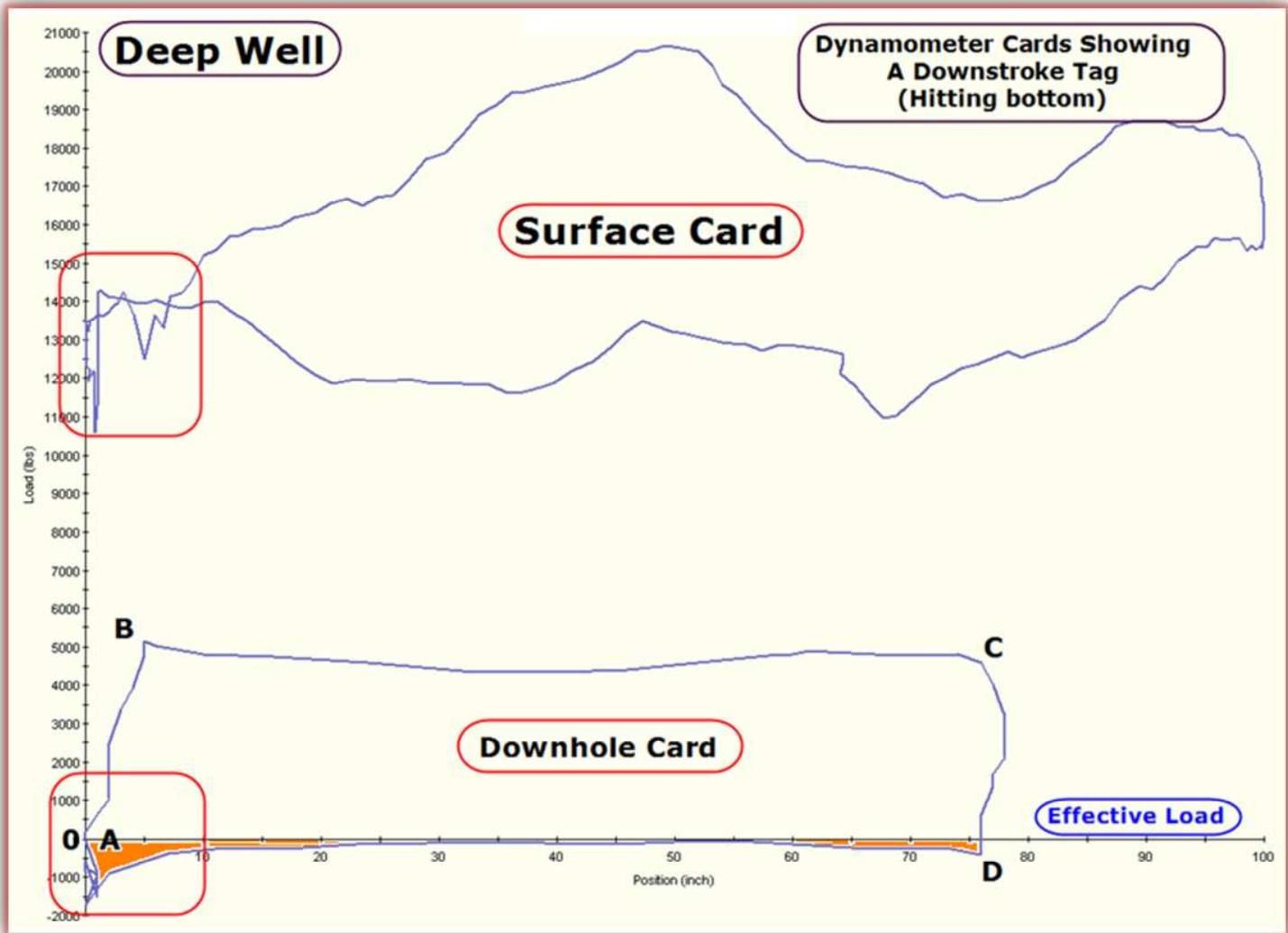


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

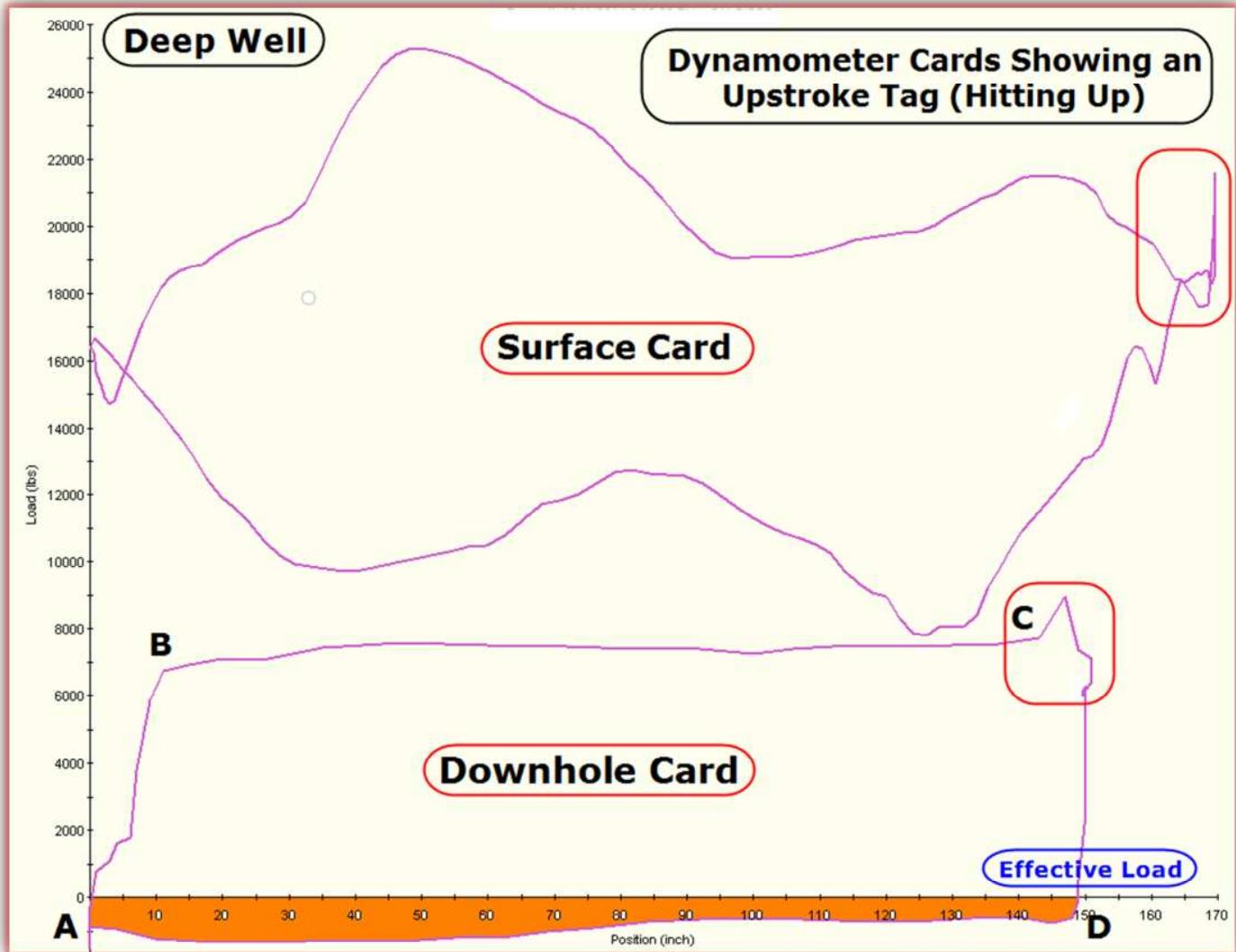
DH Cards – ‘Tagging’ (Hitting Up and Down)



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



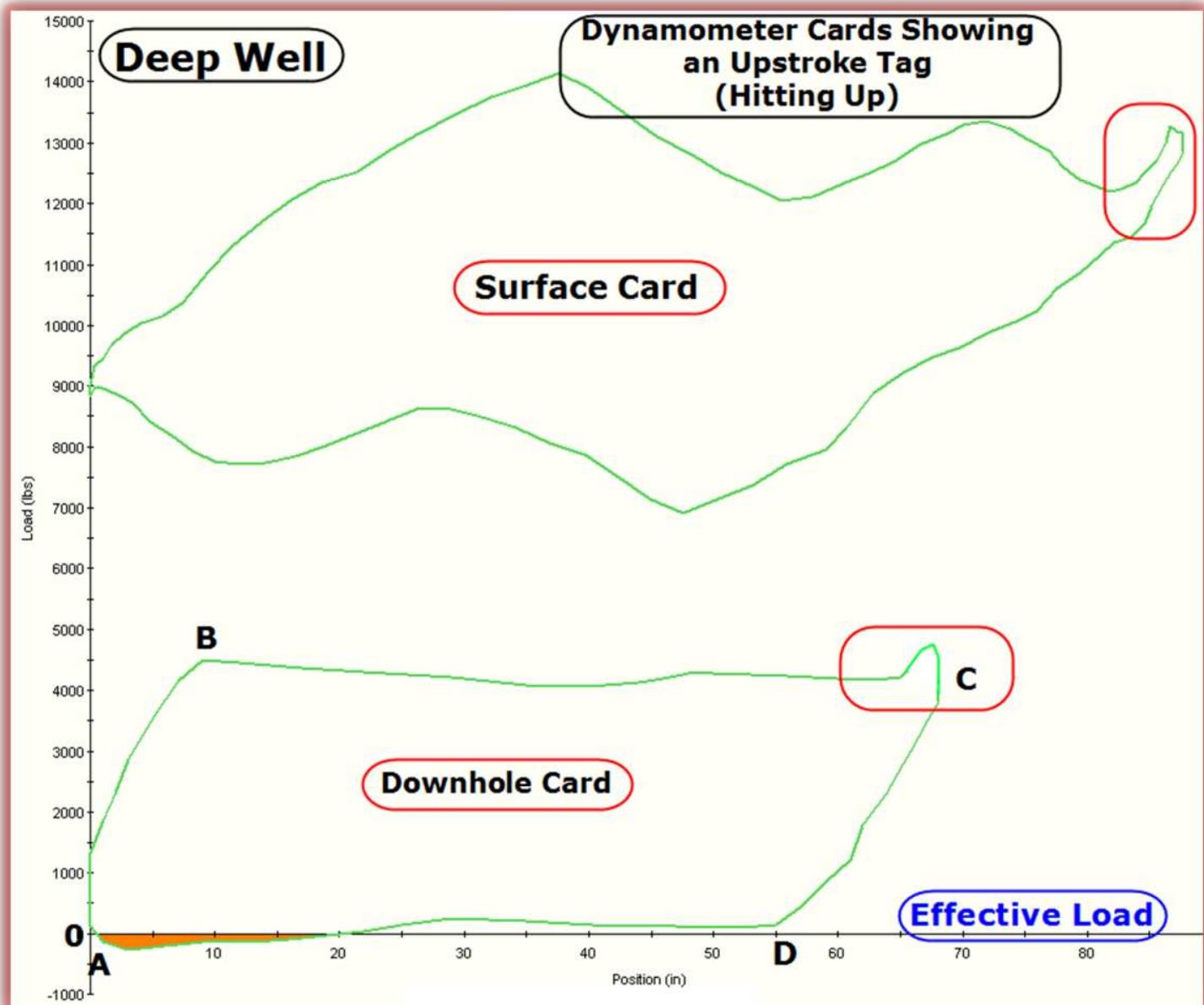
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



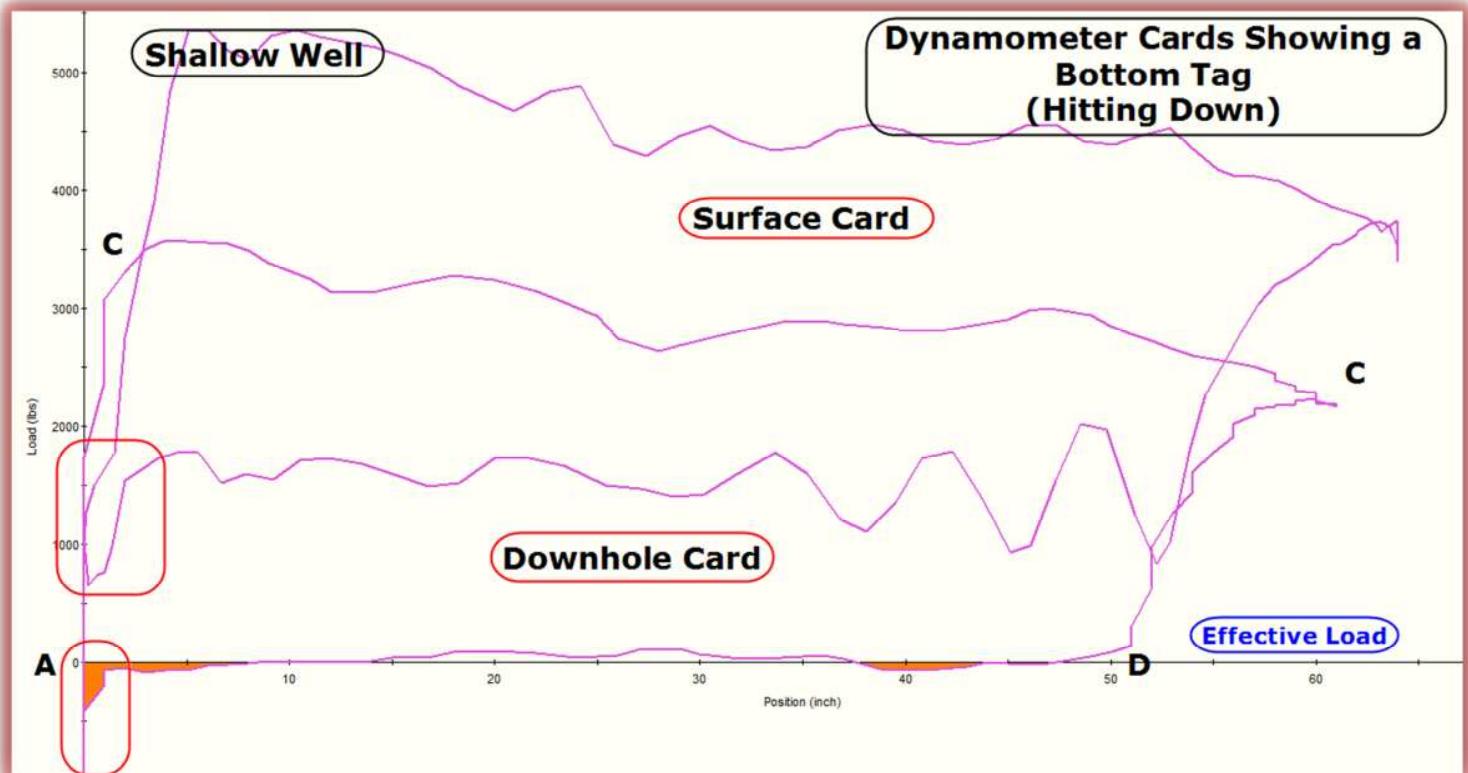
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



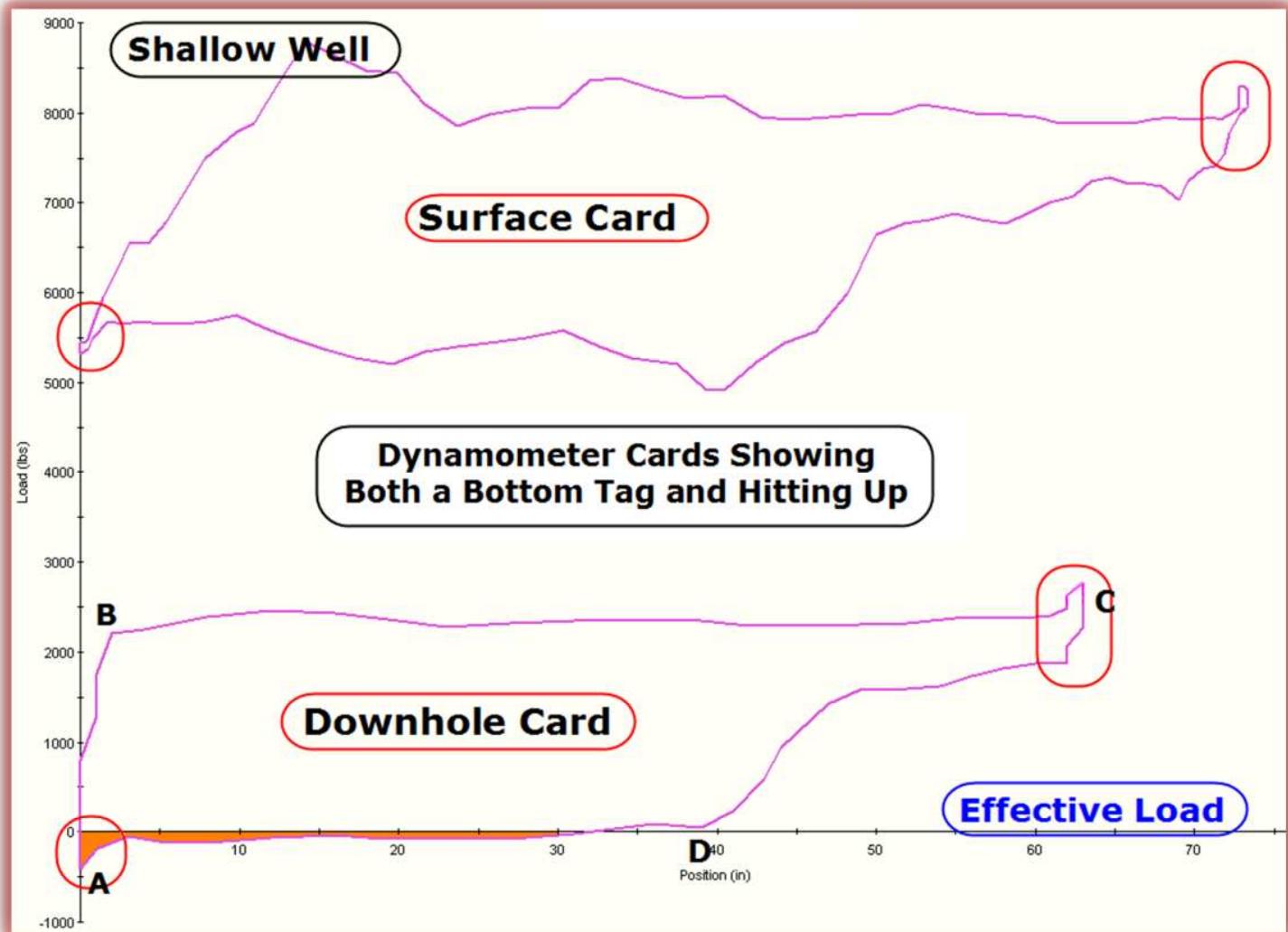
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



- Pumps can "hit" up or down or both. This "hitting" or "bumping" condition can occur in combination with any other downhole situation – 'gas interference', 'fluid pound', 'unanchored tubing', etc.
- If the pump "hits" down, a load loss (compression) will be shown at the lower left of the downhole card (at the bottom of the stroke on the downhole card).
- If the pump "hits" up, a load increase (tension) will be shown at the top of the

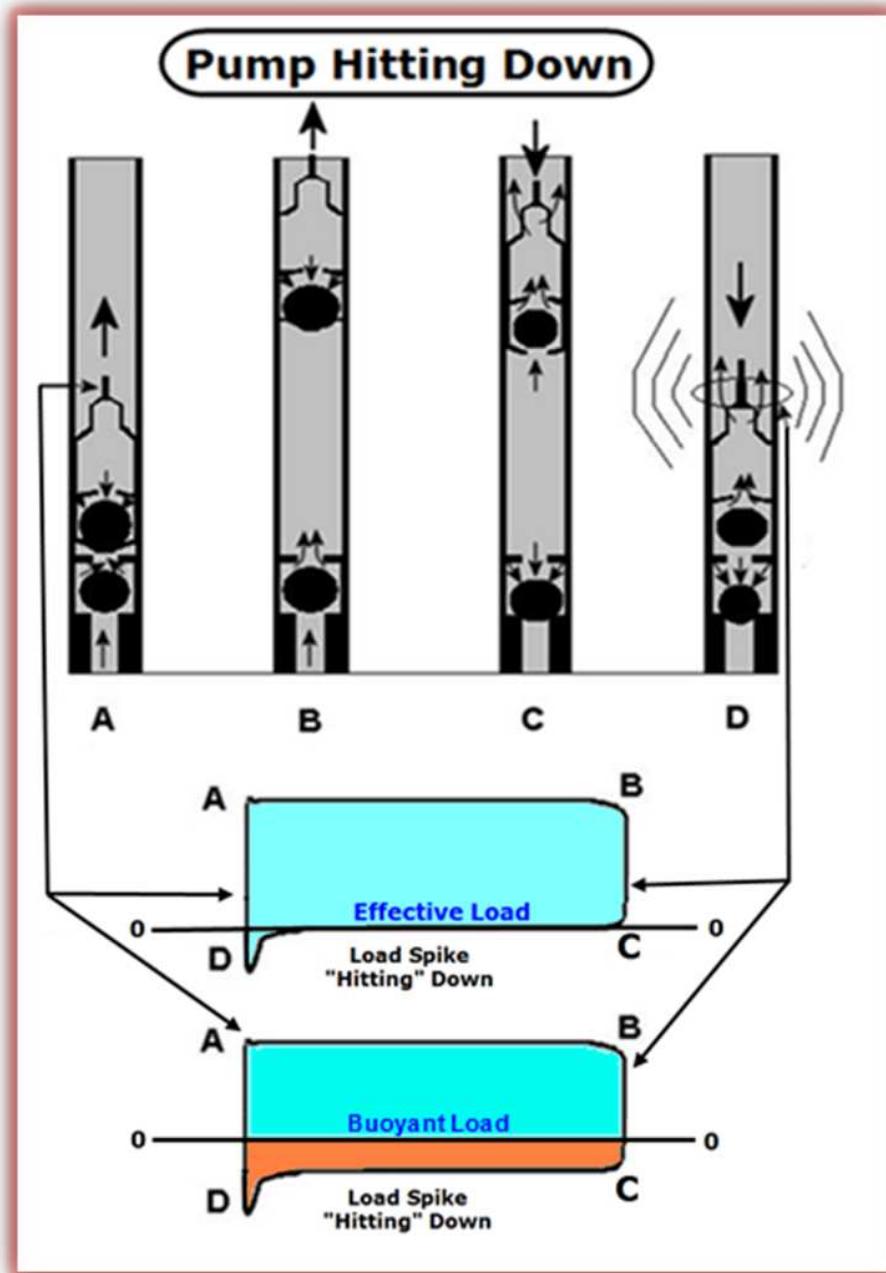


Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

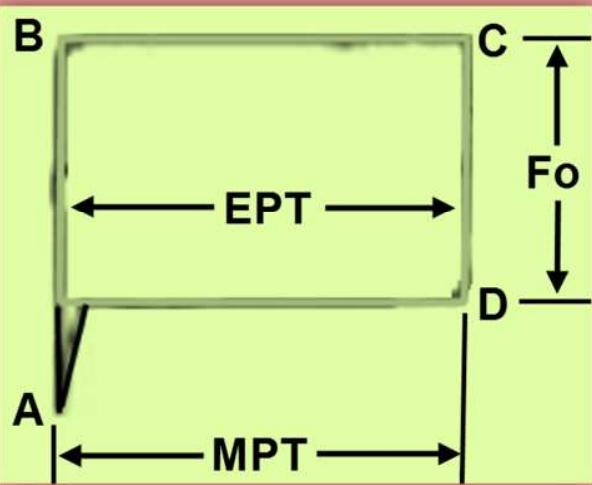
stroke (upper right on the downhole card).



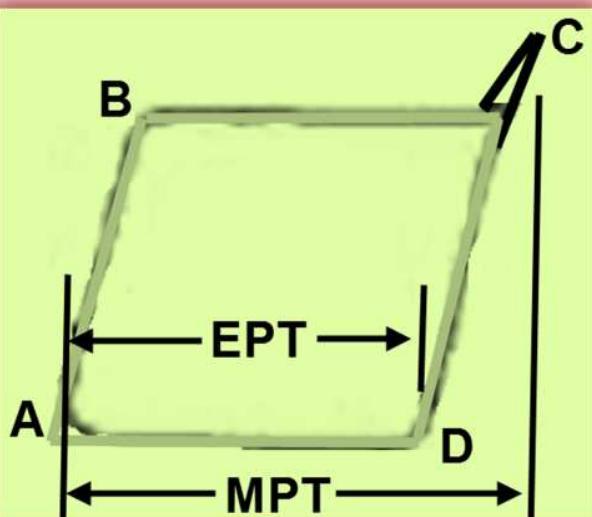
Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Tubing Anchored - Effective Pump Travel = Maximum Pump Travel



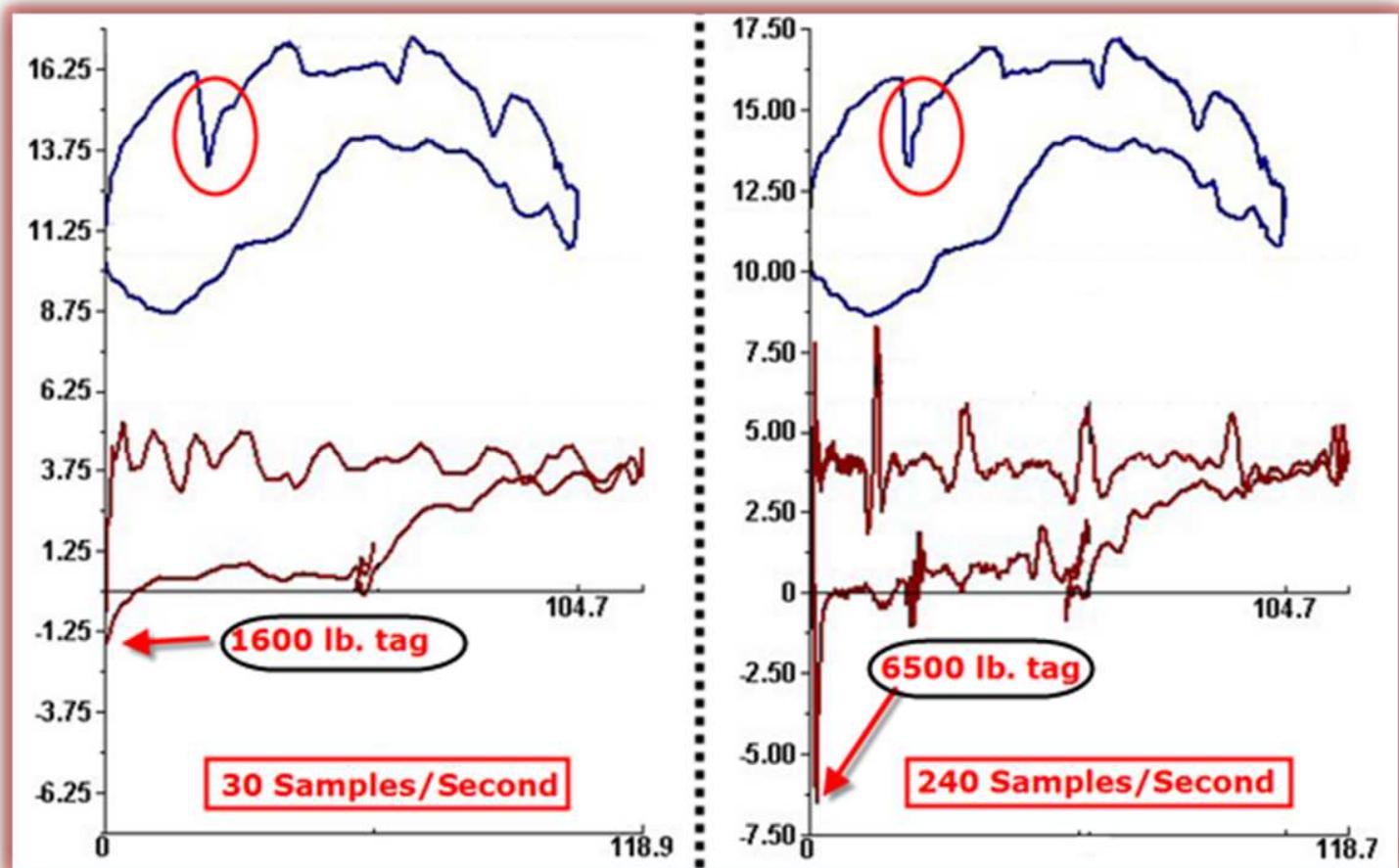
Tubing Not Anchored - Effective Pump Travel is Less Than Maximum Pump Travel

- Pumps that are identified as "hitting" up or down should be "re-spaced" to prevent equipment damage. Actual tagging down 'force' may be considerably more than indicated due to analysis program smoothing or raw card data collection rate.





Surface and Downhole Dynamometer Card Interpretation



((((ECHOMETER))))



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

✳ What happens when a well is allowed to tag bottom? These are wells producing from 7500' to 12,000' in Southeast Texas.

CDI Energy Services – Southeast Area	No Damage to Valve Rod Guide		Valve Rod Guide is Damaged From Bottom Tag	
	# of Pulls	Avg. Days Run	# of Pulls	Avg. Days Run
<i>Pump</i>	560	564	64	390
<i>Rods</i>	234	543	36	247
<i>Tubing</i>	383	506	34	322
Total	1177	541	134	334

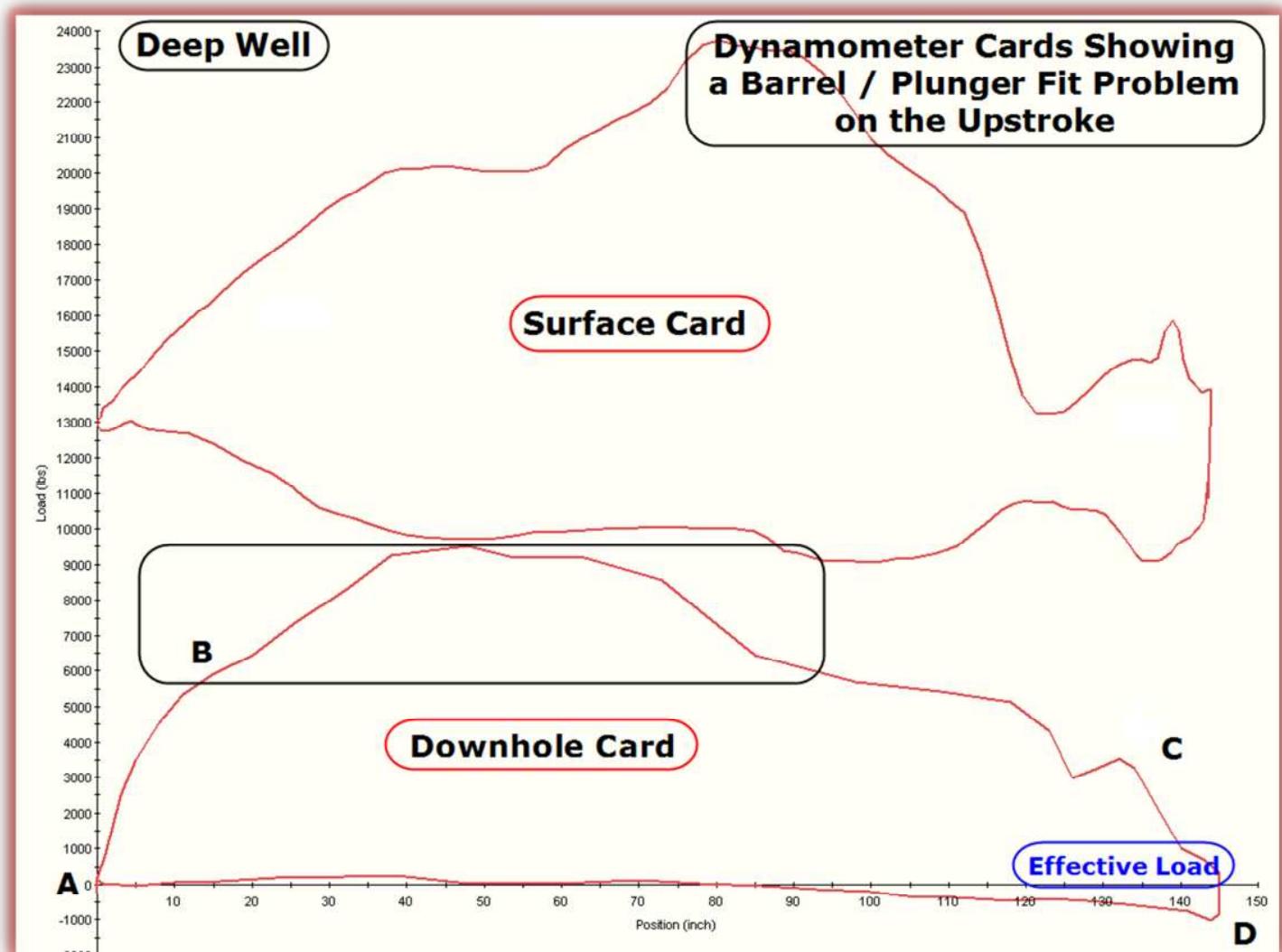


Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

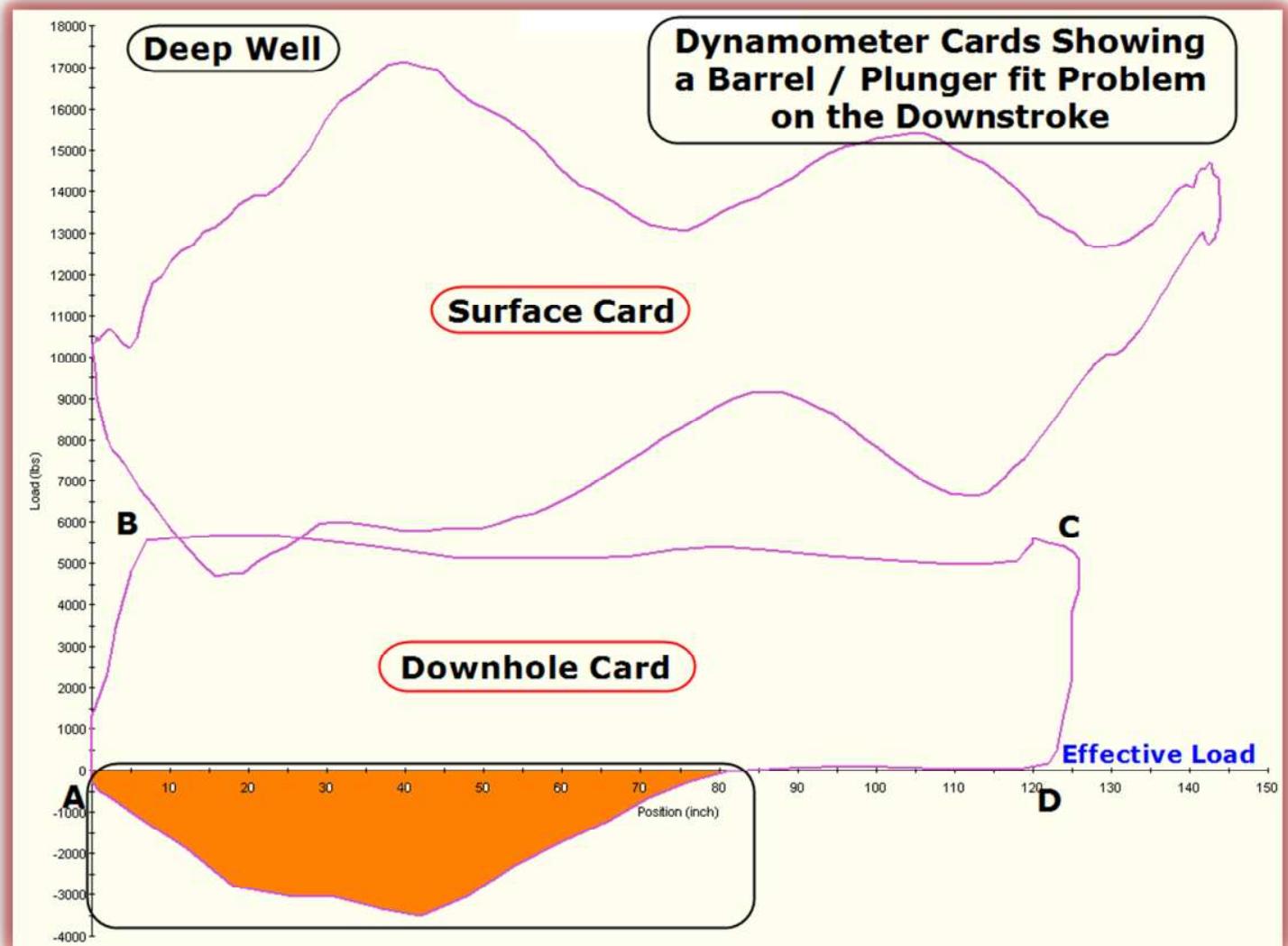
DH Cards – ‘Tight Spot’ in Barrel/Plunger Travel



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



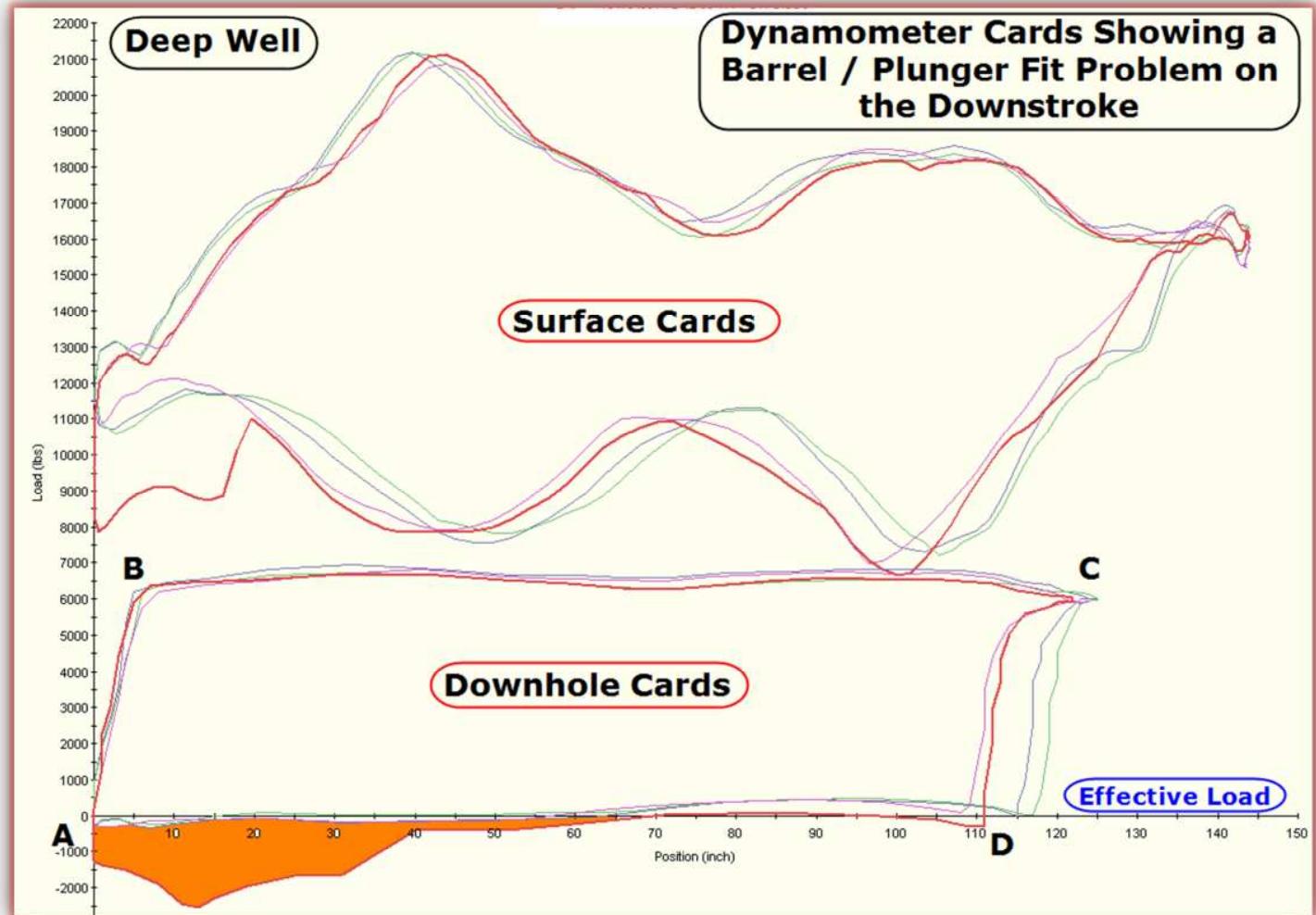
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



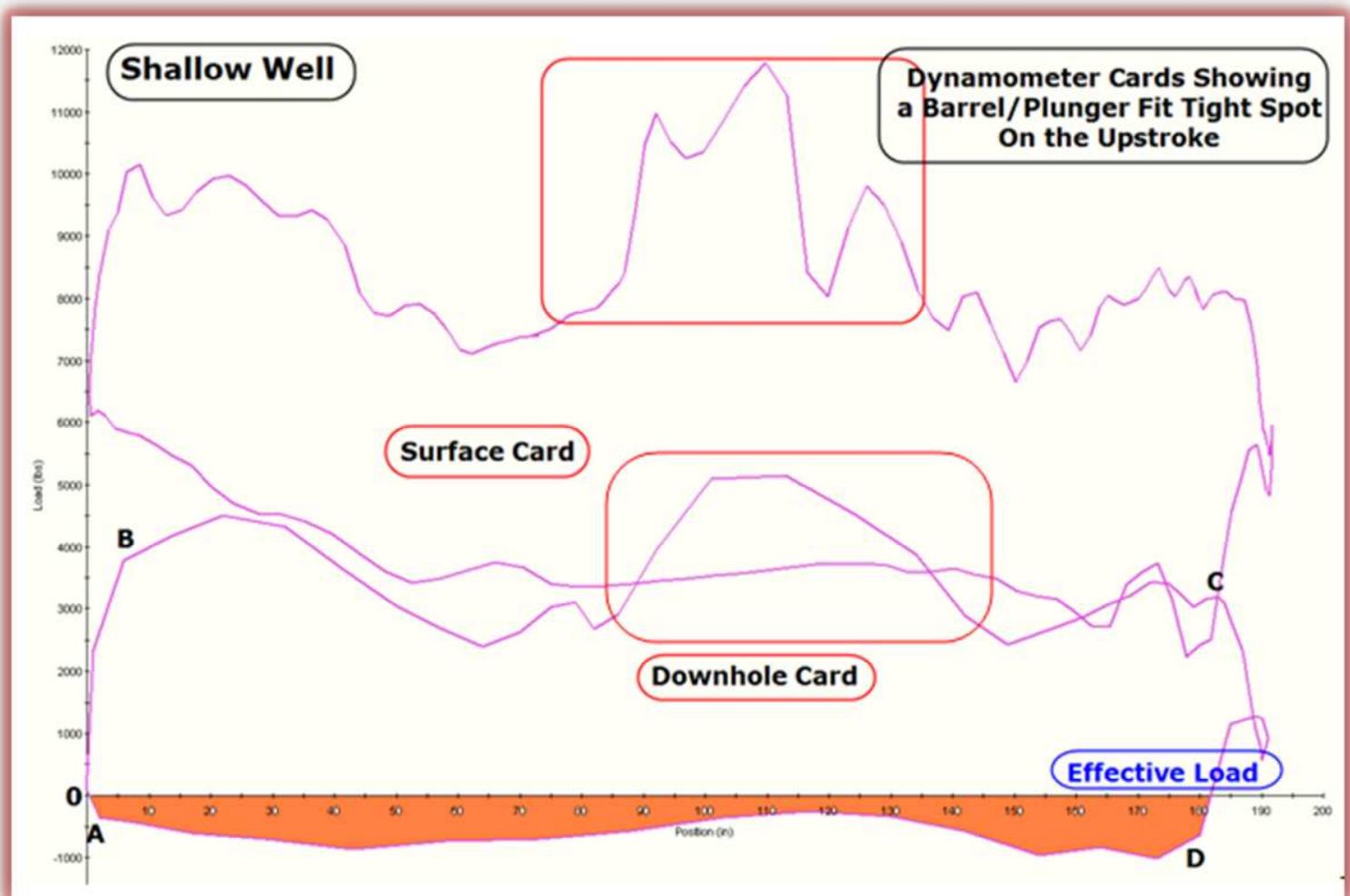
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



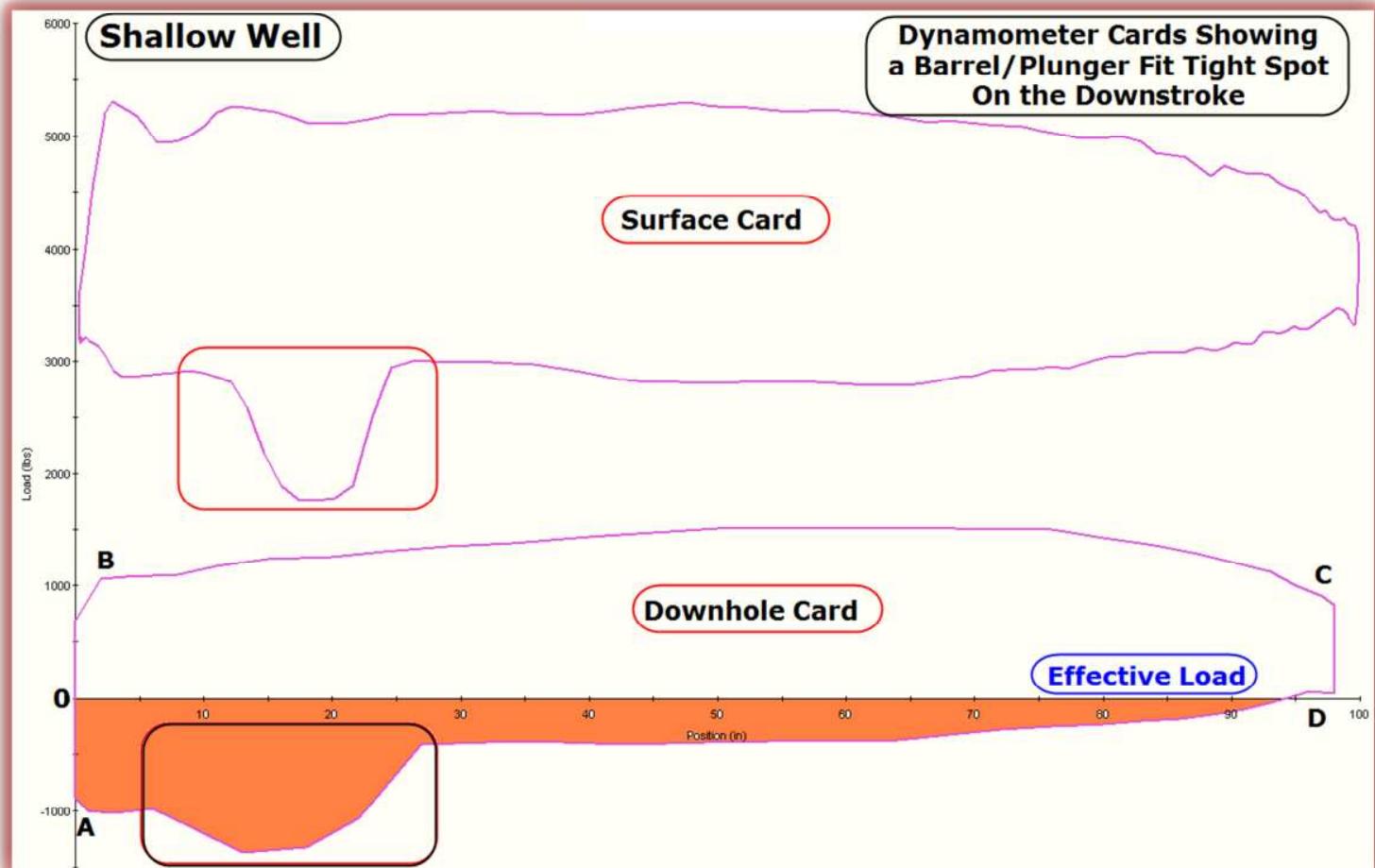
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



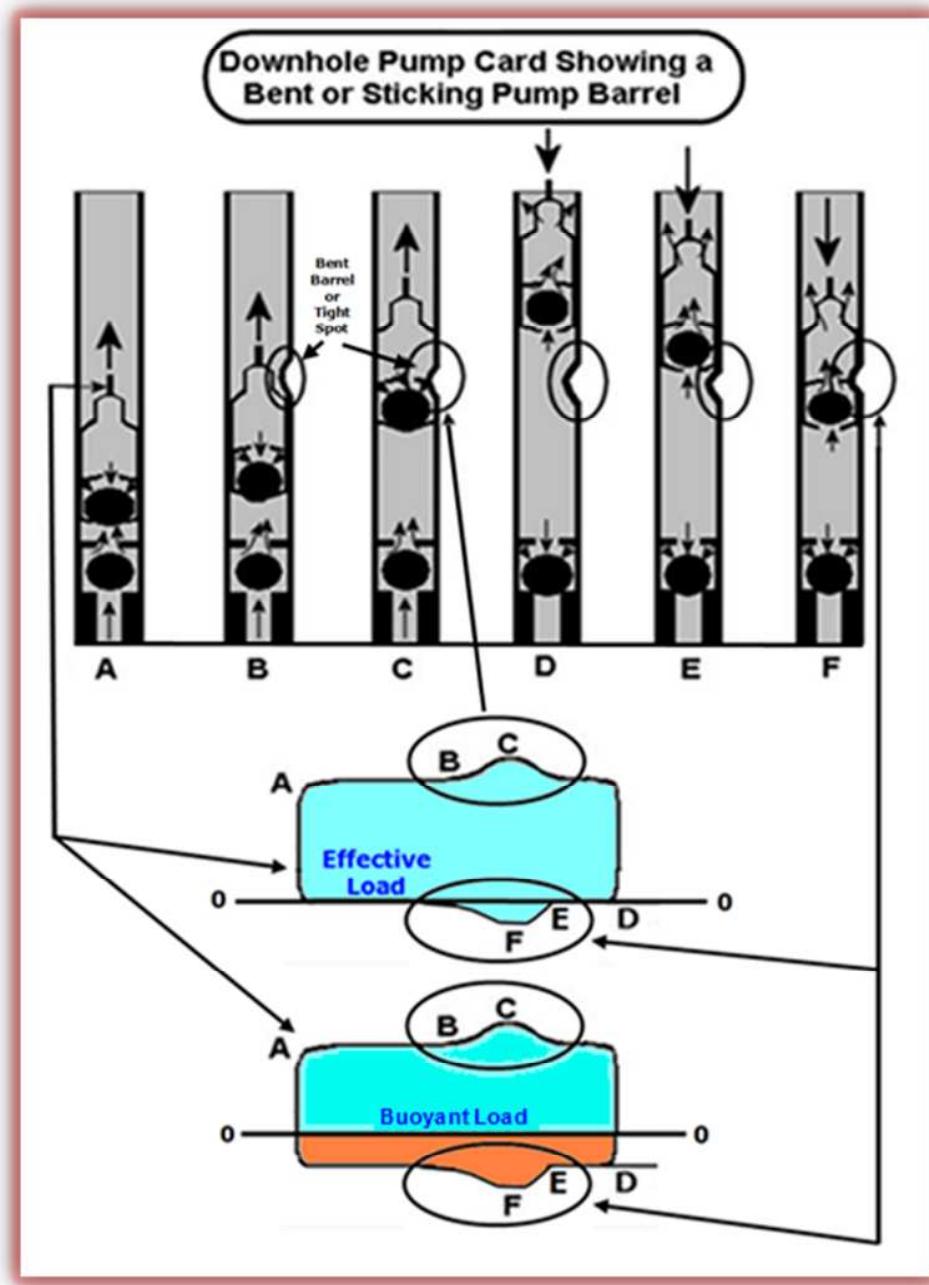
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



The graphics shown above help to explain the downhole card shape for a bent or sticking pump barrel.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Detailed Description

1. At point "A", the plunger is below the bent section and the load on the pull rod is the same as for a full pump.
2. At point "B", as the plunger reaches the "bend", the load on the pull rod increases because the plunger must "squeeze" by this portion of the pump barrel.
3. At point "C", the load reaches a maximum value and then decreases as the plunger moves away from the bend.
4. On the downstroke, the load on the pull rod is normal until the plunger reaches the "bad" spot in the barrel at point "E".
5. The load on the pull rod decreases until the plunger reaches point "F".
6. The pull rod load returns to normal after the plunger moves away from the bent portion of the pump barrel.

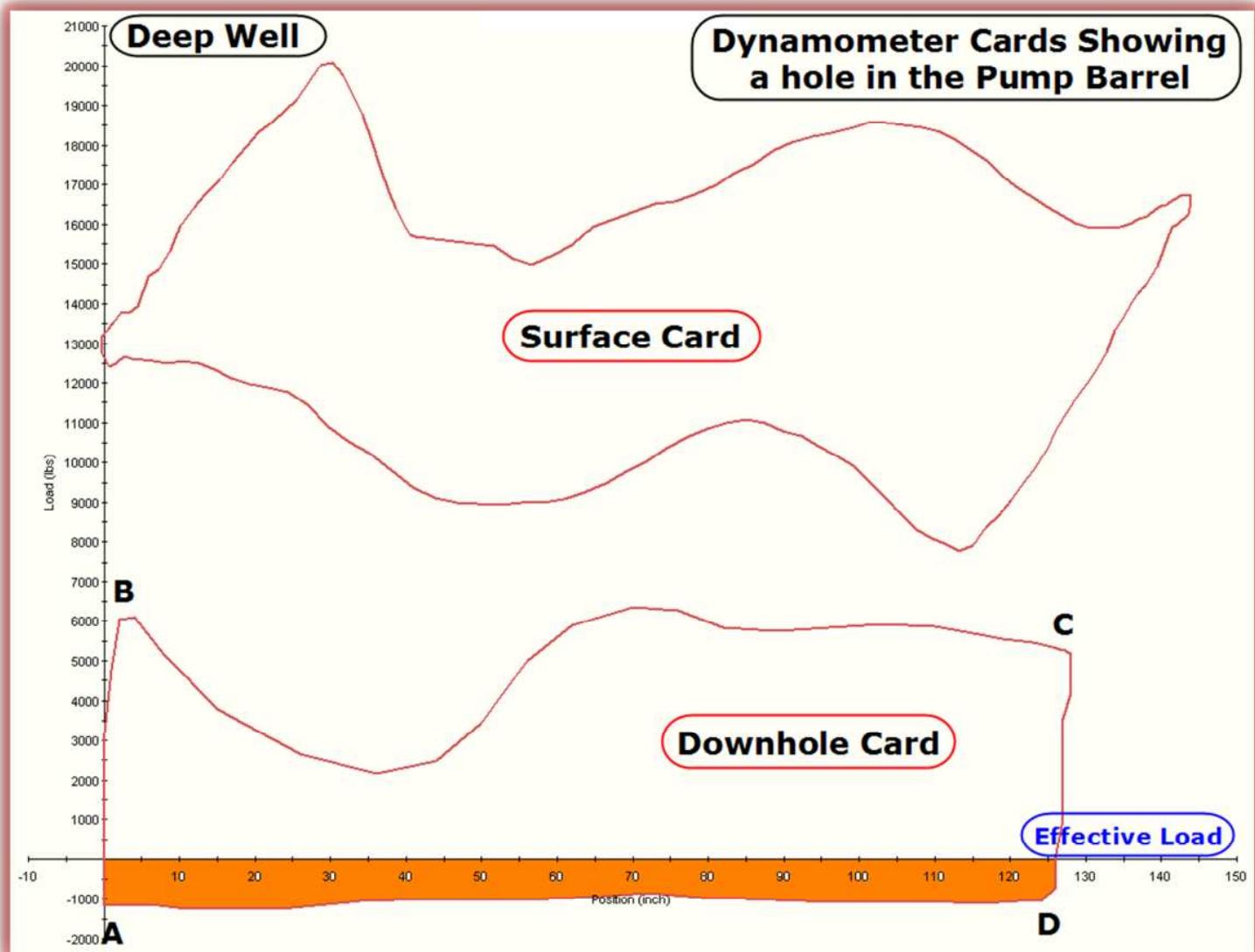


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

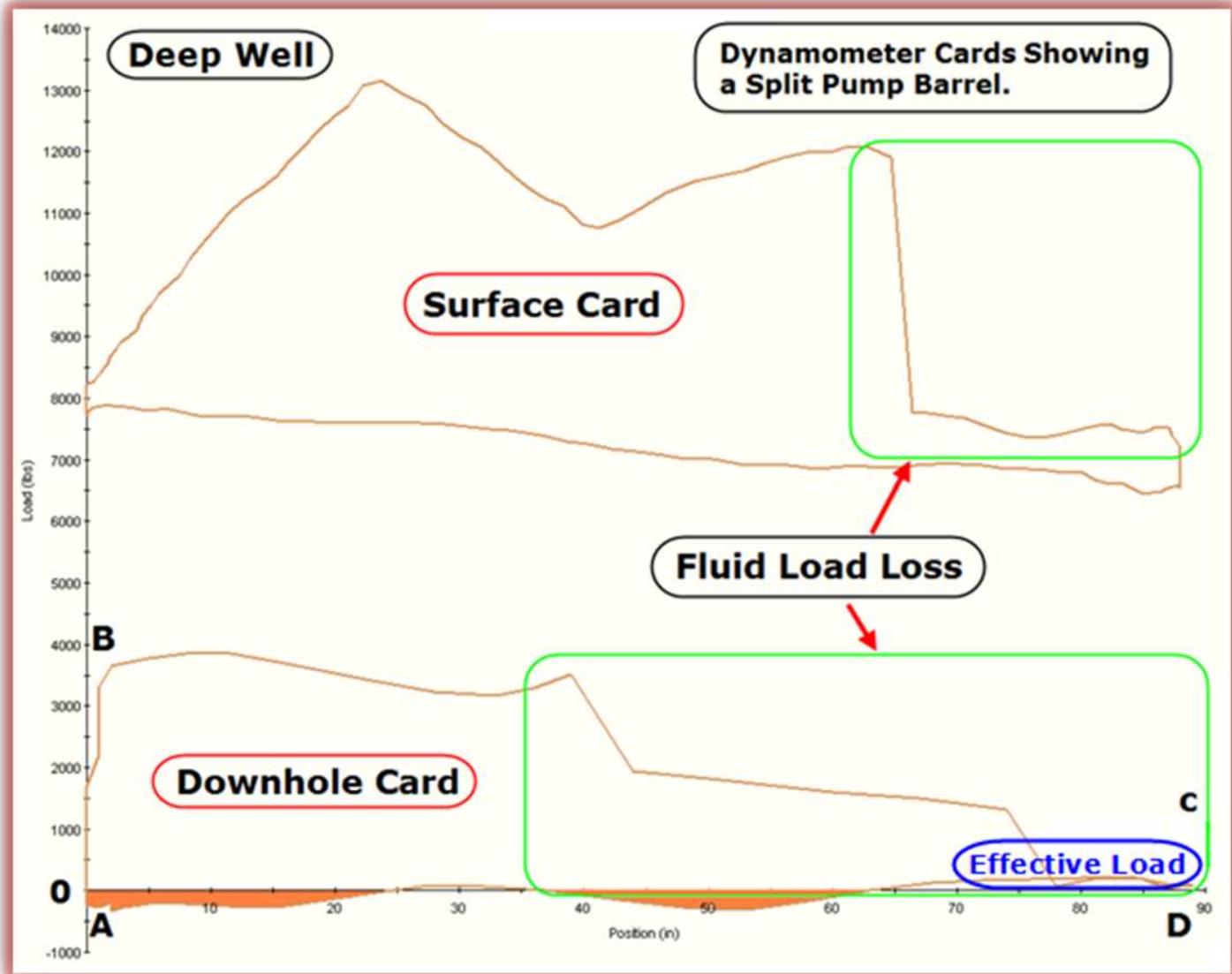
DH Cards – ‘Hole in the Pump Barrel’ / ‘Split Barrel’



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



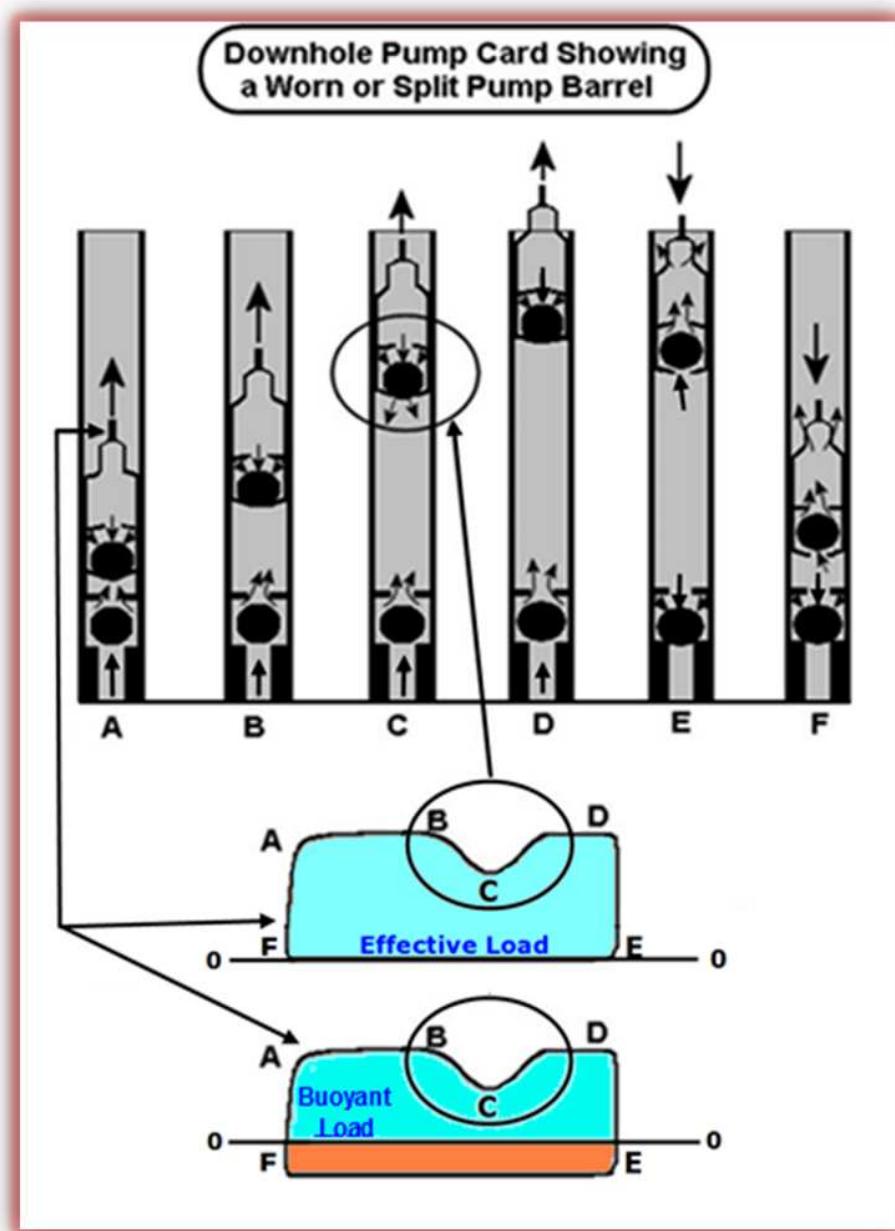
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



☞ The graphics shown above helps to explain the downhole card shape for a worn or split pump barrel.



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Detailed Description

1. From point "A" to the worn place in the barrel, the load on the pull rod is normal.
2. At point "C", as the plunger moves through the bad portion of the barrel, fluid leaks by the plunger and causes the load to decrease on the pull rod.
3. At point "D", a good seal is again established between the plunger and the pump barrel.
4. On the downstroke, as long as the traveling valve remains open, the load on the pull rod appears to be normal.
5. If, however, the pump barrel is worn, it is possible that a corresponding load increase will occur at the same place on the downstroke – if the worn spot causes enough pressure loss in the pump barrel for the traveling valve to start picking up the fluid load.
6. The pull rod load returns to normal after the plunger moves away from the worn portion of the pump barrel.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com

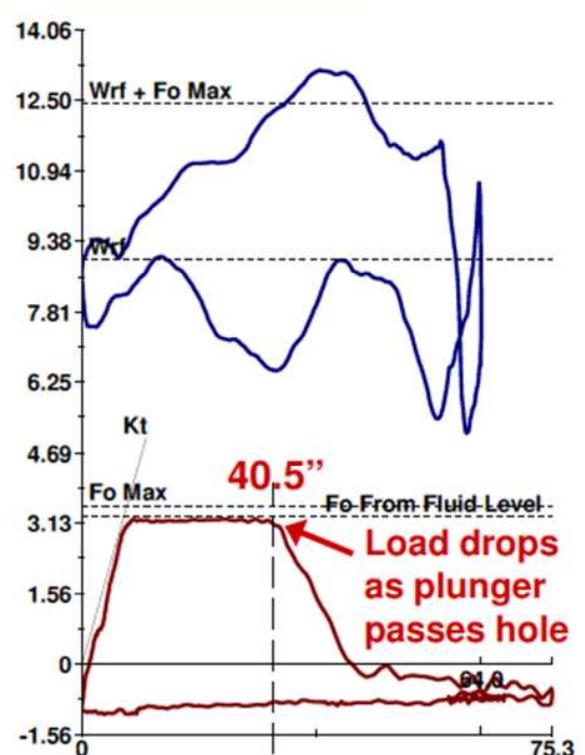


Surface and Downhole Dynamometer Card Interpretation

Hole in Pump Barrel 40.5 Inches From Bottom



Hole in pump barrel
due to corrosion



On upstroke fluid load is suddenly lost when bottom of the plunger goes past the hole, causing a much longer downhole stroke (over travel).

((((ECHOMETER))))

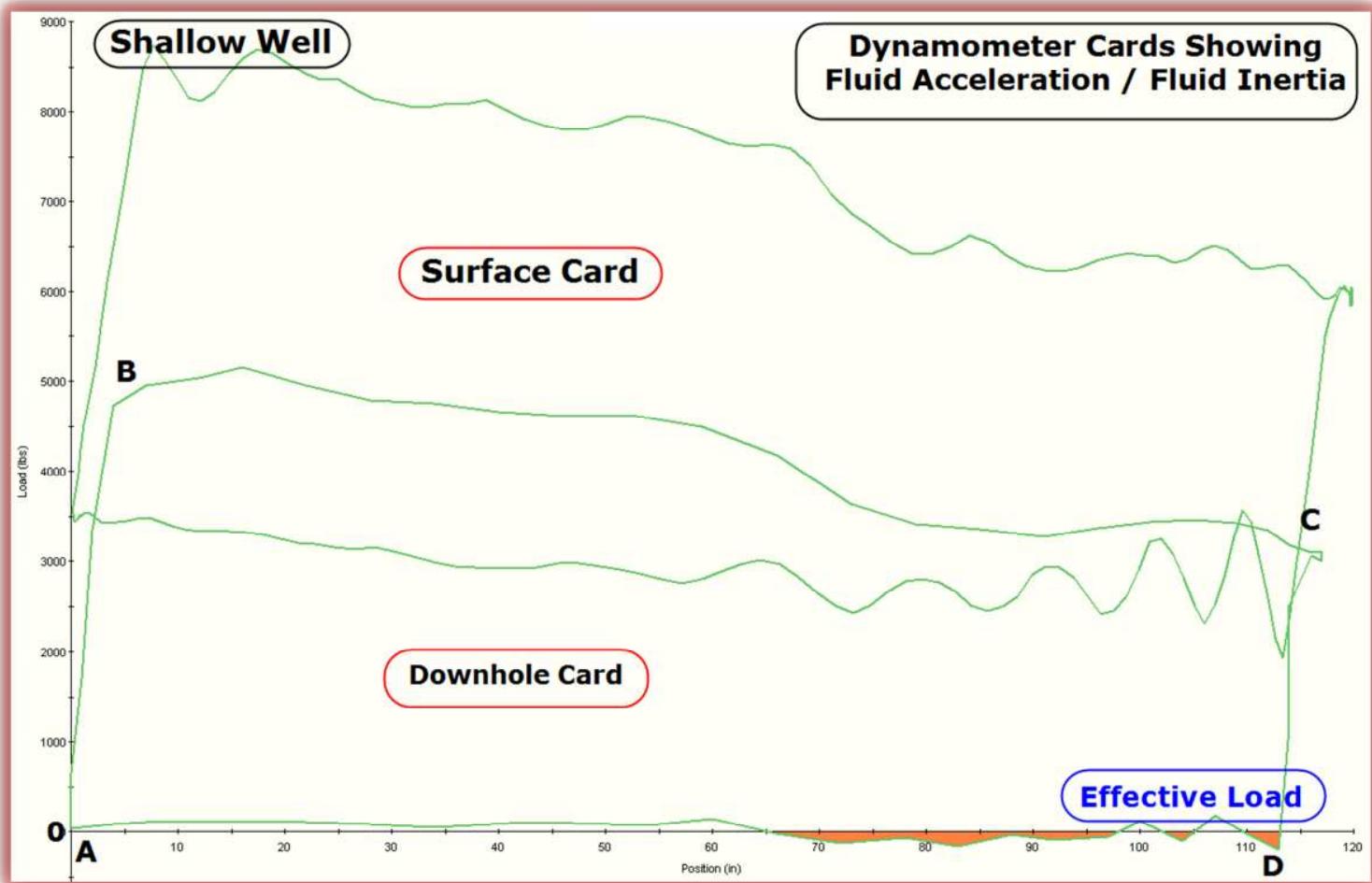


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

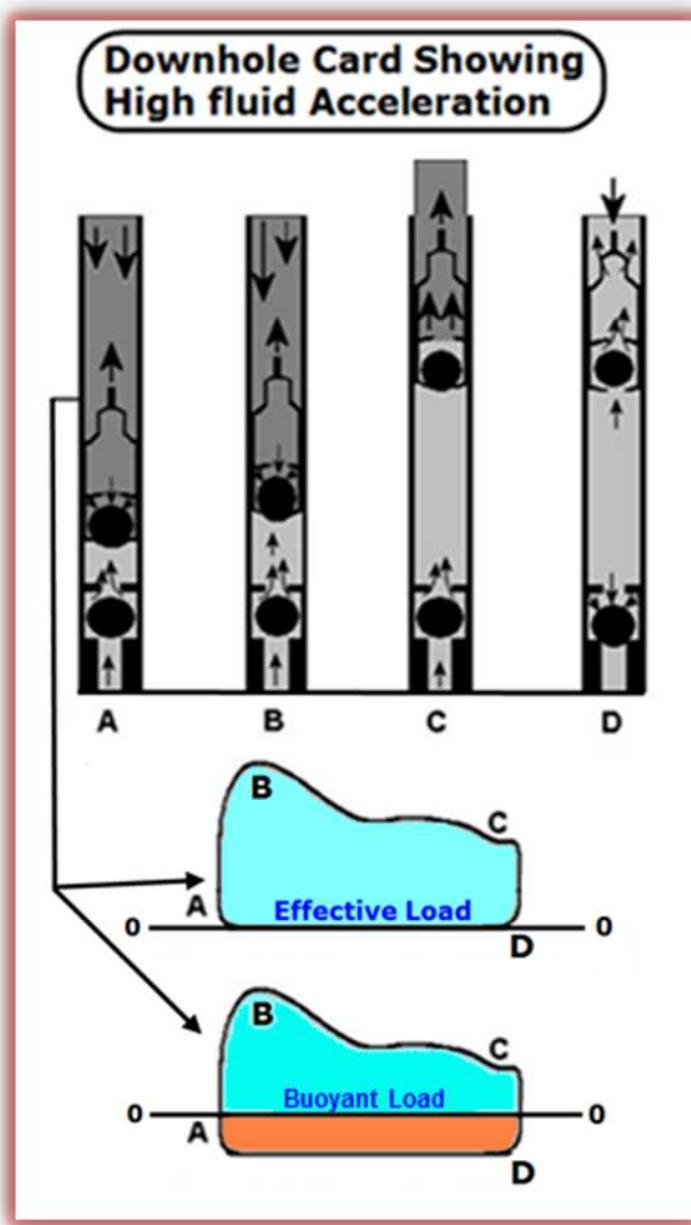
DH Cards – ‘Fluid Inertia’ / ‘Fluid Acceleration’



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



☞ The graphics shown above help to explain the downhole card shape for a full pump experiencing fluid inertia effects. This card shape is representative of wells with large pump plungers, of shallow pumping depth (less than 4000'), and a high water cut.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com

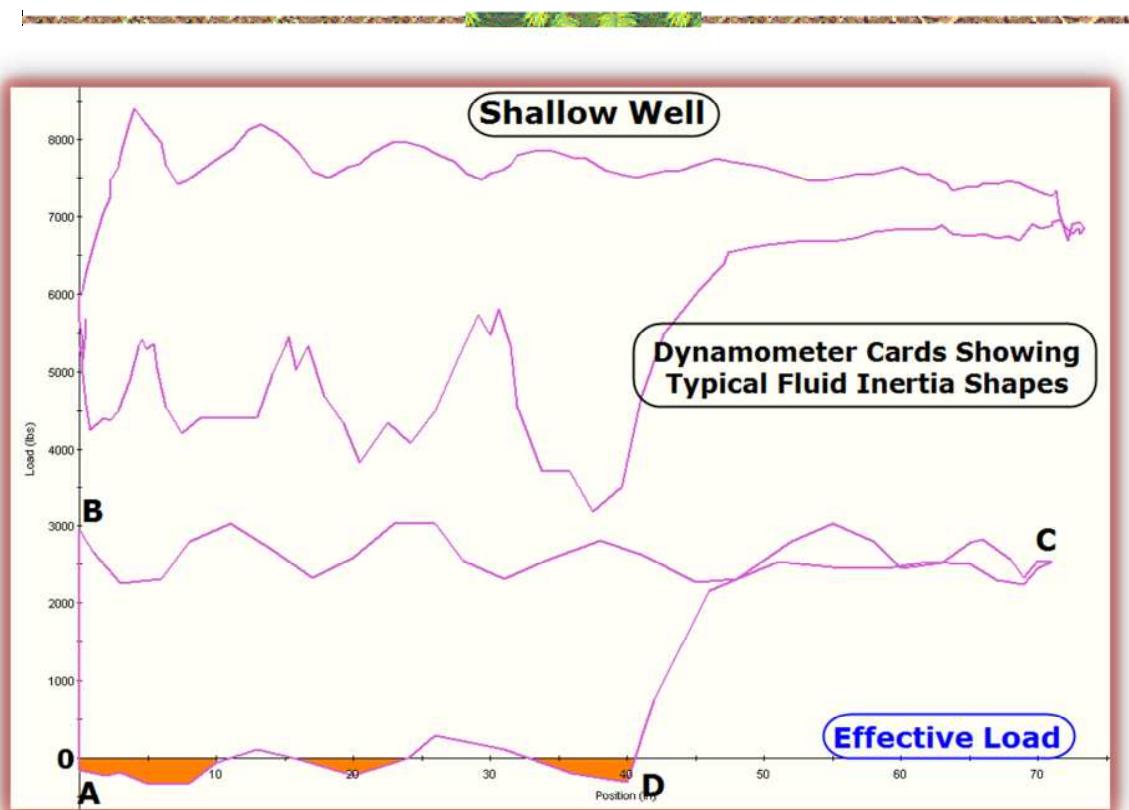


Surface and Downhole Dynamometer Card Interpretation

Detailed Description



1. From points "A" to "B", the inertia of the fluid in the tubing causes the load on the pull rod to increase as the plunger moves on the upstroke and "accelerates" the fluid above it.
2. At point "B", the load on the pull rod reaches a maximum value.
3. Between points "B" and "C", the pressure "pulse" travels up the fluid column and the pull rod drops – until the pressure "pulse" travels up the tubing and reflects back down. When this "reflected" wave reaches the plunger, it increases the pull rod load, but not as much as before.
4. The pull rod load returns to normal, assuming no further reflected "pulses" are seen by the plunger.



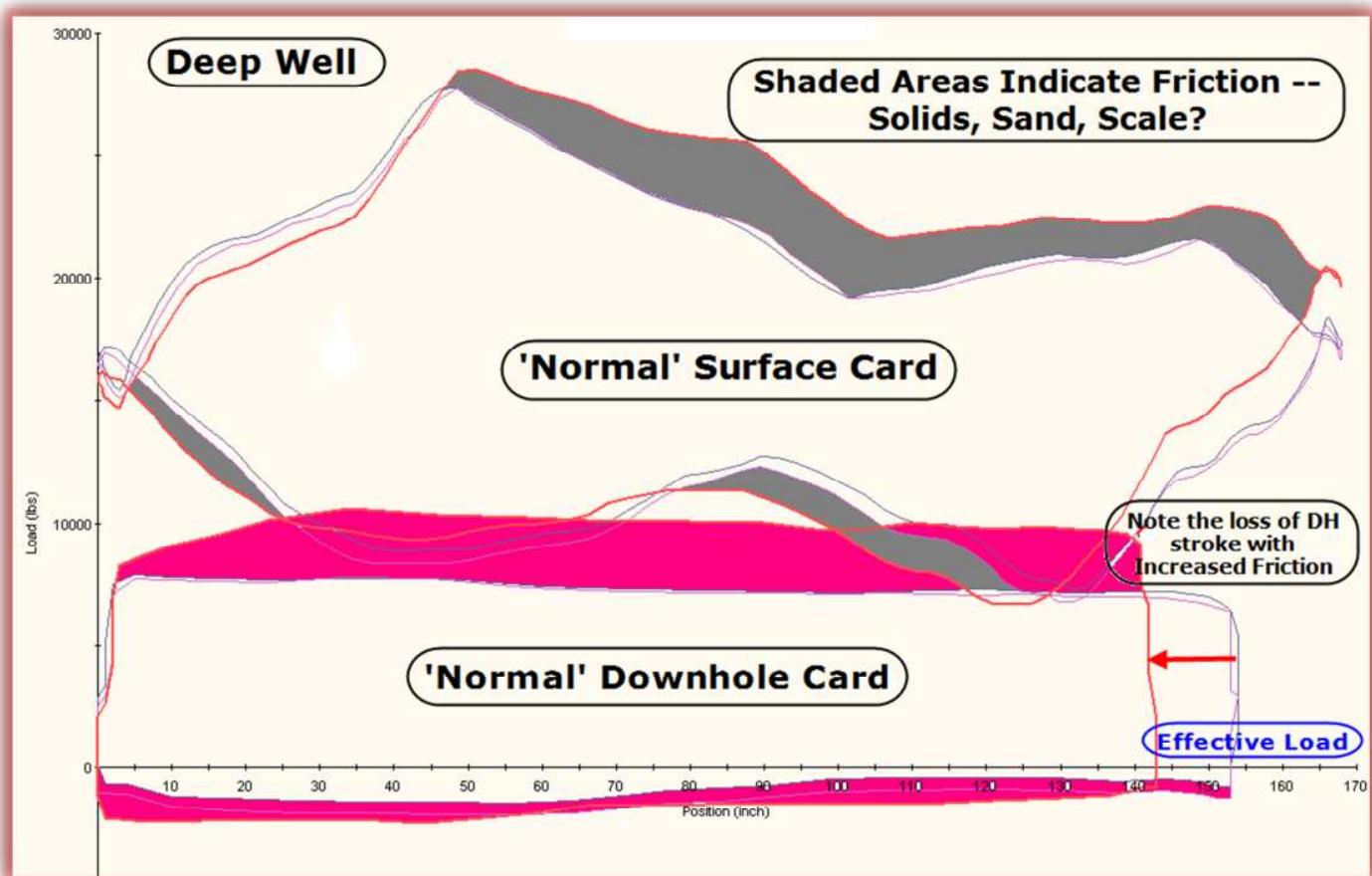
Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

DH Cards – ‘Downhole Friction’

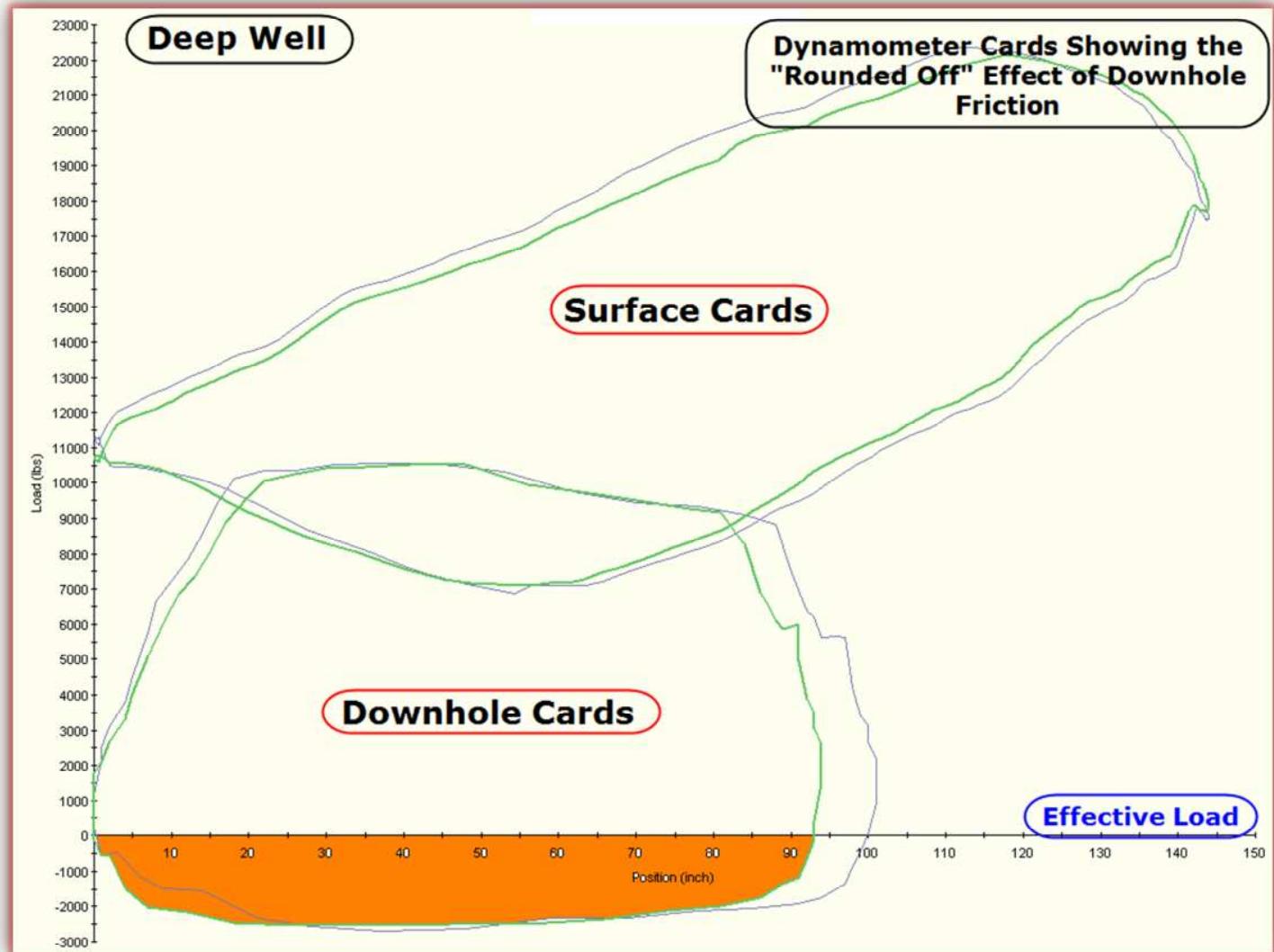
- Downhole friction adds ‘work’ to the calculated DH card – tending to ‘round’ the DH card.



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



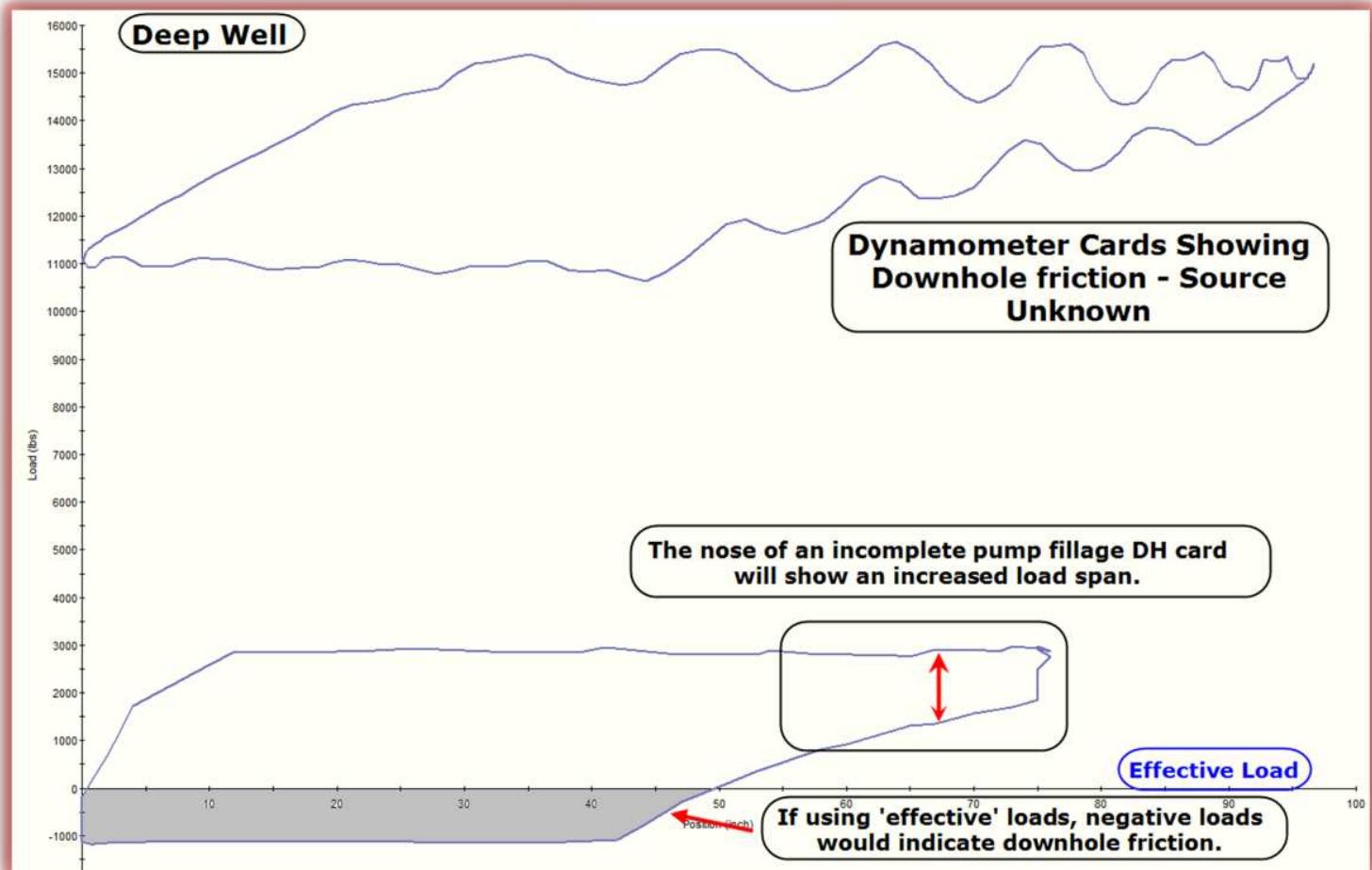
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



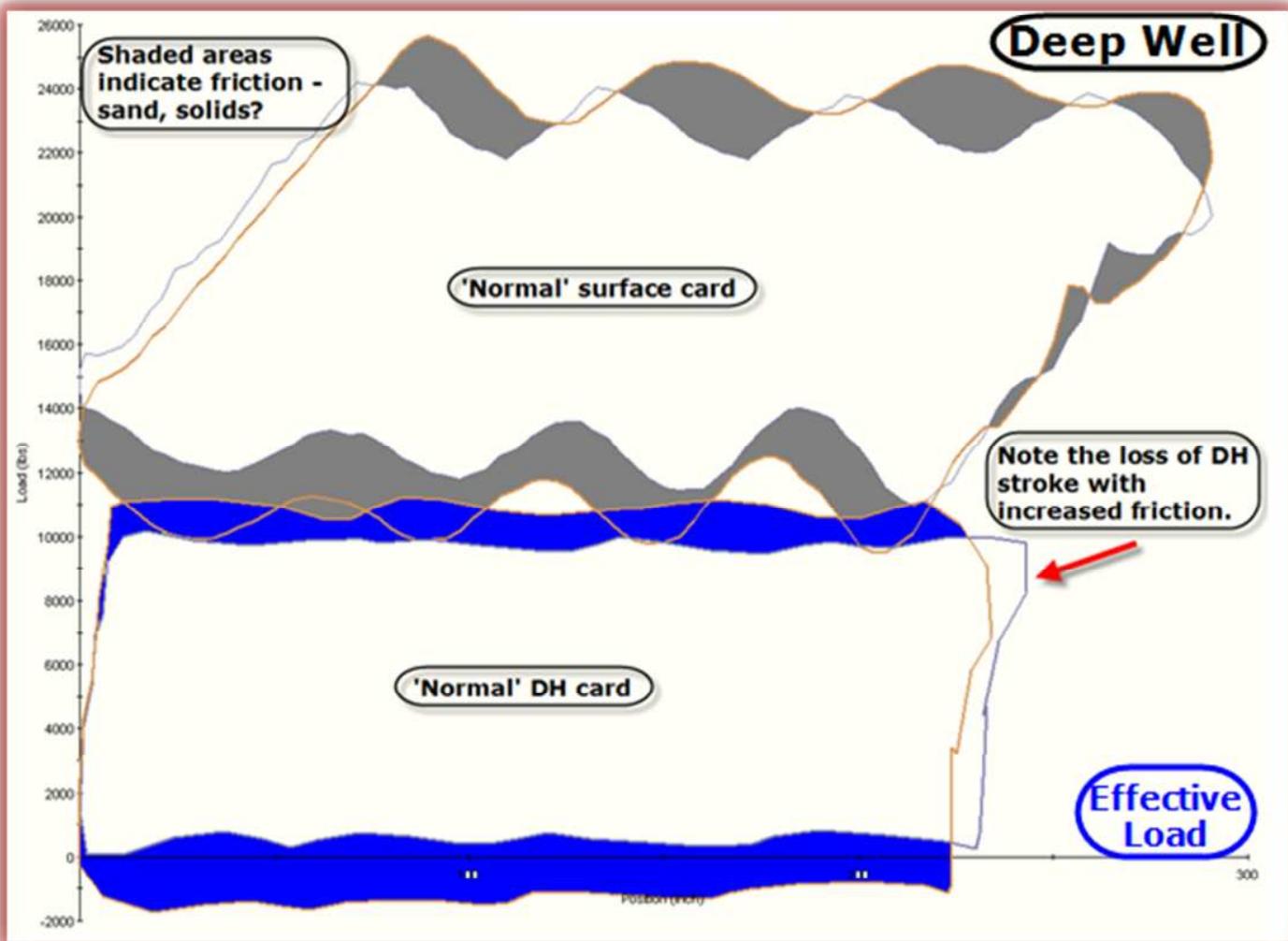
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



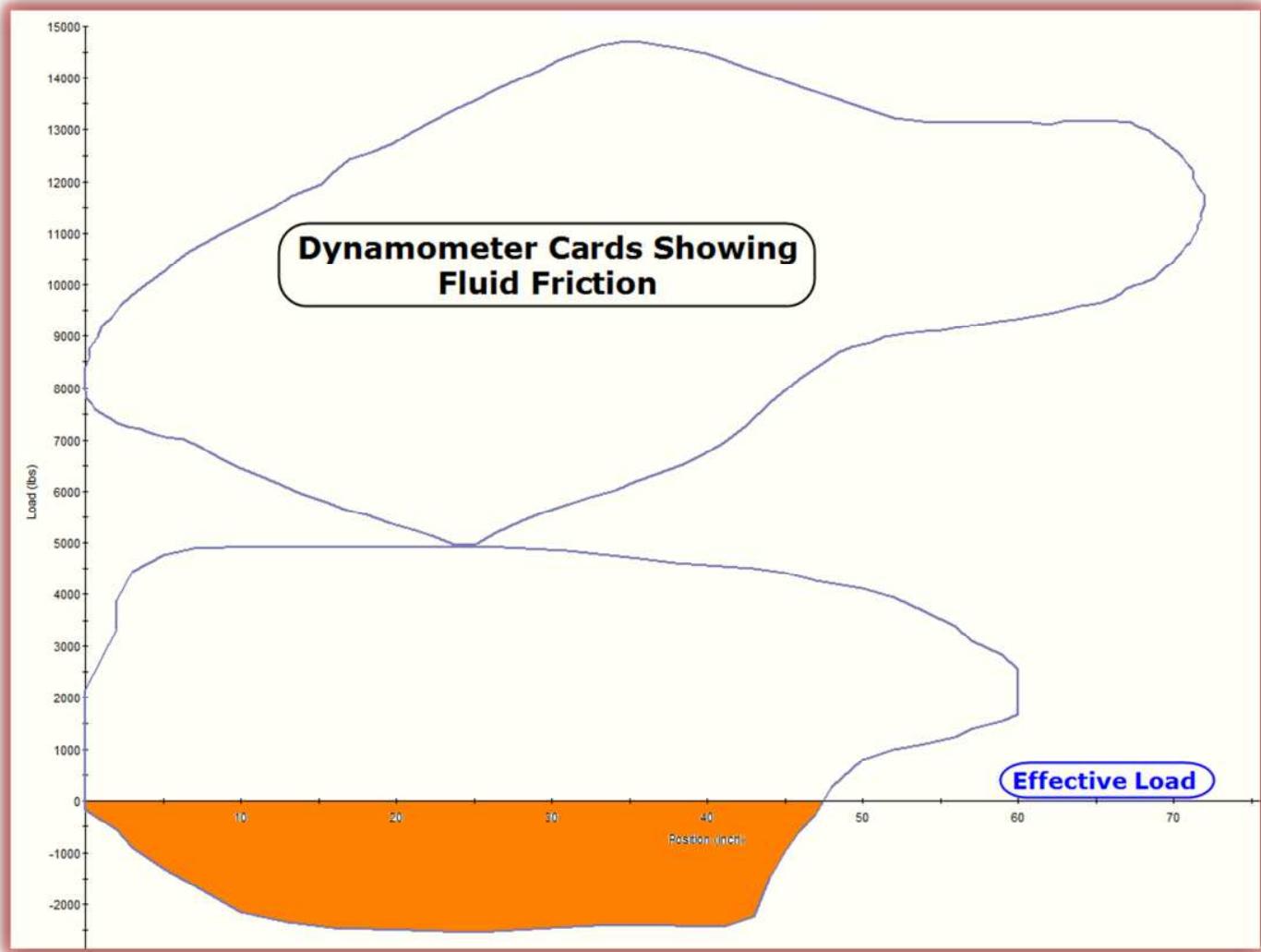
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



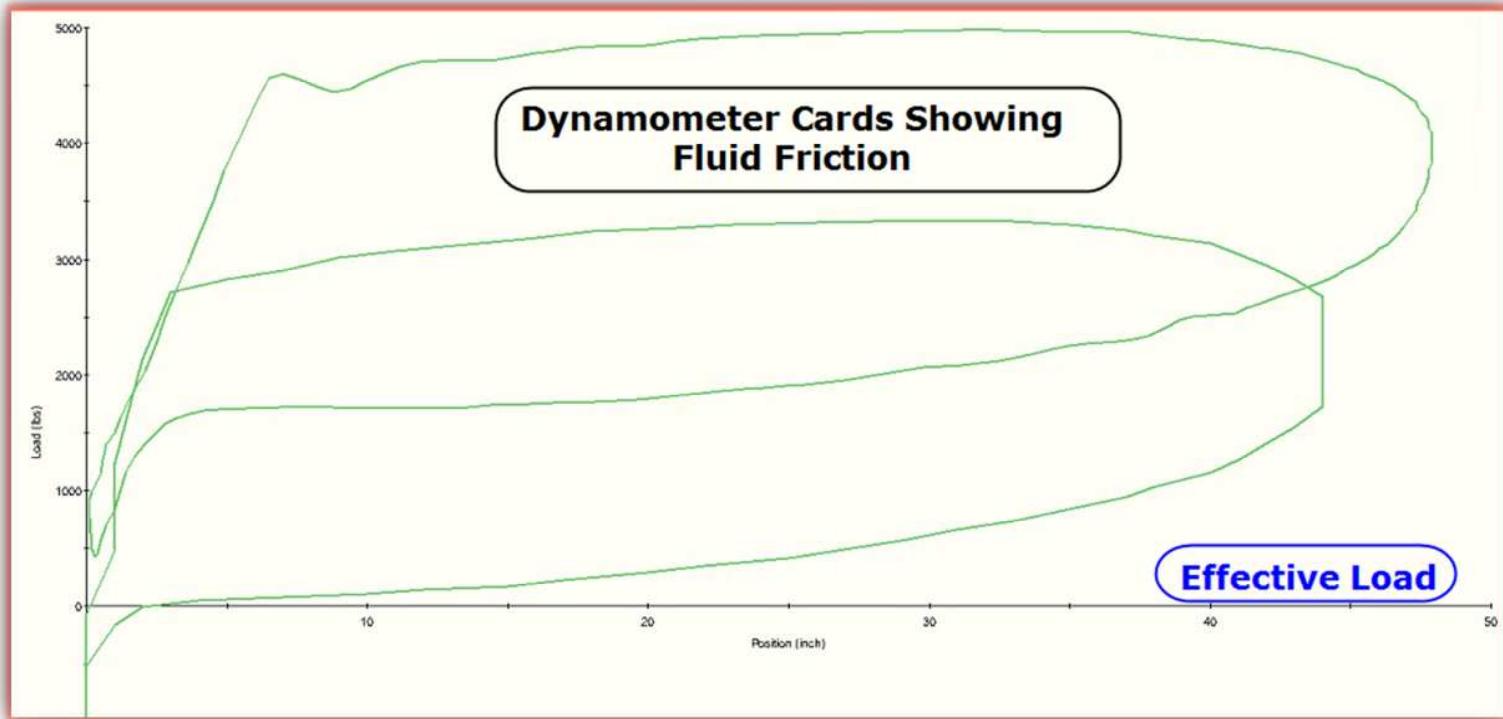
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



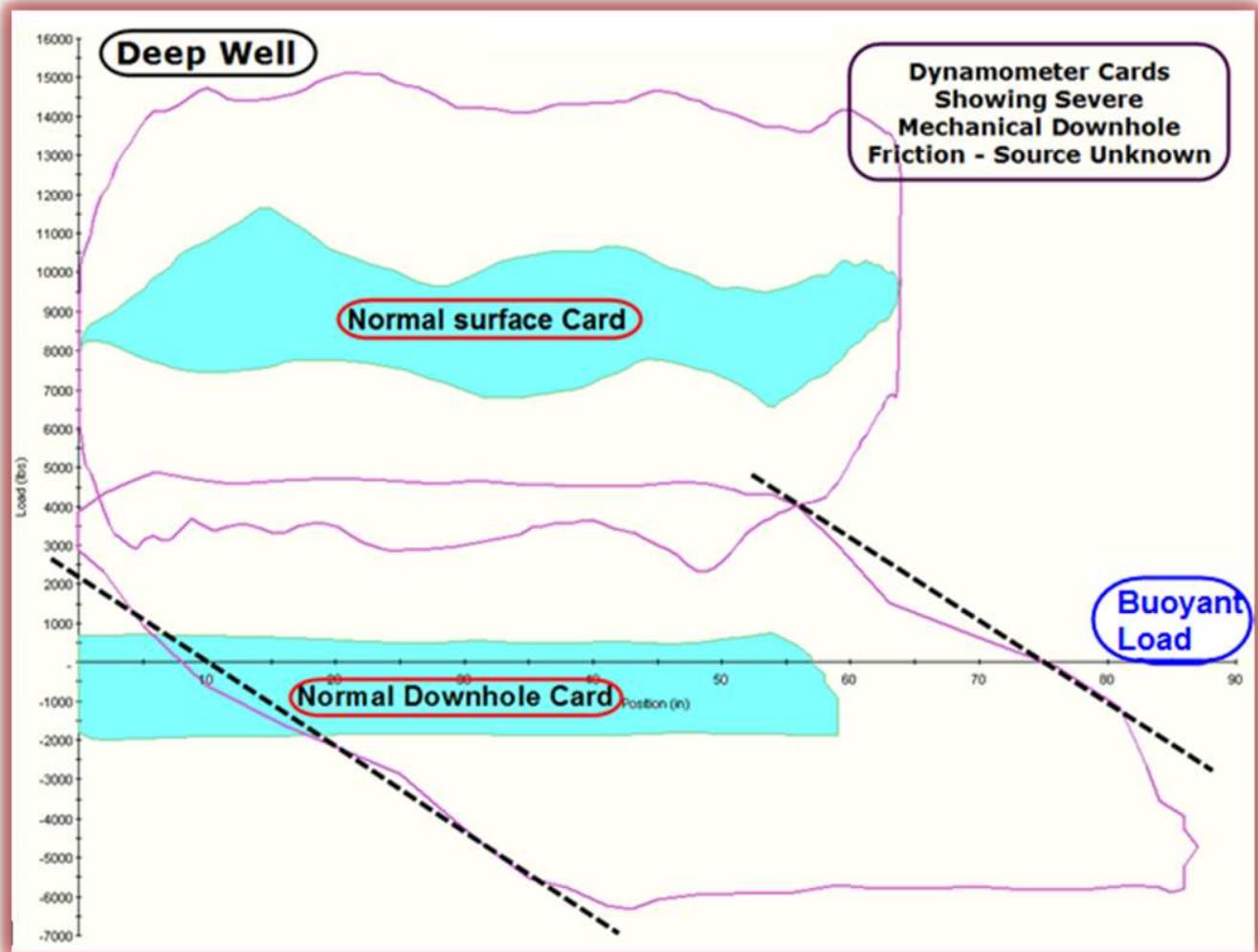
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

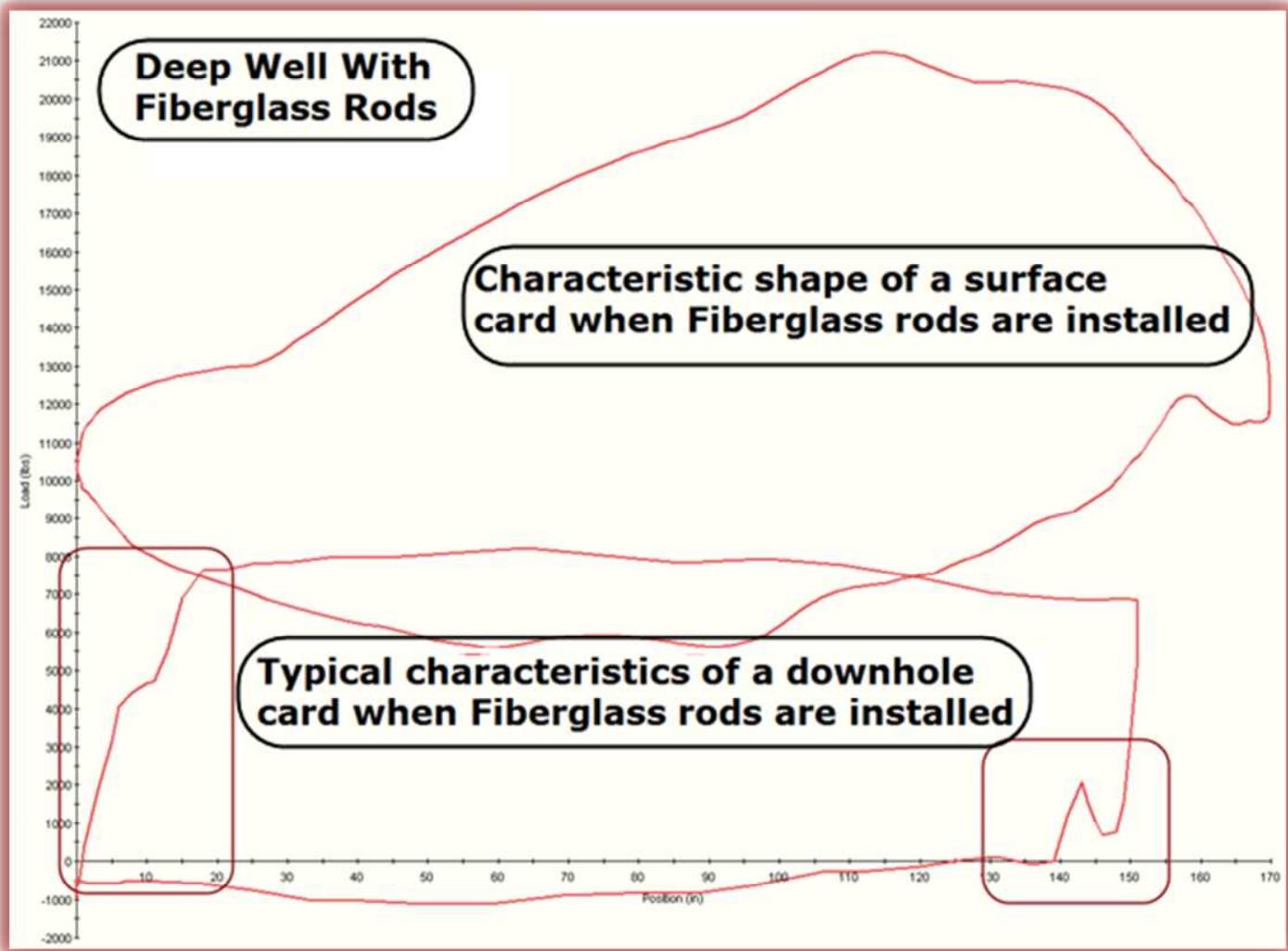


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

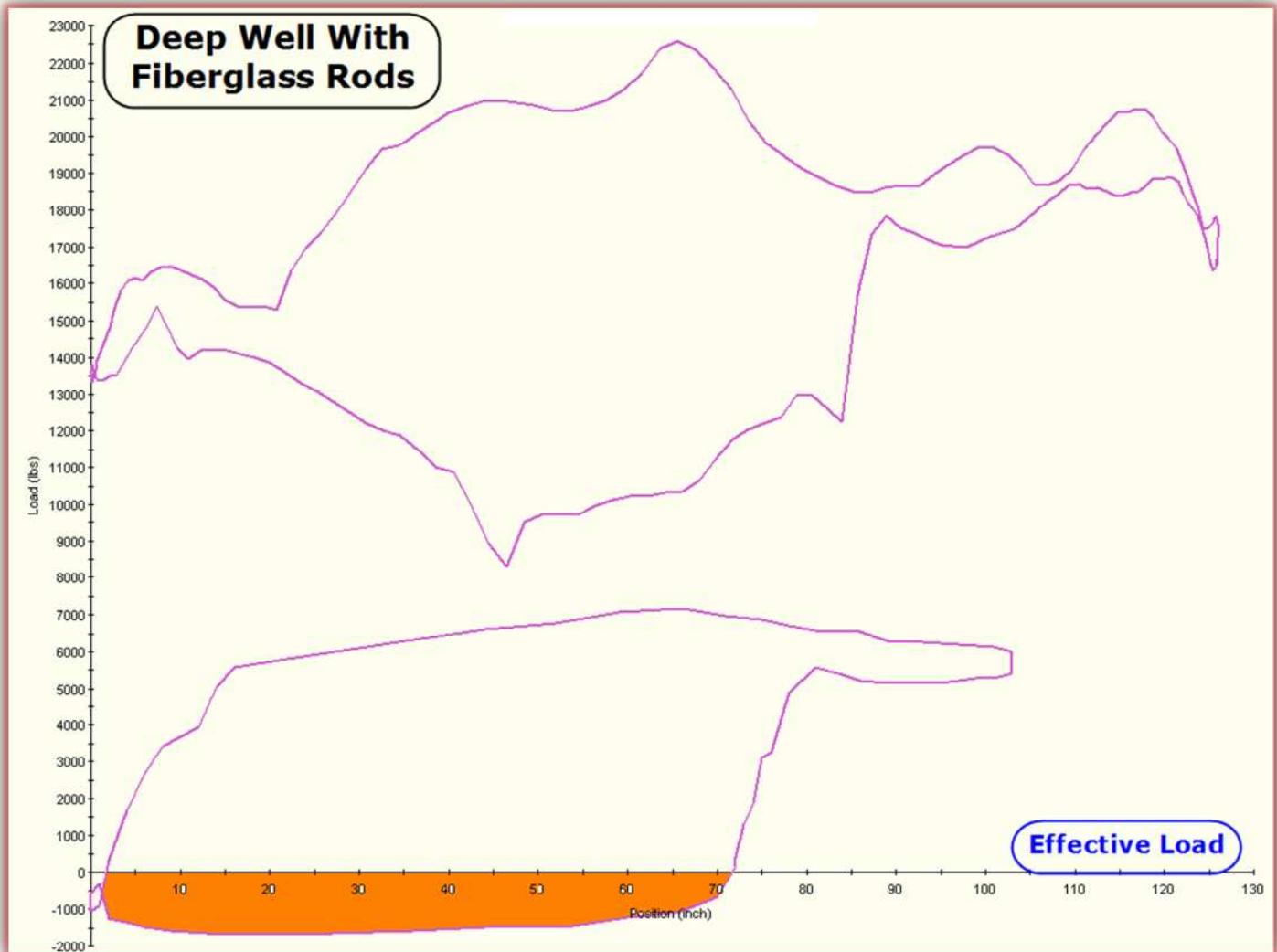
DH Cards – ‘Fiberglass’ Rod String



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



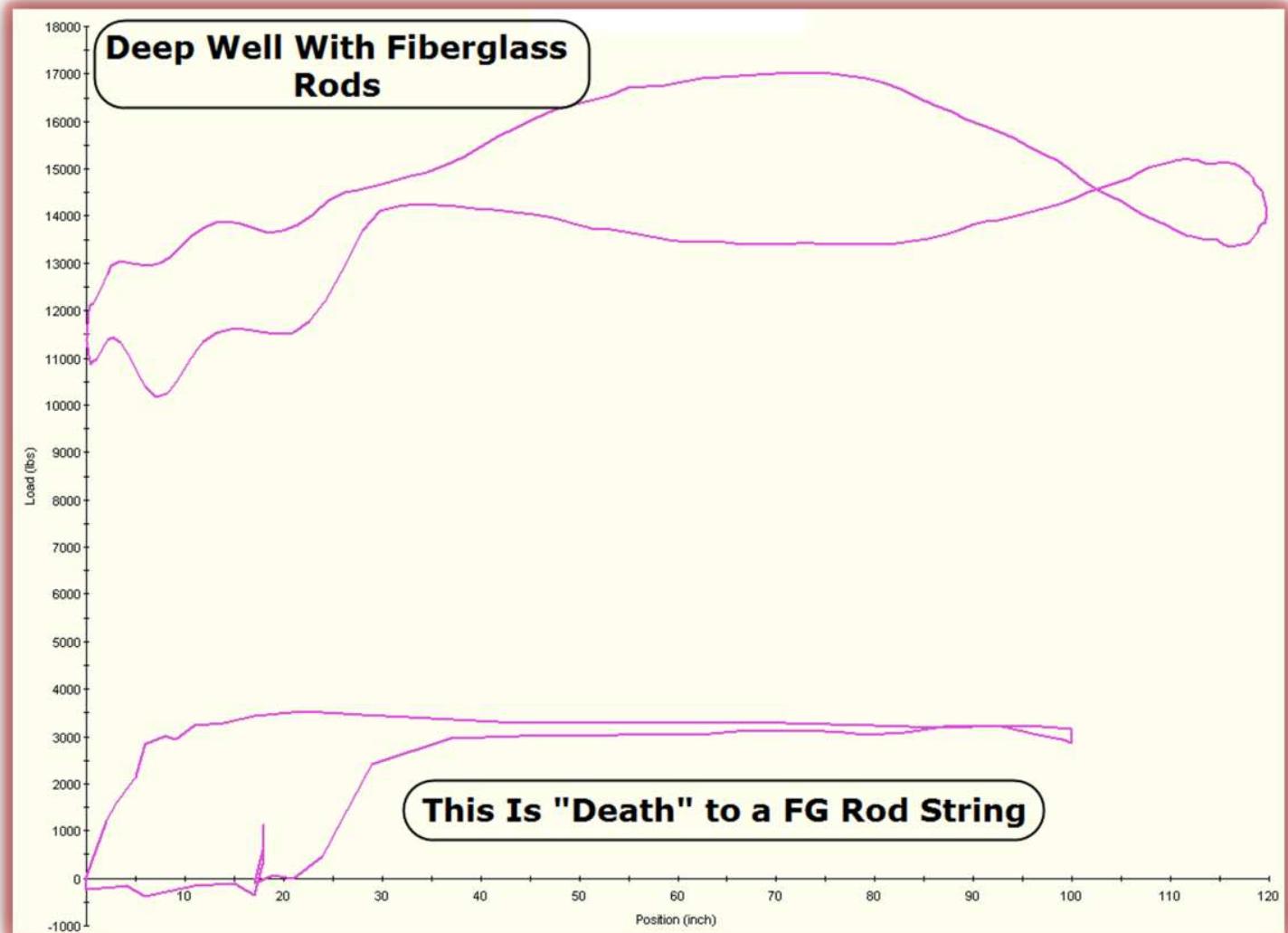
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

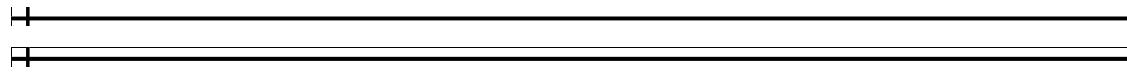
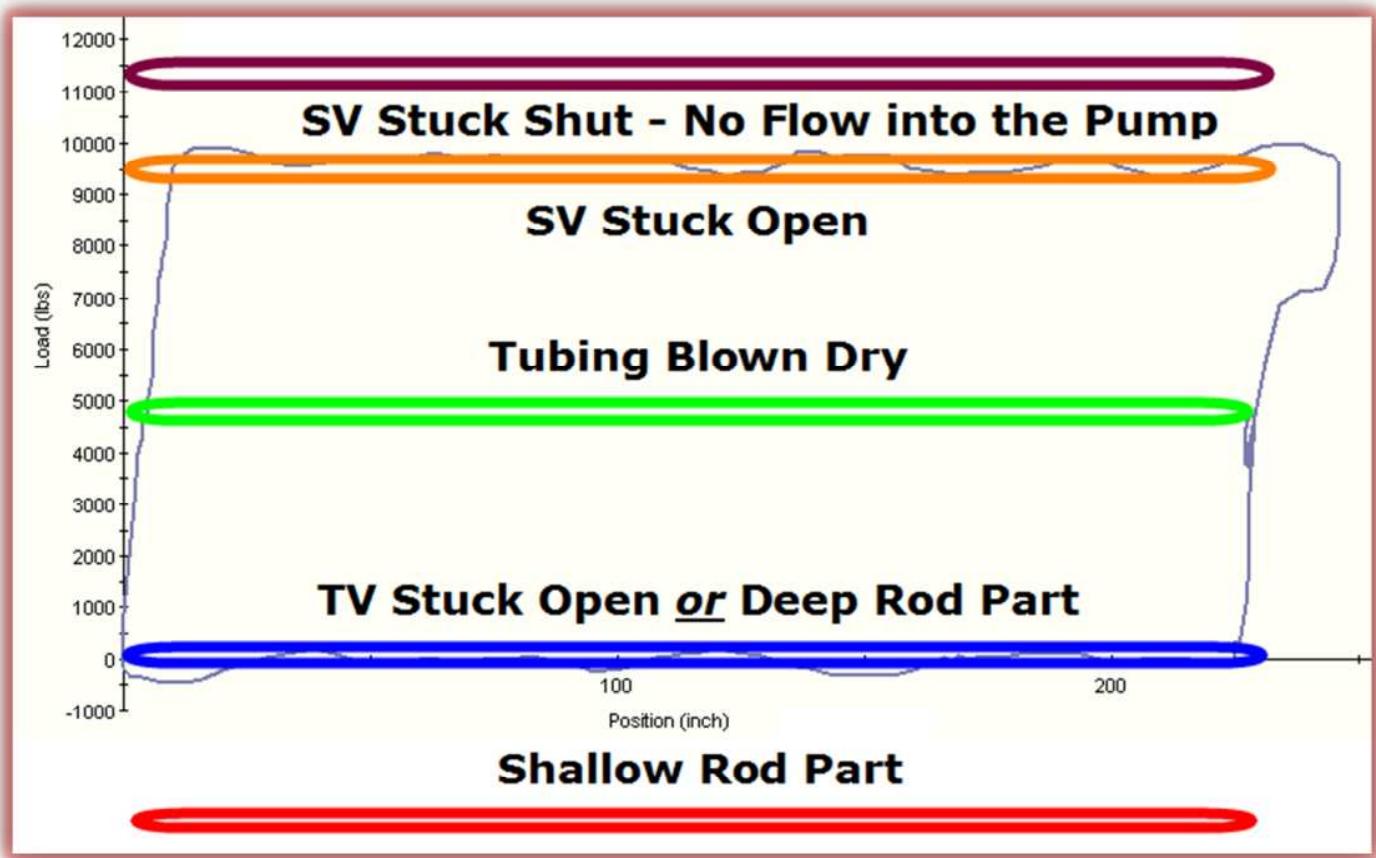


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

When Downhole Cards are 'Flat Lines'

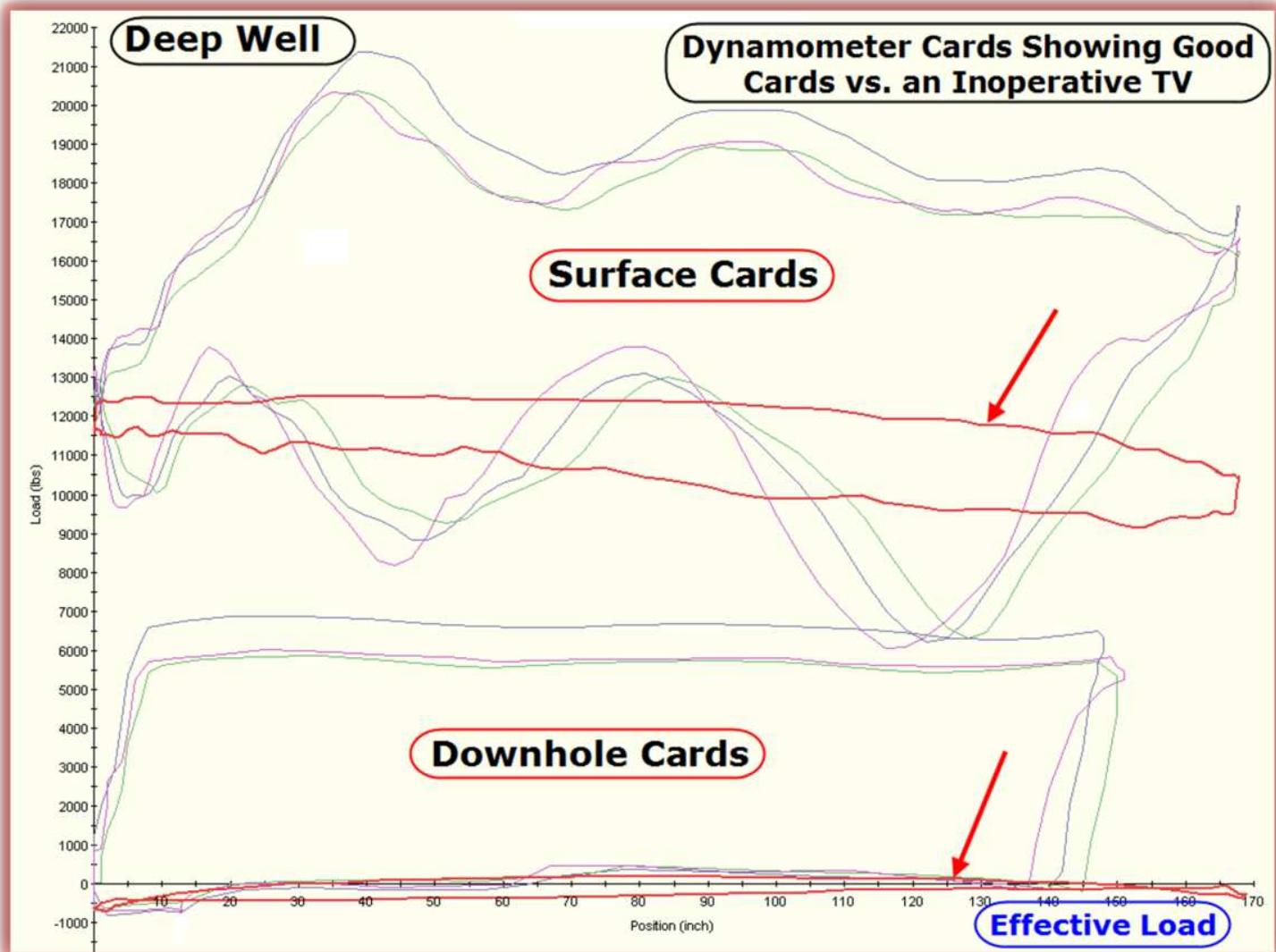


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

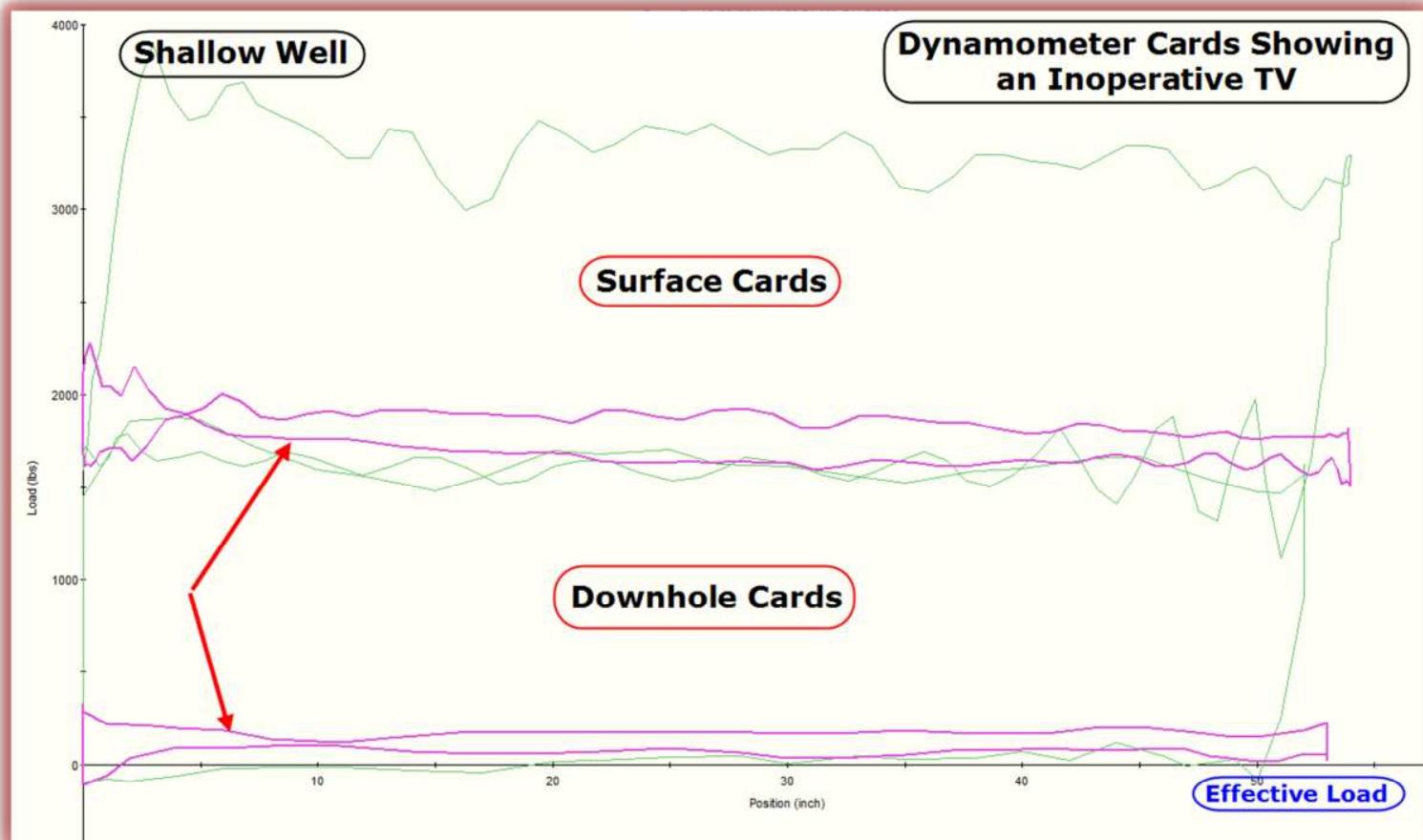
'Fouled TV' / 'Fouled SV' Examples



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



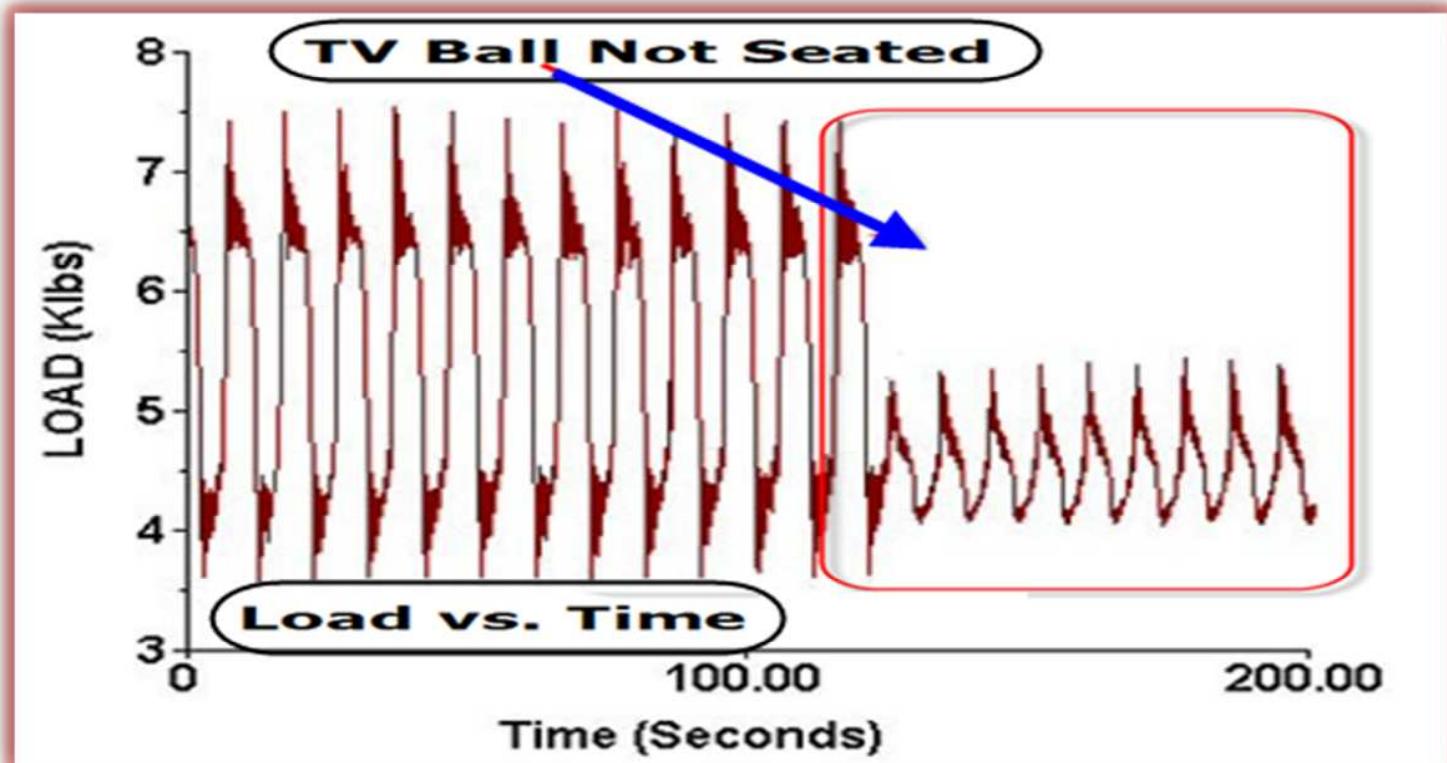
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Load vs. Time – Fouled TV

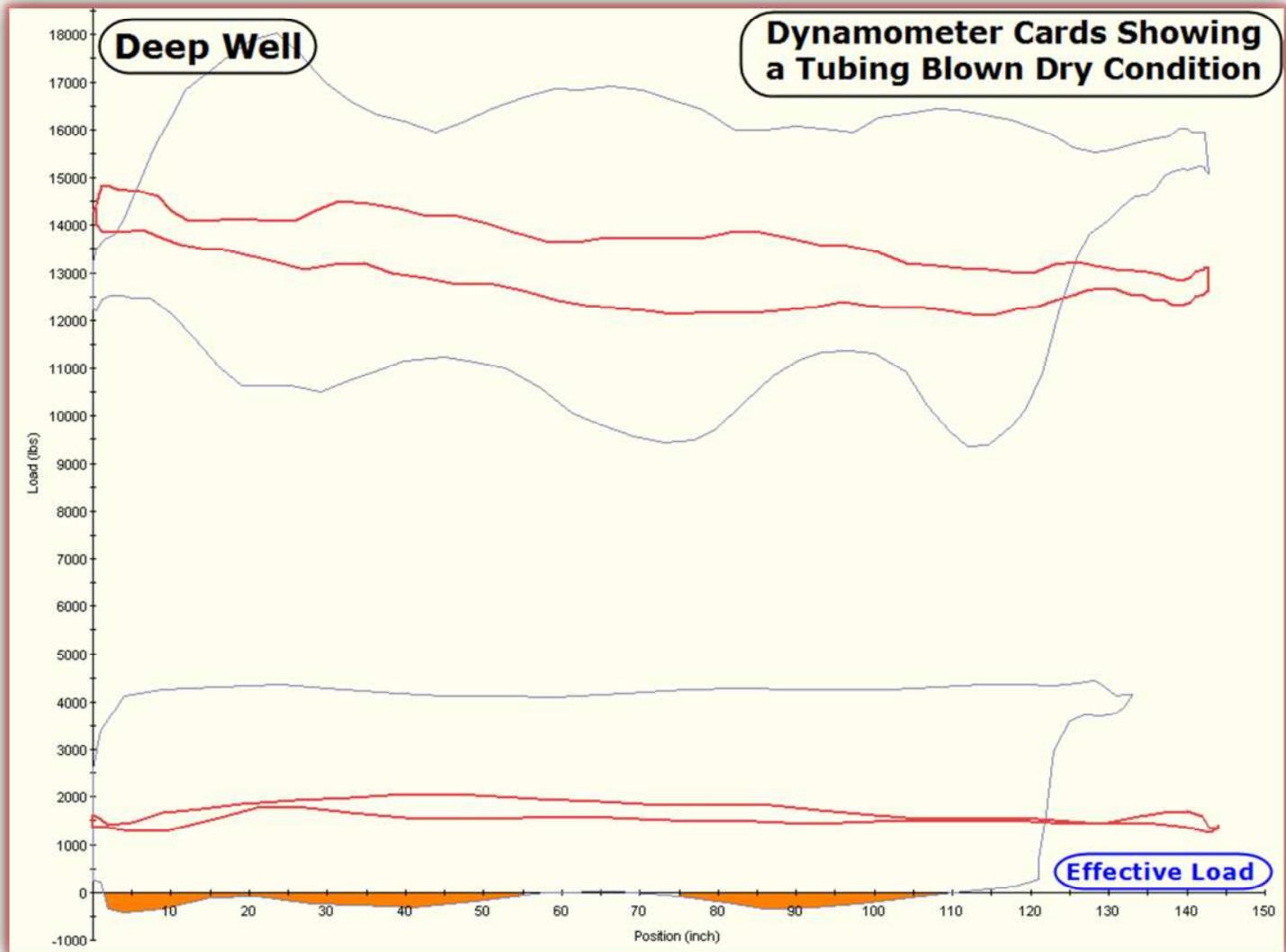
Courtesy of Echometer



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



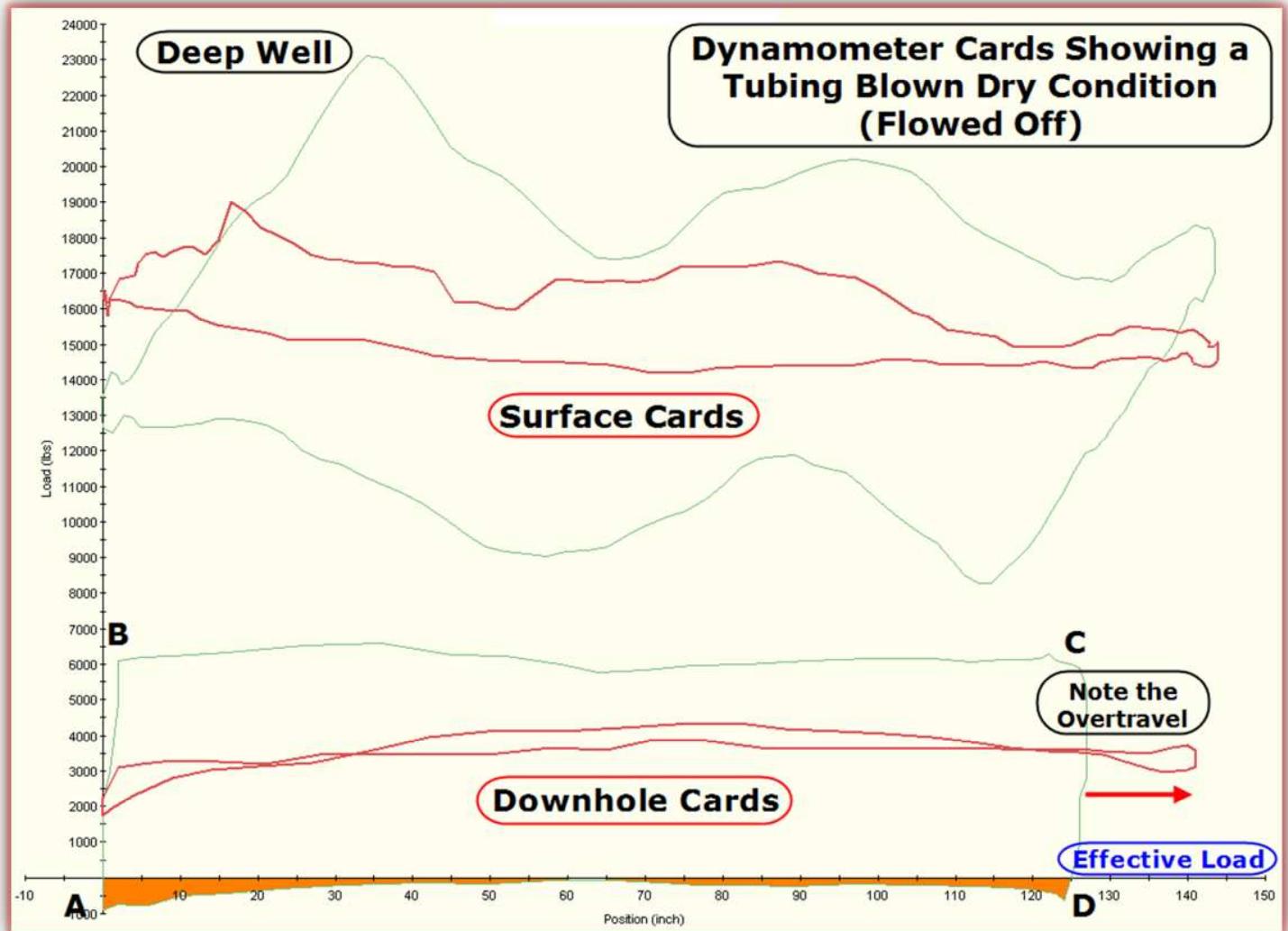
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



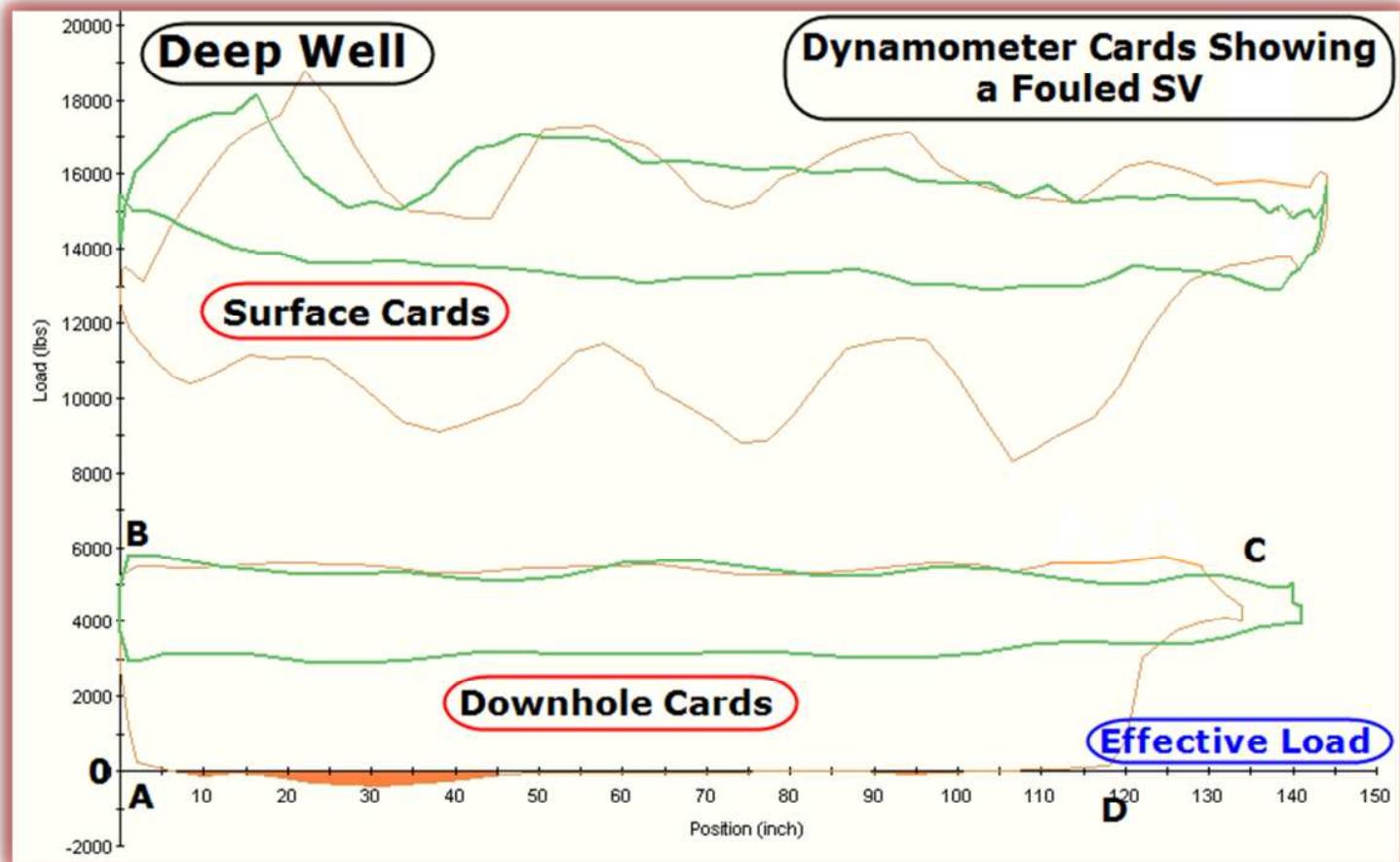
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



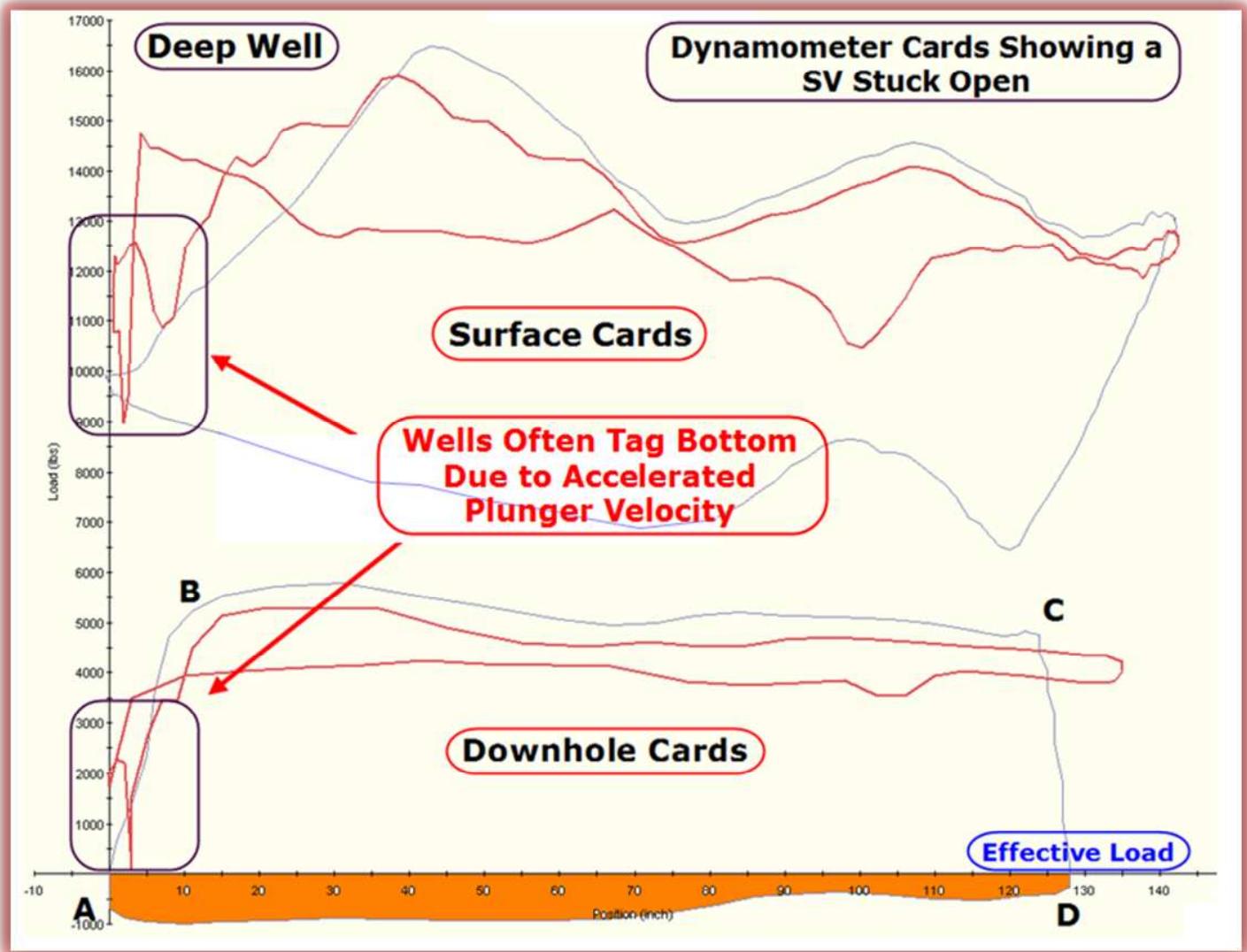
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



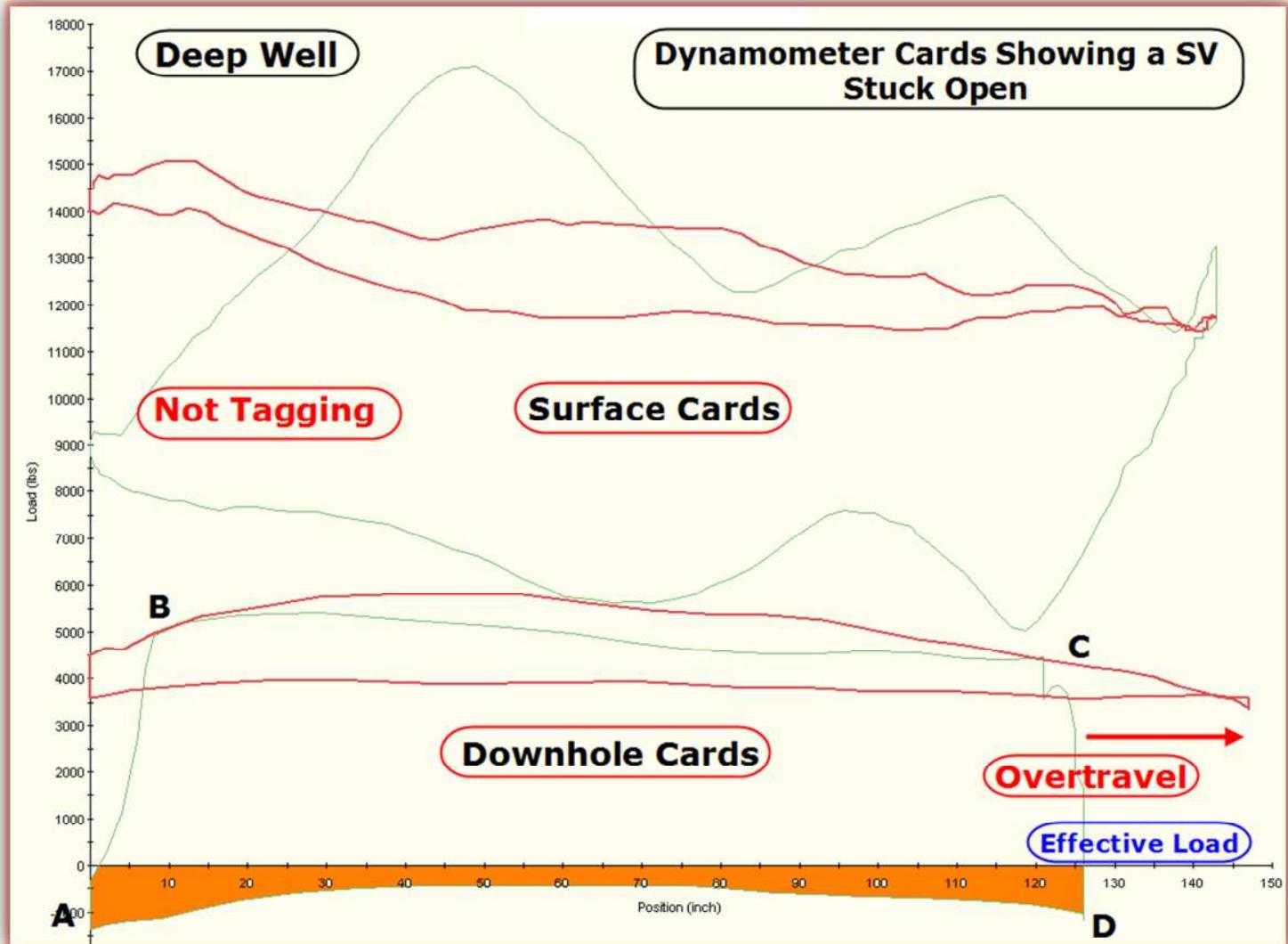
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



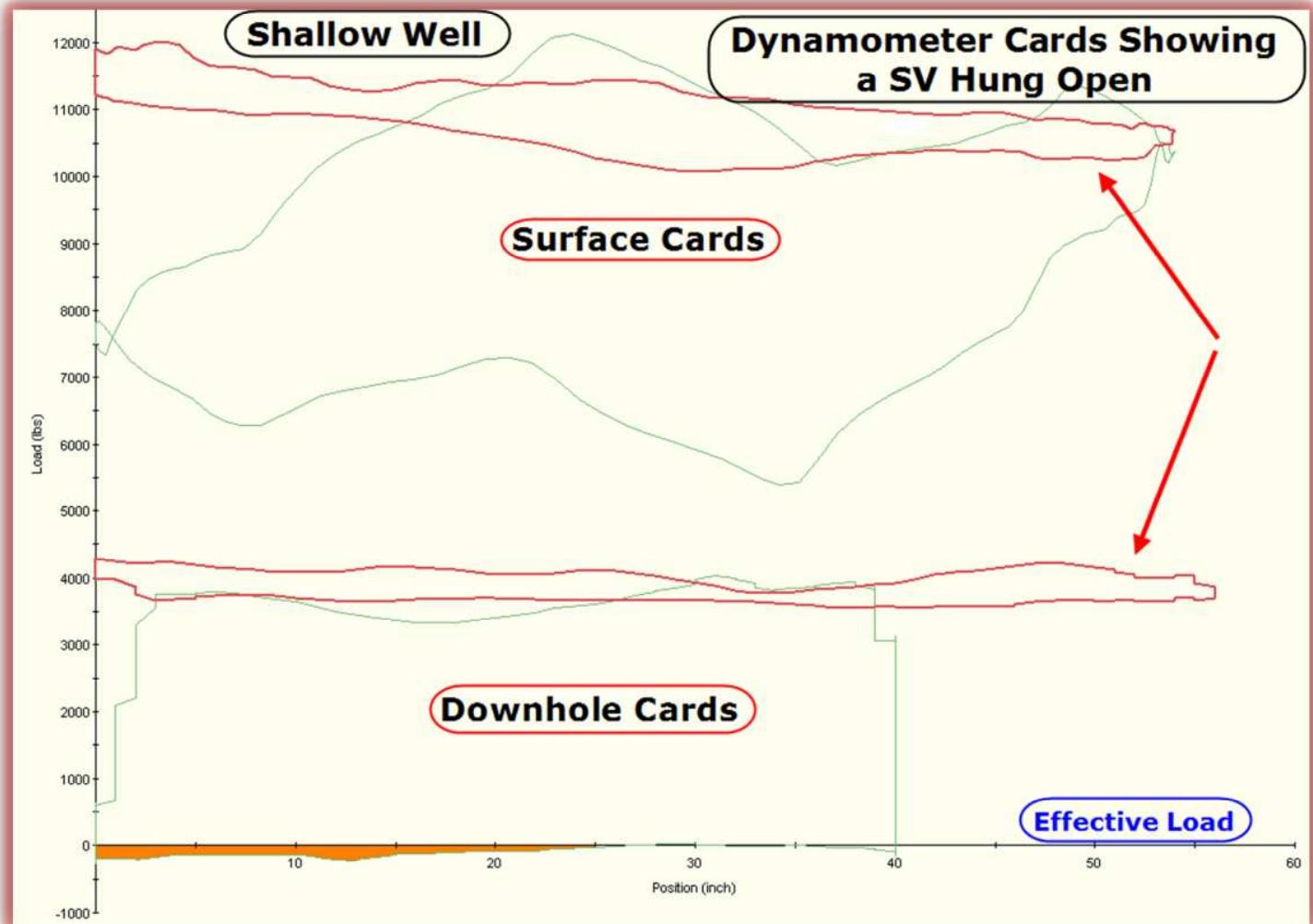
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



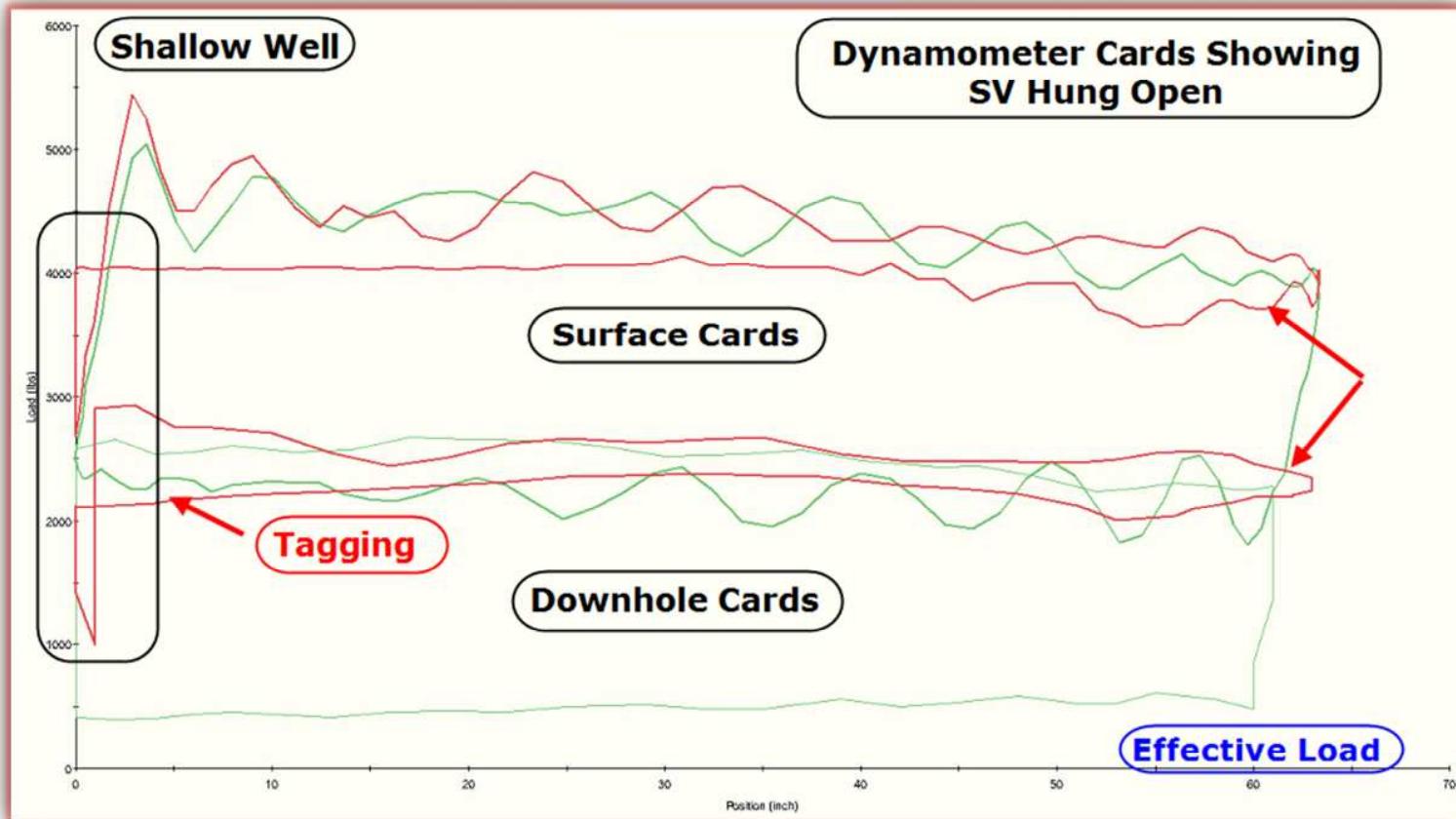
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



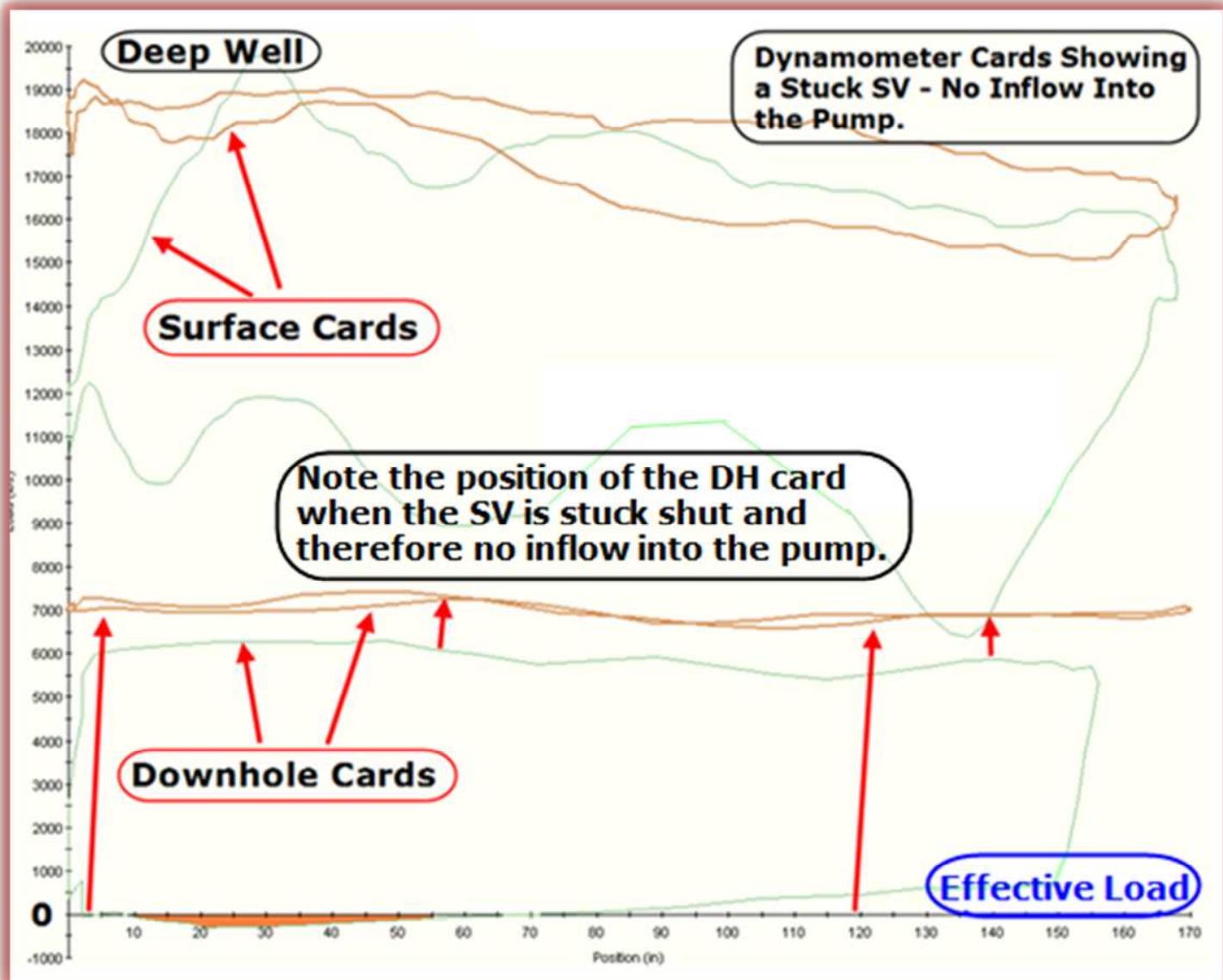
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

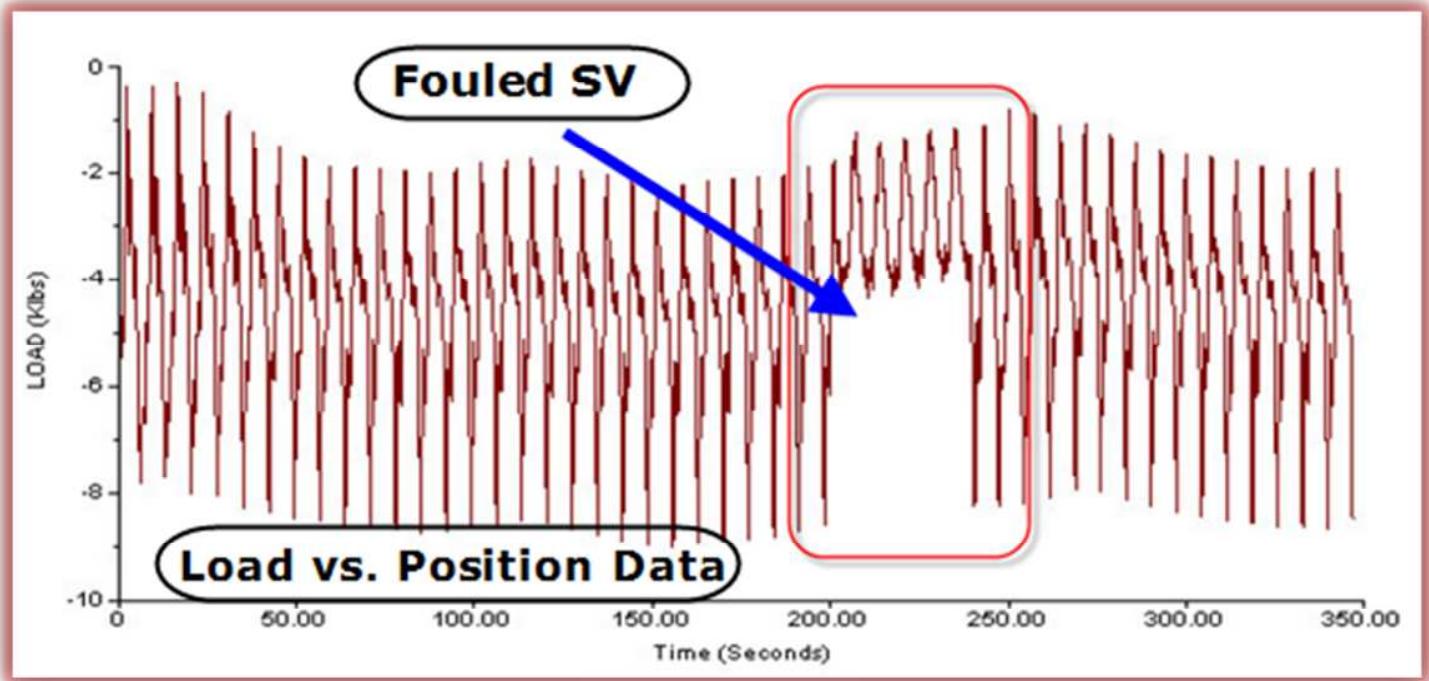


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Load vs. Time – 'SV Stuck Open'



Load vs. Time – Fouled SV

Courtesy of Echometer



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



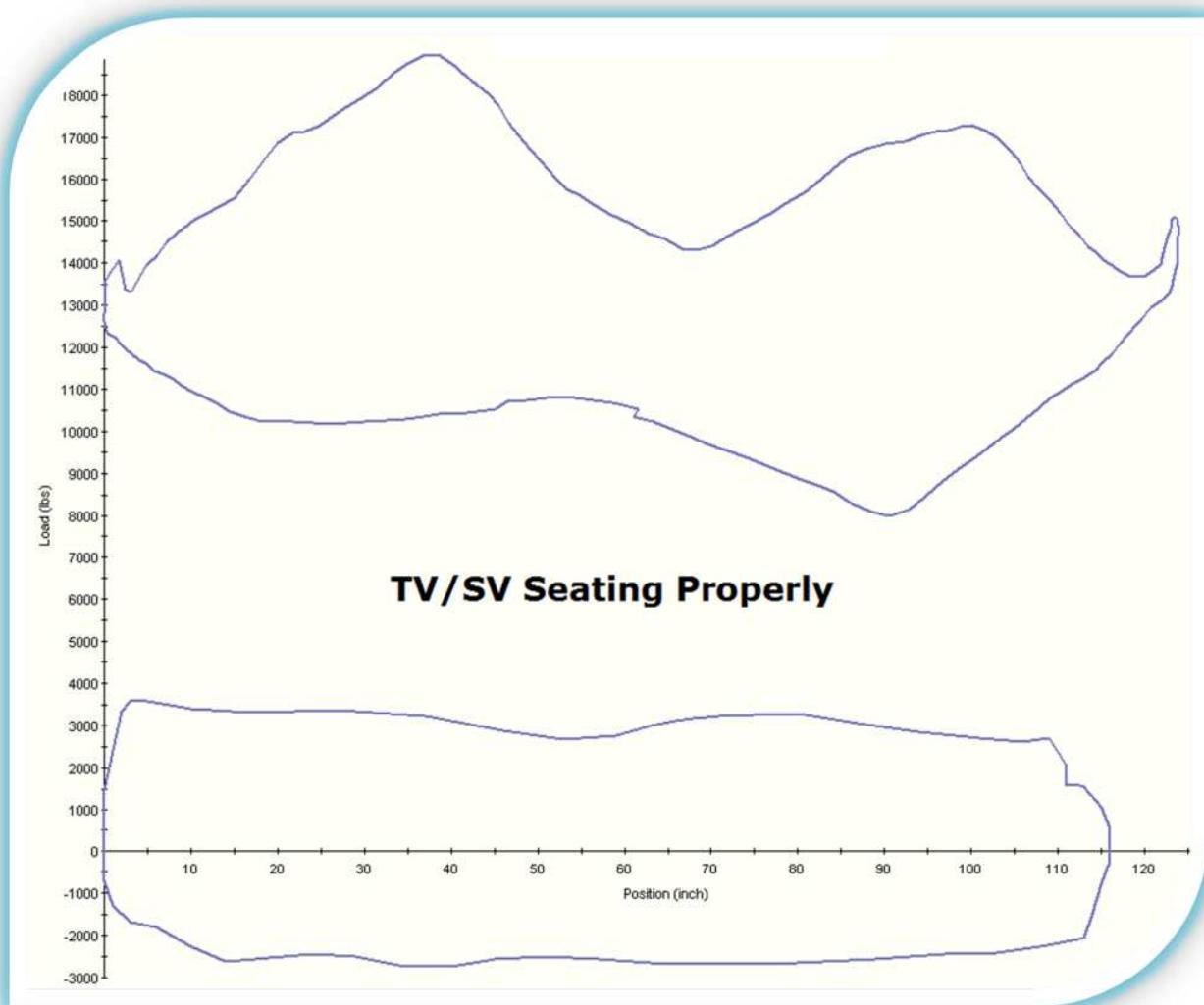
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

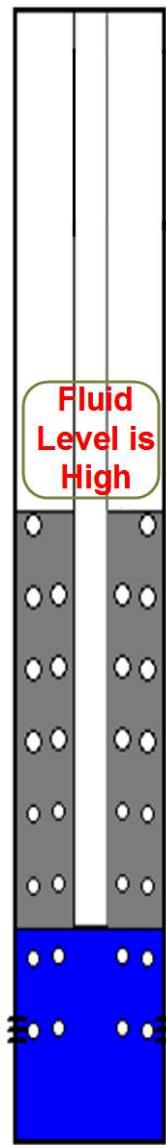
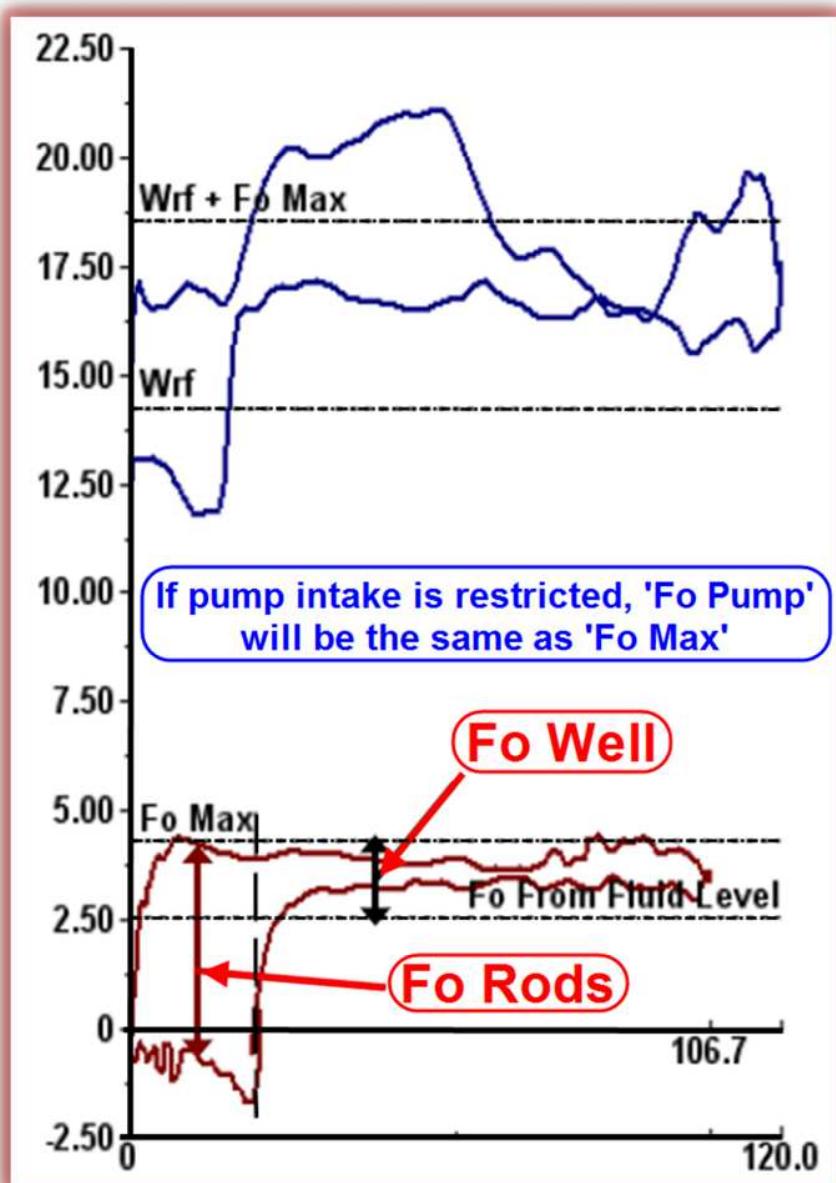


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

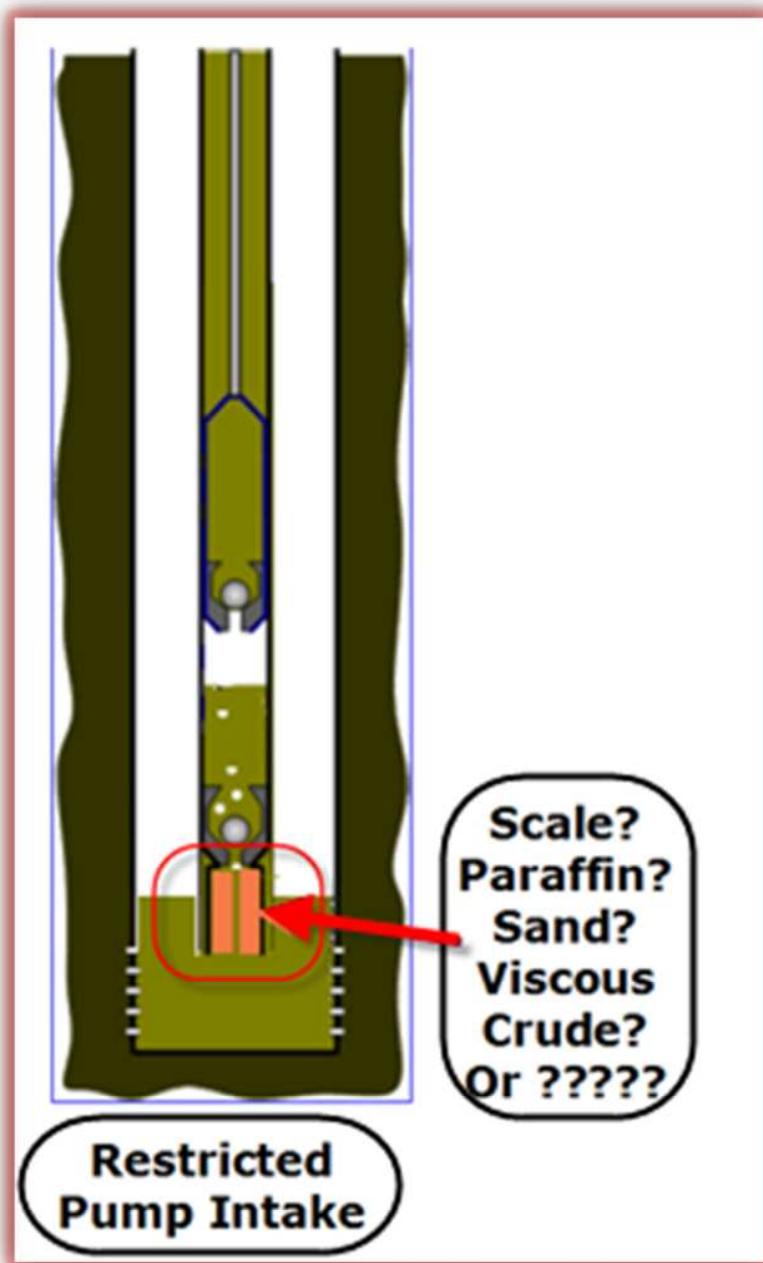
Severe 'Fluid Pound' – 'Restricted Pump Intake' (Fluid Level High)



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



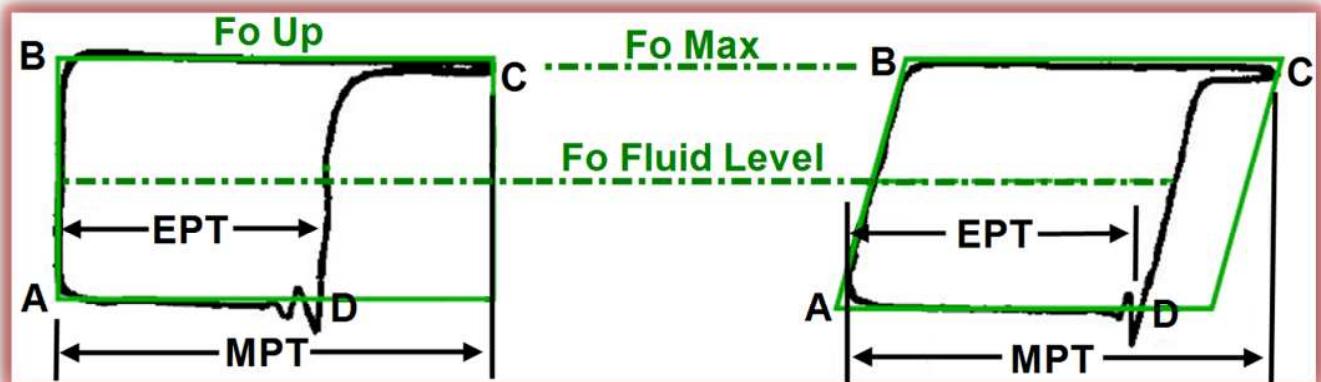
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Tubing Anchored - Effective Pump Travel Less Than Maximum Pump Travel

Tubing Not Anchored - Effective Pump Travel Less Than Maximum Pump Travel

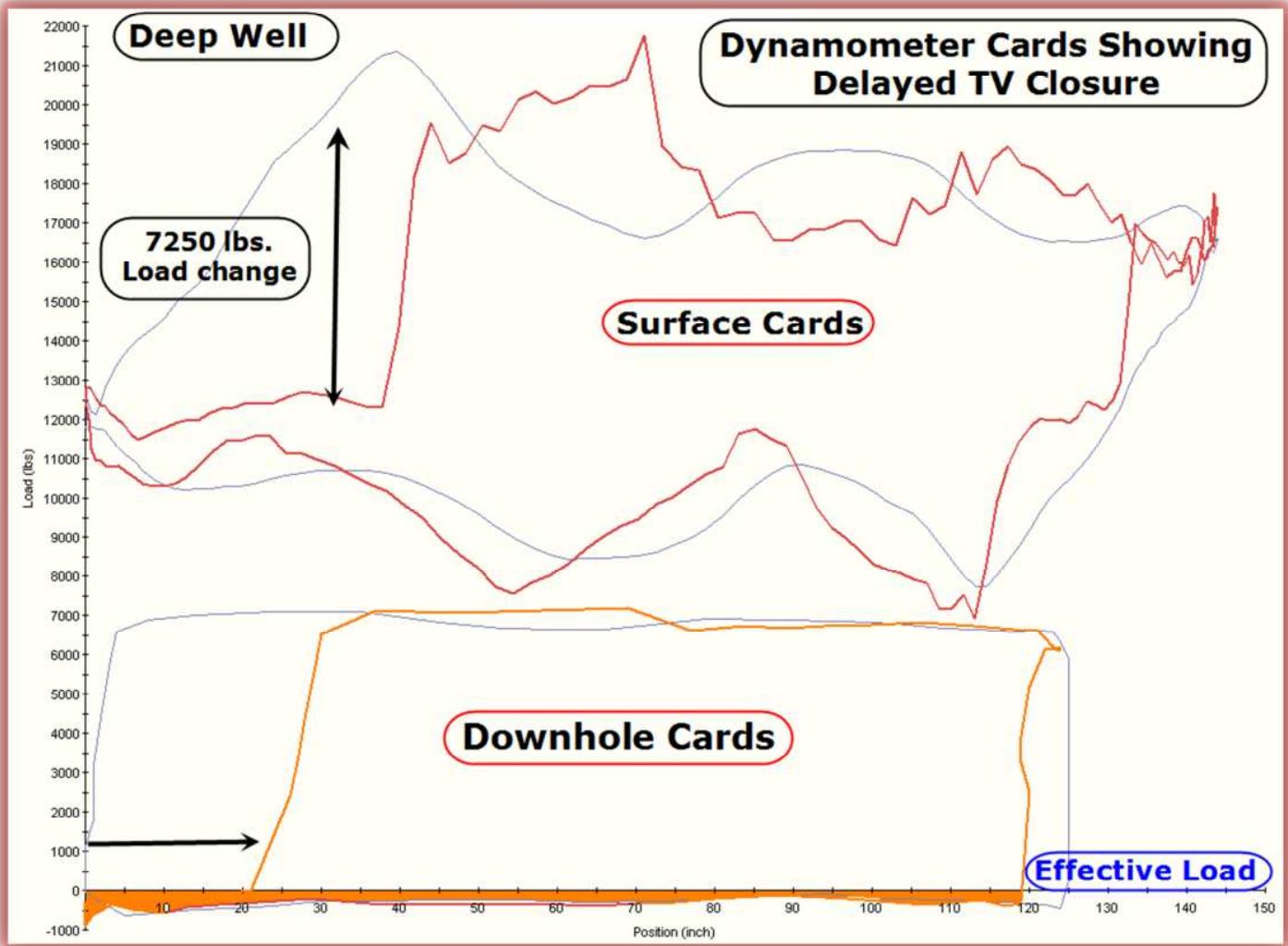


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

'Delayed TV Closure'



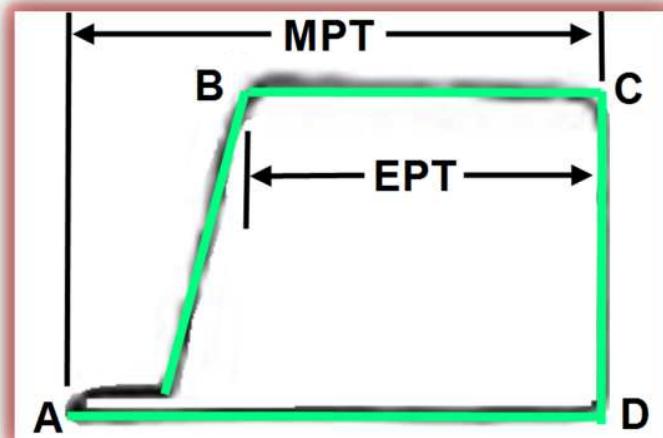
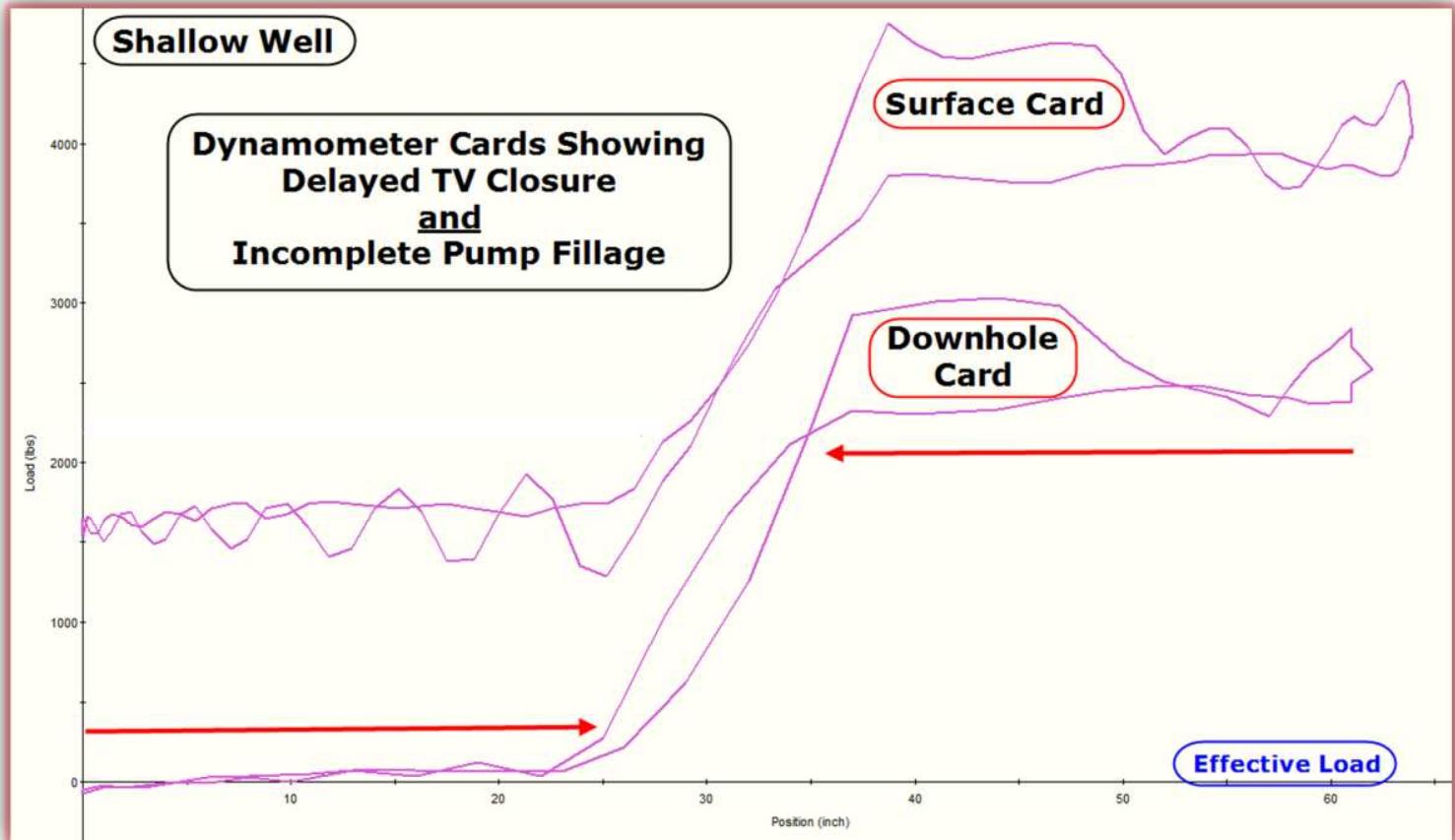
- The 'Traveling Valve Ball/Seat' does not operate (close) correctly at the beginning of the upstroke –
 - Flow is restricted by very viscous fluid in the pump
 - The TV is prevented from seating properly by solids
 - Damaged/pitted TV ball



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Tubing Anchored - Effective Pump Travel is Less Than Maximum Pump Travel

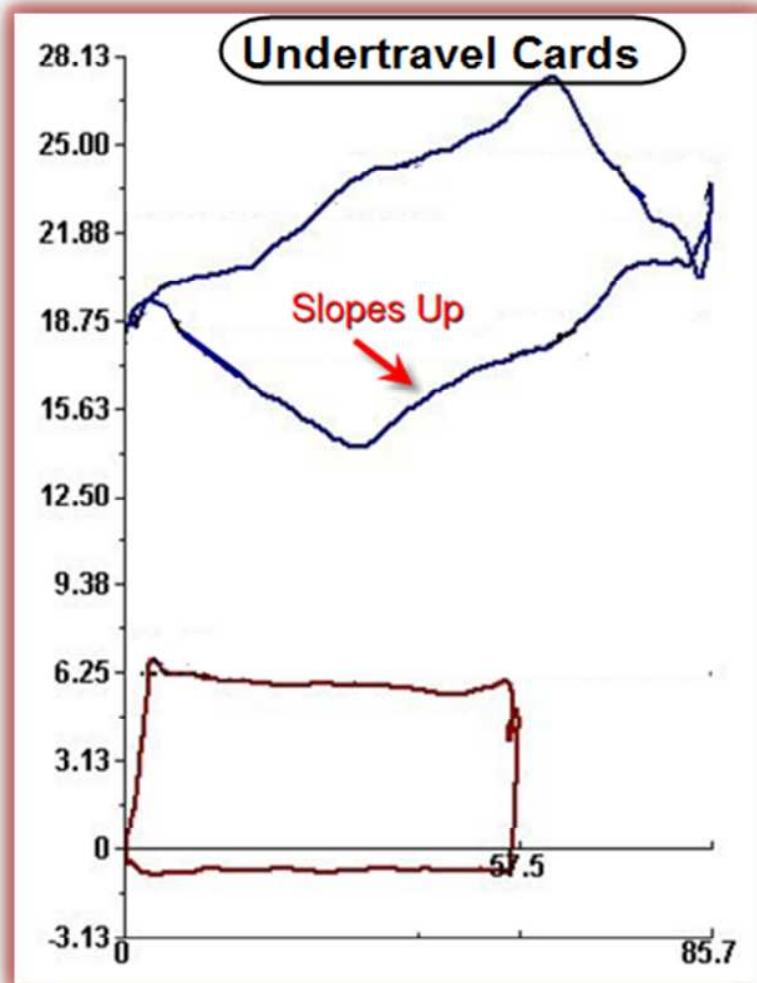


Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

DH Cards – ‘Undertravel’ and ‘Overtravel’



An ‘**Undertravel**’ surface card slopes upward from left to right. The pump plunger moves **less** than the surface stroke.

‘**Undertravel**’ is due to rod stretch from fluid load, downhole friction or other reasons.

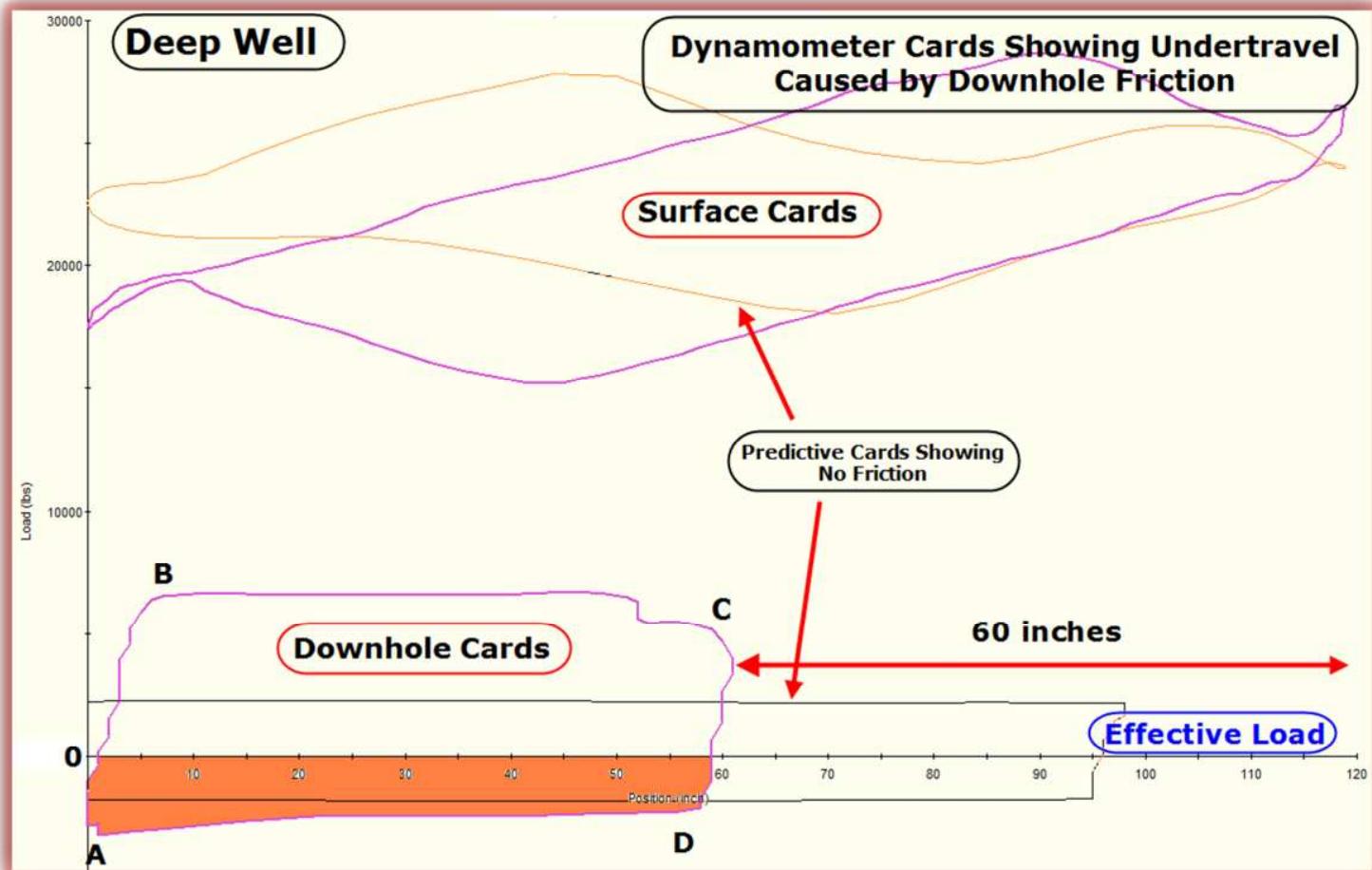
‘**Undertravel**’ cards include: stuck pumps, **plunger is too large for the rod string**, sand or scale problems, stuffing box too tight and/or paraffin.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



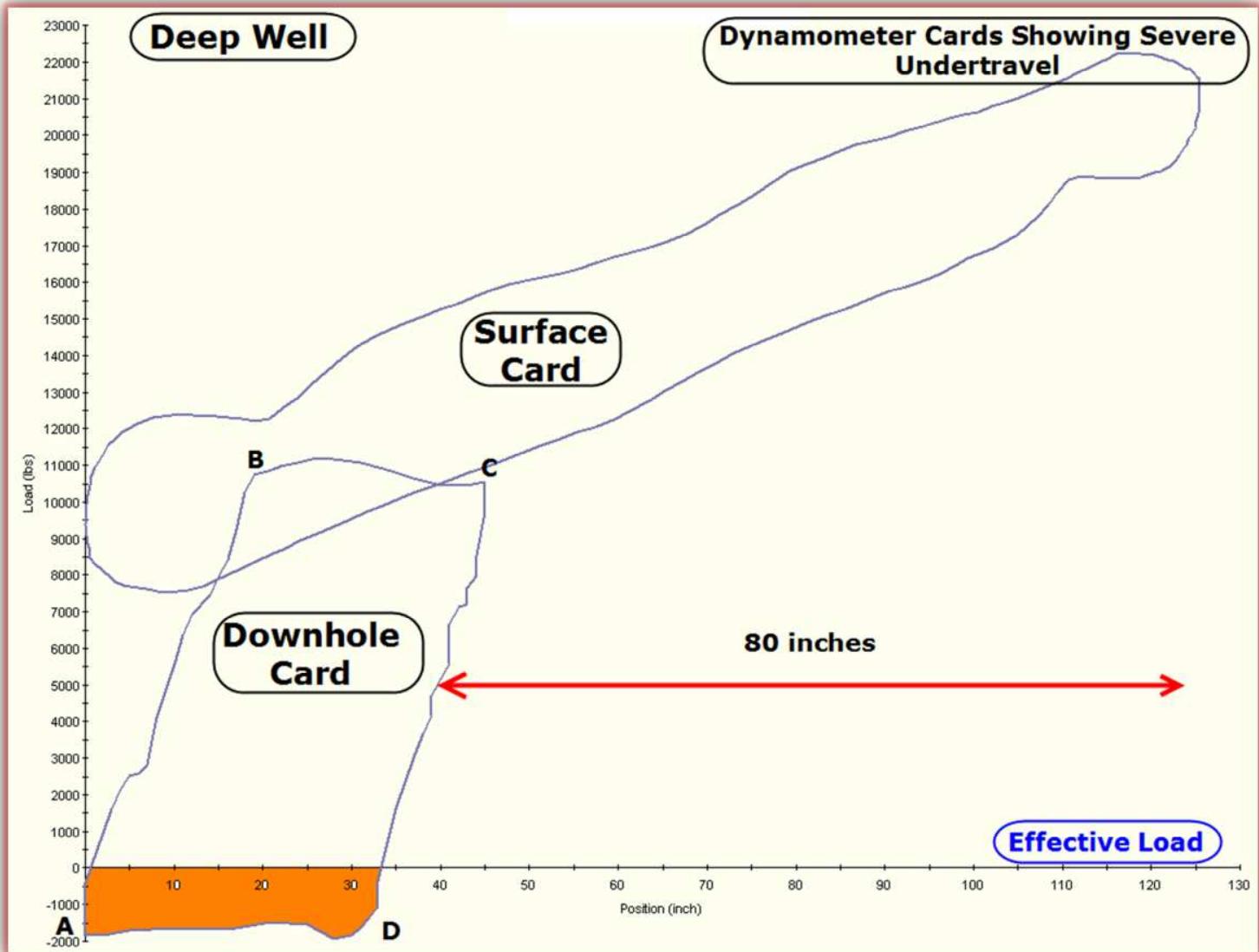
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



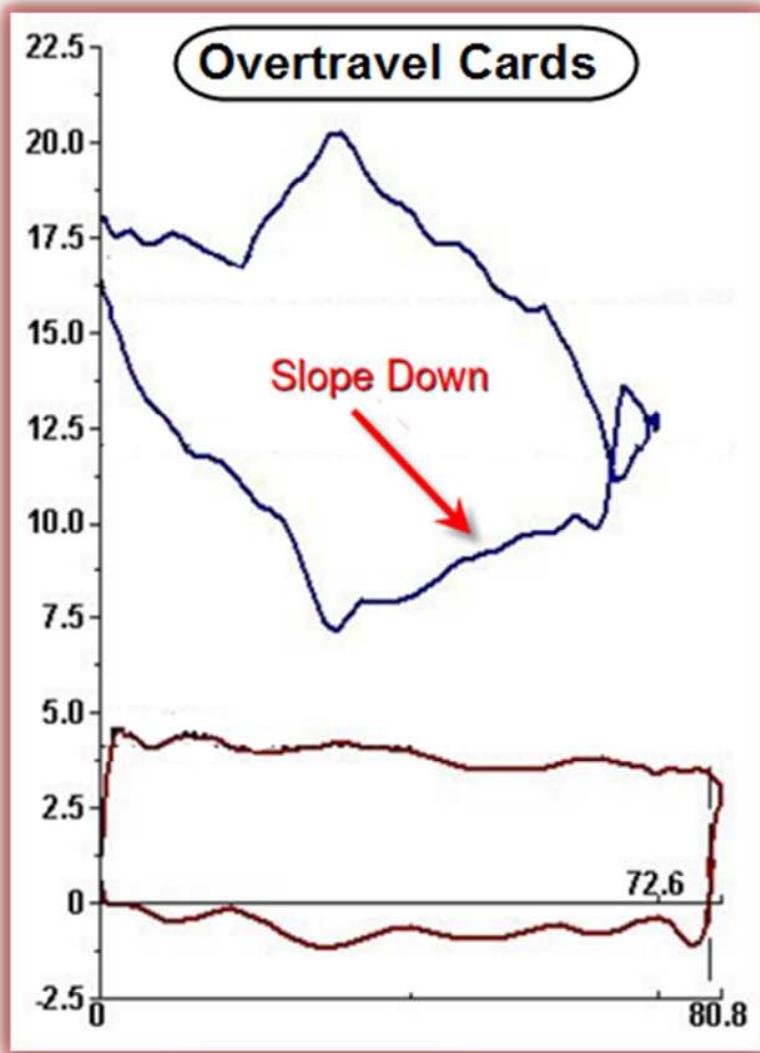
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



'Overtravel' plunger stroke is longer than polished rod stroke. The surface card slopes downward from left to right. In this example: The 80.8" plunger stroke is **more** than the 72.6" polished rod stroke. The surface stroke is reduced by 23" of rod stretch required to lift the fluid load. 'Overtravel' cards include: parted rods, flowing wells, unseated pumps, gas locked pumps, worn pumps, fiberglass rod strings or pumping at a very high SPM.

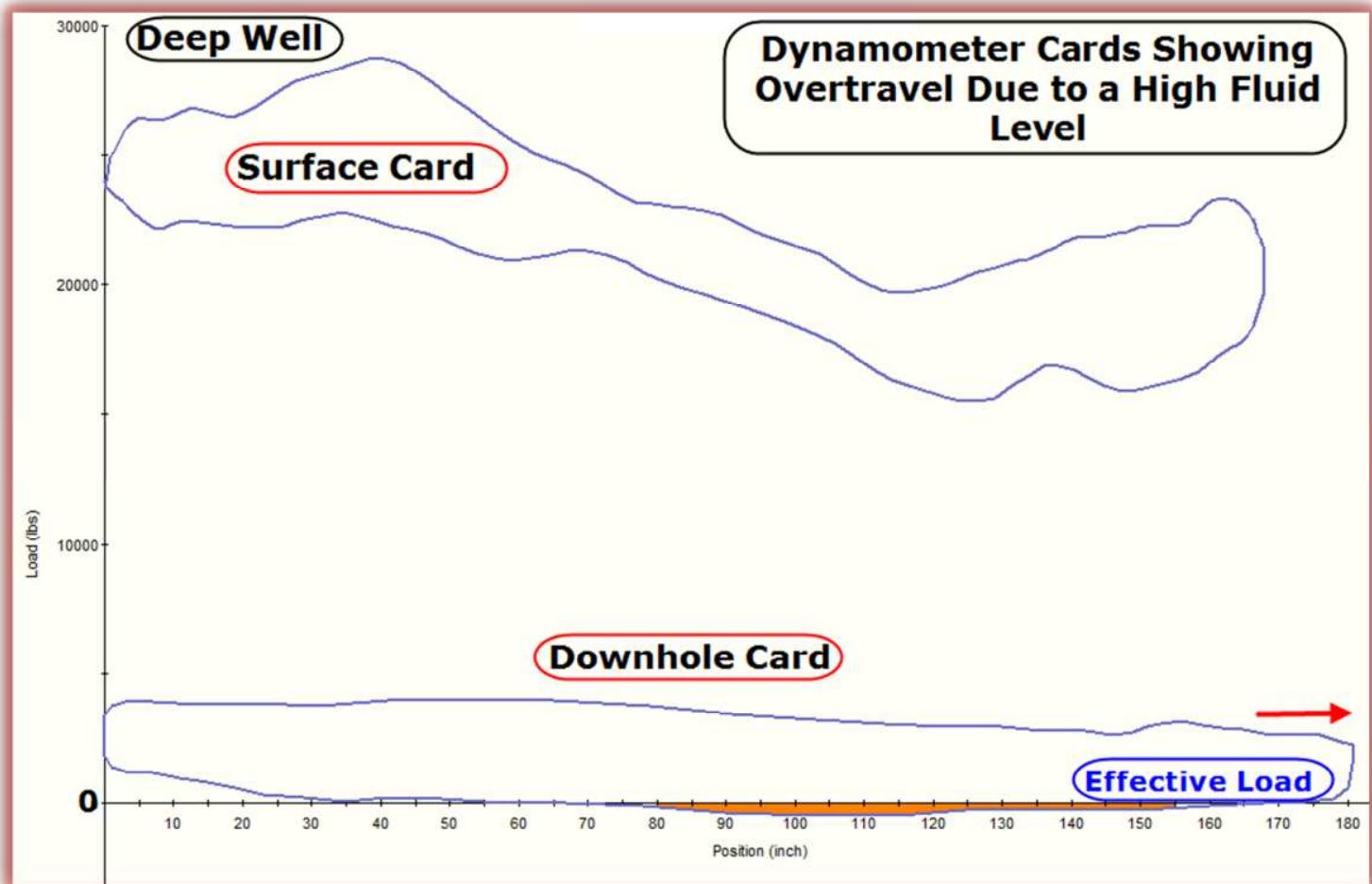
((((ECHOMETER))))



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



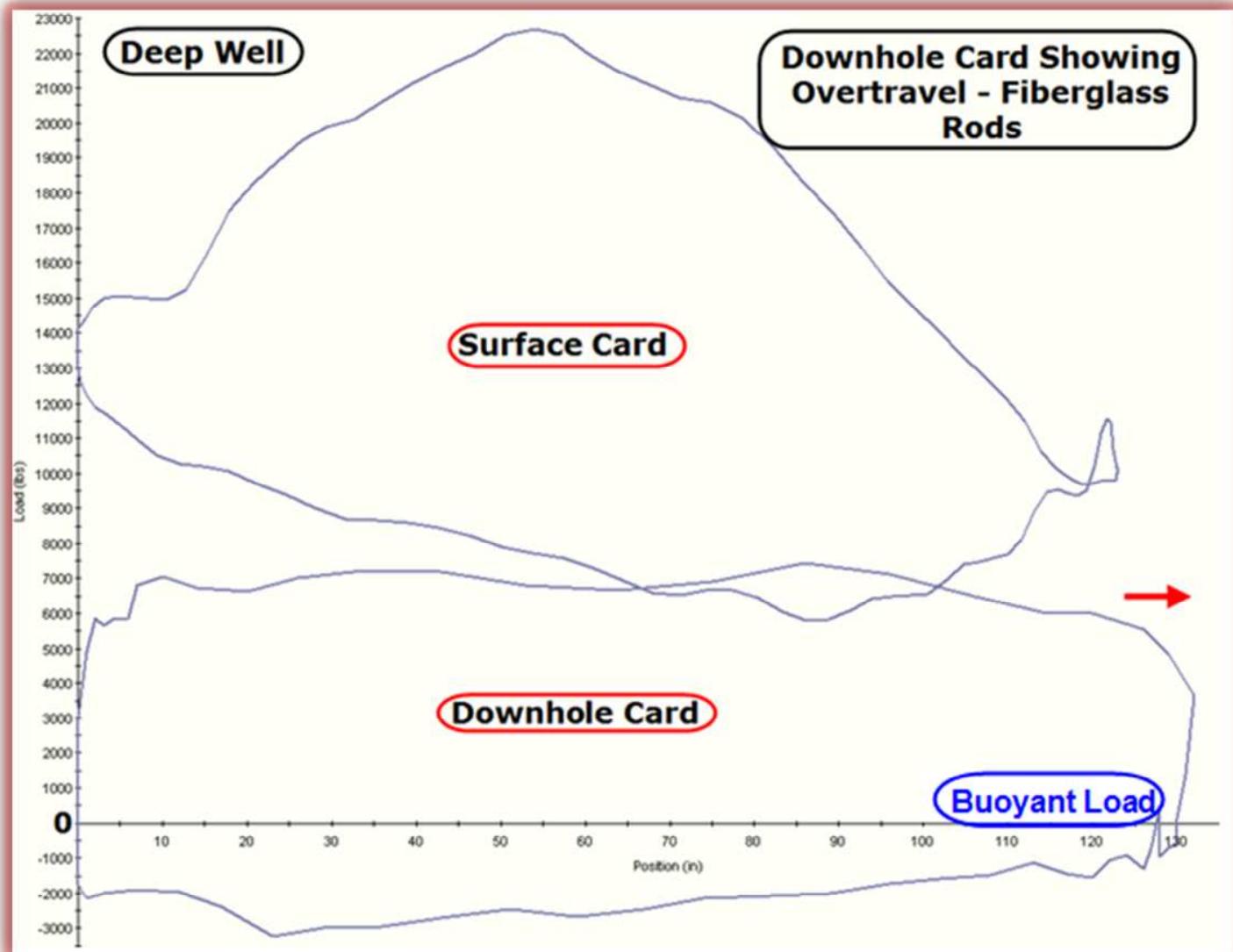
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



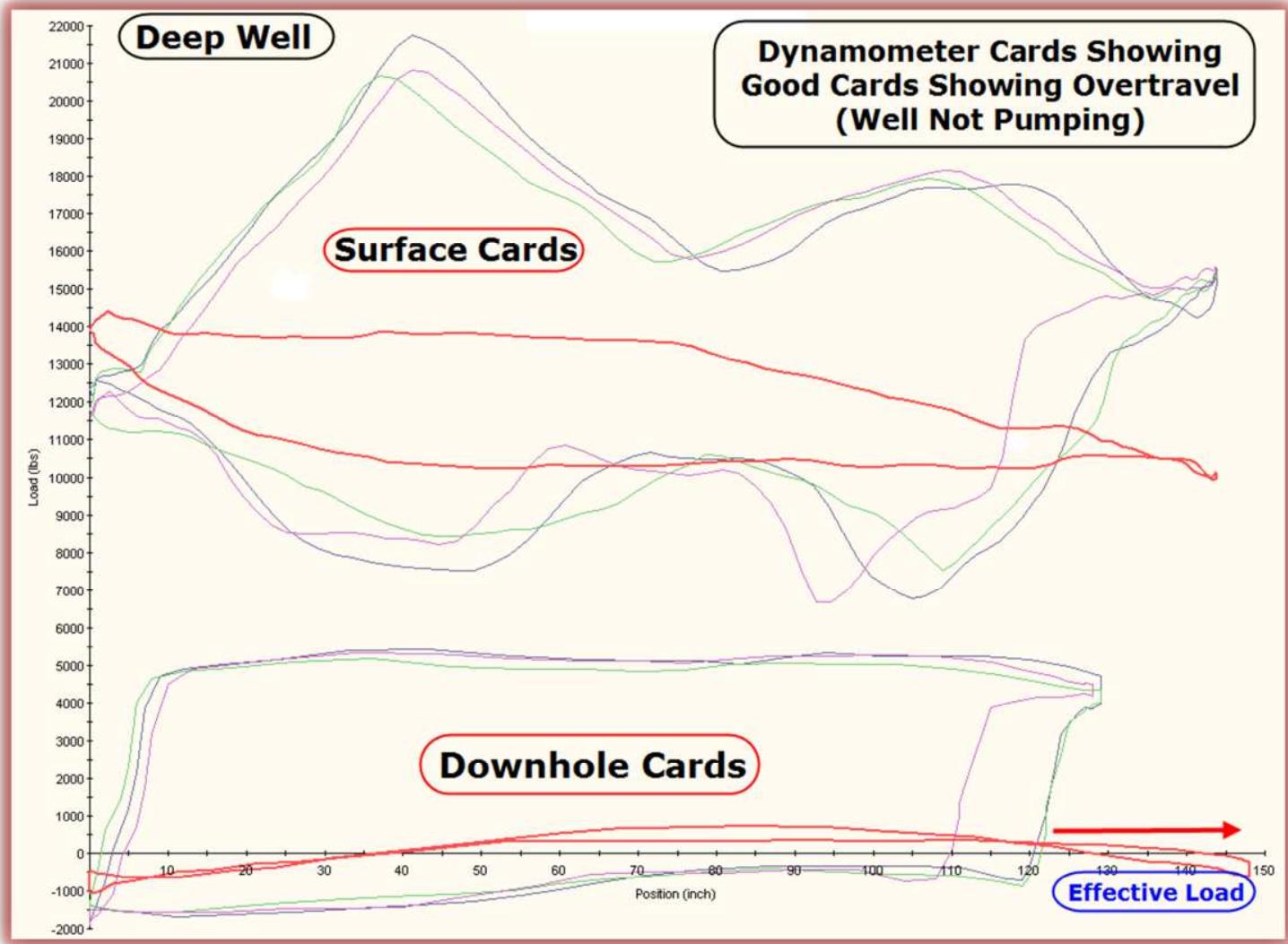
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com

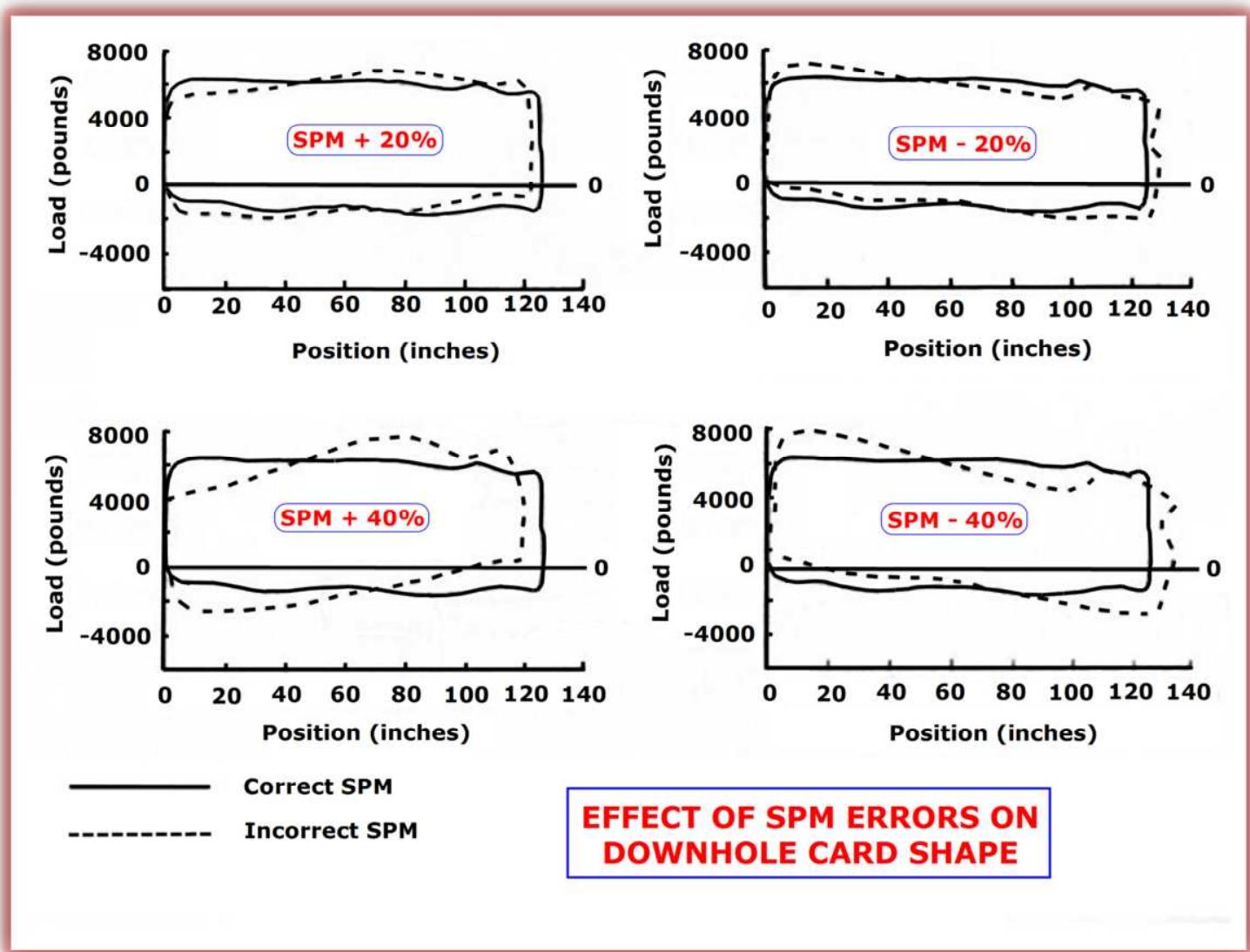


Surface and Downhole Dynamometer Card Interpretation

DH Cards – Slanted?

Incorrect 'Stroke Length'

Incorrect 'SPM'

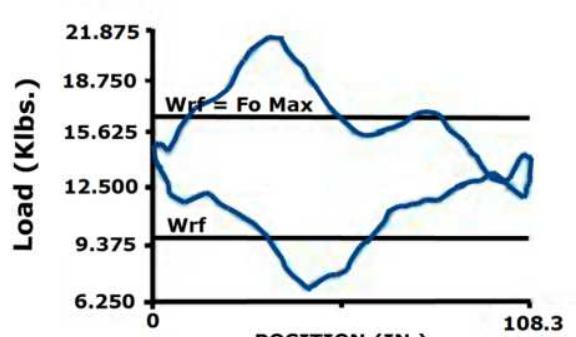
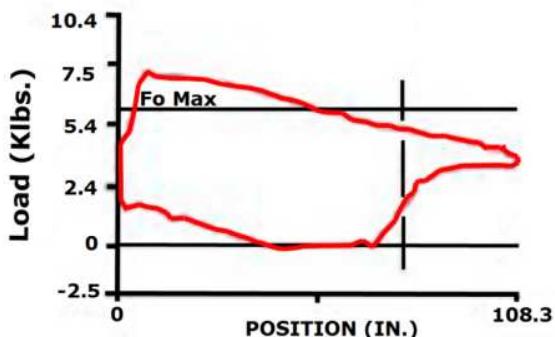
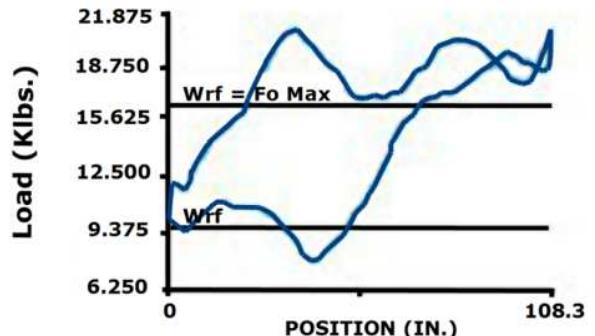
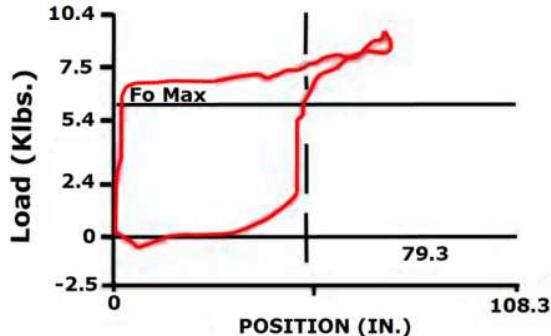


Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Bent Polished Rod (Strain Gauge)

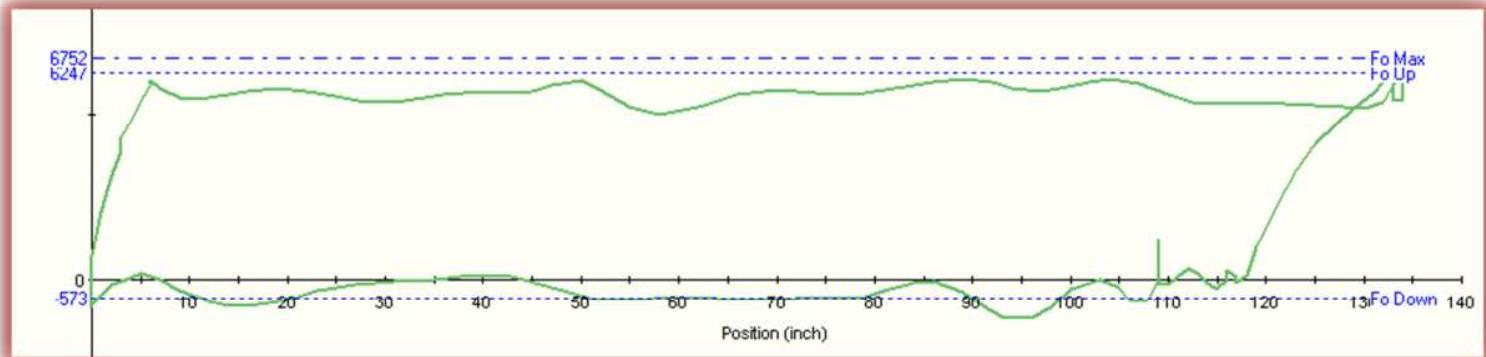


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Use 'Fluid Load' Lines – If Available



☞ ‘**F_o**’ refers to ‘fluid load’ – the difference between the maximum load lifted by the pump on the upstroke and the minimum load lifted by the pump from the downstroke.

☞ Downhole pump cards typically have three load reference lines 1) **F_o Down** – minimum fluid load, 2) **F_o Up**, maximum fluid load, and 3) **F_o Max**, the maximum fluid load on the pump plunger, *calculated by setting the pump intake pressure to zero*. Certain downhole pump problems can be recognized based on the location of the actual pump card loads with respect to these three load reference lines.

☞ Typical downhole pump card loads plot near **F_o Down** on the downstroke and near **F_o Max** on the upstroke.

☞ Inaccurate input data or unaccounted friction are the usual reasons the top of the downhole pump card plots above **F_o Max** and/or the bottom of the card plots below **F_o Down**.

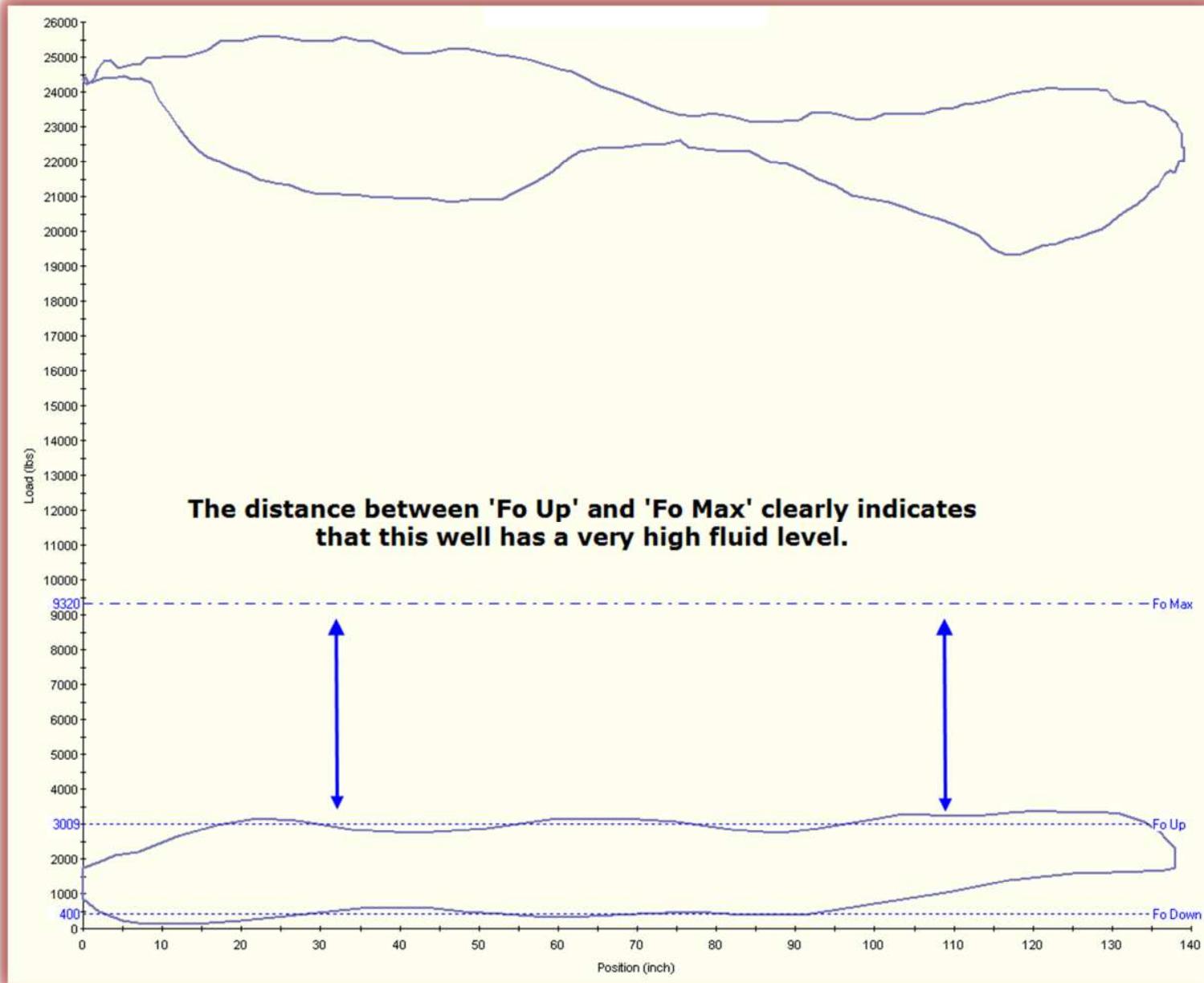


Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

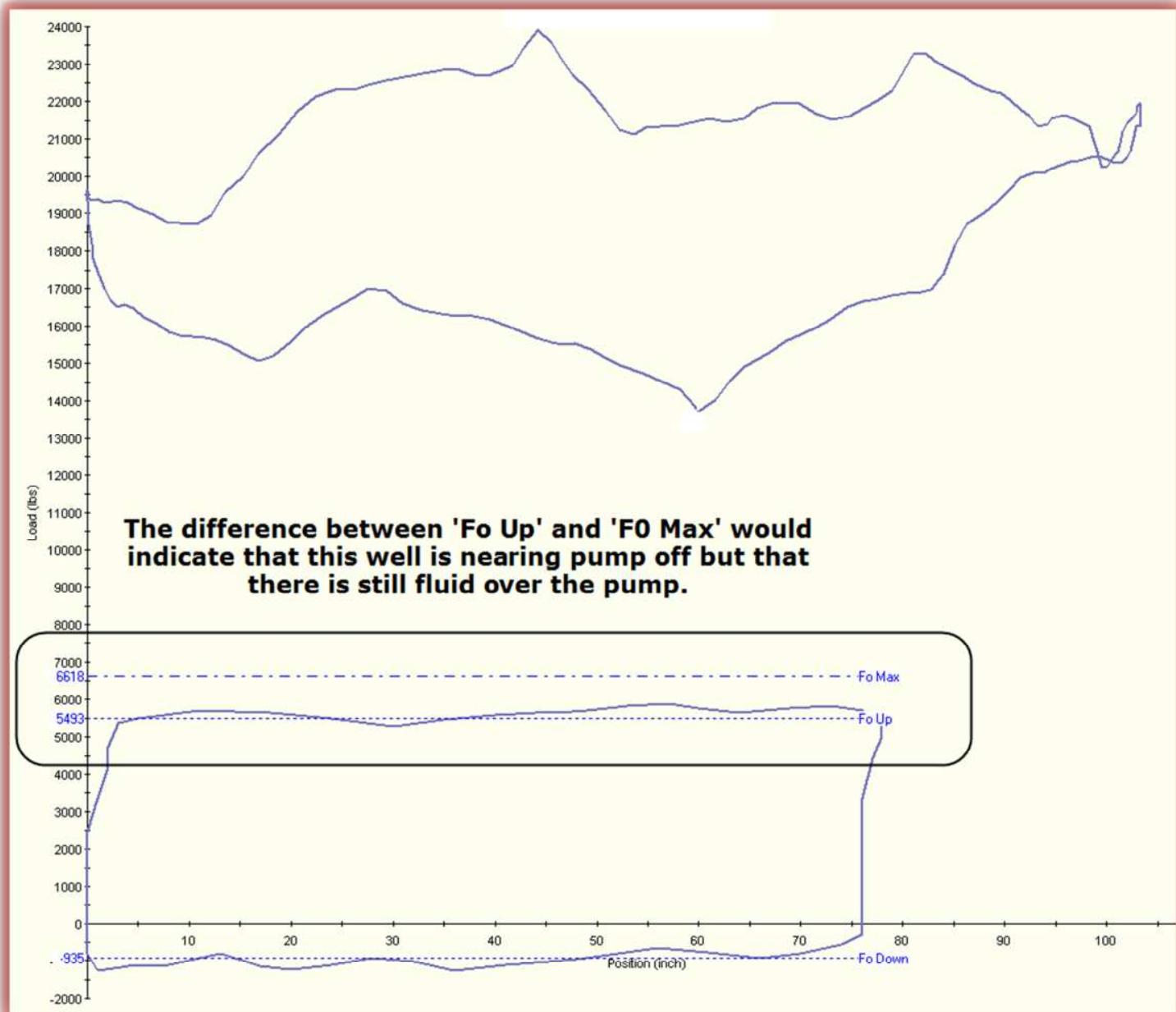
'Fluid Load' Line Examples



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



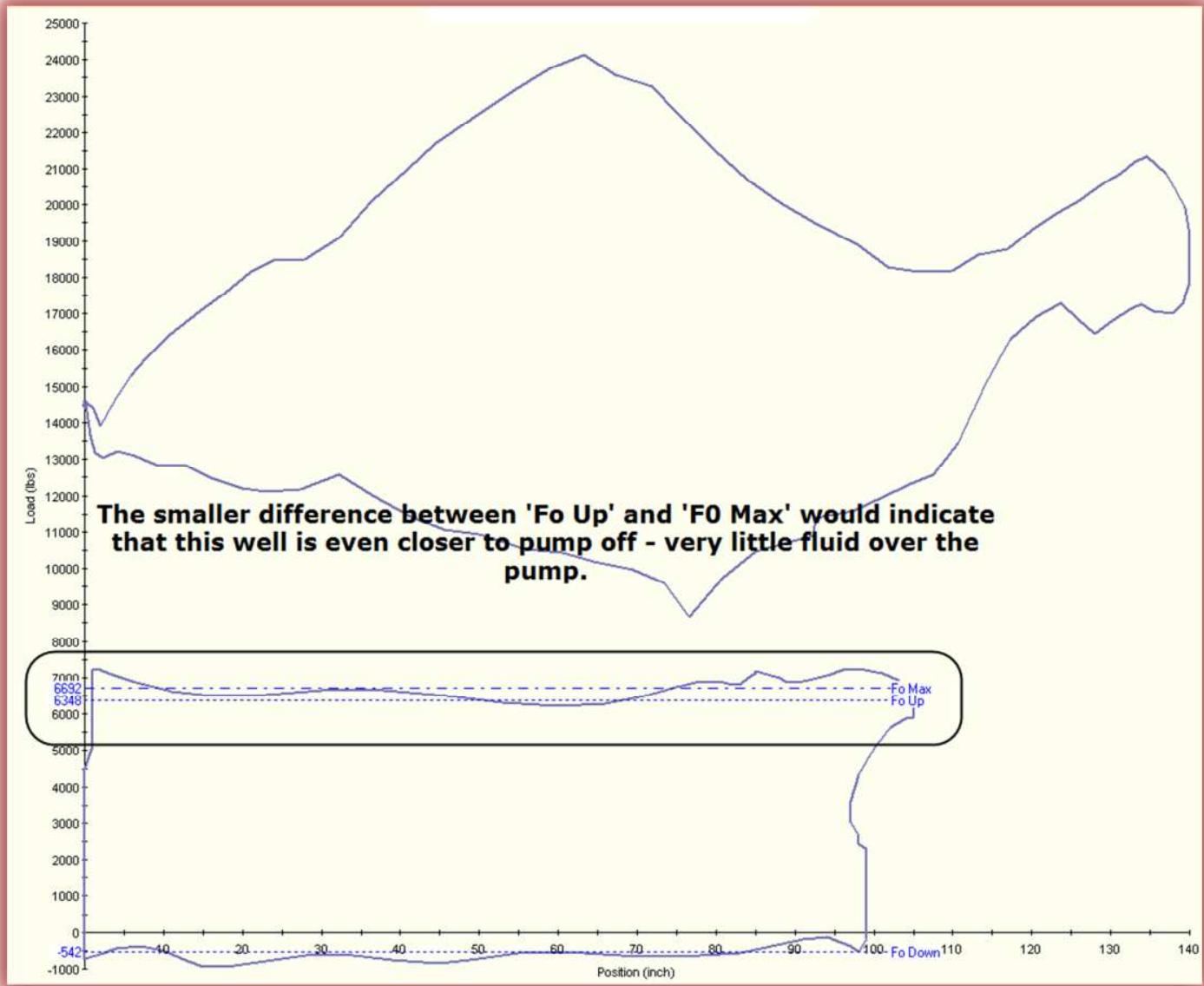
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



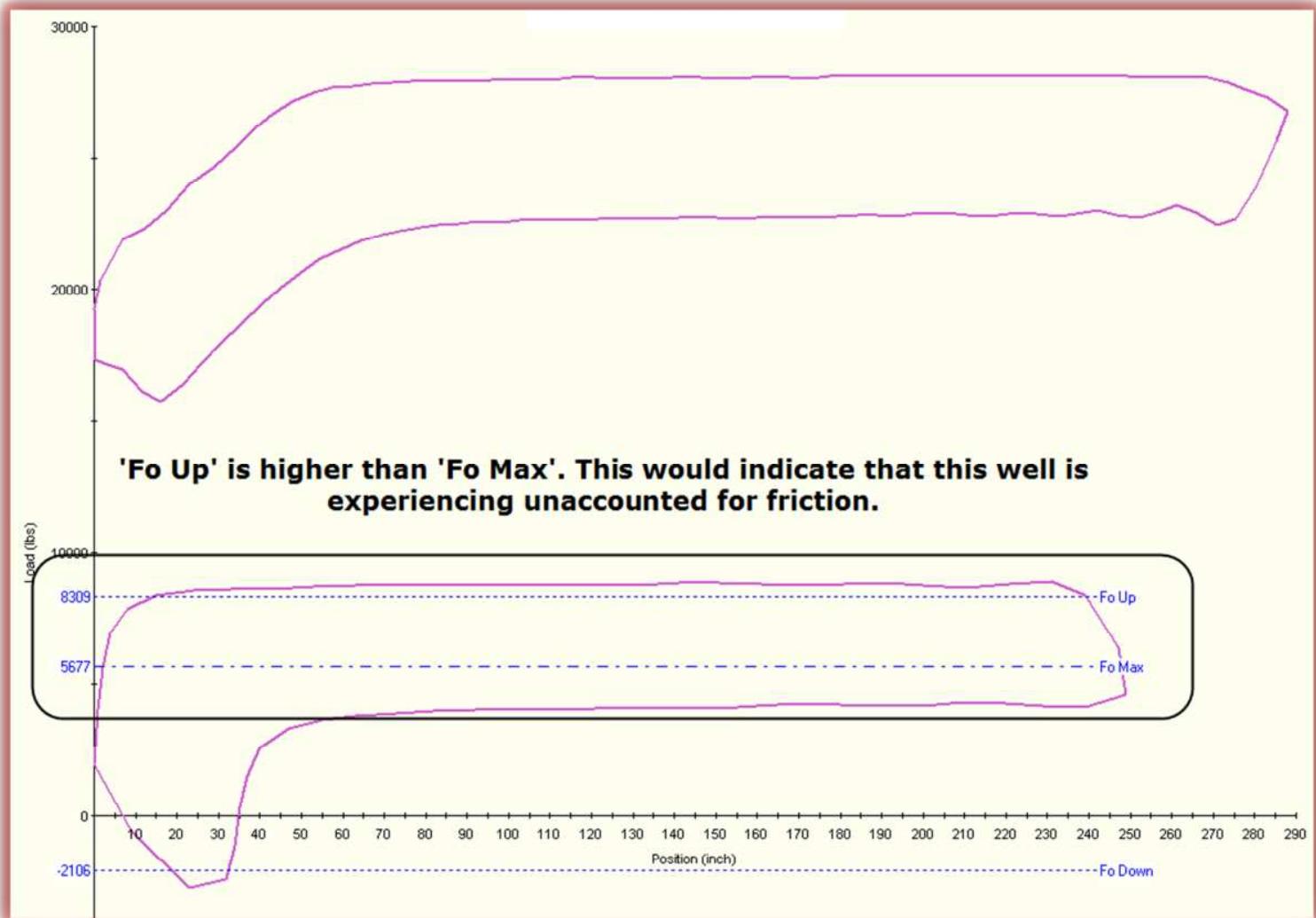
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



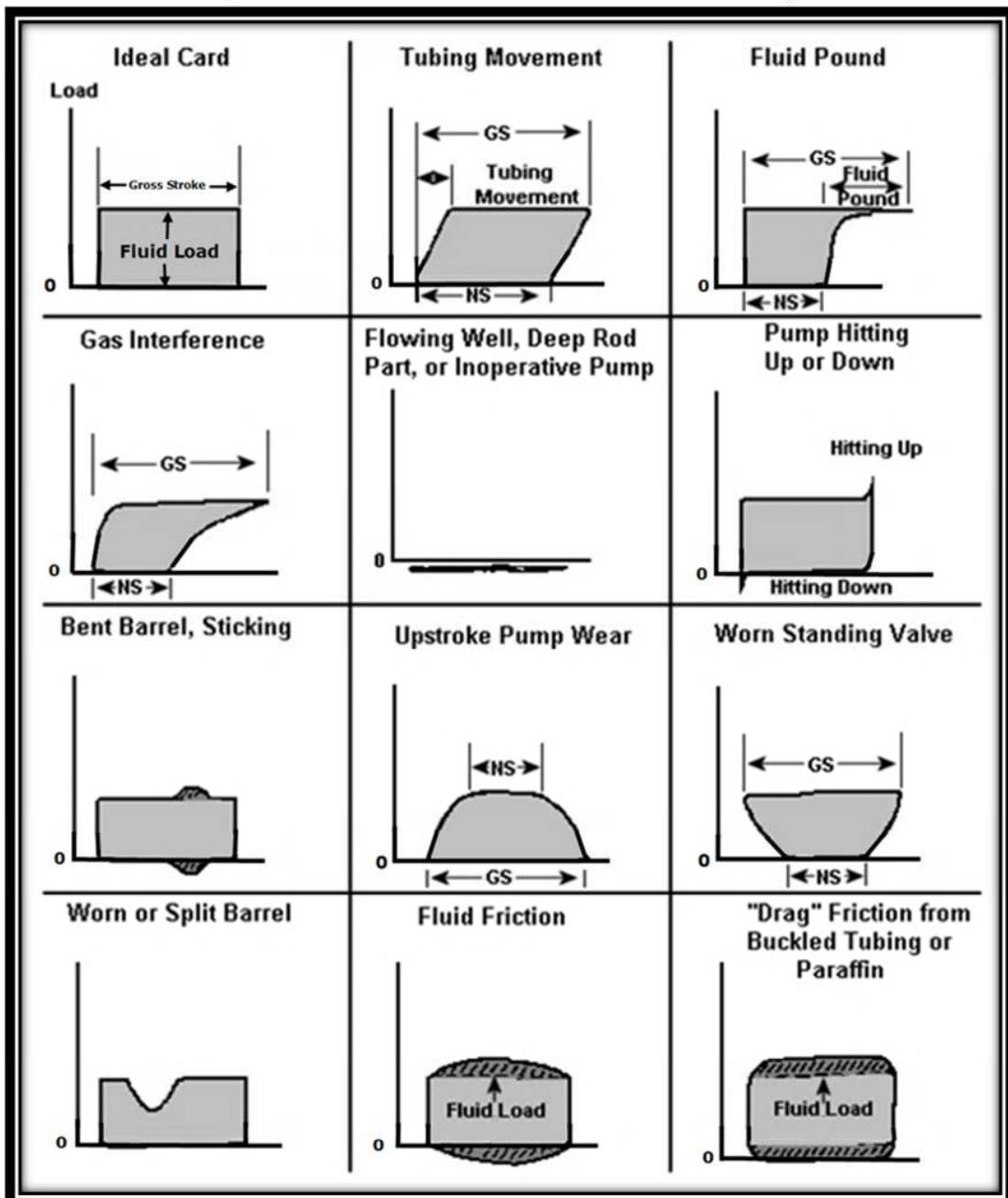
Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

DH Cards – Example Library

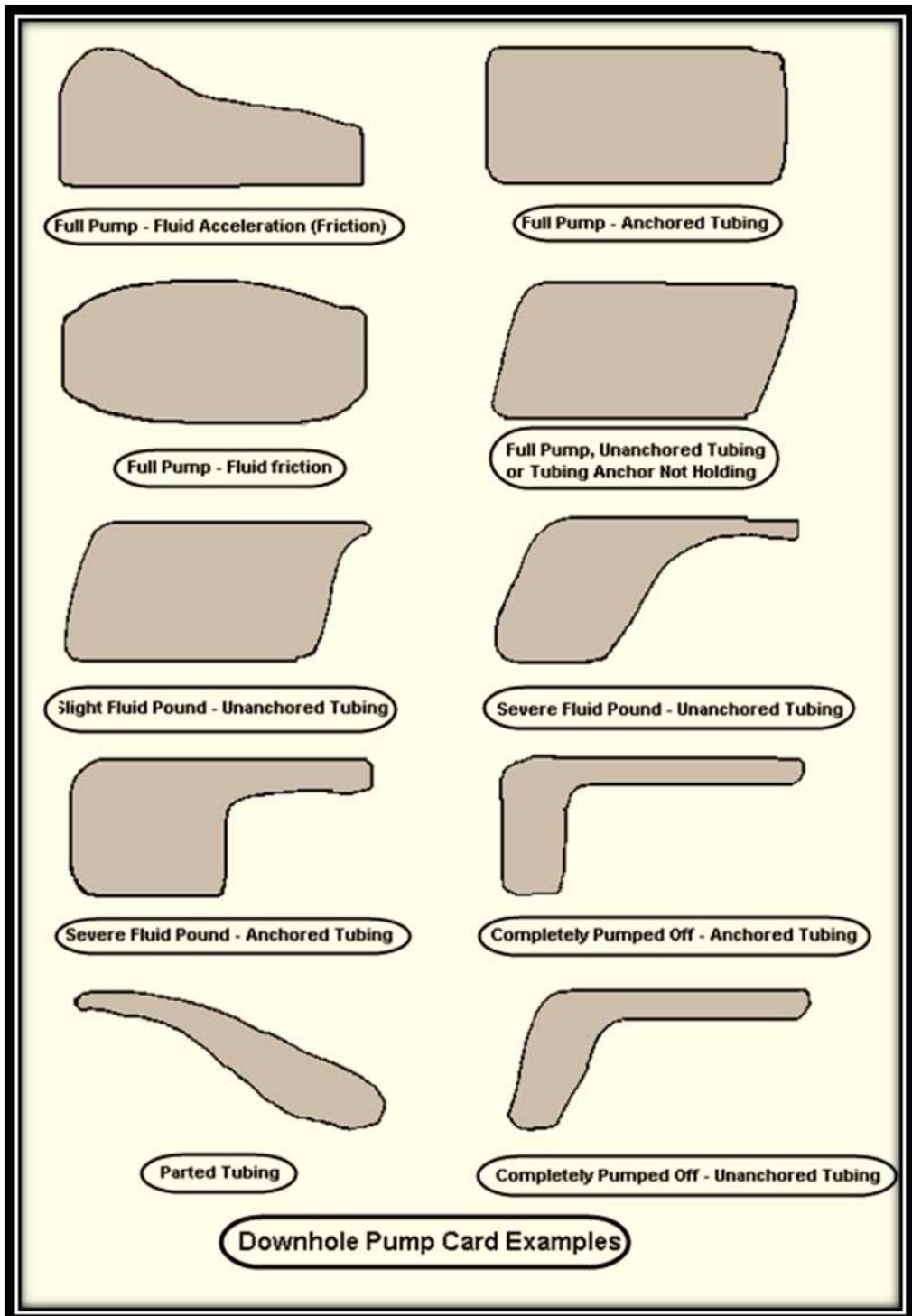
► Combinations of the following downhole conditions can occur simultaneously.



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



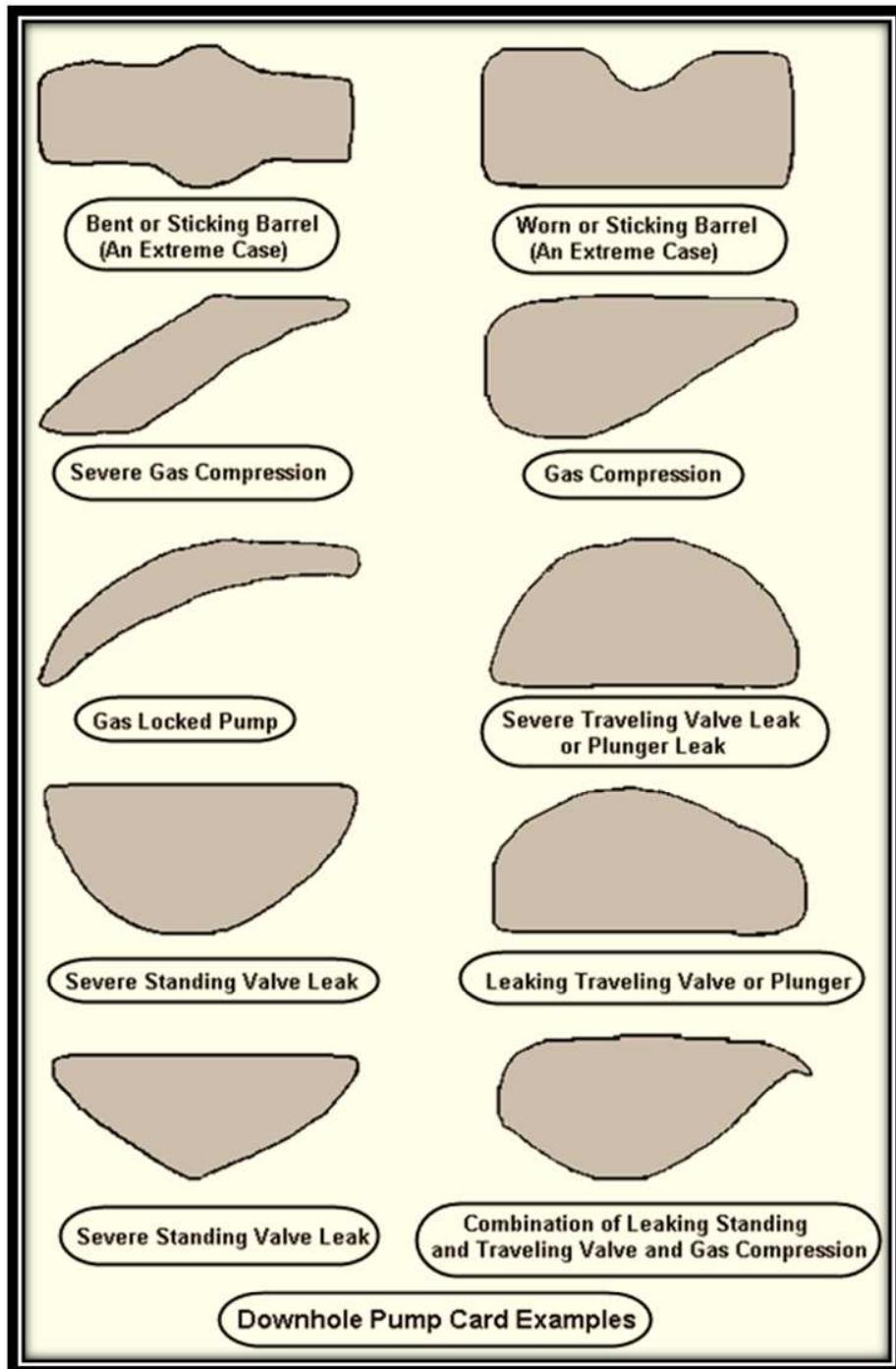
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



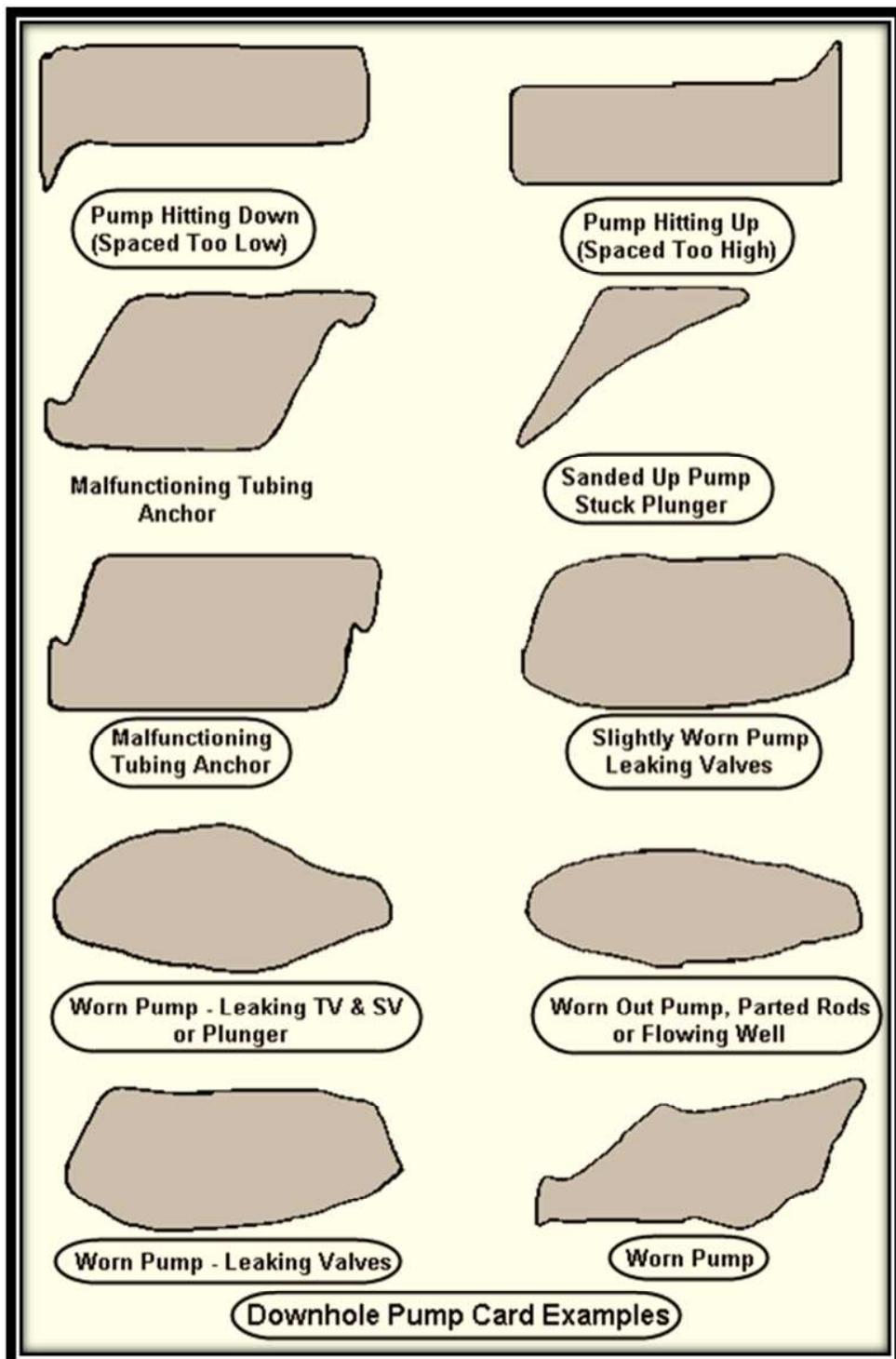
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



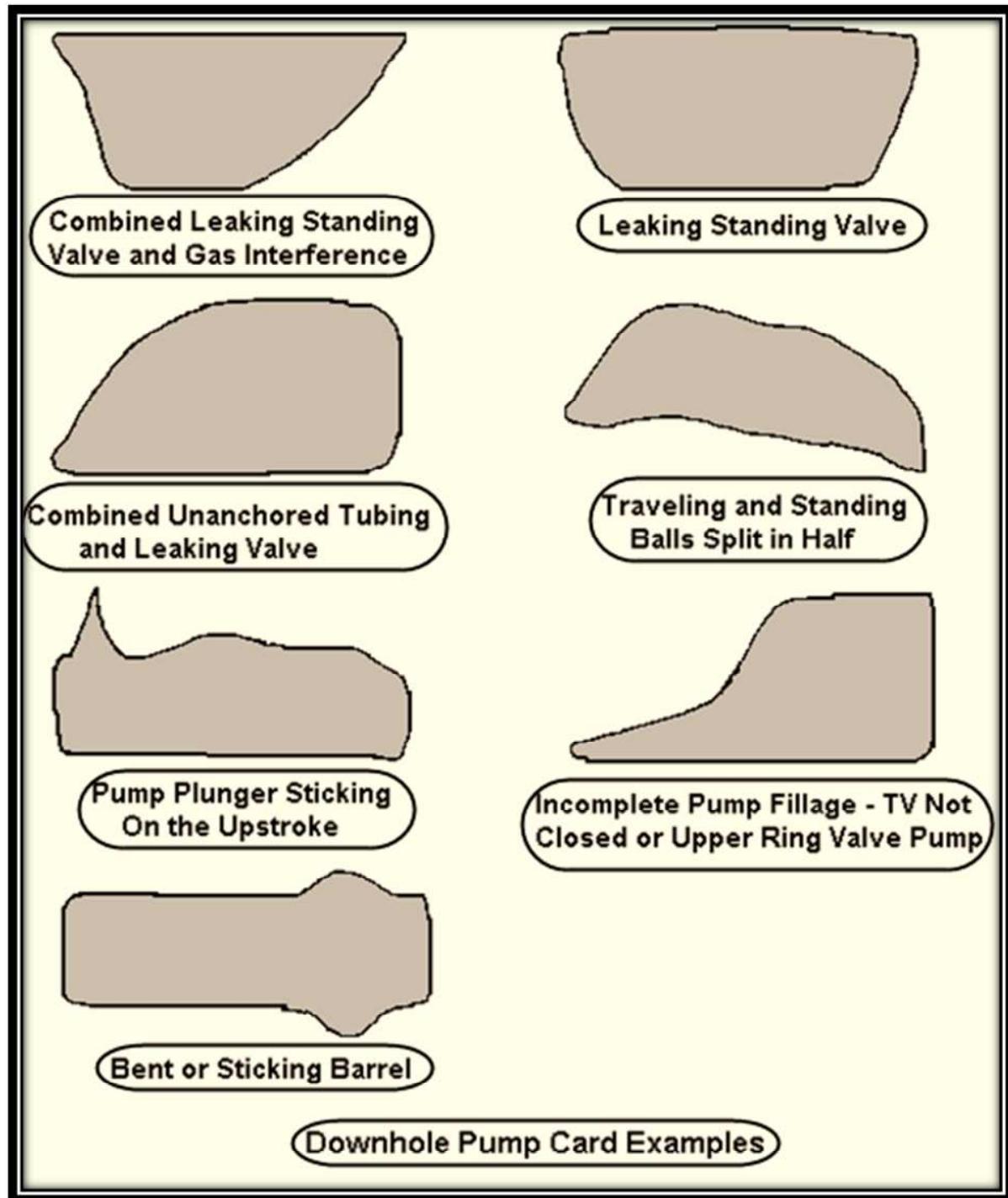
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



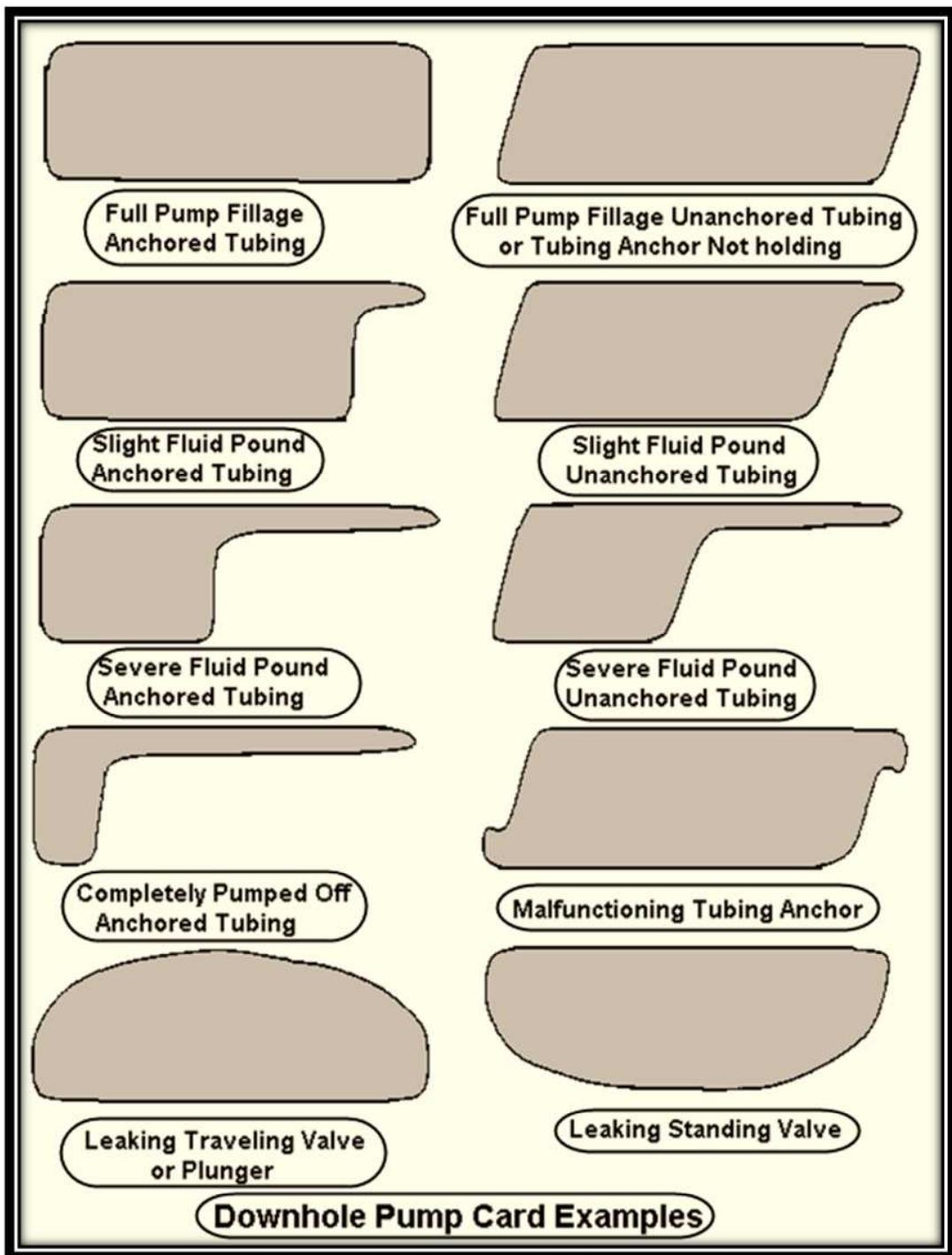
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



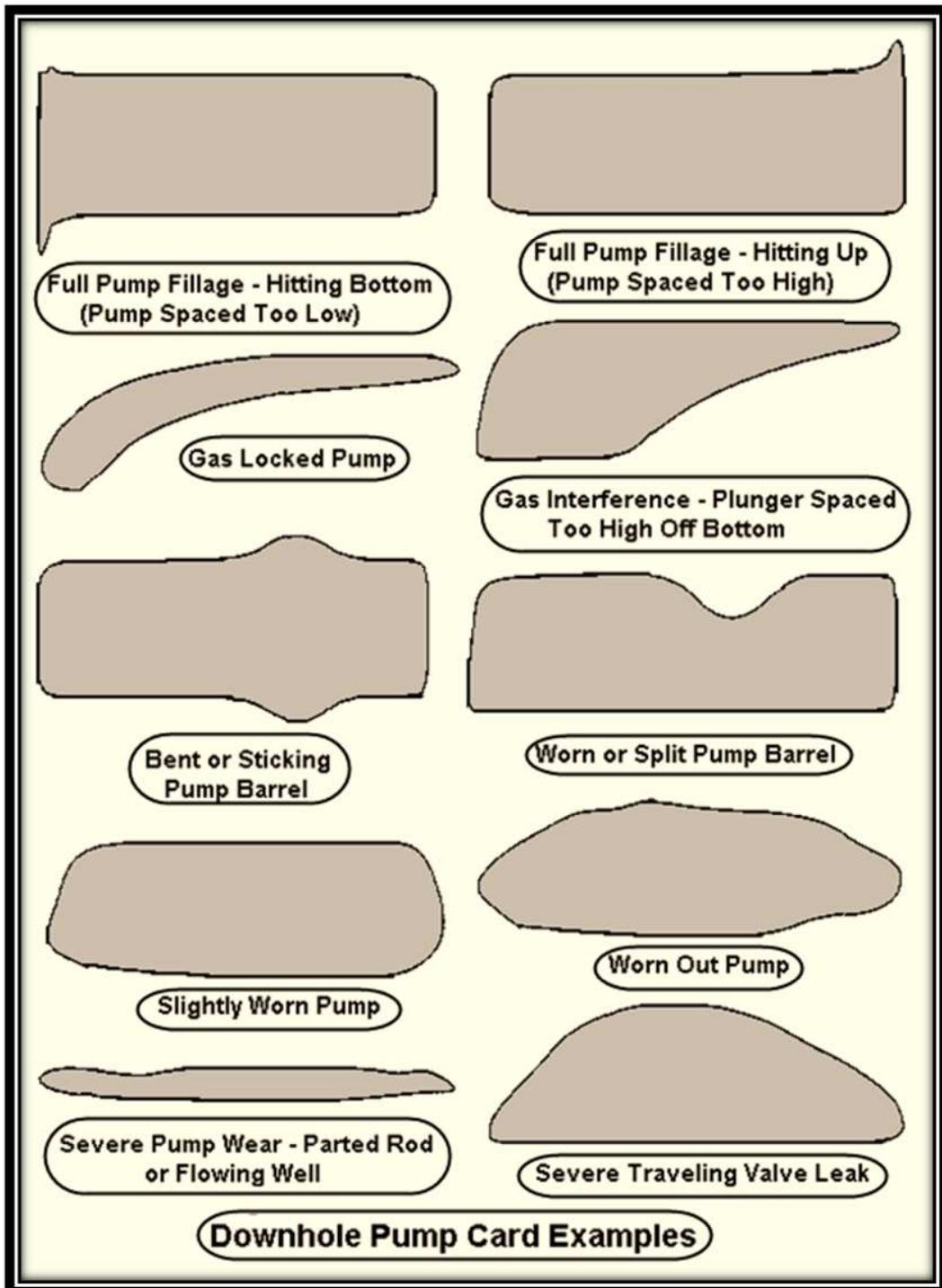
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



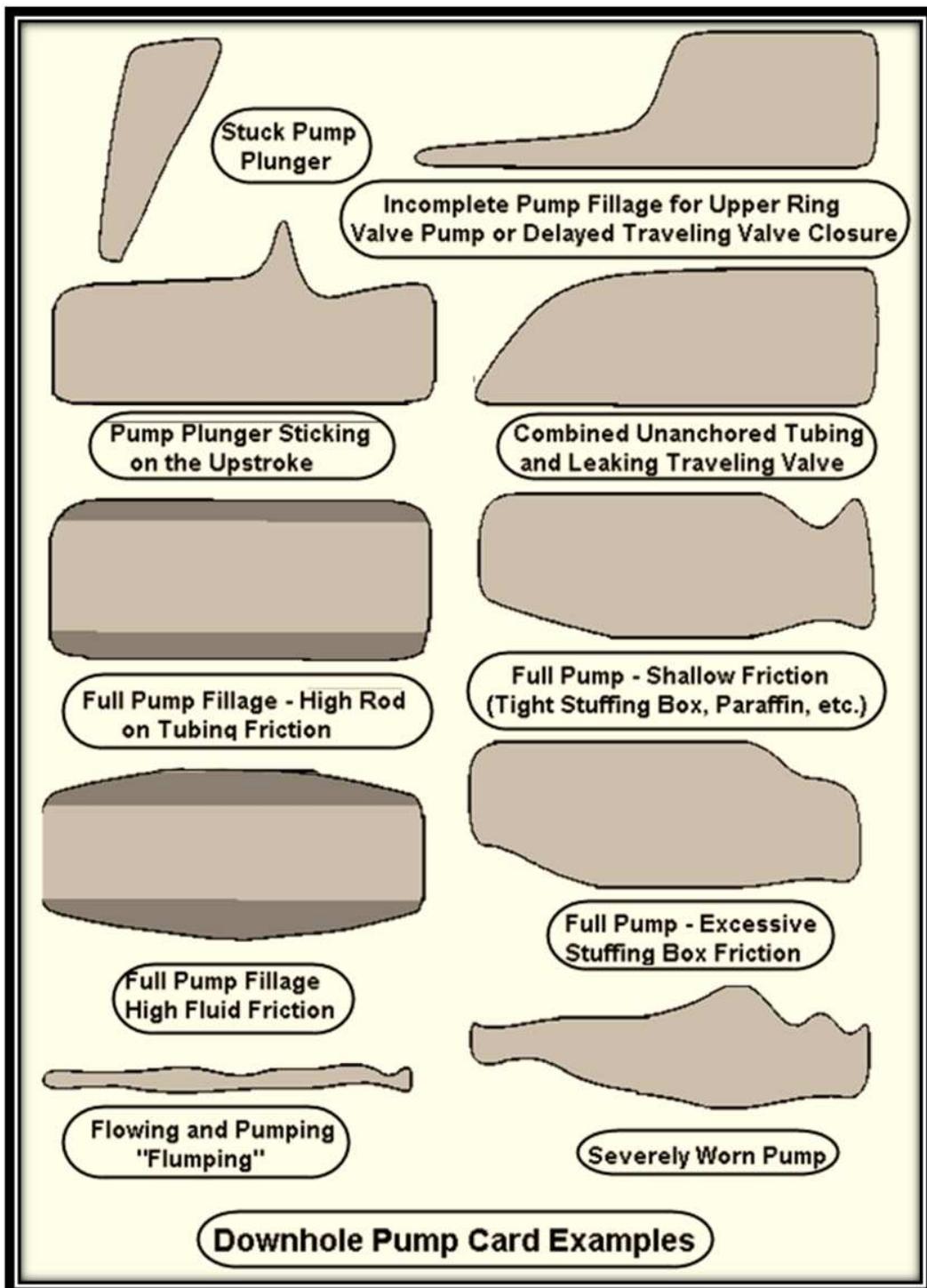
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



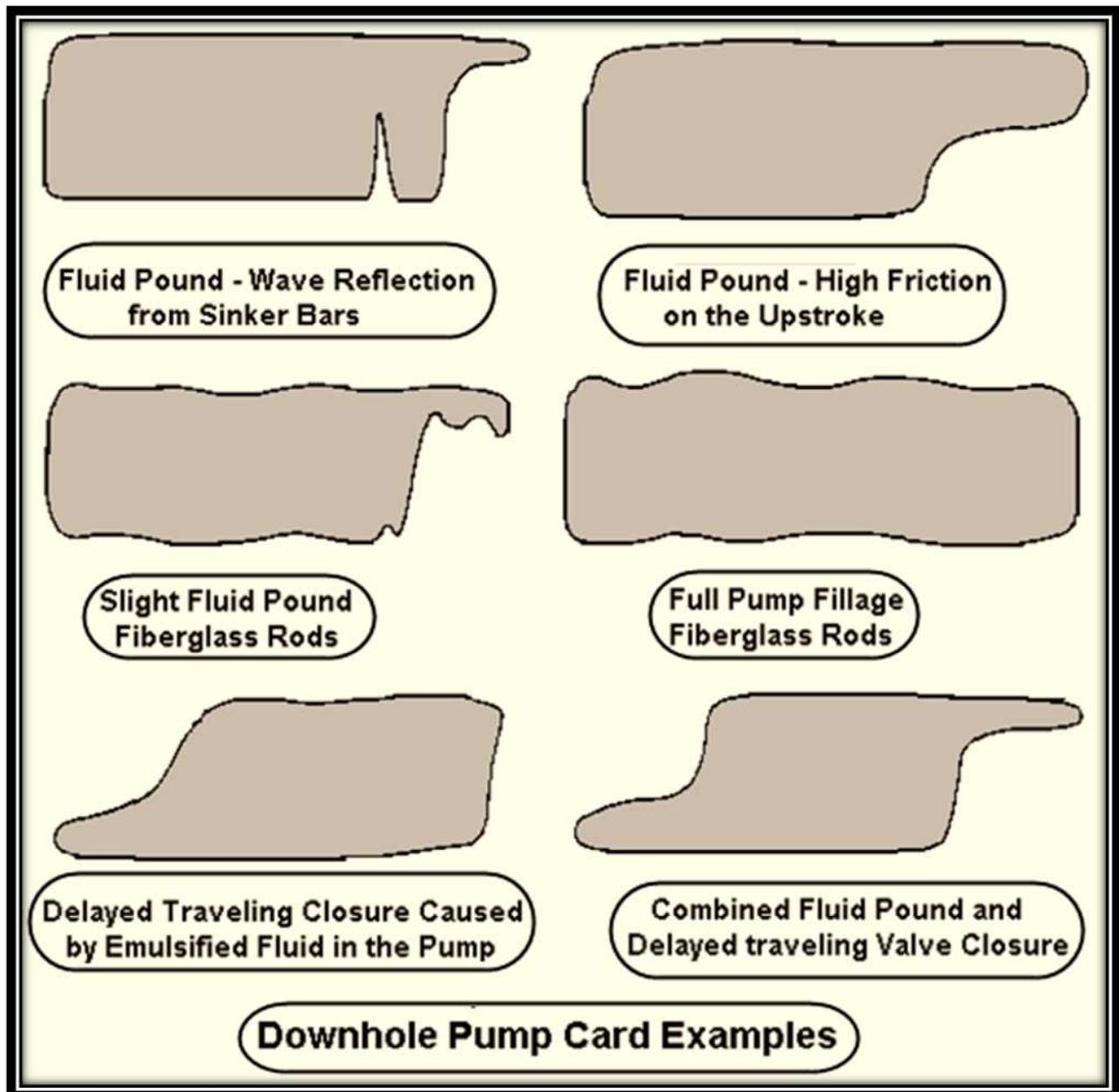
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



H
H

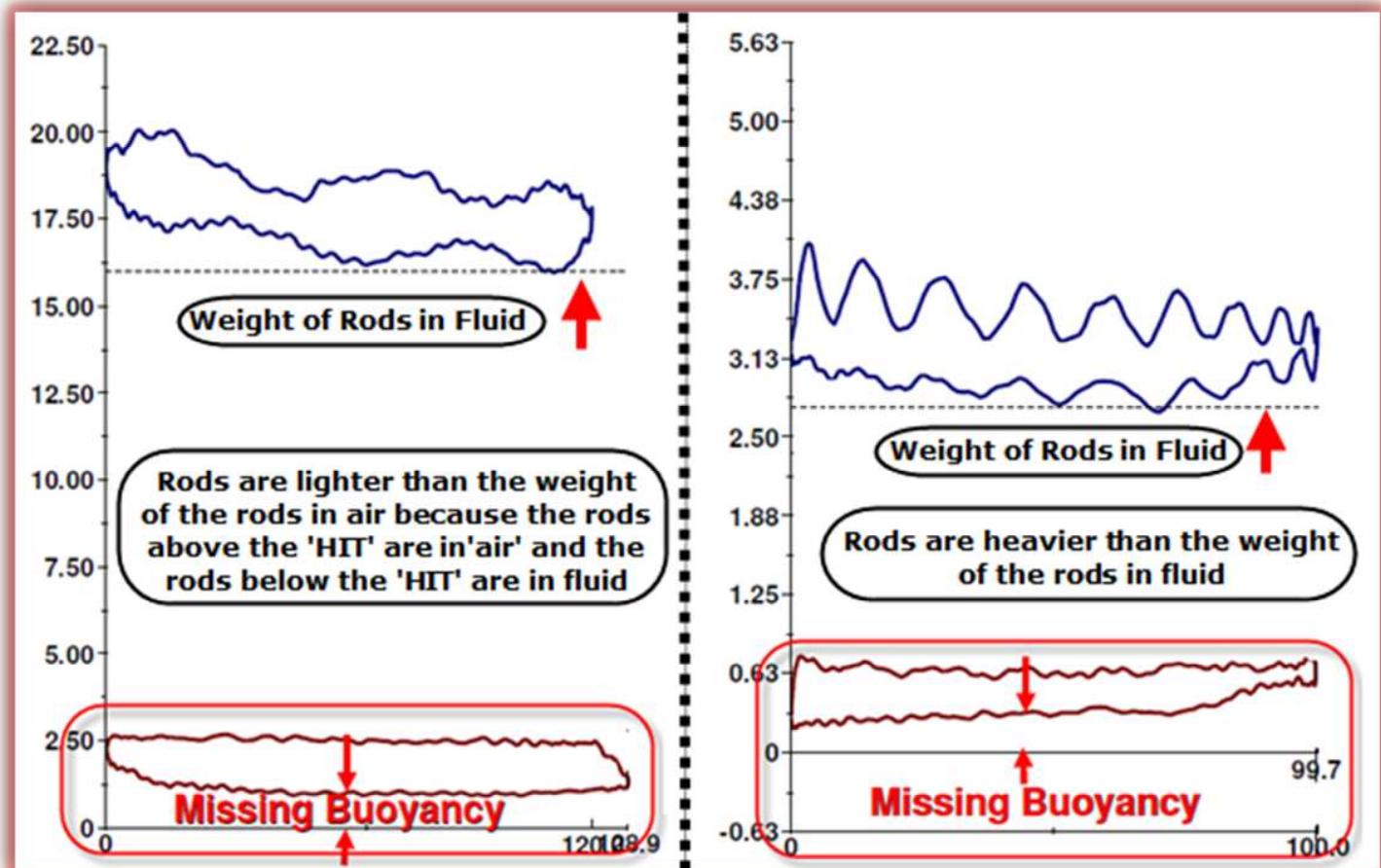


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

'Hole in the Tubing'?



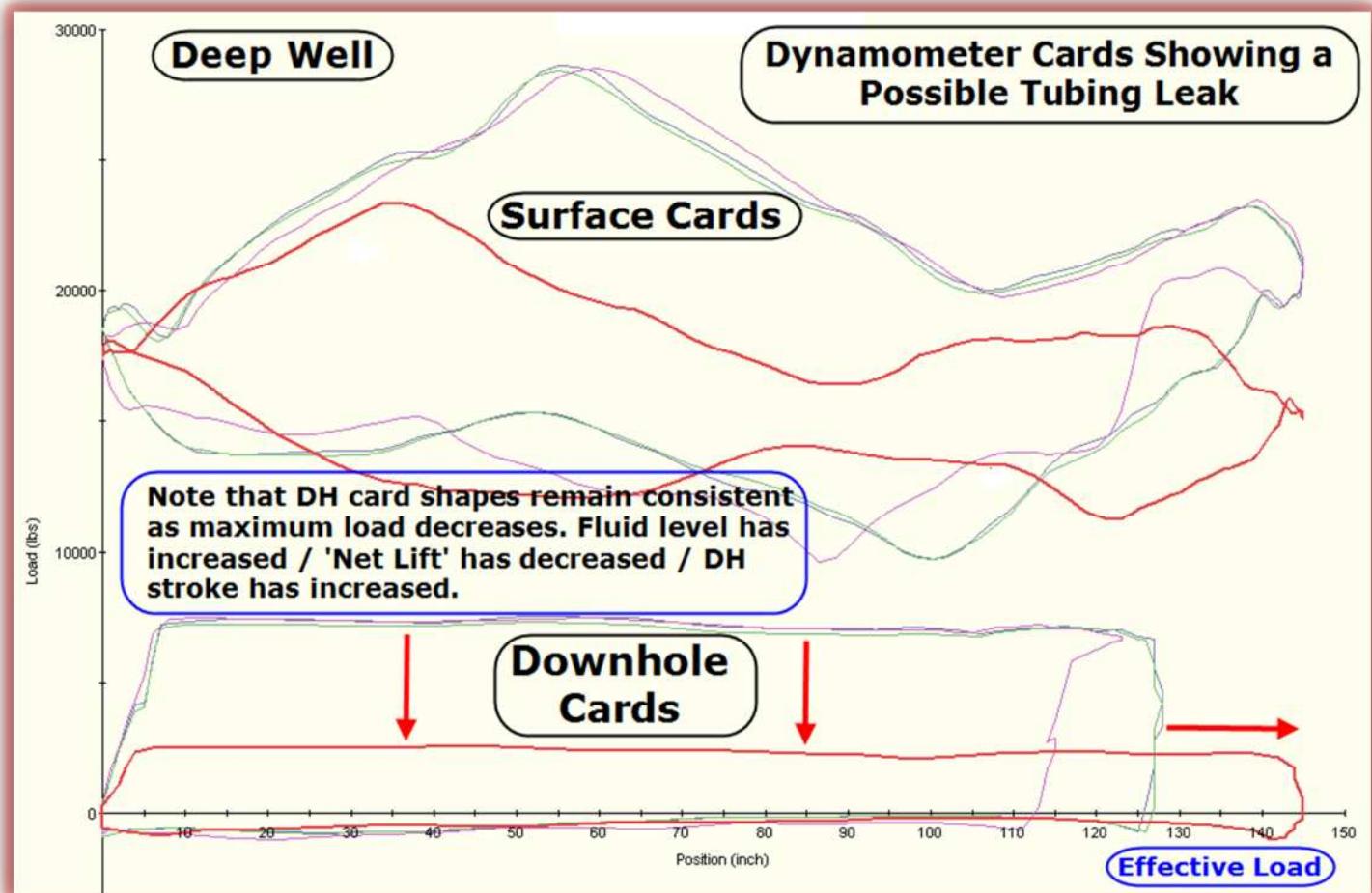
((((ECHOMETER))))



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



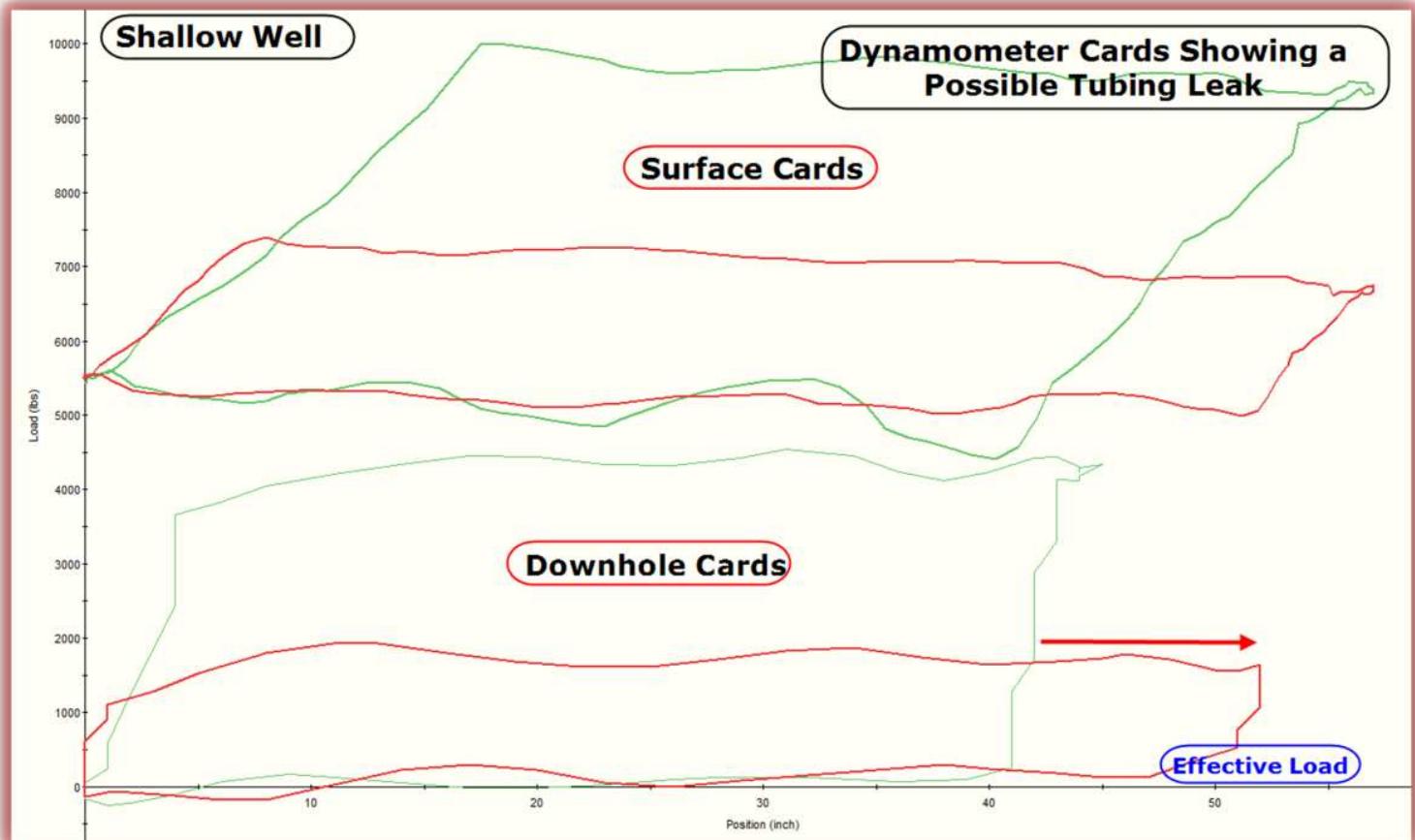
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



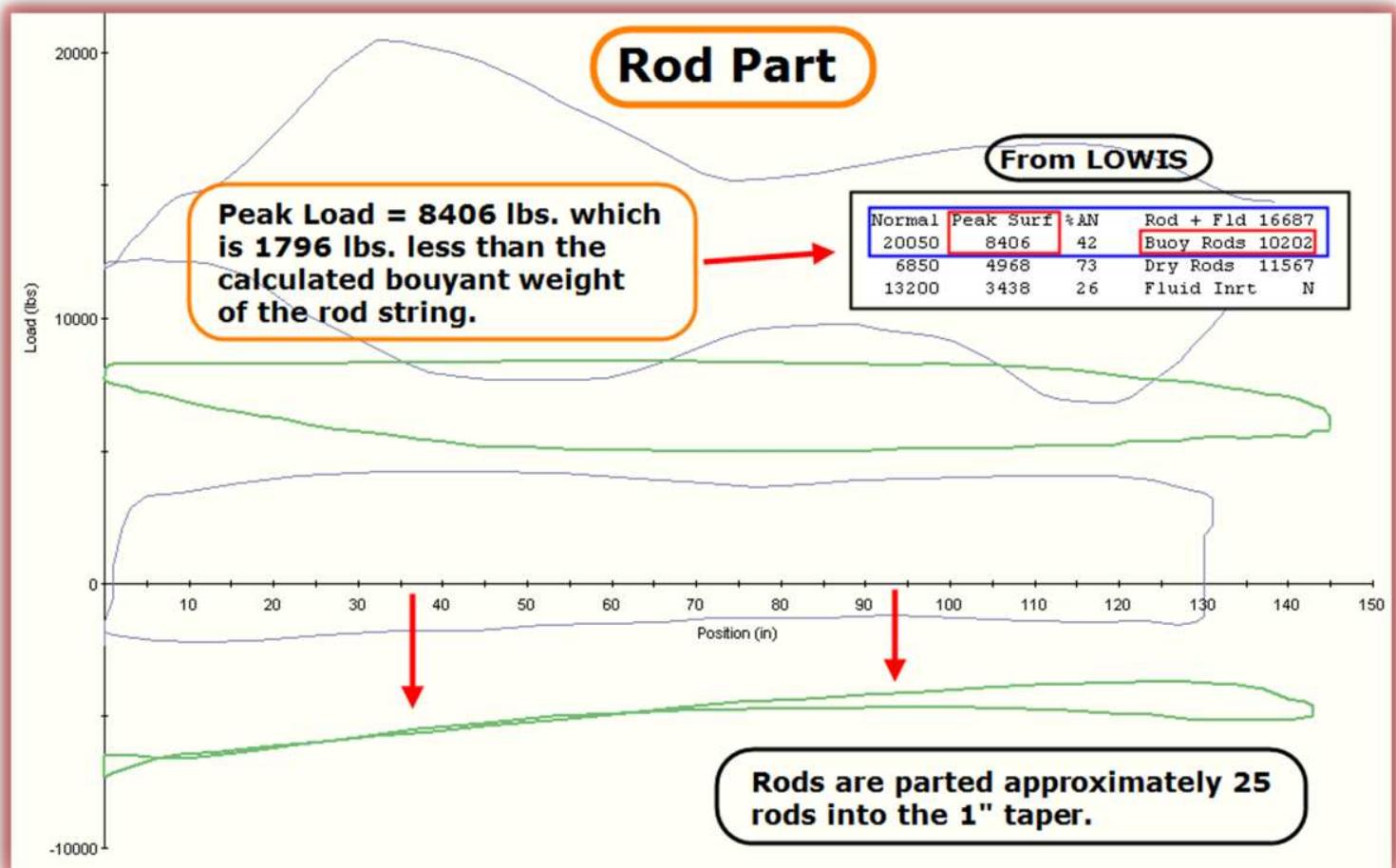
Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

'Rod Part' Examples

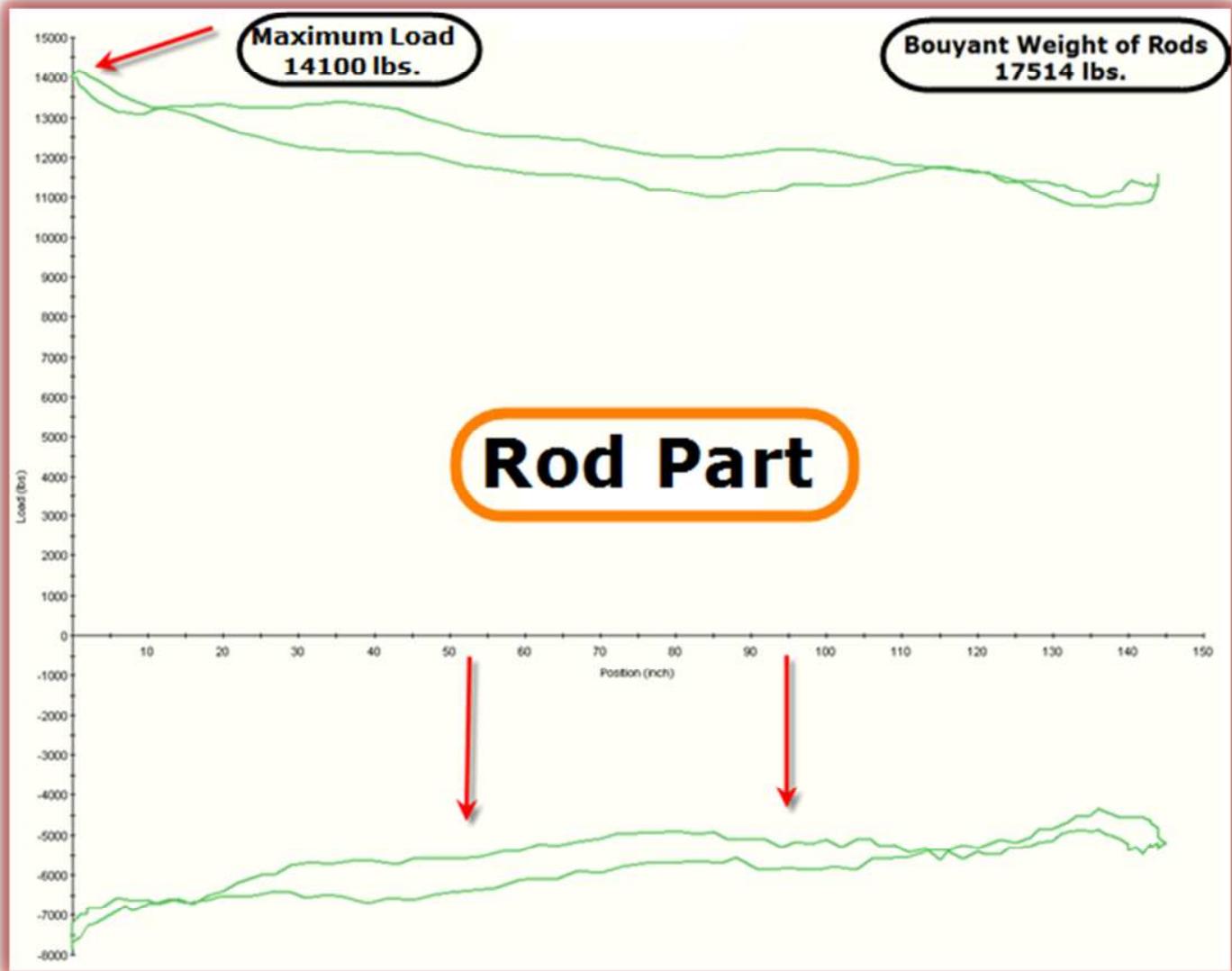
- 👉 If the static polished rod load (maximum load from the surface card) is less than the calculated buoyant weight of the installed rod string, the rods are parted.
- 👉 If the static polished rod load (maximum load from the surface card) is more than the calculated buoyant weight of the installed rod string, the rods are NOT parted.



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



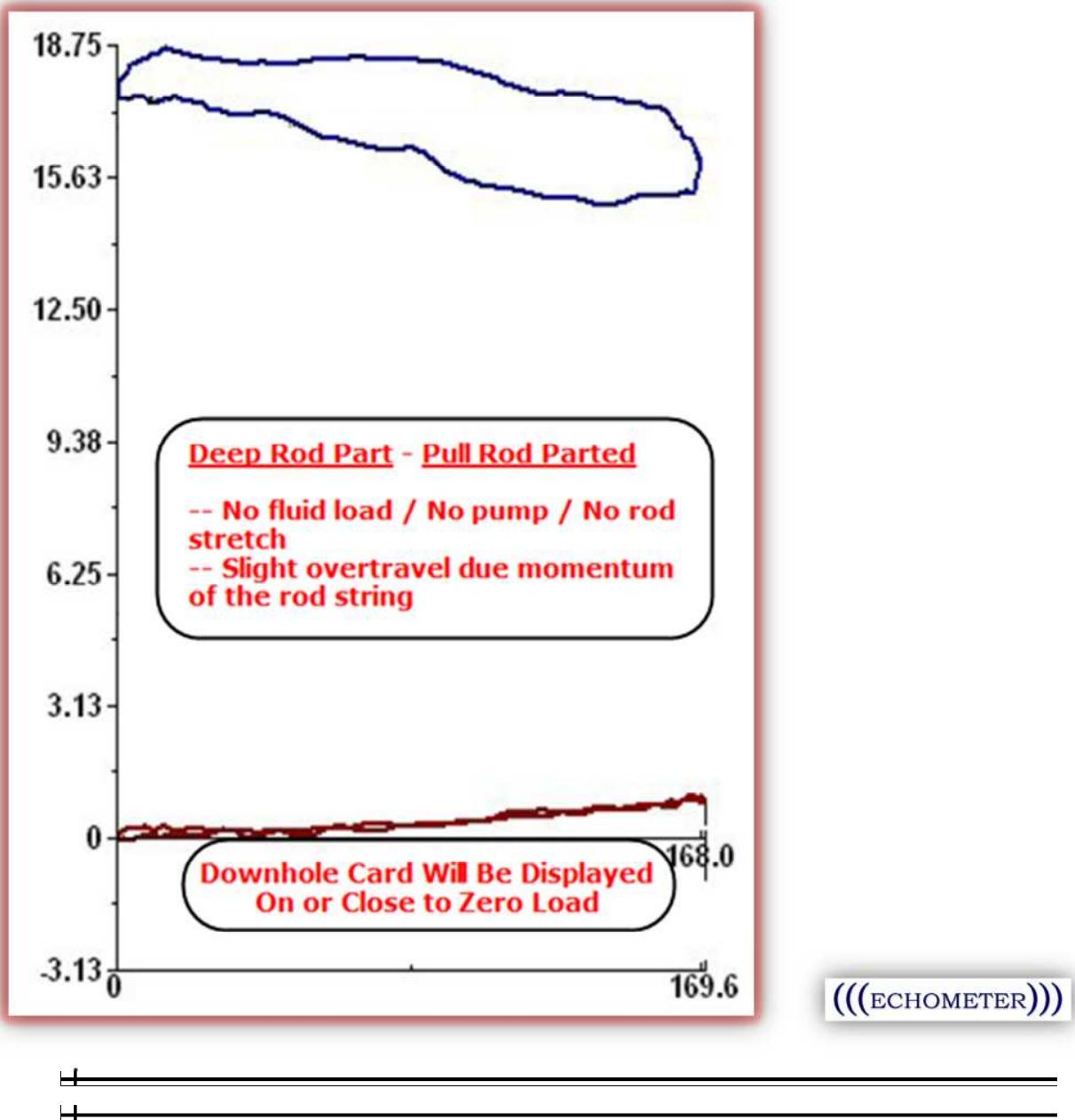
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



+

+



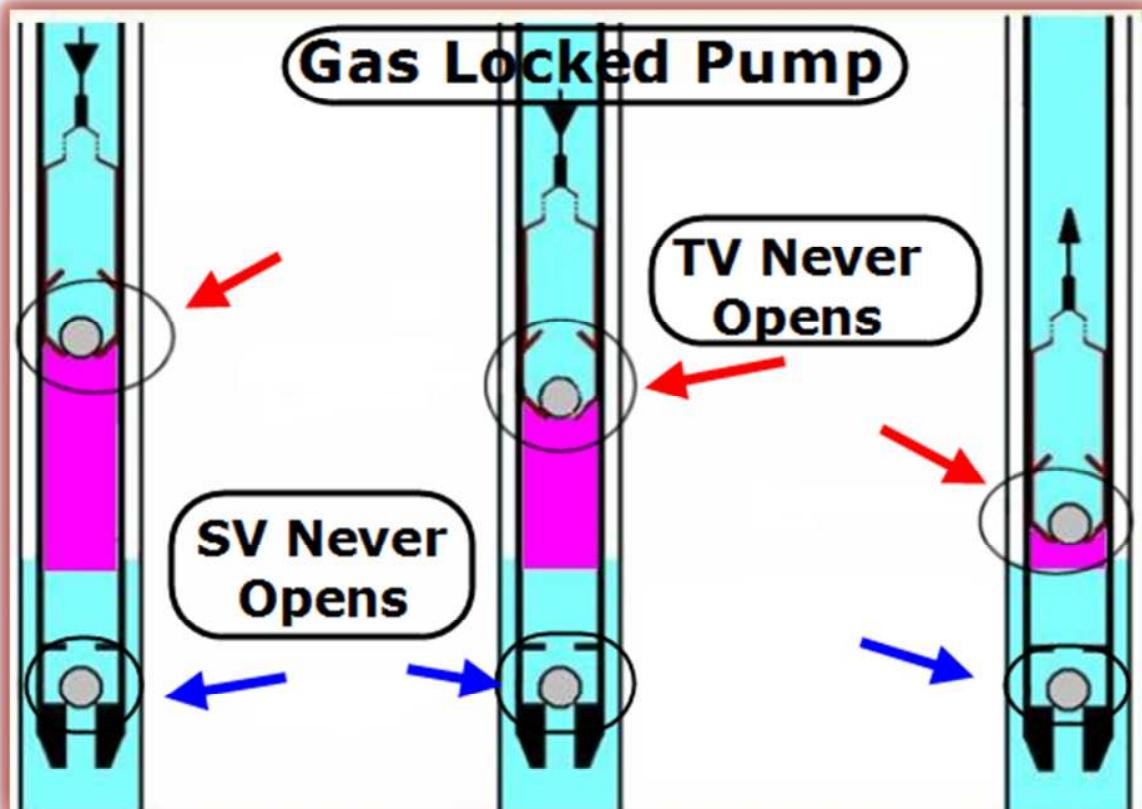
Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

'Gas Lock' Examples

- What is 'Gas Lock'?



Gas Locked Pump...Both valves remain closed because the static tubing pressure, (P_t), is greater than the pump discharge pressure, (P_d), which is also greater than the pump intake pressure, P_{int} . The compression ratio of most sucker rod pumps is too small, with the result that neither valve opens until the clearance space between valves fills by leakage of fluids past the plunger, or the fluid level is allowed to rise so that a smaller compression ratio is required to force gas from the pump into the tubing. The pressure relations are as follows:

$$P_t > P_d > P_{int}$$



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

- ➡ 'Gas lock' **CANNOT** occur if there is ANY fluid in the pump. **Do pumps have built-in 'slip' or wear over time? If the answer is yes** – then that is why one can state that "**Rod pumped wells do not gas lock!**"
- ➡ Note also that if a well is truly 'gas locked', the downhole card will display between 'Fo Up' and 'Fo Down' – touching neither.
- ➡ From Lynn Rowlan with Echometer ("Gas Locked Pump Are Not Gas Locked" – Presented at the SWPSC)

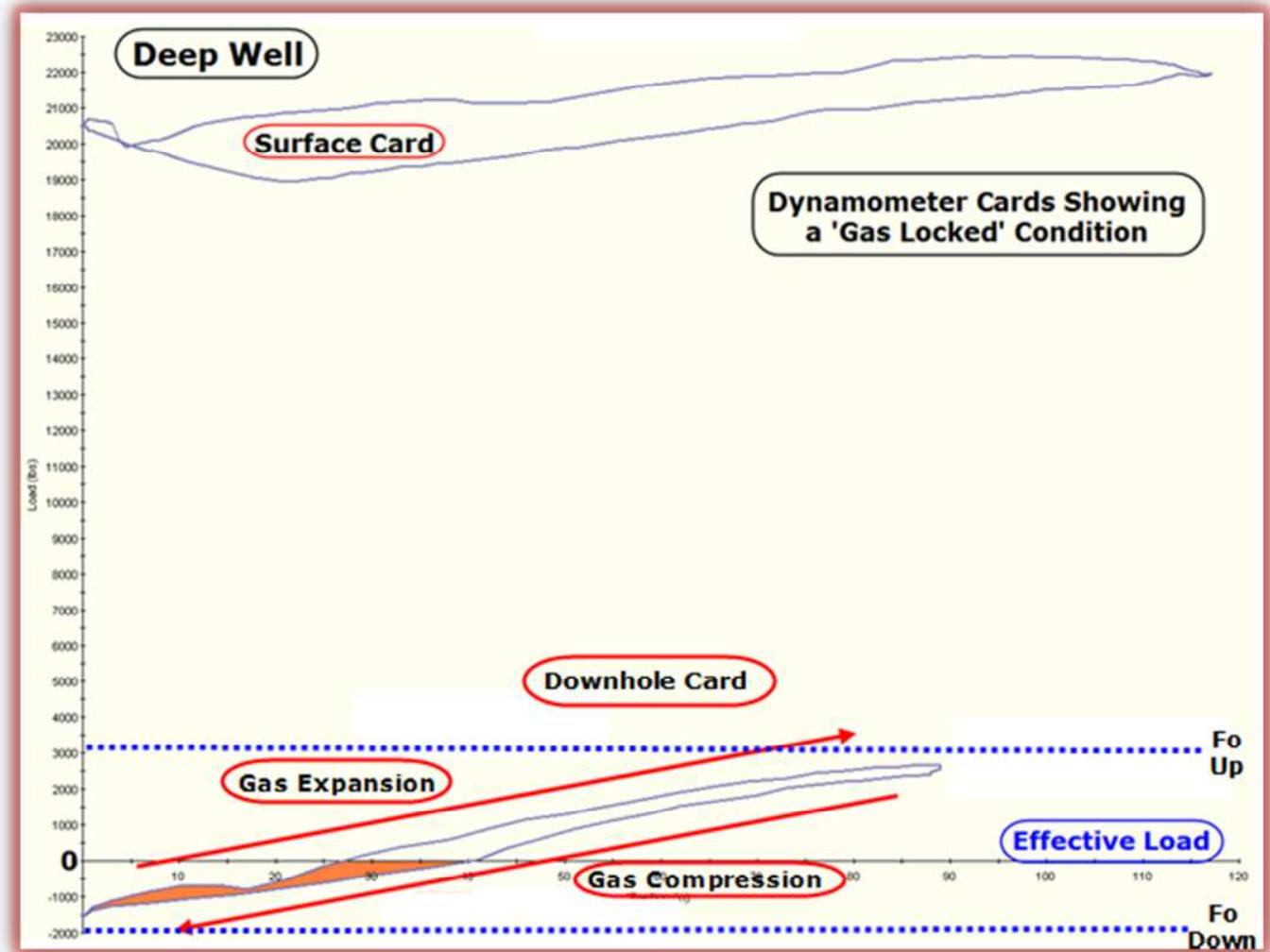
*"If the pump has clearance between the plunger and the barrel, then it is **impossible** to gas lock the pump. Unloading tubing fluids is usually caused by poor downhole gas separation, because the gas in the pump is discharged into the tubing. Pump action stops when too much gas is pumped into the tubing, because excessive gas discharged into the tubing lightens the tubing liquids causing the tubing liquids to unload from the tubing. The real problem is loss of pump action, not Gas Lock. When operators state their pump is gas locked, then the typical problem is the pump has no differential pressure across the valves and the pump will not pump."*



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



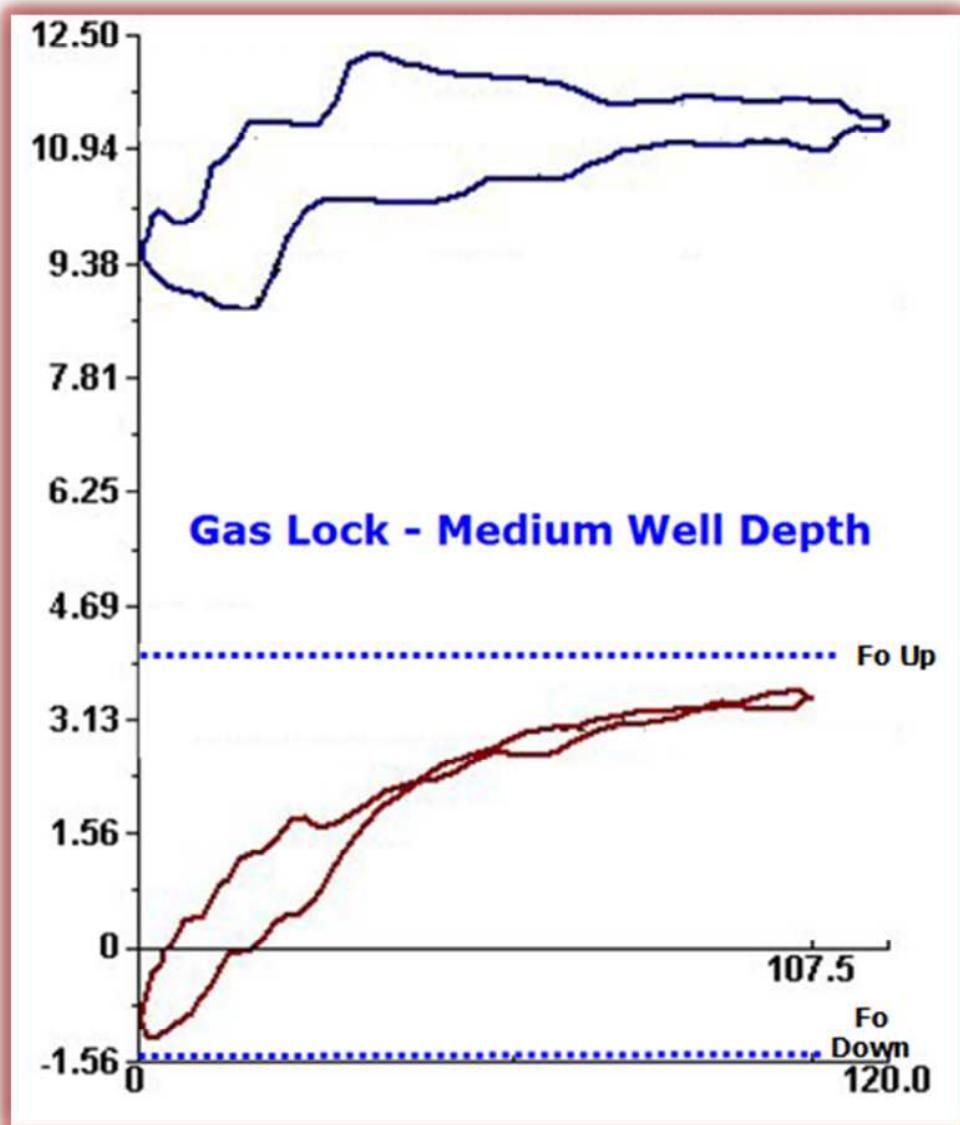
- ➡ Tubing can be anchored or unanchored when a deep well is 'gas locked' and the downhole card shape remains the same.



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



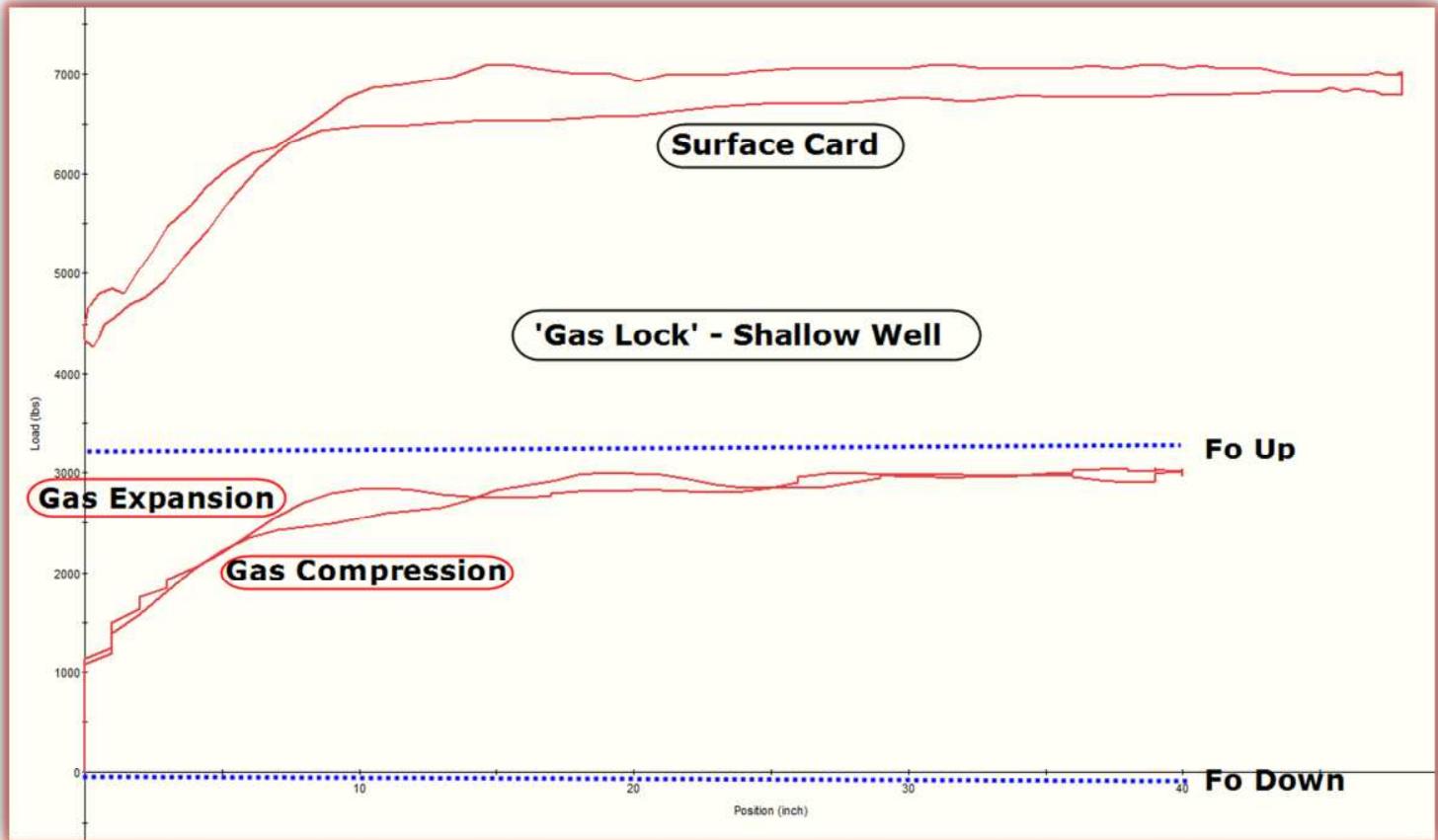
((((ECHOMETER))))



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

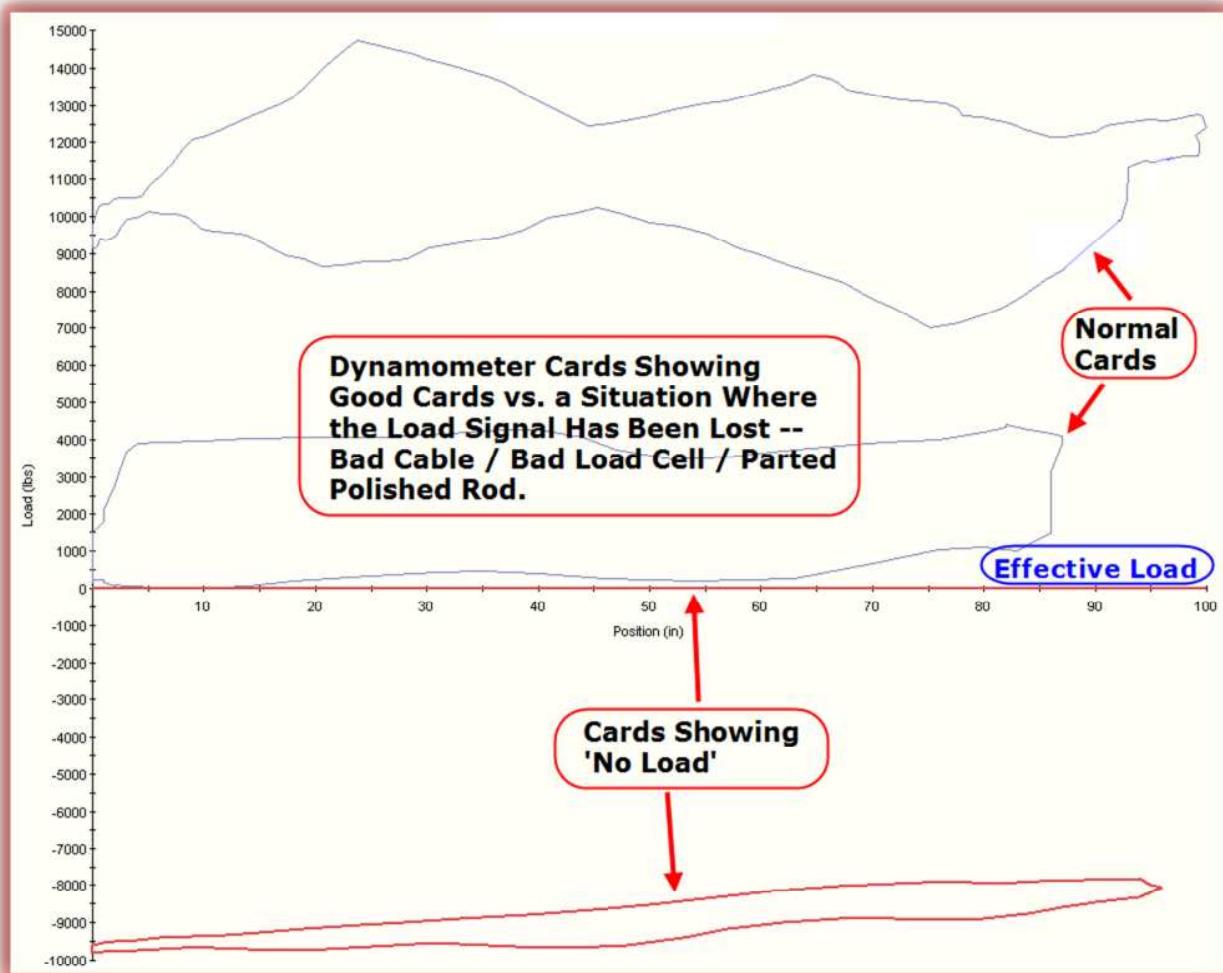


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

'No Load Signal' Example



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

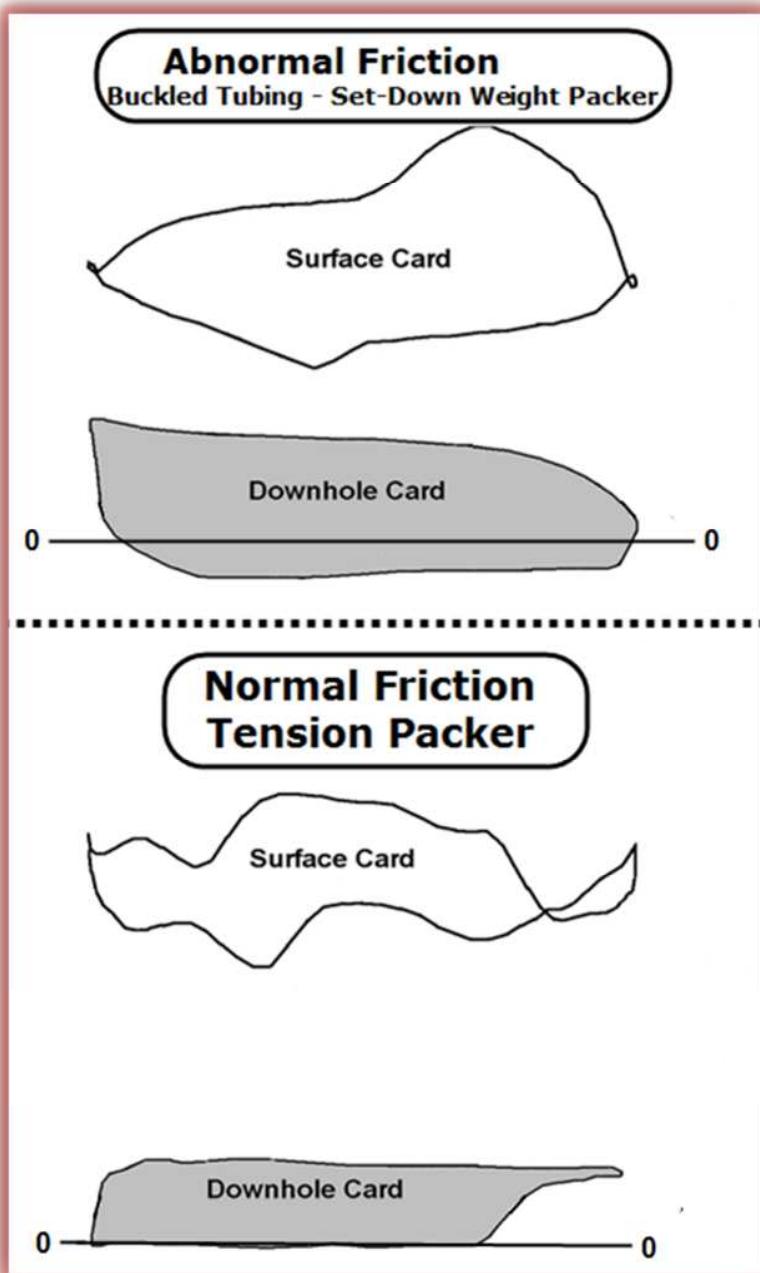


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

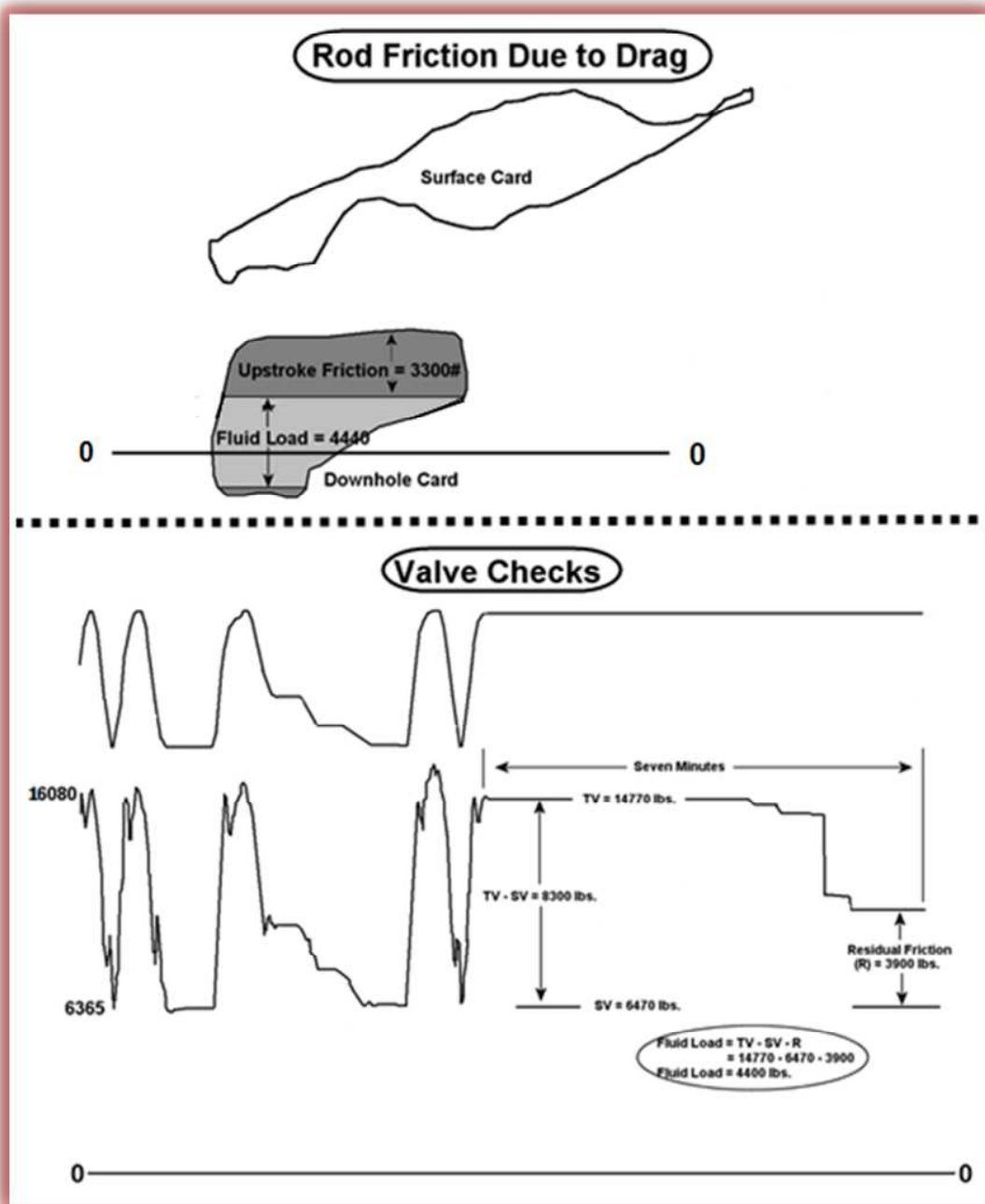
Downhole 'Friction'/'Set-down Packer'/'Buckled Tubing'



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

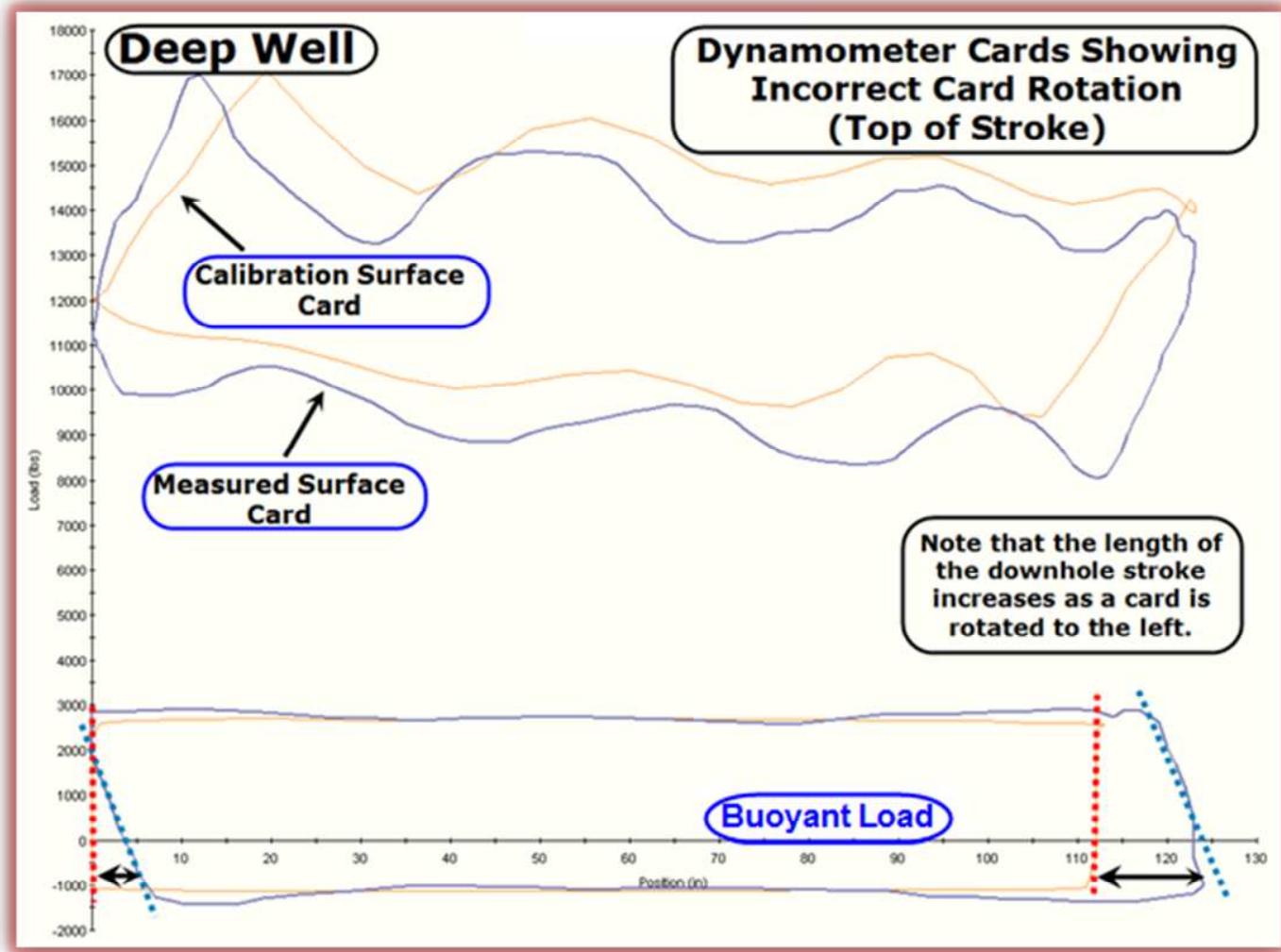


Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

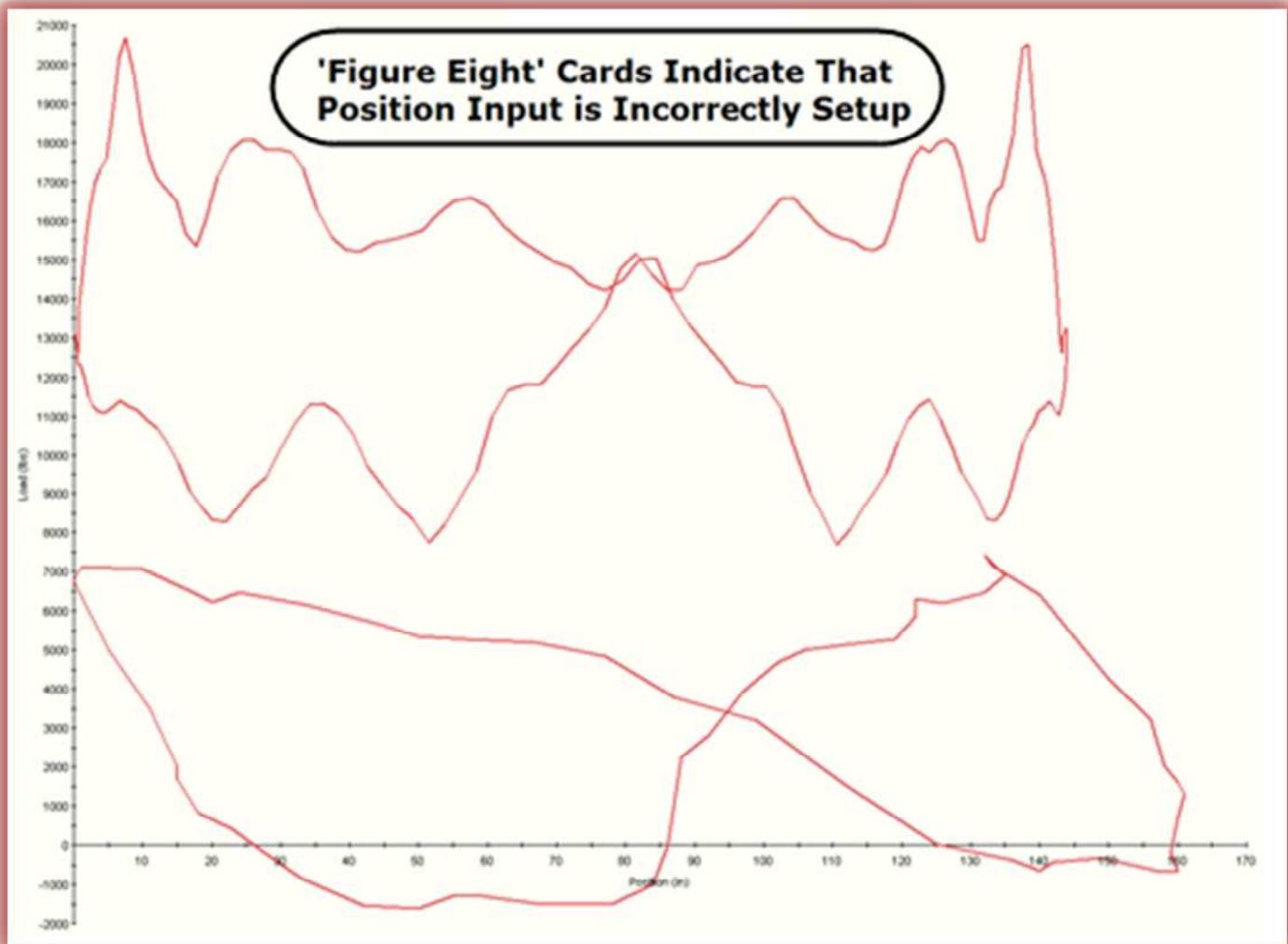
'Top of Stroke' Problems



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



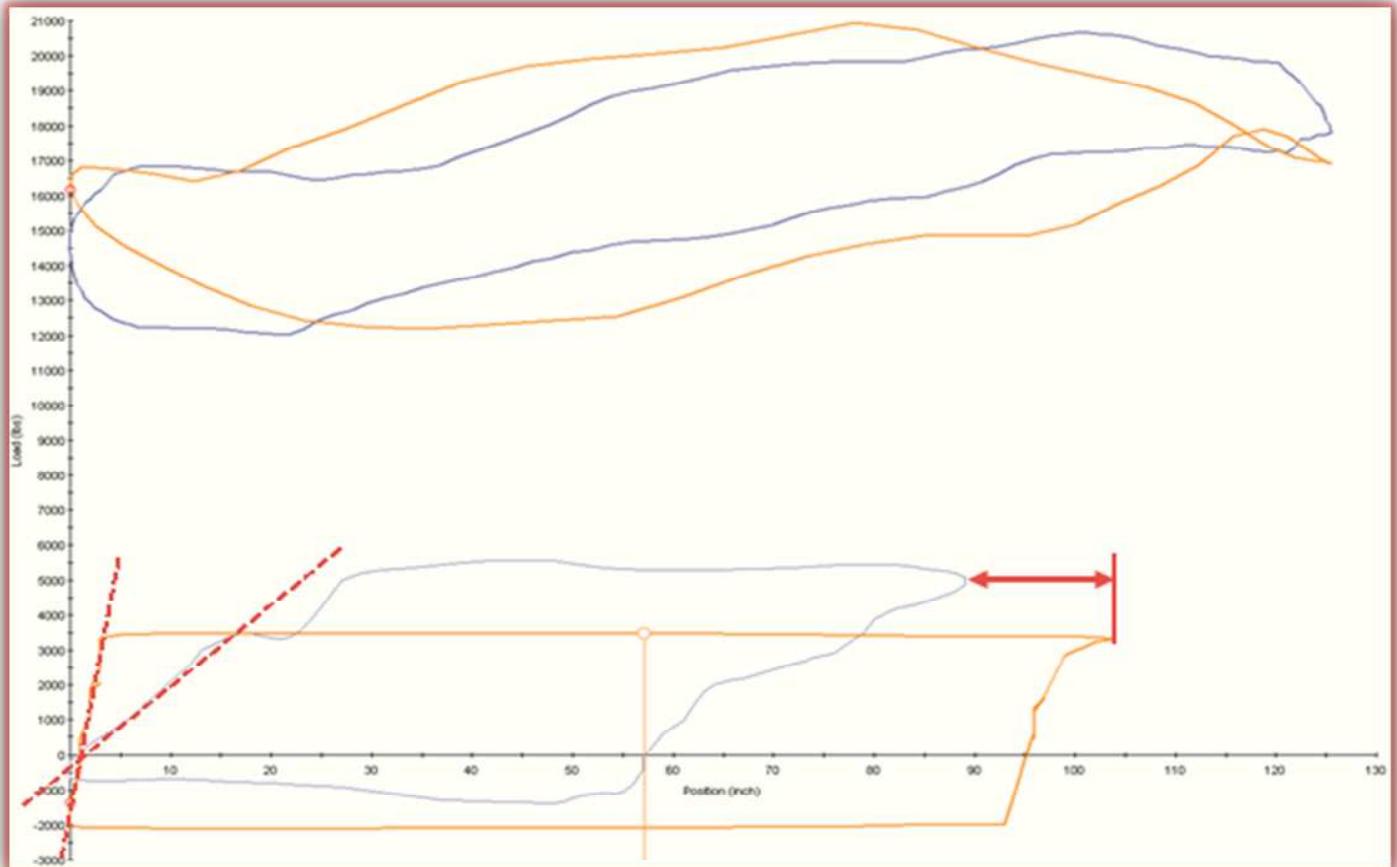
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



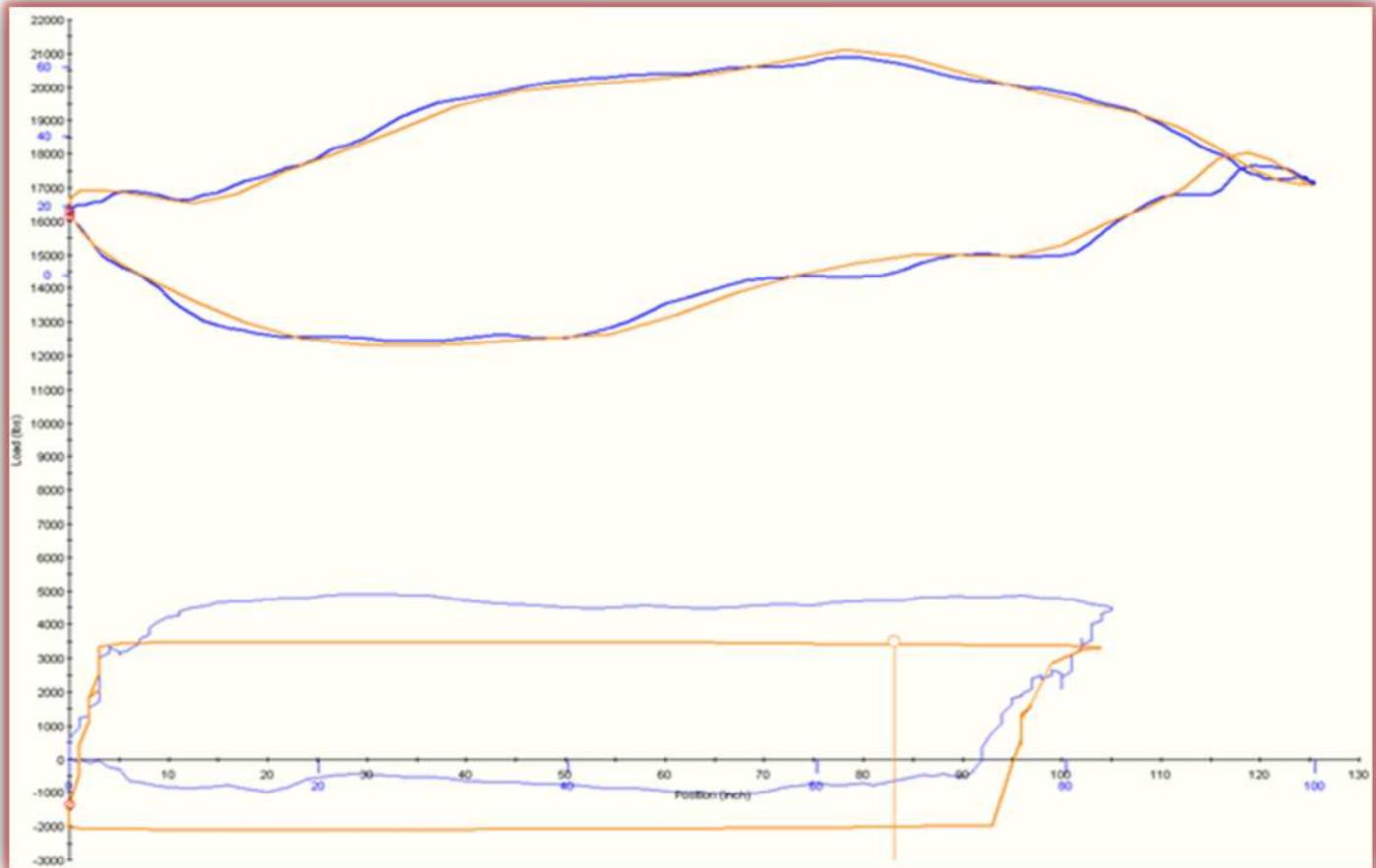
'Top of Stroke' Badly Off



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



'Top of Stroke' Corrected

	Full Card (Uncorrected)	Full Card (Corrected)
Gearbox Torque (in-lbs / %)	181,000 / 56	265,000 / 82
Peak Rod Stress (%)	75	69
Gross Stroke (in)	89.3	104.1
Net Stroke (in)	62.4	92.6
Net Stroke Displacement (BPD)	68.5	101.8

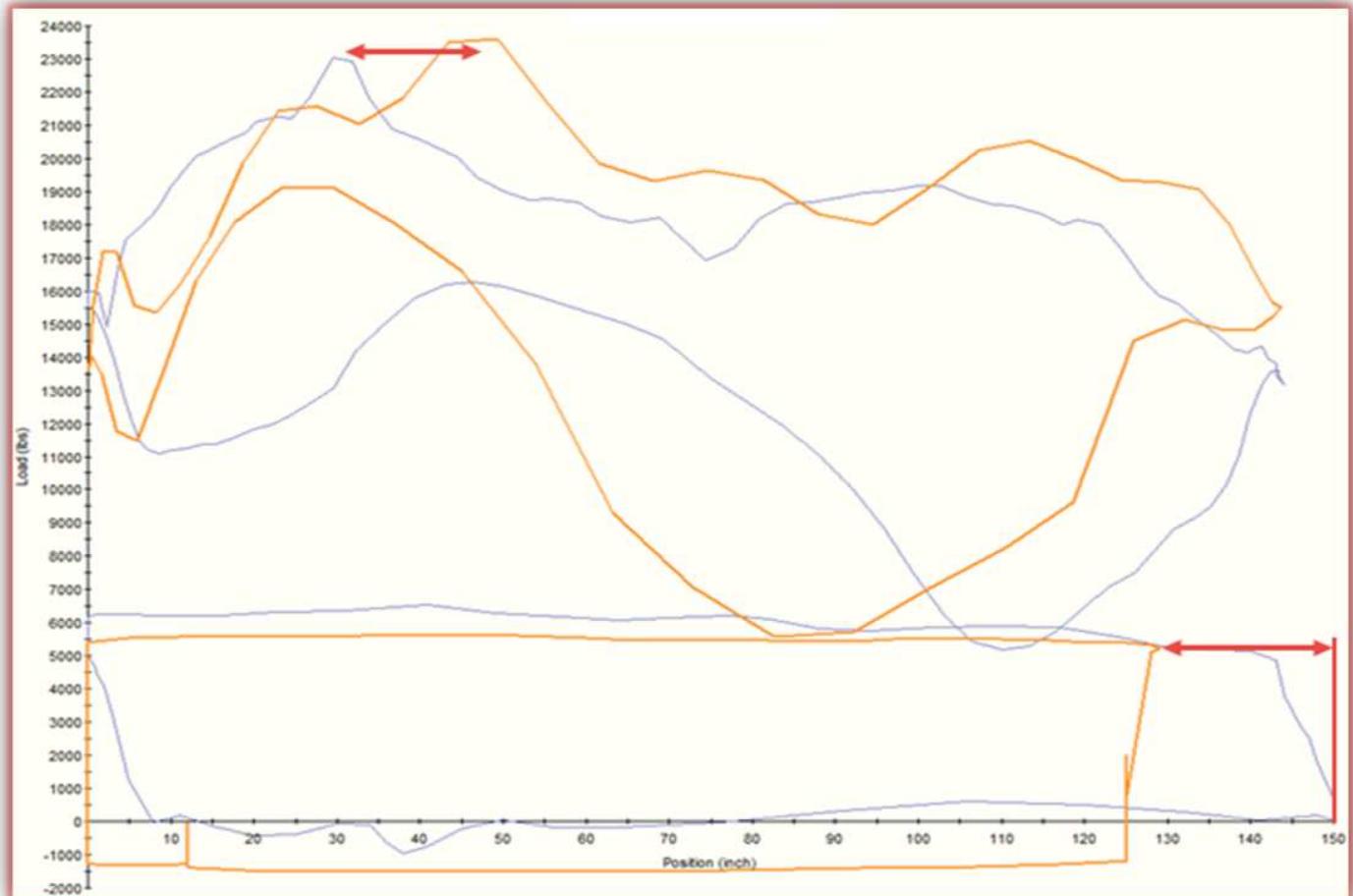
—
—



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



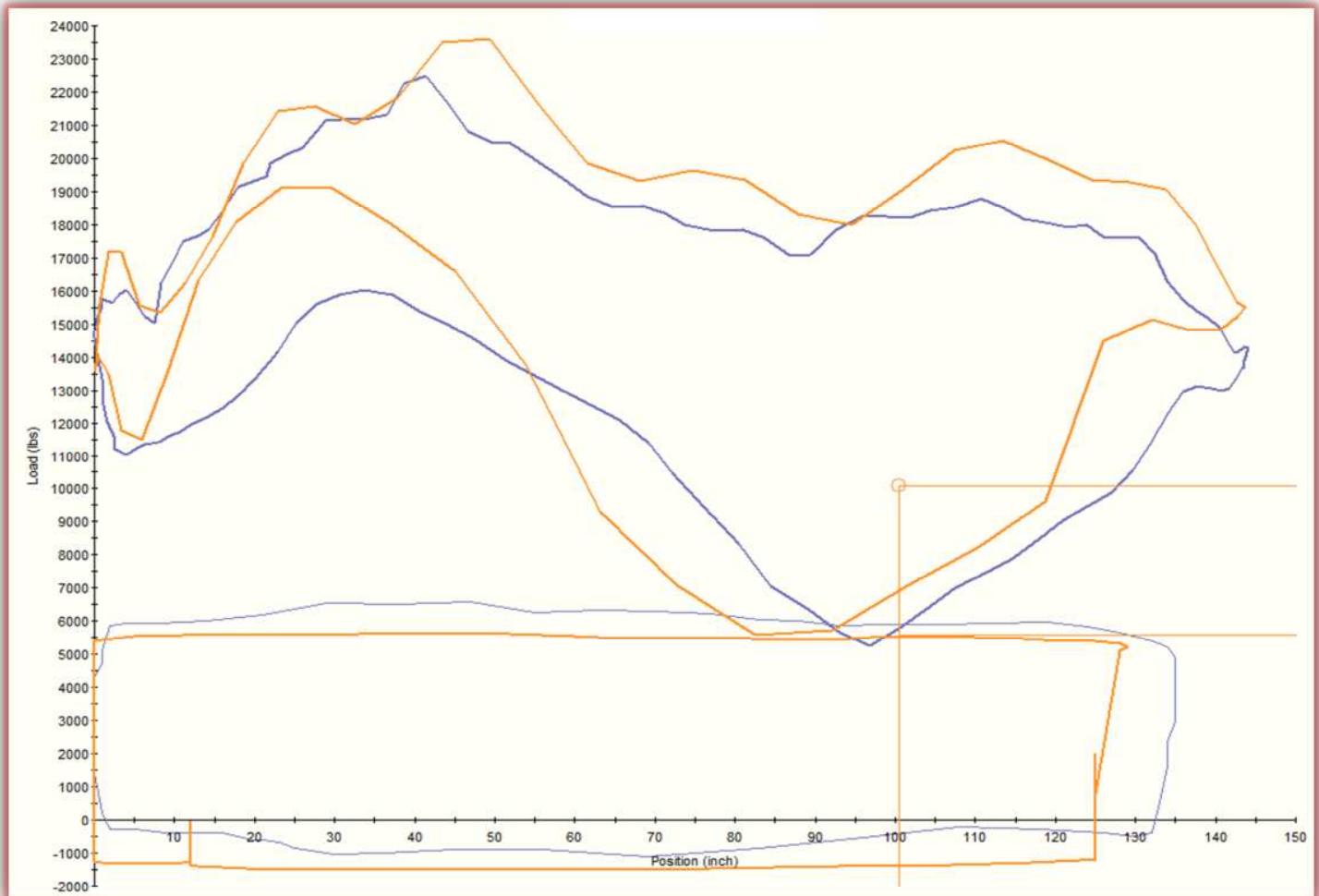
'Top of Stroke' Off



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



'Top of Stroke' Corrected

	Full Card (Uncorrected)	Full Card (Corrected)
Gearbox Torque (in-lbs / %)	419,000 / 65	436,000 / 68
Peak Rod Stress (%)	85	85
Gross Stroke (in)	151.0	137.0
Net Stroke (in)	145.3	127.6
Net Stroke Displacement (BPD)	472.8	415.3

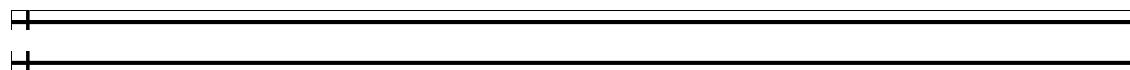
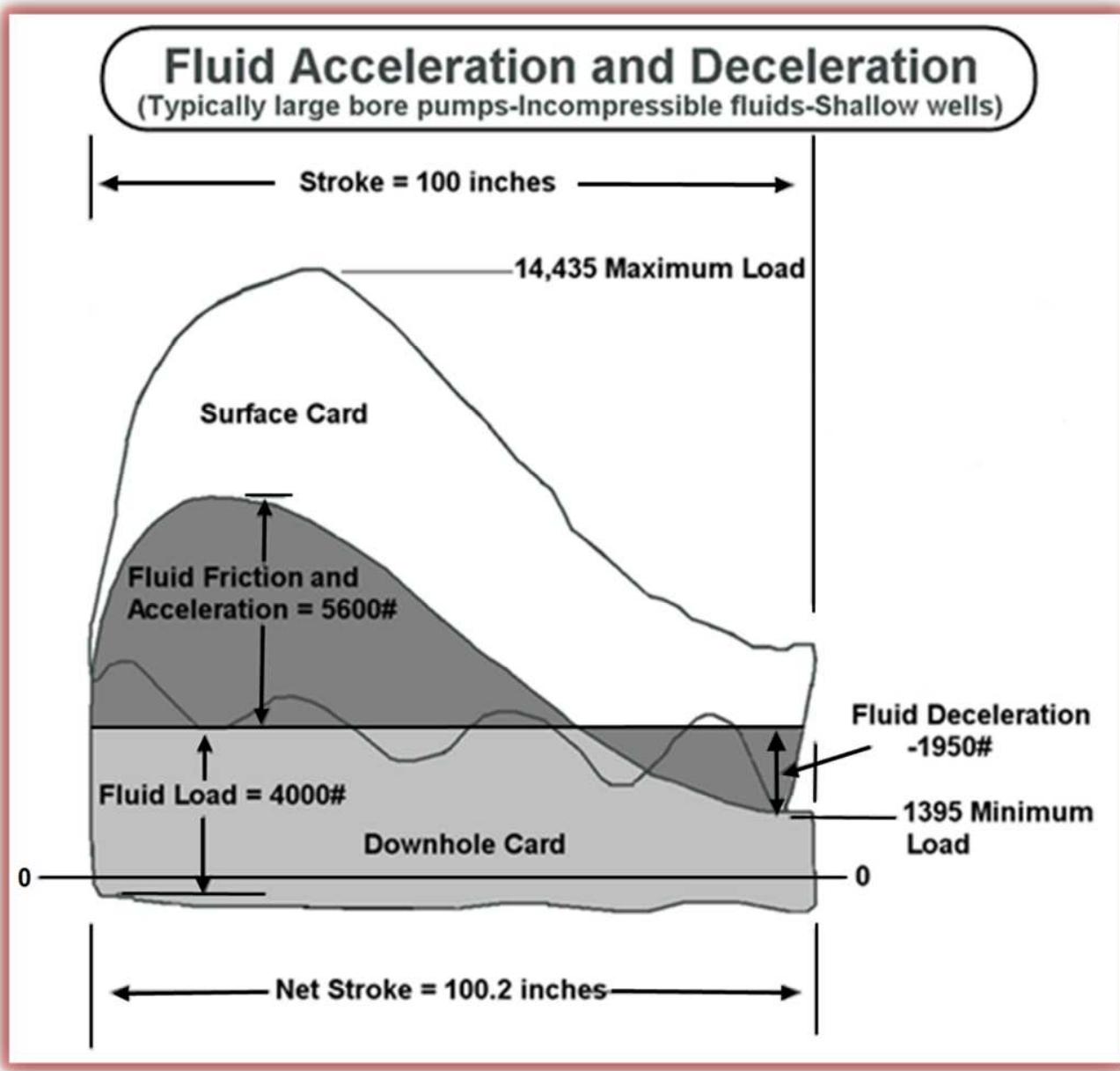


Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

'Fluid Acceleration' / 'Deceleration'

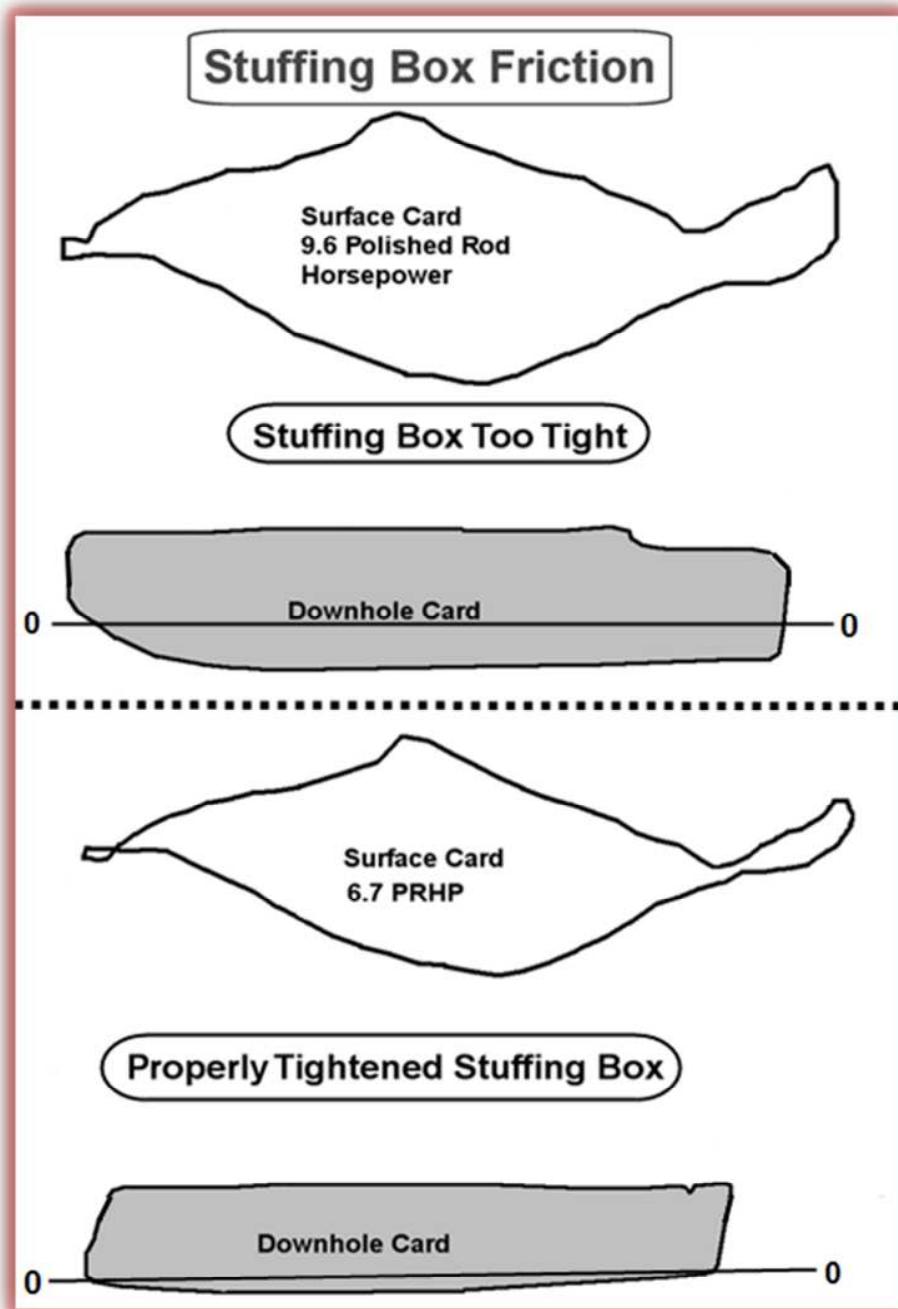


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

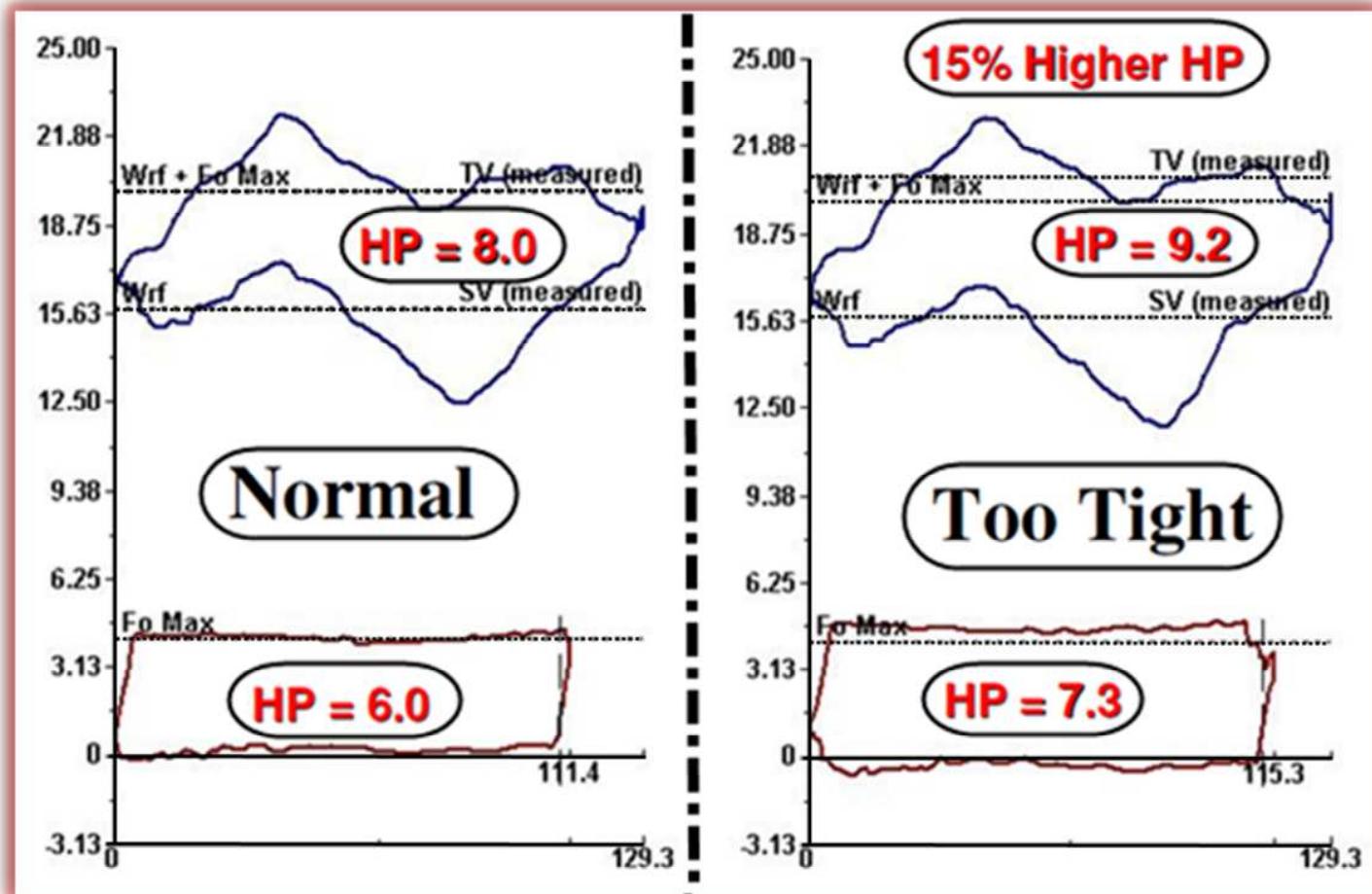
'Stuffing Box Friction'



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



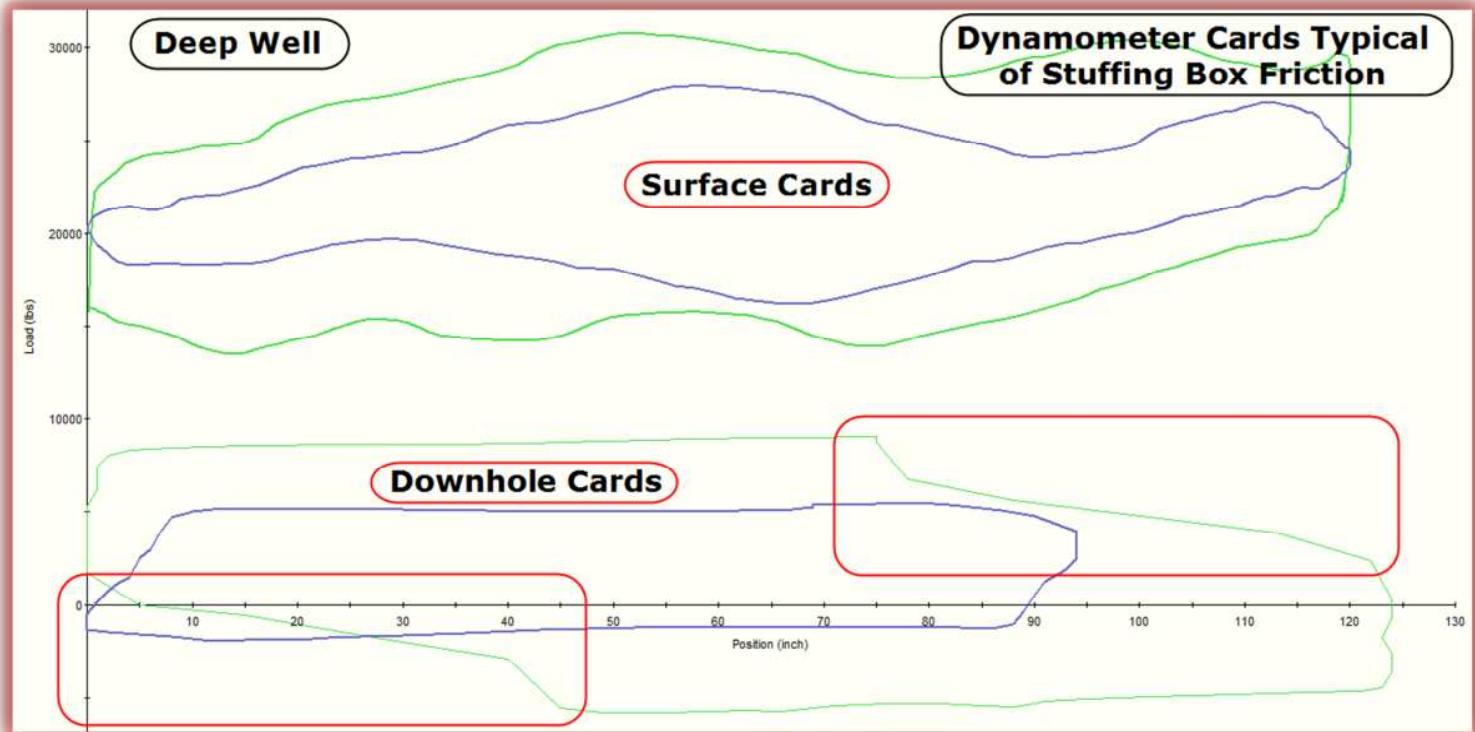
((((ECHOMETER))))



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



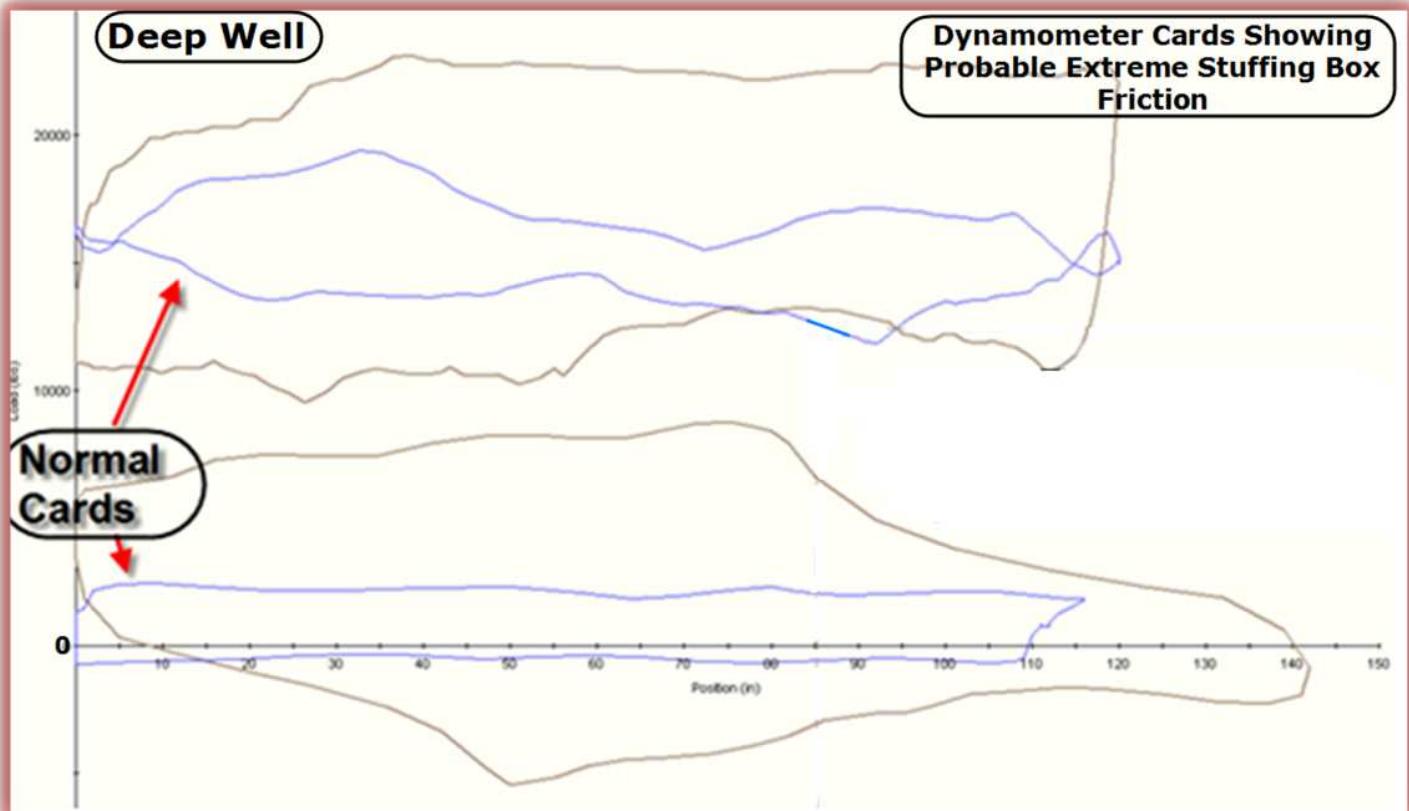
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

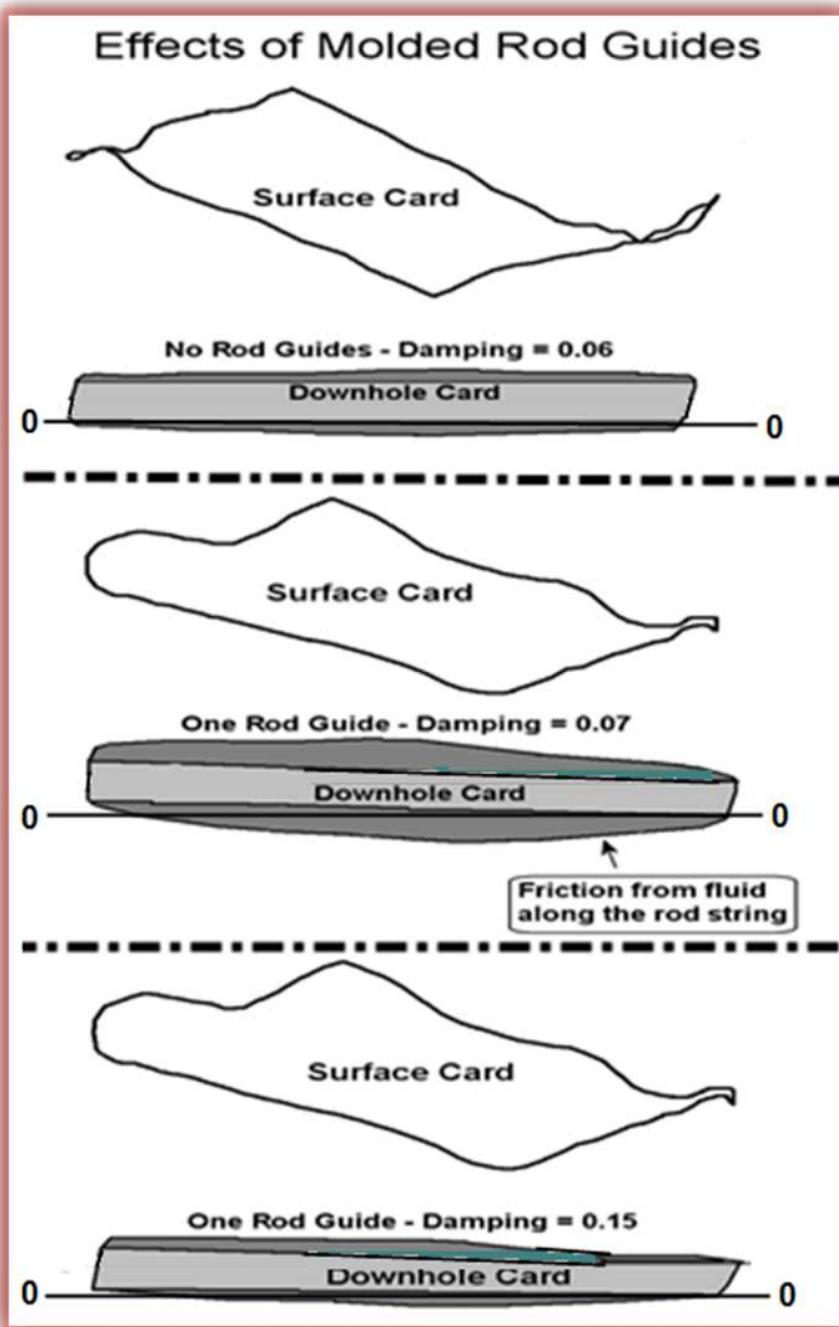


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

'Rod Guides' and Downhole Cards

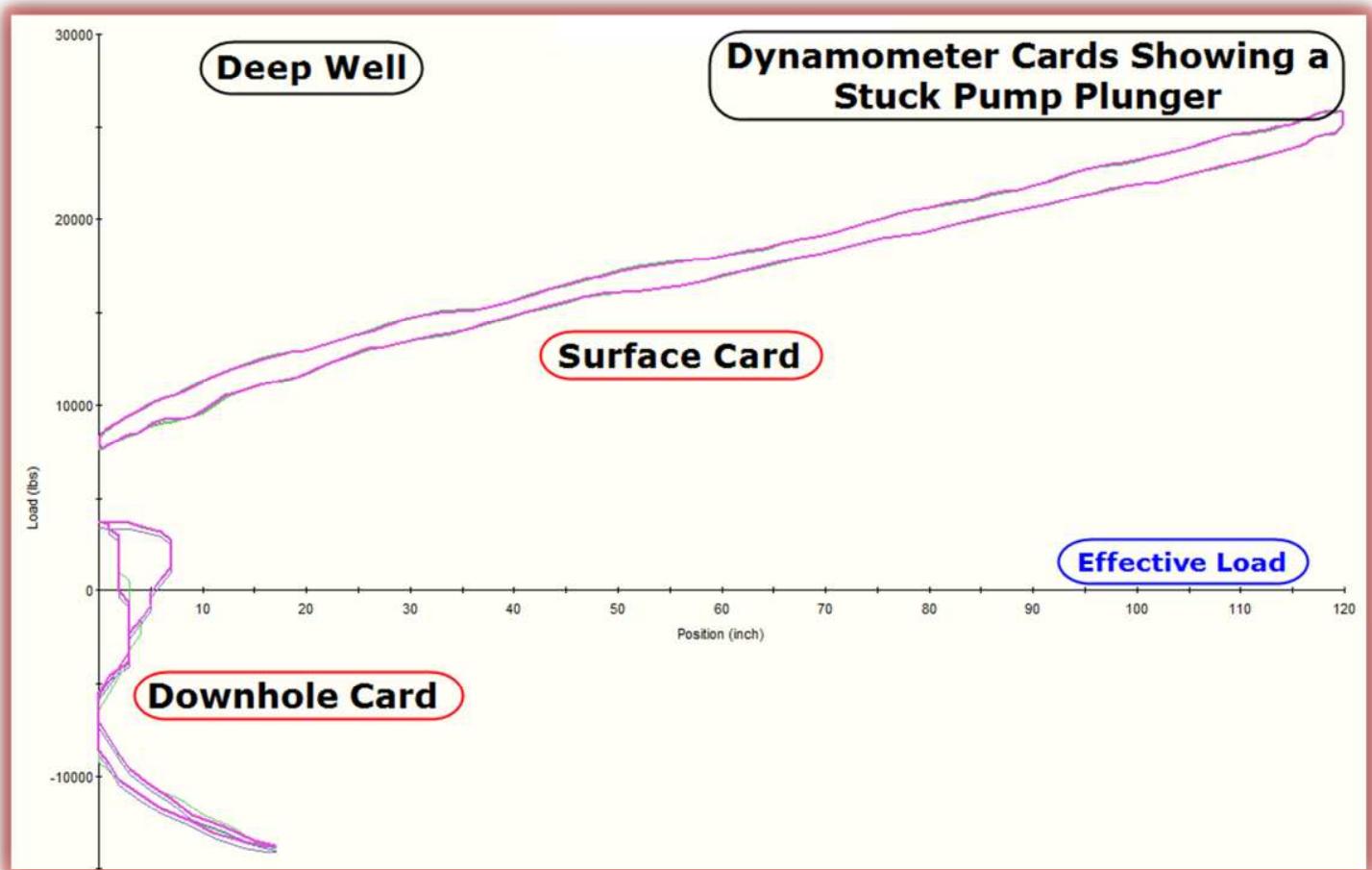


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

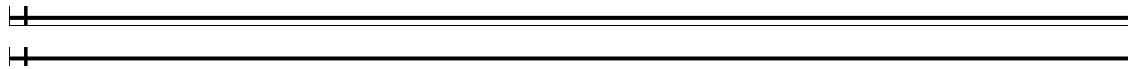
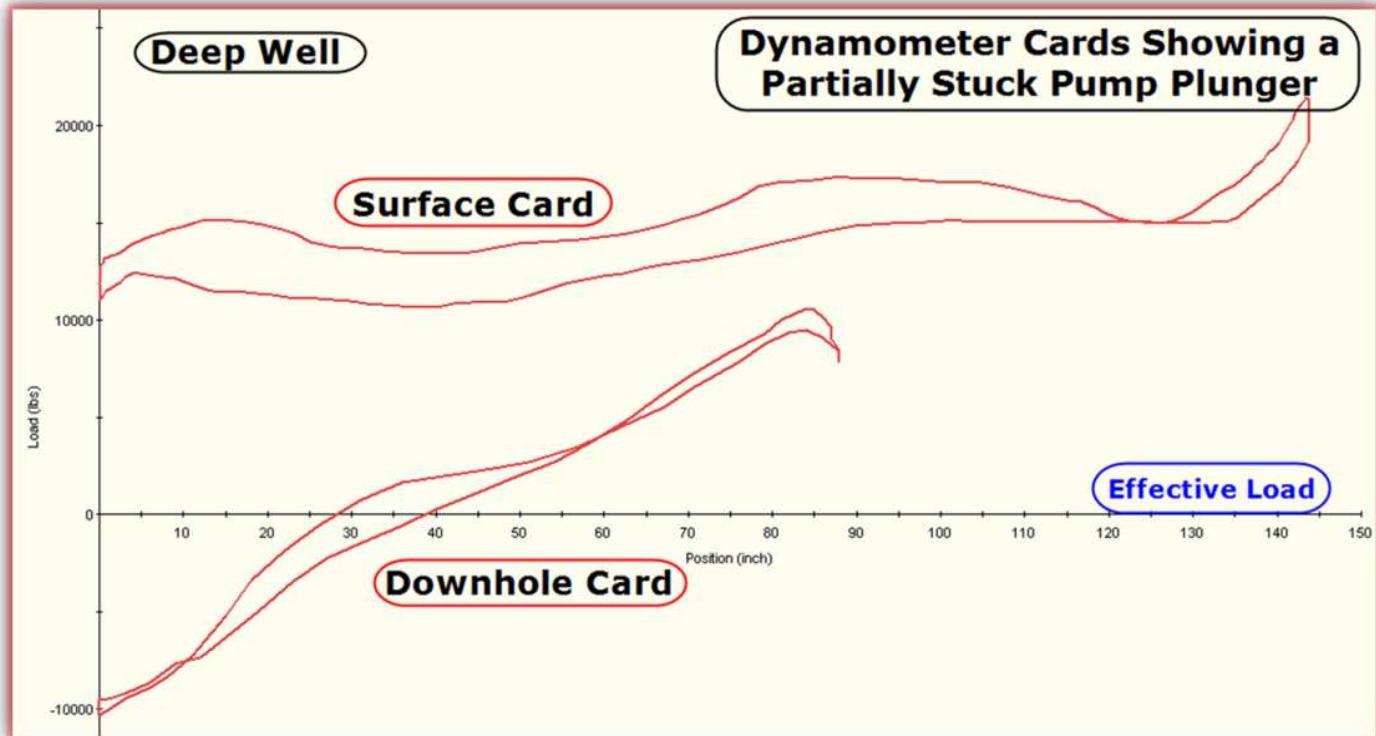
'Stuck Pump Plunger'



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



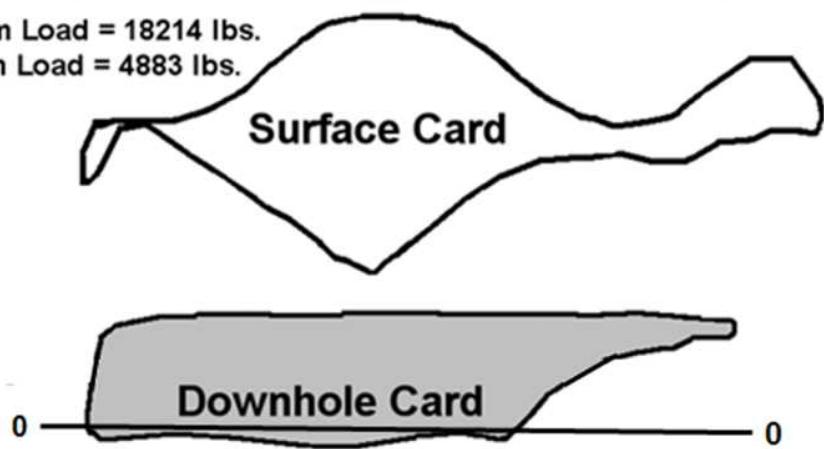
Surface and Downhole Dynamometer Card Interpretation

Effects of 'Tubing Pressure'

Tubing Pressure Effects

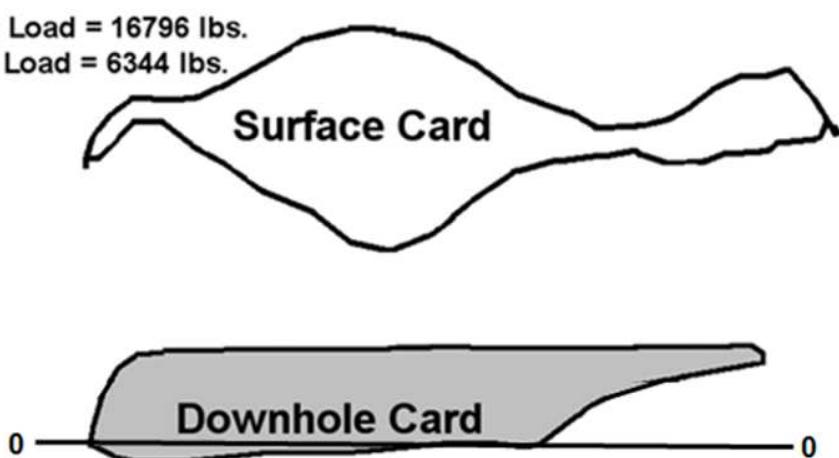
Tubing Pressure = 410 PSI

Maximum Load = 18214 lbs.
Minimum Load = 4883 lbs.



Tubing Pressure = 100 PSI

Maximum Load = 16796 lbs.
Minimum Load = 6344 lbs.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

► Why use backpressure?

- Gassy wells are often difficult to produce using rod pumps
- Horizontal laterals can and do unload a lot of gas

😊 Backpressure on the tubing can improve rod pump performance under these conditions. If the tubing unloads and pump actions stops, 200-300 psi backpressure should help – use more backpressure if required.

► Use backpressure **ONLY** if a well is 'flowing off' because of too much gas being produced up the tubing

😢 Use of backpressure on tubing results in:

- Increase in tubing gradient
- Increased fluid load on the rod string
- Increased polished rod horsepower = Increased prime mover load
- Increased rod loading / Higher rod stress range
- Increased rod stretch = Reduced effective plunger stroke = Reduced pump displacement
- Reduction in SPM due to motor slip
- Increased in the amount of friction the stuffing box applies to the polished rod

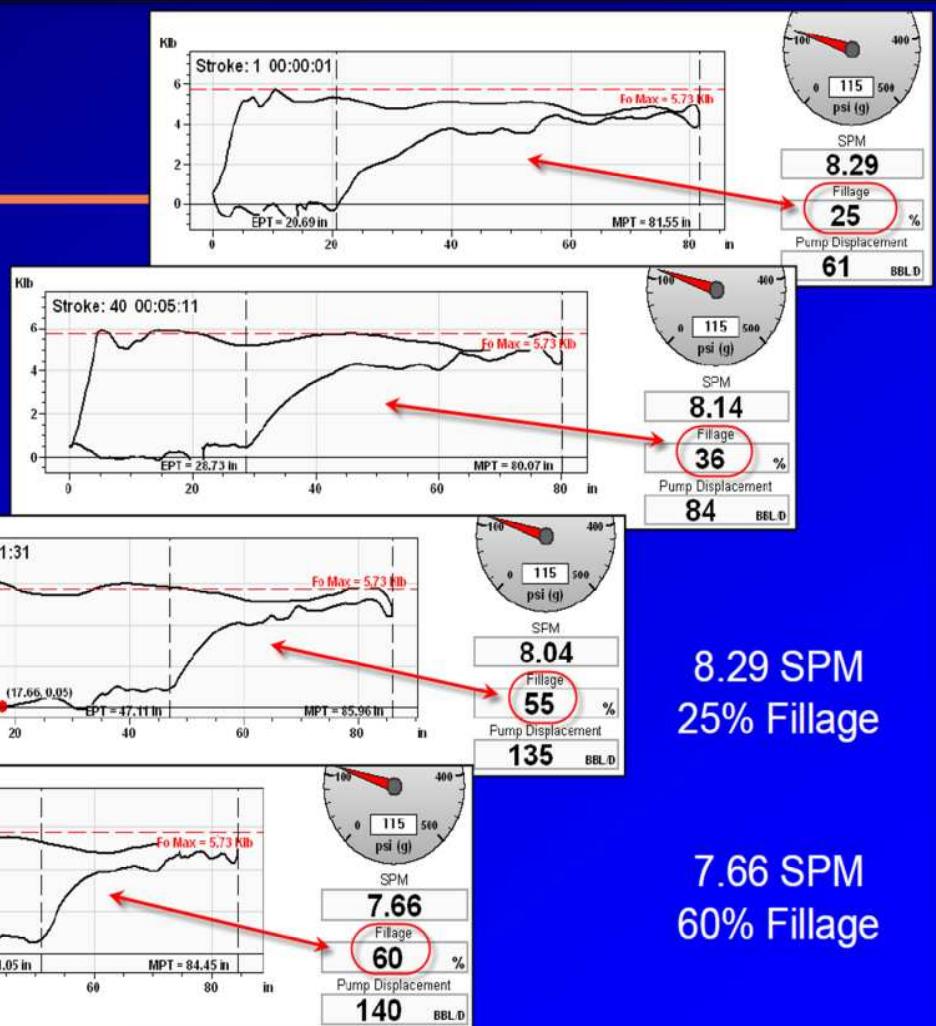


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Effect of SPM on Gas Interference



8.29 SPM
25% Fillage

7.66 SPM
60% Fillage

((((ECHOMETER))))

+

+

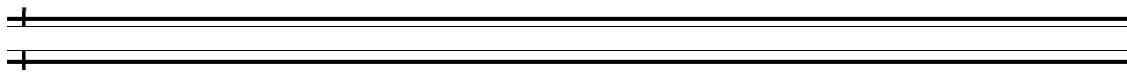
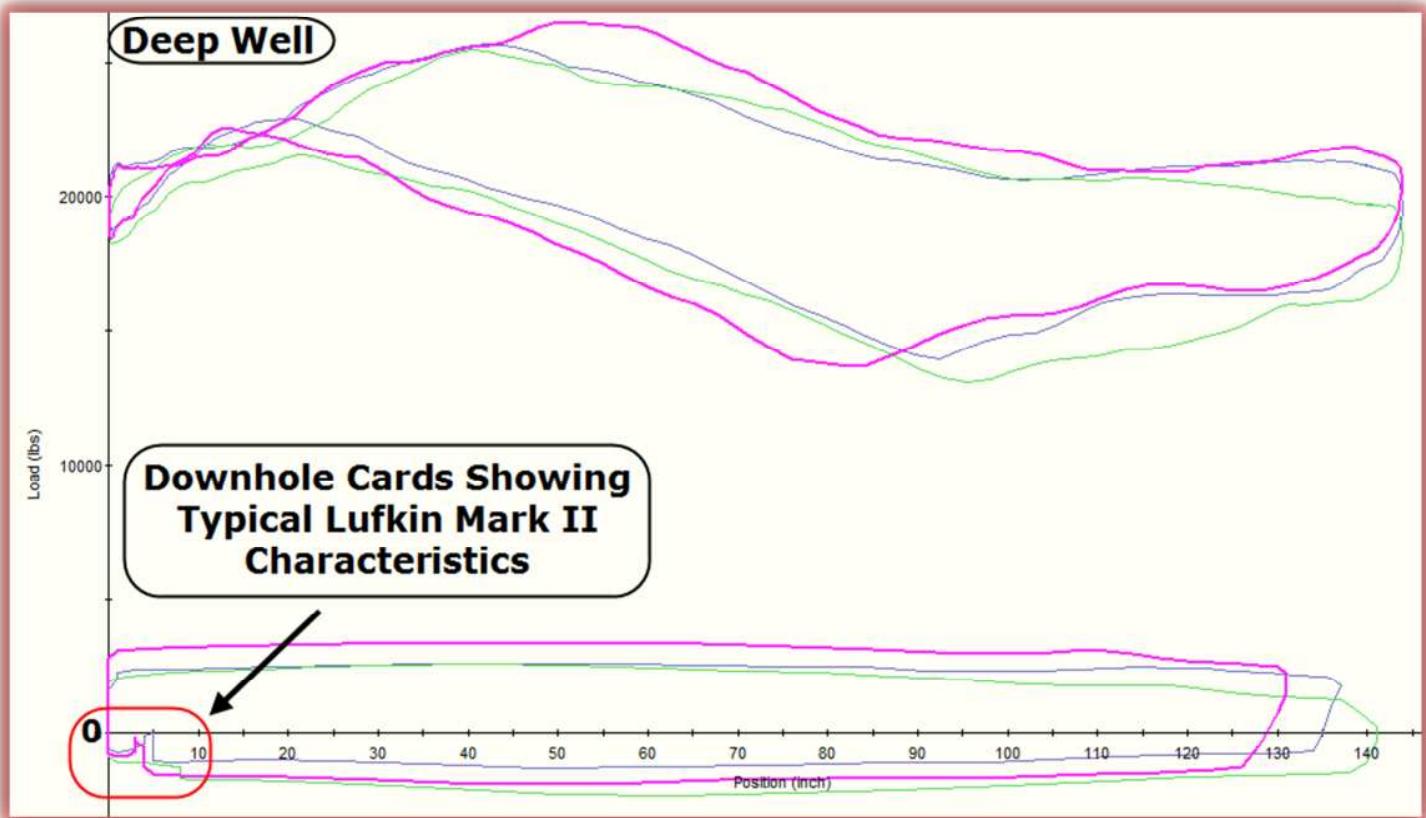


Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Lufkin 'Mark II' Pumping Unit Dyno Card Characteristics



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Things That Affect Calculated Downhole Cards

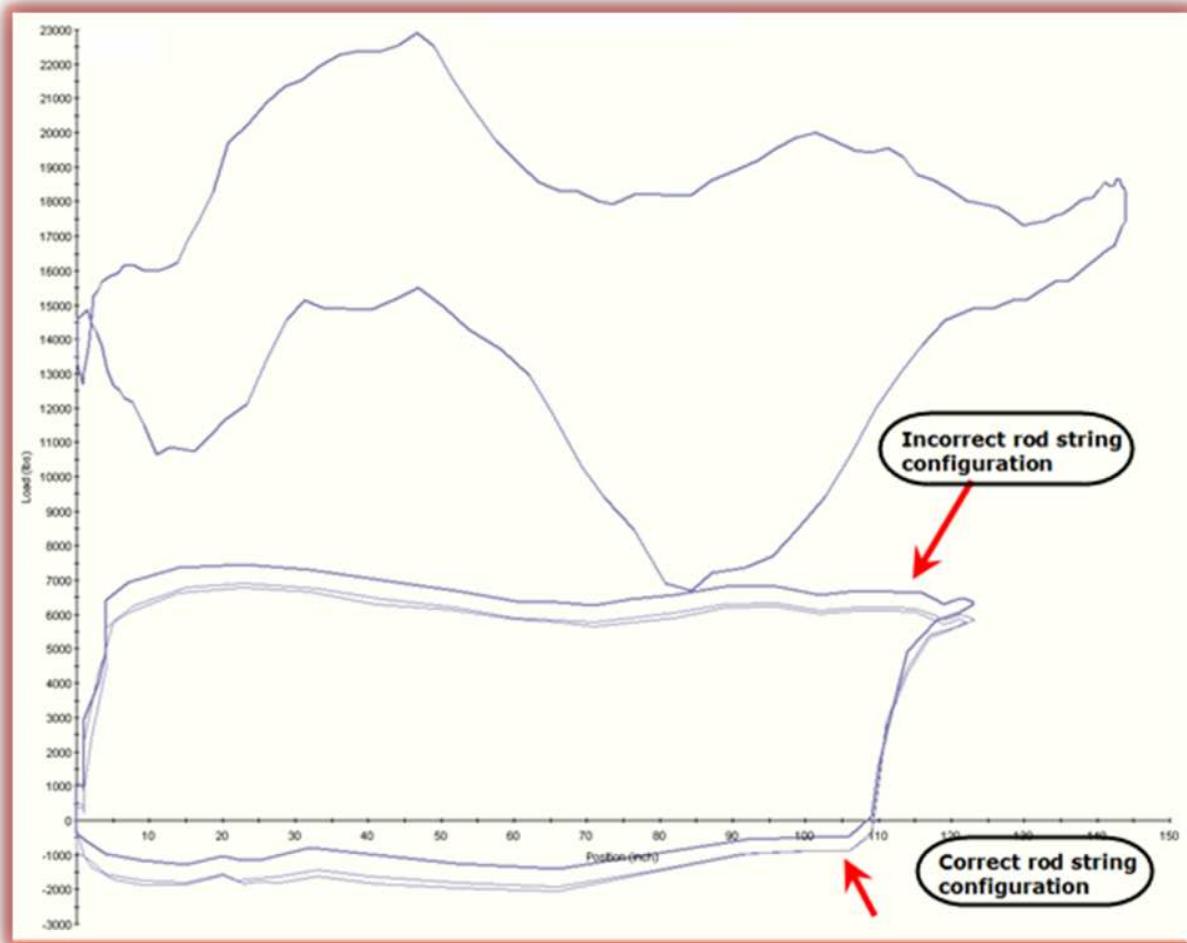
- ▶ Incorrect Surface Loads
 - ▶ Strain gauge
 - ▶ Bad calibrated load cell, load cable / connections
 - ▶ Poor Position Data
 - ▶ Position switch (Top of Stroke / Simulated Data Input)
 - ▶ Bad "real position" device /cable / Top of Stroke
 - ▶ Improper position device installation
 - ▶ Rod String Information
 - ▶ Too short -
 - ▶ Too long -
 - ▶ Wrong length per rod -
 - ▶ Wrong taper length -
 - ▶ Wrong weight per foot -
 - ▶ Wrong "Modulus of Elasticity" -
 - ▶ Wrong "Speed of Sound" -
- (?) The examples on the following slides show what can happen to the calculated downhole card when well configuration data is not correct.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



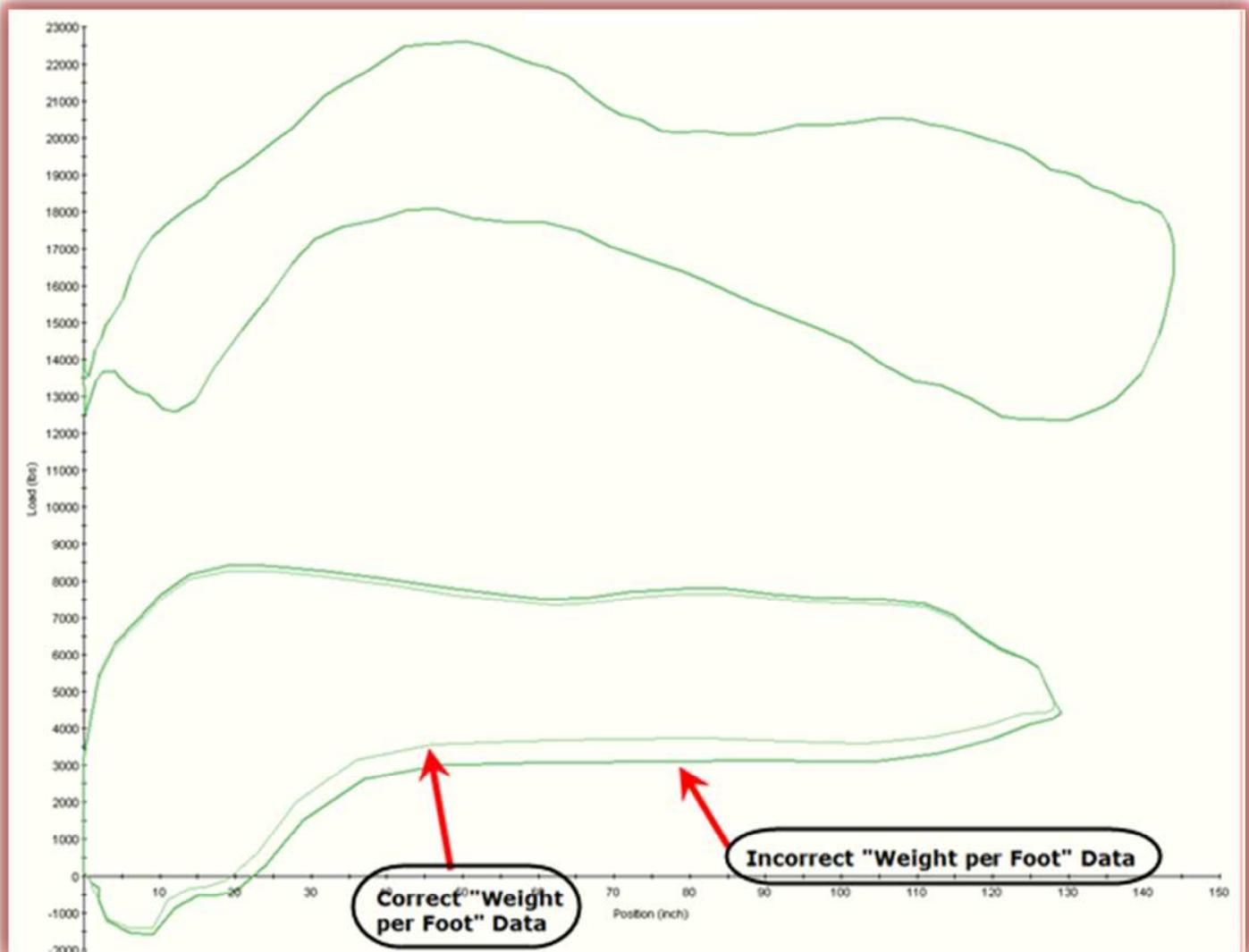
- ⌚ The example above shows the downhole card shifted up. The card is different shape because of an incorrect number of rods in the entered rod taper information in the **LOWIS Rod Configuration** panel.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



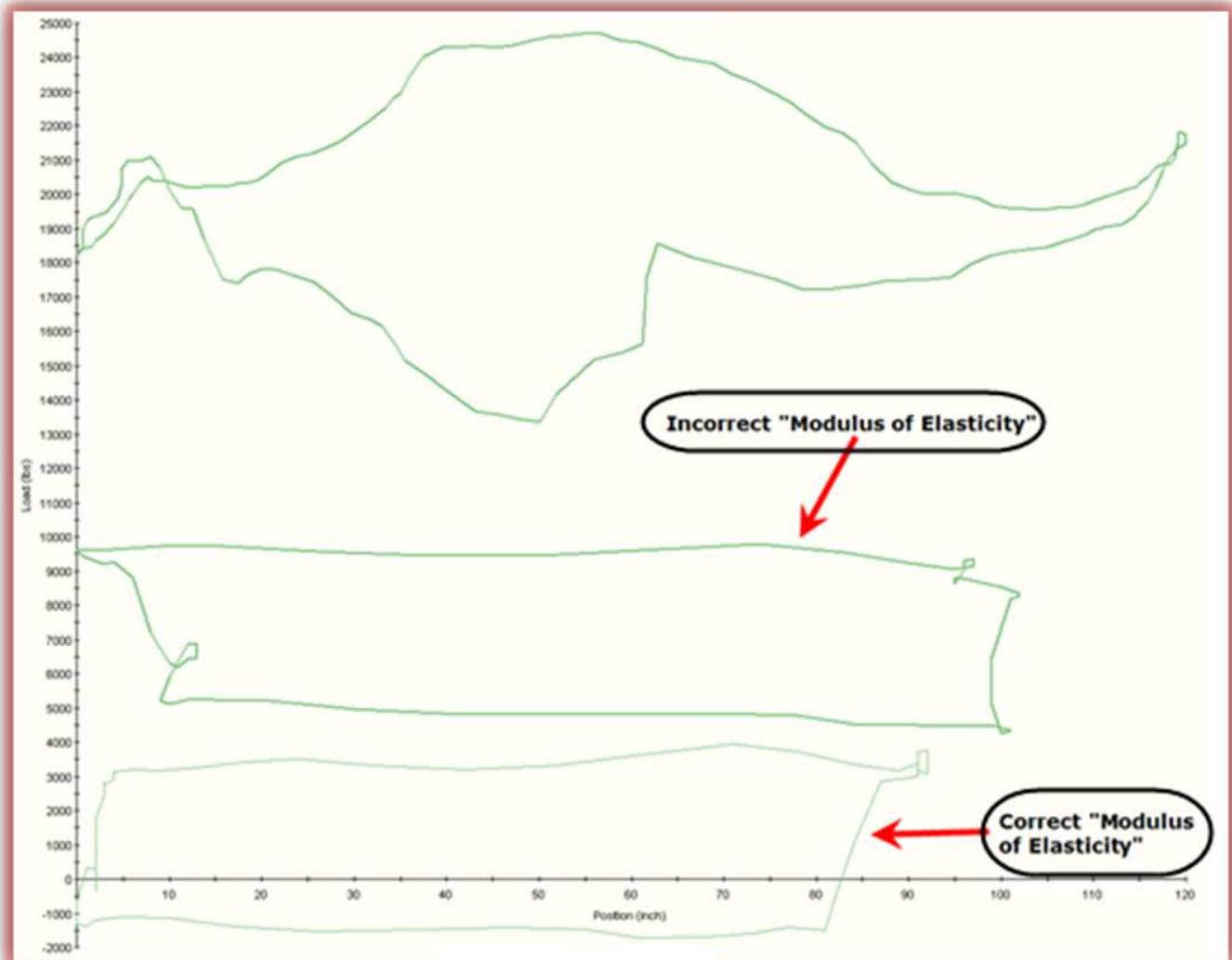
- ⌚ The example above shows what happens to the downhole card when the 'weight per foot' of each rod size is entered incorrectly in the **LOWIS Beam Rod Catalog**.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



- ⌚ The example above shows what happens to the downhole card when the 'Modulus of Elasticity' value of each rod size is entered incorrectly in the **LOWIS Beam Rod Catalog**.



Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

'Damping Factor' Effects on Downhole Cards

→ Damping Factors

- ▶ Increasing the "Damping Factors" results in smaller downhole cards/fluid loads.
- ▶ Decreasing the "Damping Factors" results in larger downhole cards/fluid loads.



Note: Changing the "Damping Factors" is one way to help "model" conditions such as excessive downhole friction or entrained gas.

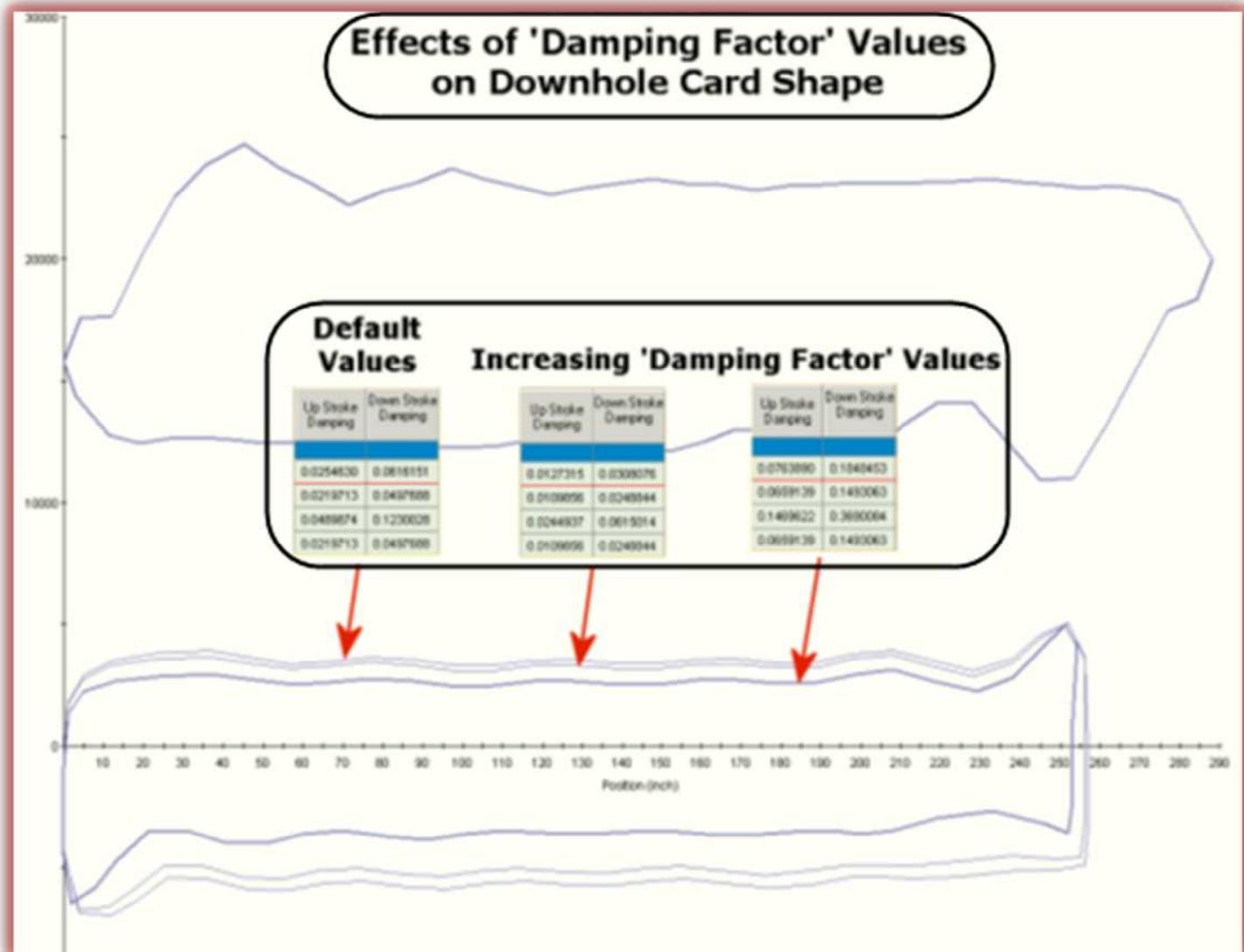
→ The examples below demonstrate the effects of increasing 'Damping Factor' values.



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



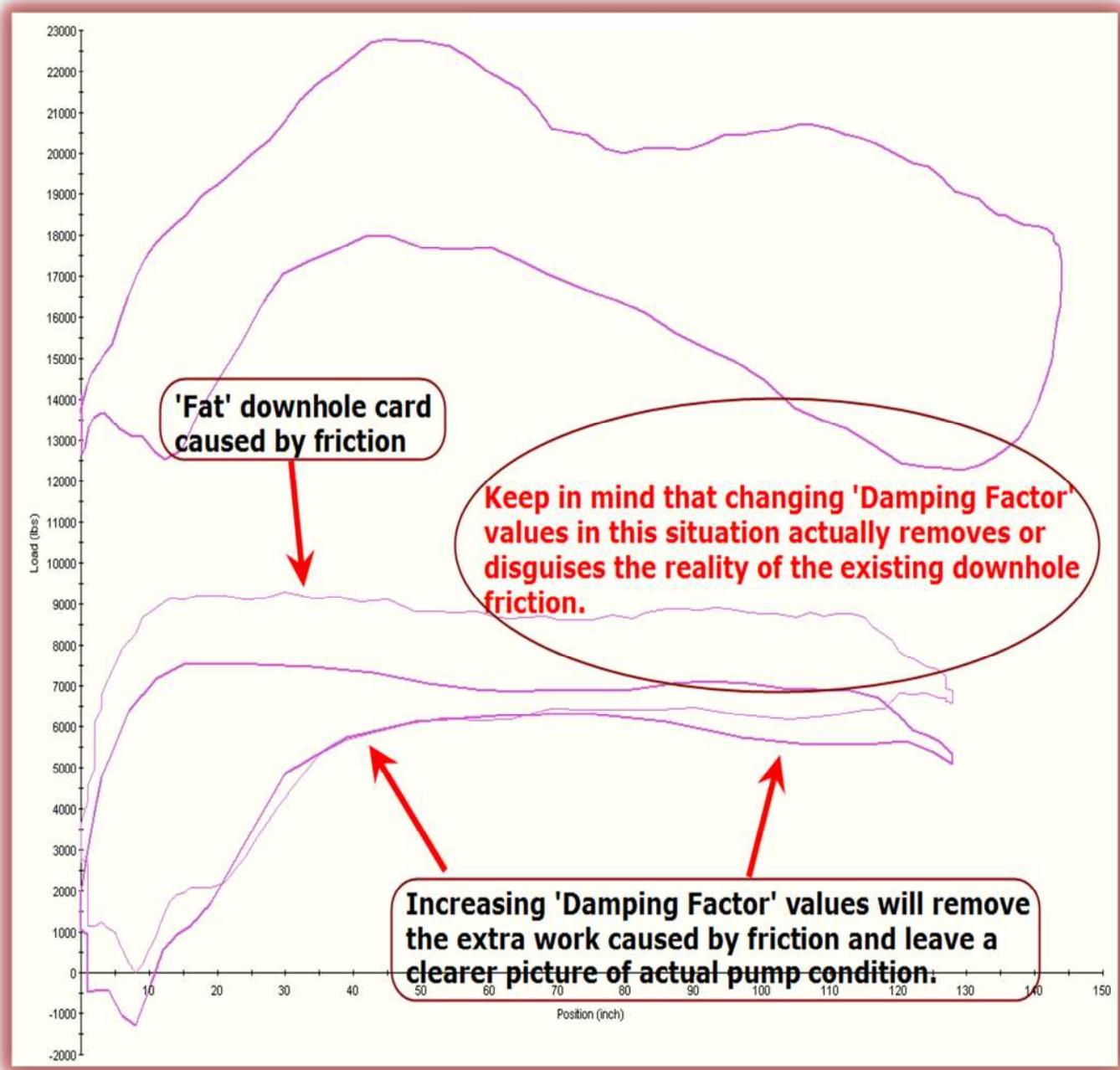
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

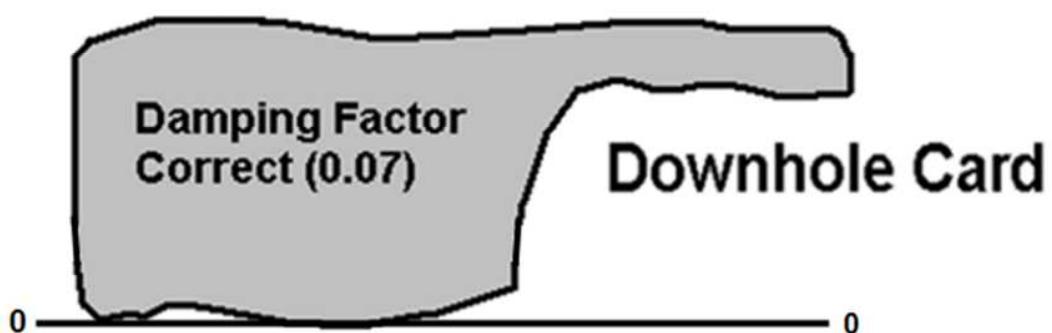
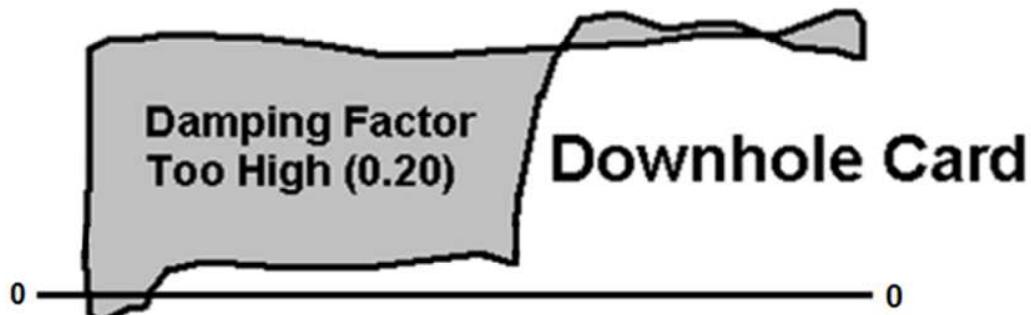


Louis Ray – Optimization Specialist / Senior Trainer
 Weatherford Production Optimization
 22001 North Park Drive, Houston, TX 77339
 Main: 281 348-1000 Mobile: 903-647-6777
 E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

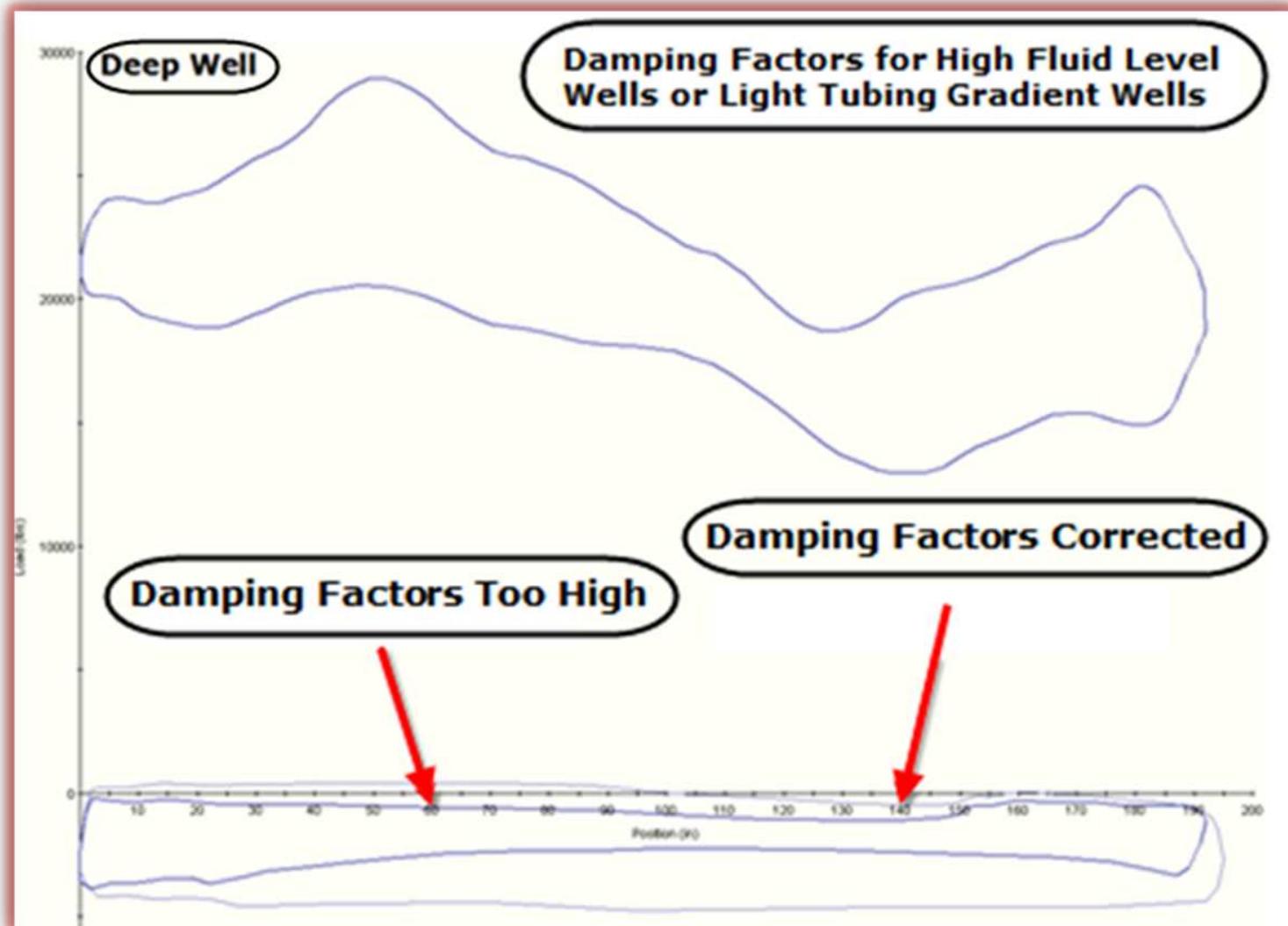
Damping Factors For High Oil Gravity and High Water Cut Wells



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



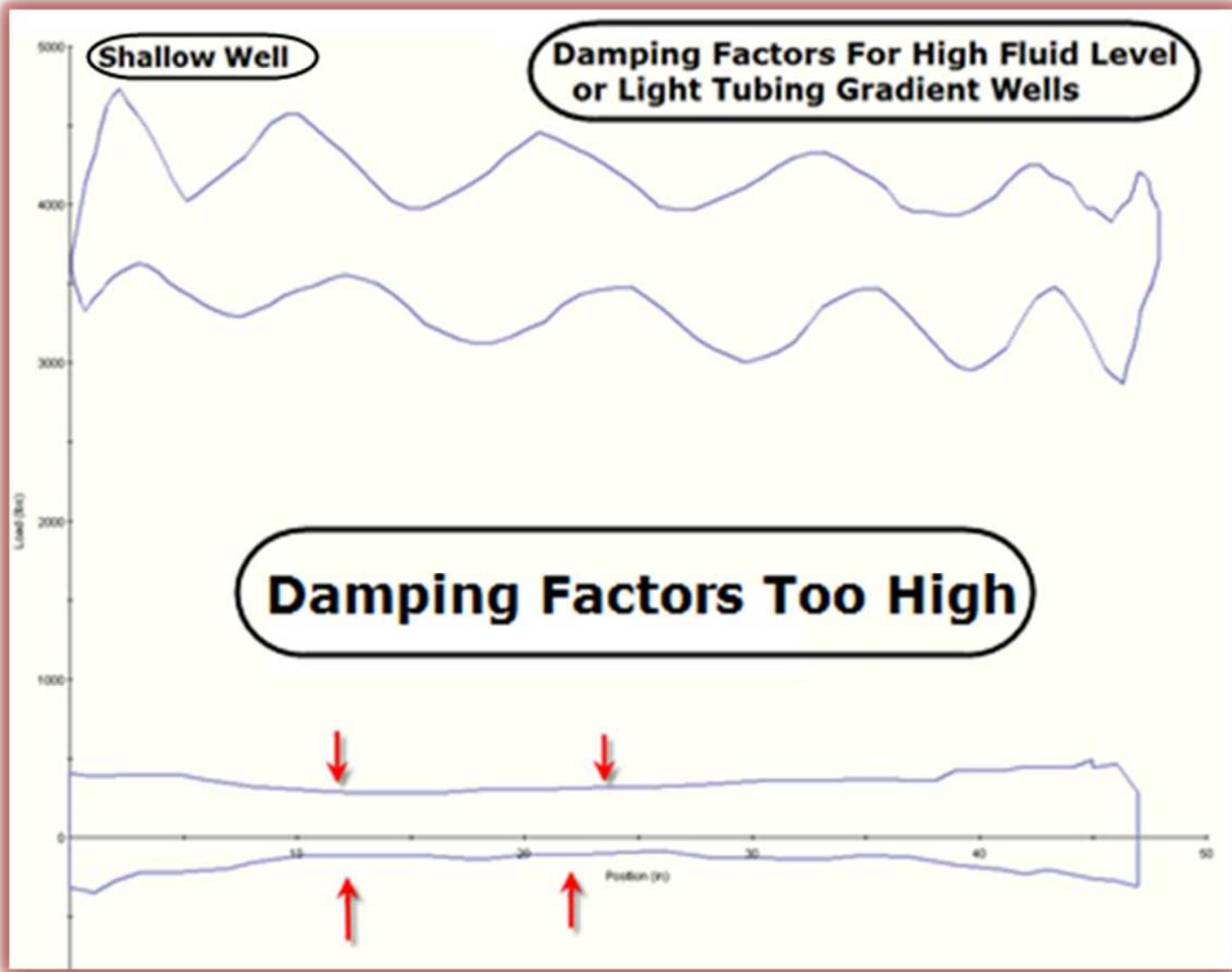
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



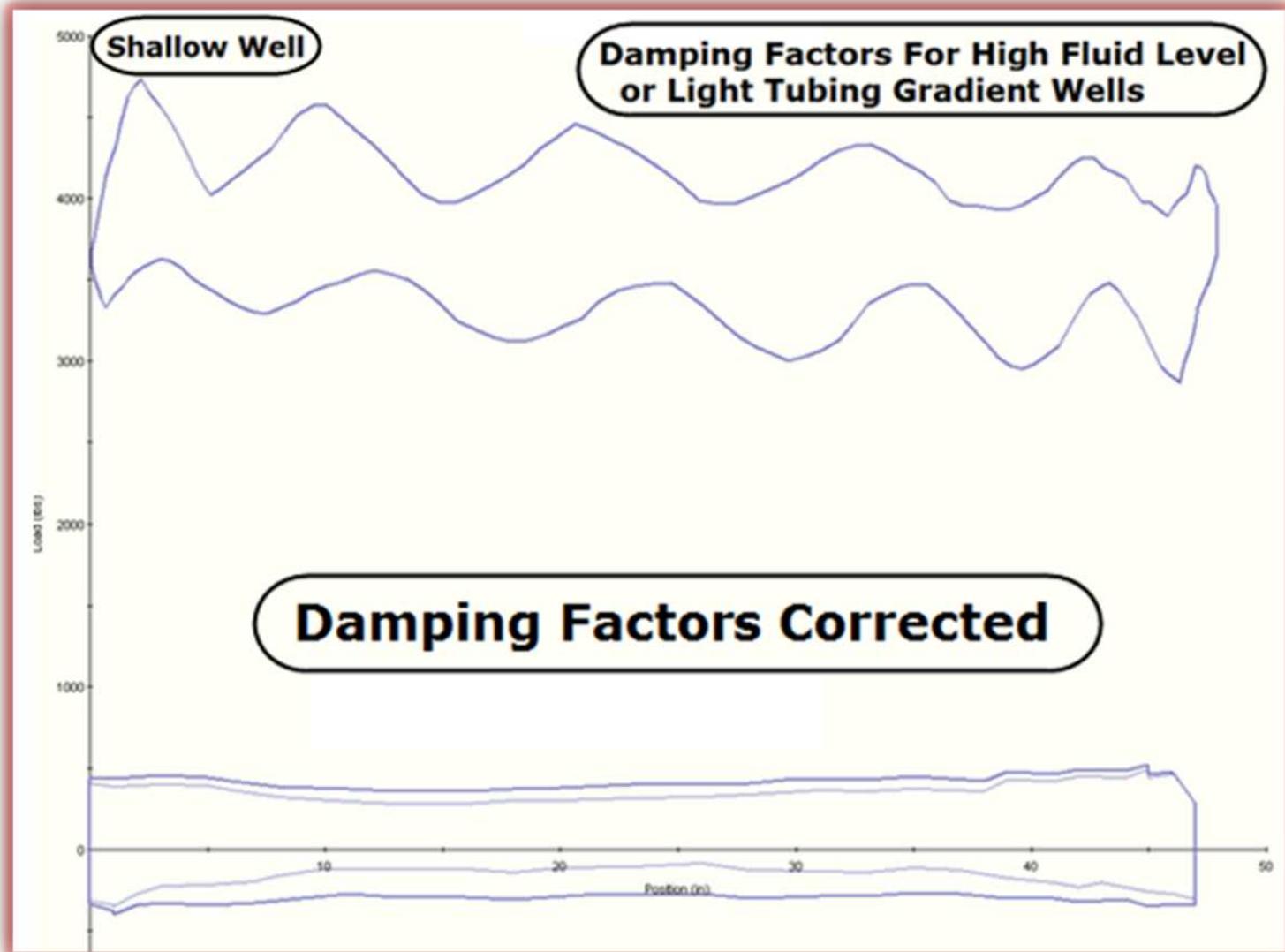
Surface and Downhole Dynamometer Card Interpretation



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

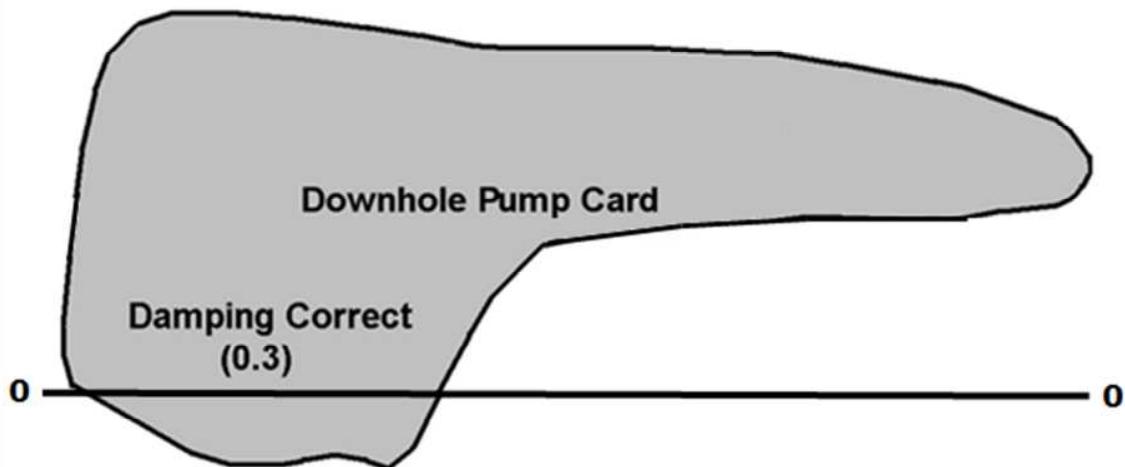
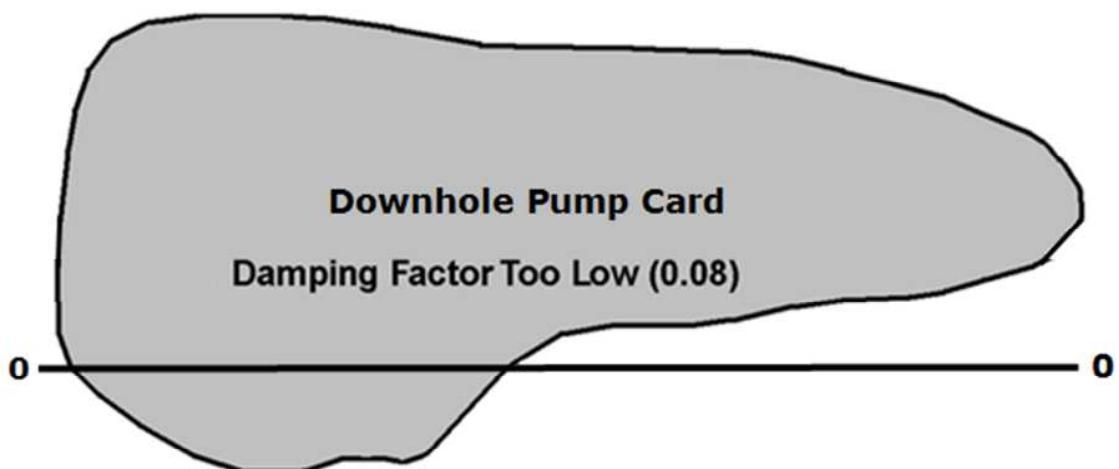


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

Damping Factors (Low Gravity / Viscous Fluids) Downhole Cards Only



—
—

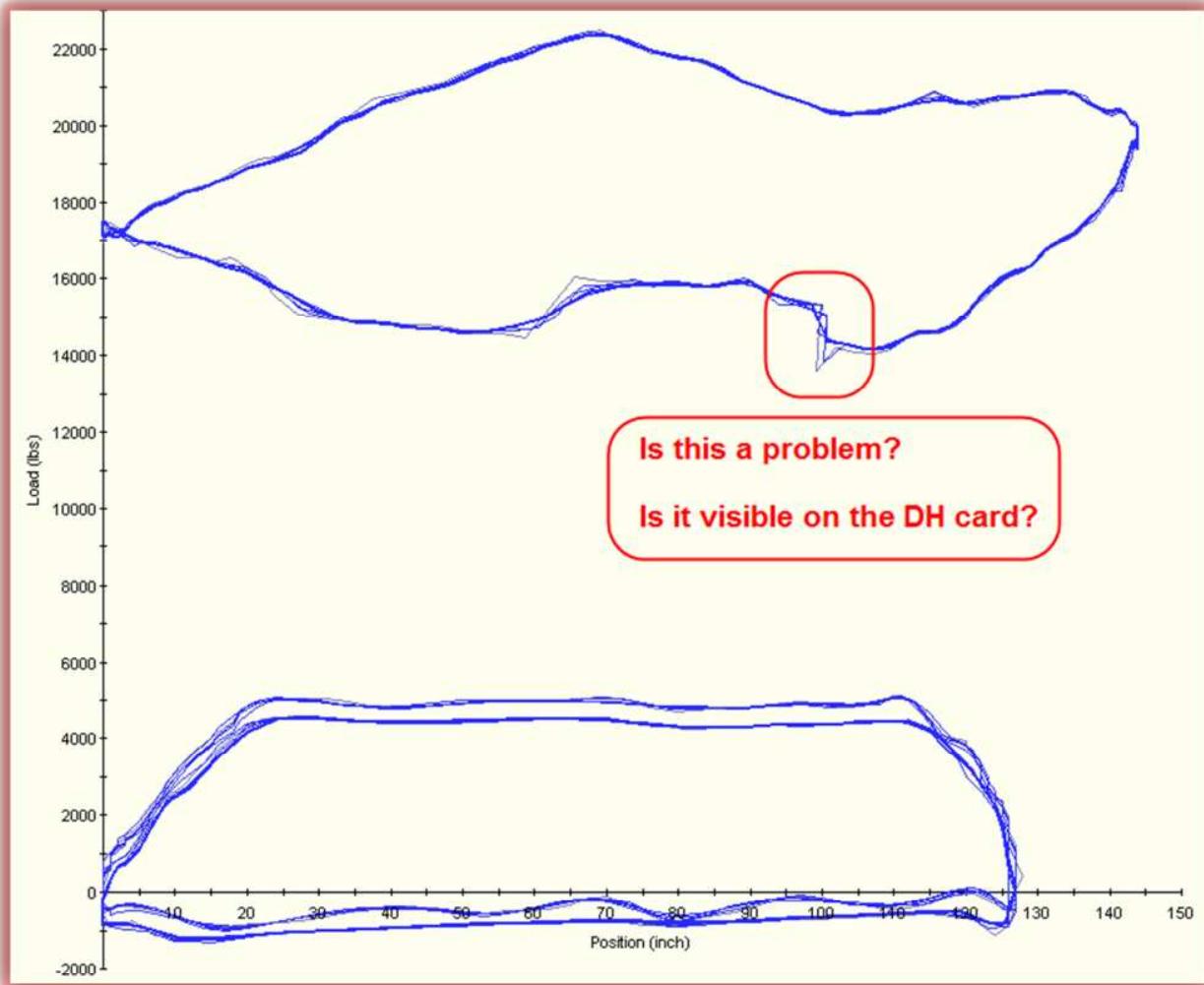


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

- Be careful not to over analyze dynamometers cards. The well will teach you if there is something happening that needs to be watched or needs attention.

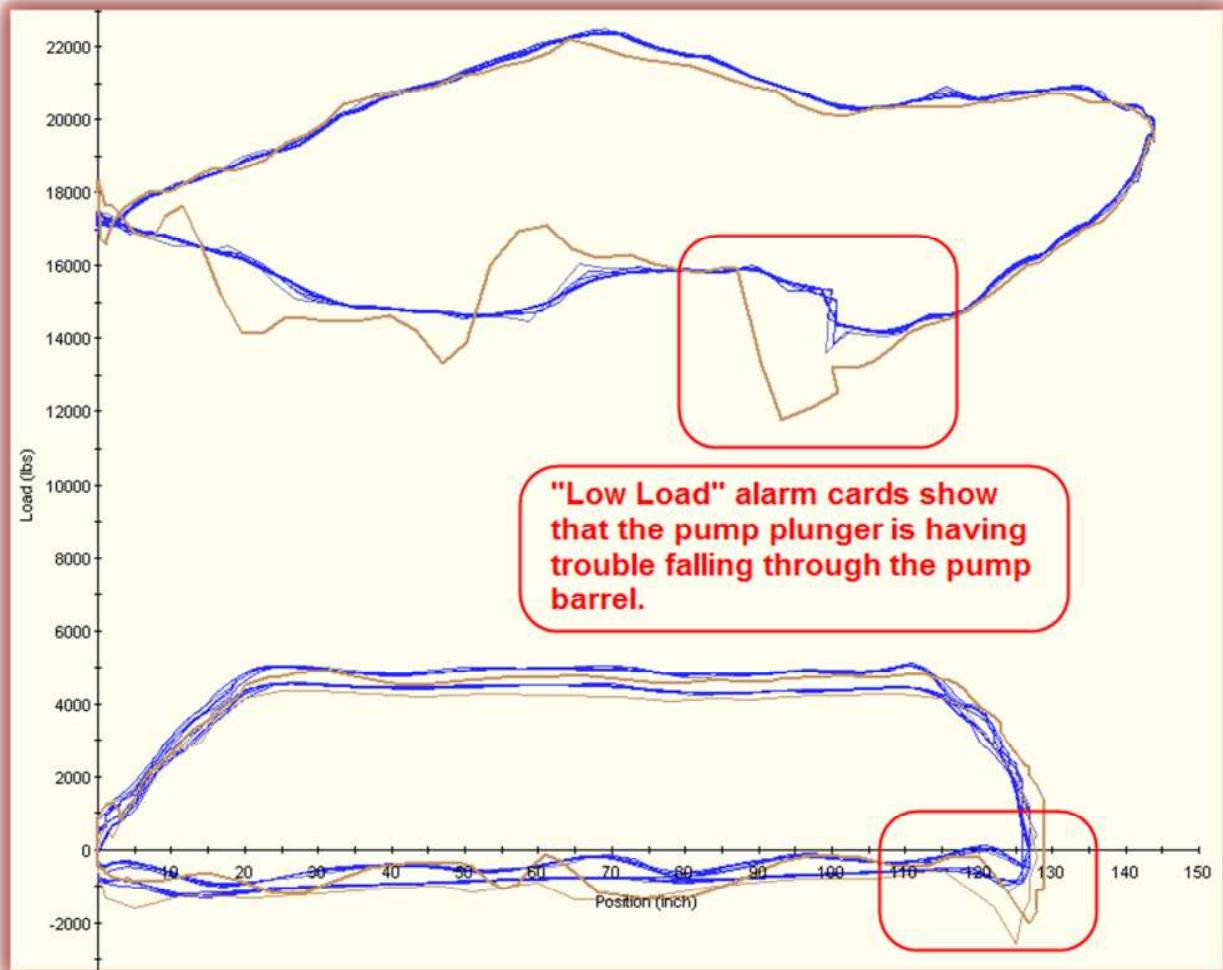


Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation

► The well will indeed teach the observer if there is something going on!



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com



Surface and Downhole Dynamometer Card Interpretation



People will now think you are a "wizard" !!!



Louis Ray – Optimization Specialist / Senior Trainer
Weatherford Production Optimization
22001 North Park Drive, Houston, TX 77339
Main: 281 348-1000 Mobile: 903-647-6777
E-Mail: louis.ray@weatherford.com Website: www.weatherford.com