OVER-TRAVEL CAN OCCUR ON BOTH THE UPSTROKE AND DOWN STROKE

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ABSTRACT
The pump stroke can be longer than the surface stroke when the dynamic motion of the beam pump system adds momentum to the rod string, resulting in the pump stroke length increasing. The pump stroke can be shorter than the surface stroke when sucker rods stretch to pick up the pump fluid load and other frictional forces. Rod stretch creates under travel dynamometer card shapes. Pumping fast or high plunger velocities creates over travel cards.

Pump position in the barrel changes when the pump is not full compared to a stroke when the pump is filled with liquid. When incomplete pump fillage occurs, the plunger tends to over travel on the down stroke moving deeper into the barrel. In some cases, tagging can occur due to pump spacing, plus increased over travel. This paper will use field collected dynamometer data to show excessive over-travel can occur on both the upstroke and the down stroke.

Introduction
The pump stroke can be longer than the surface stroke when the dynamic motion of the beam pump system adds momentum to the rod string, resulting in the pump stroke length increasing. The pump stroke can be shorter than the surface stroke because the rods stretch to pick up the pump fluid load. The surface dynamometer card down or up slope from left to right defines an "Over travel Card" or an “Under travel Card”. Rod stretch creates the under travel cards. Pumping fast or high plunger velocities created by the sudden release of load creates over travel cards.

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

Zero position for the plots of surface and pump card is typically the same from most diagnostic wave equations since about 1984. During a meeting in 1984 at Amerada Hess, the topic of “The pump card doesn’t line up with the surface card at the bottom of the stroke.” was discussed. To force the pump card to line-up with the surface dynamometer card, the minimum position of each diagnostic pump card is found and the minimum pump card position for each pump stroke is subtracted from every position point for the pump card. Subtracting the minimum position from all of the position points for a stroke forces the surface card bottom of stroke and the pump card bottom of stroke to equal zero and to cause the bottoms of the surface and pump cards to line up. When using the diagnostic wave equation to calculate the pump card, we artificially position the pump card so the bottom of the pump card will line up with the surface card. Subtracting the minimum position hides the relative position change from stroke to stroke and relative position of the plunger to the pump barrel.

While acquiring dynamometer data at a well, when the pump was filled with liquid, the pump card would not display a tag, and when pump off occurred the pump card displayed showed incomplete pump fillage with a hard tag. To tag at the bottom of the stroke, the plunger was moving to a lower point inside the barrel when incomplete pump fillage occurred. The sudden release of the pump fluid load can result in the plunger position changing relative to the tubing/pump barrel. Plotting the pump card position relative to the pump barrel will be used to compare plunger position of a pump filled with liquid versus a pump that is not filled.

The idea for this paper began about 8 years ago at the end of a presentation on the topic of over travel under travel, with a question from a person in the audience, “Does over travel occur on the upstroke or the down stroke?" This paper will use field collected dynamometer cards to show excessive over travel occurs on both the upstroke and the down stroke.

Definition of Over Travel and Under Travel

An under travel surface dynamometer card is defined by the surface dynamometer card shape sloping upward from left to right. The pump plunger stroke length is shorter than the polished rod stroke length, where a large portion of the surface stroke is lost to stretch. Under travel is due to rod stretching to overcome fluid load, fluid dampening, coulomb friction and/or other frictional forces acting on the rod string. Under travel surface and pump dynamometer card shapes include: stuck pumps, plunger is too large for the rod string, unanchored tubing, sand or scale problems, too tight stuffing box and/or paraffin. Fig. 1 displays an under travel surface and pump card where the surface card slopes up to the right at a 149 lb/in slope due to the combination of the 189 lb/in rod string spring constant (30.7 inch of rod stretch) and the 699 lb/in spring constant from the unanchored tubing (8.3 inch tubing stretch). The 5308 pound fluid load applied to the rods by the 1.5 inch diameter plunger is too large for the 76 rod string resulting in 39 inches of the 45.4 inch surface stroke being lost to stretch, where in this well the pump stroke would be very short except for the over travel of 12.2 inches from the 8.45 strokes per minute resulting in a total 18.6 inch downhole stroke. An under travel card, means that the surface card slopes upward and to the right, and the pump stroke is much less than the surface stroke. The shorter pump stroke is usually due to the plunger having a large fluid load, significant downhole friction from well bore deviation, or paraffin. The rods must stretch to pick up the fluid load and must also stretch to overcome mechanical friction, causing the rods to stretch and the pump stroke to be shortened compared to the surface stroke.

An over travel surface dynamometer card slopes downward from left to right. The pump plunger stroke length is longer than the polished rod stroke length due to over travel. Over travel surface and pump dynamometer card shapes include: parted rods, flowing wells, unseated pumps, travelling valve or standing valve stuck open, worn pumps, fiberglass rod strings, pumping at a very fast SPM or high plunger velocities created by the sudden release of pump or frictional load. The over travel surface 72.6 inch stroke and pump 80.6 inch stroke in Fig. 2 is created by the high speed 13.74 SPM adding momentum to the rod string increasing the pump stroke by 31.2 inches of over travel. The downward to the right shape of the surface card appears to "push" the rod string and pump creating the longer over travel pump stroke. The faster the unit is stroked, the more momentum/energy is stored into the rod string. That increased momentum results in increasing the down hole stroke as the energy dissipates. Generally, a longer down stroke is created as the pumping speed is increased. An over travel surface card, by definition, points downward to the right. The downward shape of the surface card appears to be pushing the pump card to a longer stroke length.

Design[1] of rod strings that result in severe over travel cards or severe under travel should be avoided. Availability of personal computer and sucker rod design software[2] has made it easy to run the software to avoid over and under travel for an optimum design and long equipment life.

Acceleration Force on Up and Down

A Fig. 3 and 4 are results from the QRod predictive design software. The design conditions are for a vertical well 5000 ft deep, 100 inch surface stroke, S, 50 psig for both pump intake pressure and tubing discharge pressure, and a 2 inch pump plunger diameter. Water gradient in the tubing allows the calculation of a 6802 pound fluid load, Fo. The predicted pump card sits on the zero load line, the sides of the pump card are vertical due to the tubing being anchored and the height of the pump card is the fluid load, Fo. The 76 rod string with a 254 lb/inch spring constant, Kr, weighs 8288 pounds in tubing fluid. To stretch the rod string the 100 inch stroke length, a load of 25,400 pounds (S x Kr) would need to be applied to the rod string. If the pump were to apply a SKr load to the rod string then the entire 100 inch surface stroke length would be consumed by the rod stretch. The pump applies only a 6802 pound fluid load, the amount of stretch caused by this fluid load is equal to (Fo/SKr) 27% of the surface stroke length. Fig. 3 displays a surface and pump card predicted to occur if the pumping SPM equals 0, where the pump stroke is shorter than the surface stroke by only the static stretch. The slope on the sides of the surface card are equal to the rod string spring constant Kr. The surface loads on the down stroke are equal to the weight of rods in fluid, SV, standing valve loads and are constant since no acceleration forces occur at SPM=0. The surface loads on the upstroke stroke, TV, traveling valve loads are equal to the weight of rods in fluid plus the fluid load, Fo, and are also constant. This is the synthetic zero SPM dynamometer card presented in API RP11L, there is no over travel since SPM =0.

As the SPM increases, the predictive program displays a pump stroke length increasing longer than the 0 SPM pump stroke by the increasing over travel. The pump stroke is equal to the surface stroke minus (–) static rod stretch plus (+) over travel. The synthetic pump card shown in Fig. 4 is predicted using QRod for a SPM of 11. At 11 SPM the pump stroke is equal to 87.1 inches (100 – 26.8 + 13.8). SPM of 11 is considered the maximum pumping speed for these conditions since the rod string would be loaded to 100% of the Modified Goodman allowable stress range. In the remainder of this paper the term over travel will be used to mean any additional pump stroke greater than the surface stroke minus (–) the static rod stretch.

The shape of the surface card and pump card changes as the pumping speed is increased; due only to increasing the SPM assuming the fluid load remains constant. The pump stroke becomes longer due to the increasing over travel. The peak surface upstroke load increases above the SV load by, F1, the dynamic force required at the surface to apply a static force Fo at the pump and the minimum surface load SV-F2 is created by the, F2, dynamic surface force transferring the Fo carried by the traveling valve to the standing valve. Fig. 4 the upstroke acceleration F1 force of 11,378 Lbs is created by the transfer of Fo from the SV to the TV at a fast SPM. The down stroke acceleration F2 force of 4,100 Lbs is created by the transfer of Fo from the TV to the SV at a fast SPM. The F1 and F2 forces are created by the transfer of Fo. When the Fo load transfer does not occur at the beginning or top of the stroke, additional over travel of the pump stroke and rod string is created.

Down Hole Pump Stroke Length Comparison

Fig. 5 shows the overlay of 6 surface and pump dynamometer cards acquired at different strokes per minute, SPM, of 1, 2.5, 5.1, 7.1, 8.3, and 9.7. The dynamometer data was acquired on 08/25/2006 during the pump slippage testing performed at the Red Raider 1 test well of Texas Tech University. The data was sampled at 60 Hz using a high resolution acquisition system and load cell. The option to make the bottom of the pump stroke equal to the bottom of the surface stroke was disabled in the pump cards displayed in Fig. 5. The sucker rod lift system installed in the well consisted of a 76 taper with 1950 feet of 7/8 and 2002 feet of ¾ inch sucker rods with a 1.5 inch diameter 4 foot plunger with 0.005 inch clearance and a 106 inch surface stroke. At a pumping SPM of 1 stroke a minute the pump card shape appears to be a leaky pump. The pump card shape is almost the same shape as the surface stroke, since the very slow 1 SPM creates very little F1 and F2 acceleration forces on the surface up or down stroke loads. The leaky pump card shape is due to the very slow pumping speed causing a high slippage rate through 0.005 inch clearances. As the pumping speed is increased from 1 to 9.7 SPM the overlay of the strokes shows practically the same bottom of the pump stroke for each SPM. The changing SPM did not result in the pump plunger moving to a different lower location for the beginning of any of the pump strokes. Since the SPM increased significantly from 1 to 9.7 SPM, the position of the pump card was expected to change, but there was not any change in the location of the bottom of the pump stroke over the 1 to 9.7 SPM change. The pump card fluid load transfer occurs at the top and bottom of the stroke (pump load transfer did not create a different acceleration force at the different SPMs), since the pump was filled with water and the plunger velocity was slow before the valve opened to allow the plunger to move on the upstroke or down stroke. This example with a liquid filled pump and steel rod string shows there is only 3.13 inches of over travel in the pump card at 9.7 SPM compared to the 1 SPM pumping speed. The pump card basic shape remained the same except for the slippage causing the typical concave outward shape on the sides of the pump card at slower SPM and the slight increase in the pump stroke due to over travel at the faster SPM. The fluid load on the up stroke remained constant, because the tubing fluid gradient was water with tubing discharge and pump intake pressure constant. Basically the pump positioned in the barrel didn't change at the bottom of the stroke. The bottom of the pump stroke remained equal from stroke to stroke. The changing SPM did not result in the plunger moving downward into the barrel. The over travel resulted in the plunger moving 3.1inches higher into the barrel, because the bottom of the stroke remained unchanged and the overall pump stroke length increased by 3.1 inches. There was a significant increase in the up and down stroke plunger velocity at the increasing SPMs, but there in almost no change in the bottom of the plunger stroke bottom location inside the barrel.

Resonating Frequency of the Rod String

Fig. 6 displays the concept that the round trip travel time for a peak load to echo down and back up the rod string to the surface is independent of the pumping speed. The time on the upstroke between the peak load and the echo/repeat of the peak load is 1.31 seconds. This rod strong has a certain resonating frequency and the frequency of this design is about every 1.31 seconds. When F1 and F2 forces occur during a stroke, then these dynamic forces repeat at the rod string frequency. This well had 3 SPM speed changes with no change in the pump fluid load. The dynamometer data was acquired at 4.85, 5.44, and 6.12 SPM. When the SPM is slow, the time for the upstroke is a longer elapsed time than at the faster SPMs. At the slower SPM the elapsed time plot shows more peak load echoes up and down the rod string for the time of one stroke, but the number of echoes per day is approximately the same based on the resonating frequency of the rod string (SPM has almost no impact). When the SPM is faster, the polished rod moves a farther distance on the upstroke and the distance changes between the echoed peak loads based on SPM, but the time between peak load echoes is the same. On the plot of load versus time, the echoed peak loads line up in time but the peaks don't line up in distance because the velocity is different for each SPM. At the faster SPM the polished rod moves farther in the same amount of time. The polished rod velocity is higher at the fast SPM and the resulting F1 and F2 forces are larger. Faster SPM and sudden changes in fluid load create acceleration forces and these forces echo round trip in the rod string at the resonating frequency of the rod string.

Incomplete Pump Fillage Impact on Plunger Position Relative to the Barrel

The pump load on the up stroke is generally the same as when a pump is filled with liquid or not filled (pumped off) and the rod weight is the same. If the pump does not fill with liquid on the down stroke, then there is some impact on surface loads due to the echo of the pump load transfer from TV to SV not occurring at the top of the pump stroke. During the compression portion of the down stroke with TV and SV closed during incomplete pump fillage, the fluid load applied by the pump to the rods is higher, thereby causing the pump stroke to be longer than when pump is full. This increased load on the rods during the down stroke changes the velocity profile and increases the average downward plunger velocity. The downward travel of the pump plunger increases and the plunger moves down farther into the pump barrel. If the pump position during the stroke were plotted relative to the pump barrel/tubing, then the bottom of stroke can be farther down when the pump is not full. If the pump is spaced close, then on a fluid pound Pump-OFF card a tag can occur, because:

1. Plunger over travels on the down stroke
2. Plunger moves deeper into the barrel
3. Tagging due to pump spacing,
4. Higher load on down stroke and higher downward inertia is created by higher downward velocity.

On several wells the behavior of the pump has been observed to be much different when the full pump card is compared to the incomplete pump fillage pump card. In a fluid pound condition at the beginning of the stroke, the fluid load is still applied to the rod string, the plunger velocity is high, while the chamber pressure is low with the TV closed and momentum stored in the rod string. In a fluid pound condition on the down stroke, the plunger velocity changes quickly as the plunger slows to compress the gas in the pump chamber from the intake pressure to the discharge pressure to open the TV. The plunger rapidly increases in speed when the TV opens. Incomplete pump fillage has an impact on the velocity profile and the energy in the rod string system.

Fig. 7 is a plot of measured polished rod load versus elapsed time on a well where the SPM is controlled by a variable speed drive, VSD. This well has some strokes showing incomplete pump fillage due to gas interference even though a downhole gas separator is installed below the pump set at 7000 feet. The variable speed drive pump off algorithm was set up for a water flood and sudden SPM changes occurred when incomplete pump fillage was identified. When pump off occurs in a water flood, then immediately SPM is reduced by the VSD to match pump displacement to liquid inflow into the pump. Gas interference is different than pump off in a well, but the control algorithm was setup for sudden speed changes where a water flood well would pump off suddenly. In Fig. 7 the SPM changes from fast to slow over a short time of 1-2 strokes. If the load range is from 14 to 24 KLbs and time for each stroke is closely spaced, then the SPM is fast. If the time for each stroke is longer and the load range is15 to 23 KLbs then the SPM is slow. The VSD appears to be in a repeating cycle of changing the SPM from 10 fast strokes and 10 slow strokes; the unit was in a repeating cycle of fast, slows down, fast, slows down, fast. The steel and fiberglass rod string has a 91 Lb/inch spring constant, which resulted in a short 80 inch pump stroke when pumping a slow 5.6 SPM and a 130 inch pump stroke when pumping a fast 9.2 SPM.

Gas Interference Seen in Pump When SPM is Slowest

Fig. 8 displays that the pump is filled with liquid at the fastest 9.2 SPM and the pump has gas interference in the pump at the 5.6 slower SPM. At 9.2 SPM and the longer 130 inch down hole stroke, the pump displacement exceeds the liquid separation capacity of the installed gas separator. The 9.2 SPM pump card was full and the next stroke displays gas interference; the VSD requires a sudden SPM change to occur when incomplete pump fillage is identified. Continuing to pump at 9.2 SPM exceeds the gas separator capacity by the high pump displacement and the VSD slows the pumping speed to 5.6 SPM. Approximately 10 consecutive strokes are required at 5.6 SPM for the gas separator to stabilize, begin to separate gas and begin to fill the pump with liquid. The pump was not full at the slower SPM because faster SPM pump displacement exceeded the capacity of the separator. Pulling in liquid too fast at the faster speed resulted in exceeding the capacity of the gas separator. A down hole gas separator operated above capacity causes flow of gas from the annulus into the pump, and the separator fails. Once gas interference begins, the VSD algorithm slows SPM down and attempts to recover from pumping too fast. This example shows the increased speed plus a full pump, then at the slow speed the gas interference increased, which is opposite of how the gas separator should behave. The fast pumping speed caused the gas separator to fail because the flow through the separator exceeded the gas separator capacity. At the slowest speed, all of the pump strokes are not filled with liquid. At the slow speed the separator is trying to recover, the gas bubbles are starting to come back out of the separator, the separator is starting to work again, and the pump is going to start to fill back up. The VSD recognizes the pump starting to fill up and starts to pump faster. As the VSD increases speed, and the pump fillage continues to increase. The VSD is increasing speed, the pump is filling up, and the separator is becoming effective with increased pump fillage. The VSD continues to increase SPM at faster and faster speed until the separator gets overridden by the high pump displacement, failing the separator and starting the cycle over again.

The down hole pump card can be plotted relative to the surface stroke bottom and force the bottom of the surface and pump stroke to match at zero position. Or the pump card can be allowed to move relative to the barrel/tubing from stroke to stroke. Notice pumping the fastest at 9.2 SPM, the position of the bottom of the plunger stroke is 26.9 inches to the left of the bottom of the surface stroke. The plunger position in the barrel changes from stroke to stroke as the plunger velocity profile changes.

Fig 8 shows the full card at 9.2 SPM is shifted to the left of the bottom of the surface stroke. The gas interference pump card at 5.6 SPM is shifted to the left of the bottom of the surface stroke by 8.4 inches. At the slowest pumping speed the gas interference is severe. Examining these two strokes to determine the best speed to operate the well, the observation would be no gas interference is present at the high speed. This conclusion would be completely incorrect. The VSD quickly changes the speed, creating large changes in pump displacement and changing how the plunger is positioned in the barrel.

Fluid Pound Creates Tag at Bottom Stroke

Dynamometer data collected at a well showed a full pump card, and when pump off occurred the pump card would display a tag at the bottom of the pump stroke. When a fluid pound happens on a stroke, then the plunger over travels and the plunger can move deeper into the barrel on the down stroke. Tagging the pump occurs due to the pump spacing, higher loads on down stroke and higher downward inertia created by the higher velocity on the down stroke. On the down stroke when the pump is not full and the traveling valve has not opened, the velocity of the plunger suddenly slows to open the traveling on the down stroke. In a fluid pound card prior to opening the TV, the full fluid load is still applied to the rod string. Fig. 9 the plunger is moving pretty fast, almost at the velocity of the polished rod. The fast velocity and rod loading quickly change when the plunger stops/slows to open the traveling valve. Once the TV opens, momentum in the rod string is not lost and the plunger accelerates, the energy stored in the rod string causes the plunger to move deeper into the barrel.

Fig. 9 is a well that tags on the pump off strokes. The pumping is 6.16 SPM and the 5439 Lb tag is severe. Sometimes a tag is wide with the beginning of the tag to the right of the bottom of the pump stroke, but this tag width is narrow and the tag appears to occur just at the bottom of the stroke. The full pump stroke bottom is positioned at zero of the surface stroke. Fig. 9 showing the tag stroke over travels on the down stroke by 5.6 inches and over travels on the upstroke by about 15 inches. The total 20.6 inches of over travel occurs on both the upstroke and the down stroke creating a pump stroke of 150 inches in the fluid pound stroke compared to 130 inches in the full pump card. The surface and pump card show the initial tag, plus the tag repeats throughout the stroke at the resonating frequency of the rod string. If the pump tags at the end of the pump off stroke, then the pump may be spaced out too close at the bottom of the stroke.

Fiberglass Rod String Creates Over Travel on Down Stroke

Fig. 10 shows incomplete pump fillage with a tag. The tag repeats throughout the stroke at the resonating frequency of the rod string. The plunger moves 22.4 inches below the bottom of the zero position of the surface stroke. This is not a pump off tag, but a tag due to lowering the fluid level in a gassy well and poor gas separation. The fiberglass rod string has a spring constant of 99 lbs/in and is pumping at 9.14 SPM.

Over Travel on Up Stroke

Fig. 11 shows 2 different examples of over travel on the upstroke. The hole in the pump barrel 30 inches from the top of the stroke results in the sudden loss of the 4000 pound pump load during the upstroke. The resulting 53 inches of over travel shown in the pump card after the load on the pump drops from 4000 to 0 pounds in less than 0.1 seconds. The surface loads drop almost 9000 pounds is cause due to the sudden transfer of the Fo carried by the traveling valve to zero load on the rod string.

The deep rod part displays 1.29 inches of over travel of the pump card stroke compared to the 168 inch surface stroke. When the rod pump is located near the pump then the pump card sits on the zero load line.

Conclusion

When you have a sudden release in load, like a fluid pound release, or a hole in the pump barrel release, then that creates an additional force/inertia/energy that has momentum in the system that causes the plunger to travel more on the upstroke or down stroke. Pumping speed creates dynamic forces that impact the elongation of the rod string. These forces may cause over and under travel of the pump plunger. Sudden release/application of pump load results in plunger position changing relative to the pump barrel. Zero position for the plots of surface and pump card is typically the same for most diagnostic wave equations since about 1984. Plotting surface and downhole cards with a common zero position is useful to compare the magnitude of the surface and plunger travel. Plotting the pump card position relative to the pump barrel is useful to compare plunger position of a pump filled with liquid versus a pump that is not filled. It's interesting how over travel can occur on both the upstroke and the down stroke, which can impact your system and cause damage by tagging on the upstroke or down stroke

References

1. Lynn Rowlan, and Norman W. Hein, Jr., "A Review of the Non-Dimensional Pumping Parameters & Their Use in Sucker Rod String Design," Proceedings of the Annual Meeting of the SWPSC, 2008.
2. QRod Design Program Download, http://echometer.com/Software/QRod/tabid/130/Default.aspx

Nomenclature:

Fo - Fluid load applied to Rods by plunger - Lbs
S - Surface Stroke Length - Inch
Kr - Rod String Spring Constant – Lbs/In
Fo/SKr - Decimal Fraction if Surface Stroke Lost to Stretch
SV – Weight of rods in fluid or standing valve load - Lbs
TV – Weight of rods in fluid plus the pump load or the traveling valve load - Lbs
F1 - dynamic force required at the surface to apply a static force Fo at the pump - Lbs
F2 - dynamic surface force due to transferring the Fo carried by the traveling valve to the standing valve - Lbs

Figure 1 – “Under Travel Surface and Pump Card

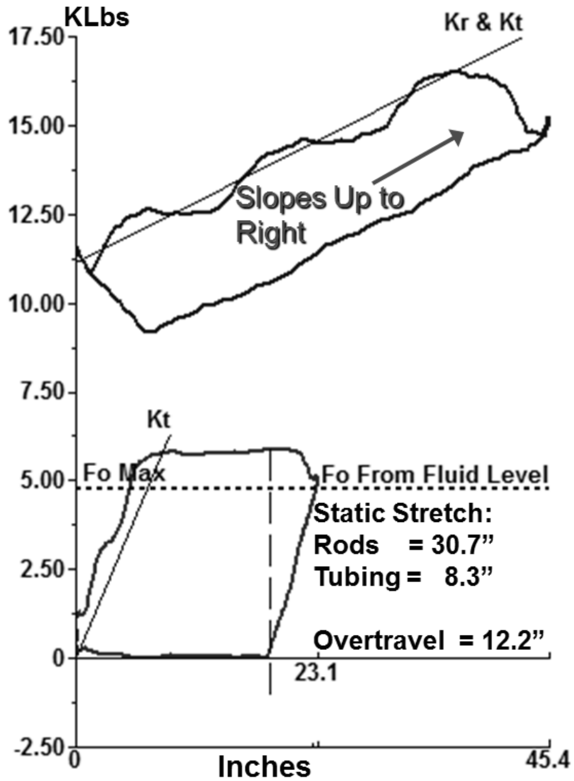


Figure 2 – Over Travel Surface and Pump Card

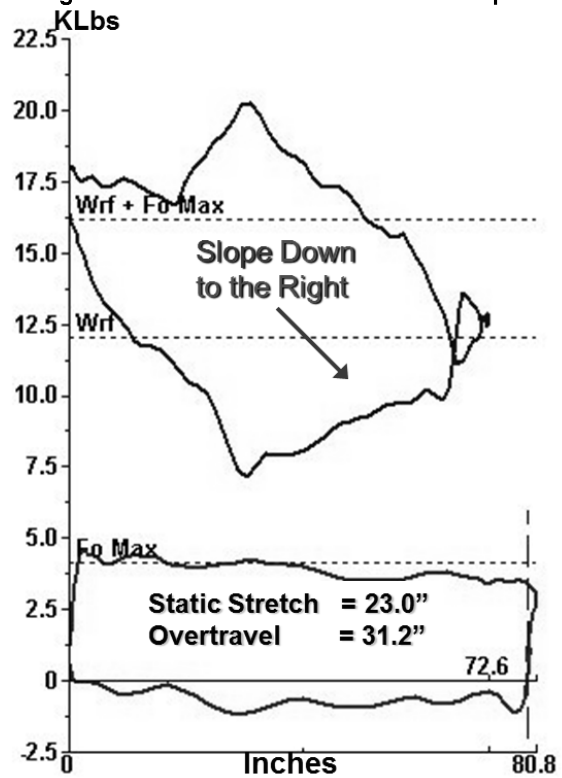
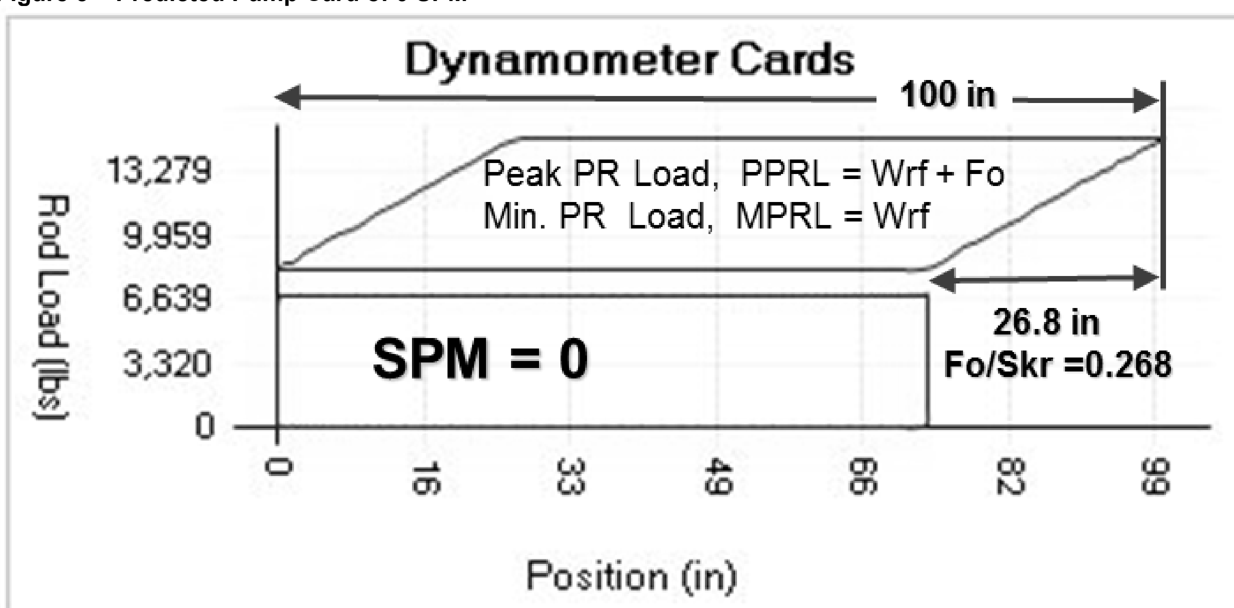


Figure 3 – Predicted Pump Card of 0 SPM



PPRL 15,089 lbs
Pump Stroke 73.2 in
Fo/Skr 0.268

MPRL 8,288 lbs
Static Stretch 26.8 in
Kr 254 lb/in

Fo 6,802 lbs
Overtravel 0.0 in
Kt 894 lb/in

Figure 4 – Predicted Acceleration Forces at 11 SPM

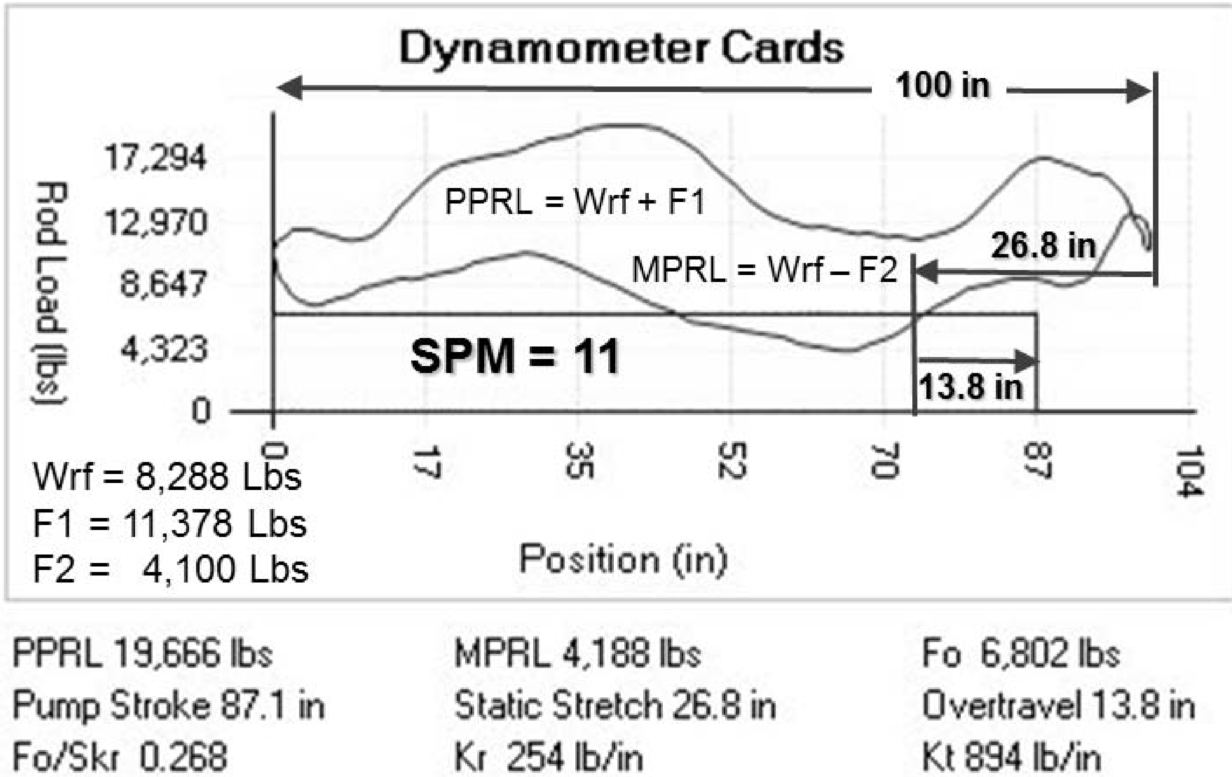


Figure 5 – TTU Test Well Overlay from 1 to 9.6 SPM

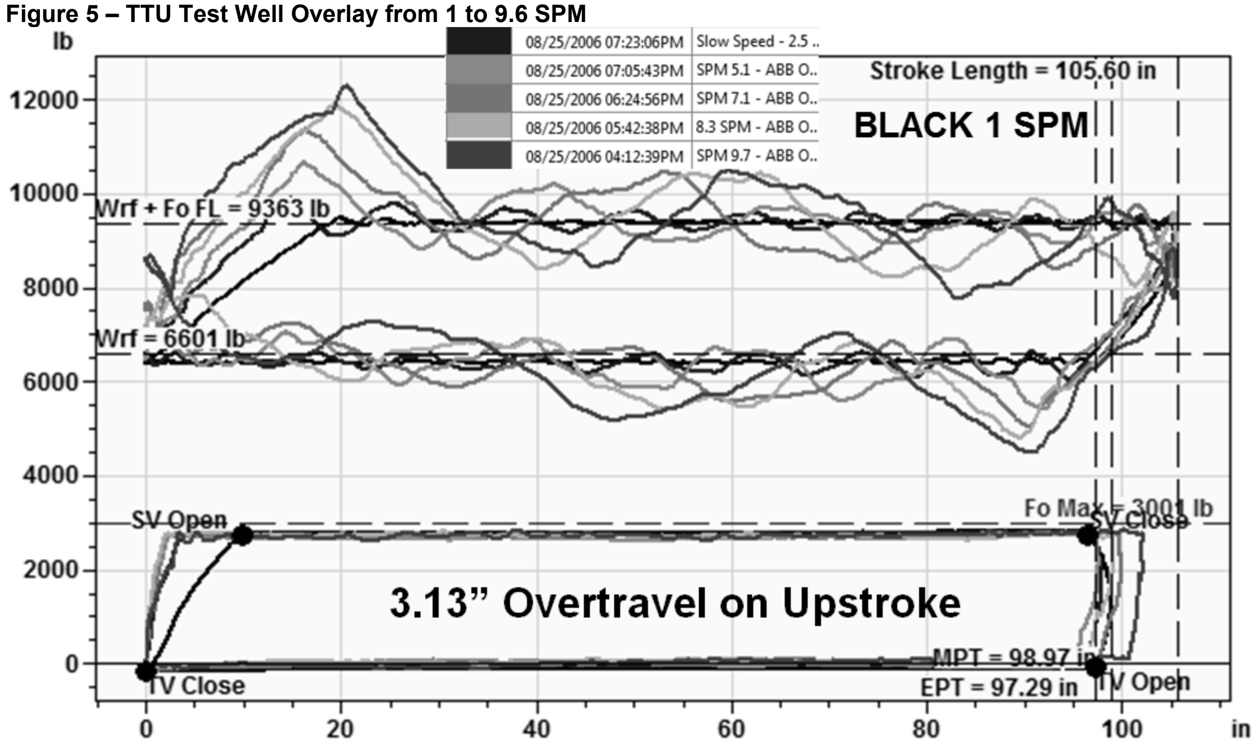


Figure 6 – Resonating Frequency of Rod String Peak Loads Align at Different SPMs

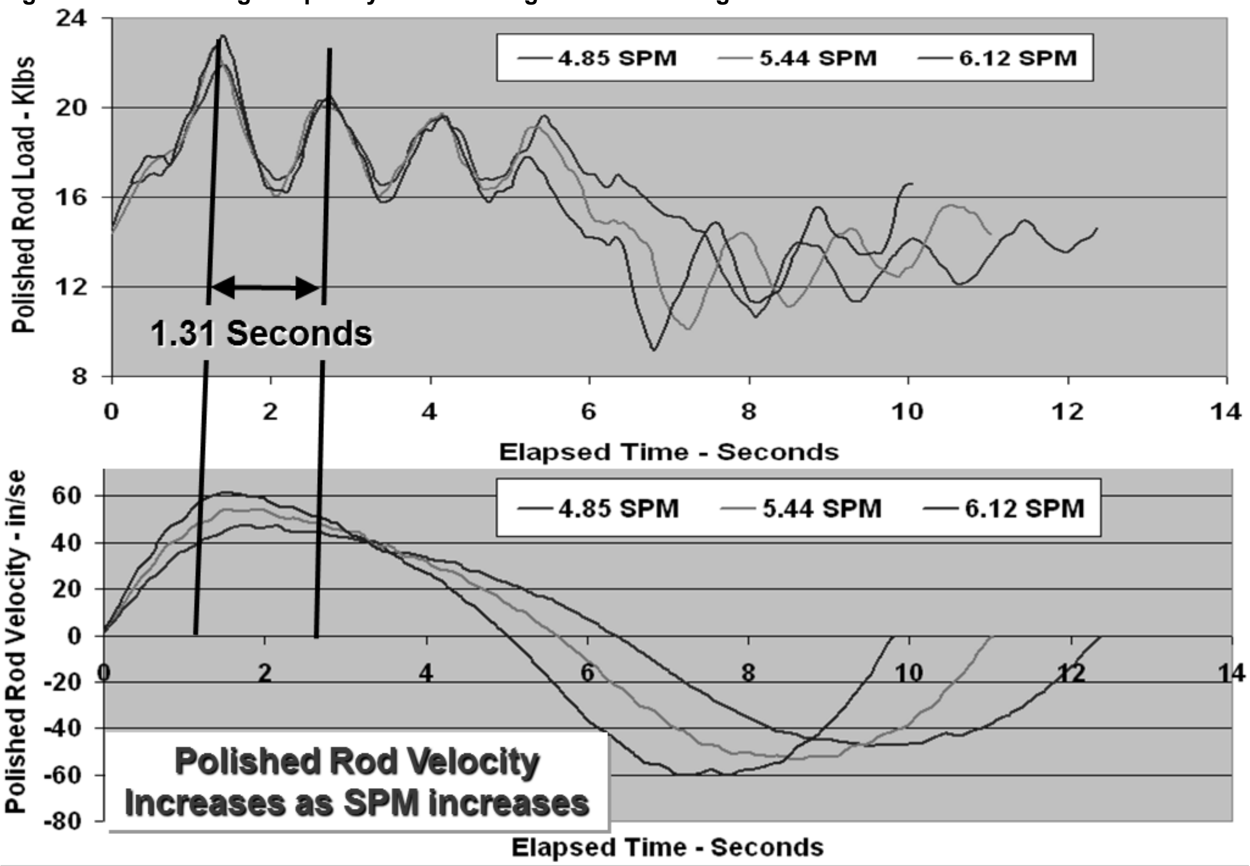


Figure 7 – POC and VSD Quickly Changing SPM from 4.5 to 9.7

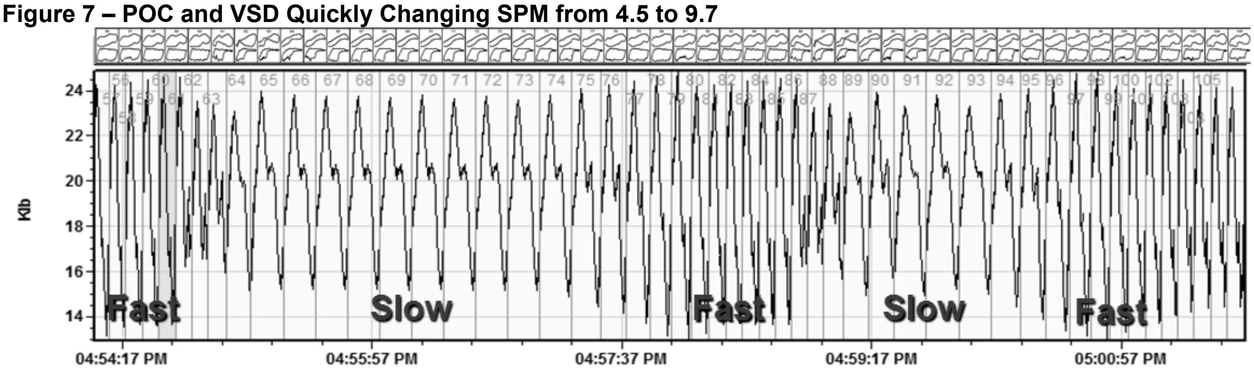


Figure 8 – Gas Interference Seen in Pump When SPM is Slowest

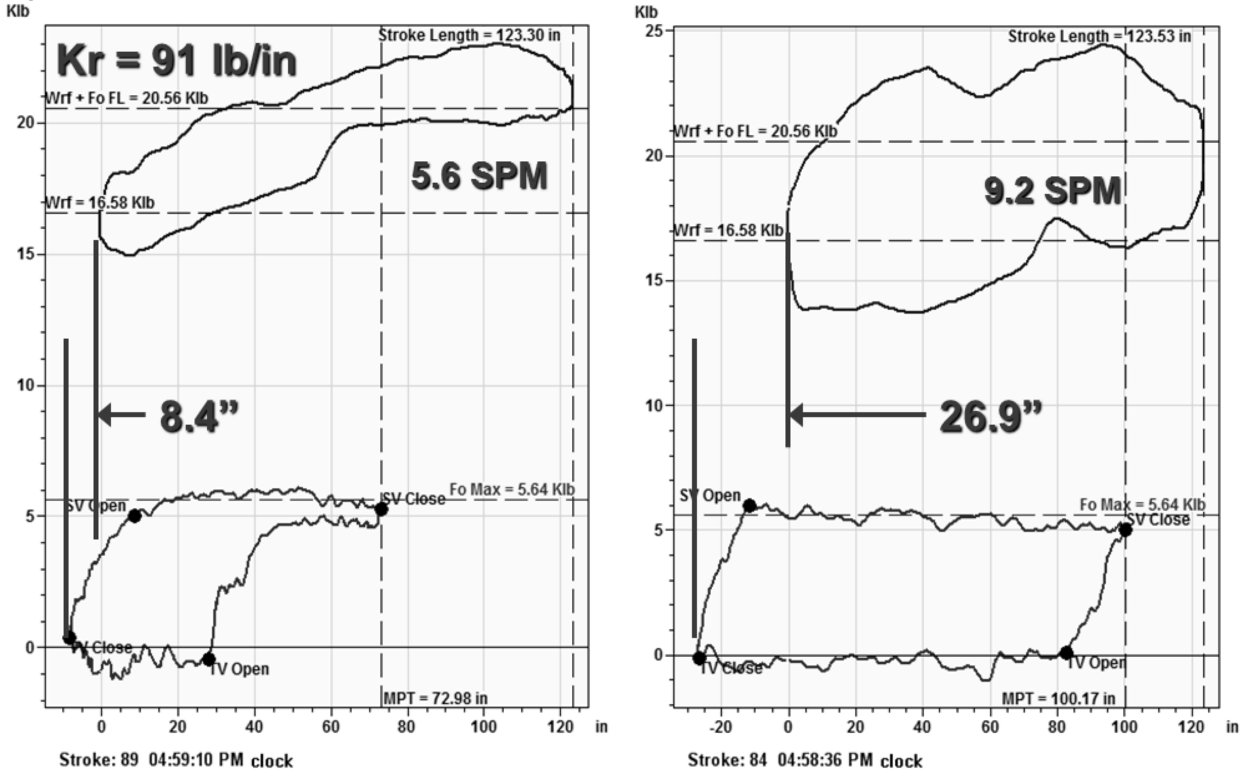


Figure 9 – Plunger Moves 5.5" Further Down and Tags Due to Velocity Profile and Momentum

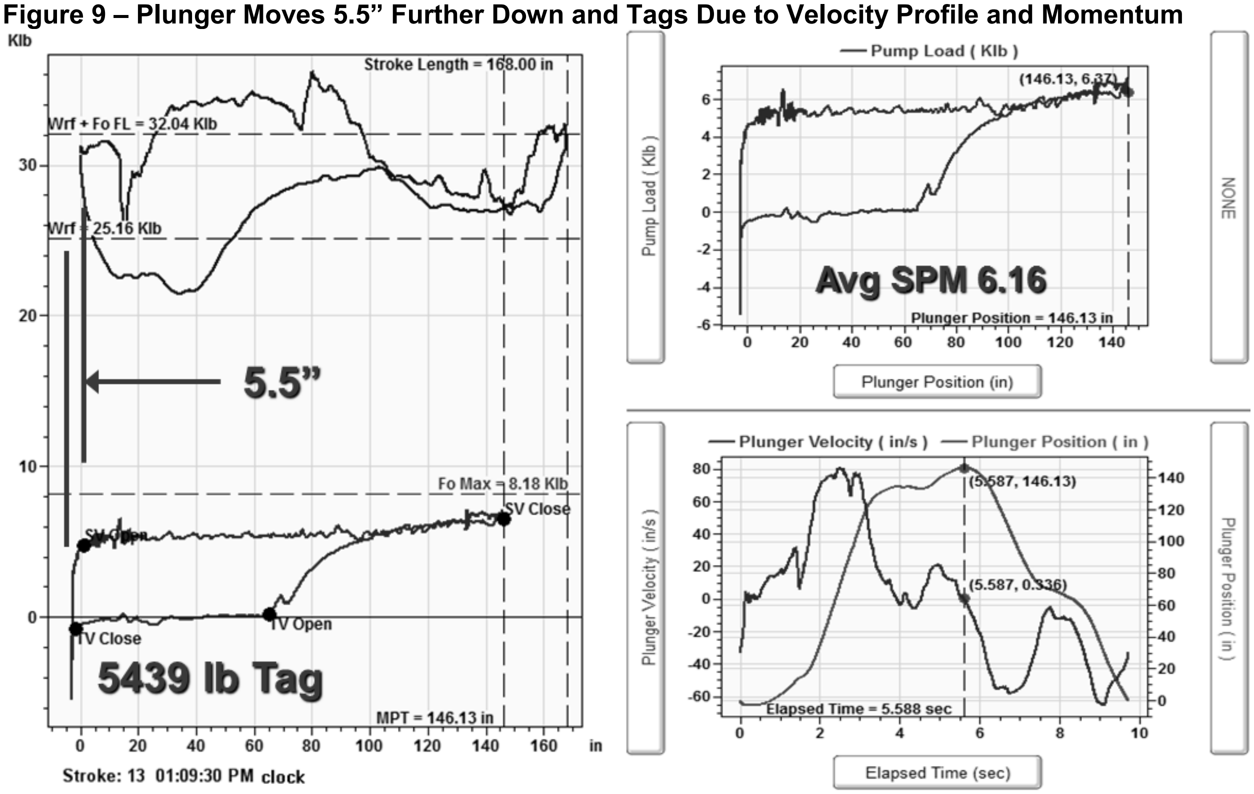


Figure 10 – Plunger Over Travels 22” Deeper into the Barrel Tags Due to Velocity and Momentum

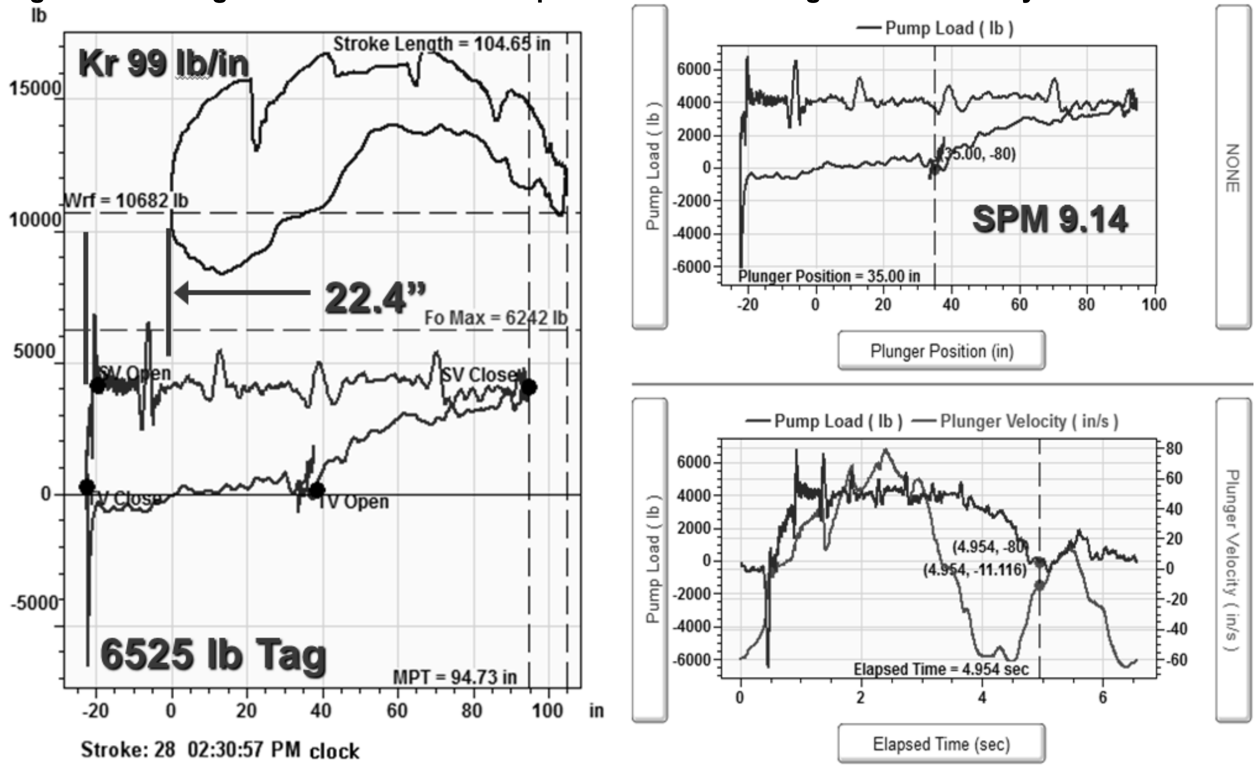


Figure 11 – Over Travel on the Up Stroke