ANALYSIS BEFORE ACTION

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ABSTRACT

The oilfield has long been known for doing things "the way we have always done it". This approach can change dramatically using new technologies and analysis methods. New technologies and analysis methods can be used to determine what is wrong with an artificial lift system; the operator no longer need to assume and take action based on a faulty assumption.

Fluid level data is acquired throughout the patch, only proper analysis and use of the data allows the operator to exploit the well to its fullest potential. Typically dynamometer data is not requested until an operator has pulled and replaced the pump with no improvement. Acquisition and analysis of fluid level and dynamometer data can be used to determine if: 1) the well is producing to its maximum potential, 2) the down hole pump is operating as expected. Examples well data collected on various wells will show opportunities for improvement, more production, more effective operation and fewer pulling jobs.

INTRODUCTION

When you go to your doctor you don't expect him to operate to determine what is wrong with you. You expect him to run diagnostic tests before taking steps to cure the ailment. You don't tell your doctor to operate because you feel bad. You don't tell your automobile mechanic to rebuild the engine in your car because it doesn't run right. But pulling the production equipment in a pumping well without knowing what is wrong with the well is done everyday ~ "The way we've always done it." New technology and proven techniques are available that can be used to determine what is wrong with an existing Artificial Lift System.

The oilfield has long been known for doing things the "way we have always done it". That approach has changed dramatically in recent years due to new technologies and developed techniques. New technologies and techniques have also been developed to determine what is wrong with an artificial lift system. We no longer need to guess what is wrong with the well and take action to workover the well based on a faulty assumption.

Acoustic liquid level tests are performed successfully in analyzing producing oil and gas wells throughout the world.[1] Understanding producing conditions determined by an acoustic fluid level well sounding is used successfully throughout the oil patch. Use of a portable system permits acoustic well soundings easier, faster, and more accurately by providing an in-depth well analysis through the acquisition and analysis of acoustic and surface pressure data. Fluid level data is used throughout the patch, but typically the information provided from the well sounding is not used to its fullest potential. Fluid level information may only be used to locate the liquid level. Making an operational change to the artificial lift pumping system based on only "Knowing joints of liquid above my pump?" may not be enough information to make the correct decision. Too often fluid level information is only used to locate distance to the top of the liquid level. An acoustic fluid level test is a diagnostic test that is performed on an oil or gas well, proper analysis of the acquired acoustic and pressure data will aid in the diagnosis of the well's problem and can be used to cure what is wrong with the well.

Dynamometer testing of sucker rod lifted wells is performed routinely in a safe and efficient manner throughout the world.[2] Advances in dynamometer and computer technology have led to quick and accurate measurement of force and position at the surface and prediction of loads along the rod string and performance of the pump. Use of a portable system permits in-depth analysis of the sucker rod pumping system at the well site. Currently in the oil patch it is typical that dynamometer data is not requested until operator has pulled and replaced the pump with no improvement. Often the dynamometer data collected after the equipment has been re-ran in the well shows the operator could have made a simple adjustment on the surface to have fixed the pumping problem or the dynamometer data shows that more rig time is needed to correct the undiagnosed downhole problem. Dynamometer data processed with software allows the analysis of polished rod power requirement, pumping unit beam loadings, rod loadings, pump power requirements, and pump performance. This type of analysis allows the operator to effectively monitor and analyze the sucker rod lift system. Not performing the dynamometer test prior to pulling the well is like the automobile mechanic just replacing the engine in your automobile without diagnosing the problem. Well problems are not solved in the oil patch just guessing with comments like: "It's the way we have always done it." "It's the pump." "Oils gone must have a casing leak." Proper diagnosis and resolution of the pumping problem using a dynamometer analysis is the first best step in identifying and correcting a downhole pumping problem. Using data to diagnose and understand the well is the best approach to correcting an operational problem with the producing well.

PROVEN ANALYSIS TECHNIQUES

Experience from analysis of many wells has resulted in the development of a methodology: Total Well Management[3] (TWM). Use of this methodology to analyze a well insures that a proper diagnosis of the well's operating conditions will be performed. Current operating conditions of an artificial lift wells can be diagnosed using the concepts of TWM. This diagnosis results an understanding of the performance of a given well. Application of the TWM methodology to a producing well can result in significant reductions in operating costs and increased oil production. A technician applying the TWM methodology can undertake a well survey including acquisition and field processing of the acoustic and dynamometer data in less than 45 minutes per well. The analysis of the acquired data is used to define the well's productivity, the down hole pump performance, the rod and beam unit loading performance. The well's production rate can be maximized and the operating costs minimized with this diagnostic analysis at the well.

While at the well as the collected data is analyzed, the goal of the technician is to answer the WELL PERFORMANCE QUESTIONS listed in Table 1 of Reference 3. Diagnosis of the well's performance from Dynamometer Fluid level, Power and Current Analysis consist of understanding 1) the inflow performance of the well to determine if additional production is possible. 2) Overall efficiency of the pumping system and is there room for improvement. 3) How the downhole pump is performing. 4) Surface loading on the pumping unit and the rod string. Application of the TWM methodology results diagnosis of producing problems and recommendation to improve the performance of the current pumping system. Recommendations to fix any problems discovered in the analysis of the collected data should be acted on. The following examples show problem situations using data collected on wells and how the problems were solved by analyzing the well using the TWM methodology.

WELL PROBLEMS

Following are general descriptions of four wells having operational problems that were analyzed and diagnosed using the TWM methodology.

Well 1 – Technician was requested to acquire data on a sucker rod lifted well after the sucker rod pump had been re-ran and installed in the well for only 24 hours of time. The sucker rod pump had tight pump clearances and new installed pump was not producing liquid to surface.

Well 2 – Technician was requested to shoot fluid level after the pump was changed because the new pump was not producing fluid to surface. Data acquired on the well showed that the tubing was partially dry. The well problem was rubber stuck in the back pressure regulating valve, proper diagnosis of the problem would have resulted in not pulling the well, where only minor service at the well head was required.

Well – 3 – Technician called to acquire a fluid level of an electrical submersible pumped well. The reason for the request was the oil production was down 40 barrels per day. Diagnosis of the acoustic fluid level shot showed that there was a hole in the tubing. The depth the hole in the tubing was determined accurately to within 4 inches of the actual depth of the ole in the tubing.

Well 4 – Technician was called to the well to diagnose a possible hole in the tubing. A pressure test truck with water was on location. The tubing was loaded with water and dynamometer data was acquired as liquid leaked out of the hole in the tubing.

Following is a detailed discussion of using the data collected on the wells to diagnose each well's particular problem.

WELL 1

Initial observation from the operator was "It's the pump, the new pump only pumped for 24 hours." Current liquid production rate test show that almost no liquid is being produced to the surface by the new pump. Upon arrival at the well both fluid levels and dynamometer data were acquired on the well. F**ig. 1** shows Bottomhole Pressure determined from the fluid level, where 532 psig is the pump intake pressure. There is a 2552 foot gaseous liquid column above the pump intake and the 18 MscfD annular gas flow rate results in approximately 52 percent liquid and 48 percent gas by volume at the pump intake. If this ratio of the fluid mixture outside the pump flowed into the pump with no additional natural gas separation, then the pump should be at least 52% filled with liquid. Tight clearances between pump barrel and plunger do not allow much fluid slip by the plunger to partially fill the pump barrel on the upstroke. The pumping unit was shut down for 10 minutes prior to acquiring the dynamometer card shown on **Fig. 2**. The pump card shows 18 barrels of pump displacement with 91 percent of the pump displacement being not filled with liquid (empty). The pump card would normally be classified as a fluid pound card. Fluid pound should mean that the fluid level should be at the pump intake and the pump capacity exceeds the inflow from the well. The loads the pump applies to the rod string during the upstroke indicate that the pressure inside the pump barrel is near a vacuum and much lower than the pump intake pressure indicated by the acoustic fluid level analysis. Since the fluid level shows 1369 feet of gas free fluid above the pump and the annular gas rate is not excessive; then this incomplete pump fillage problem is NOT due to the pump displacement exceeding inflow from the well (the incomplete pump fillage is not due to fluid pound). The problem with this well is caused by fluid in the wellbore not entering the pump.

A choked or blocked pump intake occurs in a rod pumped well with partial liquid fillage although adequate liquid is present[4] above the pump intake and the annular gas flow is insignificant. Resistance to liquid flow through the pump intake is resulting in the pump barrel being incompletely filled by the time the plunger reaches the top of its stroke. The rods and tubing in this well were pulled. The chocking of flow into the pump was determined to be from a partially blocked 2 3/8 inch by 3 foot perforated tubing sub, where only 3 holes were found to be open. Deposits of solid material were plugging the other holes through the perforated sub.

The large pressure drop through the blocked perforated sub results in a very low pressure inside the pump barrel. The pressure below the traveling valve is near zero, so that the pump load during the upstroke will be a high value very close to the value of FoMax as shown in **Fig. 2**. The general form of the pump card dynamometer for a choked pump is very similar to that of a well where the pump capacity significantly exceeds inflow and the well appears to be pumped-off. For this reason the choked pump condition is often not recognized and the well problem is often misdiagnosed as a pumped-off well. The correct diagnosis can be reached by including the information from the fluid level measurement, showing a high pressure on the outside of the pump and the pump card showing a low pressure inside the pump; where the difference in pressures is due to a blockage/choking of fluid entering the pump.

WELL 2

Initial observation from the operator was "It's the pump again; the new pump is not pumping." Current liquid production rate test show no liquid is being produced to the surface by the new pump. Upon arrival at the well both fluid levels and dynamometer data was acquired on the well. Fluid level information shown in **Fig. 3,** acquired on this well shows the liquid level is near pump intake. Intake pressure determined from the fluid level is 73.8 psig. In **Fig. 4** the initial dynamometer pump card shows the fluid load range between the up stroke loads and the down stroke loads is too low. The pump card is shifted above the zero load line[5], because the rod string in the tubing is suspended in low pressure gas and liquid is not filling tubing providing buoyancy to the rod string. The pump card is shifted above the zero load line by 1134 pounds of missing liquid buoyancy force due to the partially dry tubing. This upward shift in the pump card loads is caused by missing fluid buoyancy, since the tubing is not filled with liquid, the surface measured rod loading is are higher due to the lack of rod buoyancy and pump card loads from the wave equation calculations assume the tubing is filled with fluid.

In this well a high gas flow rate through the pump and up the tubing resulted in the tubing fluid being gas lifted out of the tubing. A back-pressure regulating valve on the tubing had been previously installed on this well to prevent liquid from being blown out of the tubing when the gas flow rate into the tubing is too high. Pump action stops when gas blows the tubing dry and there is no differential pressure acting across the traveling valve. The fluid load the pump applies to the rod string is much less than normal, because the pump is discharging against a low discharge pressure at the bottom of the tubing caused by a small amount of liquid accumulation in the tubing above the pump. For a normally operating well when the tubing is full of liquid, then the pump card dynamometer card should show the pump card resting on the zero load line on the down stroke and pump card loads on the upstroke should be near the maximum fluid load the pump can apply to the rods (since the pump intake pressure is low). In this well the sucker rod string is not fully buoyed in tubing fluid; the pump load on the downstroke is shifted upward off the zero load line by the missing buoyancy force. The dynamometer measured rod load is lighter that the normal weight of rods buoyed in air and heavier than weight of rods in fluid, because the upper portion of the rod string is without liquid buoyancy and normal fluid buoyancy exist in the lower section of the rod string below the liquid level in the tubing.

Rubber material had stuck the back-pressure regulating valve on this well open, allowing the high gas rate through the pump to unload the tubing. The rods and pump were pulled without knowing what was wrong with the well. After acquiring fluid level and dynamometer data the well problem could be diagnosed. The pump shop found nothing wrong with the pump and rods and pump were re-run in the well. After the pump was ran in the well the same problem re-occurred, this time the technician was called and the well problem was diagnosed after acquiring the data on the well. Rubber in a back-pressure regulating valve is a low cost and simple problem to correct, but the rods and pump were pulled and re-ran without any repair. A proper initial diagnosis of the well problem would have prevented a costly workover on the well, because no rig time was needed.

WELL 3

Initial observation from the operator was "I have a casing leak." The oil production rate had decreased by 40 barrels per day. The technician was called to shoot a fluid level; **Fig.5** displays the acoustic trace shot down the tubing/casing annulus acquired on the electric submersible pump, ESP, while pumping fluids up the tubing. There is an unexpected echo displaying a down kick on the acoustic trace at 1.37 seconds of elapsed round trip travel time from the surface to the decrease in the wellbore cross-section and back to the surface. The echoes from 21.78 joints of tubing were used to determine the distance of 666 feet to the down kick. A portion of the liquid being produced to the surface was discharging through a hole in the tubing. When the ESP is shut-in the discharge of liquid stops and the down kick disappeared. After pulling the tubing string the depth to the pin hole in the tubing was within 4 inches. Acoustic liquid level instruments can be used to easily look into the well and diagnose downhole problems.

WELL 4

Initial observation from the operator was "Pump is not pumping fluid to surface, but a hole in the tubing is suspected." Information from the fluid level measurement and the dynamometer data acquisition can be used together to identify what is wrong with the well. **Fig. 6** is the acoustic trace from the fluid level shot down tubing, fluid at 1271' from surface. If a sucker rod pumping well produces primarily liquid, then the fluid level shot down the tubing should be very near the surface. A fluid level 50 joints from the surface down the tubing can be an indication that there may be a hole or the pump is not holding liquid in the tubing (remember to use 25 foot joint length when shooting down the tubing and counting sucker rod coupling echoes). **Fig. 7** is the acoustic trace from the fluid level shot down the tubing casing/annulus showing the fluid at 5950' from surface. **Fig. 8** is the dynamometer data acquired immediately after loading the tubing with lease water. The full pump card setting on the zero load line indicates that the pump does not appear to be leaking liquid and the pump card fluid load on the upstroke up is near the expected loading as determined form the pump intake pressure form the fluid level shot acquired down the tubing/casing annulus. The fluid leaking from the tubing is not leaking through the pump. **Fig. 9** displays the changes in the pump card as liquid leaks out of tubing. The increase in the liquid level in the tubing/casing annulus results in less rod stretch due to a smaller fluid load and the pump stroke increases 2". The pump card plots above the zero load line, since the weight of rods in fluid increases and tubing liquid leaks out and buoyancy force is reduced. The spike load at the top of the upstroke on the pump card is caused by raising the pump spacing 3 inches with the insertion of horse shoe load cell between the polished rod clamp and the carrier bar. The pump is stroking in part of the barrel where is does not normally operate. This well has a severe scale problem so the deposits on the pump barrel wall or incorrect spacing is resulting in this tag (spike load at the top of the upstroke). Initially there was a liquid level in the tubing. When the tubing was loaded with water, running the pump did not increase the surface pressure; but the liquid ran out of the tubing. The pump operated properly when filled with liquid. The correct diagnosis on this well is a hole in the tubing.

Fluid and dynamometer data acquired on the four example wells was used to diagnose various artificial lift system problems. Fluid level and dynamometer data are powerful tools that allow a well technician to troubleshoot well problems and diagnose what is wrong with the well.

VALUE OF FLUID AND DYNAMOMETER ANALYSIS

During the year 2006 Oklahoma City operator, Scott Robinowitz implemented a project of using an experienced artificial lift technician to perform routine fluid levels and dynamometer surveys on all his pumping wells. The acquired was used to diagnose and trouble shoot well problems over the last four years and the reduction in operating cost and increase in production has helped enhance the value of the wells that Scott operates by many million dollars.

For example one particular well required pulling every 10-12 weeks at a cost of $7,000 per workover. The lifting cost for this well for calendar year 2008 was $15.38 per barrel of oil. Through diligent acoustic fluid level testing and dynamometer work the operation of the current pumping conditions were evaluated and operational problems were diagnosed. Recommendations to improve current pumping practices, making some downhole changes and running a different type of rod pump has reduced the pulling frequency and increased oil production. **Fig. 9** decline curve shows as a result of improvement of the operations of the well there was an increase in production of 10 barrels of oil and 10-12 MscfD of gas. These operational changes have cut lifting cost in half to $7.08 per barrel of oil.

SUMMARY AND CONCLUSIONS

Routine fluid levels and dynamometer on pumping wells has proven to add many millions of dollars in value to producing oil and gas wells. Use of fluid level and dynamometer data is a valuable tool to use in the diagnosis of problems encountered in operating the well. Dynamometer and fluid level can be used to determine if the well is producing as much oil and gas as possible without incurring excessive operational problems. The pump can be diagnosed and the artificial lift technician can determine if the downhole pump is operating as expected. Dynamometer and Fluid level data will point out opportunities for well improvement, more production, lower power cost, more effective and fewer pulling jobs. Dynamometer data will quickly confirm success and failure in operational changes. When the recommended changes to the well are completed, new data should be collected in a few weeks once the well is operating under stabilized conditions. The artificial lift technician should use the acquired fluid level and dynamometer data re-read the recommendations from the previous analysis of the well's data and notice if the well performance has changes as planned. The analysis step to evaluate the recommended changes is called the follow-up step of the analysis. Following-up on recommendations is how production technicians learn from their successes and failures; and their role changes from a data collector to a knowledgeable well analyst and expert well problem diagnosticians.

REFERENCES

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5. Rowlan, O.L., McCoy, J.N. and Podio, A.L.: "Reference Load Lines Aid in Analysis of the Downhole Dynamometer Pump Card," presented at the Southwestern Petroleum Short Course, Lubbock, TX, 2009

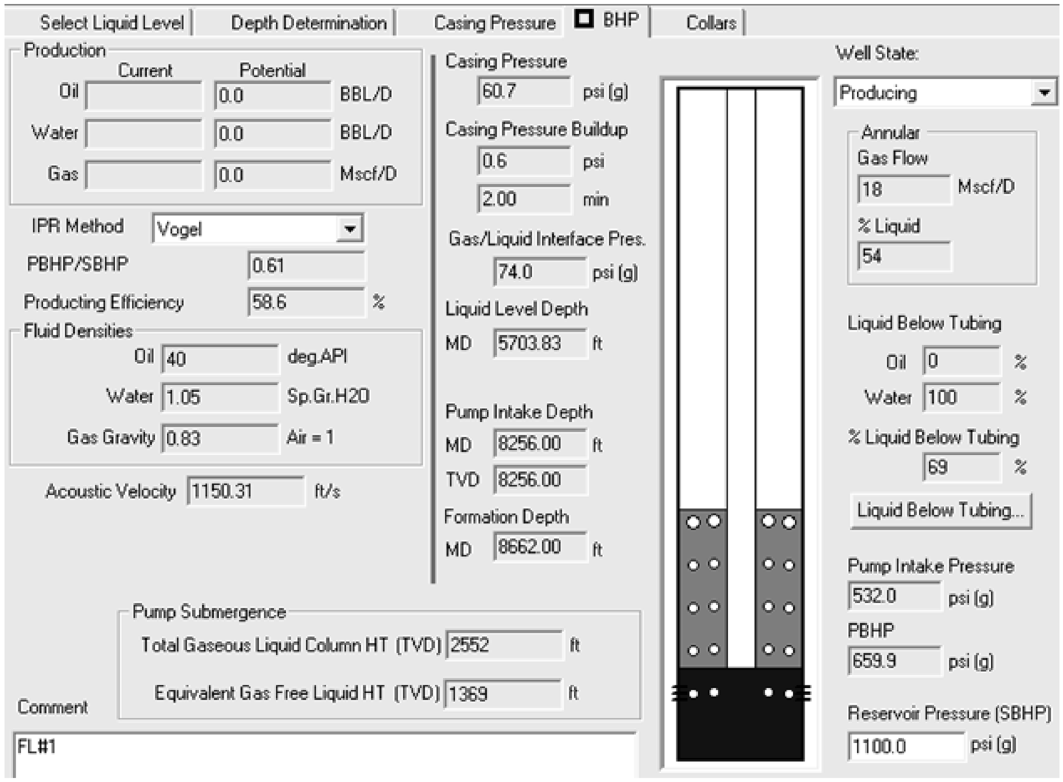

Figure 1 – Analysis Shows High Fluid Level with 532 Psig Pump Intake Pressure

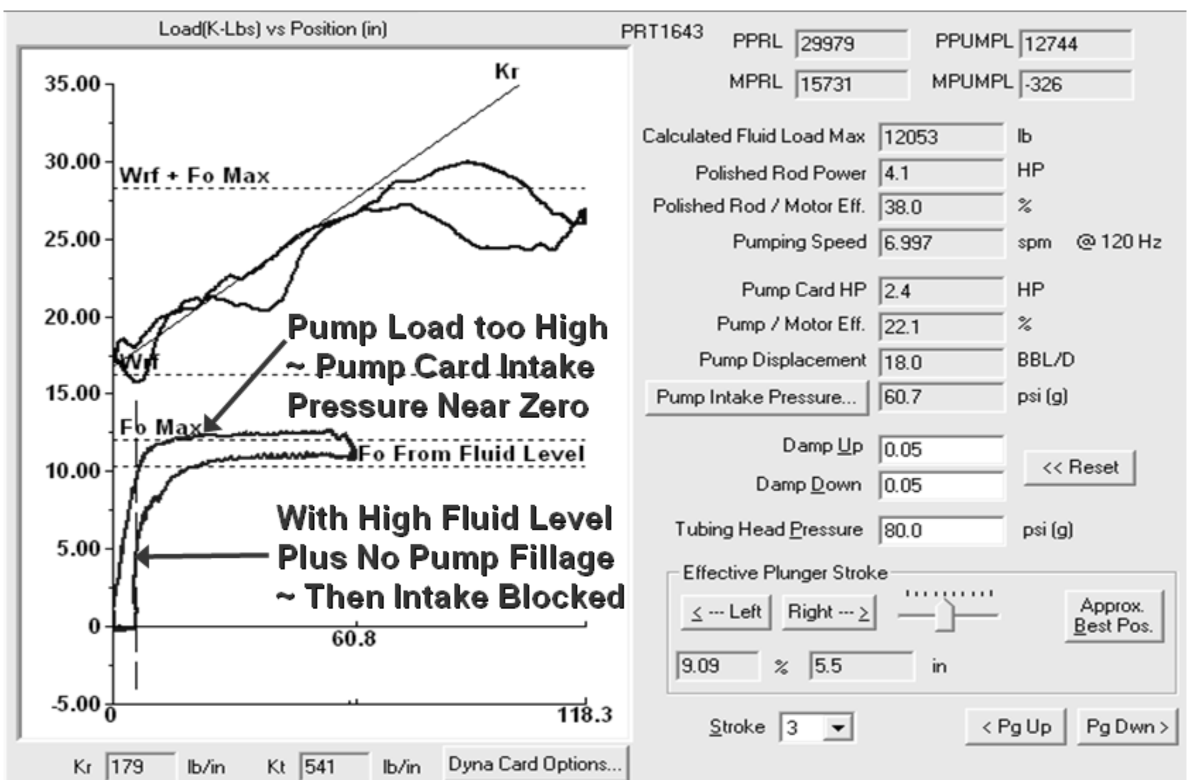

Figure 2 – Dynamometer Card Acquired Immediately After Well Down for 10 Minutes

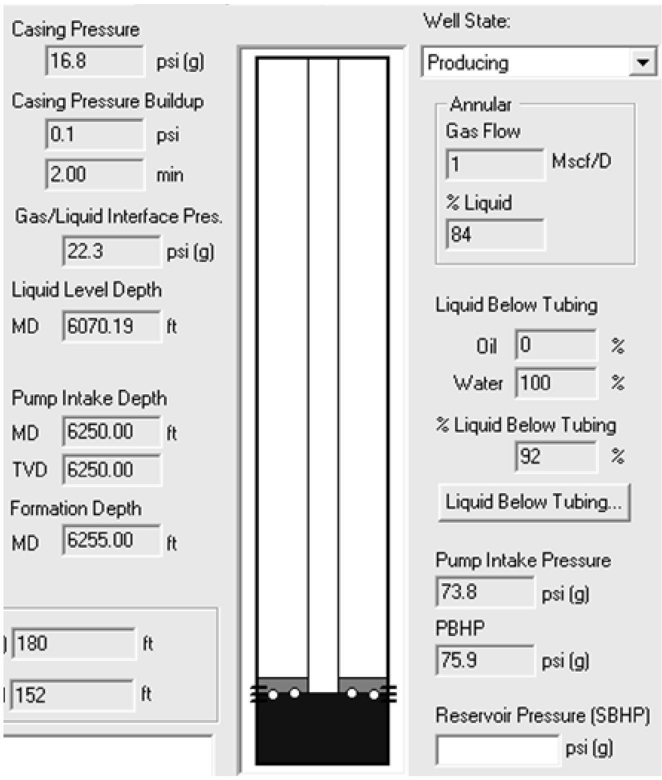

Figure 3 – Fluid Level is Near Pump Intake on the Well

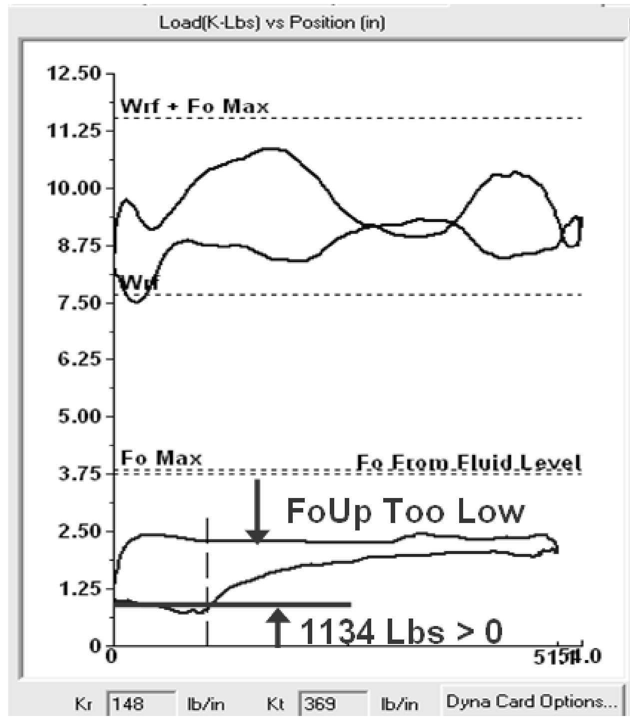

Figure 4 – Initial dynamometer card

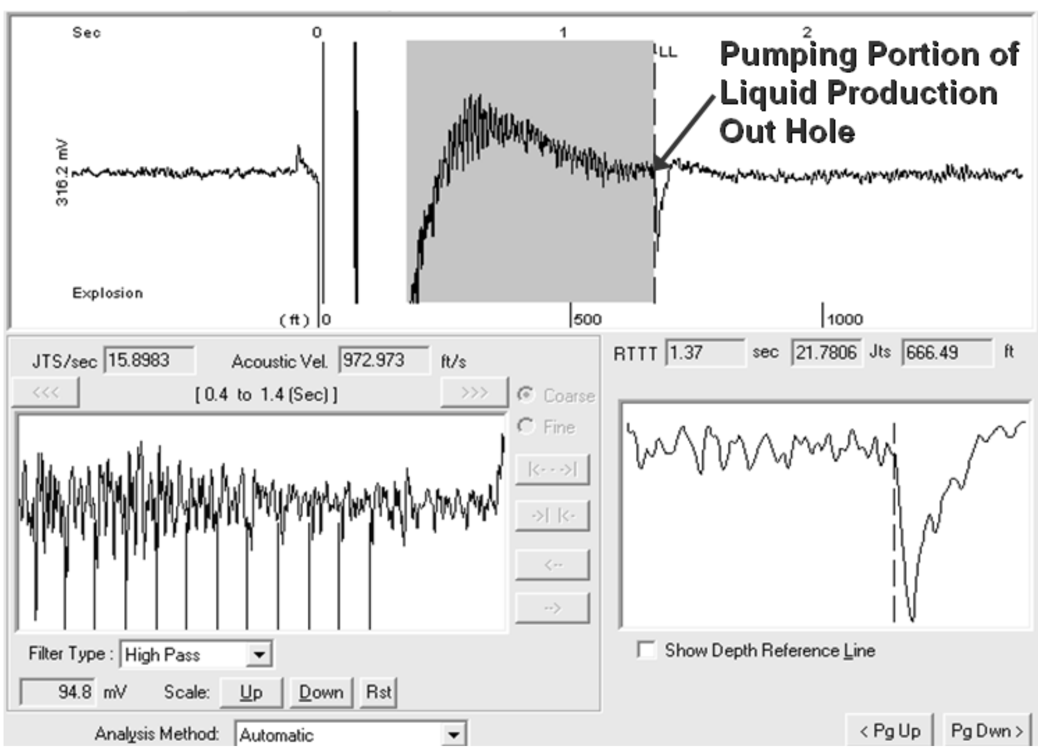

Figure 5 –Fluid Level on Well 3 Shot Down the Tubing/Caning Annulus

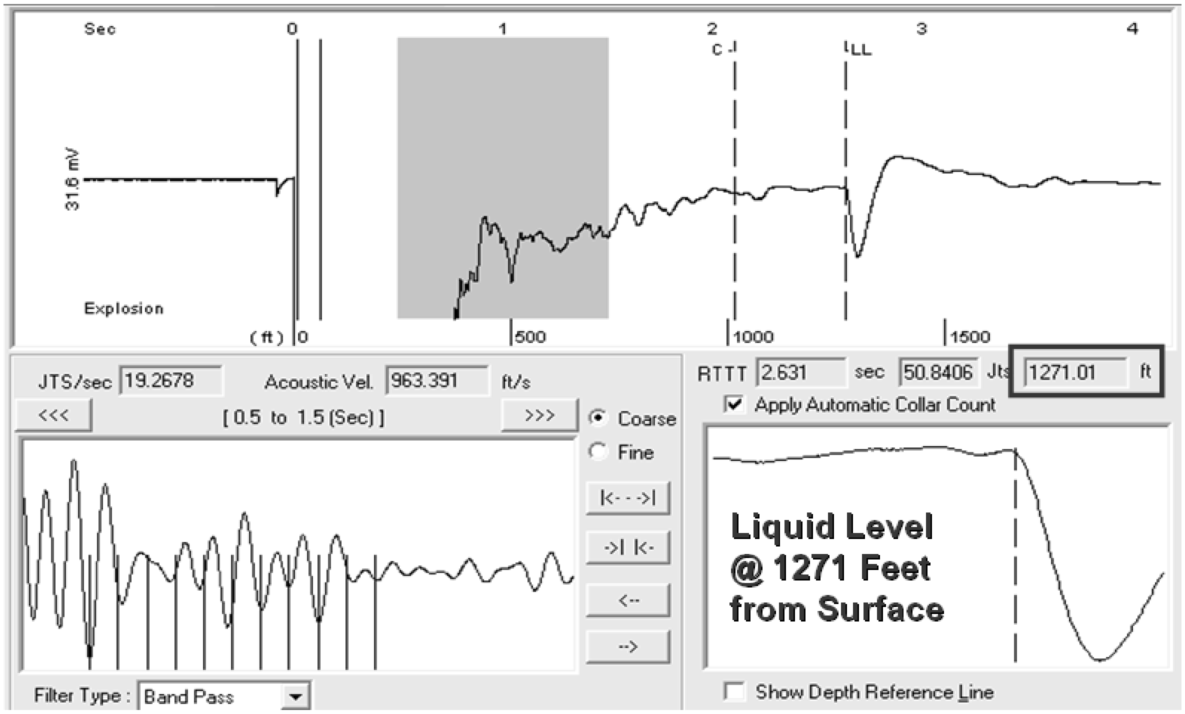

Figure 6 – Initial Fluid Level on Well 4 Shot Down Tubing Before Loading With Liquid

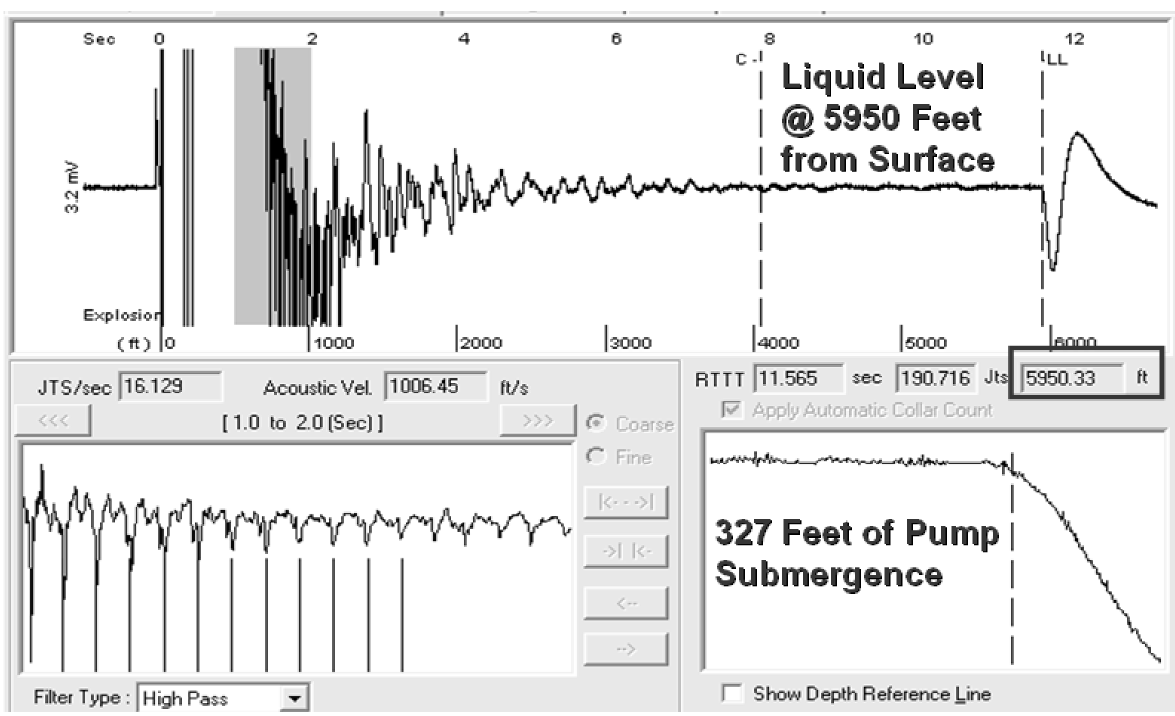

Figure 7 –Fluid Level on Well 4 Shot Down Tubing/Casing Annulus Before Loading Tubing with Liquid

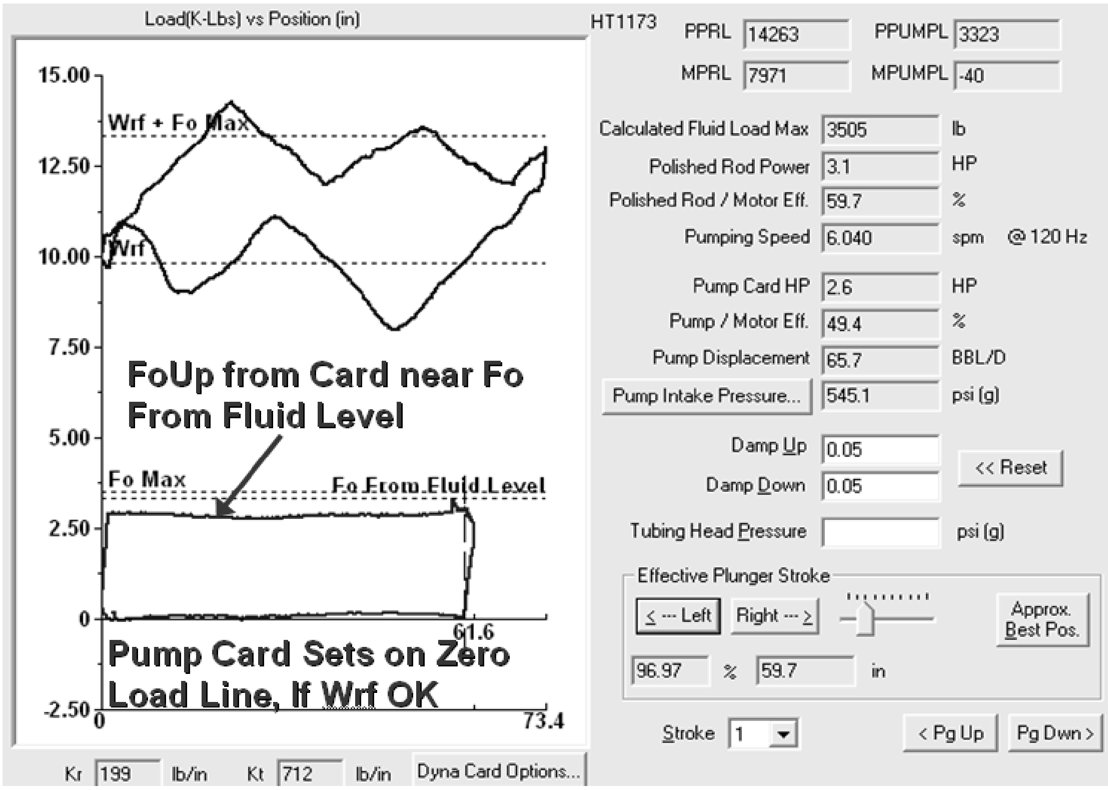

Figure 8 – Dynamometer Data Acquired Immediately After Loading the Tubing with Lease Water

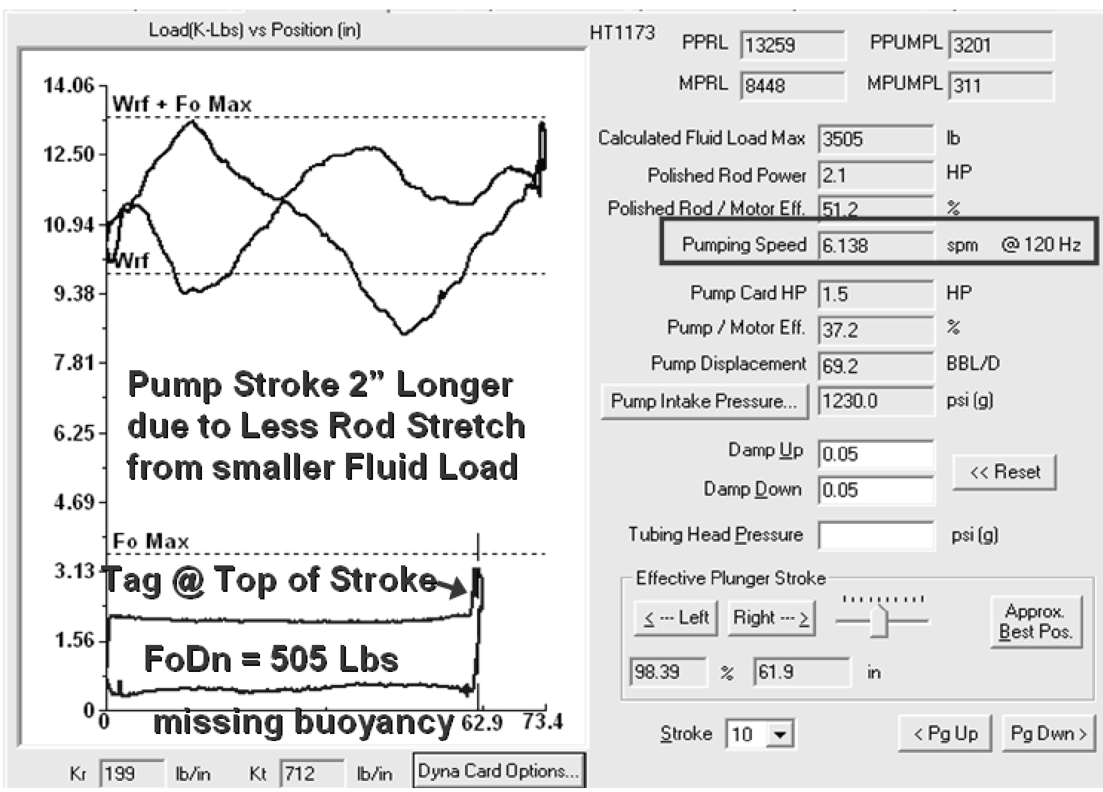

Figure 9 – Dynamometer data showing changing Pump Loads as Liquid leaks out of Tubing and Raises Liquid Level in Casing

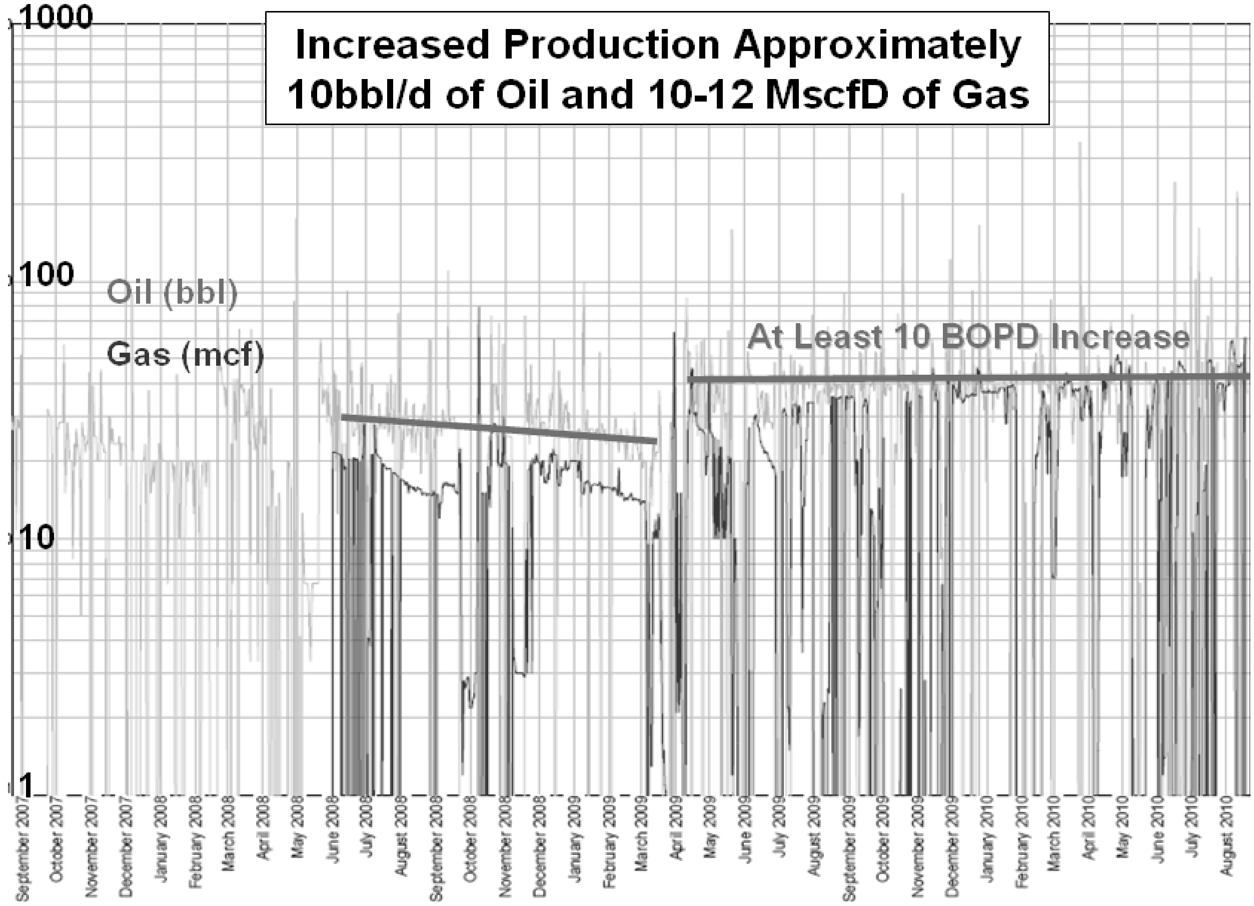

Figure 10 – Decline Curve Showing Results of Diagnosing Well Using Liquid Levels and Dynamometer Surveys