A Study of Rod Running and Pulling Practices Using Computerized Rod Tongs and A Remote Service Rig Tracking System.

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ABSTRACT:

The initial goal of a 'Remote Service Rig Tracking System'' was to continuously monitor and specifically address proper rod makeup. This was accomplished by implementing a crew evaluation, training and feedback model, wherein the rod makeup process data is measured, downloaded remotely, and interpreted. Crews are provided instruction to improve techniques based on the acquired data, and are subsequently monitored to observe expected performance improvements and define areas for further concentration.

Serendipitously, a comparison among numerous well histories and field data reveals an apparent high correlation between rod breakout energy and pending pin failures. A computerized prototype rod tong system is being deployed which will allow crews to make every connection to exact specifications yielding precise circumferential displacement and proper pre-stress. Real time data and documentation is provided as to the condition of the rod connections unscrewed and the connections made while running the rods back into the hole for service.

INTRODUCTION:

There are currently approximately 300,000 oil wells in the United States using sucker rods to transfer power from the surface to downhole. Based on an average depth of 3,000 feet, there may be over 36,000,000 sucker rods in use on any given day. Those numbers alone make it abundantly clear that properly understanding the complex relationships of the use, limitations, and handling of sucker rods is paramount to the economic success of producing oil within this country.

A significant positive economic impact to the operators of fields where beam pumping is prevalent has been made by coupling computers to precision pump off controllers (POCs) via data-links. Since its inception, there is no question that failure rates have been lowered as this technology has evolved. In the mid-seventies, when POC's were being field tested, the technology was credited with lowering failure rates in several fields by 30% or more. But, as good as they are today, the POC is only designed to assist the operator while the well is pumping on a daily basis. They cannot be used to study how the rods are being run or pulled.

To fully understand sucker rods, find ways to reduce failure rates, and look at the big picture, rod handling must catch up with the POC technology that has been so helpful to our industry. This paper addresses that advancement and is based upon studying thousands of hours of field data, conducting dozens of crew observations and interviews, and utilizing new computer technology, all in the process of determining why failures occur.

THE SUCKER ROD CONNECTION:

Pin and coupling failures, which comprise almost 40% of the rod problems, are assumed to be a progressive phenomenon. It takes time (cycles) for the rod to loosen up, leak, and then catastrophically fail. This catastrophic failure is very costly and must be prevented. Frustrating to the well operator, no obvious patterns emerge or current predictive methods exist to assist in the elimination of these failures. Some rod strings exceed 50 million cycles with few failures while wells with similar pumping conditions and rod string configurations, experience failure very early in their lives.

The sucker rod assembly is a metal to metal friction connection. To maintain its durability throughout the constant cycling of the beam pump, it must be tight enough not to back off but not so tight that the threads become deformed at yield. This preloading of the pin by tightening is affected by thread cleanliness and lubrication, as well as how much, and in what manner torque is applied to assemble the connection. When the rod is properly assembled, it will withstand changes in axial loads due to constant compression and tension changes. When improperly assembled, the connection pin will be subjected to a bending moment as the rod string cycles, and such movement will lead to leakage, corrosion, and a loose rod connection, ultimately ending in a costly, premature failure.

Figure one, courtesy of Sandia National Labs, illustrates the stresses to pins and couplings as axial forces are applied to a sucker rod connection. When properly assembled and used within design axial stress limits, a rod connection should maintain the correct tightness throughout its intended life. It should not leak, and the pin should not be subjected to horizontal moments that would lead to a "loose under a load" pin break. On the other hand, a connection will prematurely fail if the rod is not properly pre-stressed, is used beyond its design limits, or is subjected to outside forces such as fluid pounding, pump sticking, or rod buckling.

To examine dynamics of the rod connections, two emerging technologies are being used. The first is a set of computerized modified BJ rod tongs that allows a sucker rod to be made up to close tolerances. The computer measures the various components of the makeup or breakout process and each connection can be examined in great detail. The second technology involves remotely accessing field data with the UniTrak system. This data is a continuous measurement of certain critical service rig activities, and allows for the study of the energy used to make and breaks rods and how crews go about performing these tasks. When this information is combined with the wellbore pumping dynamics, patterns begin to emerge. Understanding these patterns should allow the operator to alter his wellbore operating dynamics and make adjustments in "best practices" for the service companies, leading to the next step in reducing or eliminating pin and coupling failures.

ROD BREAK OUT ENERGY:

Preliminary to the interpretation of measured data as it relates to rod connectivity issues, is an understanding of some basic concepts. One would assume, and experience confirms, that the tighter a threaded connection is made up, the more force is required to break the connection. Specifically, in the case of sucker rods, it can be said, "If a sucker rod in good condition is made up correctly, it will break correctly and very predictability." This should remain true unless during the intervening time between assembly and disassembly, the conditions to which the sucker rod assembly was subjected significantly alters the integrity of the connection. Figure 2 illustrates this concept. This is a graphic presentation of a sucker rod made up and broke out twelve times under carefully controlled conditions. The rod was cleaned and properly lubricated between each operation. The point to be made by the examination of this chart is that the breakout energy closely tracks the makeup energy for any given rod. These rods were made up and broke without being run into a well, therefore no "outside force" acted on these rods.

Applying this concept of rod breakout energy to actual wells, Figure 3 is the breakout data taken from a rod pull where the rods broke out with fairly consistent and predictable pressure. The division between the one-inch and 7/8 inch rods is quite evident on the torque curve. This well has a failure rate of .68. All service jobs were due to a pump change and one rod body part. There have been no pin or rod failures in seven years. This graph tells us that it takes approximately the same amount of energy to **start** the rods moving and to break the pin-box interface. (Peak reader circuits are used to capture the maximum pressure applied during a pre-determined time interval, in this case every four seconds.) On these charts, the readings are not taken from any specially modified tongs, and therefore the hydraulic pressure of the rig system and engine RPM has a small effect on the pressure readings at the beginning of the stall. This well has a 640 Conventional Lufkin Unit with a 144-inch stroke. The rods are loaded at 96% at a .9 service factor. The files indicate the rod string has 29.3 million cycles.

Figures 4 and **5** are from two rod jobs on a different well. This well is in the same field as the well from Figure 3 but both of these jobs (two months between failures) display a different picture of breakout energy. The energy displayed on the pull charts is in the form a wave with extremes of high and low torque in excess of 100% variance. This well has failed five times in two years (FR=2.5) with each failure attributed to a 7/8" pin failure. The rod string has 9 million cycles on it, one third of that time represented by the example in figure 3. This well also has a 640 Lufkin Conventional unit.

Figure 6 illustrates the measurements made while running the rods back into the hole on this well. It clearly indicates the rods were run right and the crew checked all breaks going into the hole.

It should be noted that different rod tongs with different rig hydraulics and pumps display different pressure values and characteristics when the rods are pulled. This is an acceptable condition as we are not currently concerned with the absolute values but are concentrating on the trends of the curves.

Figure 7 shows tight breakouts or rods that break well above the trend. This is often indicative of rod connections that have leaked and become corroded or ones that have rolled threads, but other conditions may exhibit similar results. It is a primary objective in developing the technology to determine what other measurements are necessary to properly ascertain what can be learned from such patterns.

CURRENT METHODOLOGY OF ROD MAKE UP:

Currently, the "Standard of the Industry" for properly pre-stressing or pre-loading a rod coupling is the plastic card supplied by various rod manufactures. This card is used at the start of any rod run, as a guide to set the tong hydraulic pressure to the value needed to bring the rod to the correct circumferential displacement (CD). According to one manufacturer, this card brings the rod and box threads to within ten percent of yield. Its use is critical in the assembly process to tighten the rods correctly, and when used properly, the card has served the industry well. It is also necessary to re-check the card at fairly short intervals, as the hydraulics will change due to heat as the rods are run.

A reality check from field data and crew observations uncover some major loopholes in this carding process. The card is designed to bring the threads to within 10% of yield and the distance between the white lines on the card is .4375 inches for a 7/8" Norris 78. Note in Figure 8 the use of the grease pencil to mark the line from which the crew measures the displacement. The width of that grease line is .1275 inches or 29 percent of the target .4375 inches.

The next problem that the UniTrak data revealed is that of the effect of temperature on the rod make up process. Each time the rod tongs are used to make a connection, they are brought to a full stall and the human-set by-pass valve on the rig controls the stall point. The hydraulic energy supplied by the rig system's pump remains fairly constant for any given RPM.

Figure 9 illustrates the effect of heat as the rods are run into the hole. The field data studied from UniTrak files indicate that almost without exception, the engine is running at full RPM while making rods, Due to hydraulic system inefficiencies, higher engine RPM's result in higher rates of heat build up. Because a large amount of hydraulic energy is expended in the bypass valve, even more heat is produced. As the hydraulic fluid heats up, it becomes less efficient because of fluid viscosity reduction. As the viscosity drops, the tong motor torque drops, lowering the effective force applied to the rod make up. It is obvious from Figure 9 that the rods torqued at the end of this chart are not to the same specifications as the initial rods (well outside the 10% limit). This heat effect occurred in less than 8 minutes of trip time.

Perhaps the least understood aspect of the rod tightening process is the tong itself Rod tongs get their energy to makeup a rod from two basic sources. The first source comes from the angular velocity or momentum of the moving tong table. The second is from the hydraulic pressure applied to the tongs after the momentum is expended. Both energies become contributing components in the make up process as illustrated in Figure 10.

The amount of energy available from the turning table is a function of the square of its velocity. When the shoulder point of the rod is reached, the momentum contained in this table is transferred directly (thanks to Newton's third law) to the connection. As the table speed increases, more energy in the form of momentum is being transferred to the make-up process and less energy (in the form of hydraulic force) is needed to properly pre-stress the rod coupling. Noteworthy is that the only form of force or energy that the rig operator can see at any point in the rod make process is the hydraulic force as read from his panel gage.

Figure 11 is a graphic illustration of the effect of rod tong table speed on proper rod make up. A Norris 7/8" rod was brought to the ideal card using different pressures simply by applying different volumes of fluid that changed the speed of the table. The rod could be properly pre-stressed at 600 psi, or 850 psi, or 1,150 psi, depending on the speed.

TEST and RESULTS:

To prove the "two energy" theory, a set of modified-computerized BJ-Mark IV rod tongs were used to make up sucker rods. Using Norris 7/8" rods, connections were made varying the table speed and holding the pressure constant. The tongs were allowed to stall exactly as a rig would do in the field, and at the end of each stall, the circumferential displacement (CD) was measured with a micrometer. Newton was correct. As the table speed increased the need for pressure decreased to bring the rod to the ideal card of .4375 inches.

The first chart (Figure 12) is a plot of the CD verses tong speed in revolutions per second (RPS) with the applied hydraulic pressure being held constant at 500 psi. The target CD for this rod is ,4375 inches (highlighted as the ideal range). It can been seen that as the speed was increased, the CD increased and the ideal card was reached at 1.8 RPS.

Figure 13 is for the same rod and tongs but the pressure was held at 750 psi instead of 500. Again, after each stall the CD was measured and the points indicate a steeper slope. The ideal .4375 CD was reached at a much lower table speed of 1.1 RPS. On both charts, the test was repeated many times with the same results. The rod was changed out throughout the test to avoid wearing the box or threads out.

By analyzing each rod connection when the pressure and table speed are allowed to float or vary, a three-dimensional concept can be developed that illustrates the contributing factors that must be considered when making up a sucker rod. This 3-D chart is Figure 14 which clearly illustrated the complexity of the rod make process.

It is noteworthy that these tests only contain data with speeds up to 1.8 RPS: however, some service rig tongs have been clocked at speeds of 4 RPS. Current rig systems can only measure and control the hydraulic force component of the rod make process and the momentum component is being totally discounted. At the table speeds observed in the field, good maintenance of hydraulic pressure can be severely offset by poor control of hydraulic flow rates and subsequent variances in momentum.

OBSERVED FIELD PRACTICES:

The UniTrak file in Figure 15 illustrates a common methodology in setting the tong pressure. Time interval A – B represents a changeover from **¾"** to **7/8"** rods. At point B, the operator increased the pressure from 500 to 650 psi, via the hydraulic bypass, to attain the necessary pressure to run **7/8"** rods. Note that the tongs are engaged during the process, and the RPM at point B is 40% of maximum. From point B to C, the rod man compares the card. Only 45 seconds elapse from B to C, which is not enough time to back the rods out so the card check at point C is from a static condition. The pressure at C is 100 psi more than B, which is probably due to the increased RPM but it is not at the maximum available RPM. Starting at point D, the rest of the **7/8"** rods are run into the hole. For the remainder of the rod string, the RPM is at a maximum and the tongs are spinning the connections together at higher tong table speeds. All the rods made up past point D have momentum as a significant component of total available torque, whereas at points B and C, where the pressure was set and CD was measured, do not.

Figure 16 is another practice often seen from the UniTrak data. In this example of setting the tong pressure, the experienced operator "knows his rig." Past experienced has taught him that it takes **750** psi for a **7/8"** rod. He engages the tongs and brings them to a stall by inserting a wrench in the table path. He then adjusts the pressure to a known value and there is where it stays for the rest of the run. He is not accounting for any variance in tong characteristics or changes in the system for temperature effects or gage inaccuracies.

CHECKING THE BREAKS WHEN RUNNING BACK INTO THE HOLE:

The practice of checking for loose rods while running back into the hole should be addressed. Referring to Figures **4** & **5**, some rod strings demonstrate looseness in some **form** or another. Based on these observations, "checking the rods" is a practice that should be incorporated into any "best practice" methods of well service.

This practice **as** it is done now, however, has some problems. Examining the data derived from Figures 12-16, it is clearly demonstrated that a higher pressure is needed to properly tighten a rod from a stalled tong position. In short, **two** different pressures are needed while running the rods. When a connection is made from the derrick, it might take 600 psi because the tongs are operating from a dynamic or turning state utilizing momentum. On the other hand, when the two intermediate connections are checked, the required pressure might be **800** psi to effectively check the connection. This concept is quite an operational obstacle for conventional rod tongs and rig configurations.

INSTALLING NEW COUPLINGS AND NEW RODS:

The process of installing a new coupling offers another dimension and set of complex variables that must be dealt with. On the surface, one might assume that when a new coupling is being installed at the connection, that an equal circumferential displacement would result when uniform torque is applied to the connection. This is a perfectly logical assumption as both ends start loose and the energy being applied to the coupling rod interface is uniform for both rods.

Observations and electronic carding data suggest otherwise. When the rods are being run from the derrick, the crew will normally remove the damaged coupling and start the installation process by placing the new coupling on the rod hanging in the tubing. Their natural reaction is to hand tighten the coupling to the shoulder point. The next step is to engage the rod from the derrick and then apply torque with the tongs. Field observations and checking the CD on both ends of the couplings were made. The rod-coupling interface that had the running start was correct and the rod-coupling interface that was at the shoulder point to start with was under carded.

When new rods are being picked up from the ground, the crews generally remove the thread protectors on one end and install the new coupling hand tight in groups or layers. Then they are run with the same results as above with one half of the connection right and the other half being below recommended specifications.

Allowing both rods to have a running start (exposed threads) does not seem to solve the problem. One end reaches the shoulder point first, and that seems to be the end that ends up being undercarded.

Currently, the rig operator has only three tools available to him to monitor the rod make-up:

- The pressure gage which measures hydraulic force after the tongs are stalled
- The card supplied by the respective rod manufactures
- The visual observation of the tong stall

The practicality of the matter is, as limited as they are, the crew cannot use all three of these inputs on each rod connection. To do this, it would take far too long to run a string of rods back into the hole. What really happens, is that a good crew will set the tongs to stall based on the card and then run them into the hole based on the visual stall of the tongs. Any other process would be unsafe and economically impractical.

Changes in wind, engine RPM, tong table speed, hydraulic pressure, system temperature, and even the trigger finger consistency of the tong operator will affect the rotational characteristics of the tongs, and ultimately the circumferential displacement of the makeup.

RECOMENDATIONS:

This study is based on both on-site crew observations and the detailed study of electronic files of over twenty thousand-rod connections.

- The harsh fact is that API-11BR (Recommended Practice for Care and Handling of Sucker Rods) is not being followed consistently. Most crews try but are pressed for time by their clients. Some crews do not even try.

- The method of carding with a grease pencil is hopelessly inaccurate and this method of setting the tong pressure is severely flawed. It leads to over stressing rod pins or running loose assemblies in the hole.

- Knowing the rig and tongs and setting the pressure by memory is weak at best. If one rod is inexact, they all are. Gages are often wrong and vary in condition. Is the operator remembering pressure readings at the cool or hot temperature?

- API 11BR needs to be modified to account for tong momentum and the speed of the table.

- The hydraulic system on the rig must be modified or adapted to supply uniform energy to the rod tongs and the engine RPM must not be a factor in the makeup process.

- The installation of new couplings should not be done with power tongs making up both pins at the same time. It is suggested that one half of the connection be made up with a friction wrench and checked with a card.

- It would appear that there is some helpful information to the operator in studying rod break out energy. Coupling the dyno information with the breakout energy should assist the operator in the evaluation and re-design of sucker rod strings and sinker bars.

CONCLUSIONS:

It is difficult to speculate how many rod connections are made during any year. Based on the best well count available and an average failure rate, one could easily suggest that over the course of a year, fifty million rods are broken out, made up, or checked for tightness.

It is preposterous to expect any rig crew to make each and every rod connection to exact specifications. They simply do not have the training or the tools to do this and the problem is further compounded with the current labor market, low wages, and attrition. This, however, does not negate the economic importance of the process. The only solution to the problem of rod connectivity and information gathering is to automate the process.

Note: The UniTrak Technology and the Computerized Rod Tongs are patent pending. All Graphs and Charts are copyrighted.

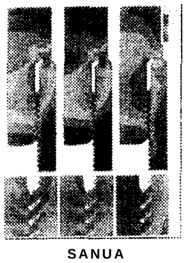

Figure 1

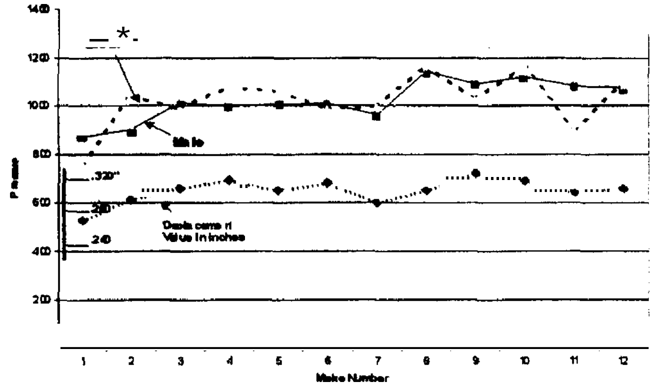

Figure 2 - Comparisons of Make and Break Pressure

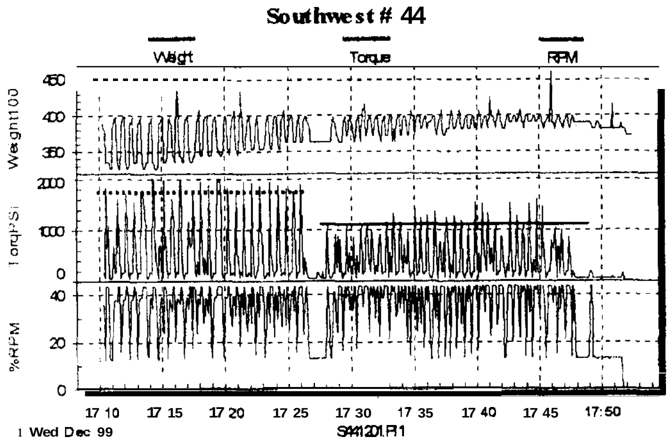

Figure 3

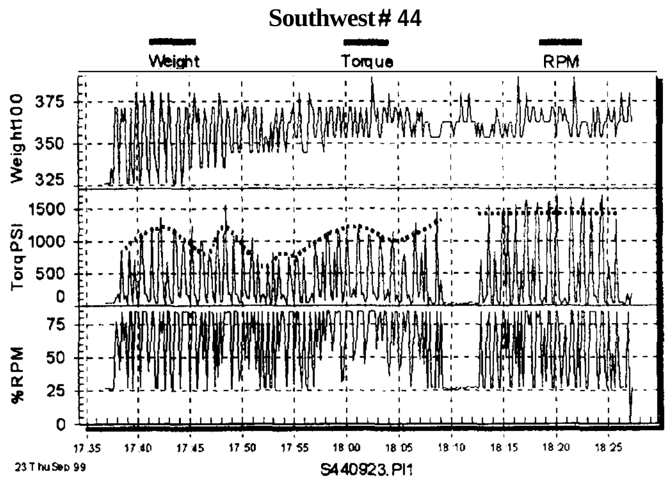

Figure 4

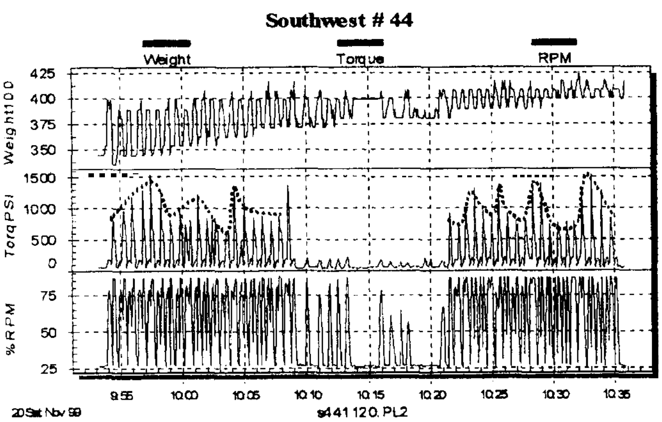

Figure 5

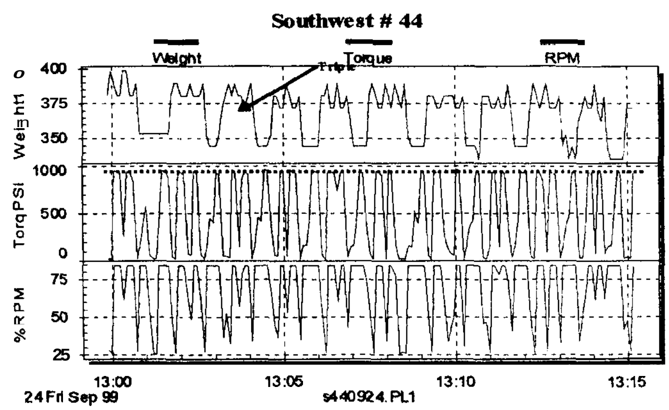

Figure 6

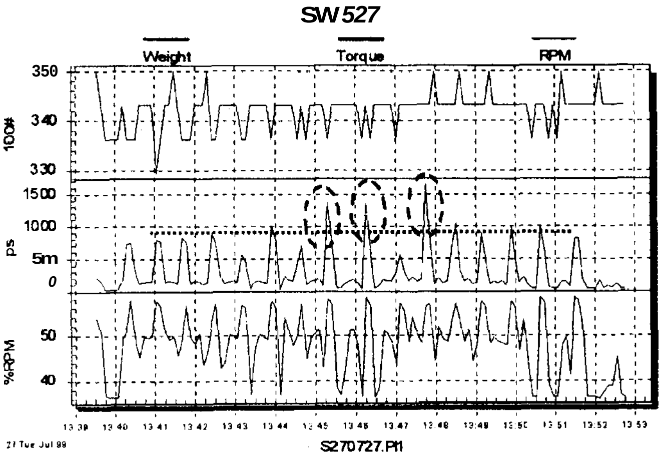

Figure 7

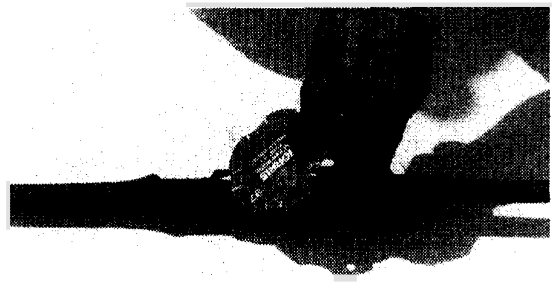

Figure 8

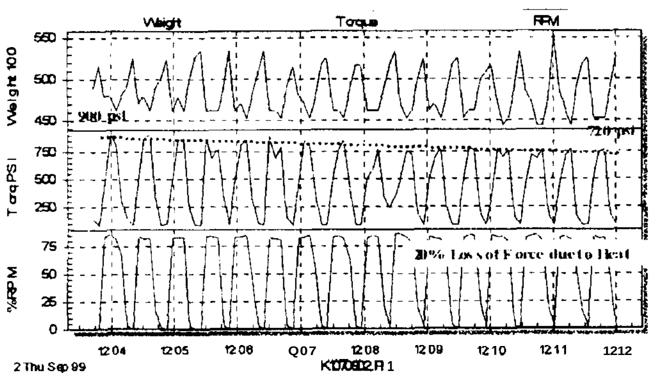

Figure 9 - Temperature Effect on Torque

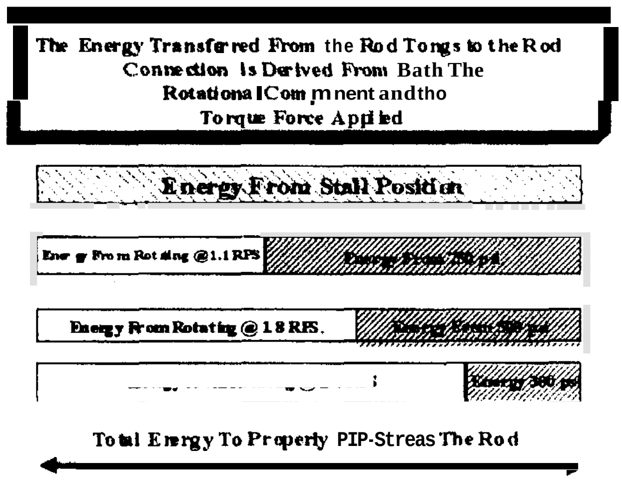

Figure 10

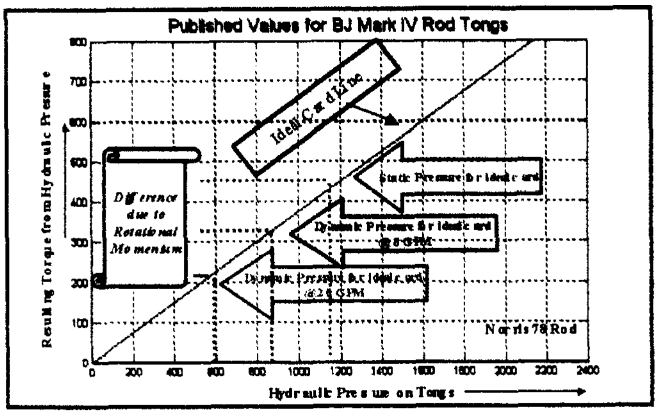

Figure 11 - Resolving Contributions of Tong Table Energy and Hydraulic Pressure on a Rod Make Up

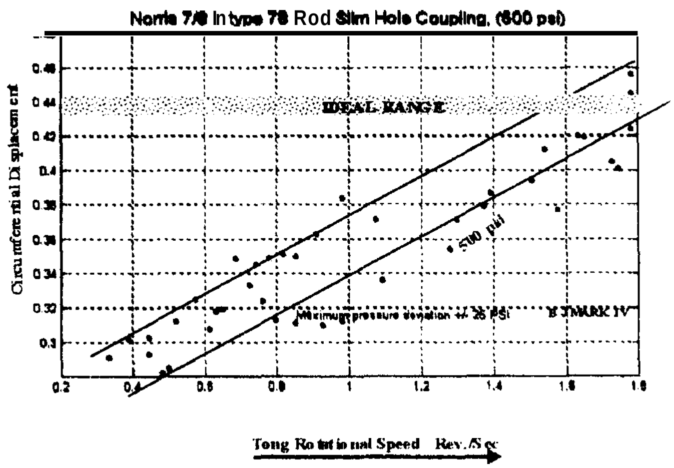

Figure 12 - Effect of Rotational Speed on Circumferential Displacement with Hydraulic Pressure Held Constant at 500 p.s.i.

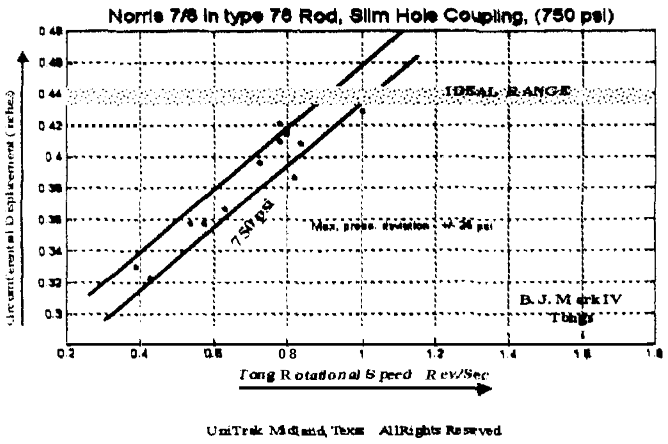

Figure 13 - Effect of Rotational Speed on Circumferential Displacement with Hydraulic Pressure Held Constant at 750 p.s.i.

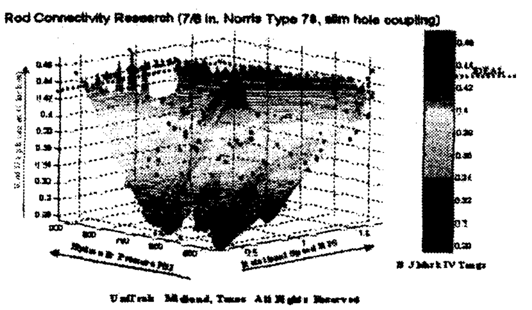

Figure 14 - Three Dimensional View of Rod Make-Up Process Effects of Speed and Pressure Circumferential Displacement

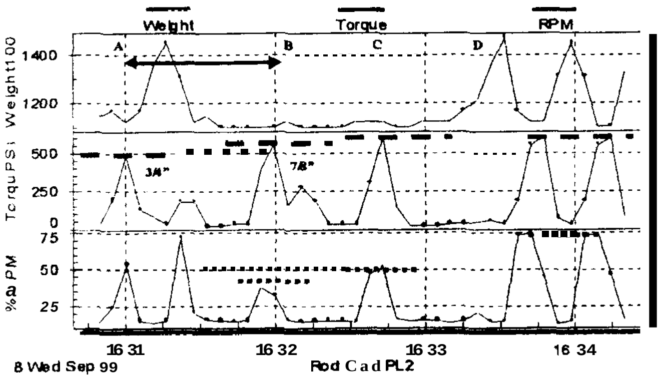

Figure 15 - Rod Card 96

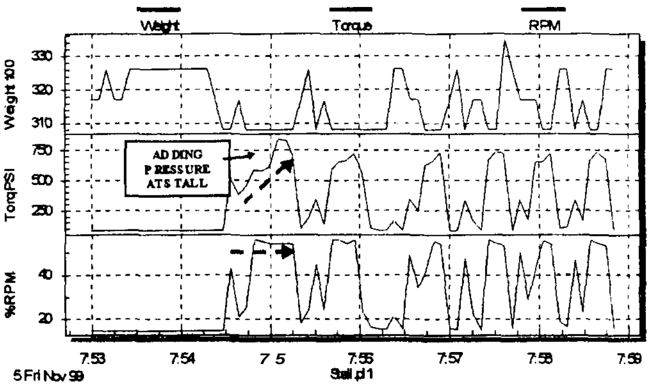

Figure 16 - Setting Card Example 1