DYNAPUMP PROJECT UPDATE

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ABSTRACT

The DynaPump is a means of artificial lift that has been gaining recognition in West Texas and Eastern New Mexico over the past two years. The DynaPump is a hydraulic, ultra long stroke pumping unit that has heavy lift capabilities. The use of solid-state electronics and computerization lower energy costs while giving new flexibility to the artificial lift process. The pumping cycle is optimized through consistent feedback of surface and down-hole conditions. The DynaPump's capability to independently adjust the speed of the up and down strokes and change stroke lengths during changing operating conditions result in well optimization while reducing surface and down hole maintenance. The DynaPump design and pumping concept results in an overall reduction in artificial lift costs.

INTRODUCTION

Over the past several decades the choice of artificial lift alternatives in the Permian Basin has been reduced to using a convention beam pump for production of less than 500-600 BBD and an ESP for those wells capable of producing more than 500-600 BBD. There are other alternatives available and some have been tried with limited success, but until recently the beam pump and the ESP were the primary choices based on economics. The decision on which type or brand of surface equipment to use for a particular well was then based primarily on the acquisition cost and the projected recurring maintenance cost with little consideration to other factors that new technology could bring to the table. The introduction of the DynaPump in the Permian Basin in 2001 has caused the OXY Wasson Clearfork Team to rethink its artificial lift acquisition criteria to include not only the cost of the surface and well equipment, but also to consider other cost and revenue factors over the projected three year life of a well in order to determine the most economical choice. This is because the DynaPump has been designed to increase the overall efficiency of a well and not just lower the cost of the pump or slightly increase the efficiency of the machine. By doing so it has created a number benefits which therefore must be measured in total to have a fair comparison to other alternatives. DynaPump has developed a calculator that can be used to evaluate artificial lift alternatives by comparing various cash flow factors for each alternative. The model will soon be available on their website, www.dynapumpinc.com. The Wasson Clearfork Team this year has focused on measuring the DynaPump energy saving and increased production benefits and will report on some examples in this paper.

THE DYNAPUMP – A BRIEF DESCRIPTION

The DynaPump is comprised of two basic components: the Pumping Unit and the Power Unit as shown in Figure 1. The Pumping Unit is a long stroke, hydraulically actuated pump that connects to the polished rod. The Power Unit is the control center that provides the ability to convert electrical energy to hydraulic power and to computer control pump stroke as needed to provide optimum pumping efficiency. The Pumping System incorporates an integrated real time pump off controller and has the capability for real time monitoring of well and/or pump performance and status. The Pumping Unit stands over the wellhead and attaches to the polished rod by means of a carrier bar. The Pumping unit comes in various sizes, depending on the maximum load likely to be encountered. The Model 11 Pumping Unit is designed for a maximum lifting load of 60,000 pounds. The Pumping Unit is comprised of a patented triple chamber hydraulic cylinder, a heavy duty structural base, two large cylinders containing nitrogen gas under pressure, and a pulley/cable lift mechanism which doubles sucker rod stroke relative to cylinder travel. The maximum polish rod stroke of the Model 11 is 336 inches.

Nitrogen gas is connected to one of the cylinder up chambers and serves as a counterbalance, basically to offset the rod weight and a portion of the fluid load. The counterbalance can be adjusted at the well simply by adjusting the pressure of the gas in the storage cylinders. The direction and speed of the pump is then controlled by sending hydraulic fluid under pressure to either the up or the down chambers of the cylinder. Since the pump is computer controlled, the speed and stroke limits can be independently established, thereby allowing for fast up strokes and slower down strokes. This feature greatly increases pumping efficiency for deep wells. The pump utilizes many feedback mechanisms to provide optimum stroke control and full monitoring of well and pump conditions. Feedback sensors on the pump include a position sensor to measure stroke position and a proximity switch to detect a possible cable break.

The Power Unit provides the driving force and control for the Pumping Unit. It is comprised of two major components: a Hydraulic Pump System, and a Control & Communications Center. The Hydraulic Pump System includes main hydraulic pumps and power drives which can be either electric motors or a natural gas engine. The system includes a sealed hydraulic reservoir and various valves and sensors that allow the patented triple chamber cylinder to function correctly. The Hydraulic Pump System is connected to the Pumping Unit by means of two primary high-pressure hoses and four secondary control/feedback hoses. The Control & Communications Center consists of solid-state electronics and motor controllers, which are designed for maintenance free operation. The electronics include computer controls that allow for the pump to be controlled by feedback for precise operation of stroke speed and position. The computer is also designed to communicate externally by means of a modem, a radio transmitter, or by using a direct telephone line. This allows the pump to be remotely monitored and controlled.

The DynaPump Pumping System has been designed to increase the overall efficiency of a well by incorporating several beneficial features:

- ***Long Stroke*** – Having a long stroke reduces rod stretch as a % of stroke length. For deep wells, the rod stretch can be a significant percentage of the overall stroke of a rod pump system, which thereby reduces the effective stroke of the down-hole pump. In general the longer the stroke of the down hole pump, the larger the fluid flow from the well. The benefits of a slower, longer stroke operation are generally known. For a given pump size and fluid production rate, the slower number of strokes per minute means fewer rod direction reversals which reduces the rate of fatigue in the rod string, thus increasing rod life. The DynaPump Model 13 has a maximum stroke length of 360 inches as compared to the longest beam stroke limit of 240 inches.

- ***High Polish Rod Load Capability*** - The well depth and down hole pump size determine the rod string design and ultimately the rod load. Larger down hole pumps increase the efficiency of a well by reducing the pressure drop of fluid as it enters the pump. This means that the differential driving pressure stays large and more fluid moves into the pump. For a given formation, the flow into the pump will be greater the larger the pump, and so will the rod load. The DynaPump, by having larger capacities and lower accelerations, can take advantage of this characteristic, thereby allowing the maximum flow to be achieved for a given well. The maximum lifting load of the DynaPump Model 13 is 80,000 pounds, which is well beyond the 47,000 pound maximum load of the largest beam pump.

- ***Variable Speed Up/Down*** – The DynaPump system allows variable speed control and allows independent up versus down speed control. Acceleration and deceleration transitions are also independently controlled during rod reversal, which significantly reduces rod stresses.

  Upstrokes move the oil from the pump to the surface. The shorter the amount of time spent on the upstroke, the less fluid leakage due to slippage past the traveling valve. For any given bottom-hole pump, a faster upstroke will therefore reduce leakage, which increases the amount of fluid pumped.

  A slower speed on the down stroke assures that the bottom-hole pump has adequate time to fill. This relates to more fluid in the pump barrel, which means more fluid pumped to the surface. A slower down stroke also reduces the compressive load on the rod which will lead to fewer rod and tubing failures.

  A system that has the capability of variable speed will then predictably have a higher volumetric efficiency if all other things are equal.

- ***Integrated Pump Off Control*** – Maximum formation flow is achieved when the fluid pumped from the casing is equal to the fluid coming into the casing from the reservoir. Ideally, the artificial lift system will vary its speed so that it continues to pump at the rate that fluid comes in from the reservoir. The DynaPump system is designed to do just that by measuring the "Up" load and slowing the down speed when a pump off condition is detected. This eliminates the inefficiencies and harmful effects of continuing to pump in a "pump off" condition. It also eliminates the need to shut the pump off which results in lost production and inefficiencies due to start up once the pump is turned back on.

- ***High Efficiency Electrical System Components*** – The factors noted above coupled with a counterweight design that incorporates virtually no inertia allow the DynaPump System to use significantly less installed horsepower drive units for the same or greater lifting load capability. The design is also based on a constant torque drive system, which results in a power factor close to one and makes the unit able to operate with smaller transformers and wiring. These factors may prove to be extremely important to operators since the DynaPump will consume less energy than other artificial lift alternatives and may eliminate the need for additional field electrical capacity when they are installed.

- ***Communication for Control and Feedback*** – The DynaPump has integrated communication and control capability due to its use of a PLC to control the pumping cycle. The PLC may be interfaced directly to a conventional or radio modem to allow remote control and monitoring capability and has been successfully integrated into CASE Services and XSPOC automation software. This feature eliminates the need to add a dedicated pump off controller for each pump that is added to a field when using automation software.

- ***Diagnostic Feedback*** – The DynaPump takes full advantage of available diagnostic feedback to provide a fully self monitored system, including detection of down-hole related problems such as stuck pumps and parted rods. The self monitoring provides warnings of impending failure conditions and also stops the pump prior to a catastrophic failure. Because of this, major expensive repairs and unscheduled down time can often be avoided.

- ***Significantly Lighter Weight than Alternatives*** – The DynaPump is significantly lighter in weight than artificial lift alternatives such as the beam pump or the Rotoflex pump. For example, an installed DynaPump Model 9 weighs 18000 pounds, including the Power Unit, while a less capable Lufkin 912 weighs 86,000 pounds installed. The lower weight translates to a number of DynaPump advantages:

  - Energy consumed to manufacture an industrial machine made primarily from steel is roughly proportional to the weight of the finished product. Thus the DynaPump is currently less expensive than comparable beam pumps and the gap is likely to widen as economies of scale come into play in the future.

  - Transportation costs are lower (from the manufacturing plant and/or from one site to another) because the unit can be transported on one flat bed truck.

  - Installation costs are lower because the DynaPump can be shipped to the wellhead fully assembled and placed into position using smaller lifting equipment. The DynaPump also requires much less massive and less costly foundations.

  - Preparation of the surface equipment for rig crew access does not require lifting equipment. The DynaPump is simply "pulled back" on its location for access to the well head.

OXY WASSON CLEARFORK TEAM EVALUATES THE DYNAPUMP

During the second half of 2001 the Wasson Clearfork Team studied the benefits of the DynaPump and discussed operating experiences with several operators using the DynaPump in California and in the Permian Basin. A trip was also made to DynaPump's manufacturing facility in Northridge, California to learn more about the system firsthand. Based on this brief investigation, the team concluded that the following DynaPump advantages should lead to cost savings for some applications:

- It can be easily adjusted to accommodate a wide range of production flows without the need to change down-hole or surface equipment. This will allow new or idle wells to be pumped off in a shorter period of time and then can be optimized to maintain pump off.

- The long, slow stroke should lead to fewer parted rods due to better control of rod stress and fewer rod reversals. The slow stroke is also expected to reduce tubing wear. These factors are expected to be particularly important for deviated wells.

- Energy consumption will be lower when compared to a beam pump or a submersible pump. This will result in lower electricity costs.

The team agreed to purchase two Model 9 DynaPumps in order to evaluate and measure the cost saving benefits. The two units were installed and began pumping operation in January 2002. The two pumps were successfully assimilated to the Case Services field automation software and were closely followed for the balance of the year. During the remainder of 2002 there were no parted rod or tubing failures on either of the two wells and the DynaPumps demonstrated their ability to control a wide range of flows, up to 900 BFPD. The two pumps also showed promising energy savings based on the power meter parameter in the DynaPump controller.

Like any new technology that is introduced, the DynaPump trial revealed a number of concerns that were quickly addressed and solved by the company: Auto startup in cold weather surfaced as a problem due to the fact that oil volume shrinks and viscosity increases for very cold oil temperatures like those encountered during a startup condition in near freezing outside air temperatures. This was solved by changing to multi-viscosity oil, adding a thermostat control, and revising the PLC logic to address the cold start condition. Another problem was related to nuisance shutdowns related to diagnostic monitoring. These issues were solved by optimizing the PLC adjustment settings and by improving the monitoring in a software upgrade. DynaPump also introduced a number of improvements for new production in 2002, including a “Super Controller” that allows speeds to be more precisely controlled under adverse operating conditions, cable guards that prevent the cables from coming off the pulleys (for a runaway or loss of load condition) and a redesigned Power Unit that significantly reduces operating noise.

Based on the favorable results experienced on the first two pumps in 2002 and the fact that DynaPump was committed to address and fix major concerns related to operating the pump in the Permian Basin, the Wasson Clearfork Team elected to expand the project in 2003. A total of 12 additional DynaPumps were added in 2003. Target opportunities for these units included a new drilling program in the NWCF field where initial production levels were projected to be 700 BFPD, replacement of overloaded beam pumps that were not able to be pumped off, and replacement of both beam and submersible pumps on severely deviated wells where well maintenance cost were very high. A program was initiated to measure the energy savings for comparable technologies in order to document the savings and to monitor other relevant cost factors, favorable or unfavorable, that could be attributed to the DynaPump. Collection of this data is on-going.

DYNAPUMP BENEFITS REVEALED

As a direct result of the evaluation project, the Wasson Clearfork Team was able to confirm DynaPump benefits in three areas: energy savings, increased production, and less down time and rig costs, particularly on deviated wells.

Energy Savings – In order to measure energy savings it was decided that the best approach would be to install a standard mechanical KWH revenue meter and measure the input power consumed over a 24 hour period. Wells were selected for each lift technology that were approximately the same depth and that were not being pumped off so that off time would not be a factor. Power was measured for four DynaPumps, six beam pumps, and six submersible pumps. Data points collected are shown in Figure 2. The power consumed in the 24 hour period is plotted versus total daily production. As expected, for a given technology it requires more power to lift more fluid. The data where normalized by computing the average KWH/Barrel flow. The calculation of this number is shown below:

Lift Technology	Average KWH/Barrel	Energy Cost to Produce 600 BFPD/Yr
DynaPump	0.70	$4,446
Beam Pump	1.36	$8,637
Submersible	4.15	$26,357

This table also shows the annual energy cost to pump 600 BFPD assuming that the cost of energy is $.029/KWH. This data is shown for comparison purposes only because in the case of the beam pumps currently in use they are unable to reach the 600 BFPD due to other limitations. This data shows that the DynaPump consumes approximately ½ the power of a beam pump and 1/6 the power of a submersible when pumping the same flow from the same depth.

Increased Production - If a particular well is not being pumped off, conversion to a DynaPump will likely increase production by allowing a larger BHP to be used without major changes to the rod string or tubing due to its heavy lifting ability, long stroke, and more precise control of the rod loads. In some cases production output may even increase if an ESP is replaced with a DynaPump due to the fact that it can fully pump off the well which in turn may favorably change the water cut ratio. Even for a well that is pumped off with a beam pump, the output will be higher for a DynaPump because the fluid level over the pump is automatically maintained without the need to start and stop the pump.

In once case, a Lufkin 912 pumping at 7.9 SPM with a 2.25” BHP producing 420 BFPD was changed to DynaPump Model 9 pumping at 4.3 SPM with a 2.25” BHP and ending up producing 505 BFPD. This was a 20% increase without changing the size of the BHP. In most cases, the BHP was increased to the next larger API pump size and production increased at least proportionally, although in a few cases the well was subsequently pumped off with the larger pump. In at least one case, the change to the DynaPump resulted in an increase in the production of oil by 25 BPD. This equates to incremental annual revenue of nearly $250,000 at today’s oil prices.

Less Down Time and Rig Cost – Certain wells have relatively high well maintenance cost related to rod parts, tubing wear out, and BHP failures. Oxy has even experienced some wells using submersible pumps that have a high rate of replacement. Of course any time a well must be pulled to complete repairs there are two negative operating factors that come into play: one is the cost of the rig crew plus the cost of the replacement parts, and the other factor is the lost production revenue while the pump is out of service. One common characteristic of the wells that have very high well maintenance costs is that they have a severe deviation profile. In these cases, beam pumps running very fast experience a high rate of parted rods even when steps are taken to use rod guides in the deviated section(s). Submersible pumps sometimes experience electrical harness damage when being inserted on deviated wells which then leads to premature pump failure. Use of a DynaPump on such wells allows production to be maintained, or in most cases increased as noted above, but with the pump stroking at approximately ½ the speed of a normal beam pump.

Figure 3 shows an example of severe well deviation on SWCU 8545. This well was reactivated in April of 2001 and was pumping 420 BFPD using a Lufkin 912 pumping at 7.9 SPM with a 2.25" BHP. However, this well experienced six (6) rod parts during its first 14 months of operation. This equated to thirty two (32) days of lost production. The beam pump was replaced with a Model 9 DynaPump as shown in Figure 4. The DynaPump is pumping at 4.3 SPM with a 2.25" BHP and producing 505 BFPD and there have been no rod parts for the 12 months that it has been operating on this well.

Another example of savings in this area is on another well with severe deviation. On this well (8538-S) a submersible capable of producing 700 BFPD was installed in February of 2003. During the past 10 months the submersible has failed three times, requiring that the unit be pulled and the cable repaired each time. A total of 30 days of lost production are attributed to this repair work. The submersible was replaced with a Model 11 DynaPump with a 2.75" BHP targeted to produce 700 BFPD. This unit has been running for the past month without a failure and is expected to now have a "normal" history of well maintenance from this point forward.

DYNAPUMP 2003 RESULTS

At the end of 2003 OXY Permian will have a total of 14 DynaPumps in operation with the first two operating for nearly two years. Results of the DynaPump trial are summarized s follows:

- There have been no rod parts attributed to the DynaPump.
- There have been no tubing failures on DynaPump wells.
- Runtimes are averaging 98.5% and are comparable to or better than beam pumps when down time related to induced down-hole failures is taken into account.
- Operation in cold weather has been addressed by pump upgrades.
- A new Power Unit Design has been introduced to address the noise issue. One of the new units is currently operating within 250 feet of a residence.
- DynaPump upgraded all of its pumps to incorporate a cable guard mechanism. This feature will provide increased safety during certain failure conditions.
- Power Units delivered after July 2002 incorporate an advanced braking system ("Super Controller") that provides more precise control of pump position and acceleration and should lead to further improvement in rod life.
- Test data shows that energy consumption is significantly lower than a beam pump or submersible when pumping the same equivalent flow from the same depth.
- DynaPump's heavy lifting capability often leads to increased production when replacing conventional equipment on wells that are not pumped off.
- DynaPump is working to improve cylinder and wire rope life. These are the two biggest concerns relative to long term maintenance costs and longevity of the units.

CONCLUSION

Measurements have demonstrated that DynaPump units operate with lower energy costs versus either a conventional beam pump or a submersible pump when pumping the same equivalent flow from the same depth. Energy consumed is approximately ½ when compared to a beam pump and 1/6 when compared to a submersible pump. The DynaPumps, operating at much slower speeds because of its long stroke, have resulted in no rod parts and no tubing failures. The uptime and total production generally exceeds a conventional pumping unit due to the fact that the DynaPump can lift heavier loads and there is less downtime related to repairing down-hole failures. Based on these results and the fact that DynaPump thus far has been committed to supporting the pump and making improvements to address operational concerns, the Wasson Clearfork Team will continue the project in 2004. DynaPump is expected to be the lift choice for applications in the production range of 500 to 1000 BFPD and may also replace selected conventional and submersible pumps on wells experiencing above average well maintenance and downtime such as those on deviated wells.

DynaPump has developed a calculator that can be used to evaluate artificial lift alternatives by comparing various cash flow factors for each alternative. The model will soon be available on their website, www.dynapumpinc.com. The Wasson Clearfork Team may collect additional data during 2004 and investigate the merits of using this model in the future.

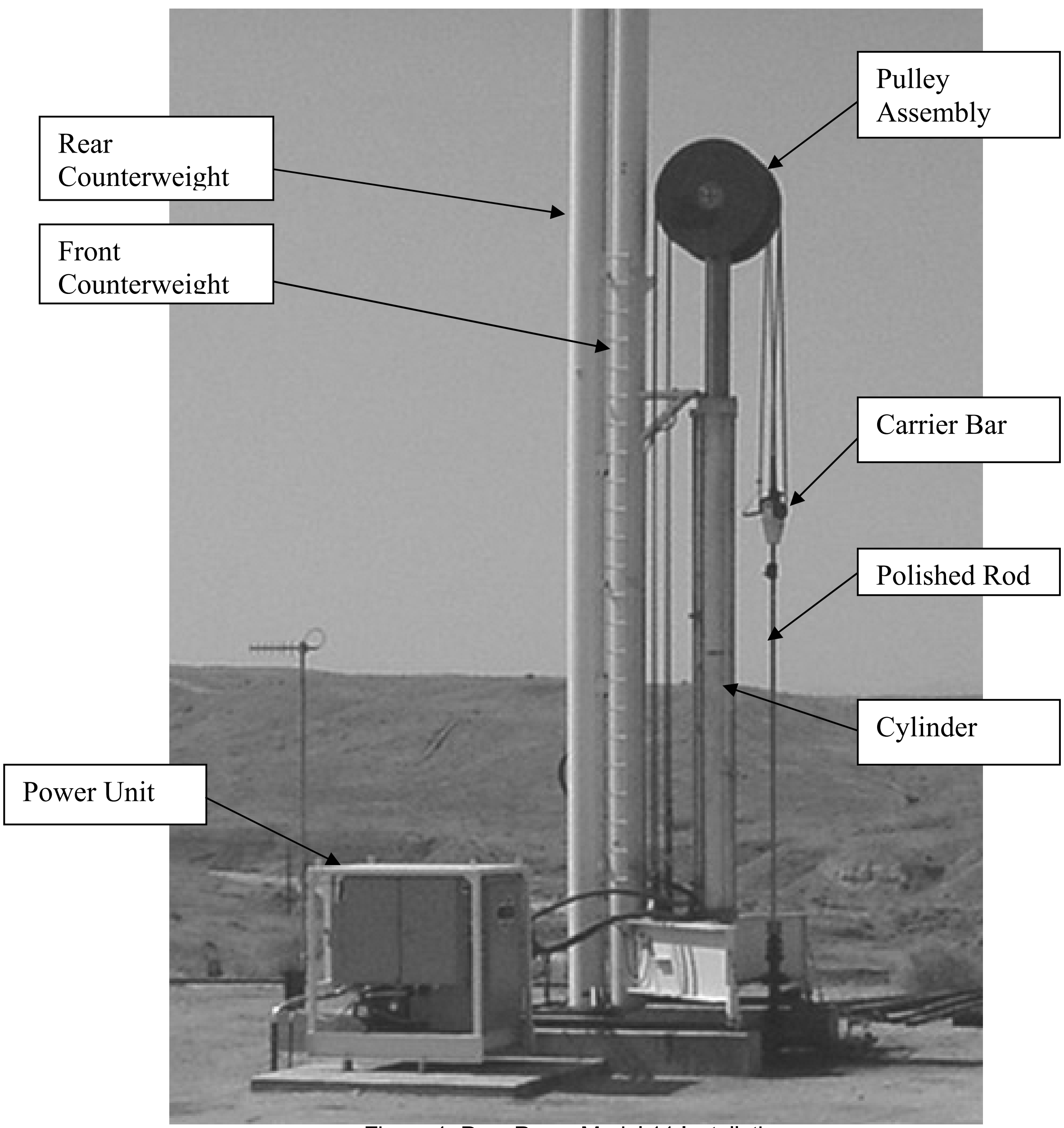

Figure 1- DynaPump Model 11 Installation

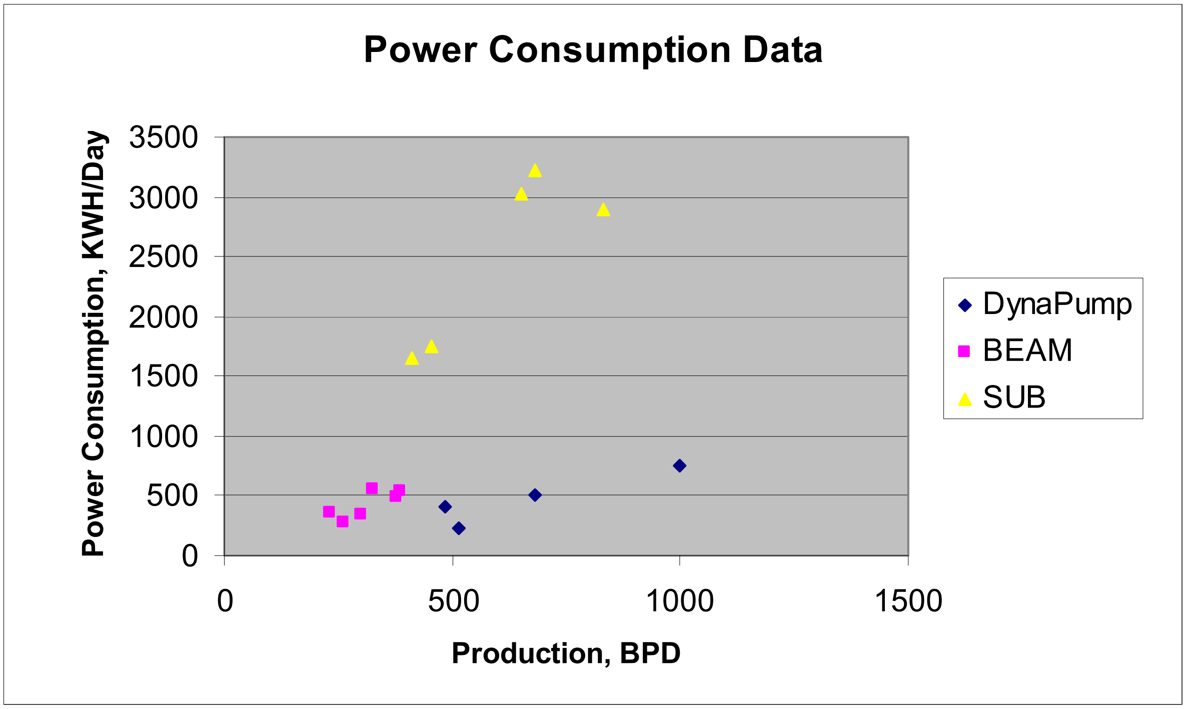

Figure 2 - Power Consumption versus Total Production

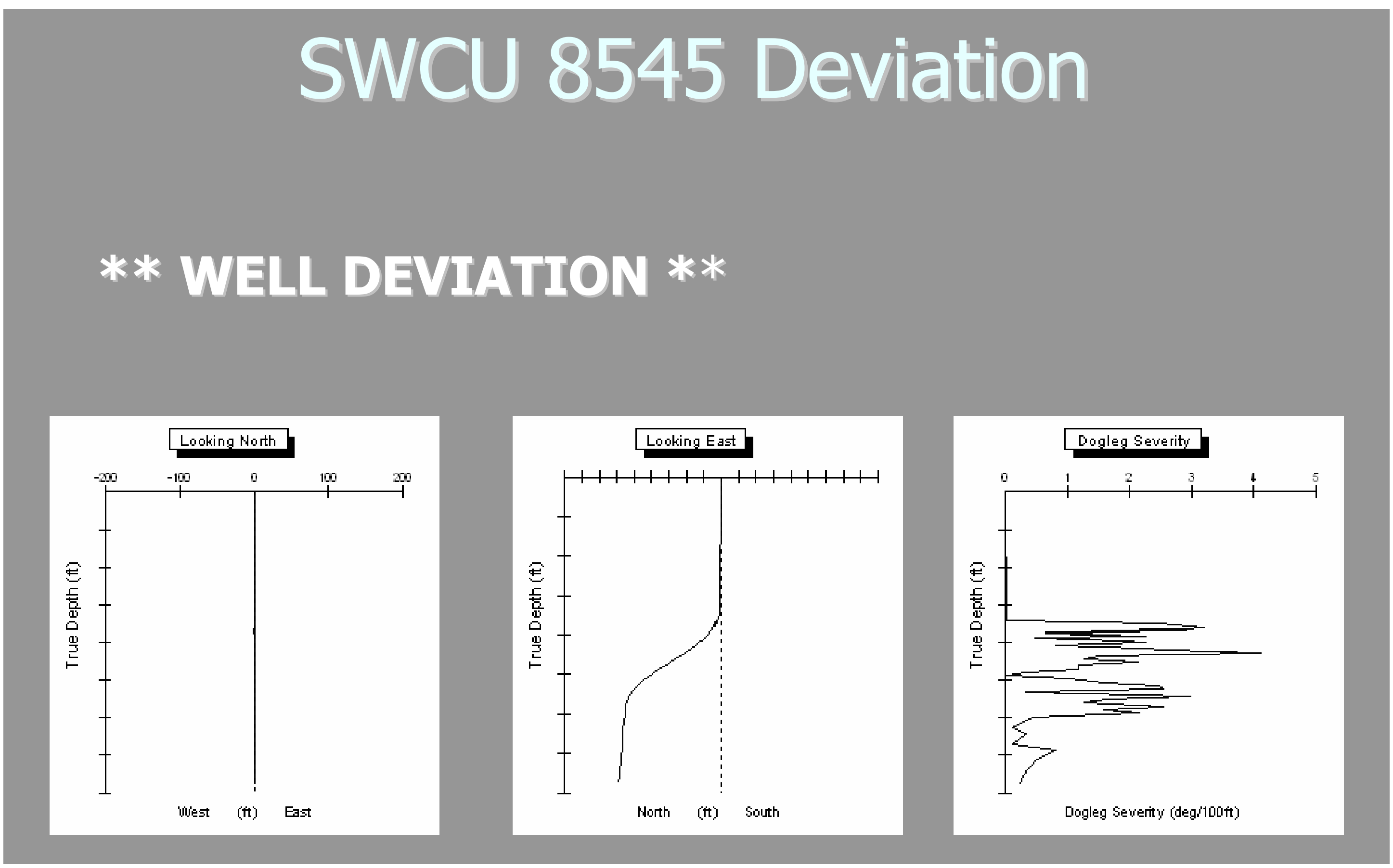

Figure 3 - Well Deviation Profile for South Wasson Well # SWCU 8545

Figure 4 - A Model 9 DynaPump Replaces a Lufkin 912 on Well # SWCU 8545