# DynaPump Field Evaluation

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## ABSTRACT
The DynaPump is a unique rod pumping system that is composed of the pumping unit and the power unit. While similar to a Rotaflex pumping unit, the long stroke feature, it uses hydraulics as the lifting mechanism. The DynaPump offers several benefits such as the use of more efficient motors, smoother rod reversals, internal pump-off controller (better reservoir inflow control), etc. The field performance of a DynaPump system was evaluated on a recent well installation.

## INTRODUCTION
Sucker rod pumping systems were introduced in the 1800s and utilized the beam section of the Cable-Tool drilling rig. These pumping systems were used until the 1920s when the "Horse-Head" pumping systems were developed. Through the years the need to produce wells at increased depths have resulted in construction of massively sized pumping units having long beams, large gearboxes, and powerful motors. The need to produce more fluid has led to increased stroke length provided by increases to both the height and the length of the beam. A drawback for the beam type of pumping unit is the limited surface stroke length. The Long-Stroke pumping units were built to lift more fluid and bridge the gap between electrical submersible pumps (esps). Although smaller capacity esps have been built, but the efficiency of an esp is less when compared to an optimum sized Long-Stroke pumping.

In the 1980s, DynaPump introduced their version of the Long-Stroke pumping units that offered long stroke capabilities, high lift loads, and variable speed control. Their design philosophy is to maximize production from a well and/or reduce power consumption.

## DYNAPUMP PUMPING SYSTEM
The DynaPump System[1] is a computer controlled sucker rod hydraulic lift pumping system. The system has two main components the Pumping Unit and the Power Unit, **Fig. 1**. The Pumping Unit uses closed loop hydraulics to move a three-chamber cylinder up or down. The polish rod is connected to the hydraulic cylinder by a 2:1 cable and pulley system using high strength nylon pulleys and steel bearings to carry the load. A nitrogen counterbalance system helps support the weight of the rods in fluid, plus a portion of the fluid load. The pressure in the two nitrogen cylinders establishes the counterbalance load and it is connected to the load only during the normal operating conditions. Injecting or bleeding off nitrogen gas pressure stored in the two back cylinders is done to balance loading on the Pumping Unit on the up and down stroke.

The Power Unit is the control center of the system. Sending hydraulic fluid to either the up or the down chamber controls the direction of the cylinder and controls the flow rate of the fluid into the chamber to determine the vertical speed. As flow is directed into one chamber, the same volume of liquid is removed from the other cylinder to keep the system in balance. As work is done heat could build-up in the hydraulic fluid, but the temperature is regulated by means of a heat exchanger. The Power Unit has the hydraulic pumps that drive the pumping unit and are powered by two efficient NEMA B motors. The Power Unit also houses the computer that controls and monitors the performance of the system. The control system continually monitors the performance of the system and reacts to changing loads and flow rates.

The DynaPump allows variable speed control and allows independent up versus down vertical speed control. The pump cycle consist of two directions with 4 accelerations and decelerations. The accelerations can be independently controlled, which can reduce rod stresses. **Fig. 2** displays the acquired polished rod position and the control of the vertical polished rod velocity during one stroke. The average constant up velocity during the up stroke is approximate 60 inches per second, with a maximum velocity of 67.3 inches per second. The average constant down velocity during the down stroke is approximately 52 inches per second, with a maximum downward velocity of 58.9 inches per second. The faster up velocity results in less fluid slippage through the pump clearances, while the slower downward velocity will result in less friction and less rod buckling on the down stroke.

## DYNAPUMP MODELS

DynaPump manufactures several models of Pumping Units and matching Power Units to cover a wide range of fluid volumes and depths, see Table 1. The Type of the pumping unit is based on the diameter of the lifting piston, where a Type 9 would have a 9 in diameter piston. The power units used to drive the pumping unit range in size from 3 horsepower to 200 horsepower. The maximum stroke length of a Type 2 is 72 inches, with a Type 13 having a maximum stroke length of 360 inches. The lifting capacity of the Type 13 unit goes up to a maximum rating 80,000 pounds. Beam pumping units and RotaFlex pumping units are compared to DynaPump units Table 2. Yates Petroleum Corporation purchased the Type 9 pumping unit because it could handle most of the production ranges in the Dagger Draw Field.

## WELL DATA SUMMARY

The DynaPump equipped well analyzed is the Warren ANW #4 well, located in the Dagger Draw Field, and operated by Yates Petroleum Corporation. The DynaPump unit is a Type 9 with a maximum of 288-inch stroke. Two high-efficiency 50 horsepower Baldor motors, a high strength rod string, and a long stroke pump are utilized. The 2 inch pump is set 123 feet below the bottom of the casing perforations, and the 1300 BPD gas/liquid separation capacity of the 2-7/8” tubing on the inside of 7” casing exceeds the pump capacity of this high volume pump, so that gas interference in the pump should not be a problem.

The Warren #4 was chosen for the installation of the DynaPump to eliminate equipment over-load and to increase oil production. The gearbox on the conventional pumping unit (C-640-365-168) on the well was over-loaded to 144% of its rating. Due to the overload on the surface equipment the well was not produced at its maximum potential and a high, FAP, fluid level above the pump intake was maintained, which resulted in lower oil production from the well.

A summary of Warren #4 well data is listed in the following table. The Type 9 DynaPump was installed on 4/16/02 and results from this long stroke unit showed an improvement in the performance of the well. Production rates were increased by 130 BFPD over the conventional pumping unit. The well is being produced closer to the maximum potential of the well by lowering the FAP by 250 feet, which resulted in an 8-barrel oil per day production increase.

**Table 3 – Summary of Warren #4 Data**

| Date | Pump Unit Type | Pump Unit Mod | Prod BFPD | % WTR | MCF /DAY | SL Surf. | SL DH | SPM | Pump Size | Calc. Prod BFPD | Pump Vol. Eff. % | FAP | Pump Depth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/7 | CONV | 640 | 298 | 98 | 49 | 168 | 163 | 7.6 | 1.5 | 325 | 92 | 505' | 7933' |
| 5/24 | DYNA | 9 | 343 | 96 | 60 | 284 | 260 | 3.5 | 2 | 424 | 81 | 254' | 7933' |
| 6/10 | DYNA | 9 | 207 | 99 | 36 | 286 | 260 | 3.5 | 2 | 424 | 49 | 419' | 7933' |
| 8/21 | DYNA | 9 | 313 | 99 | 32 | 246 | 213 | 3.8 | 2 | 377 | 83 | 665' | 7933' |
| 9/10 | DYNA | 9 | 318 | 99 | 30 | 248 | 213 | 3.8 | 2 | 377 | 84 | 613' | 7933' |
| 9/23 | DYNA | 9 | 375 | 96 | 32 | 287 | 267 | 3.9 | 2 | 485 | 77 | 434' | 7933' |
| 10/7 | DYNA | 9 | 436 | 97 | 45 | 288 | 268 | 4.2 | 2 | 525 | 83 | 194' | 7933' |
| 10/11 | DYNA | 9 | 427 | 96 | 55 | 289 | 268 | 4.2 | 2 | 525 | 81 | 147' | 7933' |

On 6/5/02, the 2” pump plunger was found to be sticking at the top of the stroke. Surfactant treatments to wash possible debris in the pump barrel were unsuccessful. The feature of an infinitely selectable stroke length of the DynaPump system was utilized to reduce the surface stroke length from 286 inches down to 246 inches. The pump plunger stroke was thereby adjusted to stroke only in the good portion of the pump barrel and the well was pumped with a shorten stroke until the pump was replaced on 9/16/02. An inspection of the 2” sucker rod pump showed heavy to severe wear on top of the plunger and light wear inside the pump barrel.

## WELL ANALYSES

Three complete well analyses were performed to fully evaluate the well’s performance and total system efficiency (09/10/02, 09/23/02, and 10/11/02). These analyses were performed on the well with the worn pump, with the new pump, and with the new pump at faster strokes per minute, SPM. The complete well analyses consisted of an acoustic fluid level survey, a dynamometer survey, valve check load test, and acquisition of motor input power at the same time the dynamometer data was acquired. The purpose of the three surveys was to monitor the change in the system efficiency and to evaluate the performance of the equipment, as the producing rate of the well was increased toward the maximum potential of the well.

**09/10/02 – Fig. 3**, **Fig. 4**, and **Fig. 5** are the display of the data acquired with the leaky pump and with the polished rod stroke shortened from 288 to 246 inches. The acoustic liquid level tests showed the highest fluid level above the pump, along with a corresponding slight increase in the production rate over 03/07/02 time period when the well was conventionally pumped. The casing annulus gas flow rate is approximately 22 MCF per day.

The dynamometer surface cards and pump card are shown in **Fig. 3**, the SPM is 3.96 and polished rod horsepower is 24.6. The pump card shows that the pump is being filled with liquid and no gas interference is present. The calculated pump displacement is 375 BPD compared to the 318 BPD tested production rate. The valve check load test in **Fig. 4** indicates that the pump leakage past traveling valve appears to be approximately 67 BPD. The standing valve did not leak and held a constant load during the test. The downhole pump should be replaced, because the leakage rate is significant and is affecting the performance of the equipment.

The power measurements shown in **Fig. 5** were obtained at the same time the dynamometer data was acquired. The overall system efficiency is 42.6%. That is, the amount of power required to raise the liquid produced by the well from the net liquid level depth is 42.6% of the power supplied to the motor. The electrical cost to produce the 4 BOPD is $9.41 per barrel of oil, based on the electric rate paid for power.

**09/26/02 – Fig. 6**, **Fig. 7**, and **Fig. 8** are the display of the data acquired with the new pump and with a polished rod stroke of 288 inches. The acoustic liquid level tests showed a decrease in the fluid level above the pump, along with a 105 BPD corresponding increase in the production rate. The casing annulus gas flow rate is approximately 33 MCF per day.

The dynamometer surface cards and pump card are shown in **Fig. 6**, the SPM is 3.91 and polished rod horsepower is 30.2. The pump card shows that the pump is being filled with liquid and no gas interference is present. The calculated pump displacement is 441 BPD compared to the 405 BPD tested production rate. The valve check load test in **Fig. 7** indicates that the pump leakage between the plunger and barrel's 0.006 inch clearance appears to be approximately 22 BPD. The standing valve did not leak and held a constant load during the test. The down hole pump is operating as expected, but additional production from the well is possible if the production rate can be increased.

The power measurements shown in **Fig. 8** were obtained at the same time the dynamometer data was acquired. The overall system efficiency is 46.3%. The electrical cost to produce the 13 BOPD is $4.20 per barrel of oil, based on the electric rate paid for power. Replacing the pump and increasing the stroke length resulted in an increase in the system efficiency, plus the increase in the oil production rate resulted in a greater than 50% drop in the electric cost to produce a barrel of oil.

**10/22/02 – Fig. 9**, **Fig. 10**, and **Fig. 11** are the display of the data acquired after the SPM was increased from 3.91 to 4.26 with the new pump and the polished rod stroke of 288 inches. The acoustic liquid level tests showed a 311 foot decrease in the fluid level above the pump, along with a 138 BPD corresponding increase in the production rate, from when the well was conventionally pumped. The casing annulus gas flow rate is approximately 36 MCF per day.

The dynamometer surface cards and pump card are shown in **Fig. 9**, the SPM is 4.26 and polished rod horsepower is 32.6. The pump card shows that the pump is being filled with liquid and no gas interference is present. The calculated pump displacement is 476 BPD compared to the 465 BPD tested production rate. The valve check load test in **Fig. 10** indicates that the pump leakage between the plunger and barrel's 0.006 inch clearance appears to be approximately 22 BPD. The standing valve did not leak and held a constant load during the test.

The power measurements shown in **Fig. 11** were obtained at the same time the dynamometer data was acquired. The overall system efficiency is 49.4%. The electrical cost to produce the 15 BOPD is $3.90 per barrel of oil, based on the electric rate paid for power. Replacing the pump, increasing the stroke length, plus increasing the speed to 4.26 SPM resulted in the highest efficiency with the lowest electric cost to produce a barrel of oil.

## EFFICIENCY COMPARISON

A good basis for comparing different types of pumping units doing work is to measure how efficiently the power is used to lift the liquids to the surface. The efficiency of the overall pumping system can be analyzed by measuring the power utilized in relation to the volume of fluid produced, such as kW-hour/Bbl. The power used per unit of volume pumped can be determined and can be used as a measure of efficiency when comparing similar operating conditions (different type pumping units operating on three different wells in Dagger Draw Field). The objective of acquiring power data is to determine the efficiency with which the pumping unit is being operated from the standpoints of energy utilization. Inefficient energy use is one of the most common operational problems experienced by sucker rod lifted wells.

The kW-hour electrical consumption of power for three wells located in the Dagger Draw Field was recorded using standard electric meters installed at each individual well site. In addition to measuring power use with a meter, five complete well analyses were performed to fully evaluate the well's performance and total system efficiency. Determining the system efficiency requires the measurement of input power to the prime mover, determination of the producing bottom hole pressure (PBHP) and accurate production test data. The total system efficiency is defined as the amount of theoretical work required to lift the liquid to the surface from the net liquid level depth divided by the amount of power supplied to the motor. The efficiency comparison between the DynaPump, an 1100 RotaFlex, and a Conventional 640 pumping unit is shown in following table:

**Table 4 – Efficiency Comparison**

| WELL NAME | # | Date | Pump Unit Type | Mod | FAP | Motor HP | Monthly Electrical Consump KWH | KWH /DAY | Sys Eff % | KWH /BBL | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Warren ANW | 4 | 3/7 | CONV | 640 | 505' | 100 | 25,020 | 634 | | 2.13 | |
| | 4 | 5/24 | DYNA | 9 | 254' | 50/50 | 29,520 | 784 | | 2.29 | |
| | 4 | 6/10 | DYNA | 9 | 419' | 50/50 | 31,320 | 844 | | 4.08 | Bad Pump, Plunger sticking at top stroke |
| | 4 | 8/21 | DYNA | 9 | 665' | 50/50 | 31,140 | 838 | | 2.68 | Bad Pump, Adjusted barrel stroke area |
| | 4 | 9/10 | DYNA | 9 | 613' | 50/50 | 28,980 | 766 | 43 | 2.41 | Bad Pump, Adjusted barrel stroke area |
| | 4 | 9/23 | DYNA | 9 | 434' | 50/50 | 28,980 | 766 | 46 | 2.04 | New Pump |
| | 4 | 10/7 | DYNA | 9 | 194' | 50/50 | | | | | New Pump |
| | 4 | 10/11 | DYNA | 9 | 147' | 50/50 | *6891 | 765 | 49 | 1.79 | *9 days metered, Down due to motor phase inversion |
| Apollo APU | 3 | 10/7 | ROTA | 1100 | 522' | 75 | *2980 | 745 | 39 | 1.77 | *4 days metered, Emergency brake did not engage |
| Aparejo APA | 5 | 10/7 | CONV | 640 | 195' | 100 | *8206 | 586 | 56 | 2.18 | *14 days metered |

On system efficiency, the Conventional 640 showed better efficiency (56%) than the RotaFlex (39%) and DynaPump (49%). However, the conventional unit had a much higher KWH/BBL (2.18) than the other two units (1.77 and 1.79 respectively). Note, the sucker rod pump in the well with the RotaFlex had a low pump efficiency of 66% and the pump was subsequently replaced. The comparison of the DynaPump to the Rotaflex shows similar system efficiencies when both of the units had worn pumps.

The overall system efficiency of a sucker rod lift system in good operating condition should be approximately 50%. Initially on the date 9/10/02 the worn and leaky condition of the down-hole pump, resulted in measurement of an unexpectedly low system efficiency of the DynaPump of 42%. Since there was an equipment problem the well was a good candidate to improve its performance and the worn sucker rod pump was replaced with new. After the well conditions had stabilized, on the date on 09/23/02 the system efficiency was determined to be 46%. The production rate was increased due to speeding up the DynaPump from 3.9 SPM to 4.2 SPM and on 10/11/02 the system efficiency was determined to be 49%. The system efficiency of the DynaPump system is comparable to sucker rod lift system in good operating condition.

## OBSERVATIONS

On a KWH/BBL basis the DynaPump performed about the same as the RotaFlex pumping unit. The pump sticking at the top of the stroke, plus fluid slipping past the worn plunger and barrel caused the DynaPump to have the lowest system efficiency and highest KWH/BBL power use. When the leaky pump was replaced with new, then the performance of the DynaPump improved. The DynaPump operated with the best system efficiency and lowest KWH/BBL power use at its maximum SPM.

## ADVANTAGES

The ease and simple control of the 1) Stroke Rate, 2) Stroke Length, and 3) Stroke Position is an advantage that the DynaPump has over beam type pumping units and RotaFlex pumping units. When the pump began to stick in the top of the pump barrel, the ability to only stroke in the portion of the pump barrel that was not damaged, increased the flexibility of the DynaPump. The ability to control the polished rod velocity throughout the stroke should result in longer rod life due to less friction on the down stroke and a lesser possibility of buckling of the rods. The ability to change to pressure in the counterbalance cylinders by injecting or bleeding of nitrogen gas makes setting the optimum counter balance very simple. A crew with a winch truck is normally required to re-position the counter weights to balance the gearbox loading, but with the DunaPump all that is required is a bottle of high pressure nitrogen gas.

## DISADVANTAGES

A loud low frequency noise produced during each stroke is one of the more noticeable features of the DynaPump. This loud noise will probably limit the use of the DynaPump to rural areas away from people, who would be offended by the loud operating noise. When performing the standing valve check load test the DynaPump would not instantly stop motion when disengaged by the operator, but would move upward a small amount causing fluid load to be applied to the rod string. This problem was caused by hydraulic pressure continuing to lift the hydraulic piston after the DynaPump was stopped. In order to properly perform the stand valve load test a second person is required to manually close a valve to stop the flow of hydraulic fluid at the same instant the unit is stopped. Any time new equipment is introduced to the oil field not being familiar with the operation of the equipment can be a problem, in this case additional training is required on how to adjust the pumping speeds and monitor the operation of the DynaPump through an external display.

**ACKNOWLEDGEMENTS**
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**REFERENCES**

1. Rosman, A., DynaPump Inc., "Computer Controlled Long Stroke Pump System", PCOS Paper #3, 4/21/2001
2. Donnelly, R.W., Introduction to Artificial Lift, PETEX, 1985

**Table 1 - Different DynaPump Models**

| Pumping Unit Type | Cylinder Size (Inches) | Maximum Stroke Length (inches) | Structure Rating (Lbs) |
|---|---|---|---|
| 2 | 2.5 | 72 | 4000 |
| 3 | 3.5 | 120 | 7000 |
| 5 | 5.0 | 168 | 15000 |
| 7 | 7.0 | 240 | 25000 |
| 9 | 9.0 | 288 | 40000 |
| 11 | 11.0 | 336 | 60000 |
| 13 | 13.0 | 360 | 80000 |

**Table 2 – Comparison of Beam and RotaFlex Pumping Units to DynaPump**

| Dyna Pump | Typical Sizes for Beam Pump Units | | | RotaFlex Long Stroke Units | | |
|---|---|---|---|---|---|---|
| Unit Size | Pump Unit Size | Rod Load (lbs) | Stroke Length (inches) | Pump Unit Size | Rod Load (lbs) | Stroke Length (inches) |
| 2 | 25 | 5,300 | 20 | | | |
| 3 | 40 | 8,900 | 36 | | | |
| | 57 | 10,900 | 54 | | | |
| | 80 | 11,900 | 64 | | | |
| 5 | 114 | 14,300 | 74 | | | |
| | 16 | 17,300 | 86 | | | |
| | 228 | 21,300 | 100 | | | |
| 7 | 320 | 25,600 | 120 | | | |
| | 456 | 30,500 | 144 | | | |
| | 640 | 36,500 | 168 | | | |
| 9 | 912 | 36,500 | 192 | 700 | 18,000 | 288 |
| | 1280 | 42,700 | 192 | 800 | 30,000 | 288 |
| | 1824 | 47,000 | 240 | 900 | 36,000 | 288 |
| 11 | 2560 | 47,000 | 240 | 1100 | 50,000 | 306 |
| 13 | | | | | | |

**Fig. 1 - DynaPump System**

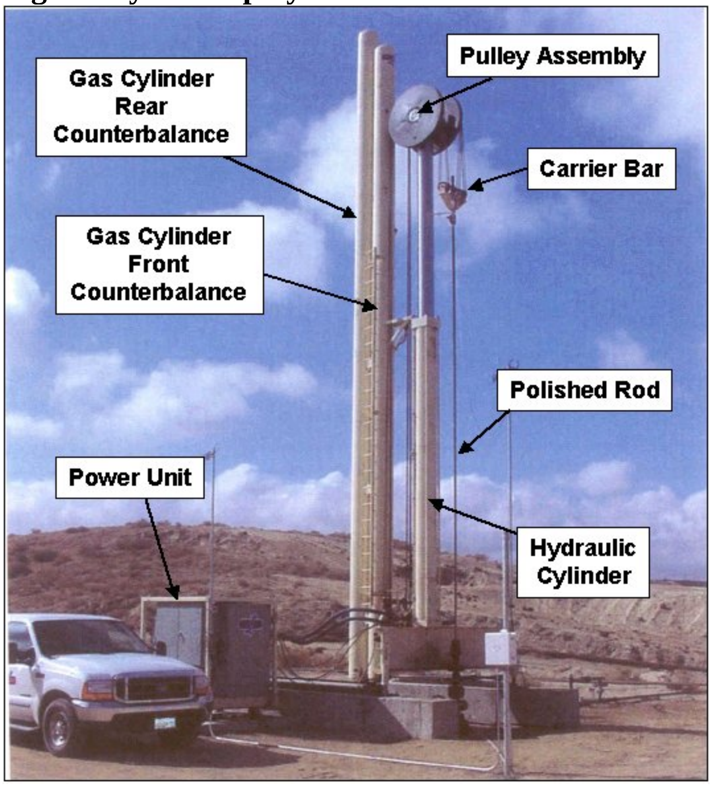


**Fig. 2 – DynaPump Control of Speed During One Stroke**

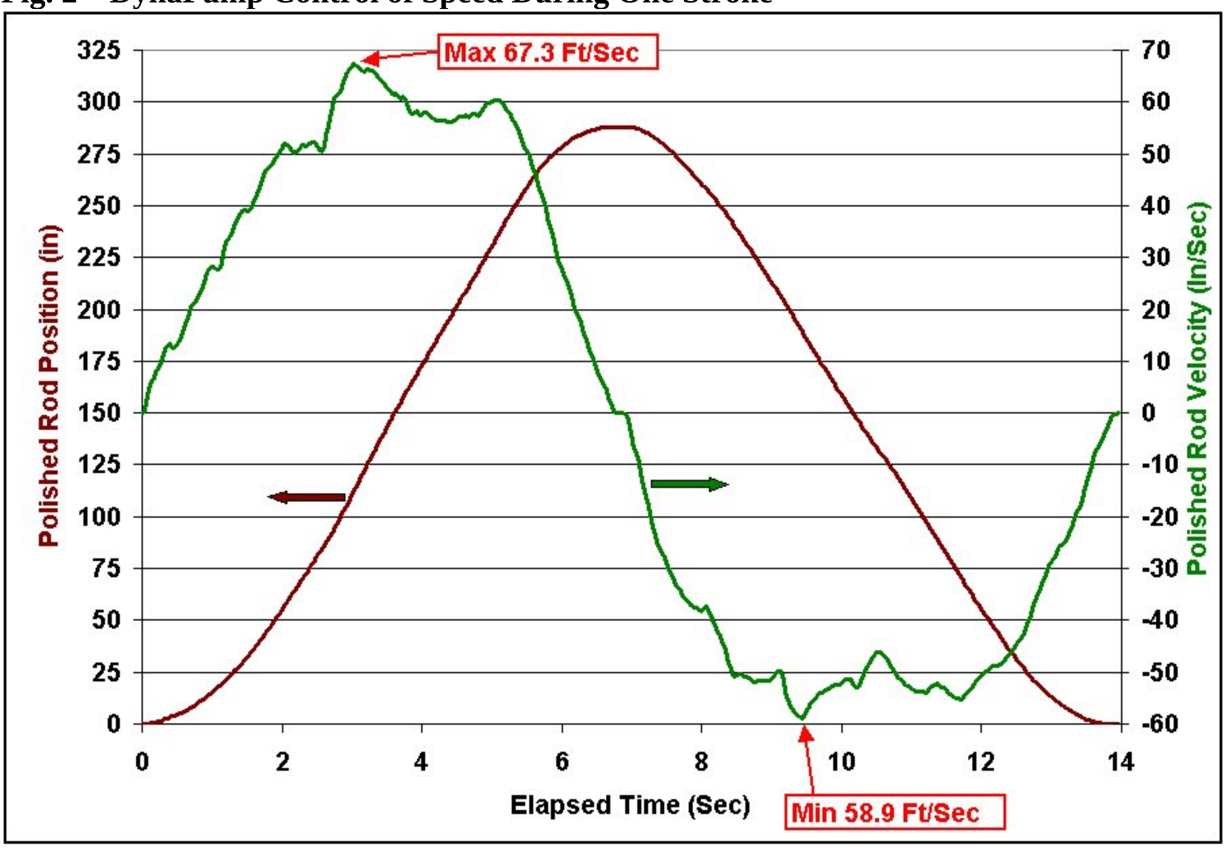

**Fig. 3 - Down-Hole Analysis, Leaky Pump with Shortened Stroke, Date 09/12/2002**

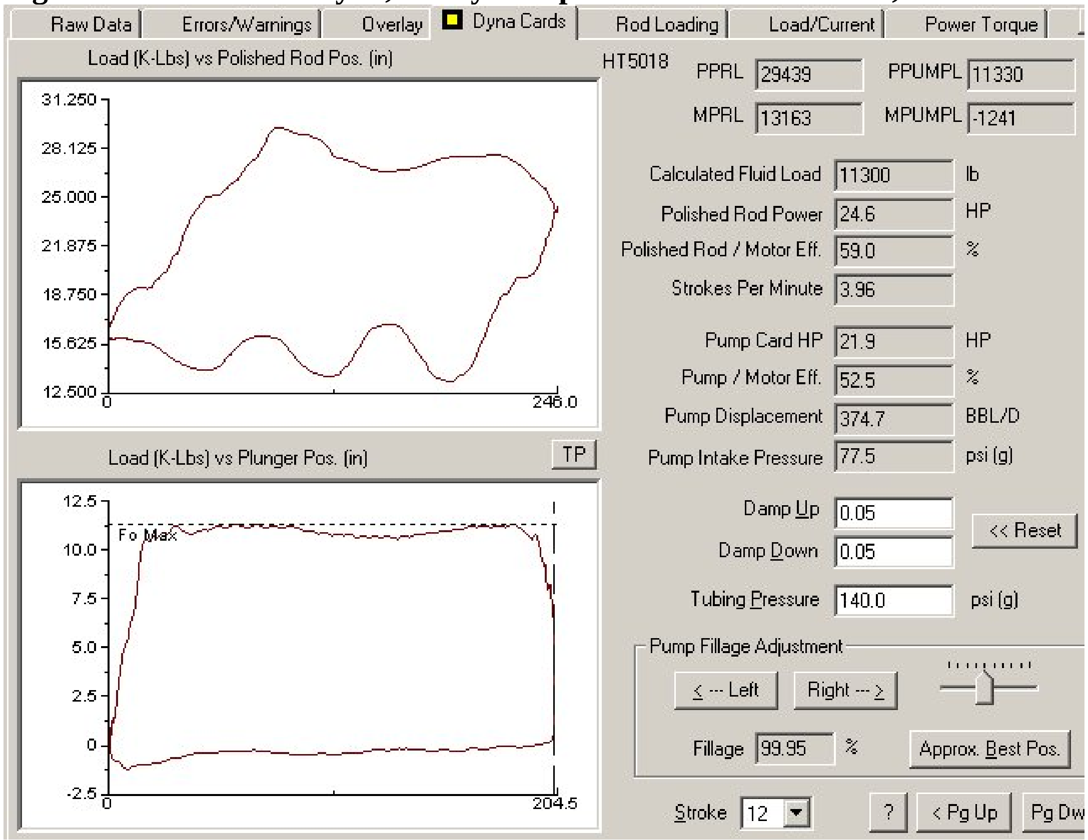


**Fig. 4 – Dynamometer Analysis, Valve Checks, Date 09/12/2002**

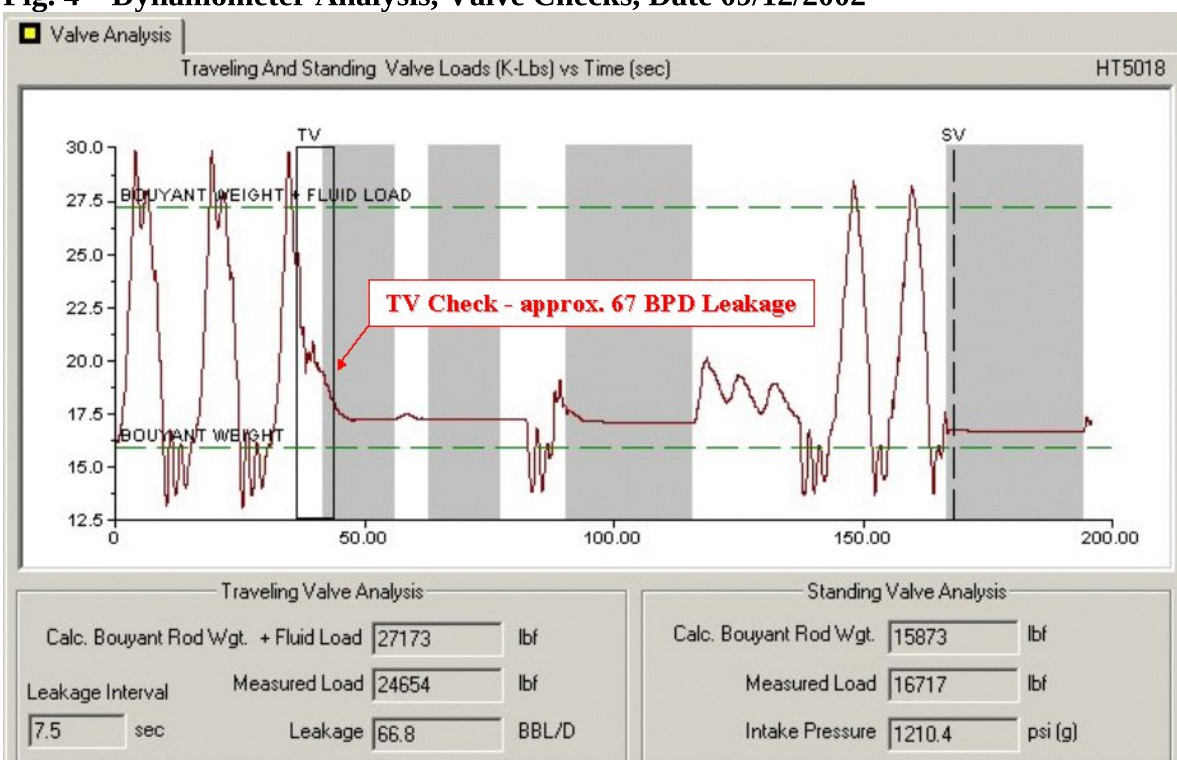

**Fig. 5 - System Efficiency Analysis, 43% System Efficiency w/ 67 BPD Leakage, 09/12/2002**

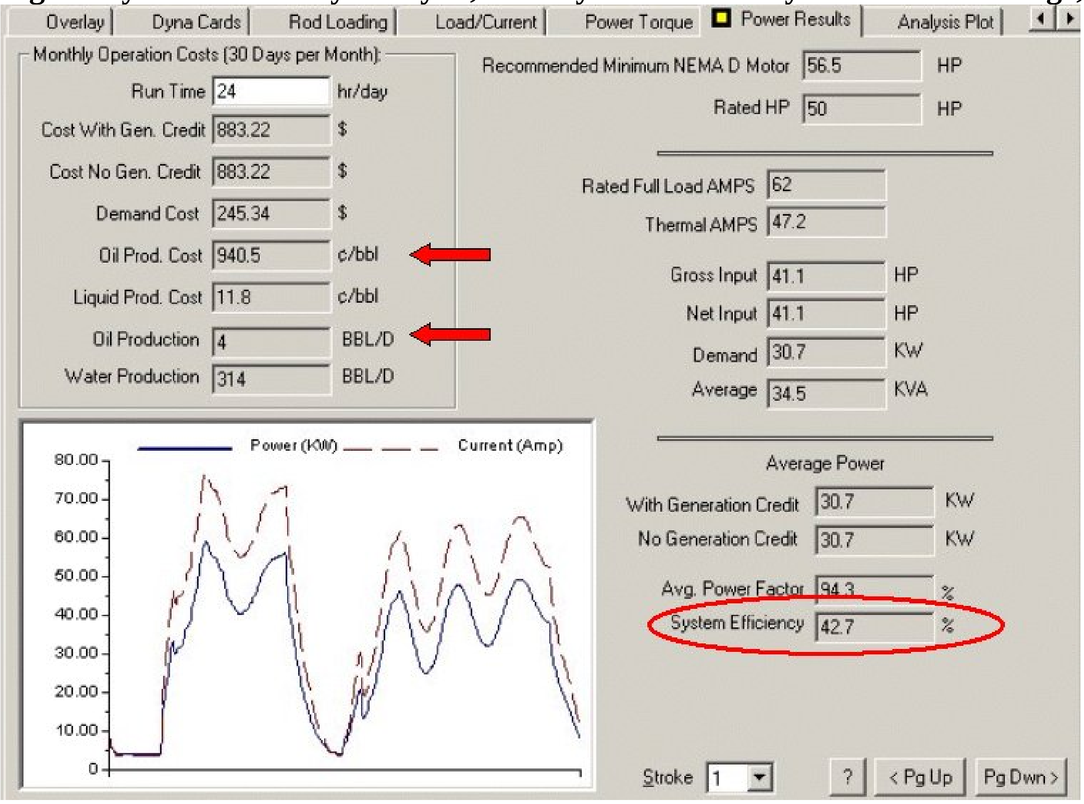


**Fig. 6 - Down-Hole Analysis, New Pump with 288" Stroke, Date 09/26/2002**

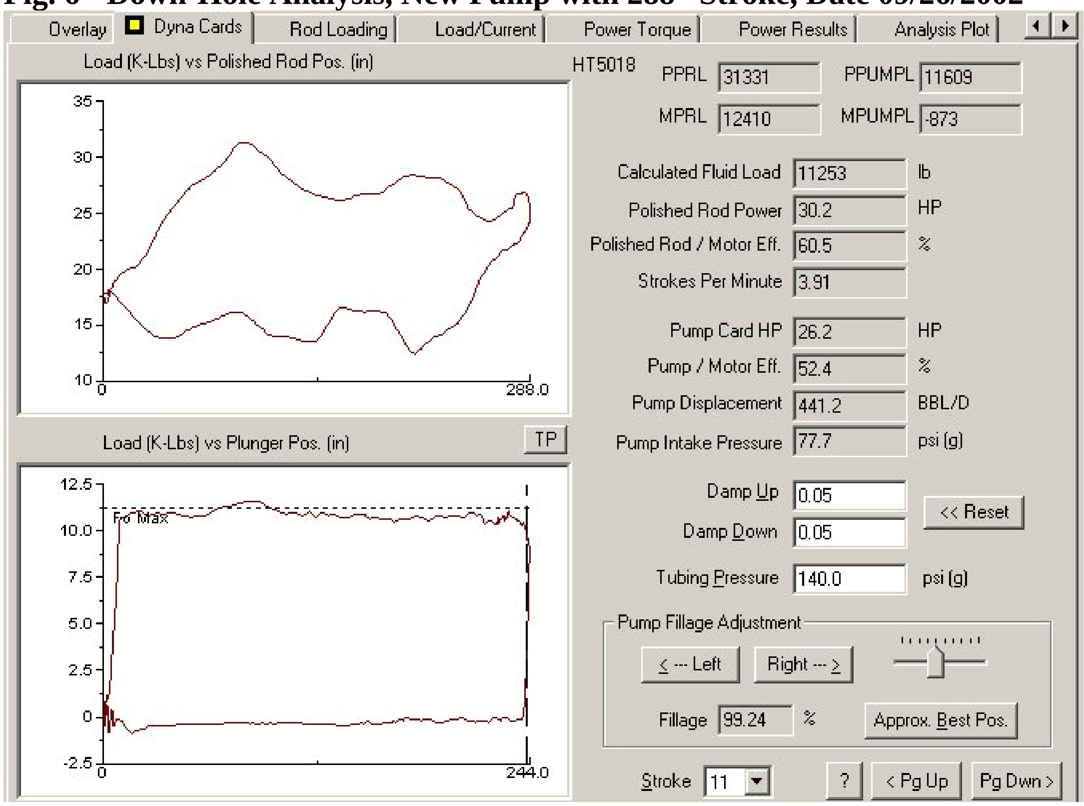

**Fig. 7 - Dynamometer Analysis, Valve Checks with New Pump, Date 09/26/2002**

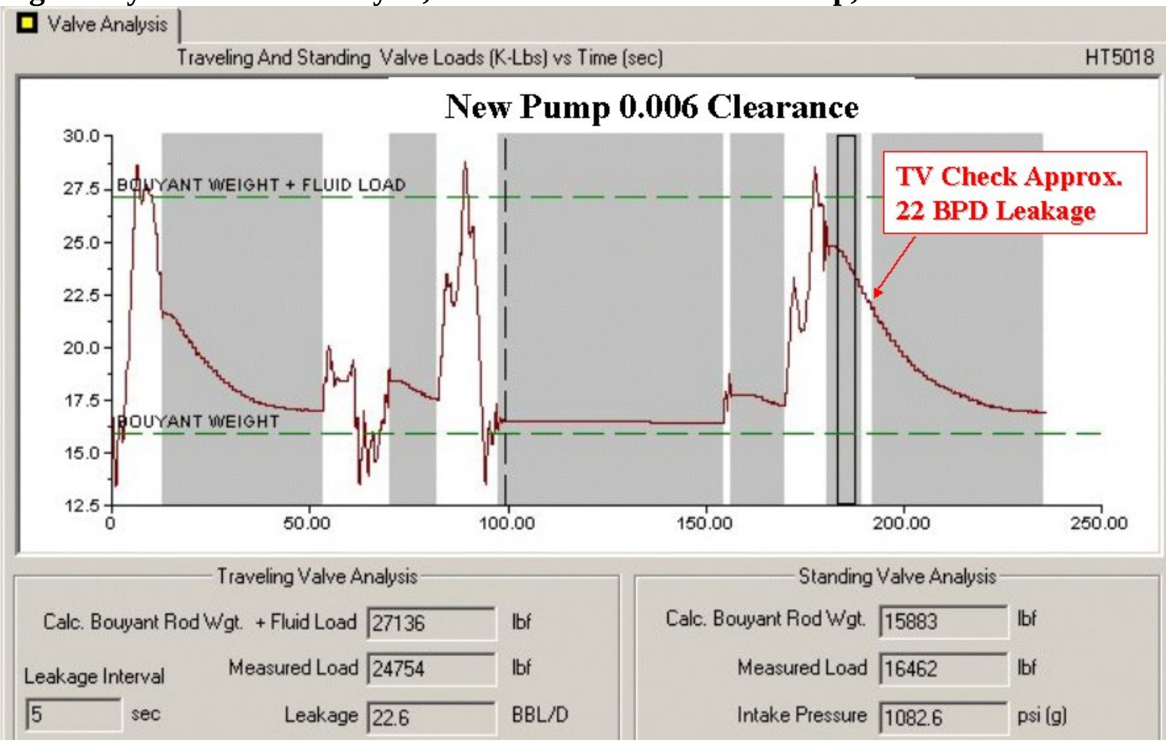


**Fig. 8 - System Efficiency Analysis, 46% System Efficiency with New Pump, 09/26/2002**

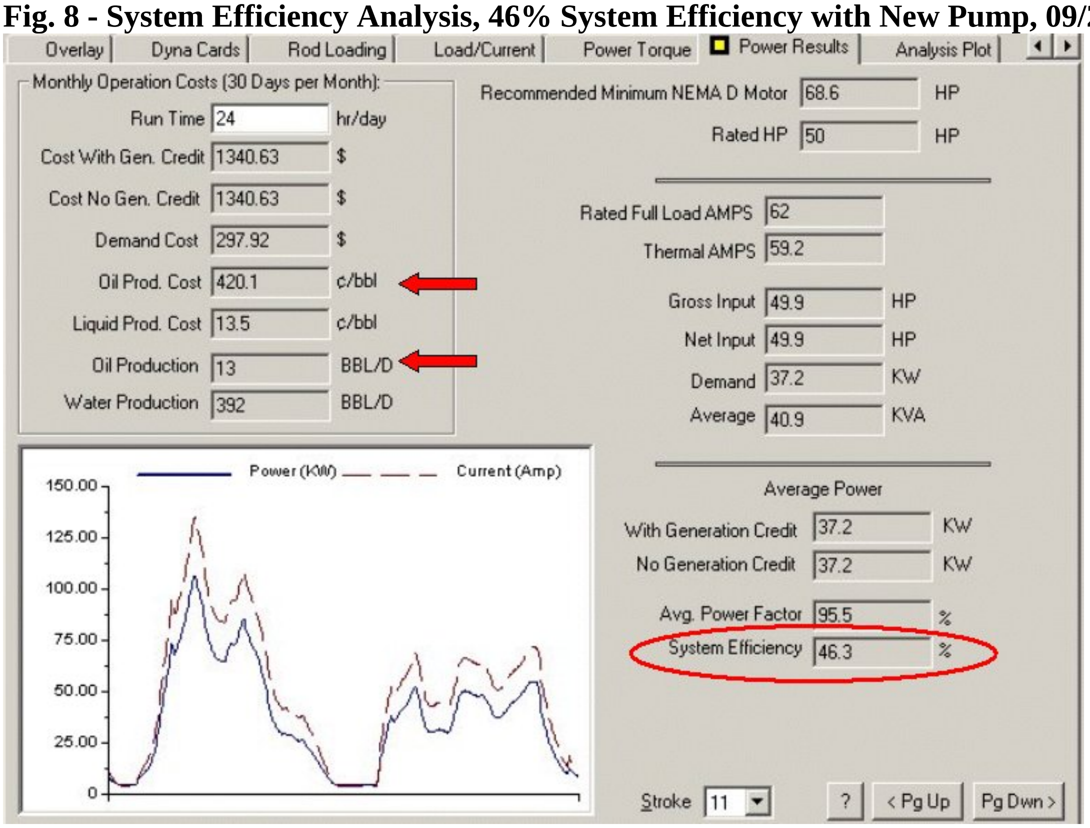

**Fig. 9 - Down-Hole Analysis, New Pump at Faster Strokes/Min, 10/22/2002**

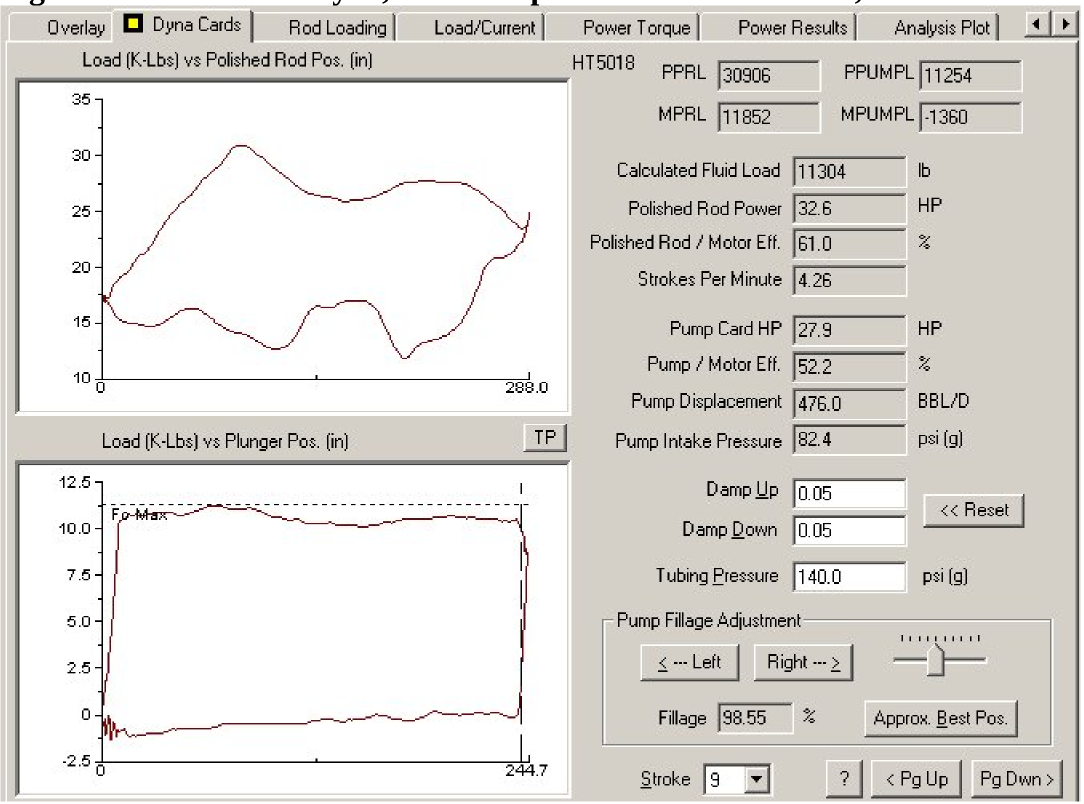


**Fig. 10 - Dynamometer Analysis, Valve Checks Fastest Strokes/Min, 10/22/2002**

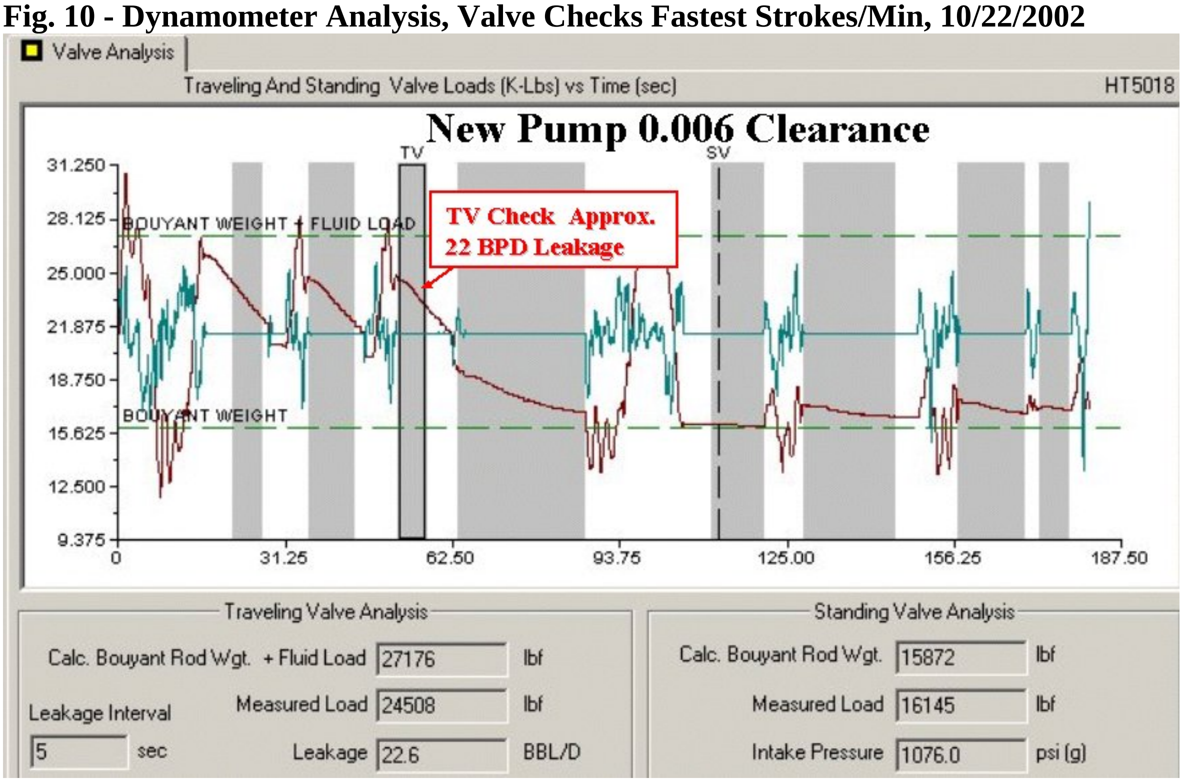

**Fig. 11 - Highest System Efficiency Analysis, Fastest Rate, 10/22/2002**