POWER CONSUMPTION TEST GLASS VS STEEL

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RED RAIDER # 1

The Red Raider # 1 is located on the East side of Lubbock, Texas, about 10 minutes from Texas Tech University. The well is 4006 ft deep with 9 5/8 in casing and a Cameron dual completion tree. The well is equipped with a Lufkin C456D-305-144 pumping unit and an ABB variable speed drive. A detailed completion diagram as completed during this test is shown at the end of the paper as Figure 1. Figure 2 is a photo of the Red Raider # 1 pumping unit.

BASIC EXPERIMENTAL SETUP

The basic experimental setup is shown in Figure 3. This basic setup was the same for all tests. The fluid used in the test was fresh water with a few parts per million of corrosion inhibitor. The rod pump pumped fluid through the system. The fluid flow was measured by a mass flow meter. Before the fluid entered the mass flow meter, it passed through a filter to remove any particles that may have interfered with the mass flow meter. Mass flow meters will only accurately measure a single fluid, in our case water. To increase the accuracy of the flow meter, a serge tank was used. To keep gas out of the system, a back pressure valve was down stream from the mass flow meter. A back pressure of 12 to 15 psi was kept on the flow line to insure the line was full of water. As long as gas was not pumped through the plunger pump, no gas could enter the mass flow meter. After the water flowed through the back pressure valve, it entered the wellhead and fell down the casing annulus back to the bottom of the well completing the loop. The inlet pressure of the pump was due to the hydrostatic column of water in the casing annulus. When the pumping unit was shut down, the water collected in the casing. When the unit was started, the fluid level in the casing had to come to a steady state so that the inlet pressure of the pump was constant throughout a test; this typically took about 25 minutes. This inlet pressure could be adjusted if necessary by opening the valve to the reserve tank and either pumping water to the reserve tank to lower the level, or increasing the level by turning the pumping unit off, lowering the casing pressure to zero and letting fluid flow out of the reserve tank and into the well bore using gravity.

The pump inlet pressure, pump outlet pressure and pump inlet temperature are measured with a Wood Group down hole instrument package. Tubing pressure and casing pressure were measured using various transducers. There were three different ports to screw in pressure transducers or gages on both the tubing and casing. This allowed for multiple transducers to be installed so that all of the RTUs did not have to rely on a single transducer. Figure 4 is a photo of the flow loop. This photo was taken before the surge tank was installed.

DATA ACQUISITION AND PUMPING UNIT CONTROL

Data could be acquired from four different units during tests. The four units were the Micro Motion mass flow meter, the Wood Group RTU, the ION RTU and the Lufkin SAM controller. The pumping unit could be controlled by an ABB variable speed drive or the variable speed drive could be by-passed and the unit could be controlled by an auto off-hand switch on the main power panel. Figure 5 is a photo of the instrument panel rack. On the left is the electrical panel, second is the Lufkin SAM controller, third is the ION Unit. The box on the far right is the Wood Group RTU. The box to the left of the Wood Group RTU is a wireless communications box. The Micro Motion mass flow meter can be seen in Figure 4. It is the triangular shaped unit.

ABB VARIABLE SPEED DRIVE

The ABB Variable Speed Drive is a 120 hp drive capable of output from 0 to 300 Hz. The unit has many features which can be used to control a pumping unit. The pumping unit can be operated with a constant input frequency or operated at a constant rotational speed.   This allows the unit to be run at very slow speeds. Changing the speed of the pumping unit with the variable speed drive is much faster than changing motor sheaves. Changing the pumping speed with the ABB variable speed drive was almost instantaneous while it took a little over an hour to manually change a sheave. When the ABB was not in use, the pump was run at 12.97 SPM. The ABB unit allowed one to adjust the speed of the pumping unit in tenth of a stroke per minute intervals down to zero SPM. The drive can be used to adjust the speed in steps smaller than a tenth of a stroke per minute by adjusting the drive parameters to different values. The unit also had data logging capability. The unit was connected to the ION RTU using Modbus protocol to record power data such as output frequency, voltage and current. In the test presented in this report, the ABB drive was bypassed, except for the high speed 15.47 spm fiberglass test. A photo of the ABB variable speed drive is shown in Figure 6.

WOOD GROUP EQUIPMENT

The Wood Group equipment consisted of a down hole Wood Group instrument package called a SmartLift Sensor, two ported subs that were connected to the SmartLift Sensor by stainless steel capillary tubes, an RTU that monitored and logged the data and about 4000 ft of ¼ in tubing encased wire that connected the SmartLift Sensor to the surface RTU. The SmartLift Sensor measured pump intake pressure, pump intake temperature, vibration, sensor current leakage and pump discharge pressure. Wood Group also had a set of pressure transducers at the surface, one to measure tubing pressure and one to measure casing pressure.

ION UNIT

The ION 7600 unit is a power measurement unit that can measure and data log each of the three power phases separately. It measures voltage on each leg, current on each leg, frequency, power received and power delivered as well as other power values. The unit was also capable of logging data from other RTUs. It recorded data from the Wood Group RTU, the Micro Motion flow meter and the ABB variable speed drive.

LUFKIN SAM CONTROLLER

The Lufkin SAM controller is a dynamometer and pump-off controller. It can record surface cards and pump cards for use during diagnostics. It can also be used as a pump-off controller. The pump-off control system was not used during this test. The Sam unit has a load cell on the pumping unit that measures the polished rod load. It also had a string gage that was connected to the pumping unit to accurately measure polished rod position and a tubing pressure transducer to measure tubing pressure. The Sam unit uses this load and position data along with pumping unit and rod string data to calculate surface cards and pump cards.

TEST DATA GATHERING PROCEDURE

The well was started and allowed to reach steady state conditions. The Lufkin SAM controller was used to store several cards during the test period. These cards were transferred to the Texas Tech laptop for later analysis. The Texas Tech laptop was connected to the Micro Motion meter and set to acquire data. Once the laptop was acquiring data the test was started. The amount of production during the test was read from the Micro Motion meter. The Texas Tech laptop was disconnected after the Micro Motion log had been saved. The data from the Wood Group RTU and ION RTU were then downloaded and saved on to the Texas Tech laptop and backed up to a flash drive along with the Micro Motion log.

The Texas Tech laptop was then reconnected to the Micro Motion meter for the next test. At this time the ABB variable speed drive was adjusted or the unit was locked out and tagged out and chained down to change the sheave. Once the speed change was complete, the next test was begun repeating the procedure.

TEXAS TECH DATA

Texas Tech collected the data recorded from the Micro Motion RTU, the ION RTU and the Wood Group RTU. The ION RTU and the Wood Group RTU both have the ability to log external data. Where possible, data from other measurement devises was recorded on both RTUs. This allowed for some form of data backup. If one unit failed to record data it would be recorded on another unit. The following lists list the data recorded by the ION meter, Wood Group RTU and the Micro Motion Prolink software. The first column is the data recorded, the second column is the data source. All of the data was graphed for each test to determine the validity of each test.

Data Recorded by ION Meter

Value	Source
Voltage AB	ION
Voltage BC	ION
Voltage AC	ION
Current A	ION

Current B	ION
Current C	ION
Power Factor	ION
Power Frequency	ION
Fluid Temperature (Thru Meter)	Micro Motion
Fluid Density (Thru Meter)	Micro Motion
Fluid Mass Total	Micro Motion
Volume Flow Total	Micro Motion
Volume Flow Rate	Micro Motion
Stroke Count	Hall Effect Sensor
Pump Intake Pressure	Wood Group
Pump Intake Temperature	Wood Group
Pump Discharge Pressure	Wood Group
Pump Vibration	Wood Group
Tubing Pressure 1	Wood Group
Tubing Pressure 2	Lufkin
Casing Pressure	Wood Group

Data Recorded by Wood Group RTU

Average Current	Wood Group
Average Voltage	Wood Group
Power Factor	Wood Group
Power Usage	Wood Group
Tubing Pressure 1	Wood Group
Tubing Pressure 2	Lufkin
Casing Pressure	Wood Group
Volume Flow Rate	Micro Motion
Pump Intake Pressure	Wood Group
Pump Intake Temperature	Wood Group
Downhole Electronics Temperature	Wood Group
Pump Discharge Temperature	Wood Group
Pump Vibration	Wood Group
Downhole Electronics Current Leakage	Wood Group
Downhole Electronics Voltage	Wood Group
Downhole Electronics Duty Cycle	Wood Group

Micro Motion Data Logged with Prolink Software

Mass Flow Rate	Micro Motion
Mass Total	Micro Motion
Volume Flow Rate	Micro Motion
Volume Total	Micro Motion
Fluid Density (Thru Meter)	Micro Motion
Fluid Temperature (Thru Meter)	Micro Motion
Drive Gain	Micro Motion

TEST DESCRIPTIONS

There were three separate tests with two different rod strings. Test 1, 2 and 3 had 2,846 feet of 87513 Fibercom and 1050 feet of 1 5/8" sinker bars, a surface stroke of 88 inches, a pumping speed of 13 SPM and a 2 inch pump. Test 4 had 2,846 feet of 87513 Fibercom and 1050 feet of 1 5/8" sinker bars a surface stroke of 88 inches, a pumping speed of 13 SPM and a 2 inch pump. Test 5, 6, 7, and 8 had an 88 API string, 105.6 inch surface stroke a pumping speed of 13 SPM and a 2 inch pump.

VARIABLES DURING TEST

Production from a rod pumped well is a function of four variables. They are as follows:

Pump Speed in SPM (Speed) This is a function of motor speed, the motor sheave, the pumping unit sheave, and the pumping unit gearbox ratio.

Down hole pump stroke (DHPS) This is a function of the surface stoke of the pumping unit, the rod string design, the size of the down hole pump diameter, and the strokes per minute.

Pump constant (PC) This is a function of the diameter of the pump plunger.

Percent run (%run) This is the percentage of time that the system is operating.

Fluid production is thus calculated by the following formula using the above variables:

$$production = Speed \cdot DHPS \cdot PC \cdot \%Run$$

Every effort was made to keep as many variables as possible constant during the test. The motor was direct connected with a 16 inch motor sheave. This resulted in a pumping speed of approximately 13 spm. The VFD was used to increase the speed to 15.5 SPM for one test, otherwise it was bypassed.

The surface stroke was reduced to 87.5 inches from 105.6 in an effort to keep the downhole pump strokes for the 13 spm tests as equal as possible.

The same downhole pump was used for all tests.

The system ran continuously during the test period. (30 minutes after study state conditions)

Surface and downhole pressures were recorded and held as constant as possible.

ROD STRING DESIGNS

The steel string was an API 88 design with 1 inch grade D rods.

The glass string consisted of 2,846 feet of 1 inch Fibercom fiberglass rods and 1,050 feet of 1.625 inch grade C steel sinkerbars.

RESULTS AND CONCLUSIONS

The first step in the data analysis was to review all of the data collected which is listed in the lists in Section 1. Once it was determined that the data was valid, the surface production rate and power usage were calculated for each test. The ION power meter measures power delivered to the pumping unit motor and power received from the pumping unit motor. This made it possible to calculate the pumping unit power usage with a generation credit and without generation credit. This test was only concerned with power usage, no cost of the power received or delivered to the power grid was considered. Average power usage in kilowatts and kilowatt hours per barrel of fluid is listed in Table 1. Both values are listed allowing for generation credit and not allowing for generation credit. Average power usage for the fiberglass sinker bar string was 0.871 kWh/bbl with and without a generation credit. This is because with the fiberglass string, the unit could be balanced were there is no power generation during the pump stroke. For the 88 API steel string, the average power usage was 0.935 kWh/bbl with a generation credit and 1.020 kWh/bbl without a generation credit. The fiberglass string design used 14.55 % less power than the 88 API string without a generation credit and 6.80 % with a generation credit.

Analysis was also performed using the surface card data collected for the test. Actual surface cards that were collected during the tests are shown in Figures 7 and 8. Predictive analysis was also performed for the tests. They are shown in Figures 9 and 10. It should be noted that for the fiberglass tests, the maximum gearbox torque was 260.9 min-lbs while the maximum gear box torque on the 88 string was 437.1 min-lbs according to the predictive programs. Also, on the fiberglass string the minimum gear box torque was -12.4 min-lbs while the steel string had a minimum of -112.4 min-lbs. Although the fiberglass string had a minimum torque of -12.4 min-lbs, it was not enough to spin the motor fast enough to generate any power. Even if it was, the negative torque was applied to the motor for a very short time on the fiberglass test. On the 88 string tests, the negative torque was applied for a much longer period of time and at almost ten times the peak magnitude of the fiberglass torque.

REFERENCES

1. Chambliss, R. Kyle: "Developing Plunger Slippage Equation for Rod-Drawn Oil Well Pumps," Dissertation, Texas Tech U., Lubbock, Texas (2005)

Table 1
Test Data

Test #	Date	Pump Intake Pressure (psig)	String	Sheave Size (in)	Pumping Unit Speed (spm)	Lufkin Inferred Production (bpd)	Surface Production (bpd)	Energy Delivered (kWh)	Energy Recived (kWh)	Average Power Usage with Generation (kW)	Average Power Usage without Generation (kW)	Energy per Barrell with Generation (kWh/bbl)	Energy per Barrell without Generation (kWh/bbl)
1	7/14/2005	146	Fiberglass	16	12.94	638.90	564.56	0	10.321	20.643	20.643	0.878	0.878
2	7/14/2005	145	Fiberglass	16	12.95	642.34	566.99	0	10.301	20.602	20.602	0.872	0.872
3	7/14/2005	145	Fiberglass	16	12.95	643.90	565.70	0	10.192	20.383	20.383	0.865	0.865
4	7/14/2005	138	Fiberglass	16 (72.5 Hz)	15.47	868.34	777.20	0	13.678	27.355	27.355	0.845	0.845
5	7/26/2005	146	88	16	12.92	625.66	542.40	0.957	11.538	21.161	23.076	0.936	1.021
6	7/26/2005	147	88	16	12.92	626.00	542.37	0.958	11.537	21.158	23.073	0.936	1.021
7	7/26/2005	146	88	16	12.92	630.12	542.31	0.960	11.517	21.115	23.034	0.934	1.019
8	7/26/2005	145	88	16	12.93	620.96	542.35	0.957	11.500	21.085	22.999	0.933	1.018

All test were 1800 seconds (30 minutes) long

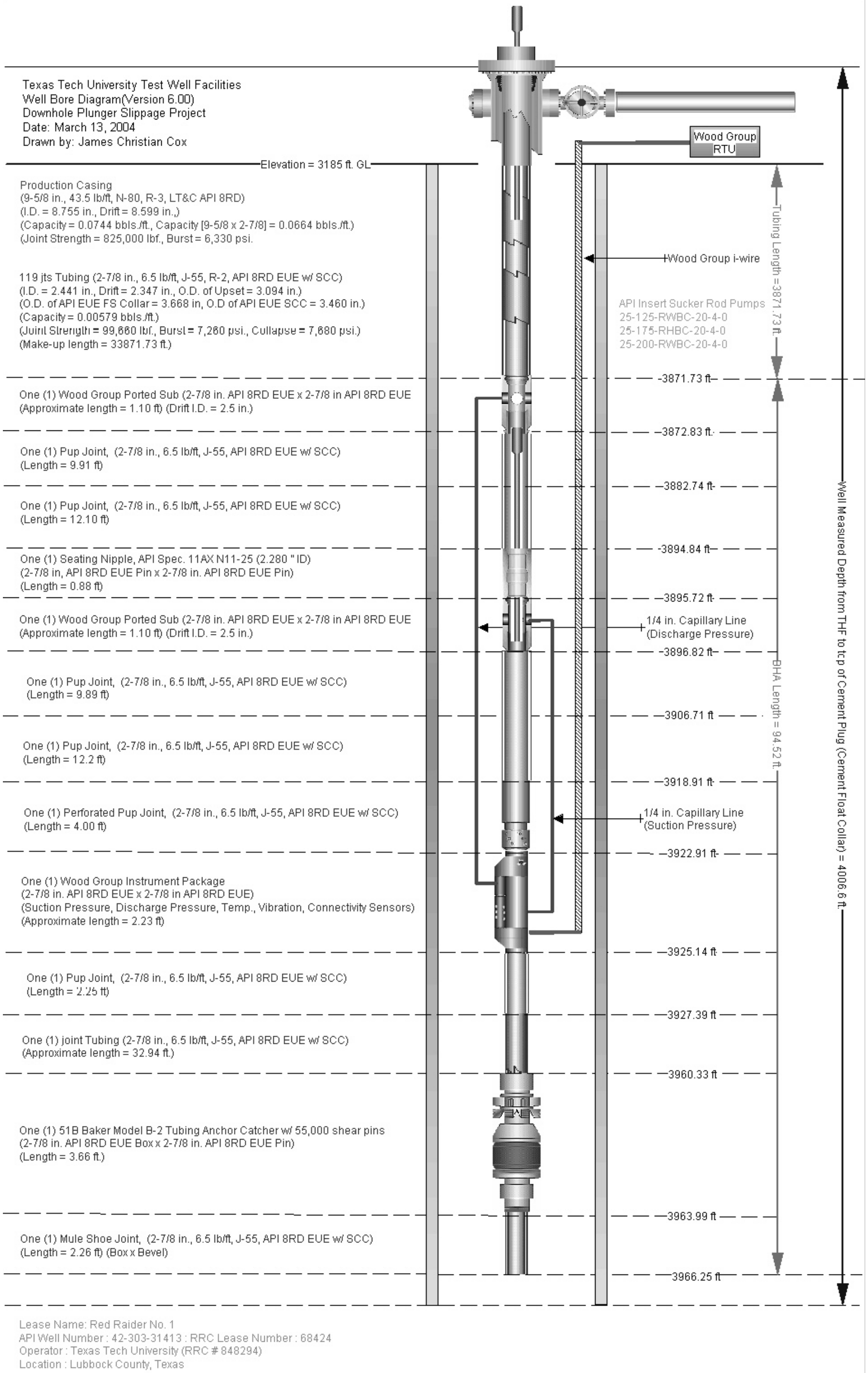


Figure 1 – Well Completion Diagram

Figure 2 – Red Raider # 1 Test Facility

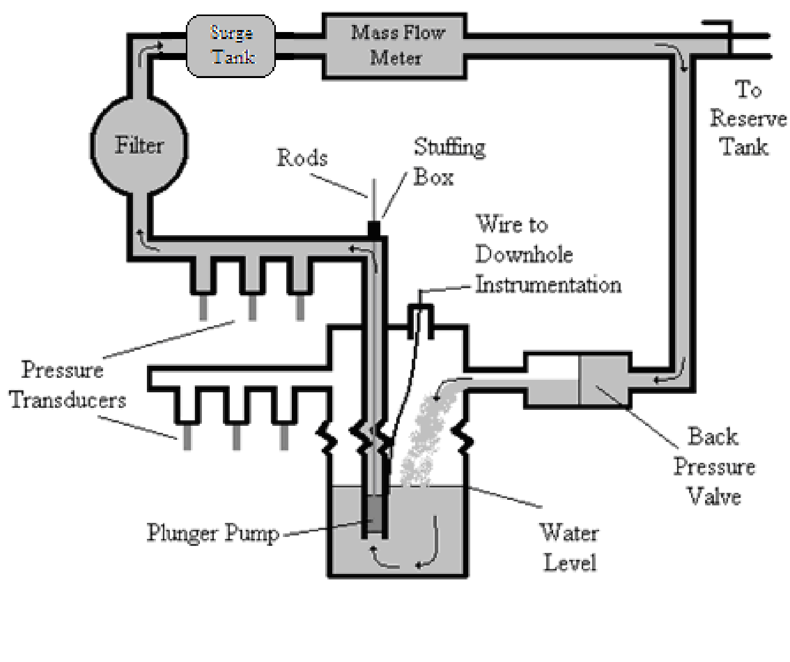


Figure 3 - Flow Loop

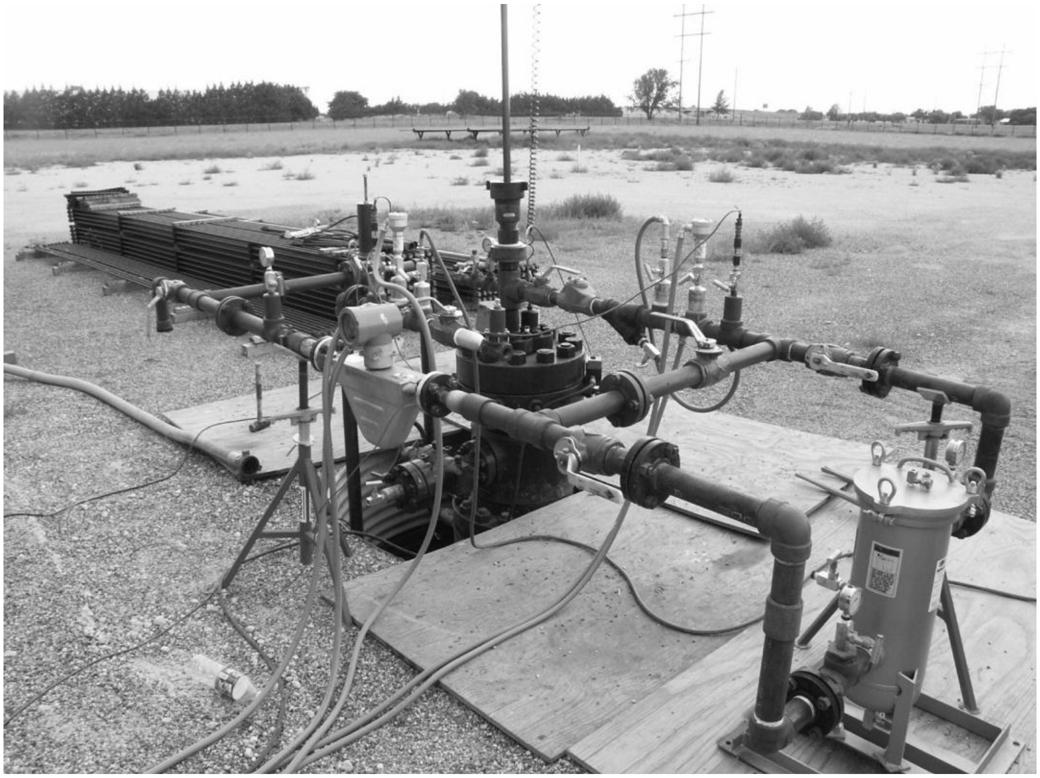
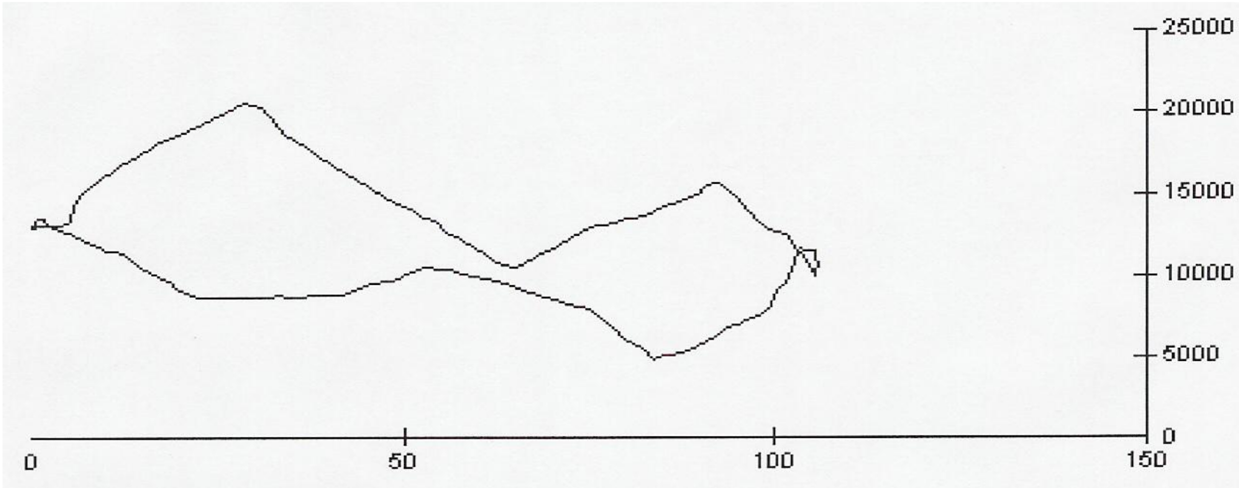


Figure 4 – Picture of Flow Loop

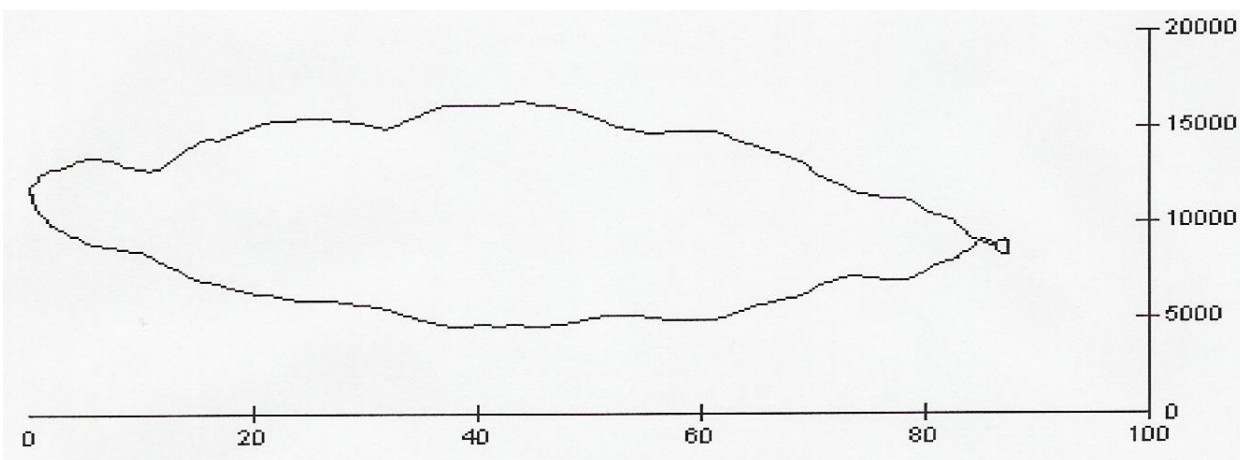
Figure 5 – Instrument Rack

Figure 6 – ABB Variable Speed Drive



Well	Red Raider # 1 – 88 API Steel String – 13 spm
Date	7/26/2005
Max Load	20642 lbs
Min Load	4883 lbs
Surface Stroke	105.6 in
Pumping Speed	13.1 spm
Polished Rod Power	20.4 hp

Figure 7 – 88 API Steel Surface Card



Well	Red Raider # 1 – Fiberglass String – 13 spm
Date	7/14/2005
Max Load	16359 lbs
Min Load	4545 lbs
Surface Stroke	87.5 in
Pumping Speed	13.16 spm
Polished Rod Power	21.8 hp

Figure 8 – Fiberglass Surface Card

**** PRIME MOVER ****

G.E. 50 HP KOF

Speed Variation (%)	: 18.4	Cyclic Load Factor	: 1.595
Power Required (hp)	: 46.9	Motor Load (% of Rating)	: 93.9
Sheave Ratio (Unit/ Prime Mover)	: 3.024		

**** PUMPING UNIT ****

LUFKIN C456-305-144 WITH 94110B CRANKS (C'WISE)

Actual Max Load (lbs)	: 22505	Actual Min Load (lbs)	: 4046
Pumping Speed (spm)	: 12.89	Max Load (% of Rating)	: 73.8
Polished Rod Power (hp)	: 26.4	Computed Surface Stroke (in)	: 106.1

**** GEAR REDUCER ****

	EXISTING	IN BALANCE
Max Torque (m in-lbs)	437.1	432.9
Min Torque (m in-lbs)	-112.4	-111.1
Counterbalance (m in-lbs)	797.8	786.9
Effective Balance (X100 lbs)	150.2	148.1
Percent of Reducer Rating	95.8	94.9

**** ROD STRING ****

	Diameter (in)	Length (ft)	Rod Type	Rod Loading
1)	1 *	3895	API D	100

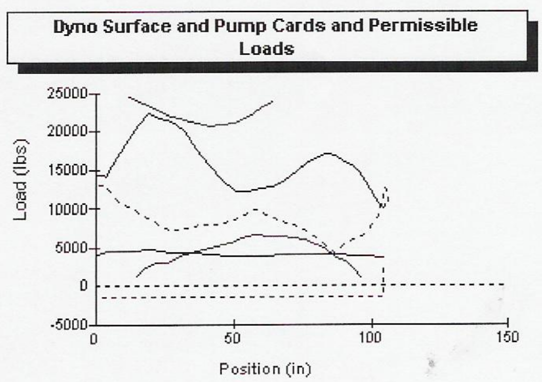
* Requires slimhole couplings.

Service Factor for Steel Rod	: 0.9		
Max Stress @ surface (psi)	: 28527	Min Stress @ surface (psi)	: 5278

**** DOWNHOLE PUMP ****

Bore Size (in)	: 2	Setting Depth (ft)	: 3895
Tubing Stretch (in)	: 0.2	Lost Displacement (bpd)	: 1
Pump Intake Pressure (psi)	: 140	Pump Spacing Guide (in)	: 4
Tubing Size (in)	: 2.875	Tubing Anchor Location (ft)	: 3850
Tubing Gradient (psi/ft)	: 0.433	Pump Fillage (%)	: 100

	Stroke (in)	BPD at 100% eff.	BPD at 80% eff.
Gross:	104.7	630 (24h/d)	504 (24h/d)
Net:	104.6	629 (24h/d)	503 (24h/d)



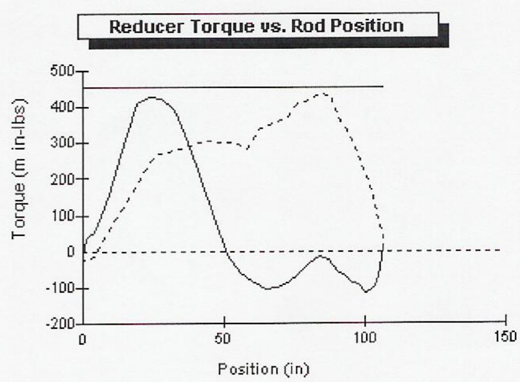


Figure 9 – Predictive Results for 88 API Steel String

**** PRIME MOVER ****

G.E. 50 HP KOF

Speed Variation (%)	: 9.1	Cyclic Load Factor	: 1.206
Power Required (hp)	: 37.1	Motor Load (% of Rating)	: 74.2
Sheave Ratio (Unit/ Prime Mover)	: 3.04		

**** PUMPING UNIT ****

LUFKIN C456-305-144 WITH 94110B CRANKS (C'WISE)

Actual Max Load (lbs)	: 16671	Actual Min Load (lbs)	: 3980
Pumping Speed (spm)	: 12.95	Max Load (% of Rating)	: 54.7
Polished Rod Power (hp)	: 25.7	Computed Surface Stroke (in)	: 87.4

**** GEAR REDUCER ****

	EXISTING	IN BALANCE
Max Torque (m in-lbs)	260.9	260.6
Min Torque (m in-lbs)	-12.4	-13.2
Counterbalance (m in-lbs)	472.4	471.2
Effective Balance (X100 lbs)	105.3	105.1
Percent of Reducer Rating	57.2	57.1

**** ROD STRING ****

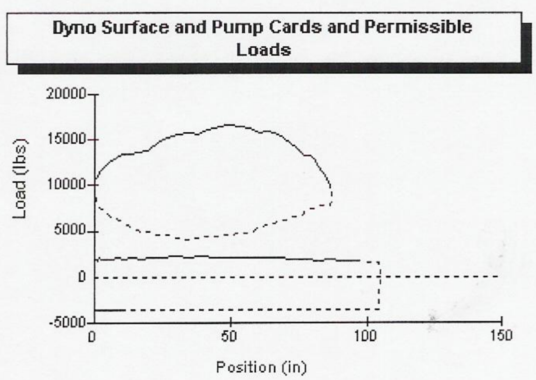
	Diameter (in)	Length (ft)	Rod Type	Rod Loading
1)	0.98	2845	FIBERCOM	68
2)	1.625	1050	API C	27

Service Factor for Steel Rod	: 0.9		
Max Stress @ surface (psi)	: 21968	Min Stress @ surface (psi)	: 5408

**** DOWNHOLE PUMP ****

Bore Size (in)	: 2	Setting Depth (ft)	: 3895
Tubing Stretch (in)	: 0.2	Lost Displacement (bpd)	: 1
Pump Intake Pressure (psi)	: 140	Pump Spacing Guide (in)	: 23
Tubing Size (in)	: 2.875	Tubing Anchor Location (ft)	: 3850
Tubing Gradient (psi/ft)	: 0.433	Pump Fillage (%)	: 100

	Stroke (in)	BPD at 100% eff.	BPD at 80% eff.
Gross:	104.8	633 (24h/d)	506 (24h/d)
Net:	104.7	632 (24h/d)	506 (24h/d)



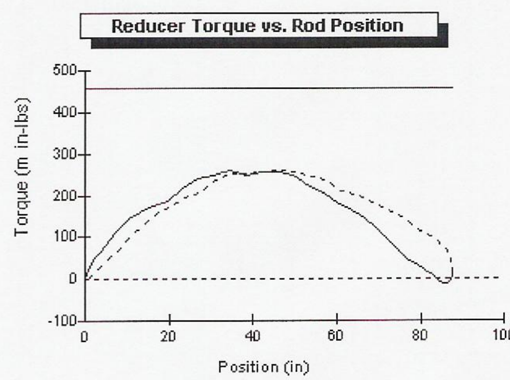


Figure 10 - Predictive Results for Fiberglass String