PUMP SLIPPAGE TEST UPDATE

R. Kyle Chambliss, Oxy Permian
Lynn Rowlan, Echometer Company
Tabrez Khan, Texas Tech University

INTRODUCTION TO PUMP SLIPPAGE

Pump slippage is the liquid that slips between the plunger outside diameter and the pump barrel inside diameter into the pump chamber between the standing valve and traveling valve when the traveling ball is on seat. Slippage into the pump barrel on the upstroke results is reduced pump displacement. Many pump slippage formulas have been developed over the years. Most of these formulas over predict the pump slippage and a more accurate formula is needed. Slippage calculations are important to determine the amount of fluid required to lubricate a plunger on a plunger pump. A slippage formula is also required to calculate the pump efficiency and plunger pump production in order to maximize production.

PLUNGER PUMP OPERATION

A plunger pump consists of a barrel, plunger, traveling valve and standing valve. The outside diameter of the plunger is less than the inside diameter of the barrel. This difference in diameter is called pump clearance and is usually expressed in thousands of an inch. The traveling valve is connected to the plunger to form an assembly, and the plunger assembly is attached to the sucker rods. When the traveling valve is closed the ball is on the seat and the closed valve acts as a check holding the fluid in the tubing. When the traveling valve is open the fluid in the pump barrel can be displaced into the tubing. The standing valve when opens allows fluid to flow into the pump barrel below the plunger. When the standing valve is closed, it acts as a check valve holding fluid in the tubing. Figure 1 is a pump card representing the load the pump applies to the rod string. On the pump card the standing valve is closed from C-D, D-A, and A-B; and the standing valve is only open from B-C. On the pump card the traveling valve is closed from A-B, B-C, and C-D and the traveling valve is only open from D-A. Pump slippage can only occur when the traveling ball is on seat.

Before the beginning of the upstroke the pressure from the tubing fluid is applied to the closed standing valve and the traveling valve is open as fluid is displaced from inside the pump into the tubing (D-A). At the start of the upstroke, A, the traveling valve and standing valve are both closed and the pressures above and below the plunger are equal. During the upstroke (A-B-C-D) the fluid load applied to the rod string is due to differential pressure acting on the plunger and is equal to the pump discharge pressure minus the pump intake pressure times the area of the pump plunger. The fluid load is gradually transferred from the tubing (A-B) as the rods stretch to pick up the fluid load. The standing valve begins to open at B when the pressure in the pump drops below the pump intake pressure, allowing fluid to enter the pump. From point B to C, the rods carry the fluid load while well fluids are drawn into the pump. At C, the standing valve closes, and the traveling valve remains closed until the pressure inside the pump is slightly greater than the pump discharge pressure. From C to D, gas in the pump (if present) is compressed as the plunger moves down to increase pressure on the fluid from the intake pressure to the static pressure in the tubing. As the fluid in the pump barrel is compressed, then the fluid load is gradually transferred from the rods to the tubing. At D, the pump barrel pressure equals the static tubing pressure, and the traveling valve opens. From D to A, the fluid in the pump is displaced through the traveling valve into the tubing as the closed standing valve holds the fluid load on the tubing.

IMPORTANCE OF PROPER PUMP SLIPPAGE

Proper pump slippage is a balance between pump lubrication to extend the life of the pump and pump volumetric efficiency. Pump volumetric efficiency is defined as the actual fluid displaced per stroke divided by the fluid displacement of the pump. On the upstroke when the traveling ball in on the seat, the pressure difference acting across the plunger forces fluid to leak from the tubing (high pressure) through the clearances between the barrel and plunger back into the pump (low pressure). Fluid leakage between the pump barrel and pump plunger is called pump slippage. Slippage is one of the factors that affect pump lubrication and efficiency. Proper pump lubrication is necessary to extend the life of the pump.

Another factor that affects the efficiency is a sticking plunger, which shortens the actual pump stroke. A plunger can stick if the clearance between the pump barrel and pump plunger is too small. The clearance must be large enough to allow an appropriate amount of slippage to sufficiently lubricate the plunger and barrel. Sand and other particles need to pass between the barrel and plunger, which could otherwise jam the pump plunger in the pump barrel. The typical amount of slippage for lubrication is 2 to 5% of the total production.

Plunger sticking or galling of metal can shorten the life of the rods and the pump. Galling of the metal is when the pump plunger and pump barrel rub together with no lubrication causing the metal to wear and become rough. In order to predict pump performance and design for proper lubrication, pump slippage needs to be accurately modeled. Pump slippage can be mathematically modeled and experimentally measurements can be done to aid in the development of the model.

OVERVIEW OF SLIPPAGE FIELD TEST

Texas Tech University, along with about a dozen companies, both operators and service companies, developed and funded a slippage field test which was performed at the Texas Tech test well facility, Red Raider # 1. The companies involved in the field test are listed in Table 1.

HOW SLIPPAGE IS CALCULATED

Slippage is the difference between what the pump should produce based on the effective plunger travel (D-A) assuming there is no leakage through the traveling valve and what the pump actually produces as measured at the surface. Wave equation programs are used to estimate the effective plunger travel and pump fillage. The effective plunger travel, from the downhole pump card calculated using the wave equation, gives an estimate of what the well should produce if there were no slippage. Production is measured at the surface while surface dynamometer data is acquired to calculate the load and position at the pump.

SLIPPAGE THEORY

It has long been believed that slippage is unaffected by pumping rate, so all of the historical formulas do not consider pumping rate as a variable.[1] The slippage consists of two elements, dynamic slippage and static slippage.[2] The static slippage is slippage due to a pressure difference across the plunger. The movement of the plunger causes dynamic slippage and the slippage theoretically increases as a function of increasing plunger velocity. Dynamic slippage occurs on both the up stroke and down stroke while the static slippage only occurs in the up stroke. On the up stroke the dynamic slippage contributes to the total slippage, while on the down stroke dynamic slippage just lowers the amount of fluid that has to pass through the traveling valve. Of the two elements that make up slippage, static and dynamic, static slippage generally is the larger of the two elements. Another thing to consider is as pumping rate increases, dynamic effects in the tubing change due to friction increase. At higher speeds, a slight increase in pressure across the plunger is expected, which would cause a slight increase in slippage with speed.

If a pump does not have 100 % fillage, there are a few things to consider. Let's say the pump is 50 % full when the plunger reaches the top of the stroke. When the plunger starts to move downward the traveling valve will not open until the pressure below the traveling valve is greater than the pressure above it. Until the traveling valve opens slippage is still occurring around the plunger. This slippage adds to the fillage of the barrel. If the pump was 50 % full at the top of the stroke, it may be 55 % full, relative to the top of the stroke, once the traveling valve opens due to fluid slipping around the plunger and filling the barrel. On this same pump that was 50 % full at the top of the stroke; some of that fillage was due to slippage on the up stroke. If there was no slippage on the up stroke, the fillage would be smaller. If there was more slippage on the upstroke, the fillage would be higher. Basically, if the pump does not have 100 % fillage, not all of the slippage contributes negatively to the pump efficiency.

Each time the traveling valve closes there will be a small amount of leakage through the valve as it closes. During field tests to measure slippage, this leakage is not considered because it is believed to be small. It also occurs in all rod pumped wells. Modeling the slippage with this leakage included more accurately models the real life slippage in a well. The slippage through the traveling valve does not contribute to the slippage that lubricates the plunger and barrel.

EFFECTIVE PLUNGER STROKE AND THE WAVE EQUATION

Effective plunger travel is not equal to the surface stroke of the pumping unit. The rod string has an elastic nature, which affects the plunger travel. There are five factors that affect the plunger travel.[3]

1. Rod and tubing stretch due to fluid loads changing from traveling valve to standing valve during the pumping cycle
2. Plunger overtravel caused by the dynamic nature of the rod string
3. Rod Vibration
4. Subsurface friction effects
5. Gas in the pump barrel

To accurately calculate plunger travel in the slippage test, a few things were done to minimize or remove as many of the above factors as possible. All new equipment was used and the well bore was almost perfectly straight, this reduced vibration and minimized subsurface friction. The inlet pressure to the pump was kept high enough that no air would enter the pump; this removed any gas interference in the pump and reduced pump vibration.

To calculate the effective plunger stroke, a wave equation program is used. These programs use the wave equation along with boundary conditions that describe various aspects of the pumping system. [4] Different companies have different programs, based on the same basic principals but with differences in the way the equations are solved or the data collected. Two different programs which will be discussed later were used during the slippage test.

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.

BASIC EXPERIMENTAL SETUP

The basic experimental setup is shown in Figure 2. 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, which will be discussed further in the next section. 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 keep gas out of the system, a backpressure valve was down stream from the mass flow meter. A backpressure 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. A surge tank between the filter and the mass flow meter was also used. This increased the accuracy of the flow meter to 0.2 %.

After the water flowed through the backpressure 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.

DATA ACQUISITION AND PUMPING UNIT CONTROL

Data could be acquired from four different units during slippage 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 an auto-off-hand switch on the main power panel could control the unit.

Mass Flow Meter

The mass flow meter that was installed on the loop was a Micro Motion F-100 Coriolis Effect mass meter. The Micro Motion meter did not have any data logging capability, so to log the data Prolink software installed on a laptop was used. Before the pumping unit was turned on, the laptop with the Prolink software was connected to the Micro Motion meter. Data logging was then started and the pumping unit turned on. That way the data being logged could be monitored to make sure the flow through the meter reached steady state. The Prolink software recorded date, time, elapsed time, density, mass flow rate, total mass flow rate, temperature, volume flow rate, total volume and drive gain. The software sampled the meter about twice a second. Drive gain recorded from the meter was basically how hard the meter was working; adjusting for substances such as any particles or gas that flowed through the meter. Generally the drive gain was less than 3 %. Anytime this gain went higher, it usually meant that the pump was pumped off and pumping some gas through the meter. When this happened, more water was added to the well bore to increase the bottom hole pressure and the drive gain went back to around 3 %.

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 data logged the monitored 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 legs or 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, but during our pump slippage test, this function was not used. The unit is attached to a load cell on the unit that measures the polished rod load. It also had a string gage that could be connected to the pumping unit to accurately measure polished rod position and a tubing pressure transducer to measure tubing pressure. The unit uses this data to calculate surface cards and pump cards.

ABB Variable Speed Drive

The ABB Variable Speed Controller is a 120 hp drive capable of output from 0 to 300 Hz. The unit has many features that can be used to control the speed of the pumping unit. In the slippage tests, the ABB controller was used to set the stokes per minute by selecting a certain fixed frequency on the controller. Using a specific size motor sheave to control the pumping speed would have resulted in different strokes per minute due to different motor slip caused by different polished rod horsepower due to lifting different diameter rod strings. For a certain diameter motor sheave, the 1 inch rod string would have higher polished rod horsepower, more motor slip, and slower strokes per minute; when compared to the lighter weight 7/8 and ¾ inch rod string. The controller made each slippage test to be performed at exactly the desired strokes per minute, independent of motor slip and the sucker rod string design. 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 manually changing a motor sheave required a little over an hour. In preliminary testing before the ABB was used to control speed, only had four pump speeds could be tested due to having four motor sheaves (6, 8.5, 10, and 12 inches). The ABB unit allowed adjusting the speed of the pumping unit in tenth of a stroke per minute intervals down to near zero SPM. In one test the SPM was set to 0.7 SPM and 4.4 BPD was produced at the surface, slowing the speed to 0.6 SPM resulted in no flow at the surface where all 30 BPD of downhole stroke was completely lost to slippage. The ABB controller was connected using Modbus protocol to the ION RTU to record power data such as frequency, voltage and current.

EXPERIMENTAL PROCEDURES

Echometer Procedure

Three Echometer Well Analyzers were used to acquire data during the 20-minute slippage tests. Surface dynamometer cards were acquired by measuring load output from a calibrated horseshoe load cell and position was determined from measured polished rod acceleration. Input motor power and current were acquired simultaneously with the dynamometer data. The analyzer calculated and recorded dynamometer cards for every stroke during the entire 20-minute slippage test. At a rate of 30 samples per second the instantaneous flow rate data was acquired from the Micro Motion flow meter and at the same time motor input current, surface tubing and casing pressure were acquired. The elapsed time and motor input current were used to merge the datasets acquired from two different well analyzer systems. Acoustic fluid level measurements were automatically acquired at two-minute intervals to track the fluid level during the slippage test. Each fluid level was used to calculate pump intake pressure. For the slippage test nitrogen gas was used to pressurize the casing to approximately 5 to 7 psi in order to improve the reflected acoustic signals compared to the noise produced by water falling down the casing from the surface back into the well.

The procedure for acquiring the Echometer data was to connect the Texas Tech laptop to the Micro Motion meter and begin acquiring data before the pumping unit was turned on. After the Echometer equipment had been connected, the pumping unit was started. Once steady state was reached in approximately 20-30 minutes, then the well analyzers began acquiring data for about twenty minutes.

After the slippage test was complete, standing valve, traveling valve, and residual friction test were performed. Once the traveling valve and standing valve test were completed, the Texas Tech laptop hooked up to the Micro Motion unit 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 next test began if it was at the same pumping speed. If the next test was at a different speed 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.

Lufkin Procedure

Lufkin dynamometer data was collected using the Sam quick dyno by Texas Tech employees. As the well analyzers recorded data, a dynamometer card was collected approximately once every five minutes and downloaded to the Texas Tech lap top for future analysis.

Once the test was completed, 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.

DATA ANALYSIS

Table 2 list the surface production, inferred productions and slippages for each test along with other data. Various speeds were used during the test. For the fiberglass data and high speed 76 and 88 string data, Echometer data was not recorded because Echometer was not on location the day the test were run. For the 0.6 to 0.8 spm test, Lufkin data was not recorded because the equipment would not acquire data at very slow speeds. Unless otherwise stated, in the following plots if both Echometer and Lufkin data was available, an average was used. Figure 3 is a graph of slippage as a function of pump speed. As can be seen in the graph, slippage increases with increasing pumping speed. Slow speed test were performed to determine the SPM where zero production was seen at the surface. Zero water was produced at the surface at a slow SPM when liquid slipped through the pump clearances at a rate equal to the volume of the pump barrel displaced by the plunger motion (where the inferred production from the plunger stroke equals slippage). This speed for the 88 string was between 0.6 and 0.7 spm. The no flow condition at the surface equates to a slippage of about 30 bbls per day. At a pump speed of about 13 strokes per minute, the slippage varies from 76 to 95 bbls per day depending on the rod string. Past slippage formulas have not considered slippage to be a function of changing the rod string design. Figure 3 shows that changing rod strings affects the pump slippage, although the effect is of a smaller magnitude than the pump speed effect.

Data presented here shows that pumping speed affects slippage. A new formula needs to be developed to accurately predict slippage. Since data for only one pump size has been gathered, any formula derived from the data would only be good for this one pump. Since changing rod strings affects slippage, then other parameters such as stroke length and pumping unit geometry may affect slippage. Two different stroke lengths were used in these tests, 105.6" for the steel strings and 87.5" for the fiberglass strings. Since no one string design used both stroke lengths, an analysis of how stroke length affected slippage cannot be formed.

Figure 4 is a plot of pump efficiency as a function of pump speed. The plot shows at very slow speeds, all of the downhole pump displacement can be lost to slippage and as SPM is increased a smaller fraction of the pump displacement is lost to slippage. It is interesting to note that although slippage increases as a function of increasing speed, the pump efficiency also increases as a function of increasing speed. For the 2" plunger diameter, slippage increases as function of increasing speed, but the slippage increases at a rate slower than the downhole pump inferred production increases. Another way to state this is that as a function of increasing speed, the pump displacement increases faster than the slippage increases.

CONCLUSIONS

The development of an accurate slippage formula is of great importance to operators of rod pumped oil wells. Improper slippage causes increased operating cost; too little slippage results in increased pump, tubing and rod failures, while too much slippage results in a reduced production rate and higher energy cost to lift the produced fluid to the surface.

The experimental setup used in the field slippage test was well planed. The tests were complex and required a significant amount of time to perform. The equipment performed as expected.

It was determined from the tests that speed affects slippage. As speed is increased, slippage increases. It was also determined that as speed increases, pump efficiency also increases. Different rod strings also affected slippage, although not as much as changing speed.

RECOMMENDATIONS

More pumps need to be tested that are of different diameters and different clearances. Only one pump diameter with one clearance was tested during this set of tests. Also, a test needs to be conducted to see how stroke length affects slippage.

Once more data is collected; a new slippage formula needs to be developed.

The pump used in this test and pumps used for future tests need to be sent back to Harbison-Fischer for static testing at there testing facility. This will also verify that the pumps were not worn during testing which would increase slippage.

REFERENCES

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3. Brown, Kermit E.: *The Technology of Artificial Lift Methods: Vol 2A*, The Petroleum Publishing

Company, Tulsa, Oklahoma (1980) 11-37.

4. Gibbs, S.G.: “Predicting the Behavior of Sucker-Rod Pumping Systems,” JPT (July 1963) 769-778.

TABLE 1
Field Test Sponsors and Participants

Research Sponsors	Development Sponsors
BP	Harbison Fischer
ChevronTexaco	Key Energy
ConocoPhillips	Lufkin Services
Echometer Company	Norris Rods
Lufkin Automation	Wood Group
Oxy Permian	ABB

Table 2
Slippage Data

Test #	Date	Rod String	Stroke Length (in)	Control Method [3]	Frequency (Hz) [4]	Pump Speed (spm)	Pump Intake Pressure Woodgroup (psig)	Pump Intake Pressure Echometer (psig)	Echometer Inferred Production (bpd)	Lufkin Inferred Production (bpd)	Surface Production (bpd)	Echometer Slippage (bpd)	Lufkin Slippage (bpd)	Average Slippage (bpd)	Pump Efficincy (%)
1-01	7/8/05	76 [1]	105.6	ABB (12")	60	9.73	gauge down	161.5	427.72	424.8	367.1	60.6	57.7	59.1	86.1
1-02	7/8/05	76 [1]	105.6	12" sheave	60	9.74	gauge down	152.6	428.11	425.6	368.0	60.1	57.6	58.8	86.2
1-03	7/8/05	76 [1]	105.6	ABB (12")	51	8.25	gauge down	165.5	357.49	350.2	301.3	56.2	48.9	52.6	85.1
1-04	7/8/05	76 [1]	105.6	ABB (12")	43	6.93	167	167.7	297.36	292.6	242.4	55.0	50.2	52.6	82.2
1-05	7/8/05	76 [1]	105.6	ABB (12")	31.5	5.03	165.7	172	214.7	214.0	163.5	51.2	50.5	50.9	76.3
1-06	7/8/05	76 [1]	105.6	ABB (12")	na	1.82	183.2	182.7	81.5	81.0	41.6	39.9	39.4	39.6	51.2
2-01	7/28/05	88	105.6	ABB (12")	.8 spm	0.80	175	178.1	39.2	NA	5.6	33.6	na	na	14.2
2-02	7/28/05	88	105.6	ABB (12")	.7 spm	0.70	178	178.1	34.4	NA	4.4	30.0	na	na	12.8
2-03	7/28/05	88	105.6	ABB (12")	.6 spm	0.60	179	178.1	29.55	NA	0.0	29.6	na	na	0.0
2-05	7/28/05	88	105.6	12" sheave	60	9.72	150	165.4	444.6	437.8	377.9	66.7	59.9	63.3	85.6
2-06	7/28/05	88	105.6	ABB (12")	60	9.71	150	151.7	444.6	440.0	378.2	66.4	61.8	64.1	85.5
2-07	7/28/05	88	105.6	ABB (12")	51	8.22	153	149.9	371.6	370.0	308.6	63.0	61.4	62.2	83.2
2-08	7/28/05	88	105.6	ABB (12")	43	6.90	156	154.6	313.4	312.6	250.9	62.5	61.7	62.1	80.2
2-09	7/28/05	88	105.6	ABB (12")	31.5	5.01	156	163	224	223.6	170.2	53.8	53.4	53.6	76.0
3-01	7/5/05	76 [1]	105.6	16" Sheave	60	12.97	gauge down	na	na	591.1	496.4	na	94.7	na	84.0
4-01	7/14/05	FG [2]	87.5	16" Sheave	60	12.95	145	na	na	641.7	565.8	na	75.9	na	88.2
5-01	7/14/05	FG [2]	87.5	ABB (16")	72.5	15.47	138	na	na	868.3	777.2	na	91.1	na	89.5
6-01	7/26/05	88	105.6	16" Sheave	60	12.92	146	na	na	625.7	540.1	na	85.6	na	86.3

A 2.00 in pump with a 0.009 in clearance and 4 ft plunger was used for all tests

1 76 string has 1468 ft of 7/8, 2000 ft of 3/4, and 400 of 7/8 rods
2 Fiberglass string had 2818 ft of 1" fiberglass and 1050 ft of 1 5/8" sinkerbars
3 When sheave size is listed, ABB was bypassed - when ABB used, sheave size is in parentheses
4 If pump speed listed, drive was set for constant speed, not constant frequency'

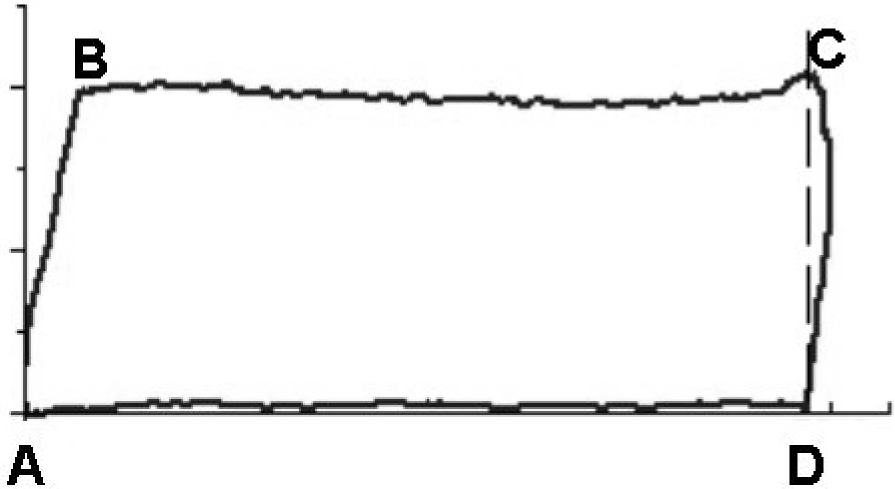

Figure 1- Pump Card

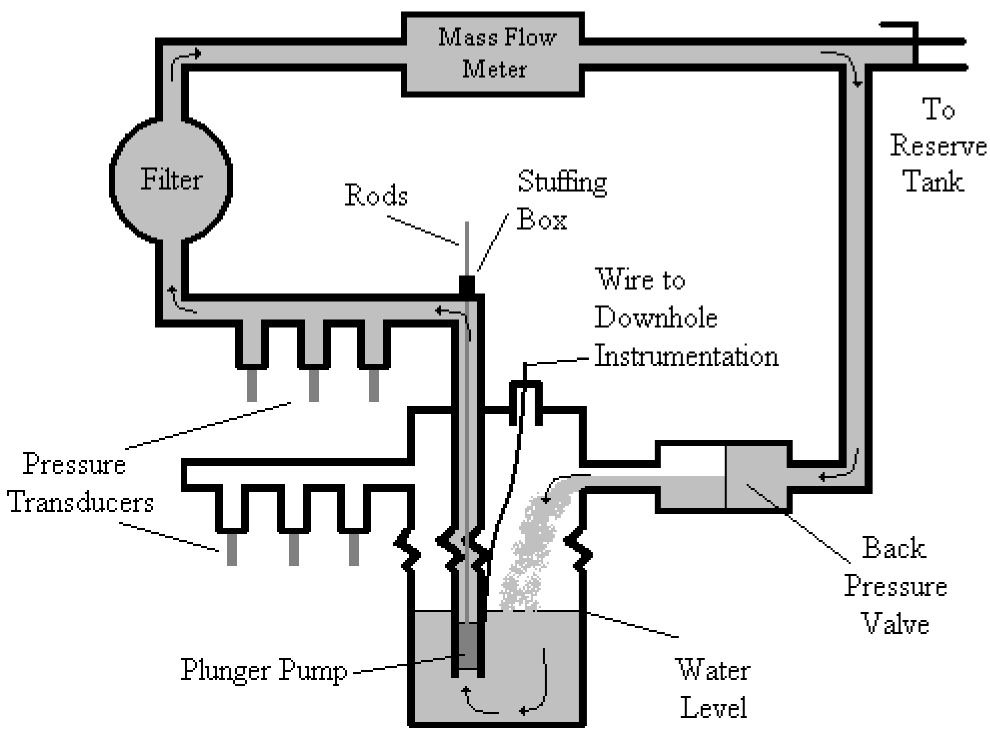

Figure 2 - Flow Loop Diagram

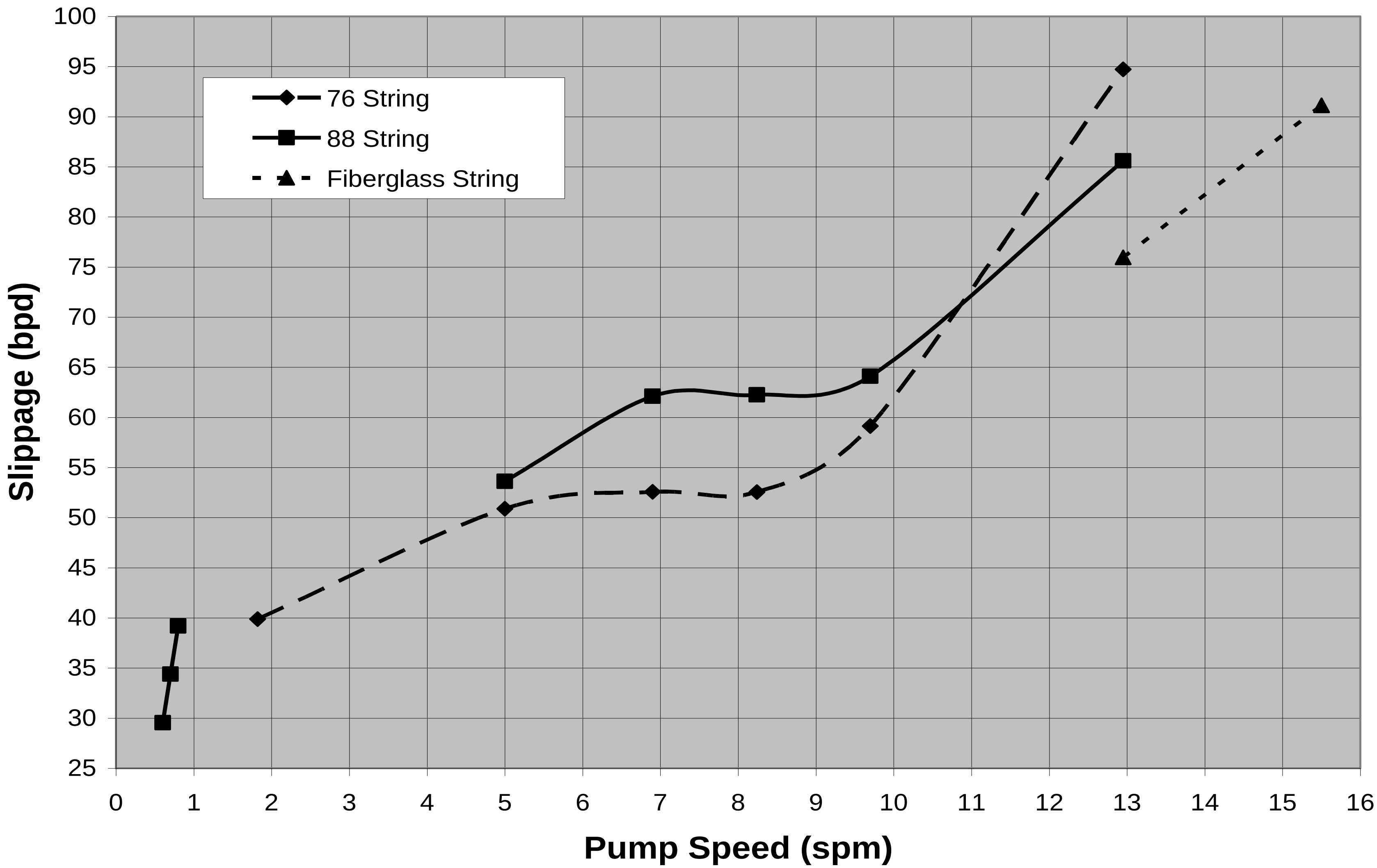

Figure 3 - Pump Slippage vs. Pump Speed

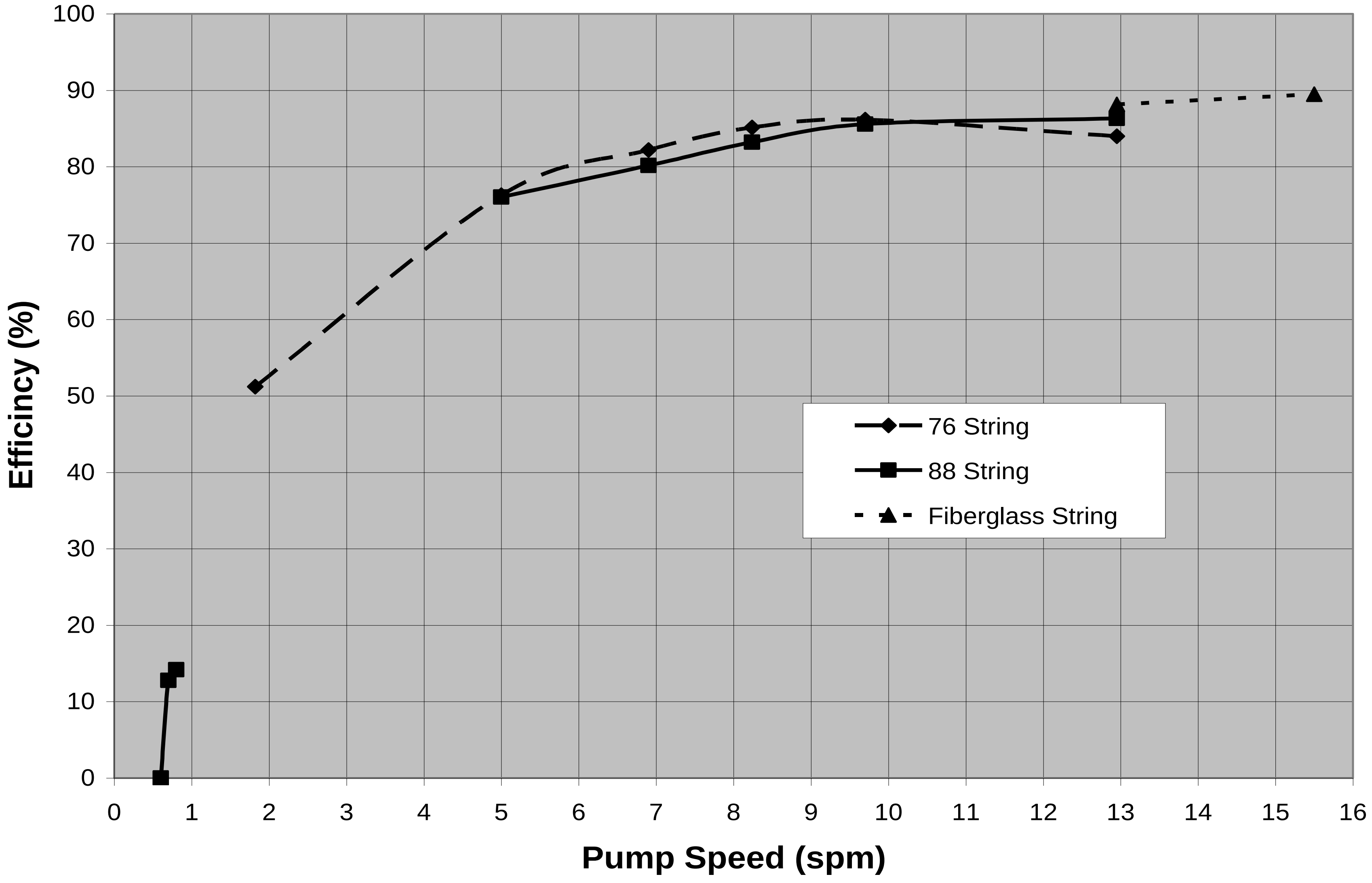

Figure 4 - Pump Efficiency vs. Pump Speed