COMPARISON OF STEEL SUCKER ROD AND FIBERGLASS/STEEL SUCKER ROD STRING PERFORMANCE

Elton J. Smith, Pioneer Natural Resources USA, Inc.
T. P. Hopper, The Fiber Composite Company, Inc.

ABSTRACT

It is often the situation that a producer is faced with multiple objectives in the design and application of beam lift systems. Included among the objectives may include: (a) lowering of high fluid levels, (b) reduction of rod failures, (c) reduction of tubing failures, (d) reduction of gearbox loading, and (e) increased system and electrical efficiencies. This paper describes the application of fiberglass sucker rods as a part of an increased effort to improve the overall system efficiency/failure ratio of numerous wells in several fields of Pioneer Natural Resources.

INTRODUCTION

Pioneer Natural Resources operates approximately 6,500 wells with a significant portion being in the Spraberry Trend of West Texas. The Spraberry Driver Unit (SDU) is located in Midland, Glasscock, Reagan, and Upton Counties.

SITUATION

Much of the SDU contains high water volume areas, and there is a need to produce efficiently. The seating nipple depth (SND) is initially set in a range of 6400' - 7200', which is above well bore perforations, to combat sand problems.

A typical location is equipped with 2 3/8" tubing and conventional geometry 228 or 320 pumping units.

Pumping systems within the Driver Unit are subject to considerable failures, with the predominant number of failures being rod breaks, rod-on-tubing wear, and coupling failure. There is a considerable need of producing more fluid while minimizing in-hole failures. Lowering the fluid levels will result in increased oil cut and increased gas production.

OBJECTIVES

In a short period of time, be able to pump fluid levels down to seating nipple depth with a minimum of down hole well servicing due to equipment changes and repairs. It is necessary to devise, obtain, and install the various pumping systems in a cost effective manner to maximize the effect of capital purchases. These goals would be best accomplished by developing a pumping system that is:

1. Adaptable to a wide range of pumping conditions by making changes at the surface, i.e. drive sheave changes (to change pumping speed), and/or stroke length changes (to shorten or lengthen surface stroke)
2. Energy efficient
3. Reliable and long lived

In operation of these systems, it would be desirable to minimize the number of times necessary to enter the well bore from rod breaks, rod–on–tubing wear, or system redesign due to changing well conditions. Any actions should incorporate the principles of the recommendations of the Pioneer "Best Practices" program.

Concerning the 649 active wells, there is adequate data available for study (production, fluid levels, failure history), thus it is possible to investigate combinations of pumping system elements (pumping unit, rod string, and pump) utilizing as much of the existing equipment as possible, minimizing capital costs (ROI), increasing production, minimizing well re-entry due to in-well failures, and maximizing electrical use over a wide range of fluid levels. Every attempt should be made to improve the production to failure rate throughout the field.

INVESTIGATION

Pioneer Natural Resources began an extensive record-keeping program with the establishment of various databases in 1994. There is a considerable amount of information for study concerning wells within the Driver Unit.

Selection of subject wells was based on:

- Fluid levels and the need to increase production
- High in-well failure rates
- Gear box loadings

Fluid Levels

Investigations were made into the various types of well conditions found within the Unit. There is a considerable need to lower the fluid levels in many of the wells. Figure 1 demonstrates the difficulties encountered in overloading existing pumping units and existing rod strings. Any attempt with the current system elements to lower the fluid levels will result in overloading of the rod string, the pumping unit, or both. Methods of combating gearbox overloading (i.e. shorter surface stroke, smaller pump diameter, or lower cycle rate) will not produce enough fluid to lower fluid levels.

Failures

In consideration of failure history, only well bore entries consisting of rod breaks, tubing wear, and coupling failure was considered. Well entries for pump replacement, clean outs, chemical treatments, etc., were not considered failures for purposes of this report. The methodology for determining failures was applied consistently throughout the investigations.

Figure 2 demonstrates the failure history of a subject well, typical of the wells within the unit. The predominant modes of failure are in rod breaks and tubing leaks, particularly in the ¾" rod area. As a group, the subject wells had a Mean Time to Failure (MTF) incidence of 234 days.

Gear Box Loadings

Rod string weight plays a significant role in gear box loadings. In an attempt to lower gear box loading, a considerable amount of ¾" rods were used to lower rod string weight.
However, due to the smaller diameter, the ¾" section is subject to forces causing rod-on-tubing wear. Sinker bars are used to lessen the effects of such forces, which in turn increase rod string weight.

Additionally, it is found that increasing cycle rate increases gear box loadings and compressive forces on the rod string near the pump. While not applicable in the subject wells with all steel/ sinker bar rod strings, increasing pump plunger diameter increases compressive forces on the rod string.

The rod string contained in Figure 1 weighs 13,374 lbs. (in air). In cases that the fluid level of the well is lowered, the effects of rod string weight on gear box loading becomes more pronounced.

APPLICATION

Various combinations of fiberglass sucker rods (FSR), steel rods, and sinker bars were compared to determine a replacement string for the above well. Considered in selection of the FSR/steel/sinker bar rod strings include:

1. Lower the total rod string weight
2. Increase the amount of sinker bars to accommodate the compressive forces near the pump (effective weight)
3. Use of larger diameter steel rods above the sinker bars
4. Increased production with available surface equipment
5. Adaptable to changing conditions by making surface changes only (drive sheave changes to change speed)
6. Improve electrical use efficiency

Figure 3 represents the selected rod string, with the production possible at various fluid levels and cycle rates. It should be noted that there are no overloaded conditions of gearbox or rod string throughout the range of speed and pump cover. These combinations of system elements are capable of producing adequate production to accomplish the objectives. The rod string contained in Figure 3 weighs 10,573 lbs. (in air)

The use of FSR/steel/SB rod strings offers improved energy efficiency throughout the range of conditions. Figure 4 demonstrates the electrical usage per BF for all steel/sinker bar strings and for FSR/steel/sinker bar strings. Additionally, the percentage efficiency improves with decreasing pump cover. Also determined, and not demonstrated within the report, the electrical use efficiency improves with increased SND.

FSR rod strings have been installed in 221 wells in the Unit. Of this number, 38 of particular interest were selected for further study. These 38 wells were identified as being converted from all steel/SB rod strings due to particular circumstances of fluid level, failure, and / or production.

ANALYSIS

The graph referenced SDU 1812A typifies much of the situation in the SDU. Prior to conversion to FSR, production of gas and oil had remained consistent over time, and there has been little change in fluid level. At the conditions found mid-2001, the 228 gearbox was overloaded, and there had been several failures in the well bore, primarily due to rod-on-tubing wear. Following conversion to FSR, production was improved over time, and mean time to failure has been remarkably improved.

An example of declining production is provided in SDU 501. Over the previous 2 years, this well had seen a gradual decline in oil production. With a 228 pumping unit, the system was overloaded and prone to failure. After the well was converted to FSR/steel/sinker bar rod string, production increased, and the fluid level was lowered to allow for gas liberation.

An example of attempts to lower fluid level is shown in SDU 619. While a 320 pumping unit was used, high gearbox loading and in-well failures were significant factors. In the 2+ years following conversion to FSR, the longer mean time to failure period has increased the profitability of the well. It should be noted that production with an all steel string would not be possible at the current conditions without gear box and rod string overloads. As noted, stimulation of this well is currently recommended.

SDU 511A demonstrated a significant response to the conversion to FSR. Production became constant for the nine months prior to conversion, as the pumping system elements were near or beyond overloaded conditions. The well had a significant number of failures. After conversion to FSR, there has been a significant cumulative increase in production over time with no in-well failures in 1,416 days to report date (12/10/03).

SPECIAL CONSIDERATIONS

The graph referenced to SDU 281A represents the use of a well to influence the conditions and production of surrounding wells. After completion, production with the steel/sinker bar rod string was not sufficient to influence fluid level, or oil and gas production. After installation of a FSR/steel/sinker bar rod string, fluid production was increased to significantly decrease the fluid level, and improving oil and gas production during the next year. At the same time, it was noticed that the production level on this well directly affected at least 4 other wells. By taking the “big view” of in-field production, it was determined to continue a high level of production on this well to improve the profitability of the other wells.

SDU 890 is presented as an example of the use of FSR to increase initial production after completion. An attempt was made to produce with a steel/sinker bar rod string until it became apparent that the use of FSR was indicated to produce a significantly higher level of production. Only after the fluid level was lowered was any appreciable amount of gas produced.

SUMMARY

There is a good mix of old and new wells with steel/sinker bar rod strings, and old and new wells with FSR/steel/sinker bar rod strings within the Driver Unit. Records of production and failures for the entire Unit were tabulated, consistent with the stated objectives. By taking the total production of the Unit, and converting to a per well basis, it was found that fluid production was increased 209% by the use of the FSR rod string program.

As part of the stated objectives, the production to failure rates entire Unit were considered to determine the effects of the conversion to FSR rod strings against the all steel rod strings Coupled with the increase in production, the BF/failure ratio was improved 192% by conversion to FSR rod strings.

RECOMMENDATIONS

Based on the results of the application of FSR in the Driver and other units, and in conjunction with the “Best Practices” of Pioneer, there are several findings and recommendations that can be made. Properly designed fiberglass sucker rod strings are indicated in existing wells in conditions of:

1. High fluid levels

2. Small pumping units
3. High failure rates
4. Lowering SND

Additionally, in consideration of the objectives, and to maximize the effectiveness of capital purchases, FSR should be included in all new drills and locations.

SND		6550'
Pumping Unit		LC 228-246-86
Surface stroke		86
Rod String		
	2350'	7/8" D
	3900'	3/4" D
	300'	1 1/2" Sinker bars
1 ¼" insert pump		

Fluid Level		Cycle Rate		
		7	9	11
FFS	FAP			
1700	4850	132	186	234
4100	2450	124	165	198
5350	1200	118	146	191
5950	600	114	138	189

red = rods overloaded
shaded = gearbox overloaded

Figure 1 – Production (BFPD) at Various Cycle Rates and Fluid Levels
All Steel/Sinker Bar Rod String

SND		6550'
Pumping Unit		LC 228-246-86
Surface stroke		86
Rod String		
	2350'	7/8" D
	3900'	3/4" D
	300'	1 1/2" Sinker bars

October-98	Replace (37) jts tbg in 3/4 section
January-99	Replace (3) 3/4 rds Replace (20 jts tubing in 3/4 section
May-99	Replace (42) jts tbg same place as Oct 98
March-00	Replace (10) tbg in ¾ section Replace Sinker Bars Replace (32) 3/4 D Replace (60) 7/8 D
June-00	Box Break in 3/4 section

Figure 2 – Failure History
All Steel/Sinker Bar Rod String

SND		6550'
Pumping Unit		LC 228-246-86
Surface stroke		86
Rod String		
	3900'	1” FSR
	2250'	7/8" D
	400'	1 1/2" Sinker bars
1 ¼” insert pump		

Fluid Level		**Cycle Rate**		
		7	9	11
FFS	FAP			
1700	4850	131	199	276
4100	2450	118	184	249
5350	1200	110	174	228
5950	600	106	167	215

There are no overloaded conditions of rods or gear box

Figure 3 – Production (BFPD) at Various Cycle Rates and Fluid Levels
FSR/Steel/Sinker Bar Rod String

		STEEL/ SB		
	Cycle Rate	7	9	11
FFS	FAP			
1700	4850	0.98	0.98	1.13
4100	2450	1.39	1.46	1.80
5350	1200	1.64	1.83	2.07
5950	600	1.74	1.99	2.16

red = rods overloaded
shaded = gearbox overloaded

		FSR/Steel/SB		
	Cycle Rate	7	9	11
FFS	FAP			
1700	4850	0.88	0.86	0.96
4100	2450	1.42	1.32	1.39
5350	1200	1.56	1.56	1.62
5950	600	1.67	1.64	1.72

Figure 4 – Electricity Use Per Unit Volume (kwh/BF)