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Field Trials of Newly Developed Positive Displacement Submersible Pump

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Abstract

The purpose of this grant was to evaluate under real world conditions the performance of a new type of downhole pump, the hydraulically driven submersible diaphragm pump. This pump is supplied by Pumping Solutions Incorporated, Albuquerque NM. The original scope of the project was to install 10 submersible pumps, and compare that to 10 similar installations of rod pumps.

As an operator, the system as tested was not ready for prime time. The PSI group did improve the product and offered excellent service. The latest design appears to be much better, but more test data is needed to show short run life is not a problem. This product should continue to be developed; the testing did not uncover any fundamental problems that would preclude it's widespread use. On the positive side, the pump was easy to run, was more power efficient than a rod pump, and is the only submersible that could handle the large quantities of solids typical of CBM production. The product shows much promise for the future, and with continued design and testing, this type of submersible pump has the potential to become the standard of the industry.

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Introduction

The purpose of this grant was to evaluate under real world conditions the performance of a new type of downhole pump, the hydraulically driven submersible diaphragm pump and compare that performance to traditional rod pumps. Eighteen pumps supplied by Pumping Solutions Incorporated, Albuquerque NM have been installed in 6 different wells to date. The original scope of the project was to install 10 submersible pumps, and compare that to 10 similar installations of rod pumps. Frequent failure of the submersible pumps have required that the pumps be replaced to maintain production and to date have not allowed for a meaningful cost comparison between the two systems.

The PSI group has improved the pump to the point where in the next report, a meaningful cost comparison can be made. The bulk of this report is dedicated to reporting the installations completed and the results of those installations and corrective actions.

Executive Summary

As of the date of this report, 18 diaphragm pumps have been installed into 6 different wells, in Oklahoma, New Mexico and Wyoming. Results from some of the 18 installations are included as part of the test data, but were not paid for as part of this project. When the project started in 2001, the diaphragm pumps being offered by PSI were very experimental, and as such, many problems were encountered. Along the way (and as a direct result of this project) PSI was able to improve the design and gained valuable data from these field tests. With out the assistance of the DOE, it is doubtful that Beard Oil would have installed more than a couple of the early, short lived units.

The primary field where the test was conducted was the Weber field, which is one of the oldest oil fields in Oklahoma. It is a nearly depleted waterflood, producing on average 1 BOPD, with 90 BWPD. The waters are extremely corrosive due to the high oxygen content, and the presence of H₂S and CO₂. Wells in this area are notorious for their corrosive properties. The harsh conditions may well have accelerated testing of the pump, and probably led to shorter runs than would be experienced in other areas. The wells tested were 1300' and produced from a shot perforated 4.5" API casing. Other tests were conducted in the Red Mountain field in Western New Mexico, the San Juan Basin in New Mexico, and Teapot Dome in Wyoming. The San Juan Basin wells were coal bed methane wells, the rest were conventional Oil Wells.

As an operator, the system as tested was not ready for prime time. The PSI group did improve the product and offered excellent service. The latest design appears to be much better, but more test data is needed to show short run life is not a problem. This product should continue to be developed; the testing did not uncover any fundamental problems that would preclude it's widespread use. On the positive side, the pump was easy to run, was more power efficient then a rod pump, and is the only submersible that could handle the large quantities of solids typical of CBM production. The product shows much promise for the future, and with continued design and testing, this type of submersible pump has the potential to become the standard of the industry.

Experimental and Operating Data

The primary field where the test was conducted was the Weber field, which is one of the oldest oil fields in Oklahoma. It is a nearly depleted waterflood, producing on average 1 BOPD, with 90 BWPD. The waters are extremely corrosive due to the high oxygen content, and the presence of H₂S and CO₂. Wells in this area are notorious for their corrosive properties. The harsh conditions may well have accelerated testing of the pump, and probably led to shorter runs than would be experienced in other areas. The wells tested were 1300' and produced from a shot perforated 4.5" API casing. Other tests were conducted in the Red Mountain field in Western New Mexico, the San Juan Basin in New Mexico, and Teapot Dome in Wyoming. The San Juan Basin wells were coal bed methane wells, the rest were conventional Oil Wells.

The table below is in chronological order, depicting the installation, the run time, the cause of failure, and the corrective action. The discussion following will show how the pump has improved over the life of the grant and how the testing uncovered design weaknesses that PSI needed to correct, and how those were ultimately corrected.

Installation Location	Date	Run Time (days)	Cause of failure	Solution
Tiger #2, San Juan	10/9/01	1	Mechanical cable damage	Reinstall with new cable
RMOTC	11/6/01	95	Frozen Output due to low surface temp	Operator Procedure
Weber #1	11/29/01	8	Electrical- due to splice failure	Reinstall with new splice
Weber #1 reinstall	12/12/01	45	Leak in hydraulic system	Crimp procedure and design
Red Mountain #12	12/15/01	710 days- still good	None- but not on continuous run	
Red Mountain #14	1/9/02	679 days- still good	None- but not on continuous run	
Tiger #2 Reinstall	1/14/02	1	Cable pinched on install	More robust cable
Weber #1	2/6/02	14	Leak in sensor diaphragm	Better QA procedure
Weber #1	2/28/02	1	Foreign material in hydraulic system	Better filtration and QA
Golden Bear #4 San Juan	3/14/02	90	Electrical due to surface switchbox	Operator Problem
Tiger #2 Reinstall	3/22/02	14	Electrical Overload	Larger Generator
Weber #1	4/5/02	21	Cow ate cable	Surface fence added
Weber #1	5/1/02	60	Outcheck backed out	Locking mechanism added
Tiger #2 Reinstall	5/23/02	4	Operator shut in pump	Operator procedure
Weber #1	7/15/02	4	Cable damage at clamp	Change clamping procedure
Weber #1	9/25/02	0	Check valve not	QA procedures

			installed	change
Weber #1	10/2/02	45	Corrosion	New PD Pump design
Weber #1	11/11/02	Pump pulled		

Data Reduction

Statistics

Raw data average run time- 105 days

Removing data points less than 4 days- 162 days

Results and Discussion

The average run time for a rod pump in the same field over the same period of time was 270 days- significantly longer than the diaphragm pump. Many of the failures are explainable and not due to pump design, but on average, the pump did not achieve sufficient run time to be considered a replacement for the rod pump in this situation. In the CBM wells, the pump did achieve a small but significant increase in gas production, about 20%, but it did not last long enough to determine if the increase is sustainable. It is interesting to note that the replacement pumps in both the Tiger #2 and the Golden Bear had much worse performance than the diaphragm pump, indicating that high solids content found in these wells make short run times the norm.

The PSI diaphragm pump design has improved significantly over the life of this program, as a direct result of this testing. The following improvements/changes were made to address problems uncovered during the test program:

More robust cable.- The project started out using low cost water well type PVC cable, this did not perform in the mechanical environment, and had gas saturation problems in CBM wells. The project switched to a Polyethylene jacket cable that performed much better.

Better Splice- The project started out using a water well type splice that is a thermoshrink sleeve with a resin filler that is designed to melt and fuse with the insulation. This type of splice is not compatible with the oil well environment, and failed several times during the course of the project. A Teflon tape splice was used later on and did not fail in several subsequent installations.

QA procedures- Many of the later failures were due to QA problems that arose when the pumps went from being hand made in Albuquerque to a factory in Oklahoma. The transition uncovered several problems that were subsequently corrected.

Corrosion- This was the most serious problem uncovered and could not be solved simply. It required the manufacturer to come up with an all stainless steel pump cover to prevent the problem.

Non-Problems- The pump did not suffer any unexplained motor or hydraulic system failures, and diaphragms removed from the tests appeared to be as good as new. Sand clogging was not a problem in any test, the pump seemed to be tolerant of an amazing amount of sand. No wear was ever detected on any of the parts.

Conclusion

As an operator, the system as tested was not ready for prime time. The PSI group did improve the product and offered excellent service. The latest design appears to be much better, but more test data is needed to show short run life is not a problem. This product should continue to be developed; the testing did not uncover any fundamental problems that would preclude it's widespread use. On the positive side, the pump was easy to run, was more power efficient than a rod pump, and is the only submersible that could handle the large quantities of solids typical of CBM production. The product shows much promise for the future, and with continued design and testing, this type of submersible pump has the potential to become the standard of the industry.