MULTI-PHASE PUMP IN WEST TEXAS

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INTRODUCTION

The Multi-Phase pump was designed in 1998 to attempt to pump wells that exhibited very foamy, compressible fluid mixtures which are inherently hard to pump with a conventional sucker rod pump. The design of this pump varies from traditional rod pumps whereby the standing valve is re-positioned at the top of the pump barrel. This factor, along with a specially designed set of seals and poppet assembly have led to the success of this pump.
An area of west Texas was targeted to try this pump after a very successful introduction to the oil patch in western Canada.

PRINCIPALS OF OPERATIONS

A key component of the Multi-Phase pump is the poppet valve situated at the top of the pump. This valve fits around the pull rod and restricts produced fluid from reentering the pump. This poppet valve differs from other common ring or load valves in that it uses rod seals and precision seal faces to provide a 100% positive seal. This positive seal allows the valve to act as a standing valve, eliminating the conventional closed standing valve at the bottom of the pump and resulting in unrestricted barrel fillage.

To maintain valve spacing and adequate compression the traveling valve is relocated to the top of the plunger (Fig. 1). Top open plunger cages can generally be designed with more flow area than closed cages. This means smaller pressure drops and less entrained gas break out. Since the Multi-Phase pump is still somewhat subject to the gas compression requirements of a conventional pump, reduced free gas does improve overall system efficiency.

This pump is distinct from all other forms of gas control equipment and pumps in that it is a single stage, zero slippage system that all but eliminates the occurrence of gas lock without using mechanical means of valve opening (which typically also result in increased valve spacing and therefore reduced potential volumetric efficiencies). What truly gives this pump a distinct advantage is that the rod seals result in several hundred pounds drag on the poppet valve assembly. This means that at the top of the upstroke when the gaseous fluid is being compressed between the two valves there is a significant "assist" occurring to open that standing valve and discharge fluid into the tubing (Fig 2). With a properly designed and spaced Multi-Phase pump this "assist" is the hundred or so extra pounds required to open the valve that even a high compression conventional pump does not have. At the beginning of the downstroke the rod seal drag instantaneously seats the standing valve poppet, alleviating the ball chatter associated with conventional valve action in high gas production situations.

EVOLUTION OF DESIGN

The positive seal ring standing valve assembly was originally developed as part of a diluent injection system for a viscous fluid pump. The original one piece poppet and composite polyurethane seat design was particularly adept at producing gasified viscous fluids with large amounts of sand. However service life was typically limited by the hydraulic rod seals or the composite seat.

More advanced elastomeric materials were used over the years to address the widening variety of fluid characteristics and operating conditions that the valve was being used in. These materials had varying levels success.

Three years ago, a major effort was undertaken to reengineer the existing valve to overcome its major limitations and enable application to an even broader range of conditions found in light oil production. The poppet was changed to a modular design (Fig. 3) to allow for more hydraulic rod seals and a more rugged wiper system without physically deforming the components to install them in the poppet. Additional rod seals provide further redundancy and extended service life as well as providing additional rod friction for improved valve action and gaseous fluid performance. The wipers allow for limited if any foreign material bypass that would otherwise reduce seal performance. Hardened components have been utilized to provide long term wear and centralization to the rod seal interface that is normally under a high degree of side loading either due to well deviation or to compressive loading. Finally, the composite elastomer seat has been replaced by a proven carbide material and matching poppet seal face.

APPLICATIONS. MATERIALS. AND SYSTEM SIZING

Although the redesign allowed this pump to be run in an almost limitless variety of conditions the Multi-Phase pump's niche is without a doubt in high GOR foamy fluids with gradients below 0.2 psi/ft.

Elastomeric rod seals and wipers are a combination of advanced nitriles and polymers that can be used in even the most severe downhole environment. The modular poppet design has allowed running to depths of 8000 ft, far exceeding seal manufacturers' specifications.

As the rest of the pump is like an API insert, all conventional materials like stainless steel, Monel, and Nickel Carbide are available.

System sizing is slightly different from conventional rod pumps in that the production chamber is above the plunger. The pull rod is now positioned between the Traveling and Standing valves, displacing area within the pump barrel. This means that the pull rod diameter has to be taken into consideration as it reduces the effective bore of the pump (Table 1). The pull rod cross-sectional area must be subtracted from the swept area of the plunger to calculate a pump constant and determine the net displacement of the pump. Even with this taken into consideration, volumetric efficiencies of the Multi-Phase pump are typically double or triple that of a conventional pump.

CASE HISTORIES

Mobil Oil and Texaco were two companies who installed Multi-Phase pumps in their west Texas fields of the Permian Basin, with pumps being installed in the Texaco Slaughter field in late November, 1999 and Mobil installing the Multi-Phase pump in the F.L. Woodley field in early February, 2000.

The Texaco Slaughter field is in the Permian Basin producing from the San Andres formation at a pump seating depth of 5027 feet. This well is a deviated, open hole completion (open hole from 5102 – 6079 feet), with the pump set at approximately 15 degrees from vertical. The San Andres formation is a light crude oil (32-35 degree API oil), high CO_2 formation with a fluid pH of 6.0 and having a chlorides content of 60-100,000 ppm. This field has been on an active CO_2 flood drive since 1994.

Due to the highly corrosive environment, the Multi-Phase Pump was equipped with a brass/Nicarb barrel, Silicone Nitride over carbide valves and upgraded with monel insert guided cages and plunger pins. The description of the pump installed was a 25-150-RHAC-24-4 Multi-Phase.

The well chosen to test the Multi-Phase pump was Slaughter **SSU** #1361H.Previous to this installation, the well was equipped with an electrical submersible pump and was averaging the following production:

	Oil	Water	Gas	GOR	GLR
Before Multi-Phase	48.3	157.6	478.5	9907	2324
Post Multi-Phase	19.4	138.3	199.5	10,310	1266
Current Production	28.0	125.0	320.0	11,429	2092

The Slaughter **SSU** #1361H well is now equipped with a Lufkin M640-305-168 unit operating in the Pitman #3 (130 inch stroke) at 8.2 spm. This well has 2 7/8 inch tubing and a 1.5 inch insert Multi-Phase pump set at 5027 feet. The rod string is an API #86 design with some 1.O-inch sinker bar on the bottom. This well has an Echometer "Total Well Management" well controller on it to monitor loads and production. A summary of loads and pump efficiencies taken over a three-month period after installation of the Multi-Phase pump exhibit excellent pump fillage and efficiency (Table 2).

All dynamometer and depression test information (Figs. 4-10) indicated minimal additional production was available (near pumped off condition). Pump intake pressures were calculated utilizing the McCoy & Gilbert methods of calculating a pump intake pressure from a casing pressure build-up vs. time. From these results, a two phase gradient of foam and fluid existed in the well with the foam segment having a gradient of 0.197 psi/ft.; changing into a solid liquid gradient of 0.345 psi/ft. deeper in the well.

At the time of writing, the Multi-Phase pump has been in this well now for over one year. The current average efficiency of this pump is 87.1% and is running at 90% of controller run time over a 24-hour period.

Average run lives of conventional sucker rod pumps in **this** field has been three years. However due to Slaughter SSU #13 16H being deviated, it is not considered to be in the same category as the other vertical wells.

PUMP LIFE HISTORY-UNIQUE OPERATING PRINCIPLES

This pump has been in **this** well for over one year. Due to the Standing Valve/Poppet assembly being located at the top of the pump, the pump is required to be spaced as close to top tap as possible to maximize the compression between the valves.

Another characteristic of the Multi-Phase pump is since the seals on the valve rod are a very close tolerance; surface testing of the pump by the service rig is very difficult. Due to the increase of friction on the Valve rod, it is recommended that a 5-cup friction hold-down be incorporated on the pump to provide for better hold-down force.

Since installation of **this** pump and two-way communication with the Texaco Operations staff, there have not been any major operational problems with this pump. Communication to understand the spacing of the pump to the top of the barrel and the pump efficiency calculations were the only two situations which required clarification,

MOBIL OIL FIELD OVERVIEW

The Multi-Phase pump was run into Mobil Oil's F.L. Woodley FL #002 well in the west Texas Permian Basin. **This** well is a vertical well with the pump landed at 4893 feet. This well is producing from the San Andres formation of the Permian Basin, with light, 32 to 35 degree API oil. The description of the pump is a **25-150-MAC-20-4** Multi-Phase.

The well is equipped with a Lufkin 228-213-120 unit operating at 8.3 SPM **X** 120 inch stroke length. The Multi-Phase pump was installed in early February, 2000 and had a run life of 94 days prior to being pulled. Prior to being pulled, the well was pumped off.

Production numbers for F.L. Woodley FL#002 are the following:

	Oil	Water	Gas	GOR	GLR
Before Multi-Phase	22.0	2.0	126.0	5727	5250
After Multi-Phase	20.0	30.0	90.0	4500	1800
Current Production	18.0	26.0	122.0	6778	2773

Upon inspection after being pulled, it was found that the poppet assembly in the Standing Valve had failed prematurely. Since **this** failure, the brazing procedure to braze the carbide insert onto the face of the poppet has been refined and there have been no subsequent failures in over 50 carbide tipped poppets installed.

The pump was pulled and a conventional pump was re-installed into **this** well. Dynamometer information for the Multi-Phase pump was limited. The information gathered initially after installation indicated a flumping well with no apparent pump function.

CONCLUSIONS

Although there have been more than 40 successful installations in Western Canada, the Multi-Phase pump requires more field-testing in Texas to evaluate its commercial viability in these area specific conditions.

It does show promise in high **GLR** wells and may eliminate the need to tap bottomhole pumps which can lead to early failures.

ACKNOWLEDGEMENTS

The authors would like to thank the engineers and production people of Texaco and Mobil Oil for providing data on the field tests along with the personnel of Quinn Pumps USA for providing logistics support.

Table 1
Effective Pump Bore

Pump Size (in)	Valve Rod Diameter 0.688	0.875	1.062
	Effective Pump Bore (in)		
1.062	0.81		
1.25	1.04	0.89	
1.50	1.33	1.22	
1.75	1.61	1.52	1.39
2.00		1.80	1.69

Table 2
Texaco Slaughter SSU #1361H Loads & Efficiencies

	Test Dates				
	12/28/99	12/30/99	01/05/00	02/23/00	02/27/00
PPRL (lbs)	13,200	13,200	13,100	13,800	13,500
MPRL (lbs)	6,800	7,000	7,000	6,200	7,200
Polish Rod HP	6.5	6.8	6.6	7.0	6.3
Rod Loading (0.85 SF)	57.1	57.0	56.9	60.7	58.3
Pump Fillage (%)	**99.4**	**98.7**	**93.4**	**96.8**	**29.4**
SPM	8.2	8.1	8.1	8.7	8.5
Surface Stroke (in.)	130	130	130	130	130
Pump Displacement	**185.0**	**187.0**	**188.8**	**207.0**	**198.6**
Oil Production (BID)	52.0	31.2	26.4	27.6	33.3
WaterProduction (BID)	289.0	150.4	144.6	139.2	159.2
Gas Production (Mcf/D)	81.0	313.7	313.2	114.4	110.7
Pump Eficiency (%)	**184.3**	**97.1**	**90.6**	**80.6**	**97.0**
Casing Pressure (psi)	104.8	64.7	82.3	63.0	59.3
Pump Intake Pressure(psi)	398.6	438.1	233.7	984.6	547.3

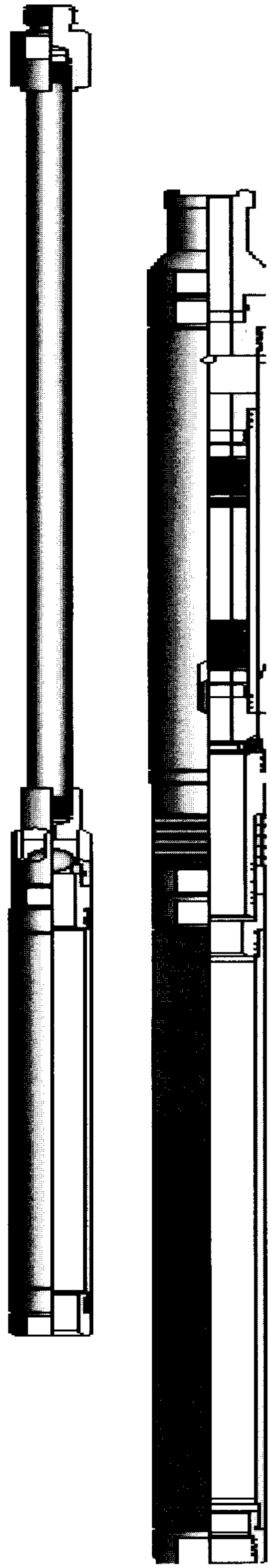


Figure 1

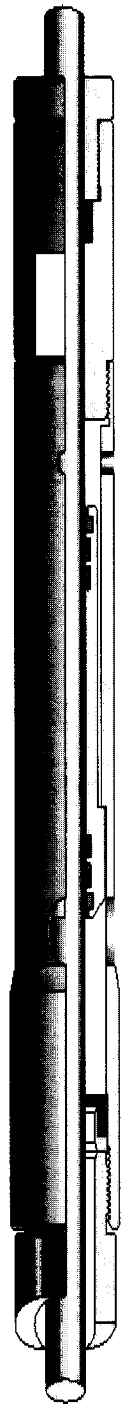


Figure 2

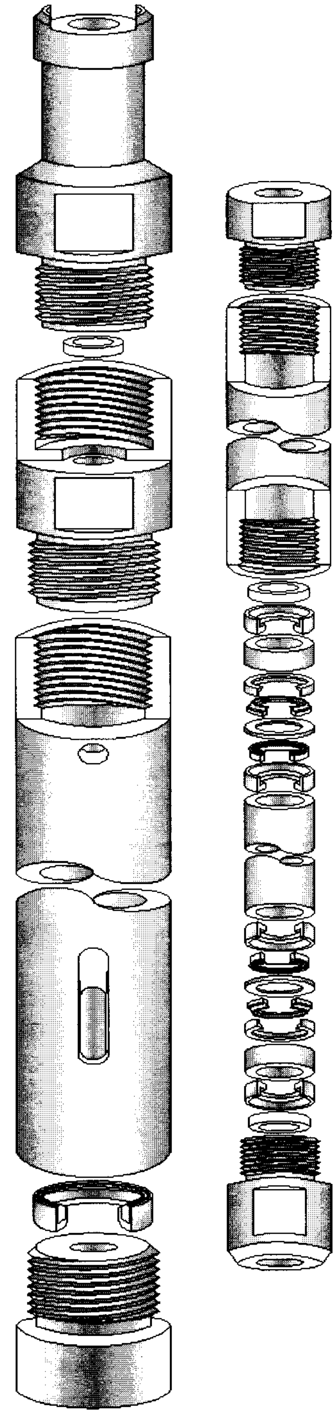
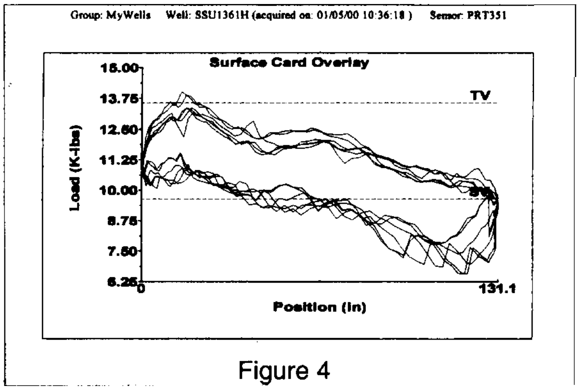


Figure 3



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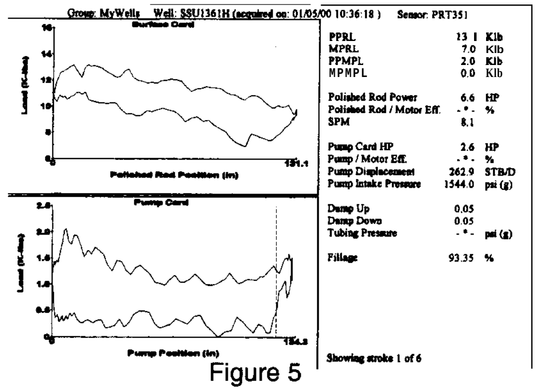
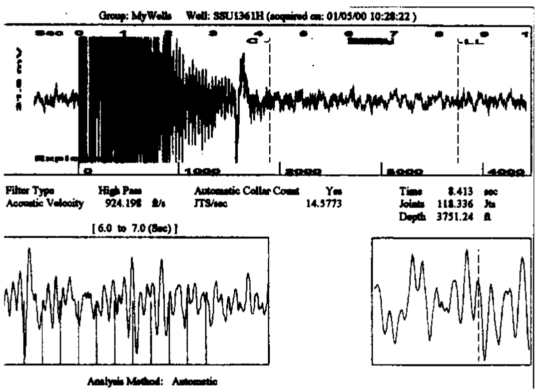


Figure 5



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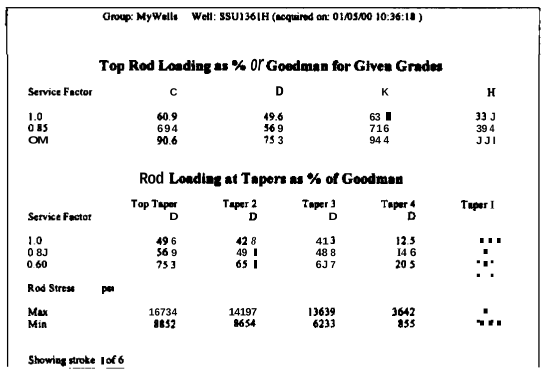

Group: MyWells Well: SSU1361H (acquired on: 01/05/00 10:36:18)

Top Rod Loading as % Of Goodman for Given Grades

Service Factor	C	D	K	H
1.0	60.9	49.6	63	33 J
0.85	69.4	56.9	71.6	39.4
OM	90.6	75.3	94.4	J J I

Rod Loading at Tapers as % of Goodman

Service Factor	Top Taper D	Taper 2 D	Taper 3 D	Taper 4 D	Taper I
1.0	49.6	42.8	41.3	12.5	
0.8J	56.9	49.1	48.8	14.6	
0.60	75.3	65.1	6J.7	20.5	
Rod Stress psi					
Max	16734	14197	13639	3642	
Min	8852	8654	6233	855	

Showing stroke 1 of 6

Figure 7

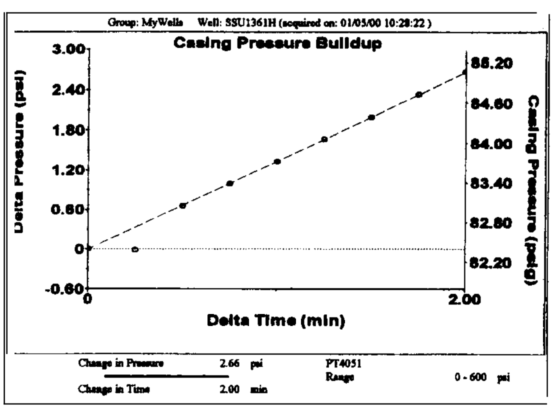


Figure 8

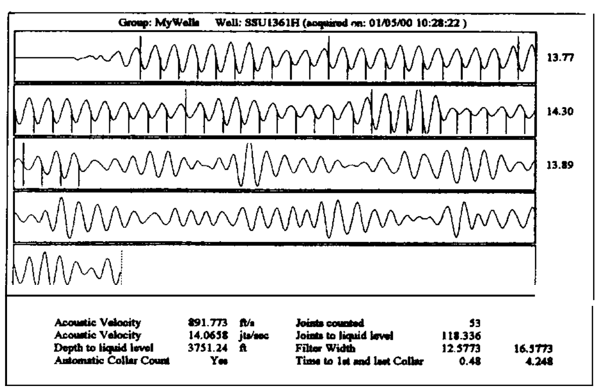
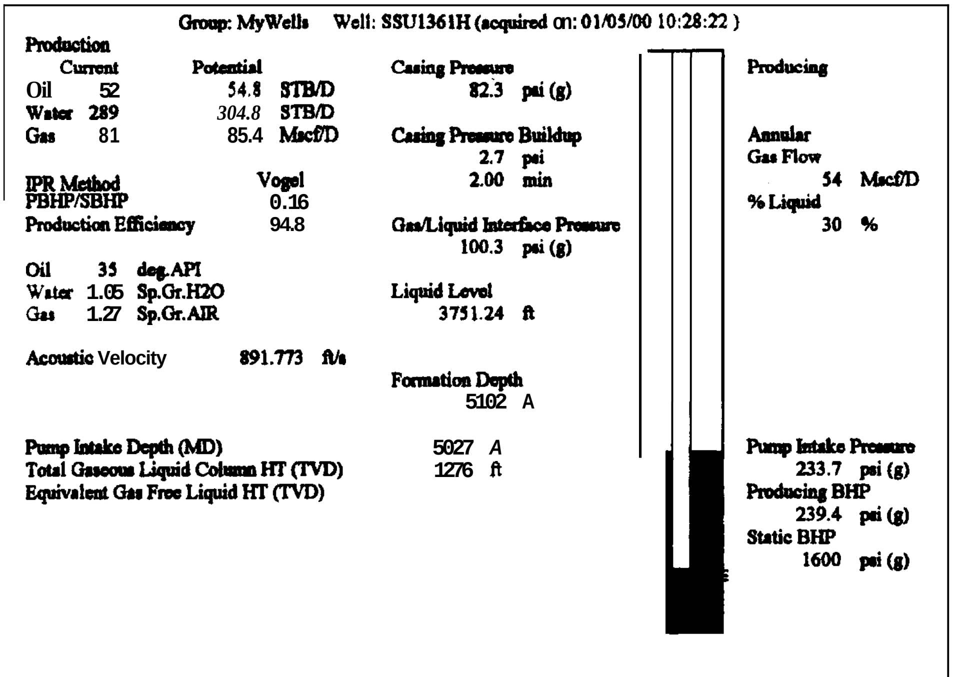


Figure 9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Production
Current Potential
Oil 52 54.8 STB/D
Water 289 304.8 STB/D
Gas 81 85.4 Mscf/D
IPR Method Vogel
PBHP/SBHP 0.16
Production Efficiency 94.8
Oil 35 deg.API
Water 1.05 Sp.Gr.H2O
Gas 1.27 Sp.Gr.AIR
Acoustic Velocity 891.773 ft/s
Pump Intake Depth (MD) 5027 ft
Total Gaseous Liquid Column HT (TVD) 1276 ft
Equivalent Gas Free Liquid HT (TVD)
Casing Pressure
82.3 psi (g)
Casing Pressure Buildup
2.7 psi
2.00 min
Gas/Liquid Interface Pressure
100.3 psi (g)
Liquid Level
3751.24 ft
Formation Depth
5102 ft
Producing
Annular
Gas Flow
54 Mscf/D
% Liquid
30 %
Pump Intake Pressure
233.7 psi (g)
Producing BHP
239.4 psi (g)
Static BHP
1600 psi (g)

Figure 10