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# Experiences and Best Practices in the use of PCP in Orinoco Oil Belt - Ayacucho Division, San Tome Area, Venezuela.

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## Abstract

*The evaluation of Progressing Cavity Pumps (PCP) in The Orinoco Oil Belt - Ayacucho Area, began in the 90's, in order to handle high and low volumes of Heavy Oil with API gravities between 8 and 10°. Currently, this Artificial Lift Method represents 40% of the wells population in this area providing 60% of daily production.*

*During the evaluation process of this technology it has been necessary to introduce improvements regarding pump design, well completion and fluids handling in order to enhance wells production, increase systems run life and reduce operational expenses.*

*Some of the best practices and technologies that have been evaluated and are still running in San Tomé wells, are: Gas Separators and gas handlers which have been installed in vertical and deviated wells, and recently in horizontal wells with successful results. Currently, this type of equipment are been evaluated in Laboratory in order to determine their efficiency. Insertable PCP Systems, in order to reduce the work over expenses. Tapered PCP, in order to minimize gas blocking condition due to high Gas Oil Ratio handled by PCP during a short production period. PCP for High Temperature which have been installed in deep wells and Steam Injection Projects. PCP with Hydrogenated Elastomers, in order to minimize problems due to incompatibility of elastomers with diluents and some components of crude oil in Dobokubi Field.*

*This paper describes technologies and experiences which main application has been to improve the behavior of PCP and increase wells' production of San Tomé Area.*

## Introduction

The Orinoco Oil Belt, contains the world's largest liquid hydrocarbon reserves (296.500 million barrels of OIP), it covers an area of 21357 square miles, and it is located within the limits of the states Guarico, Anzoátegui and Monagas. This large oil reserve is divided into four main areas, being from West to East: Boyacá, Junín, Ayacucho and Carabobo, and in turn segmented in 29 blocks of 193 square miles each one approximately. San Tomé is located in the Ayacuho area; it covers 2773 square miles, with an estimated OIP of $61.5 \times 10^9$ barrels of extra-heavy oil.

The extra-heavy oil that is currently being produced in the area has gravity values ranging between 8 and 10ºAPI, and viscosities between 1000 - 2500 cP at a reservoir temperature of 135°F. Along the production history it has been necessary to implement drilling and production technologies in order to be able to exploit the extensive extra-heavy oil reserves economically. Particularly, the use of horizontal wells and the development of artificial lift systems, have resulted in incrementing significantly the production targets to 1000 BOPD per well compared to the former 200 BOPD.

The use of PCPs has reduced the lifting cost and increase the reliability of the system. The applicability and development of this artificial lift method is presented in this paper.

## Reservoir Description

The reservoirs of interest in San Tomé, are located in middle and inferior Miocene age, consisting of unconsolidated sandstones with moderate intercalations of shale and saturated with extra-heavy oils. Reservoir quality is excellent, with porosities between 28 and 32%, and permeabilities of 3 to 10 Darcy. The reservoir drive mechanisms are compressibility of rock and fluids and solution gas drive. The most relevant reservoir properties are as follows:

**Table 1. Typical Reservoir Properties for San Tomé Area**

| | |
|---|---|
| Depth (ft) | 3,000 - 4500 |
| Reservoir pressure (psi) | 1050 - 1200 |
| Reservoir temperature, $T_r$ (°F) | 135 |
| Oil gravity (°API) | 8 - 10 |
| Solution Gas/Oil ratio (scf/STB) | 450 |
| Oil formation volume factor (bbl/STB) | 1.08 |
| Viscosity at $T_r$ (cP) | 1200 - 3000 |
| Porosity (%) | 28 - 32 |
| Permeability (Darcy) | 3 - 10 |
| Initial water saturation (%) | 18 |

**Table 1. Typical Reservoir Properties for San Tomé Area**

## Gas Separators PCPs

Performance of PCPs installed in San Tomé District has been successful in terms of production and lifetime of the pumps. However, in recent years there has been a considerable increase of GOR (>1200 scf/STB), affecting the pumping efficiency (< 40%) and decreasing pumps' lifetime, this is mainly because of high friction and low lubrication between the rotor and stator. Free gas enters into the cavities of the pump and reduces its volumetric efficiency. Large gas volume can quickly damage the elastomer; it results into gas permeation (blisters within the elastomer) or explosive decompresion (elastomer rupture).

Due the reasons mentioned before, in 2005 it become of extreme importance the evaluation of gas separators and devices to separate the gas from liquid in wells with PCP in horizontal and deviated wells. The models evaluated are: Static Helix Separator, which combines the effect of turbulent and centrifugal flow; Horizontal Gas Separator (inflow V-Shaped), which have an oscillating intake in order to deviate free gas to annulus and Poor Boy Separator, which is provided with a dip tube and mud anchor with perforations.

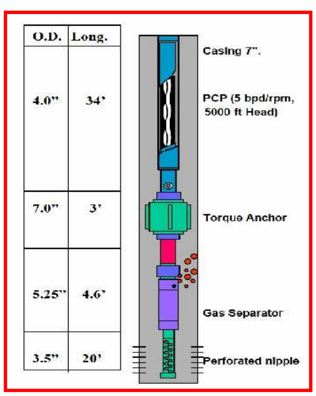


**Fig. 1. Diagram of completion with Gas Separator**

Some of the benefits of the gas separators are:

- Enhacement of the pumping efficiency by increasing the fraction of liquid inside the pump.
- Increment of liquid rates of the well.
- Reduction of the effects associated with acid gases (corrosion and abrasion) in tubing, casing and rod string.
- Increment of the elastomer lifetime for the following reasons:
  - Reduction of heating within the elastomer and prevention of gas permeation.
  - Better lubrication inside the pump.
  - Reduction of the rotor-stator contact.

The results obtained from the evaluation of 15 wells in Melones, Bare and Arecuna fields, are the following:

- Increment of production rate: 2280 bpd (14% in comparison with the original rate from these wells).
- Increment of of the pump lifetime: 12 to 18 months.
- Increment of pumping efficiency: 30 to 40%.
- Separation efficiency measured in field (viscosity of foamy oil: 2500 cP to 135 ºF):
  - 25% Static Helix Separator
  - 35% Horizontal V-shaped Separator
  - 55% Poor Boy Separator.

In addition to the field evaluation, some experimental tests were conducted at the Intevep's Artificial Lift Laboratory. Poor Boy and Static Helix Separator were evaluated at different of liquid and gas rates (test fluids were Oil: 400 cP and air). The first separator showed better separation efficiency than the second one, the registered values were 80 and 40 percent respectively (See Figure 2):

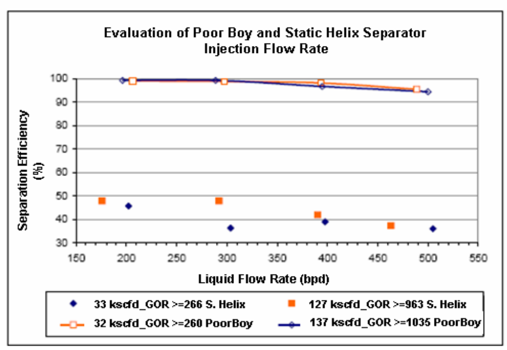


**Fig. 2. Separation efficiency obtained in laboratory tests**

## Insertable PCPs

Insertable PCPs were first evaluated in San Tome District in 2004. The equipment was deployed in two wells of Bare field, however the duration of these pumps was less than three months; the failure was related to problems with the geometry of the pump which was longer (>90 feet) than conventional PCPs and thus was affected by any severity of dogleg in the well.

In 2006, a second generation of insertable PCPs was tested for the original completion of the well MFB-665. The anchorage mechanism of this pump relies on two systems: an upper seal which is a seating nipple and a lower seal in order to prevent rotational movement. Performance of this pump in the well MFB-665 has been outstanding and after eight years the equipment is still running maintaining the required operational conditions for this well.

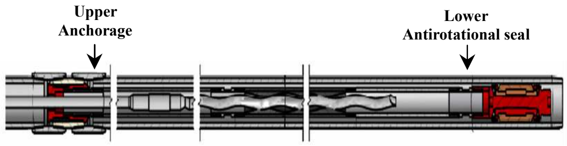


**Fig. 3. Scheme of the insertable PCP**

Between 2011 and 2012 more than fifteen insertable systems have been installed in Bare and Melones fields. The main benefit of this equipment is obtained once its replacement needs to be done, because the intervention of the well is done using a flush-by unit instead of a service rig. Cost savings for replacement of the AL equipment are around 75% and production deferment due to well service is reduced from 4 to 2 days.

Another mechanism that has been designed in collaboration with a local manufacturer allows the deployment of a regular tubular PCP as an insertable pump. This tool replaces the function of the traditional seating nipple in the production tubing. The design is based on the use of a mechanically retrievable anchorage tool at the bottom of the PCP assembly which makes possible the intervention of the well with a flush by unit directly. In this case the costs savings for equipment replacement and reduction of production deferment can be obtained at once, when the well service is executed.

## Charge PCPs

Charge pumps are short lifting and high volume PCPs which are installed below a regular production PCP. The separation principle is based on the creation of turbulence and a state of hyper pressurization in the perforated pup joint, which allows gas transfer towards the annulus between casing and pipe production, avoiding direct entrance of gas to the production PCP; this condition prevents damages to elastomer and increase the pump lifting efficiency. The perforated pup joint is located between charge and production pumps. Figure 4 shows the configuration of this system:

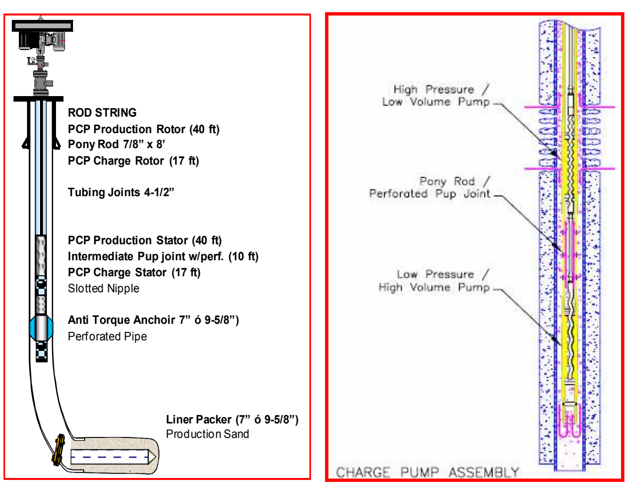


**Fig. 4. Well and Charge PCPs Configuration**

Charge pumps have proven to be a useful technology to improve liquid production in high GOR wells and maintain production in heavy oil wells with high sand cut (keeping pump intake free of sand). Some of the benefits are the following:

- Increase the liquid rates and minimize the free gas at the intake of the primary production pump.
- Increase the elastomer lifetime thus reducing the work over expenses.
- Improve the lubrication inside the pump (reduction of the rotor-stator contact).

Charge pumps were installed in 5 wells of Melones, Bare and Arecuna fields, the field results of the evaluation are the following:

- Increased lifetime of the pump (>365 days, See Fig. 5)
- Improved production rates: up to 3 times the initial figure.
- Reduced work over expenses: around $81.000 per well in one year.

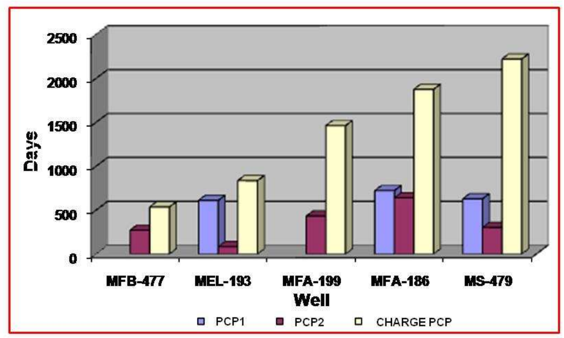


**Fig. 5. Performance of Charge PCPs tested in STM Area**

## High Temperature PCPs

Cyclic Steam Injection (CSI) has been performed in San Tome District since the early 80s. In average, a group of 15 wells is recommended annually for CSI in Bare and Melones fields. Historically, these wells have been completed using sucker rod pumps in order to handle the high temperature of the fluid after the CSI process. However, some of the candidates have been initially completed with Progressing Cavity Pumps. In these wells, it has been necessary to change the downhole equipment and surface facilities incrementing the OPEX of the project.

Since 2003, some special designs of PCPs have been evaluated as an alternative to avoid the change of completion in those PCP wells included in the CSI project. In 2003 a hybrid PCP was installed in the well MEL-153, the design included a metal stator with a lower Teflon stage in order to increase tolerance between rotor and stator. During 2005 and 2006 a next generation of these hybrid pumps was evaluated in the wells MFB526 and MFB456 respectively, the new design incorporated an upper elastomeric sacrifice stage with high content of viton and a lower metal stator.

In 2012 the all metal PCP was deployed into the well MFB722 obtaining outstanding results over a period of three months before its failure, this equipment operated at a high efficiency (75%) displacing in average 665 STBOD, 85 BWD and 320 MSCFD. A summary of the performance of each pump is presented in Table 2.

**Table 2. Performance of high temperature PCPs tested in STM District**

| Well | Average Bulk Production (BPD) | Duration (Days) | Cause of Failure |
|---|---|---|---|
| MEL-153 | 415 | 24 | Detachment of Teflon Stage |
| MFB-526 | 368 | 35 | Tear of Viton Stage |
| MFB-456 | 592 | 584 | Normal Wear |
| MFB-722 | 750 | 91 | Cracks on the surface of the stator |

It is suspected that the failure on the all metal PCP was caused by high rotor vibration; however it is intended to continue the evaluation of this pump as some optimizations have been made to the original design in order to reduce this effect.

**Fig. 6. Discharge section of the all metal PCP that failed in the well MFB-722**

In comparison with the Sucker Rod Pumping completion, the use of High temperature PCPs would represent average savings of 50% regarding Artificial Lift equipment. Additional benefits, count on reduction of production deferment after steam injection and opportunity for handling higher rates of fluids (> 800 BPD) as those expected from most thermal processes that are planned to be implemented in the area.

It is also planned to evaluate a new generation of elastomeric PCPs resistant to temperatures up to 350°F, in these new designs the elastomer is attached to the stator tube by using both chemical and mechanical bonding.

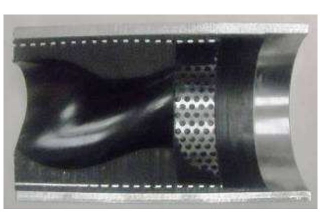

**Fig. 7. Detail of reinforcement of chemical bonding by using stainless steel net welded to the stator tube**

## Hydrogenated PCPs

One of the main problems encountered during operation of PCPs is the direct effect of aromatics on elastomers. The incompatibility between the fluids of the well, diluents and the elastomer can drastically decrease PCP lifetime.

Hydrogenated elastomer (HNBR) is obtained from a process to transform standard NBR (Acrylonitrile Butadiene Rubber) elastomer into a highly saturated nitrile. This elastomer was developed to obtain better mechanical properties, for this reason it is more resistant to acid gases ($CO_2$ and $H_2S$) and higher temperature (up to 300°F). For this application it is necessary to use a low interference between the rotor and the elastomer.

In recent years some wells in different areas have presented premature failures, being the main cause elastomer swelling. Through laboratory tests it was determined that the contents of aromatics within the crude oil was high (more than 35% according to SARA reports). This condition was affecting the performance of the PCP as the standard elastomer used in the area was NBR. In order to minimize this problem the hydrogenated elastomer was evaluated in these wells. In total, 23 pumps with HNBR elastomer have been installed, including wells of Dobokubi (where the runlife of the pumps were the shortest), Bare, Melones, Guara, Miga and Arecuna fields. The results have been successful in terms of lifetime of the pump. Comparing the runlife before and after the installations, there have been an increase from 3 to 12 months; therefore, production deferment and well service costs were reduced.

## Conclusions

- The experience with gas separators in horizontal and deviated wells, showed improvements in production (14%), increased pumping efficiency (30 - 40 %), and increased lifetime of the pump (12 to 18 months).
- The separation efficiency measured in wells for Static Helix Separator is 25%, while for the Horizontal V-Shaped and Poor Boy Separators are 35 and 55% respectively.
- Insertable PCPs provides cost savings of 75% reference to the operational cost for replacement of the pump and around 50% of service rig time saving.
- With the use of Hydrogenated PCPs, the lifetime was increased from 3 to 12 months.
- The evaluation of high temperature PCPs would allow optimisation of the current designs in order to provide alternatives for handling high production rates estimated for thermal recovery processes in STM.

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## NOMENCLATURE

| | | |
|---|---|---|
| *OIP* | = | Oil in Place |
| *BOPD* | = | Barrels of Oil per day |
| *PCP* | = | Progressing Cavity Pump |
| *Ft* | = | Feet |
| *Psi* | = | Pound per square inches |
| *°F* | = | Fahrenheit |
| *scf* | = | Standar cubic feet |

| | | |
|---|---|---|
| *STB* | = | Standard barrel |
| *bbl* | = | Barrel |
| *cP* | = | Centipoise |
| *GOR* | = | Gas Oil Ratio |
| *AL* | = | Artificial Lift |
| *STM* | = | San Tomé |
| *CSI* | = | Cyclic Steam inyection |
| *OPEX* | = | Operational Expenditure |

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