FIVE YEARS OF PCP PRODUCTION WITH HOLLOW SUCKER RODS IN SOUTH ARGENTINA

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ABSTRACT

Conventional Sucker Rods were designed and thought for Beam Pumping applications as well as their make-up process (with circumferential displacement). Unfortunately, this resulted in a significant number of connection failures (which is supposed to be stronger than the rod body).
A line of Hollow Sucker Rods (HSR) was developed with better material distribution and several other advantages but basically providing more reliability due to the fact that they were thought from the development for PCP. They include a special connection with a SEC type of threads and torque shoulder which is made-up controlling torque with a regular pipe power tong.
This paper shows the experience in a field located in south-west Argentina were HSR have been working for more than 5 years in 17 wells. Field results and failures are discussed as well as special issues to have in mind when producing with this alternative.
The operative information was collected until April 2008.

INTRODUCTION

PCP (Progressive Cavity Pumping) artificial lift systems transmit energy from the drivehead via a sucker rod string to a downhole helical pump rotor. PCP relies on rotational energy whereas conventional pumping methods rely on axial movements.
PCP sucker rod strings not only incur torsional stresses with almost constant values but also tensile and flexion stresses. Sucker rods used in conventional pumping applications, are mostly stressed axially, but can also suffer flexion which typically occurs in deviated wells or as a result of buckling.

For different stresses, different designs should be used.
Conventional pumping sucker rods, as well as their make-up procedure based in circumferential displacement (recommended in API 11BR specs.) were designed to work under variable axial loads. When the PCP system was introduced into the oil industry (in the 1980s) the only available instrument that could be used in the field to move the pumps where conventional sucker rods.
With time, production requirements were changing: deeper wells, higher production flows, oil associated to gas/sand and every time more directional wells with higher temperatures. Because of this, well workovers occurred more often because of failures associated to the energy transmission to the pump:

- Connection failures: their thread design is not capable to stand higher torques and their make-up procedure has important deficiencies for this kind of application.
- Rod body fishing: fatigue failures due to torque variations or flexo-torsion.
- Tubing perforations: wear between couplings (higher OD than the rod body) and tubing are localized and therefore reduces tubing life.

This new scenario of desired flows between 300 and 3000 bpd (50 and 500 m^3/day), depths up to 500 ft (1700 meters), dog legs severities higher than 7°/100 ft, high rotating speeds (up to 500 RPM) and high required torque (between 1000 and 2500 lbs*ft); made necessary a new design of sucker rods to work mainly under torque in combination to traction and flexion. Also, this new sucker rod should be able to work in 2 7/8" tubing.

DESIGNED PRODUCT DESCRIPTION

A family of Hollow Rods (HR) was designed to work under the mentioned requirements:

- PCPRod®1000: 1.92" (48.8 mm) body OD with flush connection for 1000 lbs*ft.
- PCPRod®1500: 1.66" (42.2 mm) body OD with upset connection to 1.97" (50 mm) for 1500 lbs*ft.
- PCPRod®1500: 1.92" (48.8 mm) body OD with upset connection to 2.36" (60 mm) for 2500 lbs*ft.

Table 1 shows detailed information of three HR models.

Materials
HR are made from hot rolled seamless pipe made of DS-852 steel which is a proprietary high strength alloy steel, with 140 ksi tensile strength. In tables 2 and 3 the chemical composition as well as the mechanical properties can be seen.

Thread / Connection
HR thread is designed to work under torsional stress. It has conical bore with 8 threads per inch profile and differential taper. Also, they have a torque shoulder with reverse angle. The pipe (rod body) has a female thread while the nipple (connector) has a male thread.

At first, it was thought that the inner space of the HR could be used for injection of little flows of diluents but when they started to be used in 2 7/8" tubing this space was also used as production flow area. For this, slotted hollow pup joints were used above the pump and below the polished rod (see figure 2 – graph B). Due to the fact that flow rates started to be very high and with sand, turbulence was produced in the nipple end and therefore it has to be modified into the connection that was finally named as *Internal Flush* (IF) connection. See figure 3.

Flush and Near-Flush Connection
Hollow Rods have external flush (PCPRod®1000) or near-flush (PCPRod®1500 & PCPRod®2500) connections which reduce tubing failures caused by rod wear. This benefit is caused because instead of locating the tubing wear in the conventional coupling length, it is distributed along the whole sucker rod.
A short description of this effect is explained in figure 1.

Make-Up
The connection make-up has to be done checking torque values. For this, it's necessary to use a pipe power tong with backup and torque control, with dies adapted for the rod body OD. Also, spiders for the same OD must be used. Finally, the use of safety clamps is recommended till the rod string is heavy enough to assure a good function of the spider (normally 10 HR).

Due to the fact that HR are pipes without a constant length, it's necessary to measure and add 5 cm (0.16 ft) for each one to account for the nipple length.

Finally, dope should be applied to the threads in order to avoid any kind of galling. Tubing dope is used.

Backspin and torque transmission efficiency
Backspin is the counter-rotate of the rod string caused when the accumulated energy in the system is released. This accumulated energy is mainly caused by the torsional elasticity of the string but is also accumulated in the produced liquid column (produces a turbine effect with the pump rotor when it's larger in the interior of the tubing than in the annular space).

If the counter clockwise rotation is not controlled, connections can be unloosened and failures can be produced because of high rotation speeds. In fact, in some cases surface equipment can be broken being a safety risk for personnel.

As HR are more rigid than conventional rods, the accumulated torsional energy in a rod string is less. For example, for a well working at 1000 lbs*ft, 1.92" (48.8 mm) hollow rods accumulate 8 turns every 3280 ft (1000 m) while 1 1/8" rods accumulate 41 turns. If we decrease the rod body diameter, the number of turns increases. On the contrary, with less accumulated turns, the backspin effect is reduced.

FIELD EXPERIENCE
Field trials started in 1999 in Argentina, where this technology was developed. Wells were under secondary recovery influence, so they recover fluid level easily when injecting more water. To reduce that level, conventional sucker rods were highly stressed and a large number of failures took place, mainly in sucker rods connections, and therefore workover costs were also high.
All 17 studied wells in this paper belong to an international oil company. Although these 17 wells are located in three different fields, they are in the same business unit. This company has some more wells working with HR in different business units.

Main objective for the use of HR was to reduce well inoperative time caused by failures in the rod string connections. General characteristics of the 17 studied wells can be seen in table 4 and in table 6 it's shown working days accumulated by each string since they were installed.

- Average working time without failures is 1115 days. There is one well (EW-11) that almost has reached 5½ years with only one day stop for drivehead change.
- These wells have worked for an average of 283 million cycles, reaching an estimated maximum of 679 million cycles (EW-02).
- The deepest well has the pump at 5806 ft (1771 m) with a gross production higher that 755 bpd (120 m^3/d).
- Highest measured torque was 1124 lbs*ft in well EW-09 while fluid level was around 100 ft (31 m) from the pump.

As most wells use 2 7/8" tubing and have a high gross production, slotted pup joints were used above the pump rotor and below the polished rod in order to allow flow through the interior of HR as well as through the annular space between them and the tubing. See figure 2 – drawing B

Chemical inhibitors injection

A continuous PCPRod®1000 injection installation (see figure 2 – diagram C and picture 2) was prepared in well EW-17. This system accumulated 121 days working at 120 RPM injecting 20 liters daily at a pressure of 28 psi (2 kg/cm^2) till injection was suspended but rods kept working in the well. Injection was suspended because the injected diluents were acid and harmed the hollow polished rod till it broke. The slotted pup joint seen in figure 2 – diagram C can be settle at any depth..

Material inspection

Visual inspection should be done every time a rod string is taken out of the well. This inspection was done in 6 wells were some type of maintenance was done, and it was recommended to reinstall the same HR string. In some other cases the recommendation has been to change the rod string due to corrosion marks/deformation.

Visual field inspection involves looking for rod body marks or corrosion pitting and/or defects on the connection (thread or shoulder deformation, corrosion or wear).

Failures

Failure analysis showed some susceptibility of the material to fail by SSC (Sulphide Stress Cracking) although rods were able to work a large number of days in sour environmental wells.
There was no problem to fish broken rods because regular coupling fishing tools can be used.

Special cases

- Well EW-03: Hollow Rods were changed after 1608 working days in order to re-thread them with the new connection (IF). Meanwhile, other used rod string, with more than 300 used days, was installed. By the moment this paper was written, this string accumulated more than 450 working days in total.
- Well EW-09: After 1256 working days it was recommended to change the rod string because of corrosion deformation. It was installed a used string that accumulated 954 working days in a 4264 ft (1300 m) deep well producing 1070 bpd (170 m^3/d) with torque values around 940 lbs*ft. Those rods have already overcome the 1100 working days. See installed rods inspection in annexes.
- Well EW-10: This well had two HR body failures. The first one occurred after 628 working days and the second one with 799 days. Both failures were associated to sour corrosion effects. After this second failure, the rod string was changed for a new one because although there were failures, results with HR were a lot better than using conventional rods.
- Well EW-15: This well had one failure associated to sour corrosion in the niple connector.

Three other wells registered rod failures and the lifting method was changed. One of these failures was in the rod body and the other two were in the connector. The ones that could be analyzed were caused by H_2S corrosion.
None of the wells with HR installed had tubing failures caused by rod wear.

CONCLUSIONS

Alternative lifting methods, like the Progressive Cavity Pumping, have been used due to the higher requirements the oil production industry has faced. In order to be able to use this method, conventional sucker rods had to be used. As they (and their connection make-up procedure) were designed for alternative pumping, with axial loads, their reliability is reduced while working mainly under torque stresses like in PCP.

The experience described in this paper of 17 wells showed that Hollow Sucker Rods specially developed for this type of applications are highly reliable even when working in sour environments.

- The HR connection is stronger than the conventional sucker rod connection so it can stand higher deformations caused by overtorque. On the other hand, the fact that they are made-up checking torque values reduces possibilities of unloosening or of dynamic make-up making them even more reliable.
- Flush and near-flush connections increase the tubing life reducing failures caused by rod coupling wear.
- Neither the HR installation, nor their fishing operation requires any special tool. Pipe power tongs and spiders adapted to the rod body OD and conventional sucker rod couplings fishing tools are used.
- Used Hollow Rods don't require any special equipment since after visual inspection, eddy current inspection can be done like in pipes inspection. Their threaded end can be cut and re-threaded if any deformation is found.

Also, HR allow fluids injection through them when using a hollow polished rod. This can be done up to any depth and increases the chemical efficiency, increases production flows, reduces paraffin deposition or viscosities and can be done even when packers are used.

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Table 1

PCPRod® HOLLOW RODS TECHNICAL SPECIFICATIONS									
Model	**Pipe OD**		**Pipe Thickness**		**Upset OD**		**Max. Operative Torque**	**Weight**	
	[mm]	[inch]	[mm]	[inch]	[mm]	[inch]	[lbs*ft]	[Kg/m]	[lbs/ft]
PCPRod®1000	48.8	1.92	6.7	0.26	No upset		1000	7.1	
PCPRod®1500	42.2	1.66	5	0.20	50	1.97	1500	4.7	
PCPRod®2500	48.8	1.92	6.7	0.26	60	2.36	2500	7.2	

Table 2

PCPRod® HOLLOW RODS CHEMICAL COMPOSITION								
% C	**% Mn**	**% S**	**% P**	**% Si**	**% Ni**	**% Cr**	**% Mo**	**% V**
0.21 0.24	0.5 0.6	Max. 0.003	Max. 0.010	0.20 0.30	Max. 0.15	0.90 1.00	0.70 0.75	Max. 0.010

Table 3

PCPRod® HOLLOW RODS MECHANICAL PROPERTIES							
Steel	**Min. YS**		**Min. UTS[1]**		**Elongation[1]**	**Charpy[1] RT 10x10** (Ref. 10 x 5 ≥ 30 J)	**Hardness[1]**
	[MPa]	[ksi]	[MPa]	[ksi]	[%]	[Joules]	[HRC (BHN)]
DS852	960	140	1015	147	10	50	32-38

[1] Referential values.

Table 4

GENERAL CHARACTERISTICS OF WELLS	
Production	200 – 1040 bpd (32 - 166 m^3/day)
Average Production	720 bpd (115 m^3/day)
Pump Depth	2800 – 5800 ft (860 – 1770 m)
Oil Gravity	28 – 35 °API
B&S Content	96%
Water Salinity	60000 ppm
Producing GOR	74 m^3/m^3
Bottomhole temperature	60 °C (140 °F)
Temperature Gradient	3 °/100 ft

Table 5

WELL EW-08 HISTORY	
1" Sucker Rod Workovers (under PCP)	**PCPRod®1000 Workovers**
13/03/2002 – Rod body failure	06/03/2006 Hollow Rods installations without failures.
13/12/2002 – Rod pin & coupling broken	
20/03/2003 – Rod pin & coupling broken	
27/03/2003 – Rod body failure	
08/04/2003 – Rod pin & coupling broken	
10/04/2003 – Pump change	
10/04/2004 - Pump change	
15/01/2005 – Rod pin & coupling broken	
26/07/2005 – Rod pin & coupling broken	

Table 6

WELL PRODUCTION DETAILS										
Well	**Installation date**	**Days without failure**	**Worked cycles[1]** (million)	**RPM**	**Pump depth**		**Torque**	**Production**		**Model**
					[m]	[pies]	[lbs*ft]	[m^3/d]	[bpd]	
EW-01	29/05/2006	672	173	179	1258	4126	500	59.5	374	PCPRod®1000
EW-02	7/12/2003	1576	679	299	1079	3539	780	165.6	1042	PCPRod®1000
EW-03	22/06/2003	1608 [A]	602	260	1068	3503	980	208	1308	PCPRod®1000
EW-04	13/01/2005	1152	343	207	1120	3674	928	191	1201	PCPRod®1000
EW-05	19/06/2004	1373	144	73	1099	3605	450	32	201	PCPRod®1000
EW-06	23/11/2003	1593	498	217	1030	3378	602	70.5	443	PCPRod®1000
EW-07	13/10/2004	1268	212	116	1043	3421	712	80.1	504	PCPRod®1000
EW-08	06/03/2006	759	158	145	1022	3352	860	134	843	PCPRod®1000
EW-09	11/05/2004	1256[B]	152	84	1110	3641	720	62.2	391	PCPRod®1000
EW-01	25/02/2004	1429	432	210	1124	3687	667	194	1220	PCPRod®1000
EW-11	12/10/2002	1986	509	178	1503	4930	900	113	711	PCPRod®1500
EW-12	9/11/2003	1607	407	176	1771	5809	840	123	774	PCPRod®1500
EW-13	7/12/2003	1579	280	123	1562	5123	916	84	528	PCPRod®1500
EW-14	26/06/2006	282	32	80	1000	3280	605	65	409	PCPRod®1000
EW-15	9/9/2007	207	54	180	883	2896	983	160	1006	PCPRod®1000
EW-16	29/09/2006	552	118	148	863	2831	624	127	799	PCPRod®1000
EW-17	31/01/2008	63	15	160	1250	4100	416	70	440	PCPRod®1000

* EW stands for Experimental Well. Torque values were calculated with PC-Pump software in some cases.
[1] Worked cycles were estimated till April 2008. Some wells had been some days not working.
[A] In well EW-03 used rods (1608 days) were changed without failure to re-thread the new thread model.
[B] Well EW-09 sucker rods were removed because of corrosion and changed for a used string coming from a well not mentioned in this work because it's no longer working with hollow rods. (Check details in *Special Cases*)

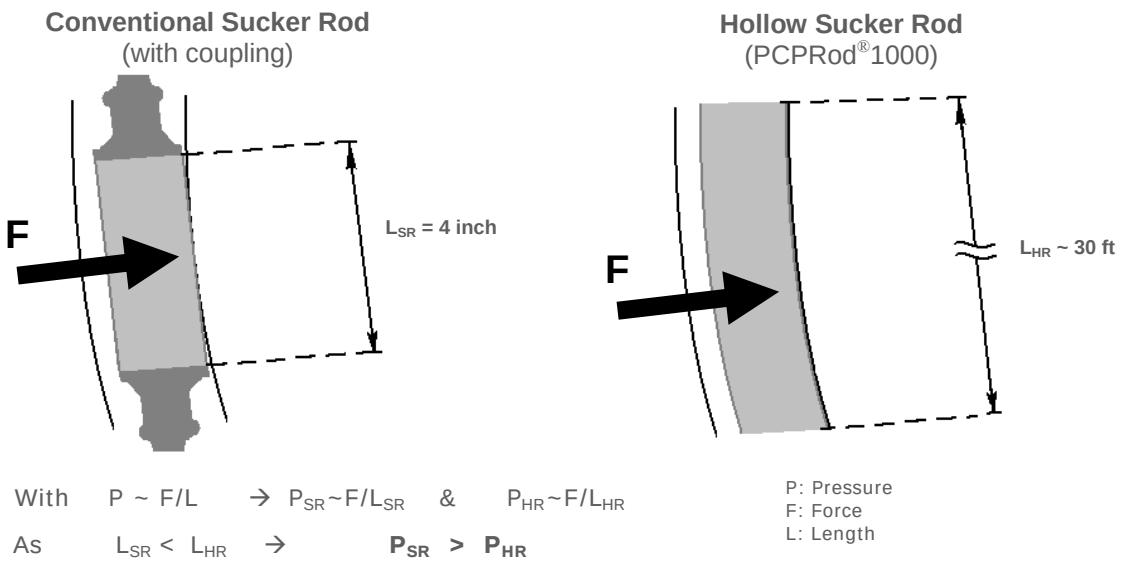
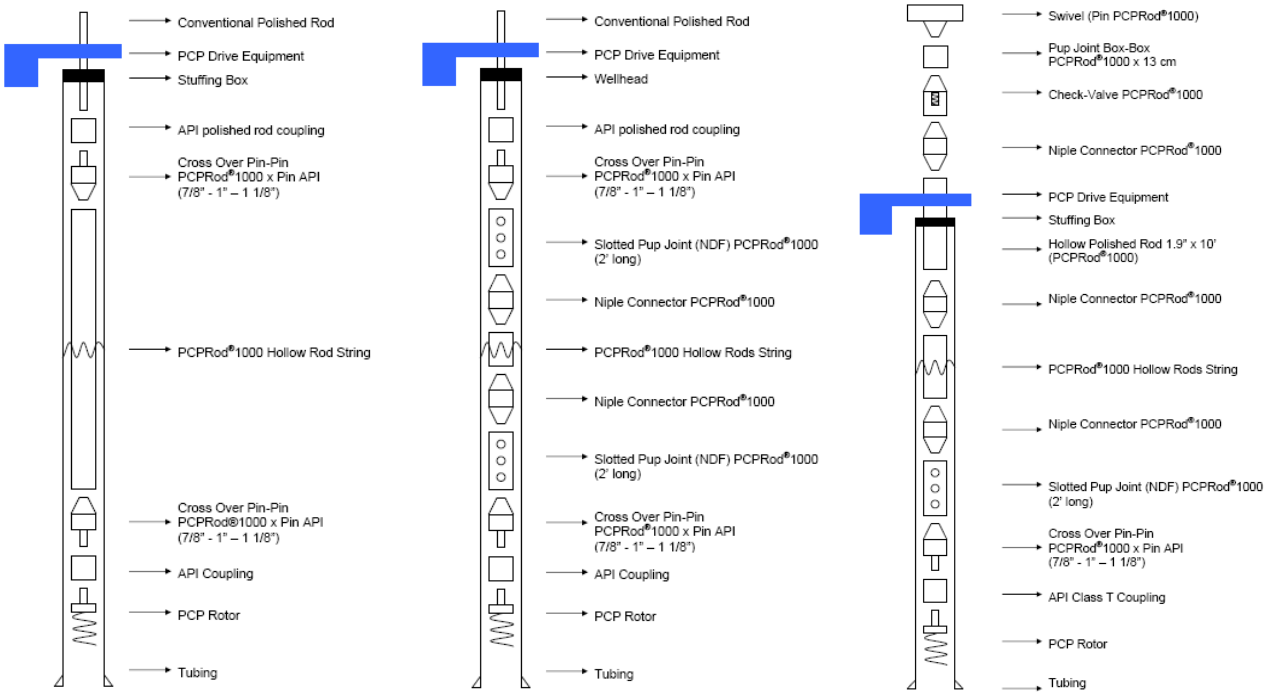


Figure 1



A) Substitution of conventional sucker rods (annular space production).

B) Production through the interior space of HR and through the annular space.

C) Injection through HR and production in the annular space.

Figure 2 – Hollow Rod Installation Graphs

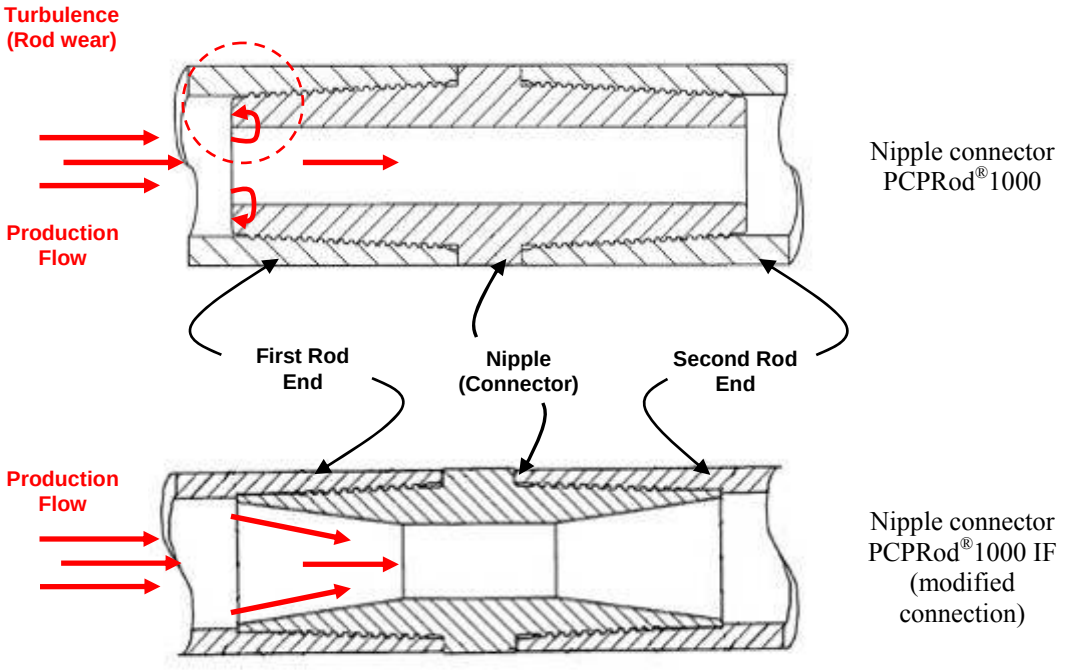


Figure 3

Picture 1 –PCPRod®1000 nipple turbulence wear

Picture 2 – Surface installation for injection through the HR while producing

Hollow Rods installed in well EW-09 inspection

These rods with 954 working days accumulated were installed in well EW-09 after inspection.

Picture 3 – Rod body and end in excellent condition.

Picture 4 – Nipple connectors without over torque or galling and keeping the original stand off.