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First Experience in the Application of Radial Perforation Technology in Deep Wells

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Abstract

This paper describes the first application of radial perforation technology with hydraulic jet and coiled tubing in deep wells with complex geometry.

Radial perforation technique utilizing hydraulic energy is being used in different places around the world with good results. Its main application is intended for marginal fields, with low productivity and shallow wells with depths between 1000m and 2000m, normally having simple geometry. Basically, several perforations can be made with this technology, in an existing well (mother well), perpendicular to the well axis and at several productive levels, thus improving the production profile around the main well or mother well.

Repsol YPF Bolivia has adopted this technology to perform a pilot test in fields with good to moderate recovery and in deep wells with complex geometry (directional wells with depths between 3500m and 3900m).

This operation was performed in three wells (Surubi A1, Paloma C7 and Surubi Bloque Bajo 109) in the Mamore Block in Bolivia.

The main challenge for this operation was to adapt equipment and tools used up to that time, to much more severe operational conditions due to greater depths, tortuosity, type of formations to be drilled and mechanical conditions of the wells.

The main subjects covered by this paper are:

1. Introduction
2. Characteristics of the reservoir and objectives for the application of this technology.
3. Geometrical and mechanical characteristics of the wells. Operative results.
4. Description of the equipment and main adaptations to new operative conditions.
5. Main problems encountered. Solutions. Operative limitations.
6. Conclusions.

The results indicate that this technology may continue being an attractive substitute for other stimulation techniques, such as fractures, acids, side tracking, etc, even with higher costs implied by its application to complex wells and with the improvements that will definitively be applied to current tools and equipment

1- Introduction

The permanent quest to increase productivity in low recovery wells has been a very good incentive for the development of new technologies to solve the economic equation in marginal fields.

In some cases, such technologies may have the characteristics needed for other applications, with different requirements, however generating results similar to those for which they were originally designed.

The specific case of the radial perforation system with coiled tubing using hydraulic energy and its application to deep wells is an example.

This technique and the associated equipment were created and designed for application in marginal fields and shallow wells with simple geometry. In the practical operation this represents low degree difficulty and reduced cost operations.

This paper details the application of this system but applying the same to non marginal fields and deep wells with complex geometry, representing operations with a high degree difficulty and high costs. Evidently, under such conditions, these projects represent a major investment risk, particularly when “adapting” a system to more severe conditions than originally designed for.

2- Characteristics of the reservoir and objectives for the application of this technology.

The wells selected for the application of this technology are located in “Paloma”, “Surubi” y “Surubi Bloque Bajo” structures, all pertaining to the “Mamore” Block, located 170 kms northwest of Santa Cruz City, in the northern portion of the Chaco basin in the department of Cochabamba, Bolivia.

The Paloma, Surubi and Surubi Bloque Bajo structures are the result of a compressive fold in the “Andina Phase”. The anticlines are easy to recognize with seismic and the structure is tectonically tranquil, making possible the easy identification of zones of interest to be penetrate.

The main oil producing formation in the Paloma and Surubi Fields is “Lower Petaca” consisting of sandy reservoirs with variable continuity deposited in a continental – fluvial environment. The regional seal consists of claystones and pelites from the Upper Petaca and Yecua formations.

The petrophysical characteristics of the Lower Petaca formation are: very variable Permeability 30 – 200 md., and Porosity between 15% and 19%

One of the characteristic of the formation during the productive life of the well is a high sand production, which makes necessary to complete the wells with sand control systems. Normally directional wells are completed with conventional gravel pack and horizontal wells with the stand alone type system.
The selected wells were:

- Paloma C 7 (PLM - C7)
- Surubi A1 (SRB - A1)
- Surubi Bloque Bajo 109 (SRB BB – 109)

In general, the main objectives in the application of this technology, to this type of wells, were geared to:

1. Increase the recovery of hydrocarbons without the need of additional perforations adding drainage areas to existing wells and allowing the interconnection of sandy channels with better petrophysical conditions.
2. Monitor sand production behavior during the productive life of the well. That is, to see is this technology would allow us to flow the wells without producing sand.
3. Demonstrate, from the operative point of view that the technology designed for shallow wells with simple geometry may be applied to more complex wells adapting the equipment adequately.

The program for the first two wells (PLM-C7 and SRB-A1) included the intervention at three productive levels with four radial wells measuring 100 meters at each level and with a 90º phase displacement, while the program for the third one (SRB BB-109) included the intervention at three productive levels with two radial perforations measuring 100 meters at each level and with a 180º phase displacement and in direction perpendicular to the azimuth plane of the well.

In addition to the above mentioned general objectives, there were particular objectives for each selected well:

Well: PLM – C7

The purpose for this case was to increase production in a damaged well with an important accumulation of oil volumes and where the remaining potential could not be produced under existing conditions.

This well is located between two other wells with good production for the area, (PLM C3: 501bpd y PLM C5: 202bpp). These wells have larger permeable thickness than our target well, thus, the horizontal extensions could connect zones with greater productive potential.

Figure 1 shows the well production history prior to the intervention. Originally, the well was completed with a conventional gravel pack. As noticed, three acid treatments were made and one anti-emulsifier. In all cases, production was increased but not maintained.

After the application of this technology, production was increased as exhibited in Table 1.

Sand production was not controlled. However, it is important to note that the behavior of same was different than with conventional perforations, where sand production eventually blocks the well when using production orifices (choke) larger than 16/64”. In this case, although sand production was important, at no time, plugging was experienced preventing the well from producing.

Due to the impossibility to control the sand production and with the intention to use a control system other than the gravel pack, a pumping of resin coated sand treatment was performed. After a production testing period, the resin coated plug located in the mother well was perforated with coiled tubing in order to improve vertical permeability.

Figure 2 shows the behavior of sand flow after the radial perforations and prior to pumping resin coated sand and figure 3 shows the behavior of sand flow after the resin coated sand treatment and the productivity increase upon improving vertical permeability by perforating the sand plug in the mother well.

Well: SRB - A1

In this case the objective was to increase production in a well where the upper section of the reservoir had not been drained and which was proven productive when perforated through-tubing.

The production profile of this well prior to the intervention was:

- Oil: 105 bpd
- Gas: 5000 scfd
- Water: 14bpd

Productivity results could not be measured in this well because of the impossibility to perform the radial perforation due to the problems described in section 5.

Well: SRB BB – 109

In this case the objective was to increase production from a well with low production volumes since completion, even though being located near wells with good production. Because of the trajectory of the mother well in the producing sand, two 100m horizontal extensions in perpendicular direction to the azimuth plane of the mother well were scheduled in order to navigate with the radial extensions within the sand of interest.

Productivity results could not be measured in this well because it was not possible to execute the radial perforations as scheduled due to operative problems described in Section 5.

3- Geometrical and mechanical characteristics of the wells. Operative results.

In addition to the description of the architecture of "mother wells", we will show you in this section the final condition of each well after the intervention.

Well: PLM – C7

Well architecture

This well has a 7" - 26 lbs/foot - N80 production casing through which the radial perforations will be done. Figure 4 shows its vertical section; the trajectory of the same has a maximum inclination of 28°, tangential section of 1470 meters and a final inclination of 10°. The maximum DGL (Dog Leg Severity) was of 2.6°/30 m.

The three levels that should be radially perforated into the Lower Petaca formation were 3582m, 3585m and 3592.5m deep, respectively.

Operative results

In this well we were able to perforate radially at levels 1 and 2. The third level (3582m) was not perforated due to an operative problem, which will be described below.

Figure 5 shows the directions and lengths of the radial perforations executed in the first two levels.

Four perforations were made in level 1 (3592,5 m) with the following characteristics:

- Minimum extension: 10m
- Maximum extension: 100m
- Total extension: 265m
- Average extension: 66.25m

Five perforations were made in level 2 (3585m) with the following characteristics

- Minimum extension: 10m
- Maximum extension: 100m
- Total extension: 337m
- Average extension: 67.40m

The total time for the execution of this intervention was 30 days, not considering the initial workover or the trip to install production.

Table 2 shows some operational points of reference and table 3 presents the distribution of time.

Section 5 describes the main operational problems in this well.

Well: SRB - A1 :

Well architecture

This well has a 7" - 29 lbs/foot - S95 production casing, through which the radial perforations will be done. Figure 6 shows its vertical section. From a geometrical point of view, this well appears as the most accessible because it is vertical and it does not present tortuosity problems.

The three levels that should be radially perforated into the Lower Petaca formation, were 3353.5m, 3347.5m and 3341m deep, respectively.

Operative results

The radial perforations could not be made in any of the levels in this well due to the impossibility to perforate the casing.

During 16 days of operation, 14 attempts were made to perforate the 7" 29Lbs/ft S95, casing without success.

Different operative points of reference were modified and combined during the attempts, the milling tool and the deflector shoe design were modified, surface tests were made, etc., not being able to find suitable conditions to perforate the casing.

The decision was to abandon the operation until problems obstructing perforation of this type of casing were solved.

Well: SRB BB - 109:

Well architecture

This well has a 7" - 26 lbs/foot - N80 production casing, through which the radial perforations will be done. Figure 7 shows the vertical section of the same. The trajectory indicated a 33° maximum inclination, 2538 meters tangential section and a 30º final inclination. The maximum DGL (Dog Leg Severity) was 3°/30 m.

The three levels that should be radially perforated into the Lower Petaca formation were 3755.5m, 3749.5m and 3746.5m deep, respectively.

From a geometrical point of view this well appears as the most complicated of the three wells for the application of this technology.

Operative results

The originally scheduled 100m radial extensions could not be reached in this well, being only able to reach a maximum of 31m in the first level and from 4 to 8 meters in the other levels.
Figure 8 shows levels and extensions reached.

The final perforation result is summarized as follows:

Level 1
- Minimum extension: 5m
- Maximum extension: 31m
- Total extension: 56m
- Average extension: 11.2m

Level 2
- Minimum extension: 4m
- Maximum extension: 7m
- Total extension: 11m
- Average extension: 5.5m

Level 3
- Minimum extension: 7m
- Maximum extension: 7m
- Total extension: 14m
- Average extension: 7m

The total time for the execution of this intervention was 18 days, not considering the initial workover or the trip to install production.

Table 4 shows the time distribution. Also, a comparison with well PLM C7 its present in this table, where some improvements on certain operations are appreciated.

Section 5 describes the main operational problems in this well.

4- Description of the equipment and main adaptations to new operative conditions.

Basically, this technology allows to make several perforations from an existing well (mother well), perpendicular to the well axis, improving in this way the production profile around the main well or the mother well (Refer to fig.9)

The operative sequence applied in this system is the following:

- After the mother well is conditioned to the depth of the levels of interest, a deflector shoe is run with the work string (Refer to fig 10), being positioned through the corresponding correlations, at the selected depth. Then, depending on the type of well and geological needs, it is oriented in the desired direction through the measurement of an orientation system (gyroscope).
- The next step consists in perforating the casing. A Bottom Hole Assembly is run through the work string consisting of: ¾" OD Milling tool + Flexible joint + ½" OD DHM. (Refer to fig. 11). This BHA is run with (½" OD) coiled tubing. Once the shoe deflector depth is reached, and the optimal operative parameters are found, the perforation of the casing starts. The time needed for this operation may oscillate between 0.5 and 0.75 hour.
- After removing the casing opening tool, the BHA for the radial perforation is run. This consists of: ½" OD Hydraulic jet + 100m ½" OD flexible hose + Connector (Refer to fig. 12). This BHA is run with (½" OD) coiled tubing. The perforation of the lateral well starts once the deflector shoe depth is reached and the optimum operative hydraulic parameters are verified. The penetration into the formation takes place using the hydraulic energy provided by the fluid going through the jet, where two main effects are generated: one is the "Pull effect" impelled by the reaction generated by the rear jets on the formation, making the system move forward in combination with the erosion effect caused by the front jets, producing the fragmentation of the rock. This way and for normal operative conditions, a 100m horizontal extension section is perforated, with a 1 ½" diameter approximately in an average of 15 minutes. The hydraulic parameters are adjusted upon the type of formation to be perforated. Figure 13 shows a schematic of the type of jet used for formation perforation.

Although the working principle of this system was adopted for Paloma and Surubi wells, several adaptations were made, both for surface and bottom hole equipments, in order to solve the particular requirements of these wells.

- The diameter of the coiled tubing used was similar to the one for shallow wells (½"OD), the only change was the type of material in order to increase the mechanical resistance (pressure and pulling) for working in the greater depths.
- In shallow wells, coiled tubing is moved only using the coiled tubing reel unit. The unit for these wells was adapted with an injector in order to obtain more pulling capacity. Refer to Fig. 14.
- The hydraulic system driving the coiled tubing unit mechanisms had to be reinforced to meet the greater operative demands. The refrigeration systems were also reinforced.
- In shallow wells and when feasible under the point of view of the reservoir, the orientation of the deflector shoe can be obtained without an orientation system. In our case, with depths at 3300 and 3800 meters and with geometries which generate much friction in the work string, to which the deflector shoe is connected, it is necessary to use an orientation measuring system to have the correct direction for the shoe, every time it is rotated 90º. Hence it was necessary to adapt an orienter sub to the work string which would allow lodging the measuring instrument without generating a restriction for running the BHA to open the casing and the perforating BHA.
- As indicated in the previous sections, PLM - C7 and SRB BB – 109 wells have complex geometries, which generate high friction. This effect is evident when running the coiled tubing into the work string. To minimize this effect, fluids with liquid and solid lubricants are used to increase the range of overpull of the coiled tubing. Table 5 shows these values.
- For this type of wells, the working parameters, both for perforating the casing and the formation, are noticeably different than the ones used for shallow wells. The correct determitation of such prameters as well as the diagnosis of possible problems when facing variations during the operation,

have been extremely important points for the operator to adapt the equipment to this type of operations. Table 6 shows some of the parameters used to perforate these wells.

5- Main problems encountered. Solutions. Operative limitations.

The general perspective of this pilot project indicates that, for the three wells that were worked on, the general results may be summarized as follows:

- PLM – C7. From the three levels scheduled only two were executed cancelling the third one due to operative problems. Out of the 800m scheduled for the executed levels, 602m (75,25 %) were reached.
- SRB – A1. It was not possible to make lateral extensions due to the impossibility to perforate the casing.
- SRB BB – 109. The longest lateral extension obtained was 31m. Out of the 600m scheduled for the three levels, 81m (13,50 %) were reached.

A detailed analysis of the main operative problems indicates that, in all cases, situations proper to the beginning of the learning curve to adapt a system are evident.

Some of the problems were:

a- Excessive operation time.

Especially evident in the first well, being the main reasons:

- Repairs on the hydraulic controls for the coiled tubing unit. This unit was working to maximum limit of its capacity, consequently reduced its maneuverability, in addition to being operated in a high temperature environment.
- Repairs of the injector head. This element had an acceptable performance down to 2900m. After such depth, the operative capacity exhibited a series of problems which were solved partially through some modifications. The problems in this element also affected the hydraulic system.
- Problems with the shoe deflector orientation system. The first adaptation of this system was on originals parts of the down hole motor and the deflector shoe. On one hand, the engaging guide that the deflector shoe has to position the down hole motor when milling the casing, was used as the orienter sub, and on the other hand, a guide similar to the one that the down hole motor has adapted in the mule shoe of the gyroscope, similar to the one in the down hole motor has to absorb the reactive torque placed on the deflector shoe socket, was adapted in the mule shoe of the gyroscope. In principle, even though the design looked like a simple adaptation because no additional elements would be placed in the work string, in fact, there were many difficulties to obtain a reliable engamenet, which forced thus to repeat many times the mule shoe engament in the guide to ensure a reliable orientation reading, causing an important time loss. For subsequent wells, the system was replaced by a conventional Orienter sub placed in the work string with dimensions adapted to these operations, in order not to obstruct the passing of BHA through the same. Proper functioning of the system was experienced during the rest of the operations.

b- Flexible hose sticking.-

This problem occurred when running in with the BHA to perforate the radial extensions in the third level of PLM-C7 well. During this maneuver, with jet and flexible hose, a minimum circulation flow rate must be maintained to provide the hose with the rigidity required to be run through the work string to the deflector shoe without any problem. In deep wells, where running from the surface to the deflector shoe depth is important, special care must be observe during the maneuvers since any problems (ex, variation in circulation flow rate) decreasing the rigidity of the hose may break or bend the same and its subsequent sticking. In our case, this problem caused the sticking of the hose and the subsequent cut of the coiled tubing when attempting to free it.

Figures 15 and 16 show the position of the flexible hose inside the work string when this type of problems occurs. When the lower end of the hose (position of the jet) rests in a way that creates resistance on the way down and the hose breaks or bends at some intermediate point due to the loss of rigidity, the upper end of the same (position of the connector between the hose and coiled tubing) continues traveling to the position shown on fig. 15 and 16 inside the work string. The modification in the Hose-Coiled tubing connector design has been an important improvement to avoid this type of problems.

c- Impossibility to perforate a 7” – 29Lbs/ft – S95 casing.

During the execution of this project, the milling of this type of casing was not solved. Several tests and simulations were made on surface with different milling tool profiles obtaining good results for test conditions but unsuccessful in well applications.

The development of new milling tool designs, the application of more powerful down hole motors and improvements in the BHA used, will be the main points for improvement to be able to perforate this type of casing with this system.

d- Impossibility of perforating horizontal extensions in SRB BB – 109.

Section 3 of this document shows the operative results for this well. The same indicates that it was not possible to reach the horizontal extensions scheduled in any of the three levels.

Two main factors may have originated this problem:

a. Excessive friction between the coiled tubing and the work string because of well geometry.

b. Excessive wash out effect in the wellbore due to the jet effect in unconsolidated formations.

Previously, we had explained that the penetration of the tool in the formation was caused by the reactive forces that the fluid generates against the formation when going through the jet orifices. Two main effects occur, one is the erosional effect caused by the front orifices and the other is the “pull effect” generated by the reactive forces against the wellbore. The latter, forces the tool into the lateral perforation. When the formation being penetrated is unconsolidated and the speed penetration rate is less than the adequate one, a strong wash out effect occurs in the wellbore, decreasing the pushing force and finally stopping the jet from moving forward.

In deep wells with geometries generating high tortuosity, the friction to overcome between the coiled tubing and the work string magnifies the above indicated problem, because in this case, a greater pushing force is required. The higher the circulation flow rate, the higher the pushing force but also the higher the risk of washing out the wellbore. It is necessary to find the correct parameters to penetrate the targeted extensions. In our case, although different tests were carried out with different parameters and modifications in the BHA, besides using different type of lubricants to reduce friction, the magnitude of the two mentioned factors did not allow to reach the desired extensions.

6- Conclusions

The criterion for well selection to test a new technical application in order to visualize the productivity and operative performance results, shall balance out the reservoir characteristics with the mechanical characteristics of the candidate well. In spite of not being able to measure productivity results in two wells, we believe that the selection criteria, in this sense, were in the correct direction. From the operative stand point and to the light of the results obtained, for this application, it can be concluded that the complexity of the wells surpassed the adaptation of this technique to succeed with these projects.

Nevertheless, it was proven that in spite of the problems and limitations encountered, the radial perforation using hydraulic energy is possible for this type of wells.

Most of the problems hindering the best performance in this operation have been diagnosed correctly, some of them solved and others on the way to being solved.

For future applications, it is still pending the confirmation that the combination of radial perforation with other methods, such as pumping of resin coated sand in horizontal extensions is a possible solution for sand control issues.

Although the cost for this type of operations is important, we believe that by improving the equipment (bottom hole and surface) based upon the present experience, this technology continues to be a very good option (cost/benefit) for deep wells with complex geometries.

Referencias

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2. SPE Bolivian Section – Incremento de la producción de petroleo y gas a través de la aplicación de la técnolgia de Coild tubing radial drilling.

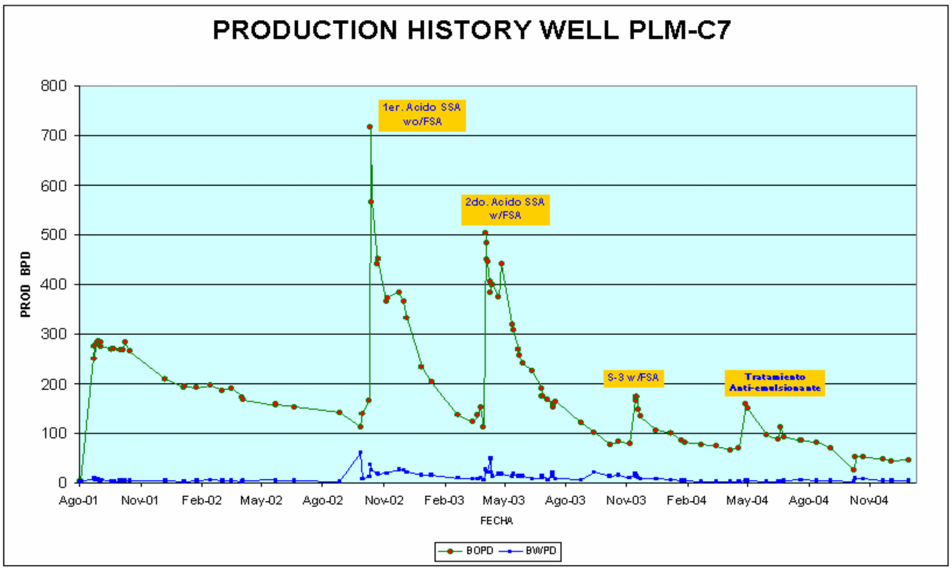

Fig. 1

PRODUCTION TEST WELL PLM-C7			
		Before L. D.	*After L. D.*
Date		21-May-05	29-May-06
Choke	n/64"	128	44
Pressure Well Head	psi.	180	350
Oil	bpd	23	196
Gas	mpcd	177	743
Water	bpd	1	42
Salinity	ppmCl	1200	3200
L. D. = Lateral Drill			

Table 1

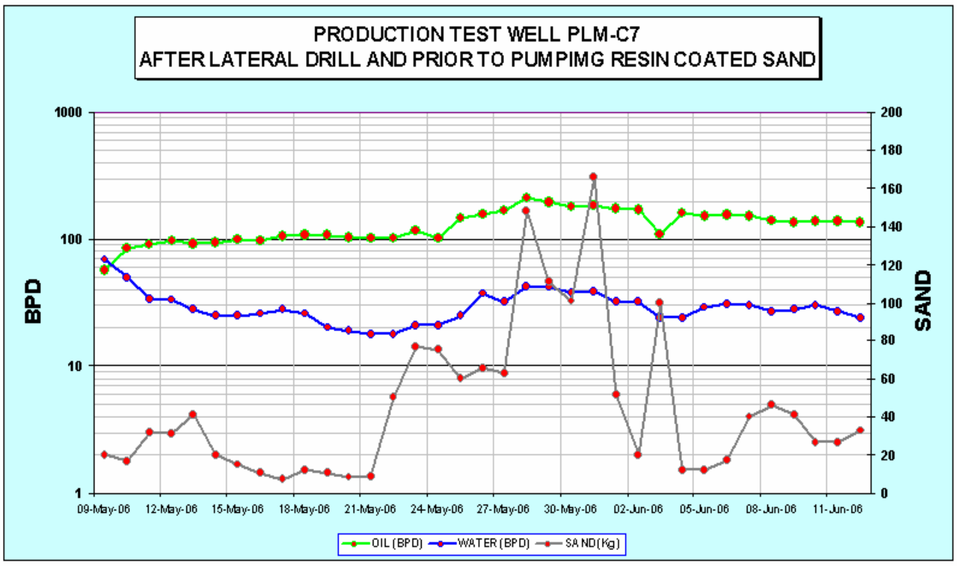
PRODUCTION TEST WELL PLM-C7
AFTER LATERAL DRILL AND PRIOR TO PUMPIMG RESIN COATED SAND
BPD
SAND
1000
100
10
1
200
180
160
140
120
100
80
60
40
20
0
09-May-06
12-May-06
15-May-06
18-May-06
21-May-06
24-May-06
27-May-06
30-May-06
02-Jun-06
05-Jun-06
08-Jun-06
11-Jun-06
OIL (BPD)
WATER (BPD)
SAND (Kg)

Fig. 2

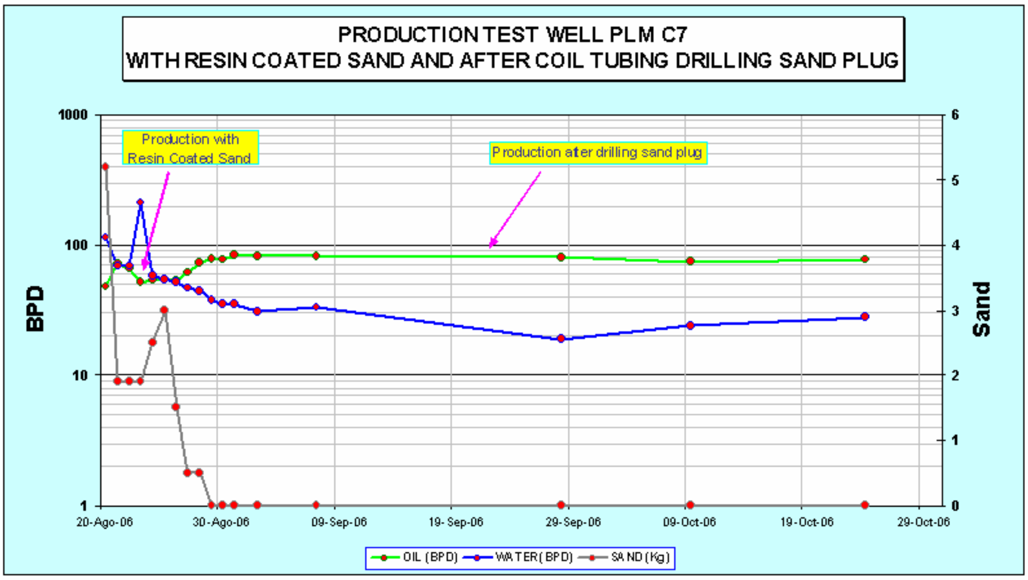
PRODUCTION TEST WELL PLM C7
WITH RESIN COATED SAND AND AFTER COIL TUBING DRILLING SAND PLUG
Production with
Resin Coated Sand
Production after drilling sand plug
BPD
Sand
1000
100
10
1
6
5
4
3
2
1
0
20-Ago-06
30-Ago-06
09-Sep-06
19-Sep-06
29-Sep-06
09-Oct-06
19-Oct-06
29-Oct-06
OIL (BPD)
WATER (BPD)
SAND (Kg)

Fig. 3

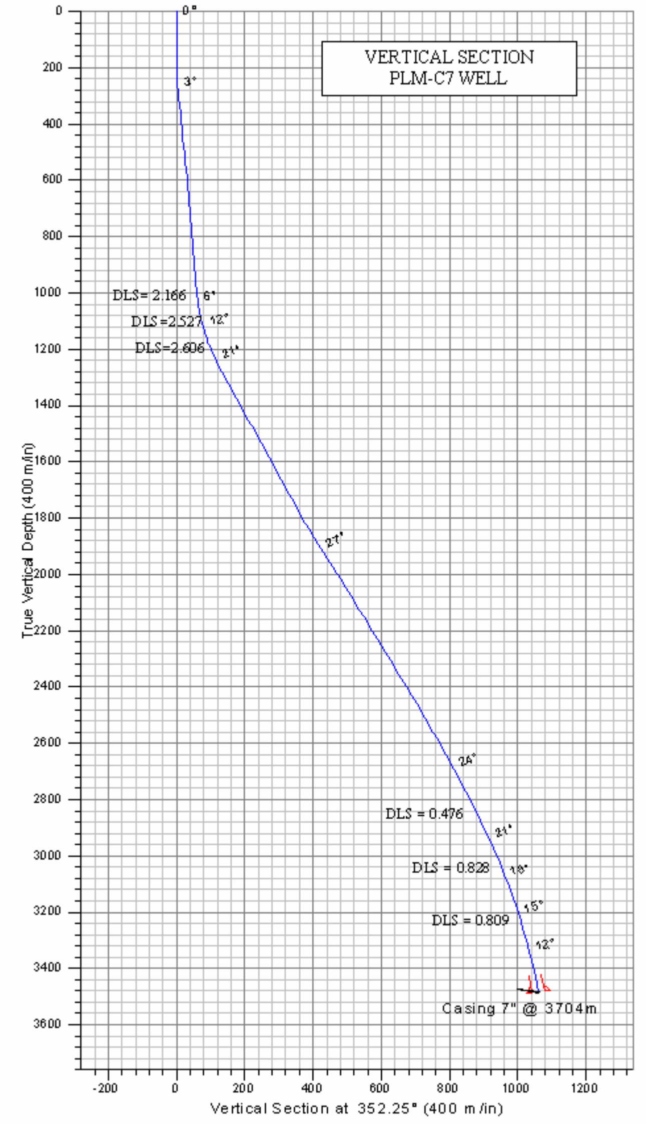
VERTICAL SECTION
PLM-C7 WELL
True Vertical Depth (400 m/in)
Vertical Section at 352.25° (400 m/in)
DLS= 2.166
DLS =2.527
DLS=2.606
DLS = 0.476
DLS = 0.828
DLS = 0.809
Casing 7" @ 3704m

Fig. 4

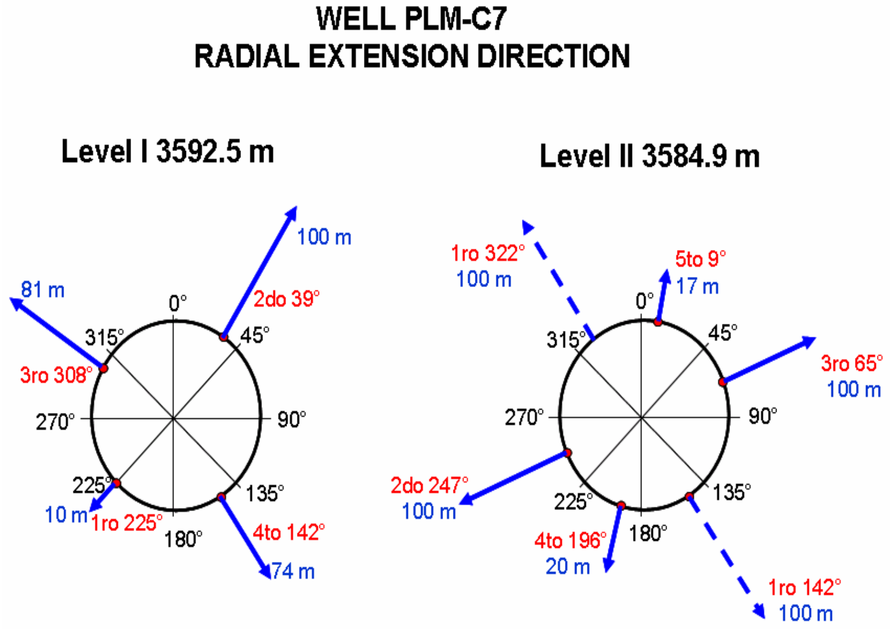

Fig.5

LEVEL	MILLING CASING (Hrs)	FLOW RATE (GPM)	PRESSURE (psi)	LATERAL	FLOW IN (GPM)	PRESSURE IN (psi)	FLOW OUT (GPM)	PRESSURE OUT (psi)	LENGTH DRILLED (MTS)	AZIMUTH °
1	1.5	4.6	7000	1	1.7	4500	2.0	6000	10	225°
1	1.5	4.6	7200	2	1.2	3200	1.4	4500	100	39°
1	1.5	5.0	8000	3	1.3	3600	1.8	4500	81	308°
1	1.5	5.0	8000	4	1.8	3000	2.1	4000	74	142°
2	1.5	4.6	7000	1	1.0	2200	1.6	3000	100	142°
2	1.5	5.0	8000	2	1.0	2200	1.8	3000	100	247°
2	1.5	5.0	7600	3	1.5	2200	2.0	3000	100	65°
2	1.5	5.0	7500	4	1.5	2600	2.3	3200	20	196°
2	1.5	5.0	7500	5	1.0	1800	2.6	3000	17	90°

Table 2

TIME DISTRIBUTION WELL PLM-C7		
OPERATION	% Programmed Hours	% Executed Hours
GYRO ORIENTATION	13.19%	19.12%
NIPPLE UP SURFASE EQUIPMENT	14.29%	5.98%
COIL TUBING TRIPPING	48.35%	26.47%
MILLING CASING	12.09%	3.44%
RADIAL DRILLING	12.09%	0.71%
EQUIPMENT REPAIR	0.00%	19.78%
WAIT MATERIAL	0.00%	24.49%
TOTAL	100.00%	100.00%

Table 3

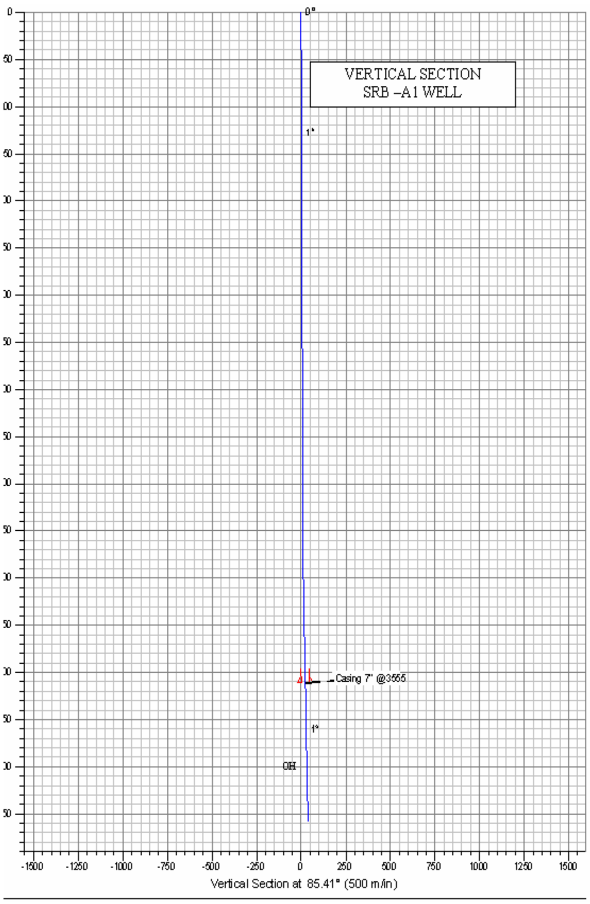

Fig. 6

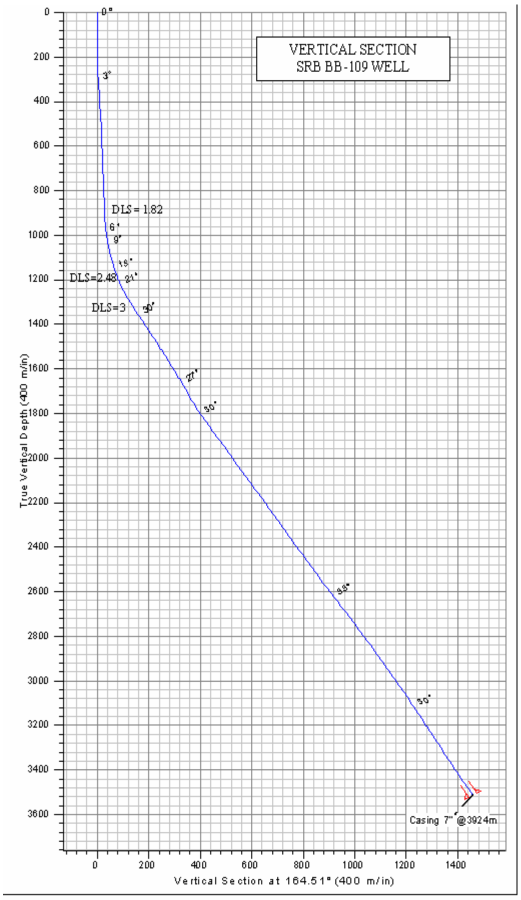

Fig. 7

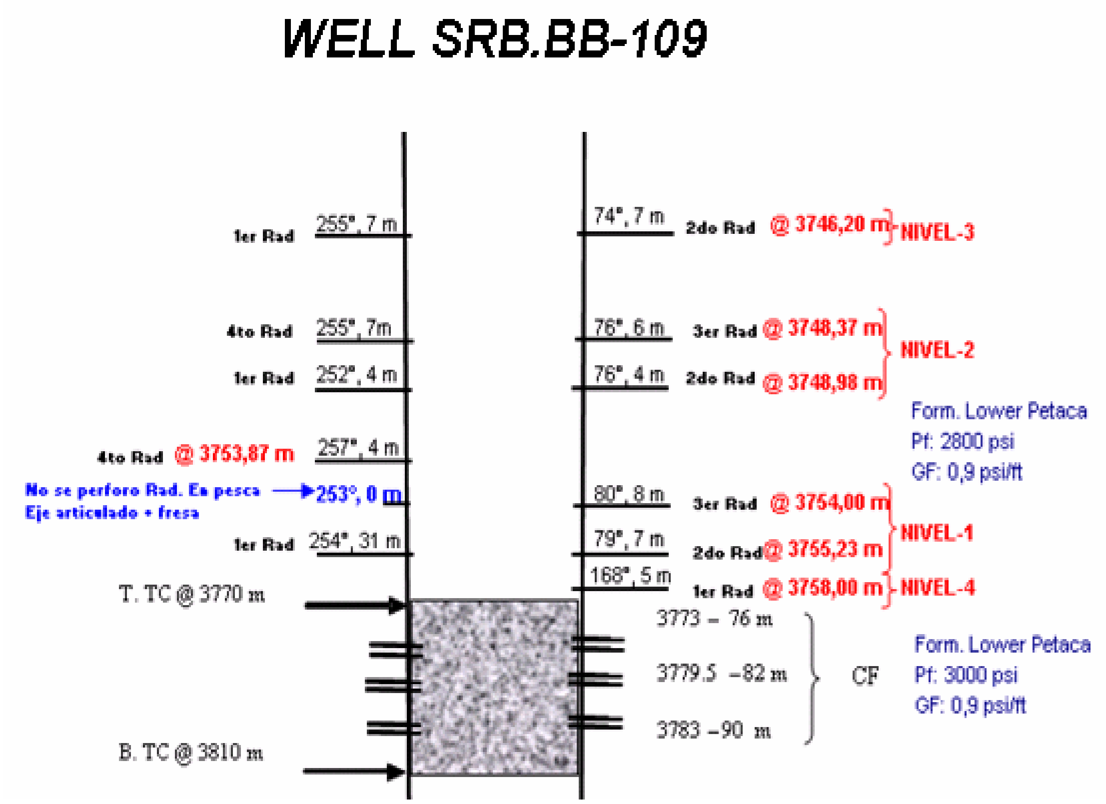

Fig. 8

TIME DISTRIBUTION		
OPERATION	SRB.BB-109	PLM-C7
GYRO ORIENTATION	12.57%	17.60%
STUCK / FISHING	0.00%	4.78%
NIPPLE UP SURFASE EQUIPMENT	7.33%	6.64%
COIL TUBING TRIPPING	27.49%	26.23%
MILLING CASING	2.62%	3.60%
RADIAL DRILLING	1.31%	0.85%
EQUIPMENT REPAIR	0.00%	18.30%
WAIT MATERIAL	0.00%	22.00%

Table 4

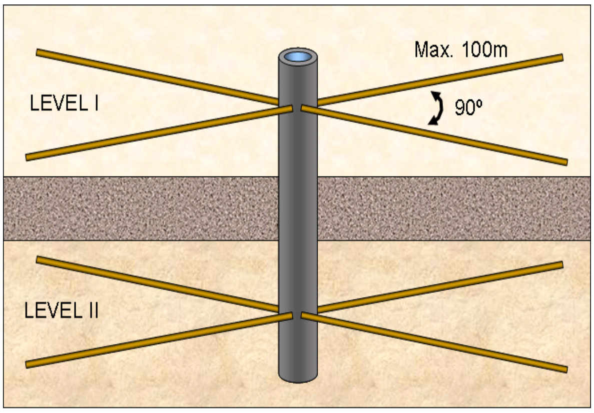

Fig. 9

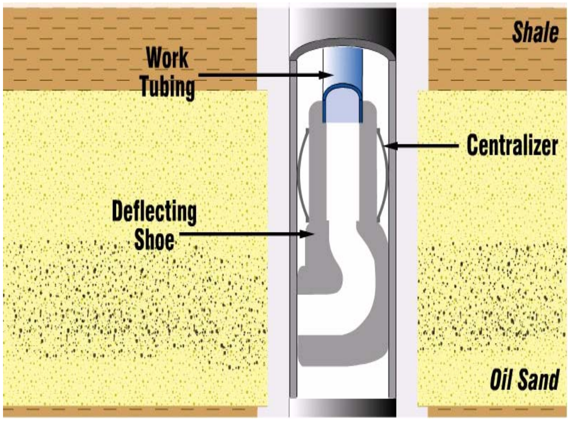

Fig.10

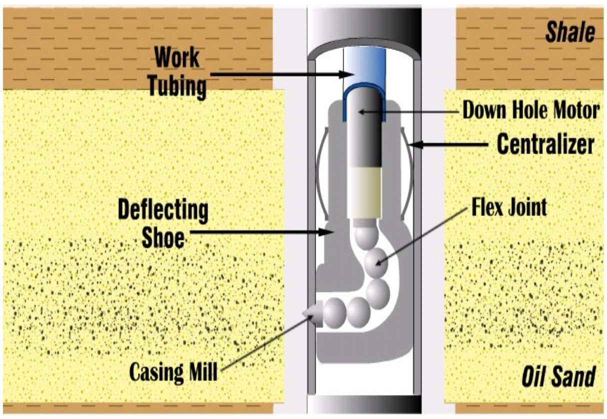

Fig. 11

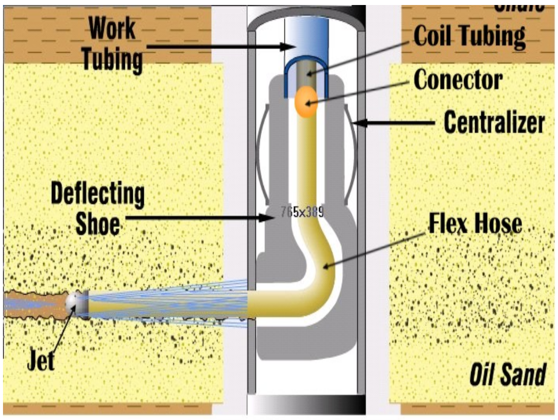

Fig. 12

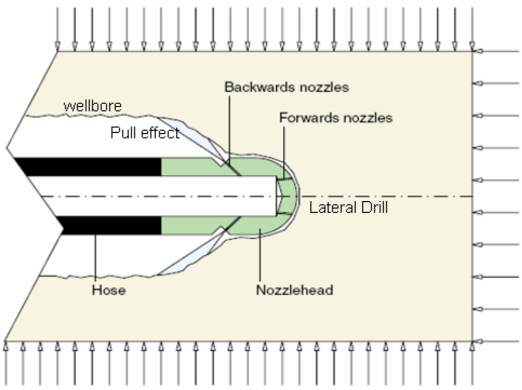

Fig. 13

Fig. 14

WELL	WORKOVER FLUID		DEPTH	DEVIATION	LUBRICANT USED	MAX STRING WEIGHT		
	TYPE	DENSITY (gr/cc)	(m)	(degrees)		Slack off (pounds)	Pick up (pounds)	OVERPULL (pounds)
PLM-C7	KCL	8,4	3592	24	NONE	3550	3800	1800
SRB-A1	KCL	8,4	3352	1	Chemical Lubricant	3450	3650	2350
SRB-BB109	KCL	8,4	3754	32	NONE	3500	3900	2600
	KCL	8,4	3754	32	Chemical and solid Lubricant	3250	3400	3100

Table 5

WELL	DEPTH (m)	RUNNING MILL			MILLING CASING				RUNNING JETS			LATERAL DRILLING		
		PRESSURE (psi)		RATE	PRESSURE (psi)		RATE (gpm)		PRESSURE (psi)		RATE	PRESSURE (psi)		RATE
		MINIMUM	MAXIMUN	(gpm)	MINIMUM	MAXIMUN	MINIMUM	MAXIMUN	MINIMUM	MAXIMUM	(gpm)	MINIMUM	MAXIMUM	(gpm)
PLM-C7	3592				7500	8500	4,8	5,0	2500	3500	1,8	1800	6000	1,2 - 2,8
SRB-A1	3352	1650	1980	2,0	7000	8600	4,7	5,1	3000	3800	1,8	2800	7000	1,8 - 3,2
SRB-BB1O9	3754	1100	1800	1,5	8300	9000	4,3	5,0	5000	6000	2,4	2200	6800	1,5 - 2,8

Table 6

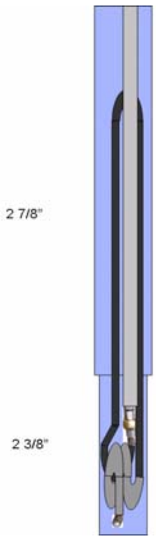

Fig 15

Fig 16