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First Application of Plasma Technology in KOC to Improve Well's Productivity

Suresh Kumar Chellappan, and Fatma Al Enezi, Kuwait Oil Company; Hussam A. Marafie, Amro H. Bibi, and Vasiliy B. Eremenko, Eastern United Petroleum Services

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Abstract

Stimulation is a well-practiced technology in oil industry to improve productivity or injectivity of a well. Plasma Pulse Technology (PPT) is a special kind of stimulation technique where oil production enhancement occurs without formation damage and without using chemical agents. PPT is based on scientific research in the areas of Geology, petro-physics, blasting theory, acoustic, wave theory and resonance theory.

Well RA-000A was identified for plasma application mainly to stimulate the very tight layer SID2 which otherwise difficult to produce through conventional perforation and to have positive production impact on nearby well RA-000B. Before application of this new technology, three intervals were perforated with last production rate @ 196 bopd with 90% water cut and closed for pressure. PNC log (sigma log) was recorded which shows that out of three perforated interval, the bottom COAL2_UCH layer having very high water saturation, the top of COAL2_UCH is having little water saturation and COAL1 LCH is almost dry. The porosity and permeability of the bottom layer of COAL2 UCH is very good whereas COAL1 LCH is having moderate rock quality. It was decided to isolate COAL 2 UCH due to very high water saturation. Also, decided to add SID layer which is very tight with low porosity and permeability

Nodal analysis was carried out to estimate the production potential after isolating the water producing layer and adding SID layer. The prosper model estimated that the selected interval will produce @ 800 to 1000 blpd with the PI of 1 to 1.5 bbl/day/psi.

After successfully executing PPT for the first time in KOC, the Production GOR test conducted after a month showed stabilized production rate of 1279 blpd, 363 bopd with a PI of 2.25 bbl/day/psi, which is two times more than the earlier PI. The liquid production is above the model predicted and achieved an incremental oil gain of 167 bopd due to plasma pulse technology, ie an increase of 85% from the initial oil production rate. In addition to this, immediately after plasma application, observed 81 psi increase in pump intake pressure of the nearby well RA-000B which is 400m away from this well. It is planned to carry out plasma pulse stimulation technique in more candidates including Rigless application.

Introduction

Stimulation is a well-practiced technology in oil industry to improve productivity or injectivity of a well. Plasma Pulse Technology (PPT) is a special kind of stimulation technique where oil production enhancement occurs without formation damage and without using chemical agents. PPT is based on scientific research in the areas of Geology, petro-physics, blasting theory, acoustic, wave theory and resonance theory. Plasma-Pulse Technology is set apart from conventional stimulation and fracturing methods. Plasma-Pulse Technology is used successfully by KOC to stimulate and enhance productivity and injectivity of oil & gas wells. (Fig 1). The capabilities and characteristic of the tool are as mentioned

- Well depth — up to 13000 ft
- Bottom hole temperature — 200°F
- Energy consumption — 1.5 KJ
- Outer diameter — 4.02 inch
- Length of equipment — 8.9 ft
- Voltage — 220 V / 50 Hz
- Input power 500 Watt

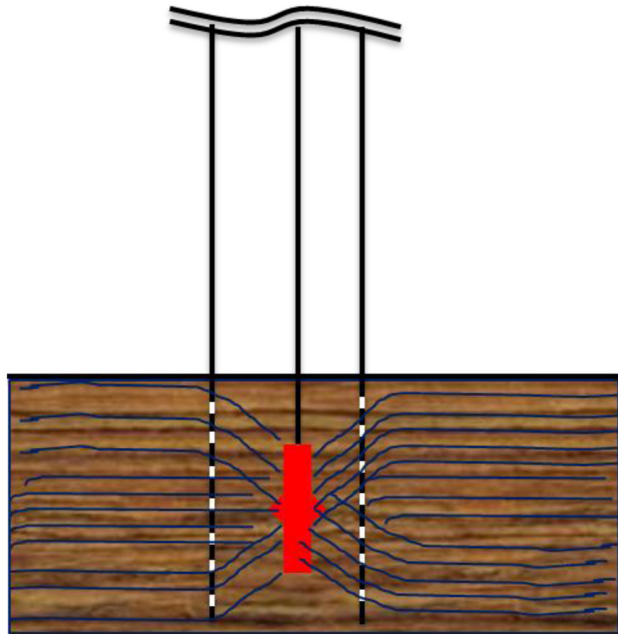


Figure 1—Plasma Pulse Technology Application

The employment of PPT is used to achieve the following;

- To improve oil recovery
- To energize the well at the development stage
- To increase the injection wells injection capacity
- To restore the well's yield or production capacity after the drop in the hydraulic fracturing impact
- Redistribute the well's intake/injection capacity profile.

Plasma Pulse Technology (PPT)

The Plasma Pulse tool creates a controlled plasma arc within a formation, generating a tremendous amount of heat for a fraction of a second. The subsequent high-speed hydraulic impulse wave emitted is strong enough to remove any clogged sedimentation from the perforation zone without damaging steel. The series of impulse waves/vibrations also penetrate deep into the reservoir causing nano fractures in the matrix which increase reservoir permeability.

Plasma Pulse Technology (PPT) is an environmentally friendly technology that allows producers/injectors to obtain sustained higher productivity/injectivity. The tool cleans the perforated intervals and changes the wells inflow characteristics by fixing near wellbore damage while increasing the mobility of hydrocarbons within the surrounding reservoir. The cleaning of the near wellbore region, increasing relative oil mobility and the generation of elastic vibrations and their resonance continues after the well is treated with PPT and can sustain an increased production flow for periods of up to twelve months or more. The resonance vibrations created in the formation make it possible to clean existing filtration channels and to create new ones at a distance over 1500 meters from the point of initiation of the plasma pulse action. In addition to the large-scale action as discussed above, this creation of plasma also allows local problems such as poor well drainage to be resolved as paraffin, asphaltenes, scales and other materials are cleaned away. This plasma-pulse technology can be applied in vertical, deviated and horizontal wells, with the proper conveyance techniques.

The principle operating procedures of PPT are very simple and can be done in quick time;

- Plasma pulse tool is placed opposite to the perforated interval.
- Initiation of the metallic conductor explosion, formation of plasma accompanied by a compression wave
- Through the perforated channels, the initiated shock wave penetrates the drainage area and propagates further on into the stratum inducing elastic vibration
- Plasma cools down, excessive formation pressure forcing the sedimentation to flow into the sump of the well, the shock wave altering into flexible volume oscillations.

Candidate Selection and Job execution

Well RA-000A is located on the North Eastern part of the field and completed in Lower Burgan (LB) reservoir. (Fig 2). The structure of Lower Burgan is a doubly plunging anticlinal structure. Lower Burgan reservoir is broadly divided into two pressure/ flow regimes separated by a sequence / lithostratigraphic unit, LBLSID4. The lower one is called as Massive or LBM and the overlying is as Layered or LBL. The Massive is composed of thick medium to coarse grained well sorted sandstone. The Layered is composed of relatively poor quality of sand with shale intercalations.

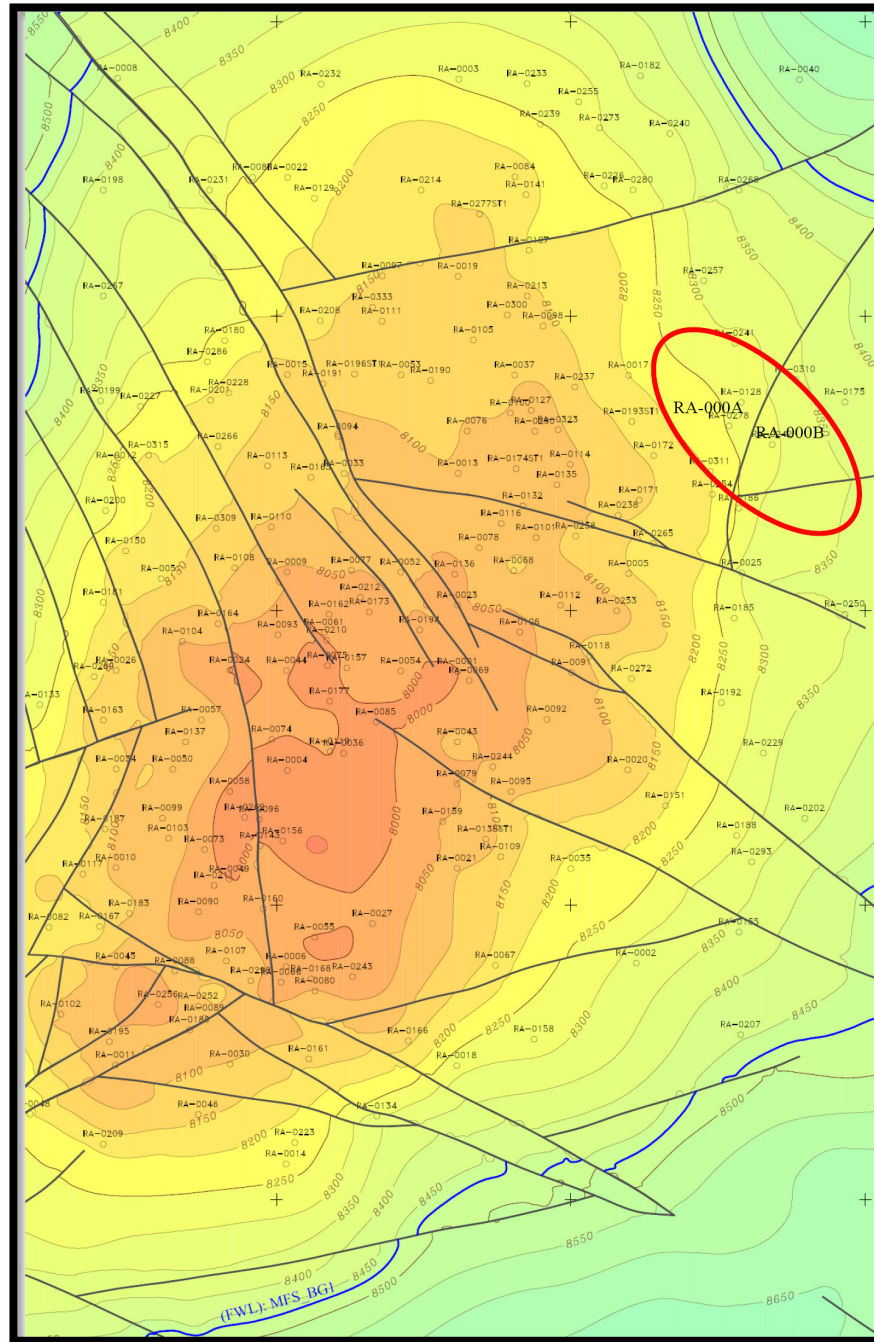


Figure 2—Structure Map showing Plasma candidate well

Lower Burgan Layered sandstone package shows significant lateral and vertical heterogeneity. This section is succeeded by first laterally extensive unit of marine mud rocks (LBSID-4) with associated shore face sandstones. It is having both progradational and retrogradational elements. The marine embayment is overlain by another package dominated by channelized sand bodies (LBLCOAL-1&2). During deposition of this section again estuarine environment identical to those described above appears to be in operation. The remainder of Lower Burgan is (LBSID-1, 2 &3) is a retrogradational package of shore face sandstones, with sporadic preservation of minor channel sandstones deposited during relative fall in sea level. This section is overlain by a thick section of stacked progradational muddy shorefaces (Middle Burgan), (Fig.3).

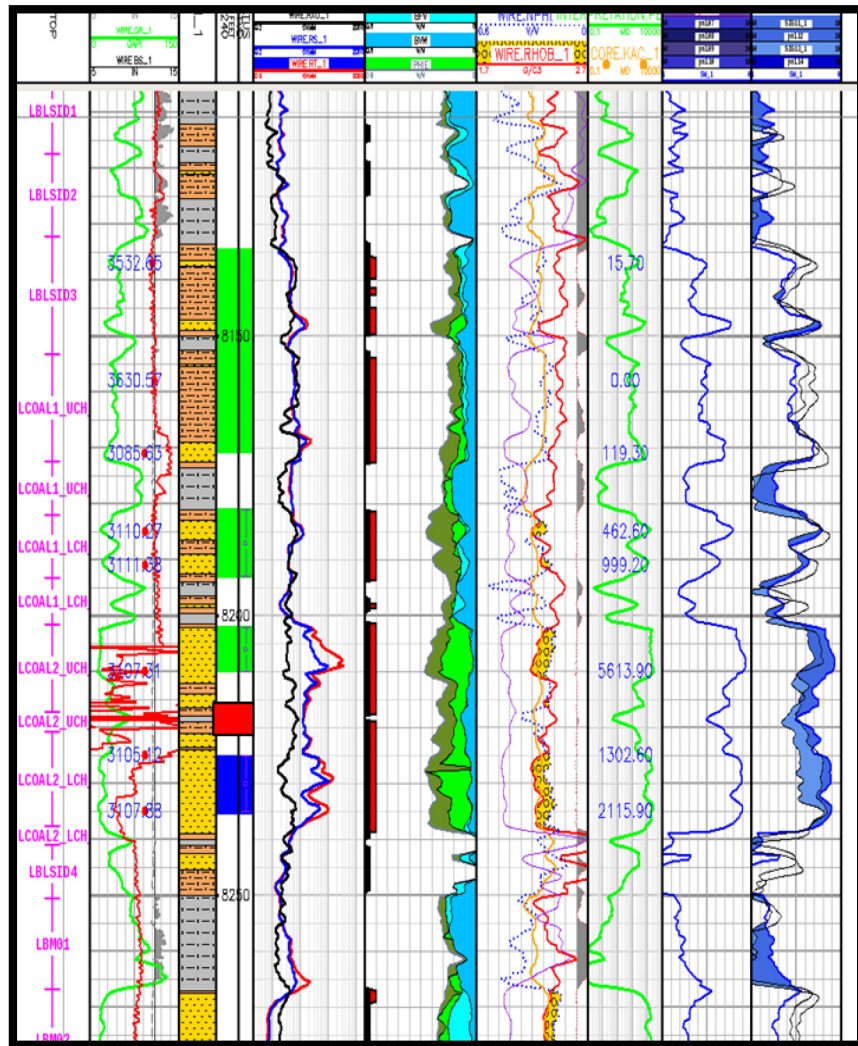


Figure 3—Petrophysical Properties showing Perforated Intervals

Initially the well RA-000A was exploited by perforating the high permeable layers of COAL 2UCH & LCH and COAL 1. Due to minimum pressure difference between the layers, all the three layers perforated and produced cummingly. The three perforated intervals produced cumulative oil of about 2 MMbbls. The last reported rate prior to PPT application was 196 bopd with 90% water cut and closed due to high water cut. Sigma log recorded to know the layer wise oil and water saturation. Due to high formation water salinity of about 220000 ppm, sigma log is very effective to identify fluid saturations. The log shows that out of three perforated interval, the bottom COAL2_UCH layer having very high water saturation, the top of COAL2_UCH is having little water saturation and COAL1 LCH is almost dry. The porosity and permeability of the bottom layer of COAL2 UCH is very good whereas COAL1 LCH is having moderate rock quality.

To improve the productivity of the well during Rig Workover it was decided to add LBL SID3 and stimulate with Plasma Pulse technology. Compare to LBL Coal 1 & 2, LBL SID3 is very tight with low permeability and low porosity. Due to variation in pressure and permeability the COAL's and SID's are not generally cummingled. Here it was decided to cummingle both by giving higher drawdown with the help of ESP. Owing to the petrophysical variation planned to execute plasma pulse with varing intensity. Accordingly, the SID3 layer was stimulated with high intese plasma pulse and the LBL layers were stimulated with relatively low intensity. The main objective is to exploit the oil from tight SID layer which cannot be produced or difficult to produce using conventional techniques and improve productivity by

removing formation skin if any in LBL Coal layers. The other added objective is to expect positive improvement in productivity of nearby well RA-000B which is located just 400m away from this well.

Prosper Model – Before and After PPT

A prosper model was constructed considering production from two existing and the added SID interval. PVT match is done using the fluid analysis of well RA-000A. Recently measured static bottomhole pressure data was used to calculate the productivity index (PI) of well before executing plasma pulse stimulation. Sensitivity analysis performed with different reservoir parameters. Thus the nodal analysis calculated productivity ranging from 800 to 1000 blpd with a PI of 1 to 1.5 bbl/day/psi (Fig 4).

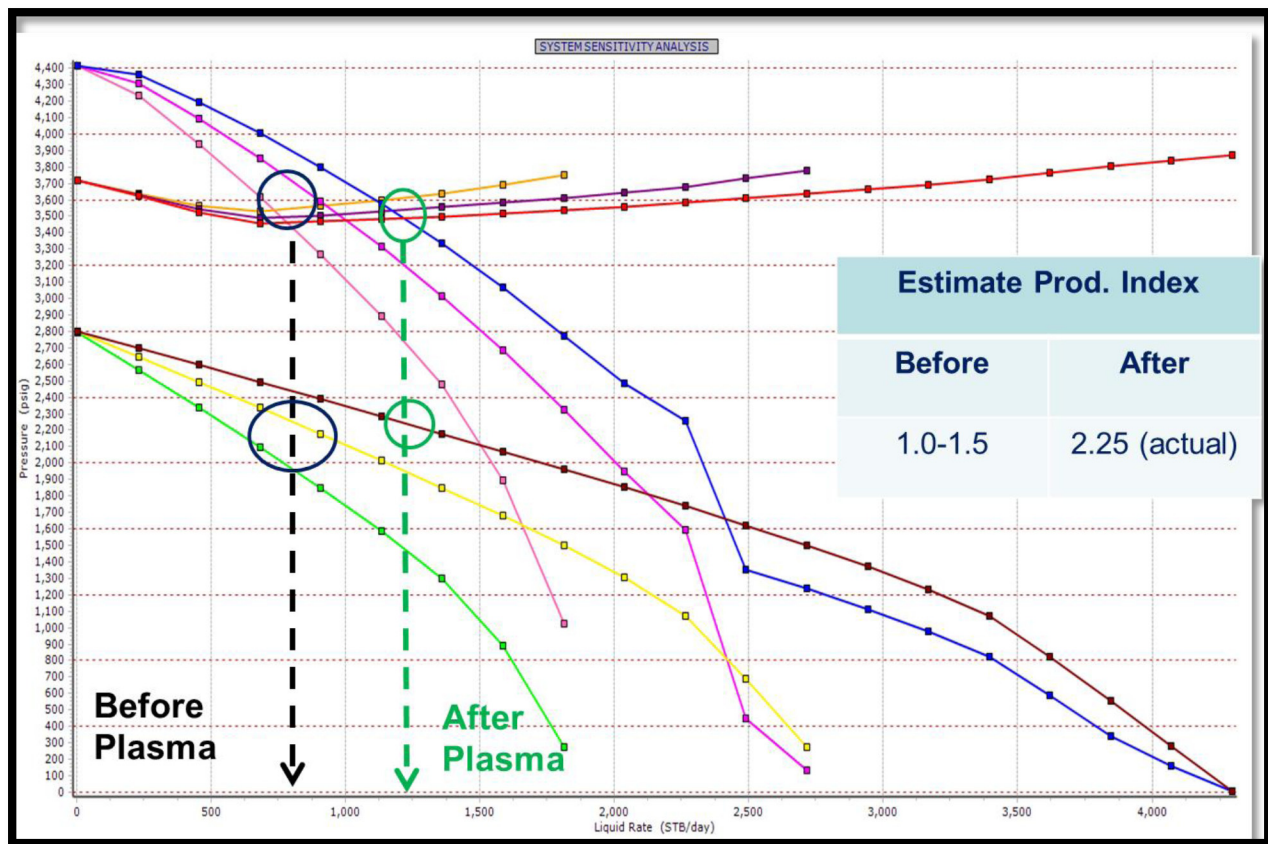


Figure 4—Prosper Model Before and After PPT

After successful execution of the job, during initial test well produced 1408 blpd with 62% water cut. The subsequent production test conducted after a month showed that the rate was stabilized @ 1279 blpd with 71% water cut. The actual liquid and oil production achieved after the plasma job is higher than model predicted. The actual PI achieved after the job is about 2.25 bbl/day/psi is almost double that of the estimated PI of 1 to 1.5 bbl/day/psi. The actual water cut after the job is higher than the expected rate. Since it's a ESP well completed with without Y tool, the well intervention to know the source of water is not possible.

The well RA-000A was producing an oil of about 196 bopd before the plasma stimulation and after the job the well is producing a stable rate of about 363 bopd. Plasm pulse job produced an incremental oil gain of 167 bopd, ie an increase of 85% from the initial oil production rate. The below Table 1 shows the Production GOR test before and after the execution of PPT.

Table 1—Production Data : Before and After PPT

Parameter	Expected production parameters before the job was done	Immediately after the job was done & ESP was connected (07.02.2014)	After the well was closed for 17 days and after the first PGOR test was done (03.03.2014)	After the second PGOR test was done (20.03.2014)
Production Rate	800 – 1000 BLPD	1408 BLPD	1279 BLPD	1220 BLPD
Water Cut	60 %	62 %	71 %	78 %
WHP	242 psi	272 psi	284 psi	240 psi
Intake pressure	1500 psi	1968 psi	1972 psi	1968 psi

Impact of Plasma on Near by Producer

It was expected that the near by wells around 1 Km from RA-000A will be affected positively. Well RA-000B located 400m away from RA-000A (both on ESP) and perforated in the same layers. After Plasma pulse application, observed 81 psi increase in pump intake pressure (Fig 5) and water cut has decreased from 48% to 38%.

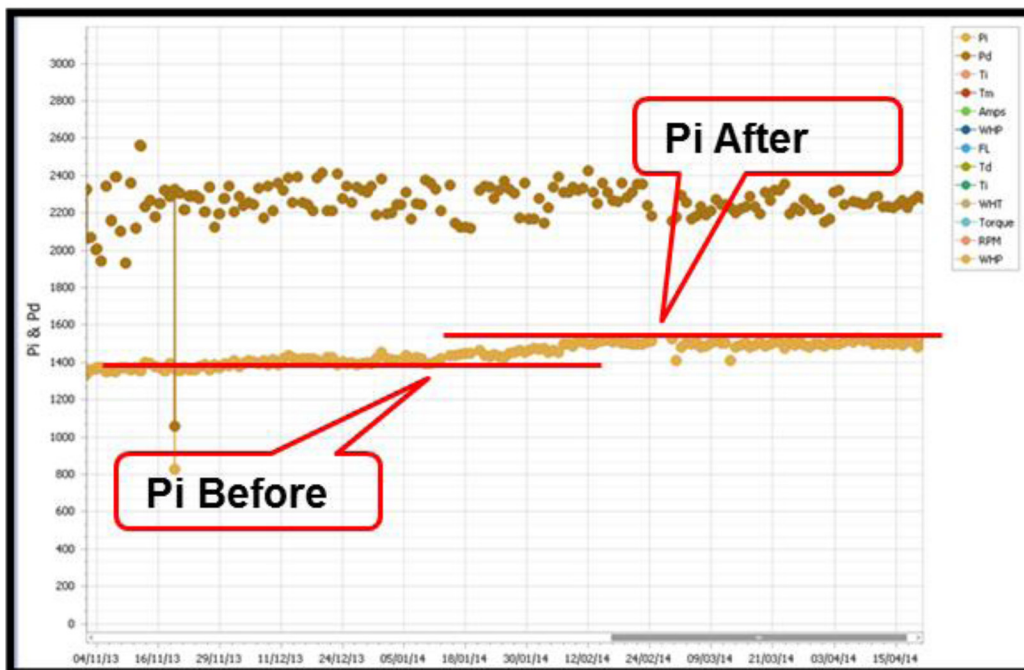


Figure 5—Increase in PIP in Nearby Well RA-000B

The log correlation of both wells shows that the sand thickness, perforated intervals and water encroachment is almost same in both wells (Fig 6).

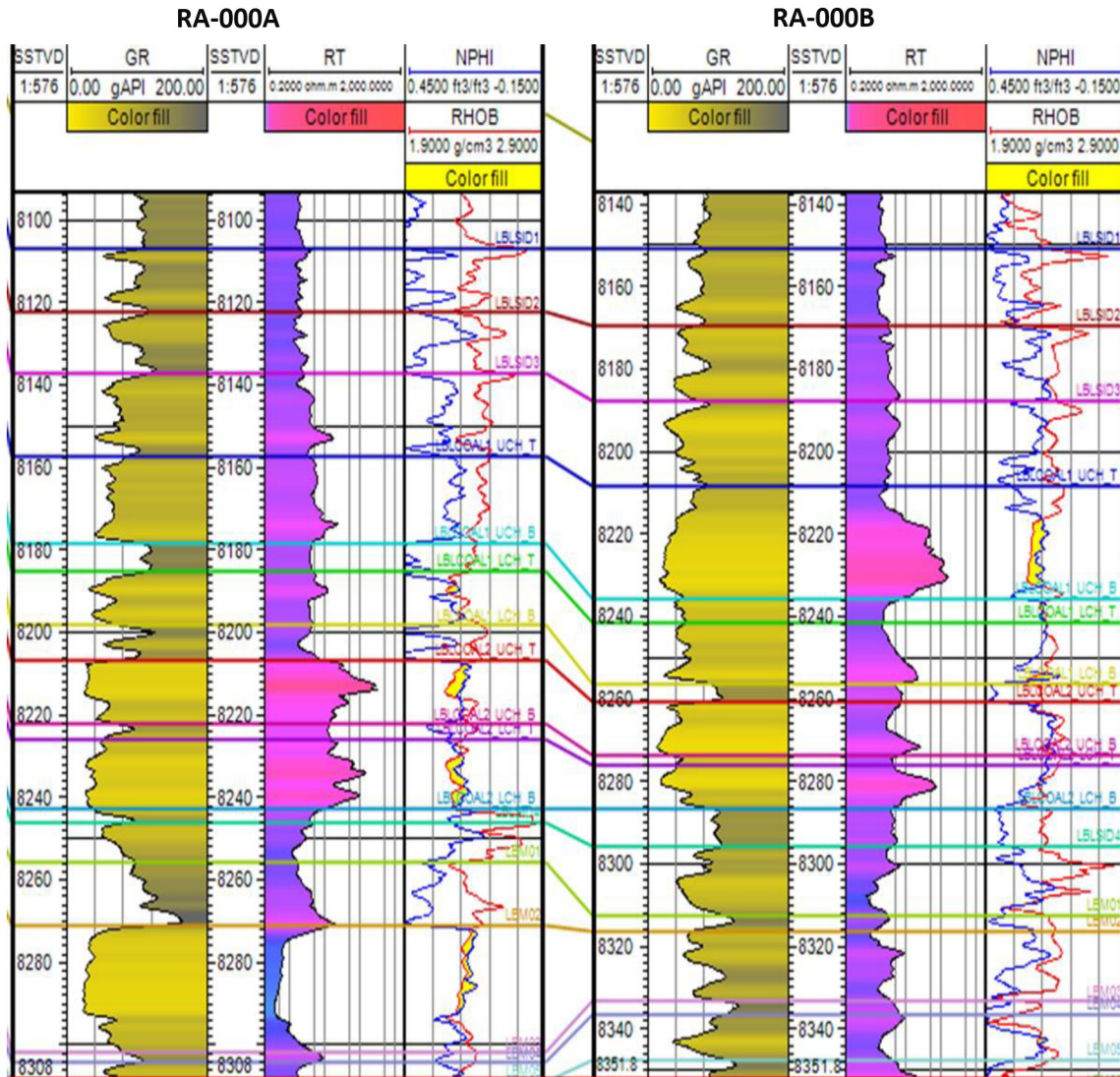


Figure 6—Log Correlation of Well RA-000A and RA-000B

The decrease in water cut is due to the fact that plasma applied only in SID2 and COAL1 LCH whereas the high water saturation COAL2 UCH is not stimulated. The Table 2 show the impact of well RA-000B due to PPT carried out at Well RA-000A

Table 2—Nearby Well Production Data : Before and After PPT

Impact on Well RA-000B		
Parameter	Before the job on (as on 01.01.2014)	After the job (as on 22.03.2014)
Water Cut	48%	38%
Intake pressure	1441 psi	1525 psi

Conclusion and Way forward

- Plasma Pulse Technology (PPT) is an environmentally friendly technology that allows producers /injectors to obtain sustained higher productivity/injectivity.
- The tool cleans the perforated intervals and change the wells inflow characteristics by fixing near wellbore damage while increasing the mobility of hydrocarbons within the surrounding reservoir
- Plasma Pulse Technology successfully tested in Kuwait for the first time in well RA-000A.
- The Productivity of the tested well increased from 1.5 to 2.25 bbl/day/psi.
- Plasma Pulse positively impacted the Near by well (~400 m) RA-000B, seen *81 psi increase in pump intake* and 10% reduction in water cut.
- The operation can be carried out very quickly and production impact is seen immediately.
- To apply and prove the effectiveness of the PPT on additional Producer and Injector well candidates
- Rigless stimulation with slim Plasma Pulse tool to be tested and the same to be applied in Horizontal wells.

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