academicJournals

Vol. 4(5), pp. 103-117, May, 2013
DOI 10.5897/JPGE2013.0153
ISSN 2141-2677 © 2013 Academic Journals
http://www.academicjournals.org/JPGE

Journal of Petroleum and Gas Engineering

Full Length Research Paper

Improving well productivity in an Egyptian oil field using radial drilling technique

Adel M. Salem Ragab

Department of Petroleum Engineering, School of Sciences and Engineering (SSE), American University in Cairo (AUC), Egypt.
Department of Petroleum Engineering, Faculty of Petroleum and Mining Engineering, Suez University, Egypt.

Accepted 22 April, 2013

Radial drilling (RD) technique utilizes hydraulic energy to create several lateral holes in different directions and levels with several lengths. These lateral holes are made by milling the casing with small bit then extending these holes laterally using high pressure hydraulic jetting. This work presents full descriptions and analysis for RD applications in one of the Egyptian oil field. Moreover, it attempts to analyze and then optimize the different means for performing this technique. Therefore, several tests was performed and analyzed. The total depths of these wells vary from 8856 to 8987 ft. The first well was laterally drilled by about 164 ft long by seven laterals and the angle between each two is 90°. The second well was drilled by 6 laterals in two different levels. Five of them extended to 164 ft, and one of them with 295 ft long. In the third well, 4 lateral holes were radially drilled with 165 ft long. After evaluation, the first well gross rate increased by 37.4%, and the net oil rate was improved by more than 31.4%; the second well shows an improvement by about 73.34% increase in gross rate, and 47.3%, an increase in the net oil rate; and the third well shows an improvement by about 14.3% gross rate, and 14.7%, an increase in the net oil rate for very short period. Several experiences have been gained from using this technology which extends the productive life of wells and accordingly of the whole field with reasonable cost.

Key words: Radial drilling, stimulation, lateral holes, hydraulic jetting, URRS.

INTRODUCTION

The well is drilled and then completed to move the oil and gas from its original location in the reservoir to the surface, and due to damage during drilling and completion operation, not all of these fluids can move to the area around the wellbore, therefore, it is always important to think about any unconventional means to reach or communicate these areas with the wellbore. One of the proposed techniques is to bypass the damaged zone which is called radial drilling (RD).

The objective of the radial drilling is to provide an extended wellbore radius by means of multiple radials from a vertical wellbore. It can be applied both in new and old wells. It is mainly used as high pressure jet flow energy to penetrate and elongate a number of lateral holes radiated from the main wellbore in the same layer or different layer. The choice of radial length, number of radials, and radial array is a function of the reservoir properties.

Radial drilling

The radial drilling (RD) is a technique that can create several small diameter drains from the well in a relatively

E-mail: adelmsalem@yahoo.com

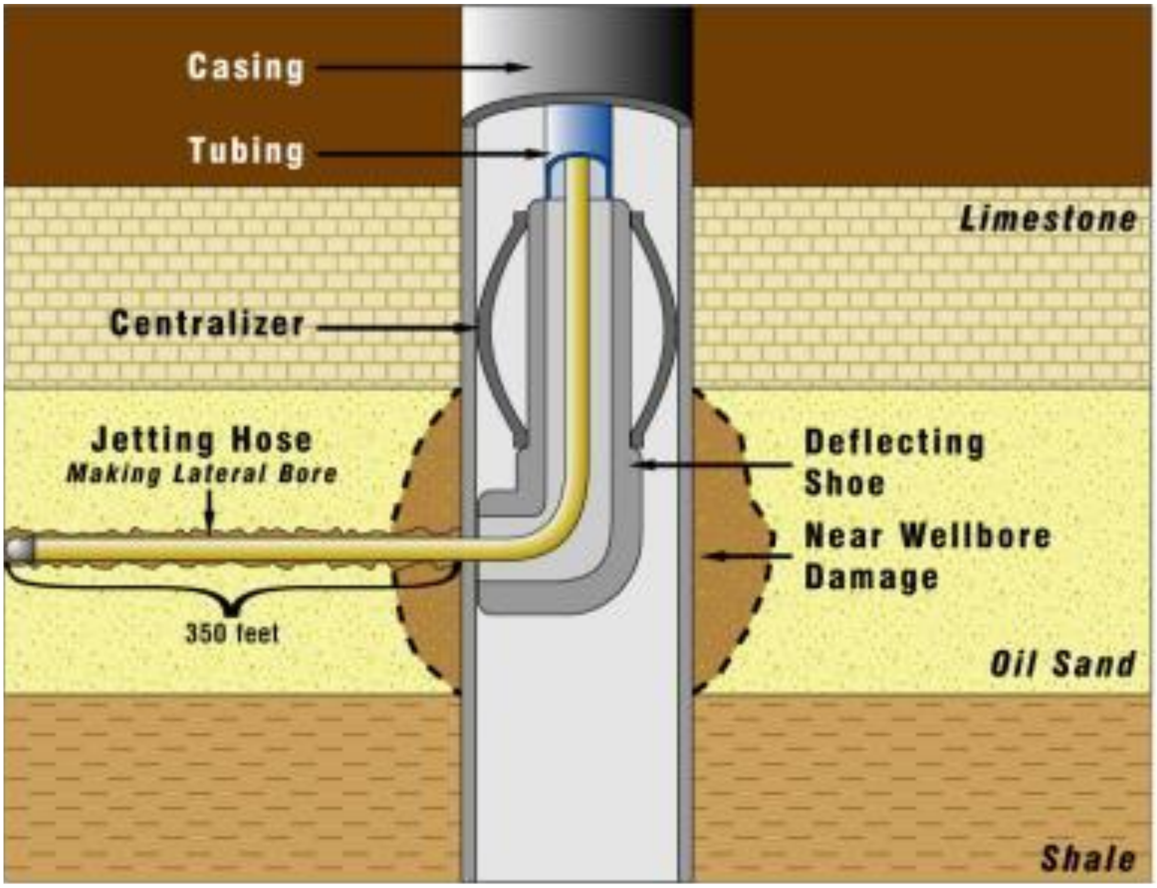

Figure 1. Radial drilling technique.

short time, normally 2 to 3 days per level. The diameter of these holes varies from few millimeters to several tenths of millimeters in the casing using high pressure fluid at selected depths and azimuth, and installed at single or multiple levels. These perforations can be extended radially up to 100 m perpendicular from the main wellbore, as shown in Figure 1. The first application of this technique had been performed in former Soviet Union (Elliott, 2011).

Working principle of radial drilling

The features of the tool are the capability to create and open a hole in the casing and subsequently jetting laterally into the reservoir formation creating a lengthy hole to bypass the damaged zone around the well which is called altered or skin area. To perform this, a special bottom hole assembly (BHA) which consists of a drilling machine; high pressure hose, and jet nozzle have been assembled. The drilling machine involves a drill bit driven by a combination of an electrical motor and a hydraulic piston, making a hole in the casing, its size depends on the bit size used. Then jetting through this hole may extend this hole to 100 m (≈ 330-ft), based on the hose length.

The components of the tool used in radial drilling mainly consist of the drilling machine and the jet drum. In addition, as depicted in Figure 1, it involves the following components:

(i) Tubing end connector
(ii) Controller unit/power pack
(iii) Anchor
(iv) Orienter/Indexer
(v) Steering-tool
(vi) Stroke cylinder.

Applications

The main application is to provide a fast and economical method to recover the remaining hydrocarbons form marginal or mature oil and gas fields.

This technique can be applied in different disciplines in oil well industry such as:

1. Well completions

2. Well stimulations
3. Directed reservoir treatment
4. Improve water injection
5. Improve vertical cleaning
6. Reduce water coning
7. New wells instead of standard completion methods
8. Water disposal and re-injection
9. Steam applications in heavy oil and tar sands
10. Mining applications (leaching).

Radial drilling benefits

Based on what have been performed on some worldwide fields, the radial drilling methods have some economical and technical benefits such as (Bruni et al., 2007; Dickinson-Dickinson, 1985):

1. Enhance production rate and recoverable reserves from marginal wells.
2. Improves injection rates in water disposal/injection wells.
3. Allows directional treatment of wells for example, acid, steam, CO_2, etc.
4. Outperforms conventional stimulation methods at a lower cost, in reduced application time and with higher potential production results.
5. Improved and extended drainage area in productive formations.
6. Radial drilling penetration greatly exceeds conventional (perforation) penetration and can reach substantially beyond the damaged area of the well-bore.
7. Reach beyond the damaged area of the well-bore.
8. Allows multi-layer application in thicker reservoir zones.
9. Most effective on old, low productivity wells.
10. No need for large, expensive rotary rigs.
11. Does not require mud pits that can damage the environment.
12. No casing milling requirement, therefore no need to circulate mud back to the surface.
13. No additional stimulation required.
14. The process is fast, average operation duration is two days per well, so no big loss in production.
15. No logging expense required.
16. No need to change well-bore configuration.

Limitations of radial drilling

Based on the previous operations using radial drilling all over the world, there are some limitations and challenges in applying such technique in oil and gas wells (Abdel-Ghany et al., 2011). From these:

1. Difficulties of penetration under porosity of 3 to 4%.
2. Maximum working depth about 10000 ft.
3. Bottom hole temperature not to exceed 120°C (248°F)
4. Maximum wellbore inclination 30° and no more than 15° at the zone target depth/zone of interest.
5. Maximum tensile strength 100,000 psi.

Radial drilling field operations

Bruni et al. (2007) show a brief description of the operation and bottom hole assembly of radial drilling technology. Radial drilling technique is described as a new coiled tubing convoyed drilling technique, were several new wells or lateral holes are jet drilled perpendicular from the mother well and into the reservoir formation, this technology is targeted for increasing the well productivity of the new and existing wells.

The following is a brief procedure for performing this job in a specific well (Figure 2):

1. Run in hole with deflector sub on drill pipe string correlating its depth with well logging.
2. Orient string with gyro.
3. Run in hole with milling tool (milling bit).
4. Pull out of hole with milling tool.
5. Run in hole with jetting tool.
6. Pull out of hole with hose, nozzle jetting tool.
7. Rotate deflector shoe and repeat operation at each lateral hole for any horizontal layer.

In another way, the radial drilling technology can be performed in three main steps, first step is milling the casing , second step is jetting the formation with high pressure nozzle and the last one is washing out the formation while pull out of hole. Figure 2 illustrates these steps.

The bottom hole assembly for milling the casing are; 1¾" bit connected with flexible shaft, both are rotated by conventional mud motor connected to coiled tubing up to surface, connected to coiled tubing unit with its monitoring system. Figures 3 to 5 show the bottom hole assembly for milling the casing.

The created hole size depends on formation strength, confining strengths and compressive loads from overburden and matrix stress, as well as on the speed of penetration of the jet. From surface tests an average hole size of 4 to 5 cm in diameter was obtained.

MECHANISM OF PENETRATION

It is reported in the literatures (Bruni et al., 2007; Buset et al., 2001) that there are four main penetration mechanisms. These mechanisms are: 1) surface erosion; 2) hydraulic fracturing; 3) poroelastic tensile failure; and 4) cavitation.

The net forces that affect to drive jetting nozzle forward can be derived from three main mechanisms; under

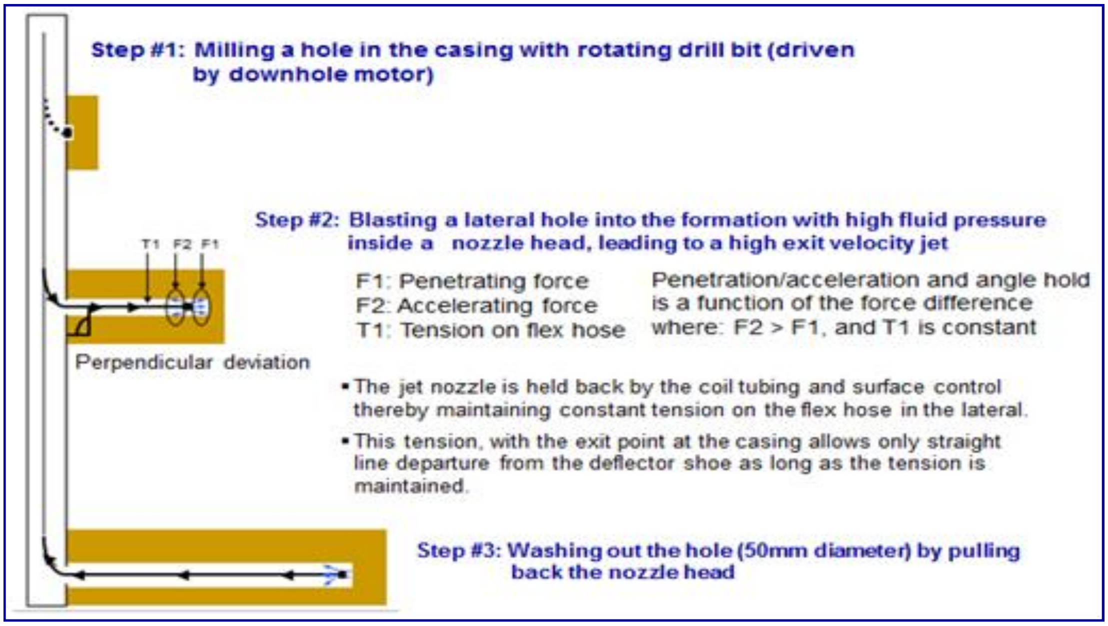

Figure 2. The three steps for radial drilling process.

Figure 3. Deflector shoe with flexible shaft inside.

Figure 4. The 1¾" bit connected to flexible shaft

Figure 5. The 1 ¾" bit and the flexible shaft connected to motor.

pressure force, jetting force and ejector force. The main mechanism is jetting force mechanism; Figures 6 and 7 show the driving mechanisms of jetting nozzle and it effect of core sample.

The BHA is gathered and then circulating with an intermediate flow rate; once the BHA is close to the baffle shoe, the flow rate is increased and the tool is slipped allowing for the introduction into the anchor. Once the hose enters the formation, it will move horizontally in the formation due to the force generated by the distribution of

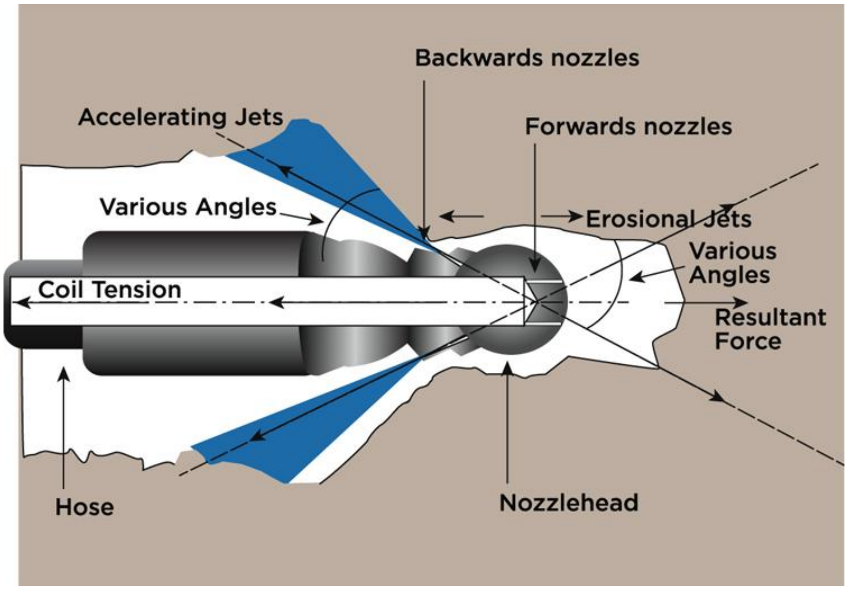

Figure 6. Sketch of the nozzle.

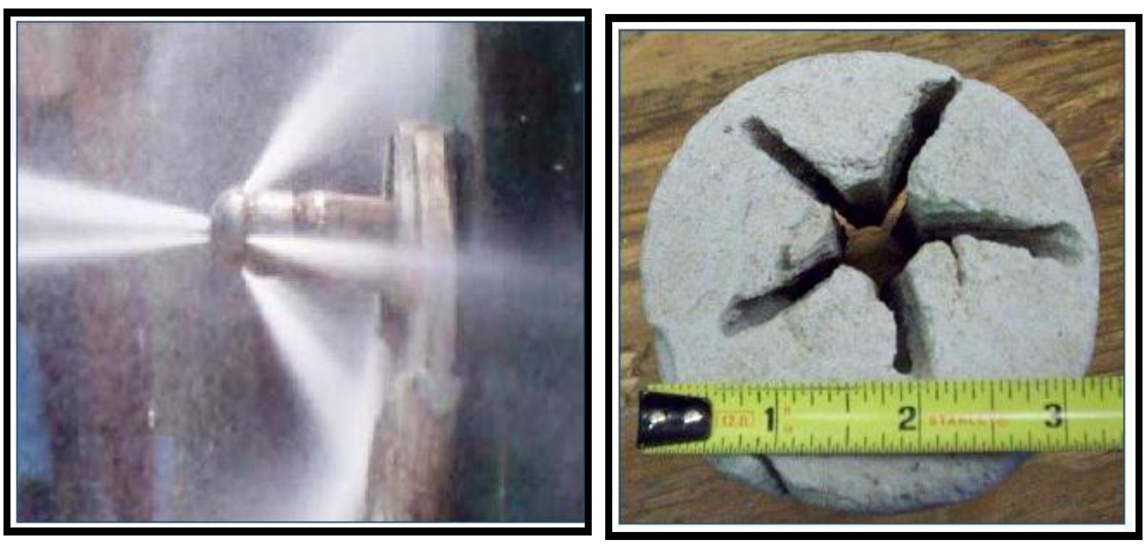

Figure 7. Jet nozzle of 8000 psi and its effect in core sample.

jet nozzles. The force S in the driving direction can be calculated from the following equation:

$$S_{jetting} = \rho u_o^2 A_o - \sum_{i=1}^{6} \rho u_i^2 cos\varphi_i \, A_i$$

Where:
A_o = Inside hose area (m^2)
A_i = Nozzle area (m^2)
u_o = inside hose velocity (m/s)
u_i = Nozzle velocity (m/s)
ρ = Density of water (kg/m^3)
φ = Angle of the nozzle.

WORLDWIDE FIELD APPLICATIONS

In 1985, Dickenson-Dickenson described a new system to drill horizontal holes of 100 to 200 ft in length, and about 4 inches in diameter, through an unconsolidated formation in Californian oil field. Then placing a 1¼ inch OD production carbon steel tube within the 4 inch diameter bore hole in the formation while drilling is in progress. The drill system uses 8000 to 10000 psi water jet drilling causes a velocity ranges from 6 to 120 ft/min. They mentioned that this drilling system is not limited to horizontal shallow, 100 to 200 foot radials, it is neither limited to a 1¼ inch production tube nor a 4 inch radial bore. The system can work vertically and can be place in very long and large tubes, moreover, it can be applied in offshore reservoirs, consolidated formations, waste disposal and mineral recovery by solution mining.

In 1989, Dickenson et al. extended their previous work not by elongating the depth of penetration but by increasing the number of radials, they named it ultra-short radius radial system (URRS). Multiple radials can be placed at the same level and on multiple levels and horizontal completions can be provided, including 100% gravel packing, *in-situ* electrolytic perforation and cutting, and flexible sand barriers (FSB's). Initial field applications were in unconsolidated formations. The basic URRS uses an erectable whip stock lowered down hole by a 4½ inch work string into an under reamed cavity or hydraulically slotted opening of 22 inch diameter. The surface water drilling fluid pressure ranges from 8000 to 10000 psi which is pumped into the long vertical work string with a conventional fracture pump (Dickinson et al., 1989).

Dickinson et al. (1992) presented for the first time the use of combination of water jet drilling and coiled tubing, URRS and quick radial system (QRS) provide multiple horizontal radials on a single horizon near wellbore. These have been done by milling of casing and under reaming of a cavity. The hardware of the URRS includes whipstock, drilling string, jet drilling, control while drilling, positional survey, cutoff and perforation, gravel packing, slotted liner, and gravity drainage.

Yonghe et al. (2000) described the application and development of using URRS by high pressure jet flow techniques, and applied this technique for two wells. They described the details of the operation in which they performed radial holes with lengths ranged from 4 to 10 m. They concluded first, that this technique can greatly increase oil recovery and oil production rate and second it needs some improvement to solve some problems before the large scale uses.

Marbun et al. (2011) reported herein discusses the application of the URRS. The specific variables like reservoir thickness, vertical and horizontal permeabilities, oil properties, well spacing, outer-boundary reservoir pressure, gravity drainage, thermal and non-thermal processes and impermeable partings within the reservoir has been studied together with drilling operation parameter like casing design, drilling fluid design, radial drilling equipment, Bottom Hole Assembly to optimize the drilling process and completion of the URRS at field.

In the North Urtabulak Oil Field in southern Uzberkistan (Bruni et al., 2007), a trail program was conducted in five existing wells using radial drilling, a coiled tubing workover technique in which lateral holes of 2-in. diameter are drilled up to 330 ft from the original well bore by high pressure water jetting. All but one of the five trials wells displayed significant post workover uplift in production, leading to overall incremental production of more than 17000 bbl in 2011.

Buset et al. (2001) in his paper titled “Jet Drilling Tool: Cost-Effective Lateral Drilling Technology for Enhanced Oil Recovery” addressed a new coiled tubing (CT) conveyed drilling technique, were several new wellbores are jet-drilled perpendicular from the mother well and into the reservoir formation. Their objective is to improve the production profile around the mother well, by penetrating the damaged skin zone, and connecting to possible hydrocarbon pockets left behind in the reservoir. They described mathematically the new CT tool in terms of the Penetration Effect, and pull effect. The first effect which is penetration mechanisms were Identified by Surface Erosion, Hydraulic Fracturing, Poroelastic tensile failure and Cavitation. The second effect, the net pull effect that works the nozzle forward can be derived from three main mechanisms: the under pressure force, the jetting force and the ejector force. Finally, they concluded that further research and testing of the jet nozzle penetration mechanism are required in order to identify the optimal nozzle configurations.

Elshahawi et al. (2001) presented several case studies performed in Belayim Fields of Sinai, Petrobel-Egypt to enhance their production. The main reasons for trying this new technique were the reduction in the wells productivity, and the rapid decline in total field production. The major wells in this field were under artificial lifting and this involved the integration of data from various sources. They showed in their study that the majority of wells in the field were suffering from severe damage. Using nodal analysis and skin modeling, the wells were then categorized based on the value of their completion factors (the ratio of actual to theoretical productivity indices), and the potential sources of damage were identified for each category.

The method used to mitigate this shortage in the wells productivity is to deep penetrating perforating charges, this had been performed after investigating the origin and the development of formation damage in Belayim Fields and how this damage was attributed to different damage mechanisms using a novel combination of nodal and damage analysis techniques.

Elshahawi et al. (2011) addressed several methods for damage removal such as vacuum strings (for perforation cleaning), surging using an atmospheric chamber (failed), acidizing (failed), demulsifiers and other chemicals to break emulsions (failed), and finally Deep-penetrating perforating. The later technique in Petrobel was the most successful productivity enhancement over the last few years. The main reasons for this success are to increase the surface area available for flow, decrease pressure drop and thus reduce the flow velocity across the perforated interval. And present three cases illustrating how deep penetrating perforating has been successfully used to remove well damage and increase well productivity, namely Well BM-30 m, Wells Sidri-3 and Sidri-4, and Well Sinai-02.

FIRST CASE OF RADIAL DRILLING APPLICATION IN EGYPT

This technique was applied for the first time in Egypt in Belayim Land Oil Field in Petrobel Company (Dickinson et al., 1989). The formation of the Belayim Oil Field is located in the central part of the Gulf of Suez along Sinai Peninsula. Belayim oil fields are characterized by multiple layered reservoirs generally formed from sand with inter-bedded shale and anhydrite from different ages. Belayim oil field main production now depend on artificial lift; secondary recovery are used (water injection).

The data of the first job are collected and analyzed in order to decide extending this technique to more other wells in the company. Many considerations had been taken into account for well selection. From these consideration, open hole logs for defining the pay zones, lithology, static bottom hole reservoir pressure, average porosity (about 20%) and permeability, cased hole logs and casing types and grades. Based on all of the mentioned parameters three wells were selected to evaluate radial drilling technique from layered reservoir zones II-A and IV. Currently, Zone IV contains about 23% of Belayim OOIP and contributes about more than 27% of production.

This technique is applied in three wells, in the first one, which was producing a commingle from two zones (Belayim and Sidri), six lateral drains at two levels was performed, five of which are 50 m long and one penetrate about 92 m long, all oriented by gyro tool. In the second well, seven laterals have been performed in Sidri formation, all penetrate 50 m long each at one different depth and oriented like a spiral by rotating the BHA at the surface one and half turn. The last well, four lateral are performed at two different depths, all are 50 m long (Abdel-Ghany et al., 2011).

In 2011, Abdel-Ghany et al. presented some experience gained from using this technique and concluded that; for one well, an increase in the rate of 75 to 130 m^3/day, for the second one, the production rate is increased from 41 to 45 m^3/day, and for the last well, the results showed no change in flow rate.

RESULTS

Case 1: Well # 1

Well #1 is produced from two different zones (zone II-A and zone IV) with an average daily rate of 251 bpd, the current static reservoir pressure is about 900 psi and productivity index is 2 barrel per day per psi, the formation porosity 20% in average, the rock permeability is varied largely, the total depth of this well is about 8856 ft and net pay thickness is 82 ft. Figure 8 illustrates the casing and perforation interval of that well. This well radially drilled on 2010 to evaluate and optimize this technique in the field.

Radial drilling job were performed on this well by milling and jetting seven lateral holes with 164 foot lateral length at different depths from zone IV as shown in Figure 8. The hydraulic jet pressures for all of them were 7000 psi. Table 1 shows the accurate depths and elongations for each lateral.

While performing RD in this well, a vacuum test was performed before and after radial drilling job to evaluate this technique. Production rate shows an increased after stimulating the well with this technique. The gross production rate increased from 252 to 346 bpd, where the net oil rate increased from 220 to 289 bpd, which means 37.5% increase for the gross rate and 31.4% for the net oil rate. Figures 9 to 11 show the results of vacuum tests before and after jobs. Table 2 shows comparison between rate before and after radial drilling job, and Figure 12 displays gross production performance before and after applied radial drilling technique. As shown in that figure, the rate maintained awhile after performing the test and then declined again but still better than before conducting the technique. This is attributed to ‘do not fill the hole with any material’ and that can keep the channel open in order to guarantee constant production rate.

Case II: Well #2

This well is produced from three zones (zone II, II-A and zone IV) with average daily production rate 471 bpd, its current static reservoir pressure is about 1990 psi at top of perforation 7126 feet sub sea level and productivity index is 1 barrel per day per psi from last vacuum test before applied radial drilling, its rock porosity is 20%, heterogeneous permeability, the total depth of this well is 8134 ft and net pay thickness is 133 ft. Figure 13 illustrates casing and perforation interval for well #2.

Radial drilling job was performed on this well by milling and jetting six lateral holes at two depths with 164 ft lateral length and one of them was 295 ft lateral length from zone II-A. Table 3 shows the full details of the six laterals performed in well #2. In the previous well, the lateral holes were drilled randomly but here in this well the lateral hole selection was based on geological maps and faults orientation so holes were made at two depths and oriented with consideration to north direction.

A vacuum test was performed on this well before and after radial drilling job to evaluate this technique. Production rate obviously show increase after stimulating

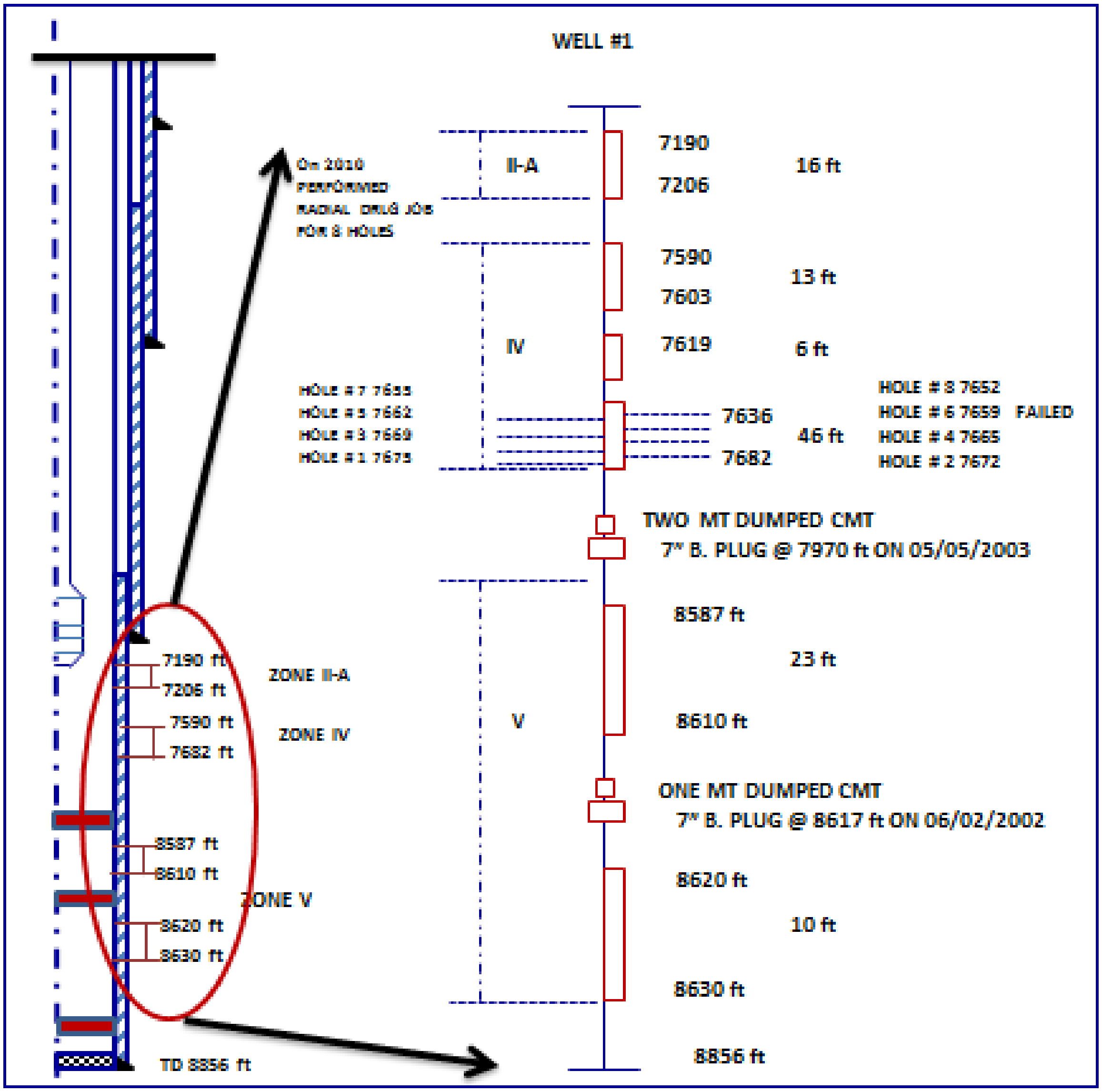

Figure 8. Casing and perforation sketch of well #1.

Table 1. Radial drilling operation performed on well #1.

No. of hole	Hole depth (ft)	Penetration length (ft)	Jetting pressure (Psi)	Remarks
1	7675.20	164	7000	
2	7671.92	164	7000	
3	7668.64	164 (L)	7000	
4	7665.36	164 (L)	7000	
5	7662.08	164 (L)	7000	
6	7658.80	***	7000	Tried two times to drill, no success
7	7655.52	164	7000	During POOH found the bit and flex shaft in side deflector shoe
8	7652.24	164	7000	

(L): Lateral.

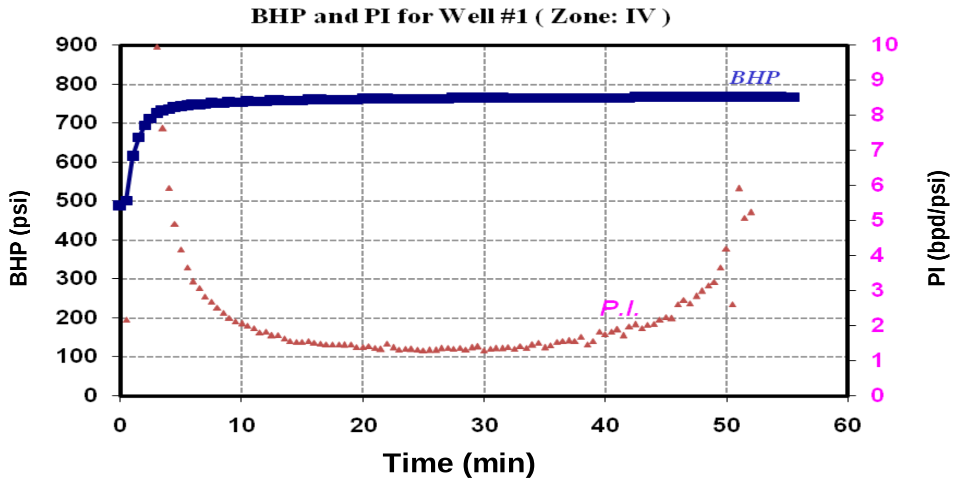

Figure 9. Fill-up test for BHP and P.I test before RD of well #1.

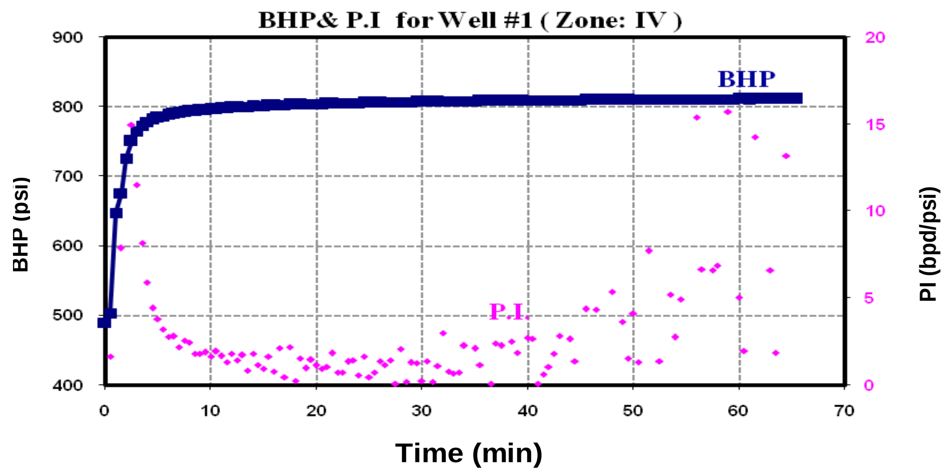

Figure 10. Fill-up test for BHP and P.I test after radial drilling.

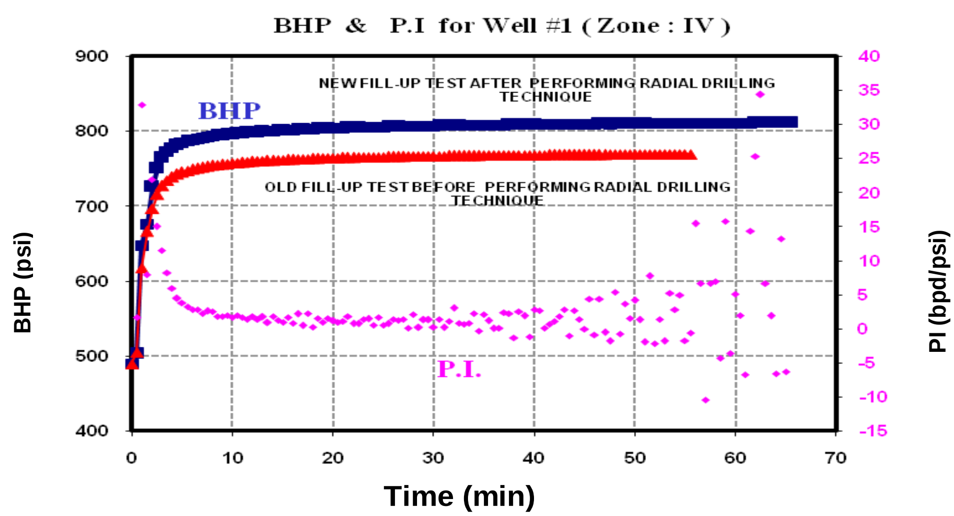

Figure 11. BHP comparison between the two tests before and after RD.

Table 2. Comparison between the rate before and after RD.

Before radial drilling			After radial drilling		
Rate (bpd)	WC (%)	Net oil	Rate (bpd)	WC (%)	Net oil
252	12	220	346	16	289

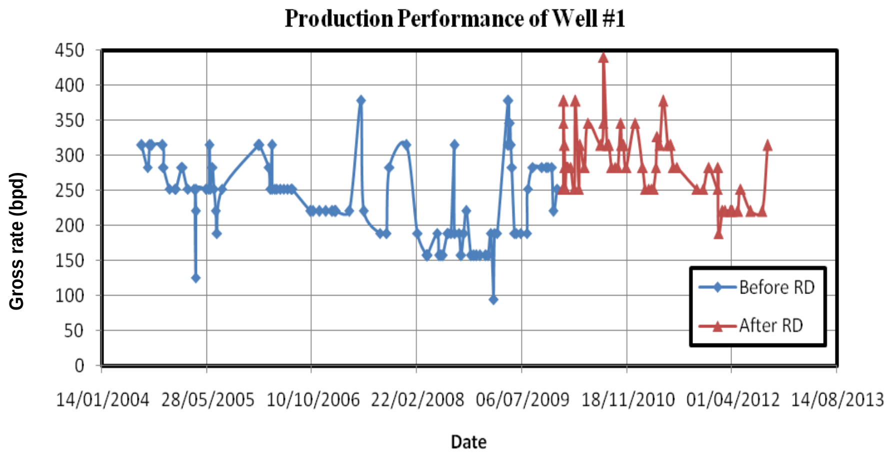

Figure 12. Production performance for well #1.

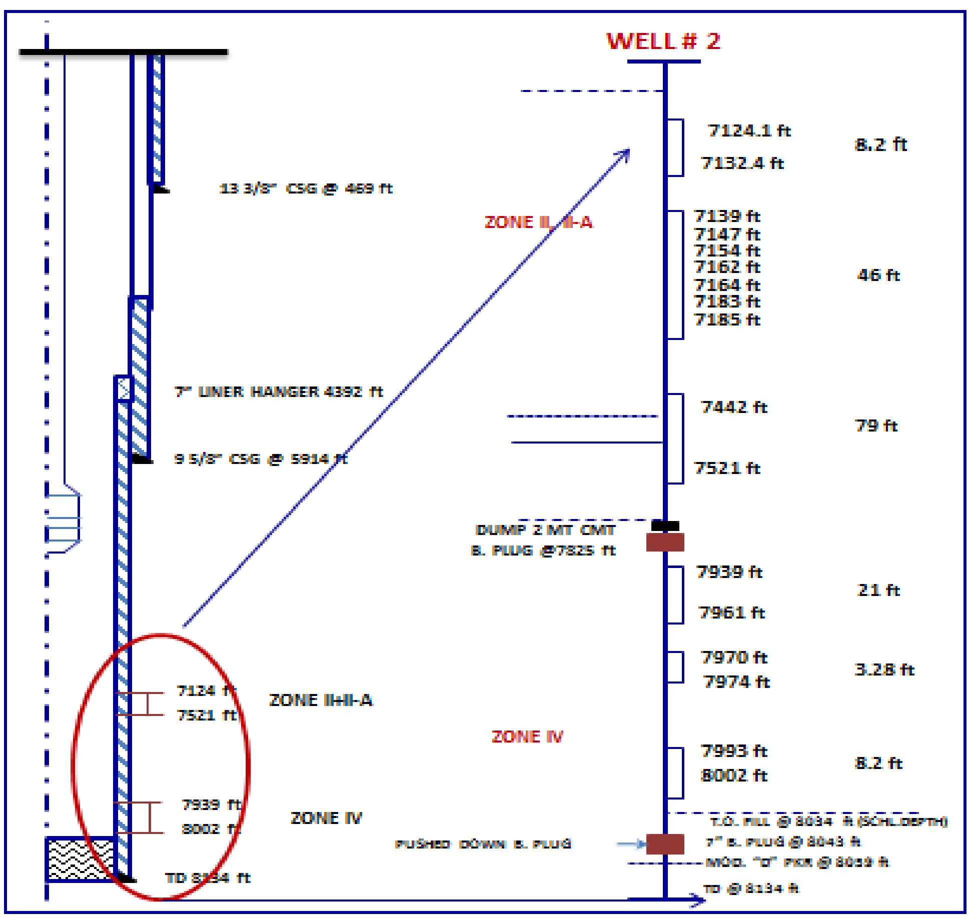

Figure 13. Casing and perforation sketch for well #2.

Table 3. Radial drilling operation performed on well 2#.

Depth (ft)	7462 ft			7449 ft		
No. of holes	1	2	3	4	5	6
Angle from north	20	150	225	20	150	240
Depth of lateral (ft)	164	164	295	164	164	164

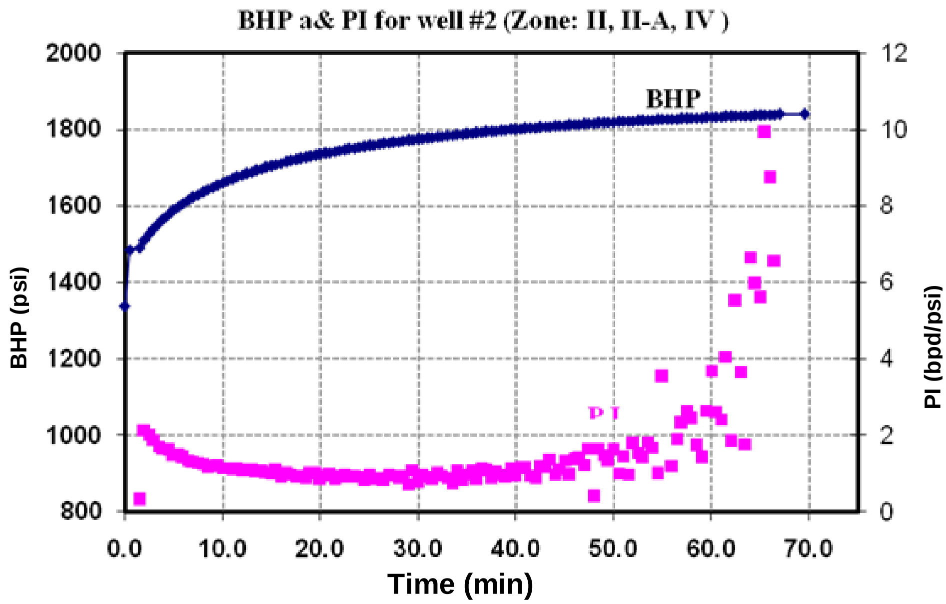

Figure 14. B.H.P and P.I vs. time, vacuum test results before radial drilling.

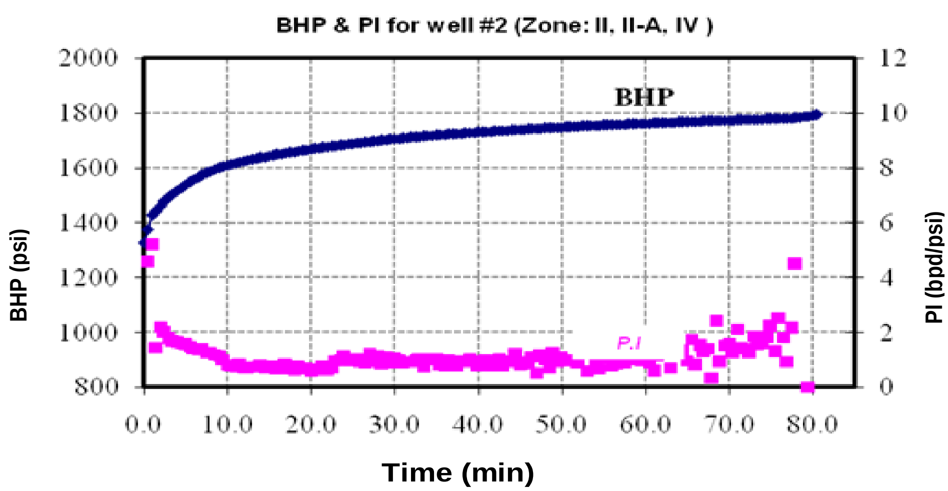

Figure 15. B.H.P and P.I vs. time, vacuum test results after radial drilling.

the well with this technique. The gross rate increased from 472 to 818 bpd immediately after the RD performed, and the net rate increased from 465 to 686 bpd. However the static well pressure decreased which mean a decrease in fluid level, and productivity index still the same. Figures 14 and 15 show the bottom hole pressure before and after RD performed respectively. Figure 16 illustrates overlapped results of well #2 before and after

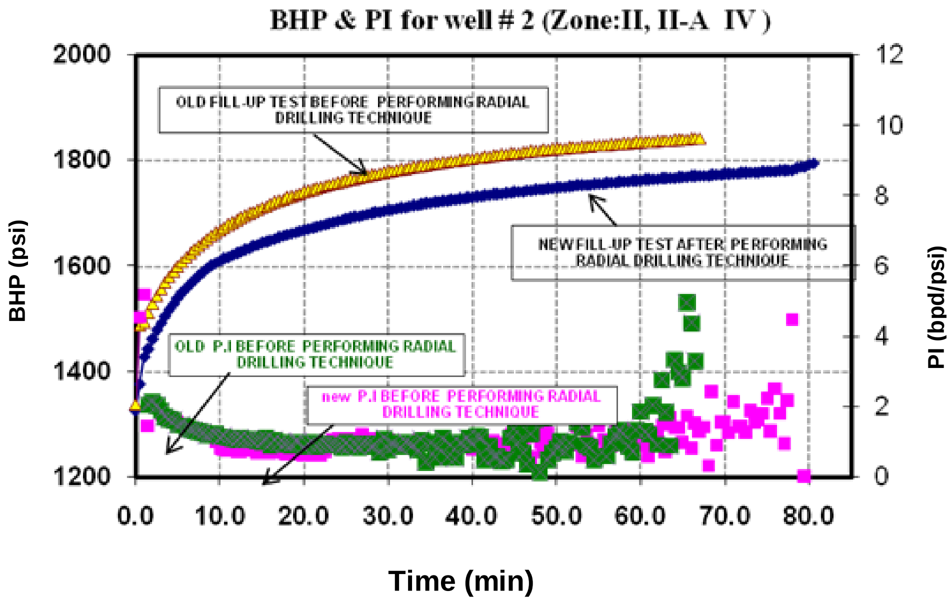

Figure 16. Comparison between the two vacuum tests.

Table 4. Comparison between rate before and after radial drilling for well #2.

Before RD			After RD		
Rate (bpd)	**WC (%)**	**Net oil (bpd)**	**Rate (bpd)**	**WC (%)**	**Net oil (bpd)**
472	1.6	465	818	16	686

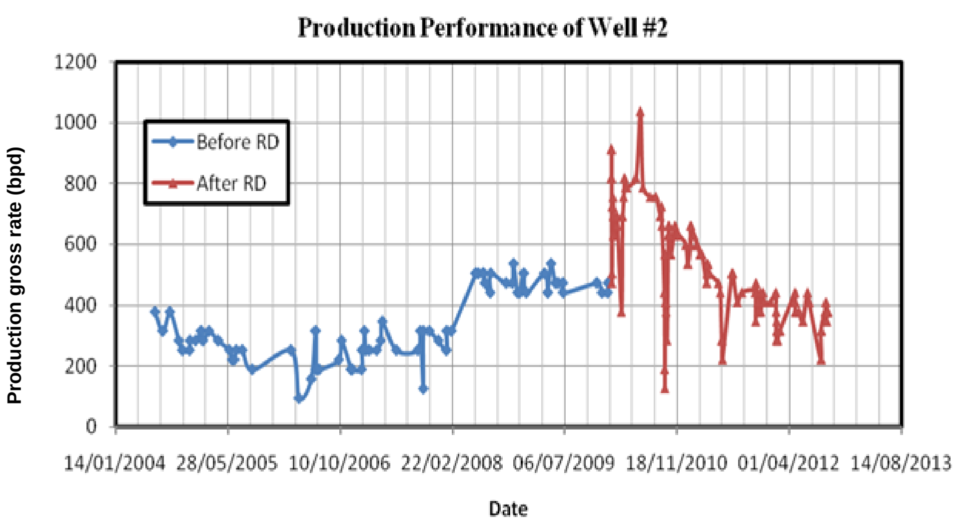

Figure 17. Production performance of well #2 before and after radial drilling.

the vacuum test. Table 4 shows comparison between rate before and after radial drilling job which mean gain in net oil production about 221 bbl/day. Figure 17 shows the production performance of well #2 before and after the radial drilling operation. It shows how RD enhances the productivity from this well and how it declines after a

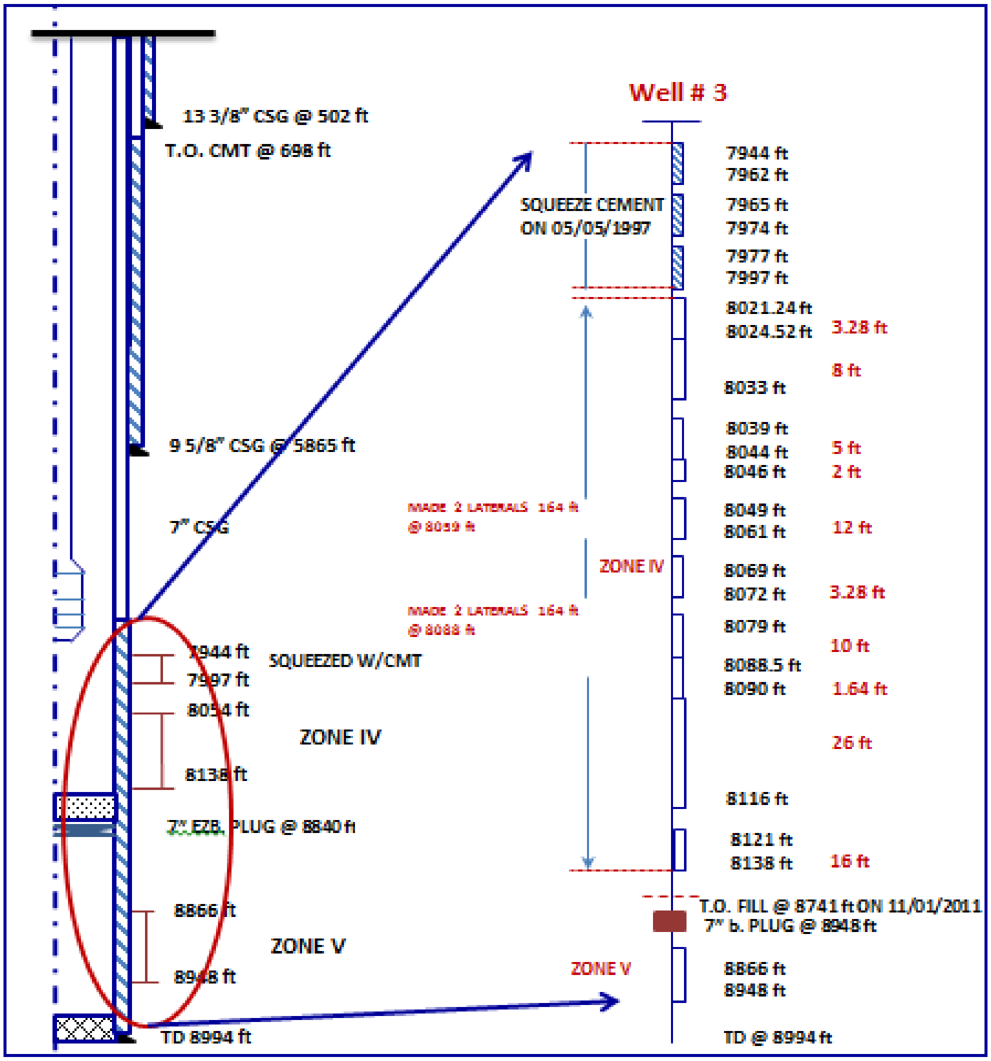

Figure 18. Casing and perforation sketch for well #3.

Table 5. Radial drilling operation performed on well #3.

Depth (ft)	8088 ft		8059 ft	
No. of holes	1	2	3	4
Angle from the north	115	295	115	295
Depth of lateral (ft)	164	164	164	164

short period of time.

Case 3: Well #3

This well is produced from only one zone (zone IV) with average daily rate 189 bpd, the static reservoir pressure is about 970 psi at datum 7900 feet sub sea level and productivity index is 2 barrel per day per psi from last vacuum test before applied radial drilling, the average porosity 20%, heterogeneous permeability, the total depth of this well is about 8994 ft, and net pay thickness is 87 ft. Figure 18 illustrates casing specification and perforation interval of well #3.

Radial drilling job was performed on this well by milling and jetting four lateral holes at two depths with 164 ft lateral length from zone IV. There were a lot of trials to make another two holes at another depth but the holes were canceled due to 1¾" bit and flexible shaft lost in hole several time, and that cause more lost time. Table 5 shows the depths and the length of penetration of each drain holes. In the first well, well #1 the lateral holes

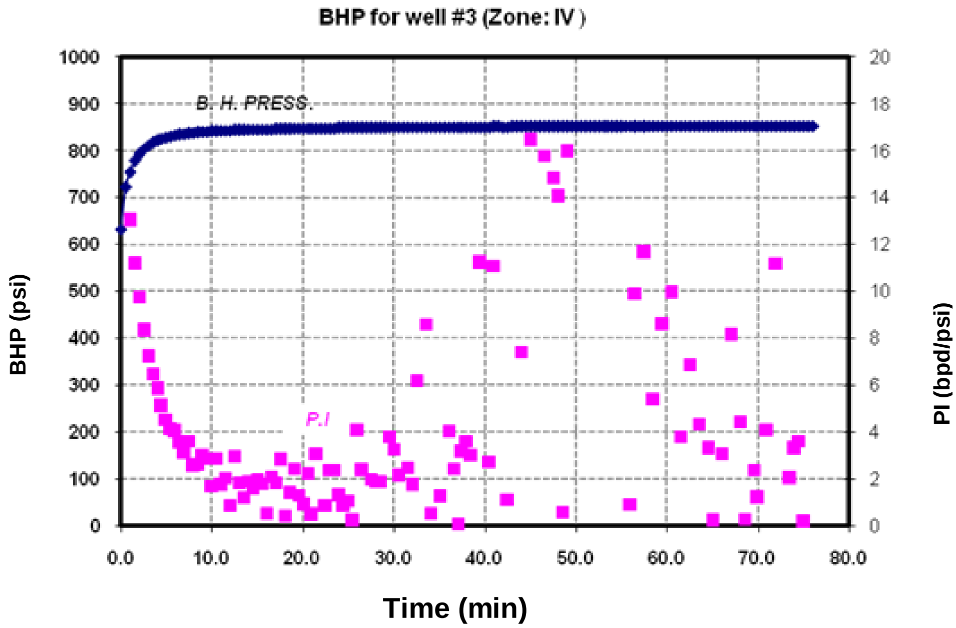

Figure 19. S.B.H.P and P.I vs. time, vacuum test results for well #3 before radial drilling.

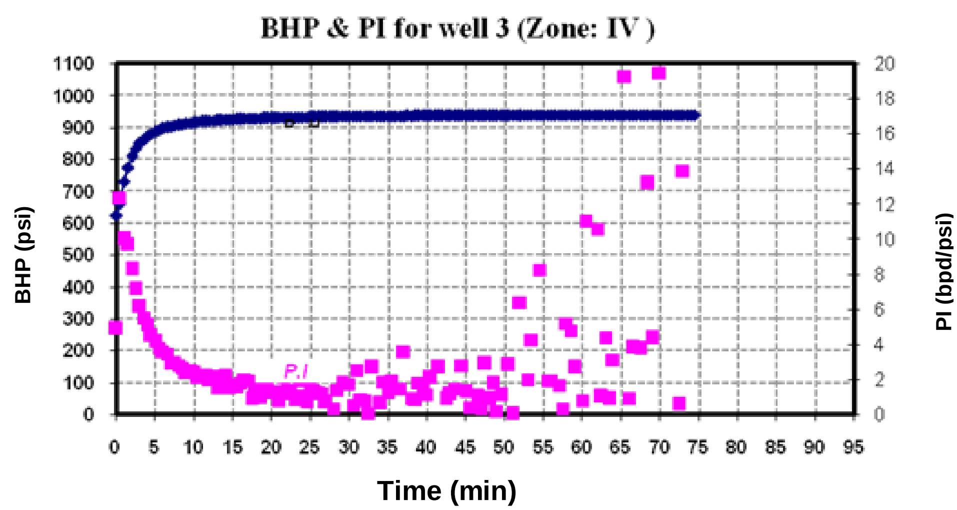

Figure 20. S.B.H.P and P.I vs. time, vacuum test results for well #3 before radial drilling.

were drilled randomly but here in this well the lateral hole selection was based on geological maps and faults orientation so holes were made at two depths and oriented with consideration to north direction.

A vacuum test was performed on this well before and after radial drilling job to evaluate this technique. Production rate show a little increase and then decreased after stimulating the well with this technique; the productivity index still the same. Figures 19 and 20 depict the bottom hole pressure and productivity index for this well before and after RD respectively. Table 6 shows comparison between rate before and after radial drilling job, Figure 21 show gross production performance before and after applied radial drilling technique.

CONCLUSIONS

The evaluation thus reveals that:

1. This technology is succeeded from the mechanical point of view as the holes were drilled successfully.
2. The well which has the deepest lateral hole length show a significant increase in production rate so as the length of lateral hole increase and the results will be

Table 6. Comparison between rate before and after radial drilling for well #3.

Before radial drilling			**After radial drilling**		
Rate (bpd)	WC (%)	Net oil (bpd)	Rate (bpd)	WC (%)	Net oil (bpd)
220	3.2	214	252	3.2	245

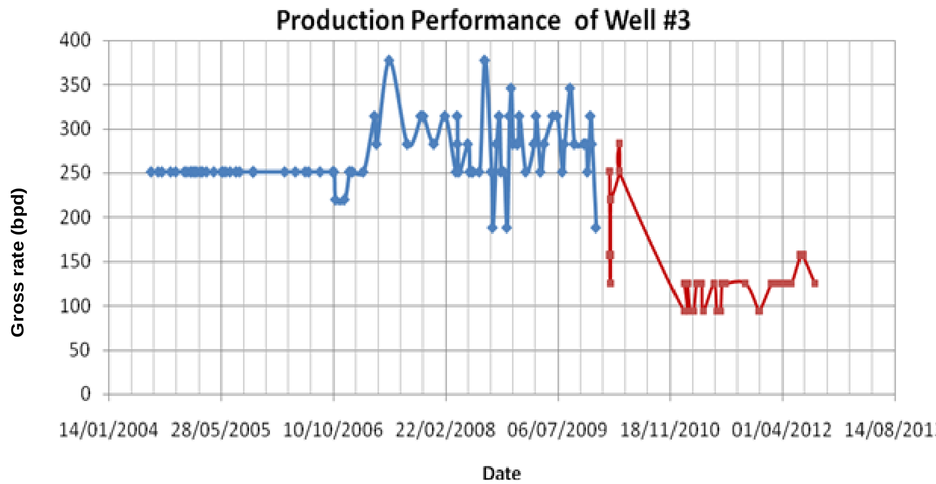

Figure 21. Production performance of well 3 # before and after radial drilling.

more good.

3. Using this technique in consolidated rock better than un-consolidated ones in order to maintain the hole open.
4. The technology has been successfully applied to provide multiple horizontal radials at the same level in a single well.
5. Radial drilling by high-pressure jet flow techniques can greatly increase oil recovery and oil production rate.
6. Before the large scale usage of this technique, rock mechanics must be considered prior to design.
7. Increase in the reservoir contact length (improve drain efficiency), therefore increase the production, control the direction of perforations, and can be low cost when utilized in existing wells.
8. Further research and testing of the jet nozzle penetration mechanism are required in order to identify the optimal nozzle configurations.
9. Easy to be applied and less expensive than other conventional techniques.
10. The experience shows that it is necessary to have petrophysical studies, rock mechanics and pressure tests, prior to intervention, to know the reservoir conditions.
11. An improvement is needed in order to maintain the rate increase in production rate, such as gravel packing or using slim tubes specially in unconsolidated formation.

REFERENCES

Abdel-Ghany MA, Siso S, Hassan AM, Pierpaolo P, Roberto C (2011). New Technology Application, Radial Drilling Petrobel, First Well in Egypt, presented at the 10th Offshore Mediterranean Conference and Exhibition (OMC) in Ravenna, Italy.

Bruni M, Biassotti H, Salomone G (2007). Radial Drilling in Argentina, SPE Paper 68504, Latin American and Caribbean Petroleum Engineering Conference, Buenos Aires, Argentina.

Buset P, Riiber M, Arne E (2001). Jet Drilling Tool: Cost-Effective Lateral Drilling Technology for Enhanced Oil Recovery. Presented at the SPE/ICoTA Coiled Tubing Roundtable held in Houston, Texas.

Dickinson W, Dickinson R, Herrera A, Dykstra H, Nees J (1992). Slim Hole Multiple Radials Drilled with Coiled Tubing. SPE 23639, presented at the Second Latin American Petroleum Engineering Conference held in Caracas, Venezuela.

Dickinson W, Anderson RR, Dickinson RW (1989). The Ultrashort-Radius Radial System. SPE Paper 14804, SPE Drilling Engineering, pp. 247-254.

Dickinson W, Dickenson RW (1985). Horizontal Radial Drilling System. SPE 13949, presented at the SPE 1985 California Regional Meeting, held in California.

Elliott S (2011). Coiled-tubing Method Drills radial Laterals to Improve Oil Production from a Depleted Reservoir. World Oil 232:10.

Elshahawi H, Siso S, Samir M, Safwat M (2001). Production Enhancement in the Belayim Fields: Case Histories. SPE 68688, presented at the SPE Asia Pacific Oil and Gas Conference and Exhibition held in Jakarta, Indonesia.

Marbun BTH, Sinaga SZ, Arliyando L, Putra SK (2012). Review of Ultrashort-Radius Radial System (URRS). IPTC 14823, presented at the International Petroleum Technology Conference held in Bangkok, Thailand.

Yonghe L, Chunjie W, Lianhai S, Weiyi G (2000). Application and Development of Drilling and Completion of the Ultrashort-radius Radial Well by High Pressure Jet Flow Techniques. SPE 64756, presented at the SPE International Oil and Gas Conference and Exhibition in China held in Beijing, China.