Implementing Smart Solution for Controlling Water Cut in South Pars Gas Field from Environmental Point of View

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Abstract

In the current decade as the result of increasing volume of waste all over the world, the effect of discharging produced water on the environment has lately signified and became an environmental concern. Therefore controlling excessive water production is one of the challenges in mature and declining oil and gas fields. Nowadays, statistics show that ratio of produced water to oil is 3 to1, and thus the largest waste stream generated in oil and gas industries, is produced water. It is a mixture of different organic and inorganic compounds especially polycyclic aromatic hydrocarbons (PAH) that has detrimental destructive effects on marine environment.

Recently water management becomes ever more important as more green fields changes to brown fields in the struggle to supply a world hungry for hydrocarbon. So improved water management practices are being implemented worldwide to maximize well productivity and reduce destructive effect of produced water discharge. Because of this environmental awareness, recently stringent regulations have established on discharge of produced water. Various methods such as drilling horizontal wells, water shut-off jobs and using smart devices have different degrees of success in decreasing water production. A smart well is the one with downhole instrumentation installed on the production tubing.

Using smart well technology in Middle East fields in order to control water production had been experienced and it had considerable outcome especially in multilateral wells. Based on strategic importance of South Pars as the greatest gas field in the world and the probability of increasing its water cut especially from deep gas layers in near future, feasibility study of implementing smart solution in south pars gas field has been surveyed. Here in this paper environmental harmful impact of produced water from this field and application of smart well technology for water cut reduction has been investigated.

Introduction

During the past 10 years, decline rates have doubled. At the same time, reservoirs are becoming more complex. They are smaller, tighter and more remote. As a result, reservoir recovery rates are less than 35%. The goal of many operators is to advance recovery rates to 60% consequently; the aggressive development of cutting edge technologies has become essential. Wells equipped with permanent down hole measurement equipment or control valves, and especially those with both, are nowadays known as smart well or intelligent completion. These systems have been installed in wells for monitoring pressure, temperature, flow rate, phase fraction and seismic. Cost and reliability are still the two reasons that cause resistance to adoption of this application. However from the results of case studies that used this technology, role of Smart well technology in controlling WC is inevitable. By the way with more service providers entering the market, prices has been going down. With the innovation of fiber optical sensors and hydraulic control systems, together with the development in quality assurance and testing procedures, the reliability has been improved significantly. However, the complex cables, valves and control systems, still cause more problems than conventional completion techniques. The service companies have been looking for more reliable technology to control flow and enhance recovery.

The most important benefit of a smart well is improved reservoir management. Since the first intelligent completion was installed in August 1997 at Saga's Snore Tension Leg Platform in the North Sea, over 300 such systems have been installed globally. One of the challenges that this technology is working on, is Controlling water cut. The impact of smart technology in reducing WC had

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been efficient in many Problematic wells. Minimizinig catastrophic environmental effects of discharing WC would be one of most important impact of smart technology. This technology was successful in many cases that other technologies were unsuccessful or so time consuming. Here we review some of these case studies & application of this smart solution for South Pars gas field.

Case-I: Reducing Water Production in PDO Field (Shuaiba Reservoir) [1]

The well is located in the Central part of PDO fields (Figure-1) which is a water flood development field with multilateral producers and injectors. At same time ESP completion configuration, ruling out possibility of conventional production logging techniques .The well came on stream in February 1999 with high net rate (1500 m3/d) and low WC. Net rate then started to decrease with increase in water cut till reached more than 95%. Eventually, the well was closed-in in January 2001. So the well was worked over to install smart well completion in early July 2002.

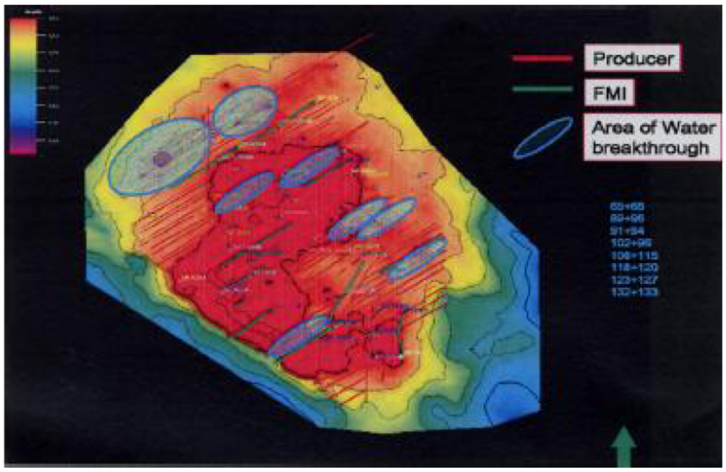


Figure 1: Shuaiba Reservior

Prior Installation Preparation:

The digital hydraulics system was run with Distributed Temperature Sensing on fiber optic in the well. The tests were successful as the down hole valves could be opened and closed from surface. Temperature monitoring was used as an indication of valves operation.

Implementation:

The well was worked over to install smart well completion in early July 2002. The well was put on production for few days to clean-out, then it put on test with production from the four legs. Thereafter, sleeves were operated by manipulating (closing/opening) valves, and all legs were tested. It was concluded that legs 1 & 4 are producing at very high water cut, whereas most of oil production comes from legs 2 & 3. The well was put on stream with legs 2 and 3 open. The production of this well could be improved by increasing oil production by more than 1500m3/d (Figure-2).

***Results** (Case-I)*:

Smart wells completion will have high impact and a step change in PDO due to expected high technology values. The technology will allow assets to have continuous, well monitoring and controlling on their wells with respect to water flooding and reservoir monitoring. This successful trial has encouraged PDO to implement this technology in more multi-lateral wells in most of PDO fields. It was planned to install smart well completion in 10 wells in the Central part of PDO fields in 2003.

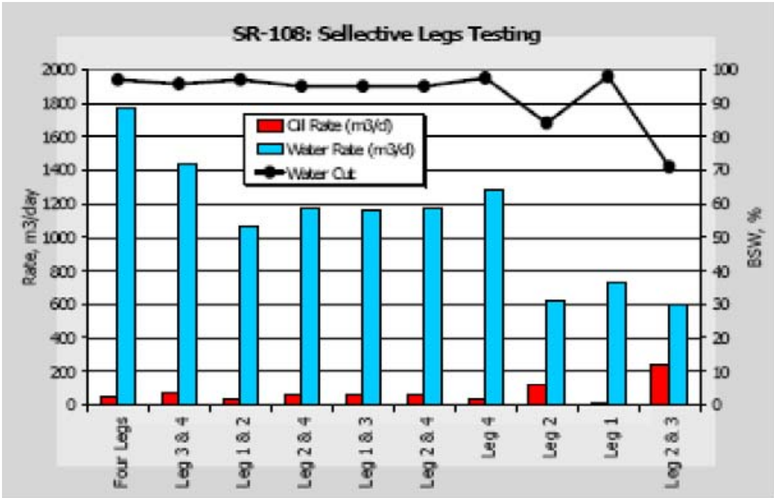


Figure 2: Production Test Data

Case-II: Reducing WC in Ghawar oil field[2]

Saudi Armco's drilling strategy witnessed a change in the last few years by drilling horizontal and extended reach maximum reservoir contact (MRC) wells. One of the objectives behind this strategy is to improve the well productivity by maximizing oil production and minimizing water production. In one of the challenging areas in Ghawar field, water will reach the wellbore much faster via the reservoir's fractures. Using the smart completion with the conventional rate testing, required longer time to reach the best possible setting for the downhole flow control valves (In order to achieve the optimum flow rate). Using the combination of smart completion and portable MPFM (Multiphase Flow Meter), resulted in reducing the water cut (WC) from 20% to 0% and maintaining the same required average oil rate (Figure-3).

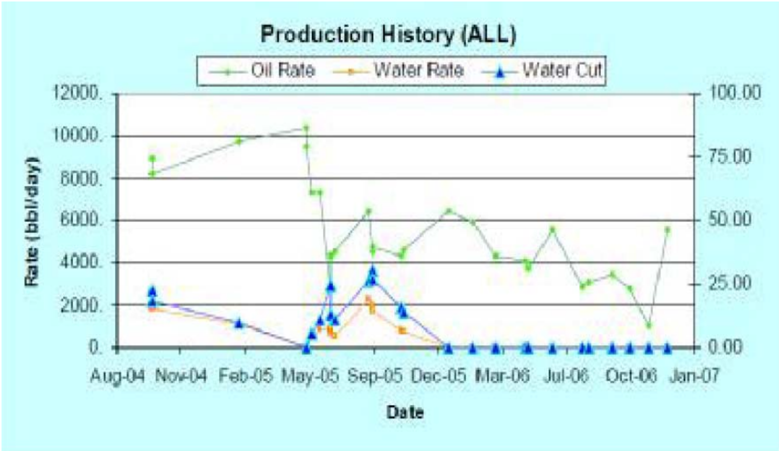


Figure 3: Production History, till 2007

Well Production Optimization

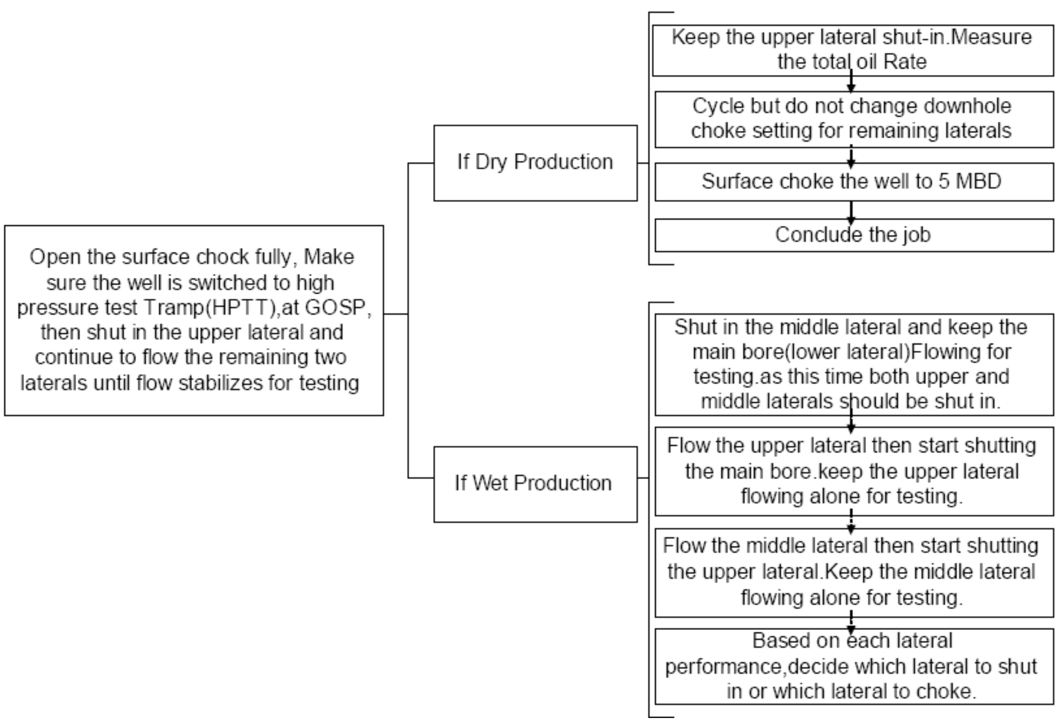
The objective is to eliminate water production or reduce WC below 5% with average oil rate of 5 MBD by effectively positioning the downhole valves across each lateral. "Each downhole hydraulic flow control consists of a choke section and actuator section driven by an indexer pin and ratchet. The choke position is controlled by means of an indexer that secures the choke in 11 incremental positions, allowing precise flow, regulation, and control; the exposed flow area and equivalent choke size for each position are listed in (Table-1).

Choke Position Number	Exposed Flow Area	Equivalent Choke Size
0	None	0/64"
1	2 x 3/16"	17/64"
2	2 x 3/16"	24/64"
3	2 x 3/16"	29/64"
4	2 x 3/16"	34/64"
5	2 x 5/16"	44/64"
6	2 x 5/16", 5 x 3/16"	59/64"
7	7 x 5/16"	79/64"
8	7 x 5/16"	95/64"
9	8 x 5/16"	111/64"
10	6 x 1"	Non-choking

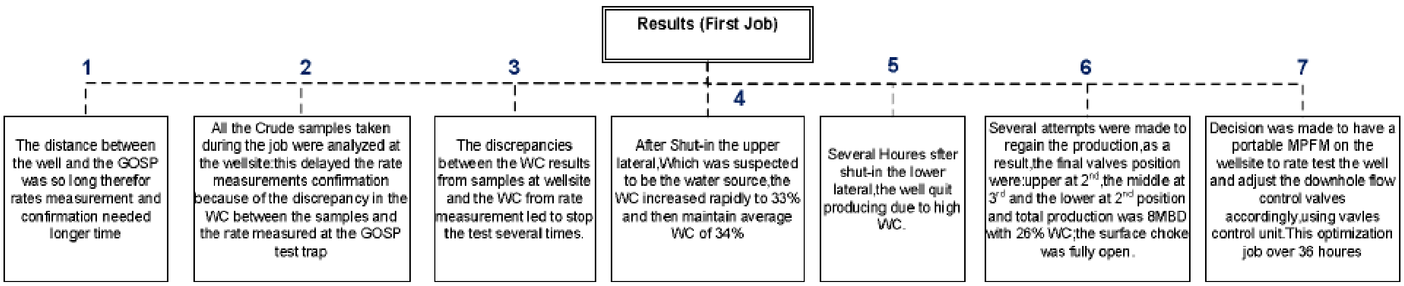
Table 1: Exposed Flow Area and Equivalent Choke Sizes

Production Optimization Job #1

Due to increased WC after completing the well with smart completion on April 2005, the production optimization job was needed to determine the major source of the produced water. Prior to rig release, the valves positions were; the upper at 2nd, the middle at 3rd and the lower at 5th position. Therefore the proposed optimization job procedure and its results were as follows:

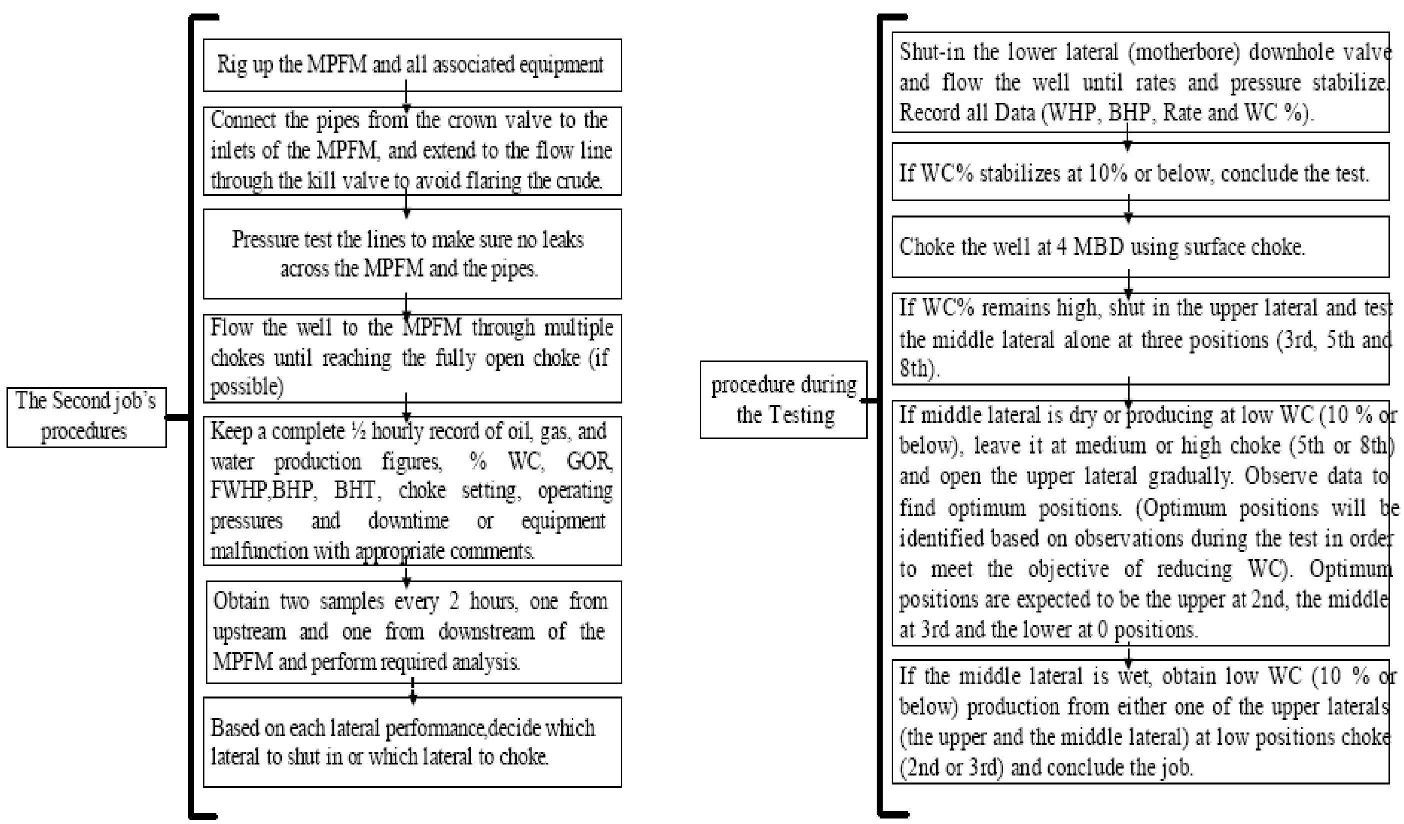


Results from the first job** (Case-II)**:

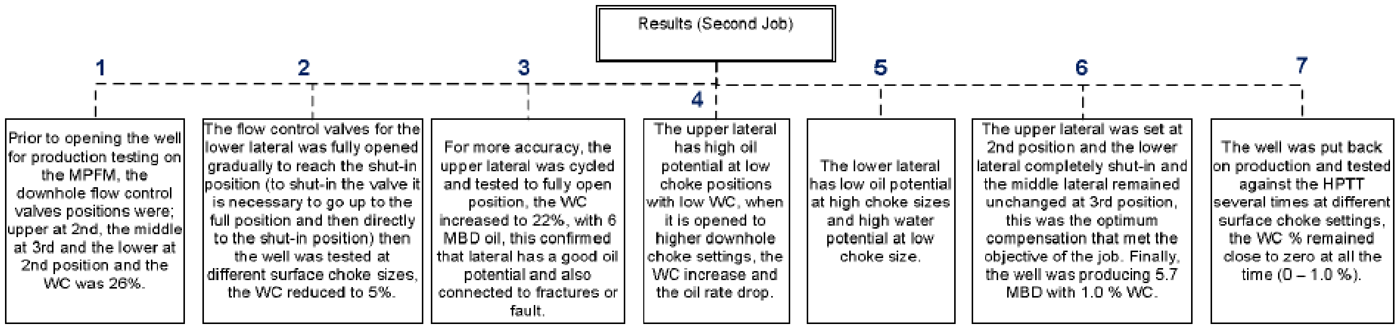


Production Optimization Job #2

Based on the results from the first job and after the WC cut increased rapidly in a short time (Figure-4) repositioning the downhole flow control valves at more accurate rate testing became important to meet the required oil production with minimum WC, after reviewing the first job's events and results. The job's procedures and its procedure during the testing were as follows:



Results from the second job** (Case-II)**:



***Results** (Case-II):*

The combination of both smart completion and MPFM resulted in more accurate rate testing and better decision making. Smart completion, MPFM and real time monitoring are the perfect combination for better and faster water cut controlling. (Figures-4 &5)

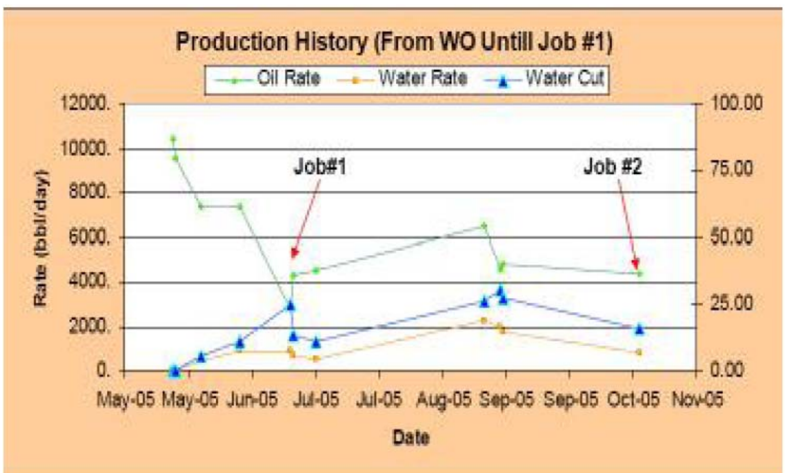


Figure 4: production history, Job #1 until Job #2

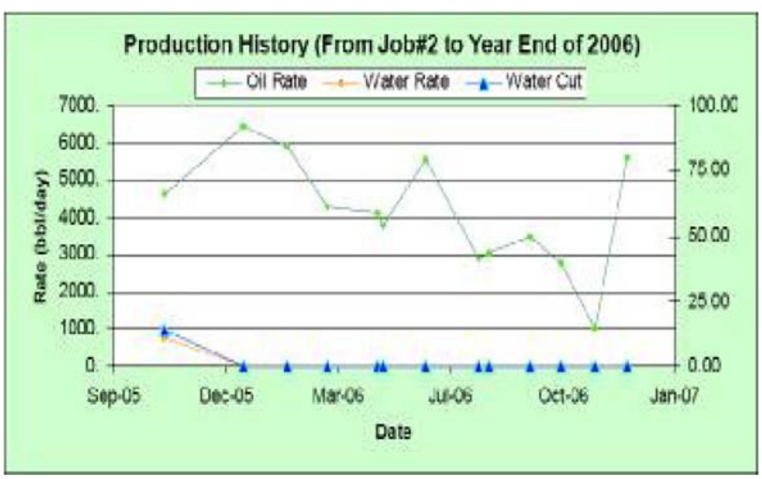


Figure 5: production history form Job #2 until end of 2006

Case-III: Water Control in Wytch Farm, Well M15, England[3]

Well M15 was based on an old ERD well M15 drilled in 1994, which had more than its fair share of problems from the start. High water cut developed shortly afterwards with the characteristics of a conducting fault. A subsequent water shut-off job was unsuccessful. In order to decrease the WC, smart Completion was installed in this well in February 1999. (Figure-6). The completion contains three identical valves (two in one lateral) that are controlled hydraulically from the surface. These valves can be fully closed or in one of five sequential, geometrically equally-spaced opening positions, (Designated as position 1, 2, 3, 4, 5 from the smallest opening to fully open. Position 0 refers to the closed position). The positions of the valves are adjusted, by cycling pressures at the surface, through dedicated control lines, in order to control water cut. Other key components included are, on-off disconnect, packers, Electrical Submersible Pump (ESP), and flow meters.

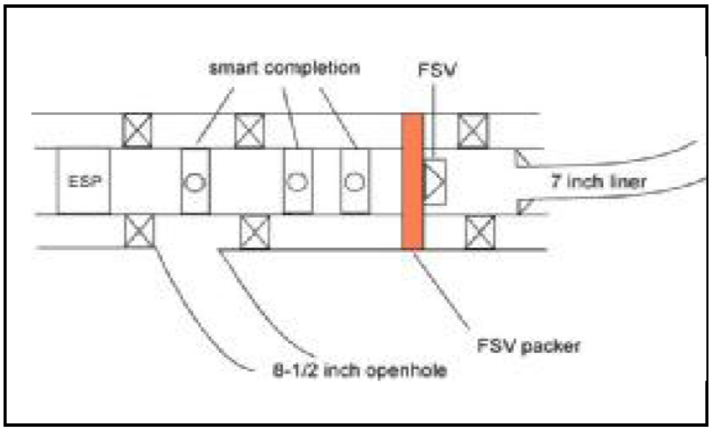


Figure 6: Wytch Farm Smart Well Completion

Results *(Case-III):*

As reported by Gai ,over the past two years the well has been controlled using the flow control devices in the completion both to maximize oil production and to cope with occasional constraints, for example in water production through the plant and in the current of the Variable Speed Drive (VSD) of the Electric Submersible Pump (ESP). The production significantly improved with the successful smart completion, (Figure-7).

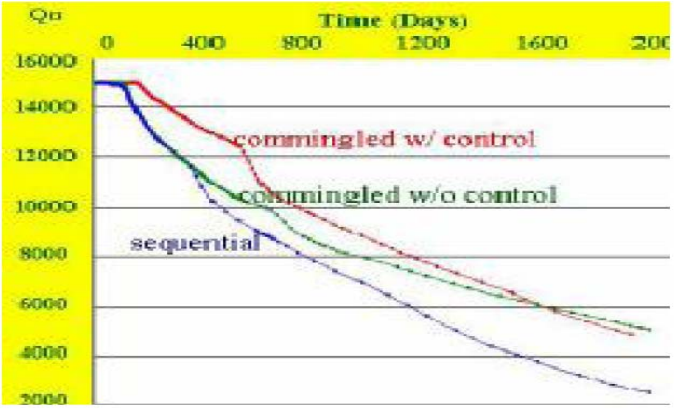


Figure 7: Well M15 oil production after becoming smart

Water Cut & Smart Technology, Environmental Point of View

Ratio of produced water to oil from mature well is approximately 3 to1. Huge amount of produced water with oil contaminants can create complex problems for treatment cycle and also have catastrophic environmental consequences on offshore echosystem. Produced water contains inorganic & organic (Figure 8) compounds especially aromatic hydrocarbons (PHA) and as result of these contaminants can create biological effects on offshore environment. Due to these consequences, management of produced water is key step in production operation and companies must evaluate reasonable solutions for reduction and control of water cut in mature oil field.

Smart technology targeted higher productivity and reduction of environmental consequences. Directional drilling & smart technology are most efficient solutions that can be applied for controlling water cut. Experiences of application of smart technology in Middle East oil fields can prove its efficient performance particularly in offshore fields. Regarding to strategic importance of South Pars field as world greatest field & eventual increase of produced water in deep layers we will describe role of smart technology in control & reduction of water cut.

Analysis of Produced Water from one of South Pars Resorvior

TEST	METHOD	UNIT	RESULT
Bicarbonate	ASTM D1067	ppm	85.4
Carbonate	ASTM D1067	ppm	Nil
Hydroxide	ASTM D1067	ppm	Nil
Oil in Water	Infrared Spectroscopy	ppm	< 1
Cations			
Calcium	Ion chromotograph	Mg/L	638
Magnesium	Ion chromotograph		136
Anions			
Chloride	Ion chromotograph	Mg/L	2288
Sulphate	Ion chromotograph		25.9

Table 2: Analysis of produced water

Comparison between amounts of oil in produced water in different well of South Pars gas field shows variety between 0.8 to 1.3 ppm.

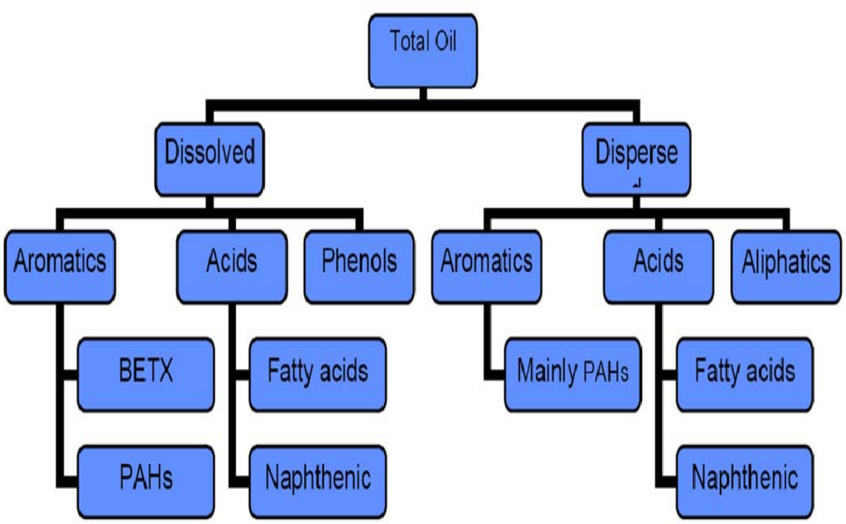


Figure 8: Oil in produced water

Environmental Challenge

In order to investigate environmental effects of produced water, EIF factor can be used. EIF can model risks & consequences of water cut discharge according to given analysis of oil composition in produced water. Hydrocarbons contaminations in Persian Gulf come from different resources but main one is offshore exploration & production industries especially production from mature reservoir that ratio of produced water can be reached to 90 percent. Figure 9 shows considerable increase of produced water from Persian Gulf resrvior.

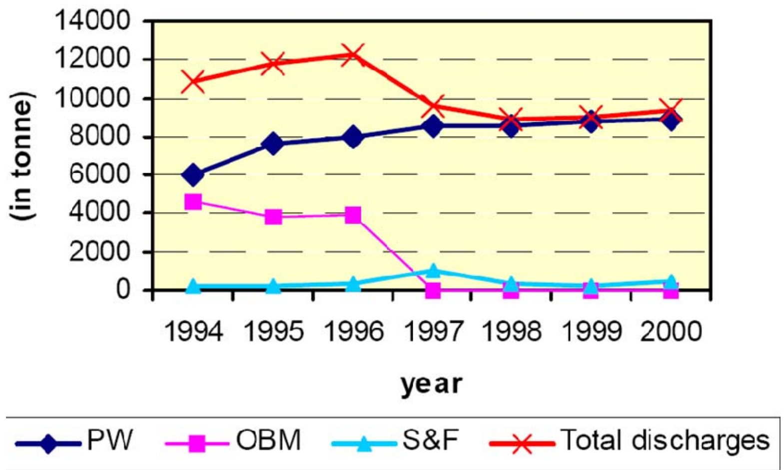


Figure 9: Increase of produced water from Persian Gulf Resorvior

Hyrocarbon contaminations are sustainable and poisonous and participate in biochemical reactions that its products can endanger marine environment. Scientists believe offshore echosystem has no defense mechanism against hydrocarbon contaminations and it is key challenge. Many of hydrocarbons have long term effects on offshore echosystem that are unknown for us and can cause extinct of marine species. Reduction of oxygen content in water as result of biochemical reactions is another challenge.

Conclusions

The study shows the potential of using Smart well technology in controlling water cut & reduction of environmental consequences. Smart technology seems to be compatiable with South Pars gas field & strategic plan for prevention of unpleasant lossess on Persian Gulf environment. Our observations and conclusions can be summarized as follows:

- Smart Technology allows assets to have continuous, well monitoring and WC controlling.
- Combination of smart technology with other technologies like MPFM increases the accuracy of WC Controlling and decreases the time to reach the best possible setting for the downhole flow control valves.
- Smart technology is highly efficient in maintaining oil production rate during the time that WC is going to increase.
- Without doubt smart technology is very promising technology in controlling WC and reduction of environmental consequences, but it will have to compete with other economical and reliable technologies.

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