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Using Smart Completion Technology to Control Water Coning Problems and Increase Oil Recovery in a Southern Iraqi Oilfield

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Abstract

This research describes the using of a new well completion technology system that enhance the homogeneous and heterogeneous reservoir deliverability and the production performance gained through a completion technique using Autonomous Inflow Control Valve (AICD) by self-decreasing/delaying water and gas progress and promoting increasing in oil production, therefore, equalizing the drawdown (ΔP=Pi-Pwf) along the well and provide a dynamic water shut-off operation and significantly increasing the economic life of a well and therefore, reducing capital and operational expenditures for the field development.

The research presents a production performance simulation results for a conventional and smart well completion technology in a horizontal well in a southern Iraqi oilfield for two stages during well life; early stage (till 2018) and late stage (till 2033). For early stage of well life, there was no significant difference in results when comparing between the conventional completion design and the smart completion design. In the contrast, the simulation results for the late life of the well showed that the well can produce for approximately 1056.7 barrel per day crude oil with a water-cut of 82 % at the year of 2033. The also revealed that the results showed that the cumulative oil production from the year of 2018 till 2050 will be 23 million barrel of crude oil and 44 million barrel of water when the well is completed with conventional completion design. When the completion design has been changed and equipped with autonomous inflow control devices (AICDs) technology and simulated the production performance by NETool Software. The simulation results showed that the oil production has been increased by 891 barrel per day (1947.3 barrel per day) and the water cut has reduced significantly in comparison with the conventional production

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completion by 17 % (65.4 %) at the year of 2033. The results revealed that the cumulative oil production from the year of 2018 till 2050 will be 31 million barrel of crude oil and 33 million barrel of water.

It has been concluded, from the reservoir and production simulation, that the application of the technology is successful and showed a clear advantage of using Autonomous Inflow Control Device (AICD) that provides better water influx control profile.

Keywords: Heel-toe effect, Inflow Control Device, Autonomous Inflow Control Device Inflow Control Valves.

1. Introduction

Well completions nowadays are not like the typical and traditional well completions methods. The complexity of the reservoirs and wells has increased that makes the horizontal, multilateral and extended reach wells are the optimum choice in many reservoirs. But there are new challenges related to such wells, whether with homogenous or heterogeneous reservoirs. One of the most common challenges is the higher pressure drawdown (difference between reservoir pressure and bottom hole pressure) that occurs around the heel section of the well than at the toe section because of the pressure drop caused by friction of fluid when flowing in the wellbore that causes non uniform fluid influx along the wellbore length and higher oil production rate at the heel section, especially when the reservoir is homogenous that leads to quick breakthrough of water or gas behind the oil taking the path of the least resistance region (heel region) and enter into the well pipe replacing oil in the production stream and making the toe section incapable to produce the remaining oil and this will lead to uneven sweep of the drainage area along the length of the well [1].

A horizontal well schematic with Heel-toe effect is shown in Figure (1) Pressure drop along the well length in a homogeneous layer make the flowing tubing pressure is lower at the heel section than at the toe and the water (blue) or gas (red) is being produced at the heel section before oil (green) that comes from toe section arrives at the wellbore making the well productive life end early [3].

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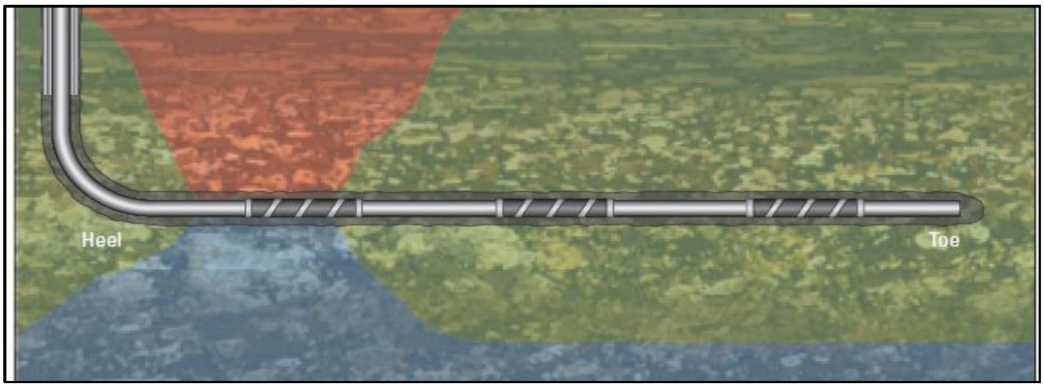

Fig. (1): Heel-toe effect in a horizontal well

The heel-toe effect problems appear most in the well that completed with smaller tubing and producing with high flow rates, this will lead to a frictional pressure losses along the the well. This effect can be eliminated by increasing the well tubing diameter or drilling a shorter laterals and this solution are not practical. This makes the zonal control is critical in such reservoirs to produce the hydrocarbons in the most efficient way and reducing the capital and operational expenditures used to develop the field in the same time [4].

2. Objectives of Study

There are two main objectives for the study:

1- Study the effect of using smart well completion (Autonomous inflow control valve) on the total liquid production rates (oil and water) in an Iraqi horizontal oil well in a southern Iraqi oilfield and compare the results with the conventional completion design during two stages through the well life.

2- Predict the cumulative oil and water production at year of 2033 once when the well is completed with a conventional completion design, once again when the well completed with smart completion design.

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3. Methodology and Case Study

3.1 Intelligent/Smart Wells

To eliminate the "heel-toe" effect challenges and control zones in a reservoir, there are different methods. Those are with a traditional sliding sleeve, or with intelligent/smart wells by using an Inflow control Devices (ICDs) or an Inflow Control Valves (ICVs).(9)

Using of intelligent/smart wells can provide the following benefits:(2)

- Increasing hydrocarbon recovery.
- Reducing the well design costs.
- Reducing well intervention operations and frequency and that gives working safety.
- Increasing the NET Present Value from the well.

Inflow Control Devices have been increasingly used in the production wells as a part of the completion to optimize and control a well and the reservoir performance. The purpose of using ICDs is to reduce the heel-toe effect, equalizing the inflow along the horizontal section of the well whatever the location and permeability differences from one region to another, making the whole section of the well contributing to the total hydrocarbon production and so optimize hydrocarbon recovery and restricting or excluding the production of undesired fluid (water and gas) from the different reservoir zones in a producing well and so allow better field production control compared to wellhead control [5].

The principle of the ICDs is to equalize the inflow by creating pressure losses at a certain flow rate, according to the Bernoulli equation. ICDs working principle is based on the differences in the physics of the fluid flowing in the reservoir. Figure (2) shows the flow rate and drawdown once without ICDs and once again with ICDs for a homogeneous reservoir with constant permeability [7].

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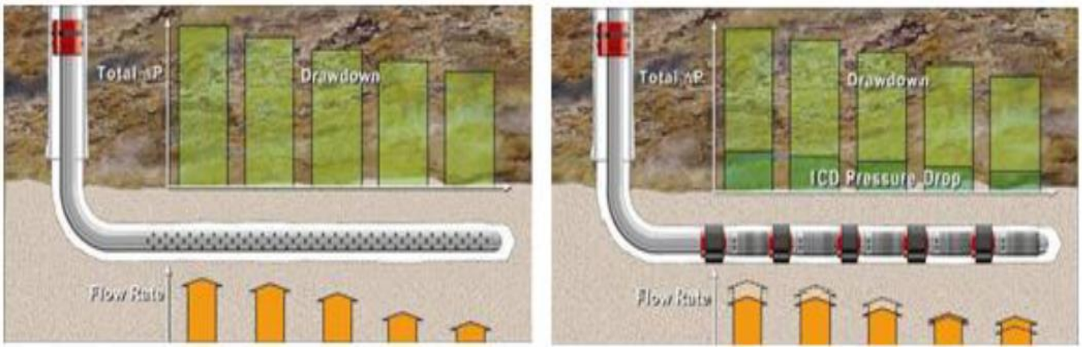

Fig. (2): The flow rate and drawdown once without ICDs and once again with ICDs for a homogeneous reservoir with constant permeability.

Four types of Inflow Control Devices (ICDs) were developed; orifice / nozzle type, helical - channel, hybrid design and the new autonomous Inflow Control Device (AICD) [6].

ICDs are installed in combination with a stand-alone sand screen (SAS), gravel pack or debris filter, and that is dependent on the formation's strength; blank pipe used to shale and fractured zones isolation; and external packers for annular isolation [7].

The main companies that supply ICDs are Weatherford, Baker Hughes, Halliburton and Schlumberger [1].

The focus in this research is to simulate a southern Iraqi oil well with the newest type of Inflow Control Devices; the autonomous ICD (AICD).

3.2 Autonomous Inflow Control Device (AICD)[8]

Autonomous ICDs are self-choking devices which react in real time to the properties of the flowing fluid. AICDs optimize the inflow performance of the wells and mitigating water and gas breakthrough by excluding the low viscosity fluids, and allows producing the the high viscosity fluids. AICDs work without any surface human intervention, without the need for electric or hydraulic power.

Vendors have been developed various types of Autonomous ICDs (AICDs), as follow:

- Statoil's RCP AICD – Typical Autonomous ICDs (AICDs).
- EquiFlow AICD of Halliburton company .

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- BECH Autonomous flow control device (AFD) that have been developed by Hansen Energy Solutions company.

The second and third types of AICDs are outside the scope of this research.

- *Statoil's RCP Autonomous Inflow Control Device*

The Statoil's RCP is designed to delay water and gas breakthrough and eliminate consequences of the breakthrough. The RCP autonomous inflow control device restricts the flow of low-viscosity fluids and allows the high-viscosity fluid to flow into the well. Figure (3) shows the flow path of reservoir fluids into a well completed with Statoil's AICD, Figure (4) shows the picture of the Statoil's RCP AICD valve.

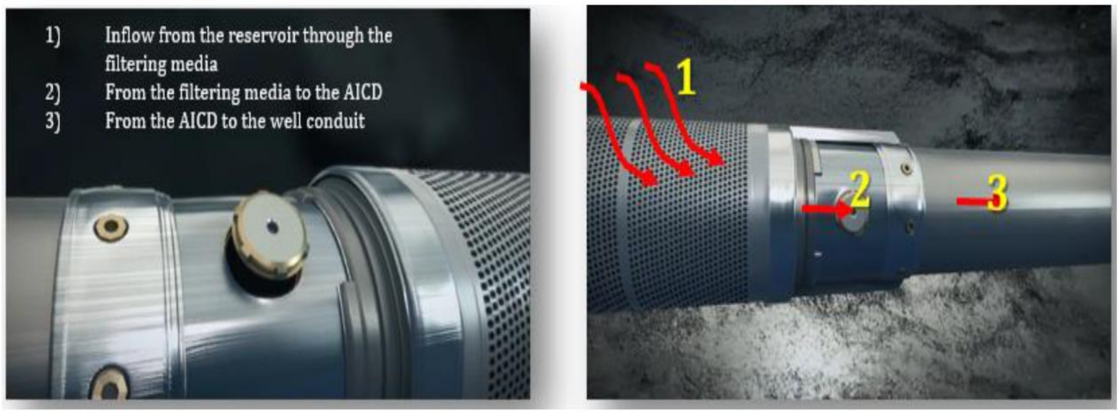
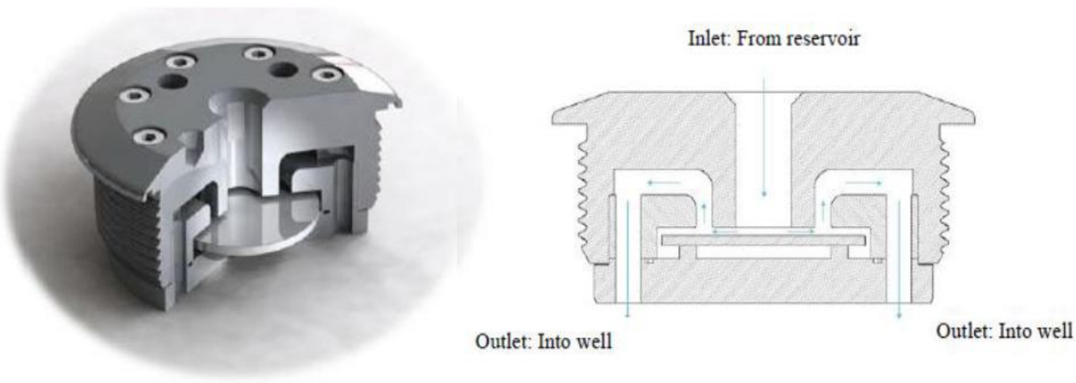


Fig. (3): Statoil RCP AICD valve with a base pipe connected in a sand screen joint



a. 3D Statoil's RCP AICD valve

b. Schematic sketch of statoil's RCP AICD valve

Fig. (4): Statoil RCP AICD valve

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The path of fluids flow is represented by arrows in Figure 4-a. The consists of a moving part in the valve which is a free floating disc and the position of that disc depends on the flow conditions and the properties of the fluid flowing to the well, when low viscous fluid flow rate restricted by the Statoil's RCP AICD valve, the disc moves towards the inlet and reduce the flow area and the flow and when the high viscous fluids flows through the valve, the disc will move downward and allows the fluids to enter the well. Bernoulli principle describes the performance of this valve, and can be expressed as follow, where P is the pressure and v is the velocity:

$$P_1 + 1/2\, p v_1^2 = P_2 + 1/2\, p v_2^2 + \Delta P_{\textit{friction loss}}$$

3.3 Economic Considerations [7]

Intelligent well completions can provide a significant net present value and the effect using this techniques can be profitable throughout many stages during well life. Figure (5) shows a summary of costs that can be largely reduced by intelligent completions.

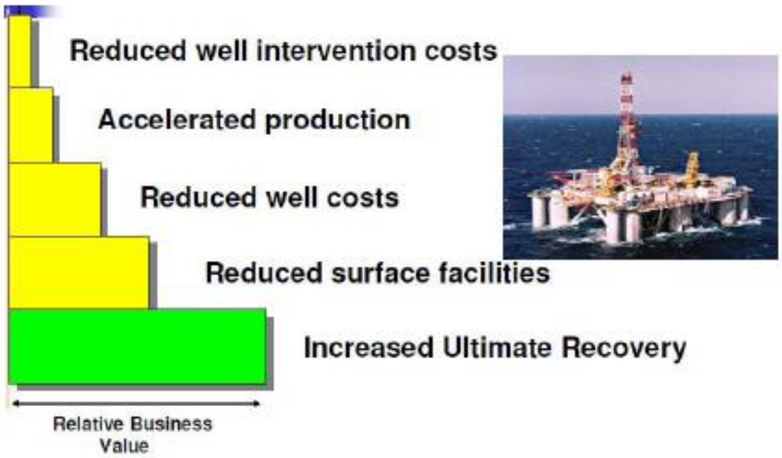

Fig. (5): Typical reduced costs by intelligent completions

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4. Well Simulation and Results

4.1 Analysis Target and Method

4.1.2 Analysis Target

The analysis section examines the influence of using AICDs in a horizontal well behavior. The horizontal well was drilled in Mishrif formation (which is suspected as a heterogeneous carbonate reservoir as from a petrophysical perspective) in one of the southern Iraqi oilfields. There will be carried out a comparison of the well performance once when the well is completed with the conventional completion and when the well is equipped with AICDs.

A target must be set, an can be flowing bottom hole pressure, tubing head pressure, total downhole rate, or total liquid rate. In this study, total liquids rate is used as a target.

4.1.2 Analysis Method

NETool software (for Halliburton Company) is used to analyze the well behavior. NETool is simulator for a well completion planning and modeling that used to model fluids flowing from the reservoir into the well. By examining the results from the modeling, it is possible to decide the best completion design for optimal recovery. When using this software for analysis, the reservoir fluids properties can be imported from for example Eclipse software, or uses values from pre-prepared tables, or entering the values manually.

In this study, the dynamic reservoir model is imported from Eclipse software.

4.2 Well Design

Figure (6) illustrates the trajectory of the well (Easting, Northing and true vertical depth (TVD)) and the well path through the reservoir which is used for the analysis in NETool software.

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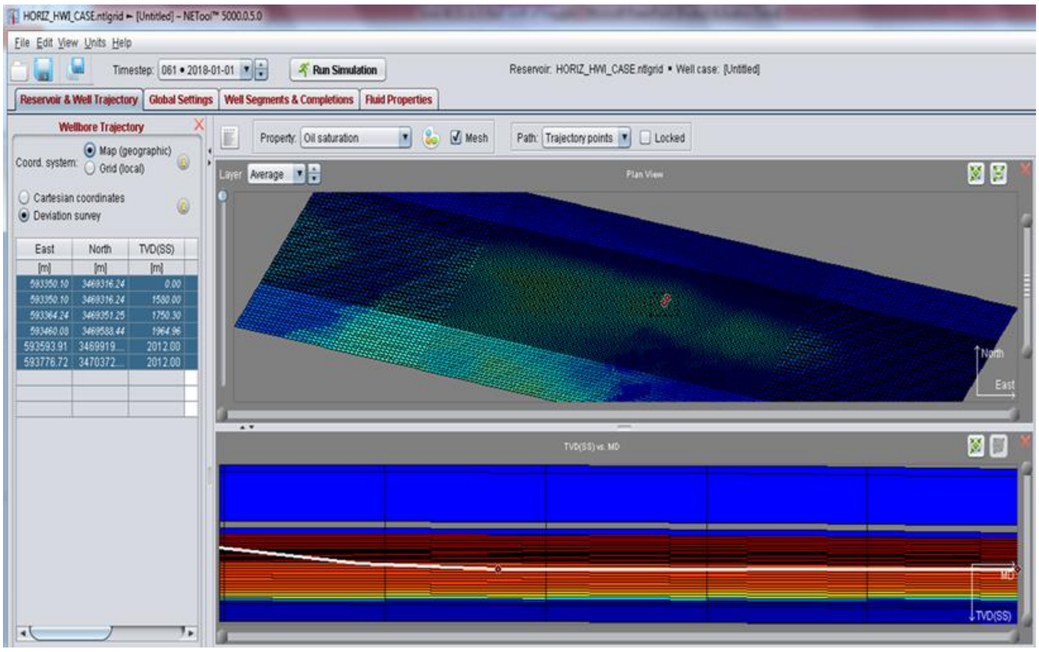

Fig. (6): Illustration of well trajectory analyzed in the study

As mentioned in section 4-1-1, well performance simulation will be carried out once with a conventional completion design, and once again with the same well but equipped with AICDs. Figure (7) shows an illustration of the horizontal section completed with a conventional design, and Figure 8 shows the design of the horizontal section equipped with AICDs.

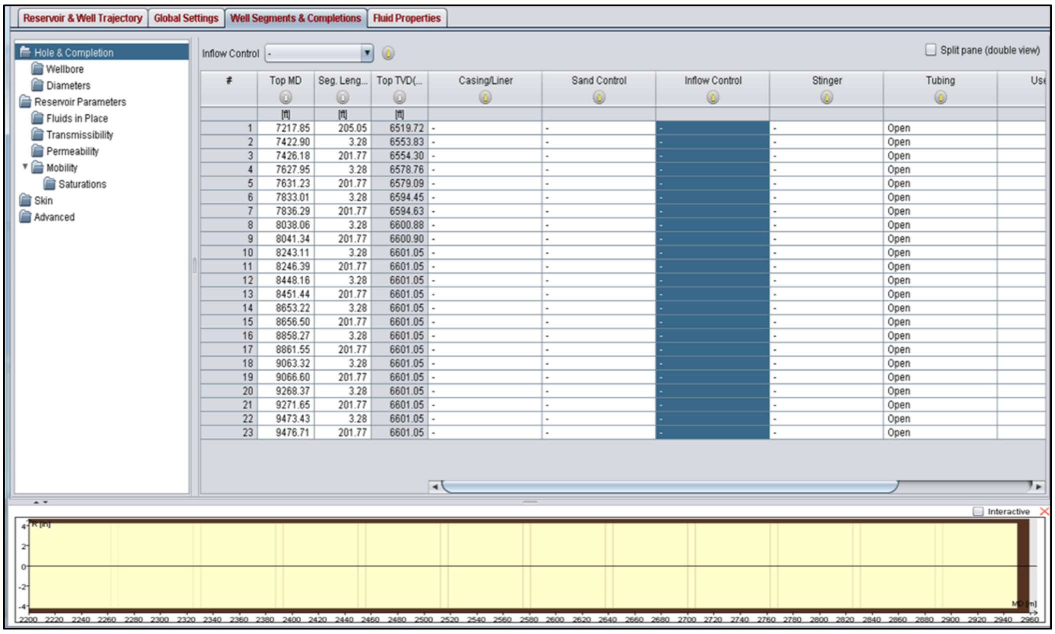

Fig. (7): Conventional Completion Design

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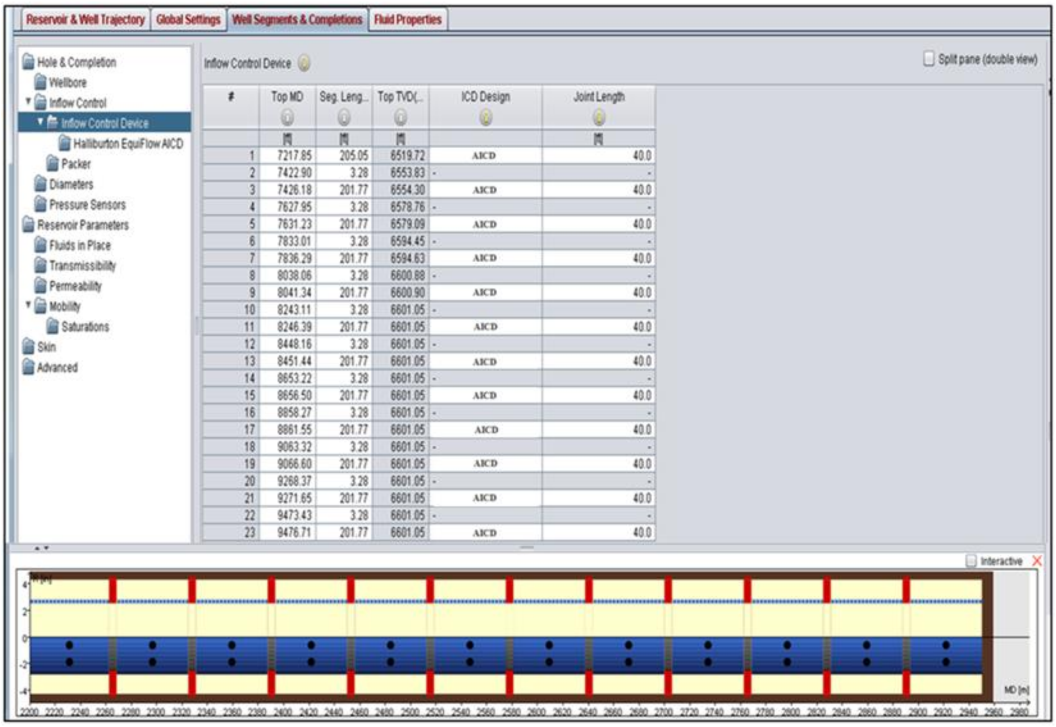

Fig. (8): AICDs Completed Well

5. Results and Discussion

Two different stages were examined during the life of the well; early life and late life. In the early stage (till year 2018), there was no water produced into the well. So when the water cut and the produced oil for the well when completed with a conventional completion was compared with the same well when completed with AICDs, there was no noticeable difference.

When late life (till year 2033) of the well were examined, comparing the conventional well with AICDs, it gave a 17% decrease in water cut and an increase in the oil rate by 890.6 barrel per day, as shown in the results summary Tables (1) and (2) below:

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Table (1) Well performance simulation results for conventional completion design

Summary Table

Run	Pressure at first node	Oil rate	Gas rate	Water rate	Liquid rate	Gas/oil ratio	Oil/gas ratio	Water cut	Downhole rate	Well P.I. Oil	Well P.I. Water
	[psi]	[STB/day]	[MMSCF/day]	[STB/day]	[STB/day]	[SCF/STB]	[STB/MMSCF]	[%]	[RB/day]	[STB/day/psi]	[STB/day/psi]
Time = 0.0 days	2713.86	1947.3	1.07258	3685.18	5632.49	550.8	1815.54	65.4273	6289.81	1.14253	1.40544
Totals for 0.0-360.0 [days]		Oil	Gas	Water	Liquid						
		[STB]	[MMSCF]	[STB]	[STB]						
		701030.0	386.127	1326665.0	2027695.0						

Table (2) Well performance simulation results for AICDs completion design

Summary Table

Run	Pressure at first node	Oil rate	Gas rate	Water rate	Liquid rate	Gas/oil ratio	Oil/gas ratio	Water cut	Downhole rate	Well P.I. Oil	Well P.I. Water
	[psi]	[STB/day]	[MMSCF/day]	[STB/day]	[STB/day]	[SCF/STB]	[STB/MMSCF]	[%]	[RB/day]	[STB/day/psi]	[STB/day/psi]
Time = 0.0 days	3691.17	1056.72	0.582043	4859.09	5915.81	550.8	1815.54	82.1373	6289.81	2.03142	9.27939
Totals for 0.0-360.0 [days]		Oil	Gas	Water	Liquid						
		[STB]	[MMSCF]	[STB]	[STB]						
		380420.0	209.535	1749273.0	2129693.0						

Figure (9) below summarize the well performance simulation results obtained by NETool software for two completion designs; conventional completion and smart completion design with AICDs

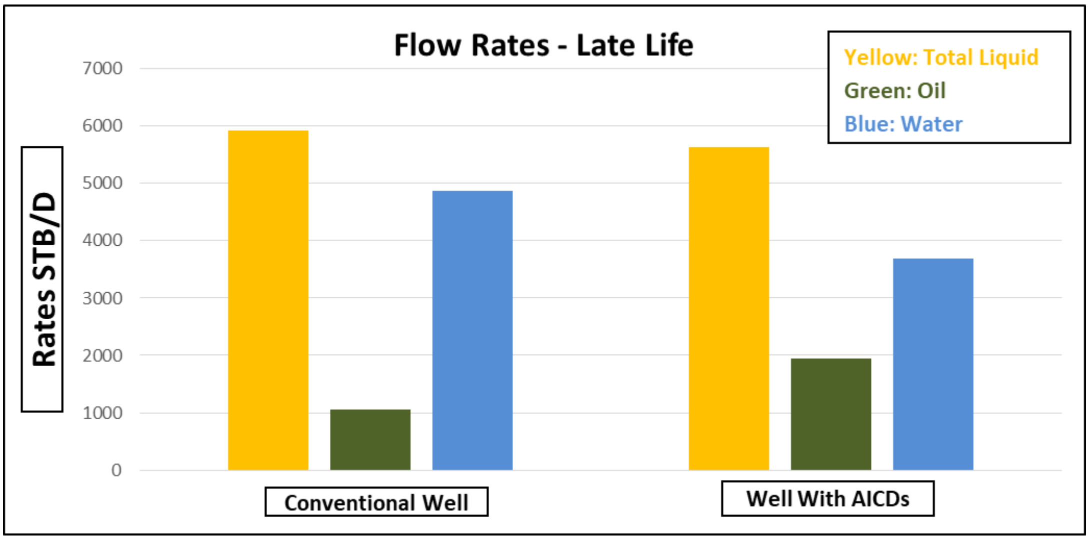

Fig. (9): Well Simulation Results

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The figure above shows that total liquid rate is higher when producing from a well completed with AICDs. This is because the AICDs restrict the fluid flow into the well giving better inflow performance.

The simulation results from year 2018 till year 2050 revealed that the cumulative oil production will be expected to be 23 million barrel of crude oil with the conventional completion design, while it will be 31 million barrel of crude oil with a smart completion design if the well is equipped with AICDs, as shown in the Figure (10) below:

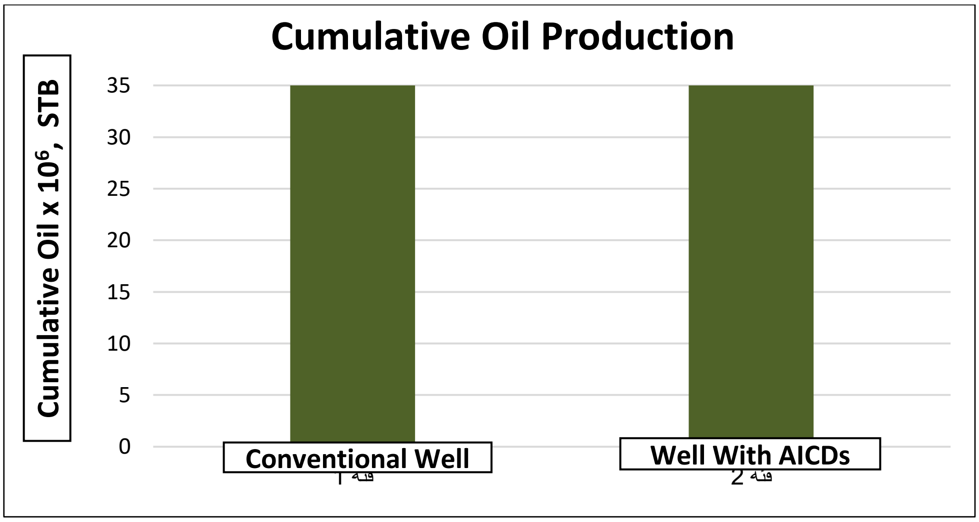

Fig. (10): Cumulative oil production (Period from year 2018- year 2050)

While the well Simulation results from year 2018 till year 2050 revealed that the cumulative water production will be expected to be 44 million barrel of water with the conventional completion design, while it will be 33 million barrel of water with a smart completion design if the well equipped with AICDs, as shown in the Figure (11) below:

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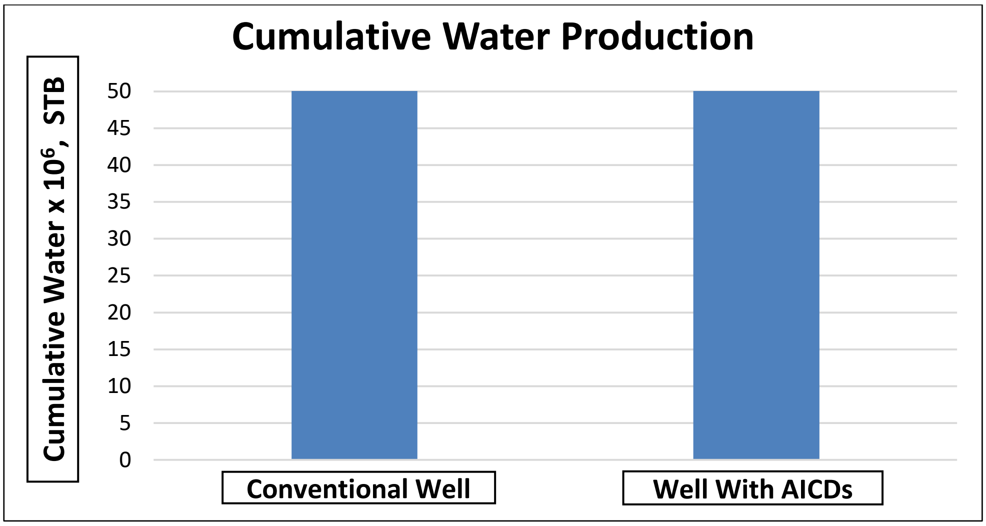

Fig. (11): Cumulative water production (Period from year 2018- year 2050)

6. Conclusions

- Autonomous inflow control devices have been showed as a successful technique in horizontal wells by optimizing and enhancing the inflow performance.
- Autonomous inflow control devices allow self-reservoir controlling especially with heterogeneous reservoir that has non-uniform petrophysical properties horizontally.
- There is no purposes in placing AICDs in a low-permeability formation as the valve restrains the flow rather the zone should be produced.
- When doing well performance simulation analysis with NETool software, several AICDs scenarios and configurations must be investigated to get the optimal completion solution and therefore optimal recovery.
- Autonomous inflow control devices allow flow from reservoir to the well. For water injection purposes, a check valve must be installed on the AICD joint.

Abbreviations and acronyms

ICD: Inflow Control Device.

ICV: Inflow Control Valve.

AICD: Autonomous Inflow Control Device.

BHP: Bottom Hole Pressure.

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