A Methodology to Optimize the Horizontal Well Production using Inflow Control Devices: A Case Study.

ISSN (e) 2520-7393
ISSN (p) 2521-5027
Received on 14th Sept, 2018
Revised on 6th, Oct, 2018
www.estirj.com

Abdul Basit Balouch[1], Naveed Ahmed Ghirano[2] and Yasir Ali Memon[3]

[1,2,3]*Institute of Petroleum & Natural Gas Engineering, Mehran University of Engineering & Technology Jamshoro, Pakistan.*

Abstract: Interest for producing fuel due to rapid development and globalization is increasing day by day. No doubt the hydrocarbon fuel resources are significant origin of vitality which are utilized in numerous methods and they have great application in the global era that's why there need is also arises day by day. One of the most revolutionary intervention is intelligent well completion with downhole devices which are called as Equalizers or Inflow control device. Intelligent wells have the advantage to improve well productivity and to provide a quick and efficient solution for almost all problems without requiring a direct intervention to the well. This paper is focused on the changes came in the results after applying the Equalizer application in the horizontal well model. The research methodology includes information about data gathering in order to make the required models. The models are generated using simulation software. In first case conventional horizontal well model is made i.e. no any data of equalizer is entered in the model. For comparison of results this case is considered as base case. While in the second case, equalizer data is also entered in the horizontal well model. After generating models, the results are analyzed and compared. In this research paper, simulation based analysis is done by analyzing and comparing the results of two cases. In case 1 the conventional horizontal well model is made and after observing the results it was concluded that well produced 0.71 million STB of oil in first 10 years of its life. In case 2 in order to improve the recovery of well, equalizer/ICDs (which are application of smart well) were attached in the same horizontal well model and it was observed that in first 10 years of well's life, 1.11 million STB of oil was produced. However, it should be noted that cumulative liquid production (10.9 million STB) remains same in both cases. In other words, it can be concluded that ICD accelerates the production process of oil.

Keywords:*Intelligent Well completion, Equalizer/ICD, Horizontal well model.*

1. Introduction

Over the last few years' techniques of well completion haveadvanced expressively by introduction of nonconventional horizontal wells and directional drilling technology in the oil and gas industry. And in recent years'various advance technologies have changed the method of development of field in order to improve the reservoir performance and to lower the intervention costs. **[1]**. The wells which are equipped with downhole measurement equipment or control valves or which includes both are called as smart or intelligent wells. In the oilfield, just as in the real world, intelligence is not always a guarantee for success, and the key question in the development of smart well technology is when the added functionality also adds value **[2].**

1.1 Intelligent well Completion

Simply intelligent completion is defined as "a completion which is capable of gathering, conveying and evaluation production of wellbore, data of reservoir and integrity of completion. It has also ability to action remotely for enhancement of reservoir control and performance of well production". Action remotely means that the system is specifically designed in a manner that command can be given at the downhole tool near or in the wellbore without needing any conventional intervention to the well. For that purpose, wireless technology is introduced and advantage of using that is that the well's energy system will be used for data transmission up to the surface and it will not need any type of installation at surface level.

The main advantages which are achieved by intelligent well completion are optimization of production and maximizing recovery although minimizing operating costs also minimizing safety hazards. **[3]**

1.2 Components of Intelligent well completion

This completion includes a remotely controlled inflow valves with sensors and packers to provide the zonal isolation. SCRAMS which is known as surface controlled reservoir analysis and management system is utilized for controlling inflow control valves to assure an efficient control of the flow in different parts of the well. The ICVs can be controlled from surface using hydraulic/electrical control lines and electrical conductors. Hydraulic force is generated by the hydraulic control line and delivered to the SCRAMS module which distributes the force to the different sides of the ICV piston using solenoid valves. The electrical control line allows the delivery of power and signals from the Well controller to all the equipment in the wellbore using a high speed-telemetry system. [1] A schematic of this system is shown in Figure 1.

Corresponding author Email address*: abdulbasit4616@gmail.com*

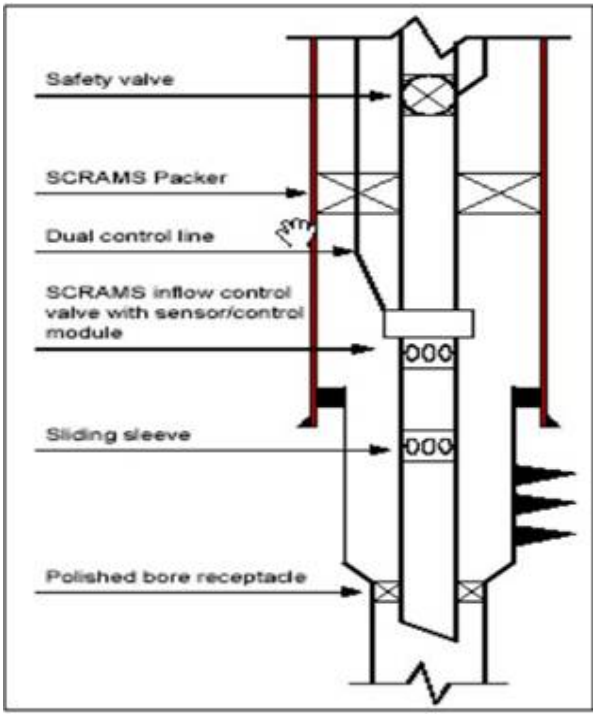

Figure 1: Components of IWC. (*Smart Well Completion* Gaith Arfaoui, Dipl.-Ing. Abbas Zamani The University of Leoben)

1.3 Surface Data Acquisition & Control System

In order to achieve advanced well management, the surface control system (SCS) of smart well is utilized. Actually SCS is an update of intelligent well's downhole well control system. It also gives optimization and computerization for the tools of downhole. For ensuring the connectivity between the SCS and downhole devices the electrical, optical or hydraulic conduits are utilized. The intelligent completion permits control of method through which production of hydrocarbons is made as well as injection of fluids is made in the reservoir.

Surface control can be characterized in three elements: process outputs, controlled variable and manipulated variable. Process outputs are those factors which are continuously monitored with the help of system of downhole monitoring (sensors), simply they describe state of system. The controlled variables are those factors which control the process outputs like water cut, pressure and other few properties. The manipulated variable are those variables which are associated to the downhole equipment. They also allow the process control (e.g. valve position).

1.4 Wireless Technology

This technology is originated because with time the need for number of control and monitoring devices increased, the only reason is to improve recovery of hydrocarbons, the company named Tendeka holds the credit to develop this technology. For wells in which the cable system was proved as a failed system or not installed this wireless scheme found as the best choice. An advanced type of software is used for the purpose of smart well control.

Data of downhole is transferred to surface via pulses of pressure. However, production of well is choked for small time for creating pressure pulse, which will be detected on pressure gauges. The well's energy system will be used for data transmission up to the surface and it will not need any type of installation at surface level. Wireless control of inflow valves is also offered so there is no need of any cable connection in devices which also save expenses of connectors at downhole and control lines.

Downhole Components used in intelligent completion are discussed below:

1.5 Inflow Control Devices

Inflow control device is a passive component of intelligent completion whose function introduced is to equalize flow of reservoir along the wellbore length. This equipment was very first introduced in Norsk Hydro field in the year 1992. Fluid of reservoir which is entering from outer side of tool will flow along the base of pipe in the screens. Afterwards hydrocarbons will then flow into chamber before entering orifice. And in the end the oil is going to flow from large holes in casing. **[1].** Figure 2 shows sketch of ICD.

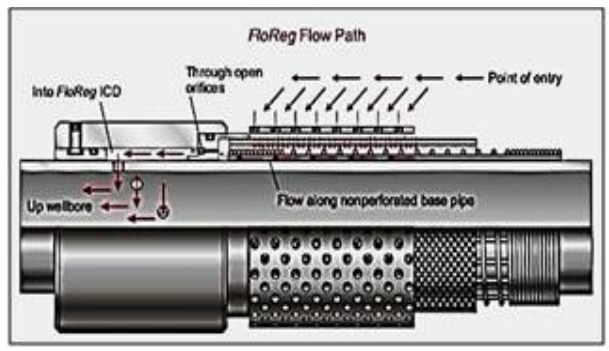

Figure 2: A sketch of ICD.(*Smart Well Completion* Gaith Arfaoui, Dipl.-Ing. Abbas ZamaniThe University of Leoben) [1]

1.6 Equalizer

Equalizer production system is another type of inflow control device which creates the flow behavior that maximizes drainage from specific reservoir. And they are also long lasting. Dependable designs deliver long-term, reliable performances so well life can be prolonged and improve recovery. Equalizer devices can be installed 50% faster than the standard one. As shown in figure 3.

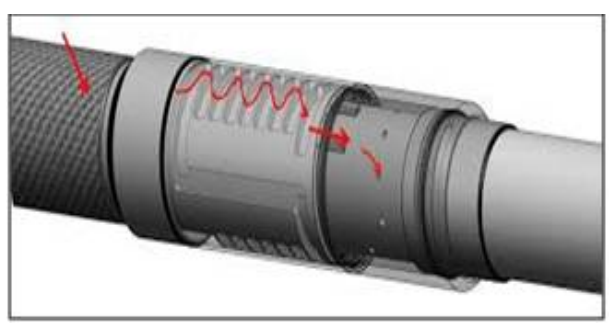

Figure 3: Equalizer. (*Equalizer Portfolio* Devex conference 2014 by Baker Hughes)

1.7 Inflow Control Valves

An inflow control valve (or interval control valve) is a remotely operated downhole component that used to partially or completely choke flow. It is controlled from surface by means of electro-hydrostatic actuation (EHAs) or hydraulic systems. ICVs are installed between the different separated zones of the well. The old versions of ICVs were four-piston ICV, in those there was a choke which provides only a full closed/open and two intermediate positions. In that ICV there was not an ability to fully control the well, so for that purpose its solution was to use infinitely variable inflow control valve. Currently inflow control valves are of easier mechanism of operation and they can also bear conditions of high pressure and temperature.**[1]**As shown in figure 4.

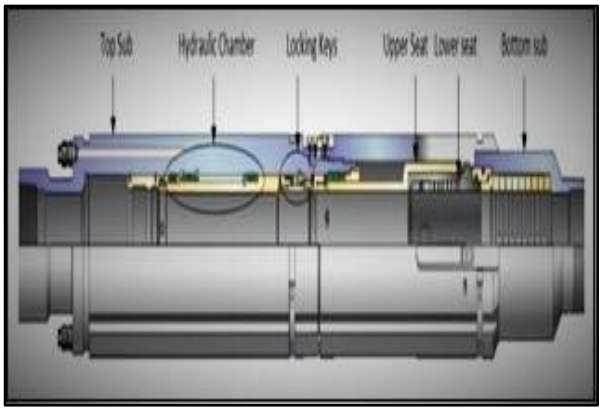

Figure 4: Inflow control valve.*(Smart Well Completion* Gaith Arfaoui, Dipl.-Ing. Abbas ZamaniThe University of Leoben) [1]

1.8 Review of Relevant Data

In this paper a case study is presented which is detailing comprehensive analysis of performance and design of downhole valves. It also defines the process which is actually used to improve design of downhole valves based on field data. Modelling work depends on the latest operating envelope in order to ICV can be utilized to get recovery rates that satisfy both well production pattern and management of reservoir plan. The conclusion achieved after review of paper are: i. After bearing in mind different fluid and reservoir properties the actual performance of valves varies. Lateral production can be controlled bychokes at surface because downhole installed valves can't provide anticipated control **[11].**

In this journal intelligent completion application in offshore field of Qatar named Al Khalij. The field is basically carbonate reservoir of high heterogeneous composition. The details of this paper contains planning, execution and design of intelligent completion which is applied in well and this paper also covers the values which must be considered for development of field **[12].**

In the offshore reservoir of Malaysia 45 wells were drilled and completed using ICD. Smart well completion design process from drainage and injection point selection is defined. After various practical implementations, field performance evaluations and critical engineering studies the Malaysian E&P companies have developed several oil-rim reservoir production strategies and effective methods of drilling and completion of smart wells to get more recovery of hydrocarbons **[20].**

This paper evaluates the application of annular flow control valves (AFCVs) which are surface controlled in order to improve wellbore cleanup and both AFCVs and ICDs for improvement in production. The research focuses on carbonate rock reservoir which is tightly packed and the wellbore is horizontally drilled with three different compartments. After thorough study it is concluded that these three compartments exhibit "moderate", "excellent", and "poor" productivity. **[21]**

It has been noticed that the multilateral well technology is proved as successful by providing accurate management of reservoir and for development of reservoir. This paper provides an overview of advantages gained by improving the efficiency of completion operations and well drilling in multilateral well. The field which is made under consideration is Kuwait's field.**[22].**

In this paper experiments have been made in order to observe the production optimization of well named Lei632 using inflow control valves. These devices can be used for reliable and correct data monitoring and transmission because along with these devices optical fiber sensor and electrical sensors are installed in the well. The design of ICVs can be controlled correctly and dependability, for certifying flow control realization in smart wells.**[23].**

2. Problem Statement

Interest for producing fuel due to rapid development and globalization is increasing day by day. No doubt the hydrocarbon fuel sources are significant origin of vitality which are utilized in numerous methods and they have great application in the global era that's why there need is also arises day by day.In this paper problem is basically the low recovery of oil due to high connate water saturation. Now the main problem is how to increase the recovery of oil in the presence of high connate water saturation. In response to this problem, the paper is based on the application of equalizers/Inflow control devices (smart well) in horizontal well. The main function of ICD is restricting the flow of fluid from reservoir into the well, making the well profile of inflow more uniform. ICDs significantly increase the recovery of well as comparing to wells without ICD. So for analyzing the results in both the cases (with and without ICD) horizontal well models are generated and results are analyzed.

3. Objectives

The main objectives of this paper are below:

- To make a reservoir simulation model of horizontal well.
- To make a reservoir simulation model of horizontal well equipped with Inflow control devices/equalizers.
- Comparison of both models.

4. Methodology

In order to make horizontal well models real time data is collected from the field as well as it is validated. The next step is to put that data is the modelling tool. Generally, the data used in tool are grid geometry data, PVT data, relative permeability and well completion data. In geometry section parameters for making the reservoir model are entered. In the section of physical parameters PVT data is entered which is basically about fluid properties. Relative permeability curves are plotted by entering the values of saturation using the model Stone 1. The last step is to enter the wellbore parameters and the values related to well completion tools. The production of first 10 years is observed in this paper. After making both the models graphs are generated which will be analyzed and discussed below.

The reservoir properties are gathered and collected from the field. This includes petro physical data, fluid/PVT data, reservoir data etc. Some of these properties are mentioned in the following tables. However, production formation is sandstone at the depth of 8000 ft. while its thickness is 90 ft. The reservoir also contains connate water, other properties of reservoir data, component data, rock data and overburden/unburden data are given in tables 1,2,3 and 4 respectively.

Table 1: Reservoir Data

Component model	Oil/Water/Gas
Average porosity	30%-20%
Average permeability	400 md-800 md
Reservoir pressure	3800

Table 2: Component Data

Component	Heat Capacity (BTU/lb./ft.)
Water	1
Oil	0.53
Gas	0.51

Table 3: Rock Data

Rock Type	Grain Density
Type 1	160

Table **4**: Overburden/under burden data

Condition	Density	Heat Capacity	Thermal Conductivity
Overburden	160	0.2	10
Under burden	160	0.2	10

4.2 Grid Data

The well model is generated by putting the data of grid sizes in the grid section of model as below:

Table 5: Grid input

Component	From	To	Grid Size (ft.)
X	1	40	100
Y	1	10	50
Z	1	15	6

The generated model is shown in Figure 5.

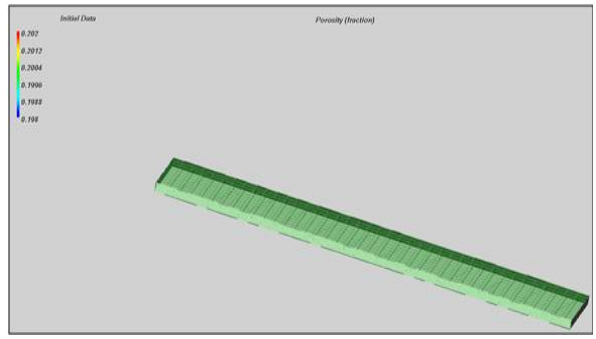

Figure 5: Reservoir 3D model

Table 6: Well data of conventional horizontal well

1	Tubing Size	5 ½”
2	Tubing Length	40”
3	Rating	1.6
4	Equalizer/ICD size	5 ½”
5	Equalizer/ICD length	40”
6	Ratings	1.6
7	Flowing Radius	0.375 ft.
8	Roughness	0.0006
9	Discharge co-efficient	1

4.3 Well Modeling (well description)

Case 1: Horizontal well model

The well is drilled at the depth of 8045 ft. and the MD of horizontal well is 3400 ft., the azimuth of the well is 90°.The length l section is 4000 ft. and vertical section’s is 500 ft. Other data is mentioned in table 6. The well model is shown in Figure 6.

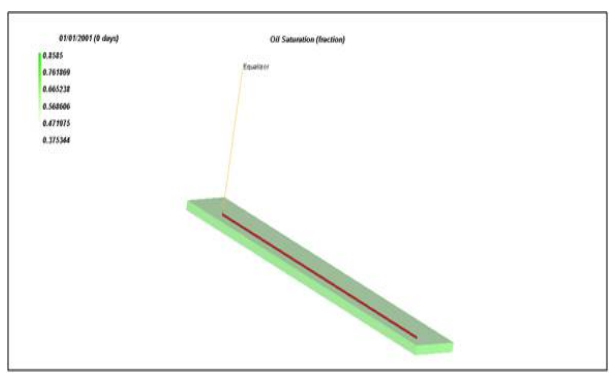

Figure 6: Horizontal well model

Case 2: Horizontal well model with attached ICDs

This well is also drilled at same depth with same azimuth and MD is also same but in this model inflow control devices are installed after every interval of 120 ft. The equalizer/ICD and tubing are installed alternatively in the completion, very first component is equalizer/ICD, second one is tubing and the sequence goes on. Other data is mentioned in the table 7. Model is shown in figure 7.

Table 7: Well data of horizontal well with ICD

1	Tubing Size	5 ½”
2	Tubing Length	40”
3	Rating	1.6
4	Equalizer/ICD size	5 ½”
5	Equalizer/ICD length	40”
6	Ratings	1.6
7	Flowing Radius	0.375 ft.
8	Roughness	0.0006
9	Discharge co-efficient	1

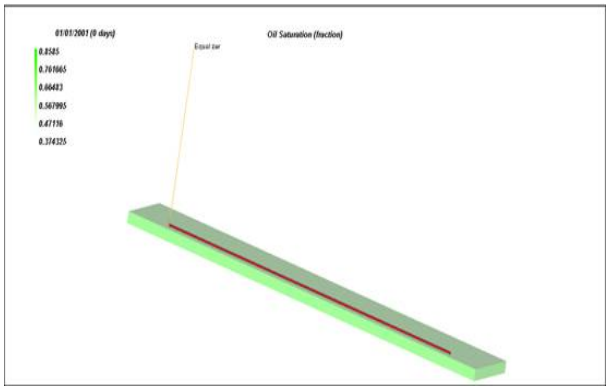

Figure 7: Horizontal well model ICDs attached

5. Results and Discussion

5.1 Case-1: Horizontal Well Model

This case is also known as base case because in it, horizontal well model curvesare generated with conventional completion string i.e. no intelligent completion data has been entered. The well has produced 0.71 Million STB of oil in 10 years.

The oil production in initial days of well is about 3000 STB/day. But soon rapid decline occurs in oil rate due to connate water and in 10 years the production reaches to 64 STB/day, which can be seen in figure 8.

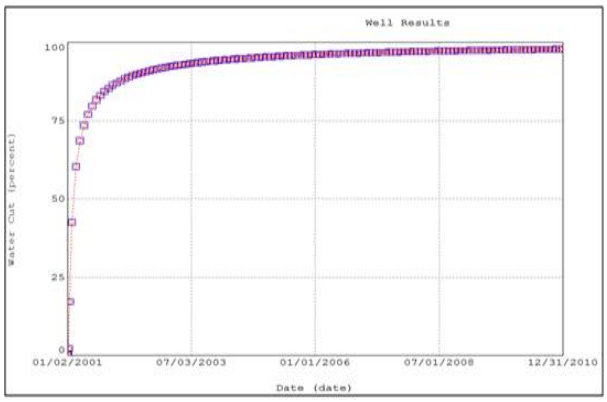

Figure 8: Oil Production curve

In the initial days of production water cut was low but in the 10 years’ connate water saturation causes the high water breakthrough of about 97%, which is shown in figure 9.

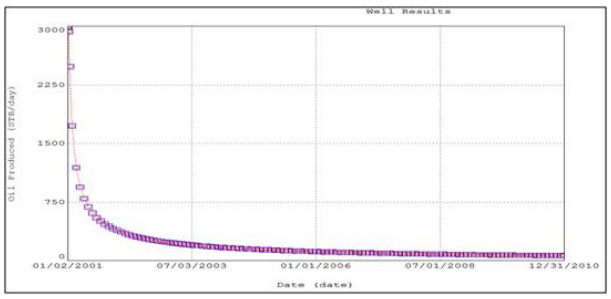

Figure 9: Water cut

Figure 10 shows the cumulative oil (0.71 Million STB) and cumulative water (10.2 Million STB) production in the conventional horizontal well for 10 years.

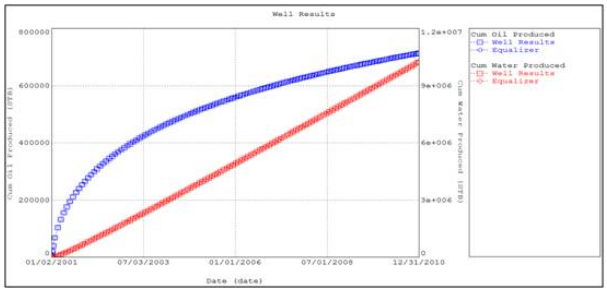

Figure 10: Cumulative production

After entering the required data in software the following results are obtained.
Oil=0.71 Million STB
Water=10.2 Million STB
Cumulative=10.9 Million STB

5.2 Horizontal well Model with ICD attached

In this case horizontal well model results are generated with attached completion string of smart well i.e. inflow control devices data has been entered, while reservoir data and other data is same except well data. The well produced 1.11 Million STB of oil in 10 years. The oil production in initial days of well is about 3000 STB/day, however in 10 years the production reaches to 120 STB/day as shown in figure 11.

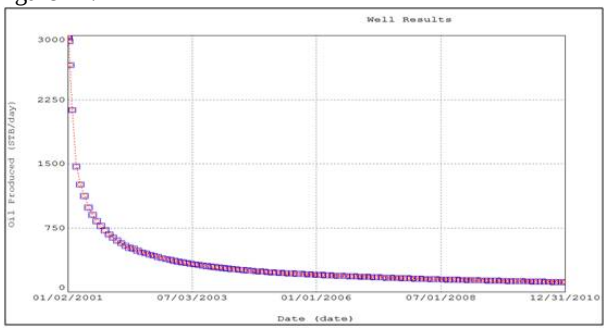

Figure 11: Oil production curve of ICD attached

Due to connate water saturation water breakthrough occurs in this case also which causes the water cut to reach at 96% as shown in figure 12.

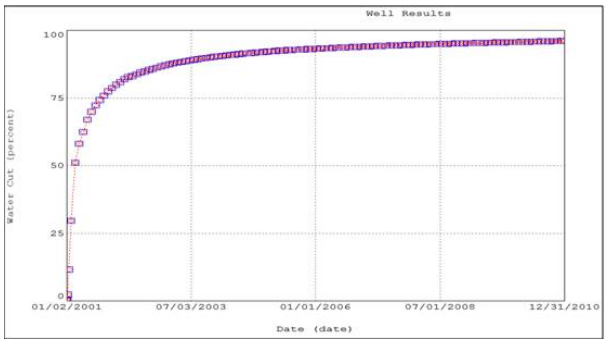

Figure 12: Water cut of ICD attached well

Figure 13 shows the cumulative oil (1.11 Million STB) and cumulative water (9.83 Million STB) production in the ICD attached horizontal well for 10 years.

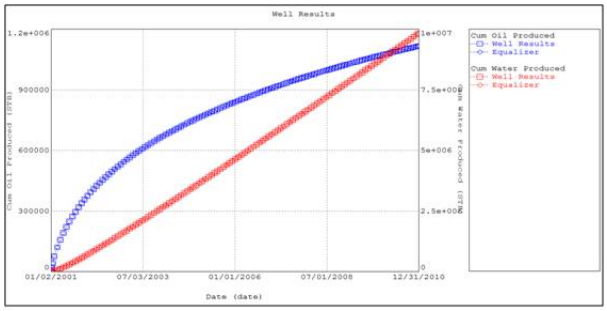

Figure 13: Cumulative production

After entering the required data in software the following results are obtained.
Oil=1.11 Million STB
Water=9.83 Million STB
Cumulative=10.9 Million STB

5.3 Comparison of Both Models

In order to compare oil production rate of both models ms excel graph is generated in figure 14, in which it is clear that oil production rate in well with ICD attached is higher than conventional well

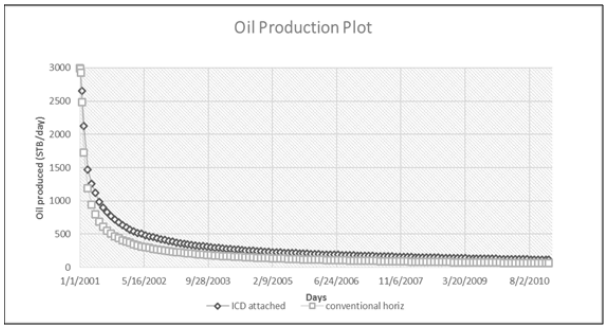

Figure 14: Comparison plot

6. Conclusion

The findings are concluded as follows:

In case 1 of this paper horizontal well model is generated with conventional completion string, i.e. no any ICD data is entered in this case. After simulating, it was observed that

well produced 0.71 Million STB of oil and 10.2 Million STB of water out of 10.9 Million STB of cumulative liquid in 10 years.

However, in case 2, parameters of inflow control device have been entered in the well model to analyze the recovery of the well. After making the well model and analyzing the results, improvement in the recovery of the well is observed and due to attachment of ICDs the recovery of the oil has been accelerated while water production has been decreased. The well-produced 1.11 Million STB of oil and 9.8 Million STB of water out of 10.9 Million STB of cumulative liquid in 10 years. In both cases it should be noted that cumulative production is same, but oil production is high in case-2 where ICDs are attached. So after obtaining above results it is concluded that inflow control devices improve the recovery of the well.

References

1. Gaith Arfaoui, Dipl.-Ing. Abbas Zamani *"Smart Well Completion"* The University of Leoben.

2. Jansen J.D *"Smart wells"* 2001.

3. Robinson Mike *"Technology Today Series"* Production Engineering Technologies. (2003).

4. Coats K.H. et. al. *"Compositional & Black oil Reservoir Simulation"*. 13th SPE Symposium on Reservoir simulation in San Antonio. SPE-29111. 1995

5. Soleng H. et. al. *"Gridding for petroleum Reservoir Simulation"*. Norwegian computing Center.

6. Zhang John J. et. al. *"Reservoir Simulation and Geomechanical modelling in Leming Lake"* , Alberta. 2004

7. Ghorayeb Kassem et. al. *"Multiple Reservoir Simulations Integration: An Alternative to Full field Simulation in North Kuwait Jurassic complex"*. SPE ATCE Colorado USA. Paper no. SPE-115881. 2008

8. Freyer Rune et. al, *"An Oil Selective Inflow Control System"*, European Petroleum Conference UK, Paper no. SPE-78272-MS. 2002

9. Glandt Carlos A. et. al.*"Reservoir Aspects of Smart Wells"*. Society of Petroleum engineers West Indies 2003. SPE-81107. 2003

10. Naus Mark et. al. *"Optimization of Commingled Production Using Infinitely Variable Inflow Control Valves"*, SPE Production & Operations, Paper no. SPE-90959-PA. 2006. 2006

11. Saeed Mohammed Al-Mubarak et. al.*"Improved Performance of downhole Active Inflow Control Valves through Enhanced Design*: Case Study", ADIPEC UAE, Paper no. SPE-117634-MS. 2008

12. Carpenter Chris *"Successful application of Intelligent Completions in Al Khalij Field"* JPT Editor Paper no. SPE-0525-0111

13. Abdullah M. Qahtani,et. al.“*Flow Simulation in Inflow Control Valves using Lattice Boltzmann Modelling”*, Saudi Arabia Section Technical Symposium and Exhibition, KSA, Paper no. SPE-136935-MS. 2010
14.
15. A. Zarea Marwan et. al. “*An Integrated Performance Model for Multilateral Wells Equipped with Inflow Control Valves”*. Paper no. SPE-142372-M. 2010
16. Das Om Prakash et. al.“*A Novel Workflow for Intelligent Well Inflow Control Valve Design by Integrating Reservoir Dynamics to Facilitate Proactive Reservoir Management in Minagish Field*”. West Kuwait, Paper no. SPE-170803-MS. 2012
17. Yadav Varun et. al. “*Evaluating the Performance of Intelligent Completion*”. Paper no. 150408. 2012
18. AakreHavard et. al. “*Smart Well with Autonomous Inflow Control Valve Technology”*, Paper no. SPE-164348-MS. 2013
19. V.E. Botechia et. al. “*Analysis of Inflow-Control-Valves Shutdown effects in Well Production and Economics”*. Paper no. SPE-169368-MS. 2014
20. Eltaher Khalid Eltazy et. al. “*Autonomous Inflow Control Valves – their Modelling and “Added Value*”. Paper no. SPE-170780-MS.2014
21. Chan keng Seng et. al. “*Smart Horizontal Well Drilling and Completion for Effective Development of Thin Oil-Rim Reservoirs in Malaysia”*. Paper no. IPTC-17753-MS.2014
22. Wayne Stone Terry et. al. “*Flow Control Valves and Inflow Control Devices Optimized for Wellbore Cleanup and Production.*” Paper no. IPTC-18002-MS. 2014.
23. Suresh Zac et. al. “*Challenges and Lessons Learned During Completion of Intelligent Multilateral Wells in Minagish Field, West Kuwait”*. Paper no. SPE-191742. 2018
24. Huang Zhiqiang et. al. “*Study of Intelligent Completion System for Liao he Field”*Elsevier Procedia Engineering Volume 15, 2011.

About Authors

Abdul Basit Balouch completed his B.E Petroleum & Natural Gas from Mehran University of Engineering & Technology Shaheed Z.A Bhutto Campus Khairpurmir’s in year 2014 and did M.E in Petroleum Engineering from Mehran University of Engineering and Technology Jamshoro in 2018. He worked as a Treasurer of Society of Petroleum Engineers (SPE) in Mehran UET Khairpur chapter in 2013-14.He has done traineeship in Oil & Gas Development Company Pakistan. His research work interest includes Drilling Engineering, Reservoir Simulation, Well testing, Well logging and interpretation, Well modelling and Production Optimization.

Naveed Ahmed Ghirano is an Assistant Professor in Institute of Petroleum and Natural Gas Engineering, Mehran University of Engineering Technology, jamshoro. He completed M.E in Petroleum Engineering from same institute. His Research work interest includes Reservoir Simulation, Smart Well Technology, Reservoir Engineering, Production Engineering, Well testing and Production Optimization.

Yasir Ali Memon is a graduate in B.E Petroleum & Natural Gas from Dawood University of Engineering & Technology Karachi in 2015 and completed his M.E in the field of Petroleum engineering from Mehran University of Engineering and Technology Jamshoro in 2018. He has worked as a Trainee in Oil & Gas Development Company Limited Pakistan. His Research work includes Production optimization, Reservoir Modelling, Production Engineering.

Acknowledgement

We would like to pay our regards to the Institute of Petroleum & Natural Gas Engineering, Mehran University of Engineering & Technology Jamshoro for allowing us to perform simulation work in institute’s laboratory. We also wish to present our special thanks to teachers of institute for their continuous support and guidance.