

PRODUCTION OPTIMIZATION OF AN OIL RESERVOIR

Mohammed Abdalla Ayoub, Abdollah Esmaeili

Universiti Teknologi PETRONAS (UTP) – Malaysia

Abdalla.ayoub@petronas.com.my

esmaily_ab@yahoo.com

ABSTRACT

The production of hydrocarbon fluids is via production system. The production system has different parts with different features. Assurance in optimized performance of this system is requiring precise knowledge of its different parts. The production system can be categorized into three major parts. These are Inflow that related to fluid flow through porous media, vertical well flow (from sand face to the wellhead choke), and flow through surface facility.

By using available models, any part of production system can be modeled. Inflow information of production system such as reservoir pressure and temperature, fluid type and porous media characteristics and vertical well flow information (well geometry and pressure control devices) can be used to model the production system. After modeling of the production system, any problem can be specified and then proper methods are applied to rectify the system.

Selecting proper tubing and wellhead choke sizes are essential to maximize reserve recovery in depletion drive oil reservoirs. In this study two wells of an oil reservoir were analyzed to determine optimum tubing and choke sizes for production optimization. Database bank consists of flowing, static and buildup test were utilized. Data were analyzed with PANSYS and PIPSEIM software. Nodal analysis technique was used to analyze tubing and choke sizes for these wells. Also, effects of skin damage change on IPR curve and well deliverability were examined.

INTRODUCTION

The production system can be divided to main three components. These are inflow (fluid flow through porous media), vertical well flow (from sand face to the wellhead choke), and flow through surface facility. In order to optimize the system, any one of these segments must be evaluated separately. Well analysis is the most important step to optimize oil production. The goals of well analysis are to determine the flow rate at which well will produce with a given well-bore geometry and completion configurations (first by natural flow); to determine under what flow conditions the well will produce which can be related to time as the reservoir depletes; to select the most economical time for the installation of artificial lift and to assist in the selection of the best artificial lift method; to optimize the well conditions and system geometry in order to increase produce flow rate;

to analyze each component in the well system to determine if it is restricting the flow rate unnecessarily when compared to the flow capacities of the other system components.

The objective of production optimization methods is to find out that component of the well which is restricting the rate below the maximum possible. Well inflow performance relationship (IPR) and tubing performance relationship (TPR) are the basic requirements for well analysis. Accurate well test and flowing data must be obtained then the proper IPR and two phase flow correlation models applied for successful analysis. Then mathematical models of other well components can be used to complete the predicted well performance.

There are many oil and gas wells in an oil field that have not been optimized to achieve an objective

rate in an efficient manner. In fact, many wells had been routinely completed in a manner such that their maximum potential rate cannot be achieved. These wells can be analyzed by applying optimization techniques to evaluate well component such as tubing size and choke size. The effects of change in any one of this component on the entire producing system are very important and can be graphically displayed using well analysis. Tubing size and choke size are important components that must be optimized for production of an oil reservoir. This paper is rating the effects caused by single components on the entire production system using PANSIM and PIPESIM software's.

ANALYZING WELL PERFORMANCE

Analyzing well performance is an important step to optimize production by improving production techniques. The analysis can be performed by well tests and examination of the field data. Data gathering was the main problem in this study. For this purpose we selected two wells; A and B in this reservoir with their various data such as flowing, static, PI tests, fluid property and well geometry data. Then PI test data was analyzed by the PANSYS software. The PI tests were done in a short time, therefore they cannot detect the correct magnitudes of skin and permeability and they show only an approximate value of the skin and permeability. Then by using PIPSIME software, tubing size and choke size of these wells were examined. Also for analyzing the effect of inflow performance in the production, skin factor and reservoir pressure were analyzed. Tables 1 and 2 show the well, reservoir and fluid properties data and production condition of the wells A and B, respectively.

Table 1 - Wells, reservoir and fluid property data

Well	A	B
Bubble Point Pressure (psig)	4398	4398
Bubble Point Temperature (°F)	220	220
Oil Compressibility @P _b pressure (psi ⁻¹)	1.45E-5	1.45E-5
FVF(Bo) @ P _b (bbl/STB)	1.5131	1.5131
Oil Gravity (°API)	34.9	34.9
R _s @ P _b pressure (scf/stb)	1053	1053
Viscosity @P _b Pressure (cp)	0.2892	0.2892
Well Radius (inch)	3.504	2.496
Well Radius (ft)	0.292	0.208
Average Porosity (%)	13	12.5
Average S _w (%)	24	25
Type of Completion	cased – hole	cased – hole
Interval (ft)	11686-11867	12057-12480
Formation Thickness (ft)	112.5	144

Table 2 - Production condition of the wells A and B

Well	A	B
Production Rate (STB/d)	1000	3000
Well-bore Flowing Pressure(psig)	3893	4582
Reservoir Pressure (psig)	4230	4837
Productivity Index (STB/d/psig)	2.97	12
Wellhead Pressure (psig)	915	1460
GOR (Scf/Stb)	1030	1020
Gas S.G	0.77	0.76
Water cut (%)	0	0
Choke Size (1/64 inch)	24	32

PI TEST ANALYSIS

PI Test of Well A

For this well a PI test was analyzed. The radial flow plot and log-log plot of this test are shown in Figures 1 and 2.

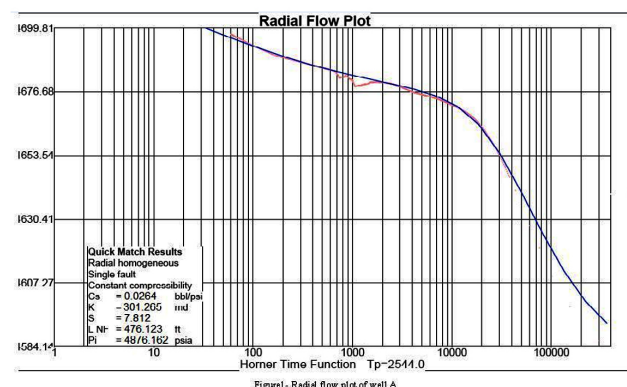


Figure1. Radial flow plot of well A

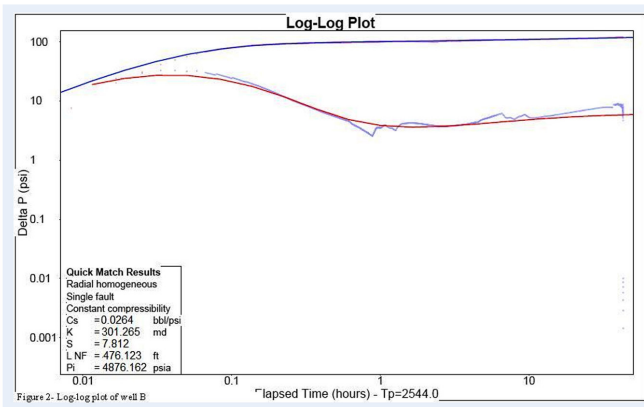


Figure 2. Log-log plot of well B

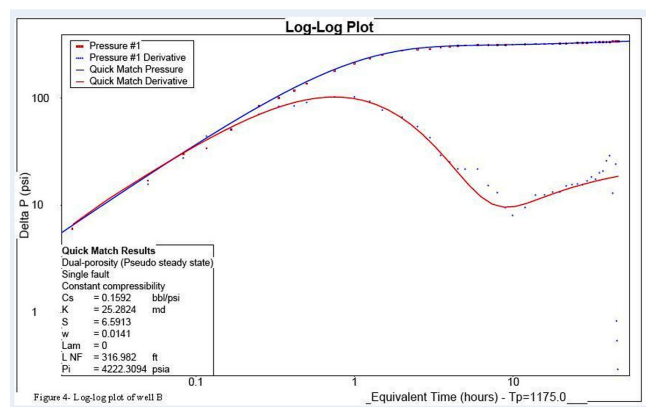


Figure 4. Log-log plot of well B

PI Test of Well B

For this well a PI test was analyzed. Radial flow plot and log-log plot of this test are shown in Figures 3 and 4. As shown in these figures, single fault dual-porosity (pseudo steady state) model gives an acceptable match.



Figure 3. Radial flow plot of well B

Results of the PI tests which are analyzed by PANSYS software, including the skin factor and the reservoir permeability, are summarized in Table 3.

Table 3 - Skin factor and reservoir permeability for Wells A and B

Well	A	B
Skin Factor	7.812	6.5913
Permeability (md)	301.265	25.2824

ANALYZING THE PRODUCTION CONDITION OF THE WELL A AND WELL B

Flow Correlation Matching

By using flow correlation matching, different two phase flow correlations such as Hagedorn and Brown Revised (HBR), Duns and Ros (DR), Orkiszewski (ORK), Tulsa Hagedorn and Brown (THB), Beggs and Brill Revised (BBR), Original Beggs and Brill (BBO), Govier and Aziz (GA) and Mukherjee and Brill (MB) were selected to predict pressure drop in the wells A and B (Figures 5 and 6).

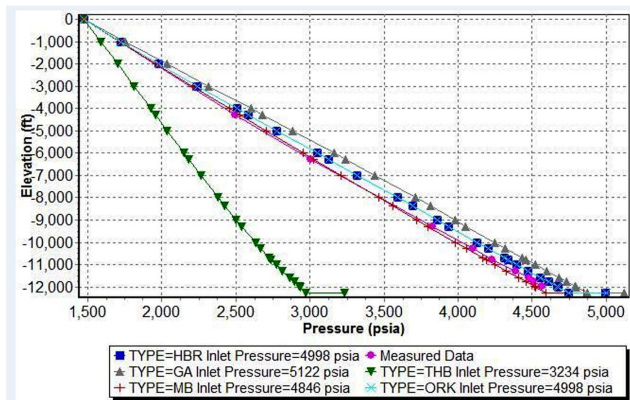


Figure 5. Flow correlation matching for well A

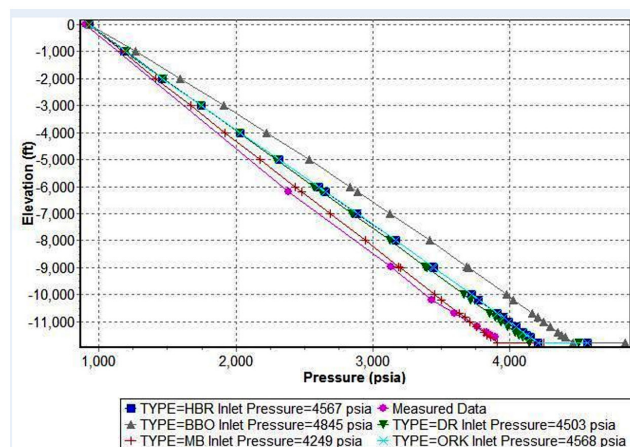


Figure 6. Flow correlation matching for well B

Tubing Size Analyzing

The production tubing is one of the main components of any production well system. The wrong choice of tubing can lead to disastrous consequences later on during the life of a well and so, the economies of scale need to be properly scrutinized. According to the pressure data of the wells A and B, the following IPR correlations were used: 1- Combination Vogel and PI correlation for the well A 2-Vogel correlation for the well B.

The tubing sizes were varied between 2.2" and 6.184" and all other parameters such as GOR, wellhead pressure, static pressure and etc. for any one of these wells are held constant. Results of analysis are shown in the Figures 7 to 14. Figures 7 and 8 show the IPR and TPR curves for these wells.

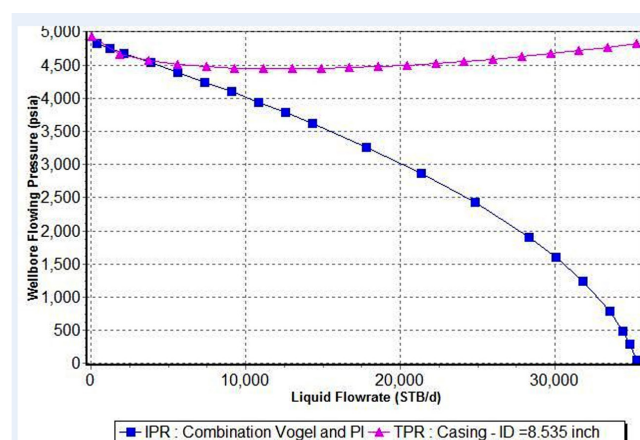


Figure 7. IPR and TPR curves for well A

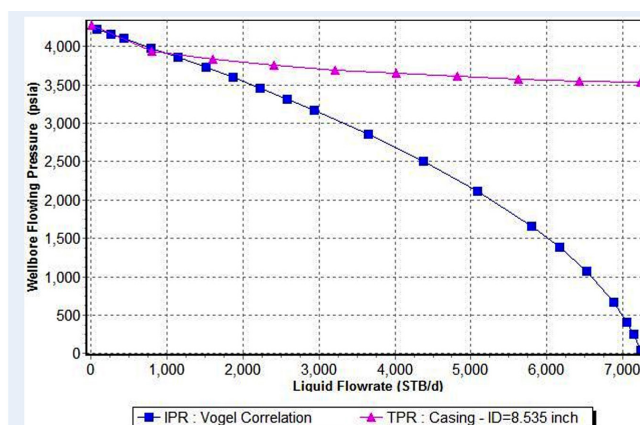


Figure 8. IPR and TPR curves for well B

Nodal Analysis

Figures 9 and 10 show the IPR and TPR curves for different tubing size of the wells A and B which are developed using nodal analysis.

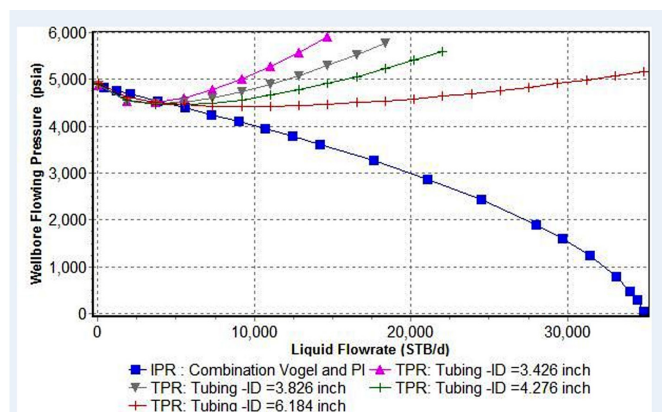


Figure 9. Tubing size performance analyzing for the well A (nodal analysis)

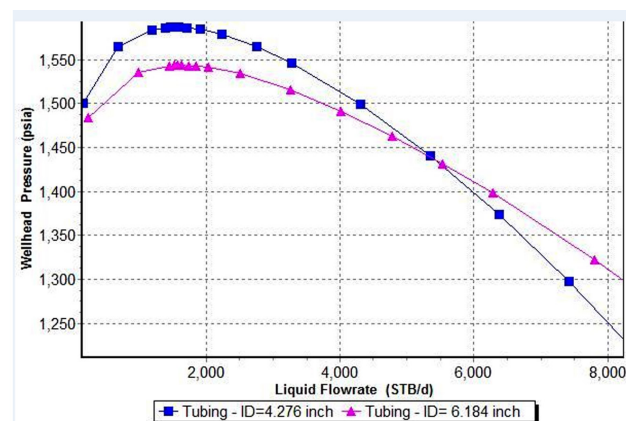


Figure 11. Wellhead performance analysis for well A

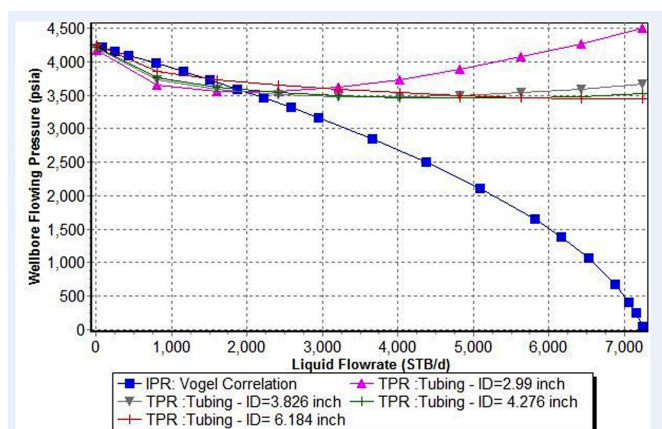


Figure 10. Tubing size performance analyzing for the well B (nodal analysis)

Figure 12 shows the change of flow rate vs. wellhead pressure in the well B for three cases (1) tubing size =2.99" (2) tubing size =3.428" (3) tubing size=3.826".

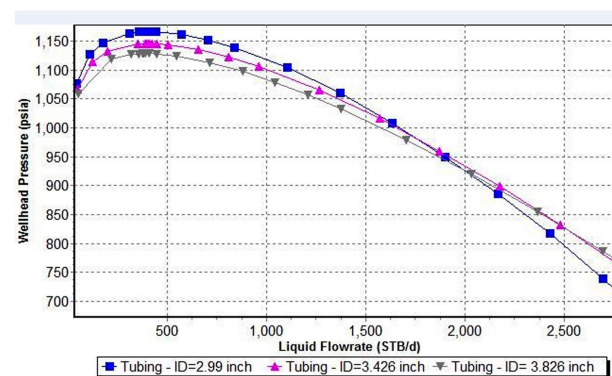


Figure 12. Wellhead performance analysis for well B

Wellhead Performance Analysis

Figure 11 shows the results of the wellhead performance analysis for well A in two cases; (1) tubing size = 4.276", (2) tubing size = 6.184".

Choke Size Analyzing

For analyzing choke performance, the optimum condition for downstream pressure (P_2) was assumed to be equal to 710 psia and 640 psia for wells A and B respectively. Figures 13 and 14 show CPR and WPR curves for wells A and B when the Gilbert and Ashford correlations are used for critical and states.

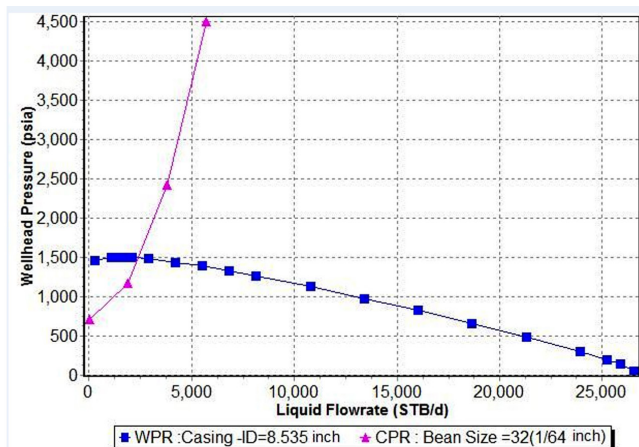


Figure 13. CPR and WPR curves for well A (using Gilbert and Ashford)

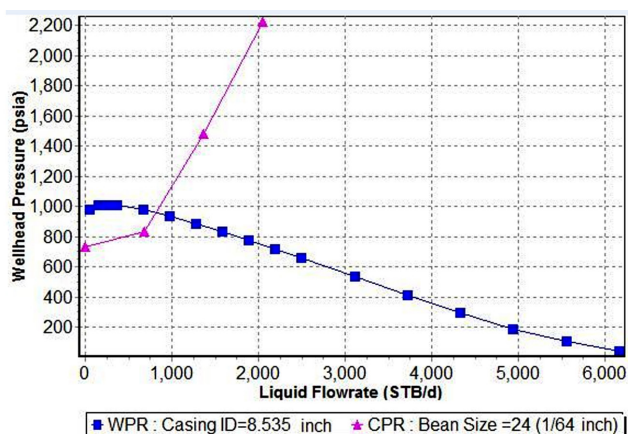


Figure 14. CPR and WPR curves for well B (Using Gilbert and Ashford)

As shown in the Figure 13, for well A, the predicted operation conditions ($q=2200$ STB/d and $P_{wh}=1500$ psia) differ from real operation conditions ($q=3000$ STB/d and $P_{wh}=1460$ psia). Furthermore, this figure shows that flow behavior in the choke is at sub critical state. But in this well ($P_2/P_1 > 0.55$) which shows the flow in the choke is at critical state. Also as shown in Figure 14 for well B, the predicted operation conditions ($q=700$ STB/d and $P_{wh}=950$ psia) differ from real operation conditions ($q=1000$ STB/d and $P_{wh}=915$ psia). Also flow behavior in the choke is at critical condition. But in this well ($P_2/P_1 < 0.55$) and flow in the choke is at sub critical state.

Reservoir Pressure Effects

For analyzing the reservoir pressure depletion, we assume that the gradient of pressure decline in the reservoir is 40 psig /year. Figure 15 to 16 show the effect of the reservoir pressure depletion on the IPR curves and production rates for the wells A and B, for two conditions: 1- When the wells produced by casing 8.535" 2- When the well A produced by tubing size 4.276" and well B produced by tubing size 2.99". All other parameters such as GOR, wellhead pressure and etc. were held constant.

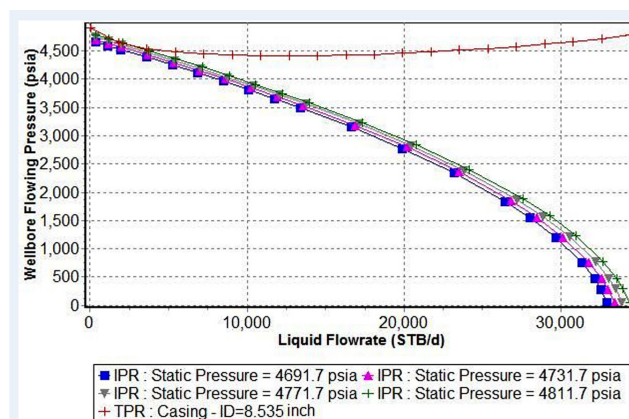


Figure 15. Effect of reservoir depletion of the well A (Casing 8.535")

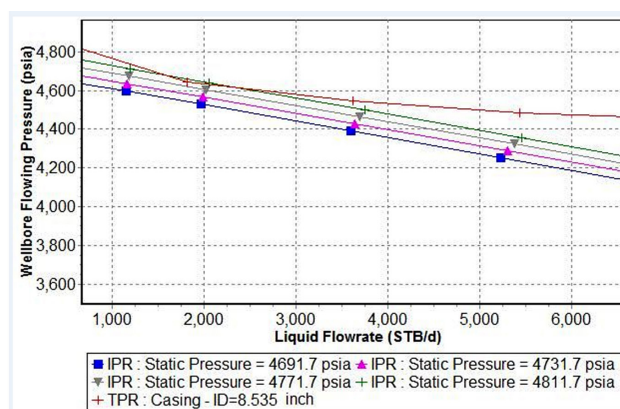


Figure 16. Effect of reservoir depletion of the well KL-15 (Casing 8.535")

Skin Effect

For analyzing the skin effect on IPR curves, pseudo-steady state equation for inflow performance relationship (IPR) were used. Figure 17 and 18 show the effects of skin factor on the IPR curves, for wells A and B.

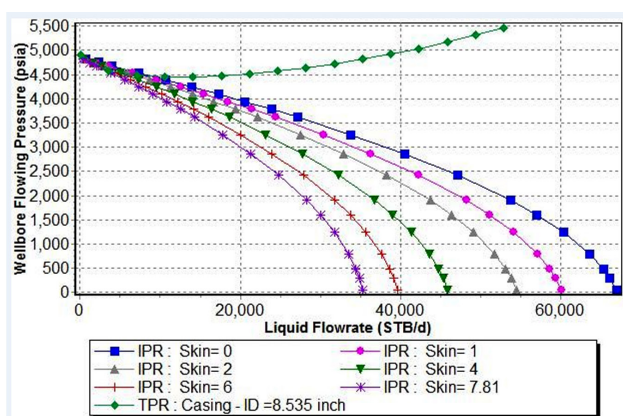


Figure 17. Effect of skin factor on the IPR curves for well A(Casing 8.535")

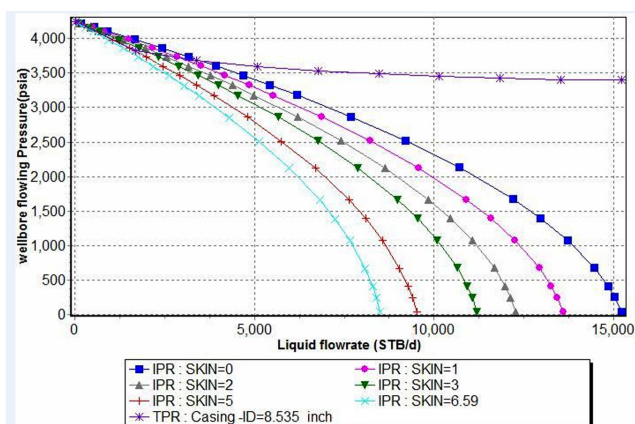


Figure 18. Effect of skin factor on the IPR curves for well B

CONCLUSIONS

1. Well analysis is an excellent method for showing how the overall well performance optimization and objective flow rate on the oil wells can be done.

2. According to current results, the flow correlation matching for wells A and B, in contrast to measured data, the predicted value for pressure drop (in the wells columns) with the Mukherjee and Brill (MB) correlation is more accurate than other correlation.
3. Achong and the API14B correlations can simulate the choke performance on critical and sub critical conditions of these wells.
4. According to result of tubing size analysis, production rate of these wells via casing 8.535" is at unstable state.
5. The proper tubing and choke bean sizes for well A are found to be 4.276" and 40/64" respectively. By using these tubing and choke bean sizes, the flow rate increases from 3000 STB/d to 4800 STB/d and is at stable state.
6. If the reservoir pressure decreased to 4771 psia, but all other parameters such as GOR, wellhead pressure are held constant, well A cannot produce with the casing 8.535" on natural depletion. But if it is completed with the tubing size 4.274", it can produce until the reservoir pressure decreased to below 4691 psia.
7. The proper tubing and choke bean sizes for well A are 2.99" and 32/64" respectively. By using of these tubing and choke bean sizes, the flow rate increases from 1000 STB/d to 1900 STB/d and production is at stable state.
8. If reservoir pressure decreases to 4164 psia, but all other parameters such as GOR, wellhead pressure and etc. are held constant, the well B with the casing 8.535", cannot produce on natural depletion. But, if it is completed with the tubing size 2.99" it can produce until the reservoir pressure decreased to below 3964 psia.

9. Based on the results of the positive skin effect, the inflow performance cannot be an optimistic one. If the skin damage decreases, inflow performance curves will be improved considerably and the flow rates do indeed increase. Thus, these wells need a cleanup program and stimulation to remove the damage.

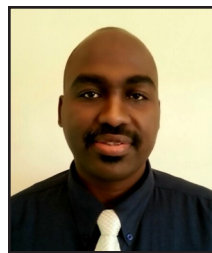
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REFERENCES

- [1] Bilgesu, H.L. and Ternyik, J.: "A new multi-phase flow model for horizontal, inclined, and vertical pipes" SPE number 29166, presented at eastern regional conference and exhibition held in Charleston, WV, U.S.A, 1994.
- [2] Dias-Couto, L.E. and Golan, M.: "General inflow performance relationship for solution-gas reservoir wells" J.Pet.Tech, 285-288, Nov. 1981.
- [3] England, B.: "Introduction to well testing", Schlumberger training book, March 1998.
- [4] Frear, R.M. Jr., Yu, J.P. and Blair, J.R.: "Application of nodal analysis in Appalachian gas wells" SPE number 17061, presented at the SPE eastern regional meeting held in Pittsburgh, Pennsylvania, 1987.
- [5] Gallice, F. and Wiggins, M. L.: "A comparison of two-phase inflow performance relationships" SPE number 88445, presented at the SPE Mid-Continent operations symposium, Oklahoma City, Oklahoma, 1999.
- [6] Golan, M. and Whitson, C.H.: "Well performance", IHRDC publisher, 1986.
- [7] Guo, B.: "Use of wellhead-pressure data to establish well-inflow performance relationship" SPE number 72372, presented at the SPE eastern regional meeting held in Canton, Ohio, 2001.
- [8] Holmes, J.A.: "Modeling advanced wells in reservoir simulation" SPE number 72493, Distinguished Author Series, 2001.
- [9] Klins, M.A. and Clark, J.W.: "An improved method to predict future IPR curves" SPE number 20724, presented at the SPE annual technical conference and exhibition held in New Orleans, 1993.
- [10] Klins, M. A. and Majcher, M. W.: "Inflow performance relationships for damaged or improved wells producing under solution-gas drive" J.Pet.Tech, 1357-1363, Dec.1992.
- [11] Khodamoradi ,D.: " Investigation of diffusivity coefficient of Ahwaz Bangestan reservoir by well test analysis and acidizing jobs" M.Sc Degree Project, June 2006.
- [12] Mukherjee, H. and Brill, J. P.: "Liquid holdup correlations for inclined two-phase flow" J.Pet.Tech, 1003-1008, May 1983.
- [13] Orkiszewski, J.: "Predicting two-phase pressure drops in vertical pipe" SPE number 1546 presented at 41st annual fall, meeting held in Dallas, Texas, 1967.
- [14] Sukarno, P. and Tubing, E. L.: "Inflow performance relationship for perforated wells producing from solution gas drive reservoir" SPE number 29312, presented at the Asia pacific oil and gas conference and exhibition, kuala lampor, 1995.
- [15] Tarek, Ahmad, "Reservoir engineering handbook", 2rd, Golf professional publishing, 2001.

AUTHORS' INFORMATION



Mohammed Abdalla Ayoub is a lecturer at the Petroleum Engineering Department, Universiti Teknologi PETRONAS, Malaysia. Previously, he was an assistant professor at the Petroleum Engineering Department at University of Khartoum, Sudan.

Dr Ayoub holds an MSc in Petroleum Engineering from KFUPM, and a PhD from UTP, Malaysia. His main interests include hybrid EOR techniques, application of Artificial Intelligence tools into petroleum engineering related problems. He is a member of the Sudanese engineering council as well as SPE.



Abdollah Esmaeili received his Diploma in Mathematics & Physics in 1990. He obtained his B.Sc and MSc. in Petroleum Engineering from Petroleum University of Technology (PUT), Iran. He is currently pursuing his PhD in Petroleum Engineering

at Universiti Teknologi PETRONAS (UTP), Malaysia. He has been working as a reservoir engineer in the oil & gas industry for the past 20 years for companies like National Iranian Oil Company (N.I.O.C), National Iranian South Oil Company (N.I.S.O.C), Aghajari Oil & Gas Production Company (AJOGPC). He also taught petroleum reservoir engineering courses in universities of Iran. He has written several papers in petroleum engineering which were accepted for presentation in international conferences. He has attended several international conferences worldwide as a speaker. He has led several international scientific master classes and workshops worldwide.