Predicting oil well performance by nodal analysis using well test data

AL-AYEN UNIVERSITY ,COLLEGE
OF PETROLEUM ENGEENIRING
Thi-Qar , Iraq

Supervisor Dr
Ayed Chwaied

Ali Aziz Hamdan, Durgham Adil,
Hassn Feisal, Ansam Neama,
Jouhar Jafer, Ali Sajet,
Ali Kareem Baher

Email: olmezorhan22@gmail.com

Abstract— **the study aims to know the performance of the production of wells in the future and to know the parameters that affect the rate of production, improve the rate of production and maintain the stability of wells In order to meet the economic aspect of future field development. Work was done on five wells from the Nasiriya field (NS-6, NS-7, NS-8, NS-9, NS-10).The results were reaching each of the operating point for each well, finding water values for each well, finding production values when changing well head pressure, can be open chock to (64/64) even if the reservoir pressure drops to 3000 but taking into consideration pressures of well head. Conclusion, it was concluded that when the reservoir pressure reaches about 2700 psi the wells don't flow. Recommendation to maintain optimal production values and not to produce less than bubble pressure.**

Keywords**; PIPESIM; Nodal analysis; Prediction; Optimization; Well Performance.**

I. Introduction

Nodal analysis is a technique in which helps optimizing oil and gas PRODUCTION. It is used to calculate the pressure drop at different nodes by changing various parameters within the production system, so the pressure difference is calculated from the bottom hole to the separation uNITS ON THE TOP OF THE SURFACE [1] in 1954, Gilbert presented the same concept of inflow performance relationship (IPR) for the purpose of enhancing oil field production rate and flowing bottom hole pressures. The concept focused on the depletion pressure and flow rates only, which are simplistic and not consider many other factors such as skin factor, reservoir condition [2]. Nodal analysis can be more helpful by using computer software. Conclusions about optimum point of petroleum production can be drawn from the intersections of the IPR (Inflow performance

Hydrocarbons have great rule in the petroleum production. The objective of optimization is maximizing hydrocarbon economic and environmental criteria great rule in the petroleum production. The objective of optimization is maximizing hydrocarbon production and minimizing operation costs under economic circumstances outflow of petroleum production optimization is based on some parameters such as tubing, flow line, and separator pressure. Petroleum production optimization should meet the requirements in technical, economic and environmental criteria Nodal analysis is the method used to evaluate the performance of combined production systems. There are two curves that represent the capacities of the inflow and of the outflow, and the intersection of the two curves gives the optimum value of

relationship) and OPR (Outflow performance relationship) curves also known as VLP (VERTICAL lift perFORMANCE RELATIONSHIP) CURVES. [3] SHOWS the symbolic relationship between Inflow and outflow curves. The study of inflow and

PIPESIM Overview

PIPESIM is a computational fluid dynamics software (CFD) product that allows you to accurately replicate how different fluids (defined here as both liquids and gases) behave. It delivers flow assurance to organizations that deal with oil, water, and other fluids by simulating how they will perform during transport and storage. [4].

Well test is the process of obtaining information about a reservoir through examining and analyzing the pressuretransient response caused by a change in production rate [5]. Well test objectives Well test analysis provides information on produced fluids, initial pressure and well and reservoir properties Longer duration testing (production testing) usually carried out. Development well: On producing wells, periodic tests are made to adjust the On producing wells, periodic tests are made to adjust the reservoir description and to evaluate the need for well treatment, such as work-over [6] Because a lot of money is spent on improving production in the fields, so the use of node analysis and the use of the PIPESIM allows identifying problems and solutions before they occur in terms of choosing pipe diameters, choosing wellhead pressures,

and defining throttle openings, so an ideal and stable production is maintained. The objectives of production optimization can be to improve the efficiency of the reservoir inlet or to reduce the output flow efficiency. The results can be more production with reduction in pressure drop/drawdown. As a rule, the production of sand and high water influx indicate the need to revitalize the environment of the downhole gas well. The reservoir and on the well. Usually, the test objectives can be summarized as follows: Exploration well: On initial wells, well On producing wells, periodic tests are made to adjust the reservoir description and to evaluate the need for well treatment, such as work-over [6]

Because a lot of money is spent on improving production in the fields, so the use of node analysis and the use of the PIPESIM allows identifying problems and solutions before they occur in terms of choosing pipe diameters, choosing wellhead pressures, and defining throttle openings, so an ideal and stable production is maintained. The objectives of production optimization can be to improve the efficiency of the reservoir inlet or to reduce the output flow efficiency. The results can be more production with reduction in pressure drop/drawdown. As a rule, the production of sand and high water influx indicate the need to revitalize the environment of the downhole gas well.

IPR : describes how much the reservoir can flow liquid into the wellbore when well bottom hole pressure (BHP or Pwf) is being reduced.

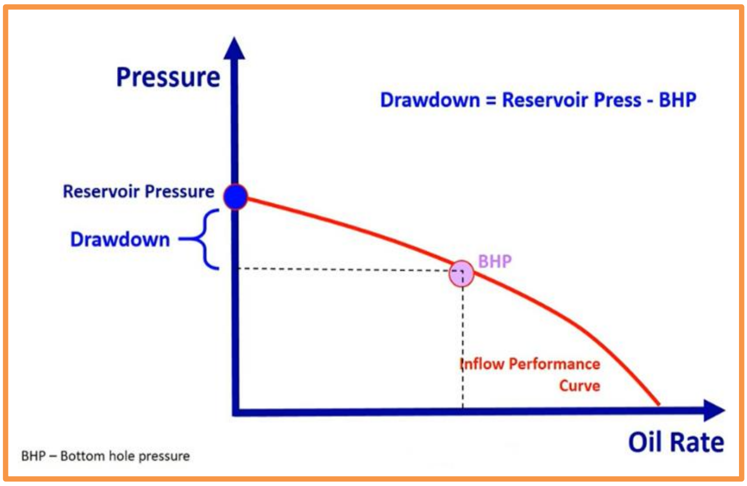

Fig .2 intersection between IPR and VLP

VLP: describes what the BHP should be for each flowrate inside the Tubing.

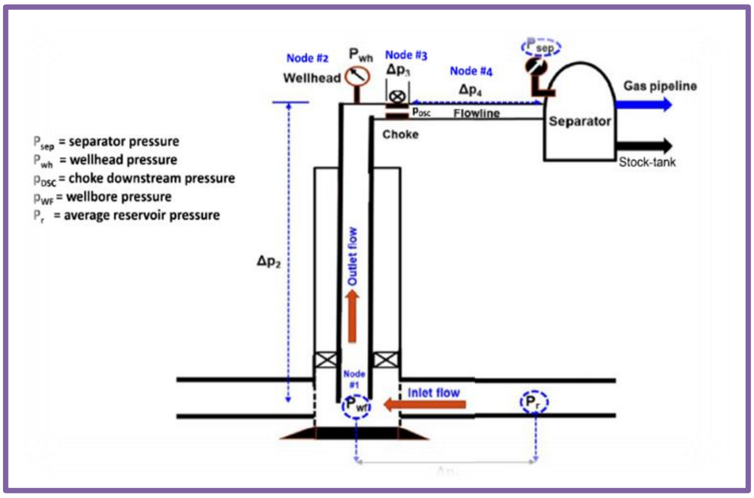

Fig .1 Location of various nodes in the Production System.

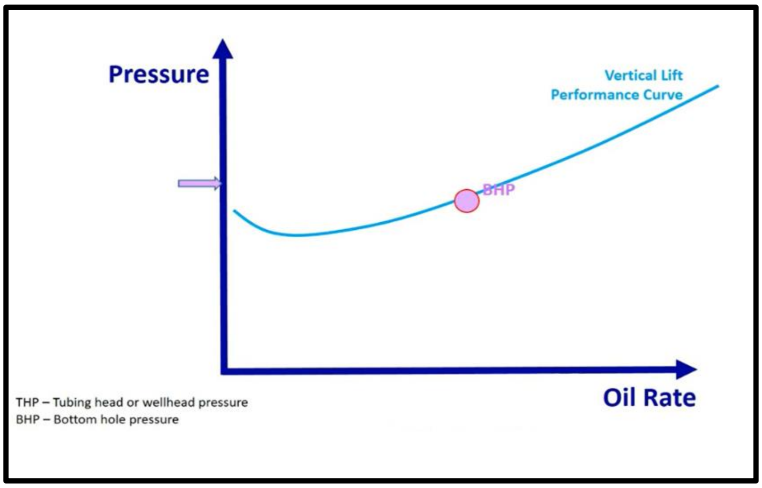

Fig .3 Show vertical lift performance

II. Methodology

After collecting the field data for the Nasiriya field, PIPESIM a software was worked on where a design model was built by entering the information of the tubing diameter and depths, casing diameter and depths, downhole survey, completion of wells, surface equipment PVT and reservoir characteristics, for the five wells, method it is black oil method ,also has been calculated J index By using pi entry had been calculate IPR for all wells and validate data , and trying to select the best method to calculate the VLP correlation ,also matching data. The evaluation of the six producing wells was carried out in

Calculating the internal flow pressure of the wells based on the production rates and measurements of the flow pressure at the well head and the internal closing pressures.

Relying on the selected methods for the vertical flow of producing wells from the part of the study of the productive assessment of wells from the available reservoir study, recent measurements of the internal flow pressures of the producing wells for the purpose of representing them in the above software and conducting the matching process to choose the best methods for vertical flow and calculating the internal flow pressure so that it is close to field measurements.

Relying on the study of evaluating the physical properties of Mishref reservoir / Nasiriya field, the main physical properties of Mishref reservoir oil in the flow model.

Field data

Table 1.Reservoir Properties

Pb (psi)	GOR (scf/stb)	Oil Gravity	Gas gravity
2238	548.36	24.5	0.8361

Table 2. Details of wells

Well no.	WHP (psi)	Reservoir pressure (psi)	PWF (psi)	Q bbl./d
NS-6	680	3580	2667	4121
NS-7	660	3544	2967	2384
NS-8	630	3416	2771	3197
NS-9	673	3437	2906	3545
NS-10	670	3497	2893	4124

Table 3. Completion details for five wells.

Well no.	Casing Depth (m)	Casing diameter	Tubing (m)	Diameter (inch)
NS-6	443	13.375	1915	4.5
	1563	9.625		
	2113	7		
NS-7	443	13.375	1910	3.5
	1563	9.625		
	2111	7		
NS-8	443	13.375	1910	3.5
	1563	9.625		
	2111	7		
NS-9	441	13.375	1906	3.5
	1563	9.625		
	2100	7		
NS-10	441	13.375	1890	3.5
	1564	9.625		
	2099	7		

III. Results and Discussion

The well data was utilized to analyze solution methods in determining optimal production rates. Decline curve analysis was applied to identify the fluid production optimization in vertical wells. Applying well PI equation, the results that will discuss it in this part.

Results analysis of NS-7

At first nodal it to get on operating point for NS-7 by calculate J index, and using Dun & rose modified correlation.

	Operating point	ST Liq. at NA	P at NA
		STB/d	psia
1	Flowrate=2278.867 sbbl/day	2278.867	2404.567

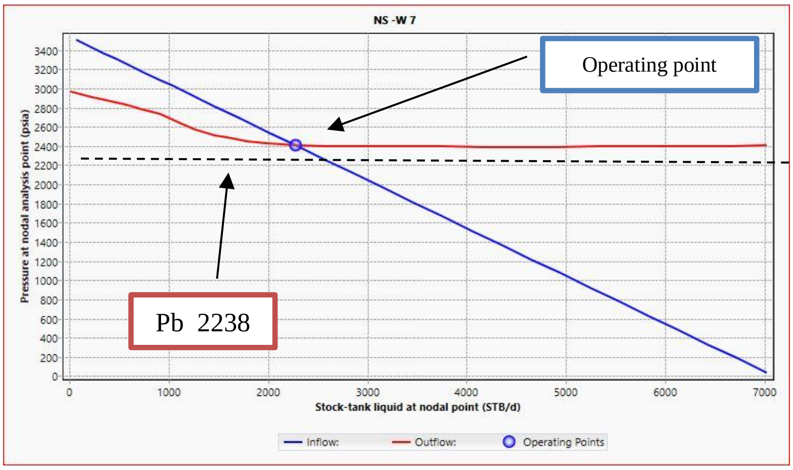

Fig .4 Show operating point of NS-7 this Curve show intersection between IPR and VLP.

After assuming value of WHP to make sensitivity of well head pressure on flow rate, from (300 – 1000) psi, the result it's shown in blow figure so the best value to select it , is 600 (psi) ,because the flow rate is stable and pressure of production above bubble point pressure.

From the **Fig .5** can be noted the following:

The production rate increases when the flow pressure at the well head is reduced from the actual, which is equal to 640 psi.

But if the flow pressure at the well head is higher than the actual flow rate, the production rate will decrease with the increase in the internal flow pressure.

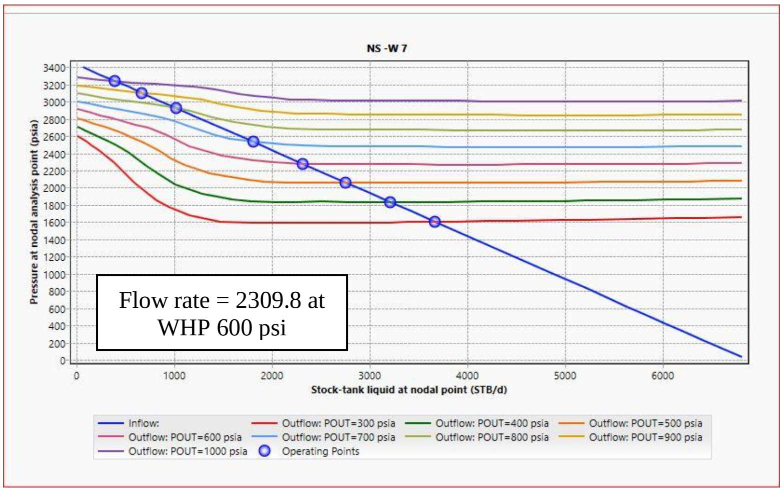

Fig .5 sensitivity of well head pressure of NS-7.

	Operating point	ST Liq. at NA	P at NA	EVR max.
		STB/d	psia	
1	POUT=300 psi...	3662.427	1604.787	0.2380456
2	POUT=400 psi...	3206.917	1832.541	0.1813923
3	POUT=500 psi...	2746.374	2062.813	0.1397291
4	POUT=600 psi...	2309.892	2281.054	0.1079415
5	POUT=700 psi...	1806.691	2532.654	0.07873336
6	POUT=800 psi...	1015.706	2928.147	0.04165473
7	POUT=900 psi...	667.0668	3102.467	0.02605402
8	POUT=1000 ps...	394.2559	3238.872	0.01479025

It can be noted that not always the large the diameter

Of the production pipe, the production increase,

Because it needs a lifting force from the bottom of the

Well to the top whenever tubing diameter increase.

So the tubing 3.5 (inch) is more suitable because it

Give more production and more stability.

	Operating point	ST Liq. at NA	P at NA
		STB/d	psia
1	IDIAMETER=3 ins Flowrate=2...	2286.171	2292.914
2	IDIAMETER=3.5 ins Flowrate=...	2298.299	2286.85
3	IDIAMETER=4 ins Flowrate=2...	2248.9	2311.55
4	IDIAMETER=4.5 ins Flowrate=...	2146.593	2362.704
5	IDIAMETER=5 ins Flowrate=1...	1980.96	2445.52
6	IDIAMETER=5.5 ins Flowrate=...	1677.683	2597.158

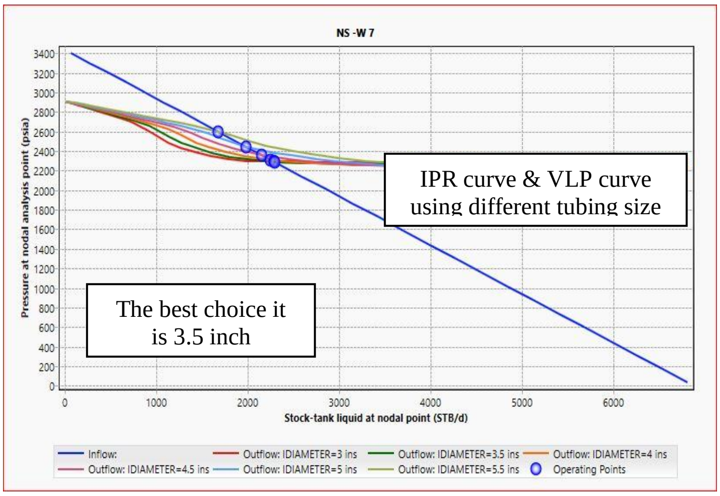

Fig .6 sensitivity of tubing size for NS-7 after assuming values of chock size between (22 , 32, 38,44,64) to make chock sensitivity ,the result it is shown in **Fig.7**

It can be open chock to (64/64) at reservoir pressure with well head pressure it isn't less than 470 psi .

	Operating point	ST Liq. at NA	P at NA
		STB/d	psia
1	DBEAN=0.343...	1014.482	3097.839
2	DBEAN=0.5 in...	1897.659	2803.447
3	DBEAN=0.6 in...	2375.604	2644.132
4	DBEAN=0.7 in...	2762.341	2515.22
5	DBEAN=1 ins...	3539.362	2256.213

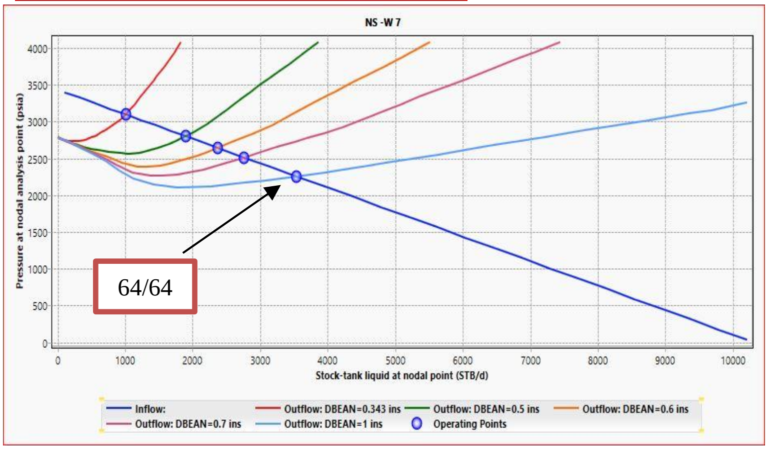

Fig.7 show sensitivity of chock size at reservoir pressure 3544 psi.

It can be open chock to (64/64) if reservoir pressure drop to 3000 psi with well head pressure it isn't less than 530 psi.

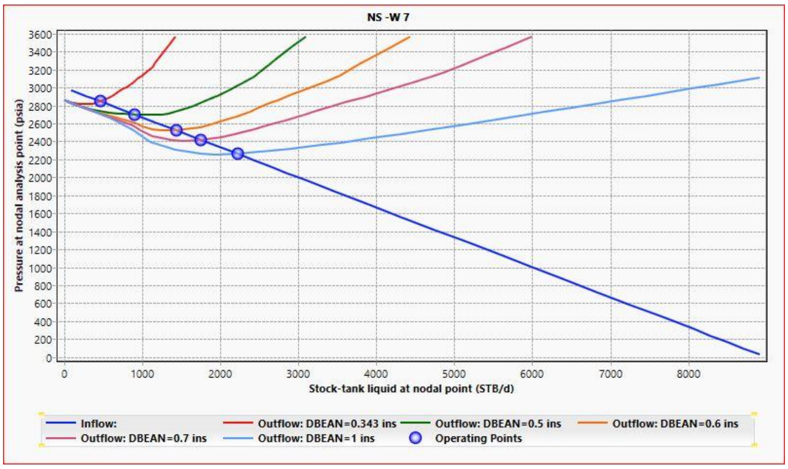

Fig.8 show sensitivity of chock size at reservoir pressure 3000 psi

by assuming values of reservoir pressure between (1500,1800,2100,2400,2700,3000,3300,3500) psi.

It is expected that with the continuation of Production operations, the reservoir pressure will Continuously decrease, so the sensitivity of model and Its impact on production after the pressure drop has been worked out

	Operating point	ST Liq. at NA	P at NA
		STB/d	psia
1	UNCONVERGED PWSTATIC=1500 psia Flowrate=...		
2	UNCONVERGED PWSTATIC=1800 psia Flowrate=...		
3	UNCONVERGED PWSTATIC=2100 psia Flowrate=...		
4	UNCONVERGED PWSTATIC=2400 psia Flowrate=...		
5	UNCONVERGED PWSTATIC=2700 psia Flowrate=...		
6	PWSTATIC=3000 psia Flowrate=428.0708 sbbl/day	428.0708	2785.965
7	PWSTATIC=3300 psia Flowrate=2005.221 sbbl/day	2005.221	2297.39
8	PWSTATIC=3500 psia Flowrate=2442.455 sbbl/day	2442.455	2278.772

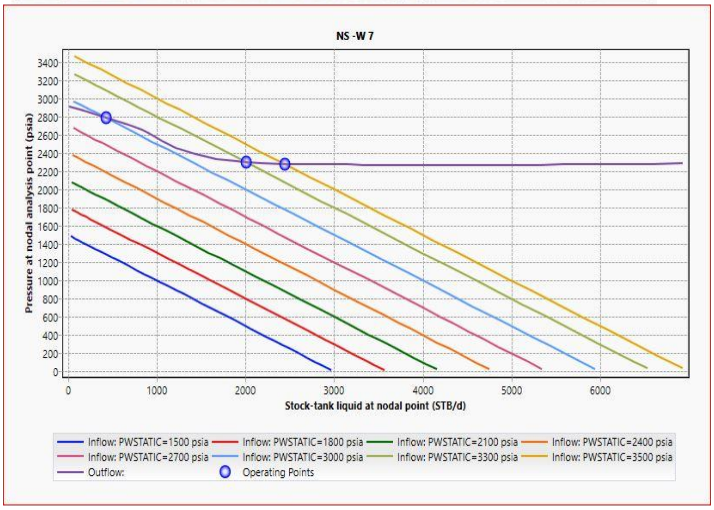

Fig.9 show after reservoir pressure drop (inflow Sensitivity)

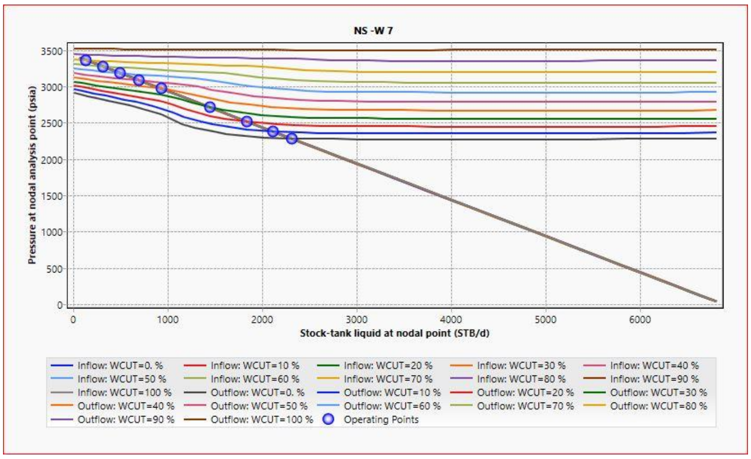

Fig.10 water cut effect on production for NS-7

Results analysis of NS-8

At first nodal to get operating point for NS-8 by calculate J index , AOF , and using Beggs & Brill correlation

	Operating point	ST Liq. at NA	P at NA
		STB/d	psia
1	Flowrate=3076...	3076.088	2293.871

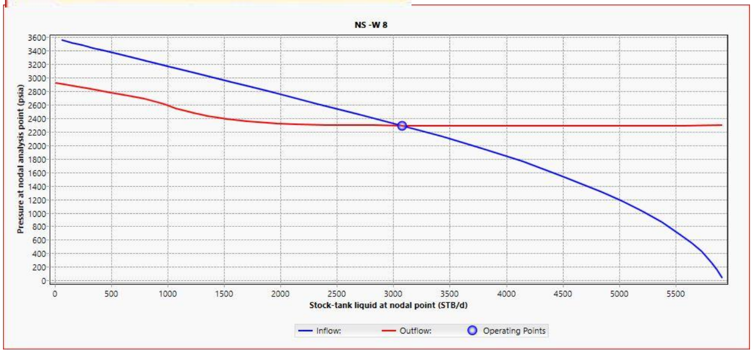

Fig .11 Show operating point for NS-8 and intersection between IPR and VLP.

As it is clear the effect of GOR on production, and as the GOR increases, the production increases

So it appears GOR at 700 (scf/sbbl) its more production but the pressure under bubble point

	Operating point	ST Liq. at NA	P at NA
		STB/d	psia
1	GOR=200 scf/sbbl Flo...	1140.056	3013.757
2	GOR=300 scf/sbbl Flo...	1424.495	2908.409
3	GOR=400 scf/sbbl Flo...	2181.988	2627.856
4	GOR=500 scf/sbbl Flo...	2810.478	2395.082
5	GOR=600 scf/sbbl Flo...	3330.526	2202.472
6	GOR=700 scf/sbbl Flo...	3717.358	2059.201

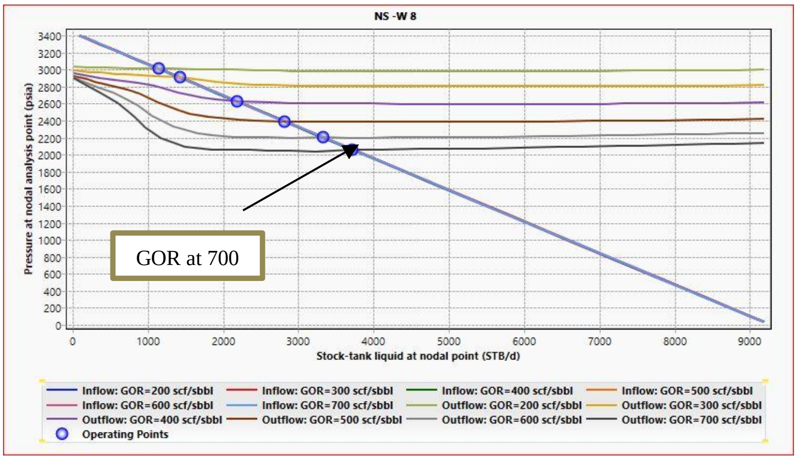

Fig .12 Show sensitivity of GOR for NS-8

	Operating point	ST Liq. at NA	P at NA
		STB/d	psia
1	POUT=450 psi...	3795.015	1946.059
2	POUT=500 psi...	3583.727	2053.587
3	POUT=550 psi...	3358.694	2162.981
4	POUT=600 psi...	3122.605	2272.782
5	POUT=650 psi...	2887.408	2377.719
6	POUT=700 psi...	2640.521	2483.64
7	POUT=750 psi...	2391.829	2587.405
8	POUT=800 psi...	2140.869	2691.971
9	POUT=850 psi...	1851.832	2812.403
10	POUT=900 psi...	1465.295	2973.46

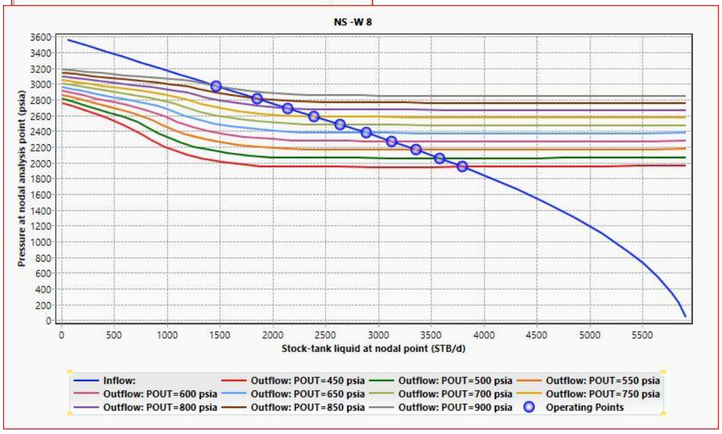

Fig .13 sensitivity of well head pressure for NS-8.

It is expected that with the continuation of production operations, the reservoir pressure will continuously

Decrease, so by assuming values of reservoir pressure

Between (1500, 2000, 2500, 22700, 3000, 3468) psi.

	Operating point	ST Liq. at NA	P at NA
		STB/d	psia
1	UNCONVERGE...		
2	UNCONVERGE...		
3	PWSTATIC=31...	2131.727	2310.471
4	PWSTATIC=34...	2979.262	2296.57

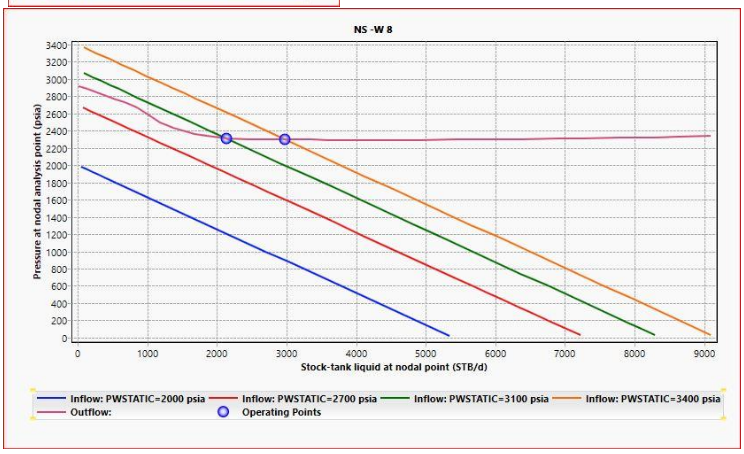

Fig.14 show reservoir pressure drop (Pressure sensitivity)

As is clear show in fig.15, when reservoir pressure To 3000 psi, it is possible to open chock size to (64/64) With well head pressure it isn't less than 500 psi.

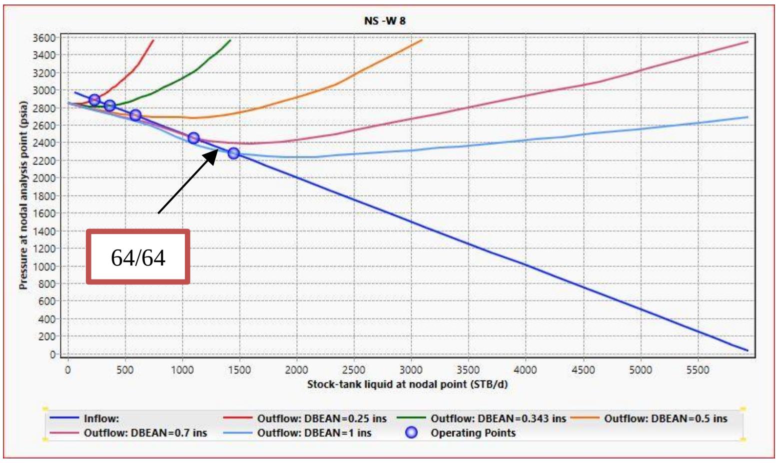

Fig.15 show sensitivity of chock size when reservoir pressure decline to 3000 psi.

by assuming value of water cut from (45 % - 85 %) whenever water cut increase production rate decrease, so when value of water cut become more than 85 % the well will be more difficult to product because it need more force to lift fluid from bottom to up , when it reach to 75% ,the production rate almost reach to 500 STB/d.

	Operating point	ST Liq. at NA	P at NA
		STB/d	psia
1	WCUT=45 % Flowrate=2795.718 sbbl/day	2795.718	2737.07
2	WCUT=55 % Flowrate=2107.185 sbbl/day	2107.185	2909.204
3	WCUT=65 % Flowrate=1024.354 sbbl/day	1024.354	3179.911
4	WCUT=75 % Flowrate=542.7224 sbbl/day	542.7224	3300.319
5	WCUT=85 % Flowrate=121.2783 sbbl/day	121.2783	3405.68
6	UNCONVERGED WCUT=90 % Flowrate=...		

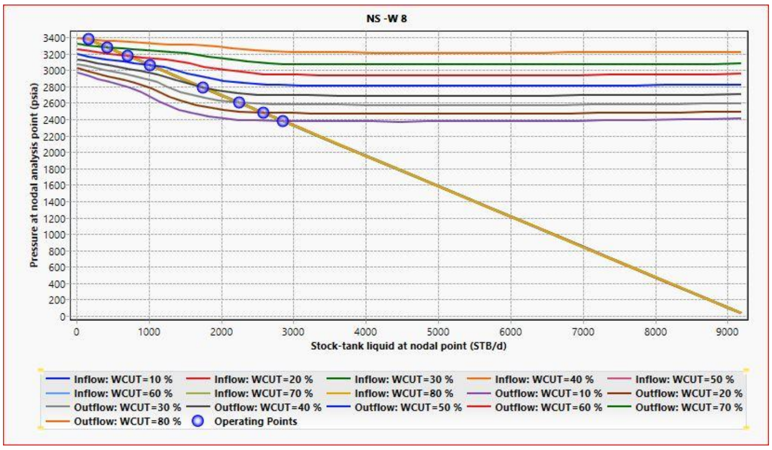

Fig.16 water cut sensitivity for NS-8.

Results analysis of NS-8

To calculate operating point at first node and using Dun &rose Original method

	Operating point	ST Liq. at NA	P at NA
		STB/d	psia
1	Flowrate=3999...	3999.961	2317

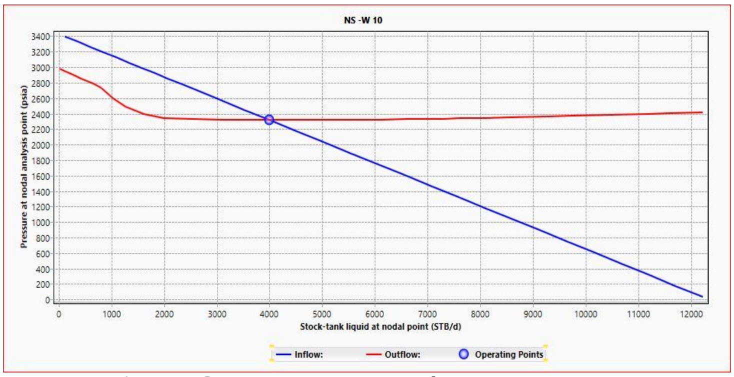

Fig .17 Show operating point for NS-10

by assuming value of WHP to make sensitivity of well head pressure on flow rate, from (480 – 880) psi, the result it's shown in Fig.18 the best value to select it , is 680 (psi) ,because the flow rate is stable and pressure of production above bubble point pressure.

	Operating point	ST Liq. at NA	P at NA
		STB/d	psia
1	POUT=480 psi...	5490.675	1902.913
2	POUT=580 psi...	4757.001	2106.711
3	POUT=680 psi...	4005.648	2315.42
4	POUT=780 psi...	3239.208	2528.32
5	POUT=880 psi...	2494.184	2735.271

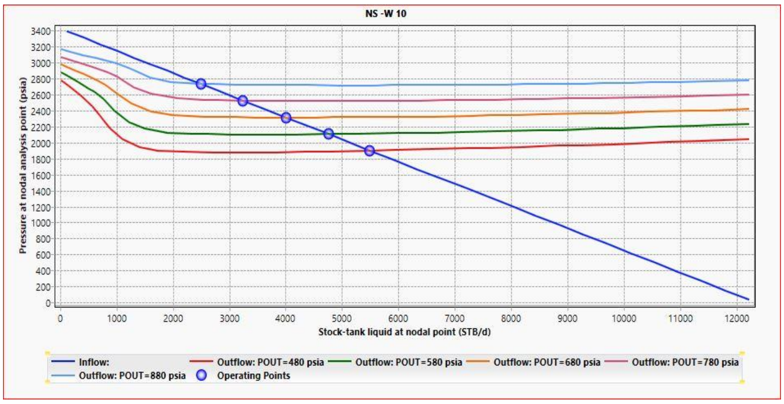

Fig .18 sensitivity of well head pressure for NS-10.

	Operating point	ST Liq. at NA	P at NA
		STB/d	psia
1	WCUT=25 % Flowrate=3122.46 sbbl/day	3122.46	2560.75
2	WCUT=35 % Flowrate=2694.202 sbbl/day	2694.202	2679.71
3	WCUT=45 % Flowrate=2141.77 sbbl/day	2141.77	2833.164
4	WCUT=55 % Flowrate=902.0103 sbbl/day	902.0103	3177.542
5	WCUT=65 % Flowrate=439.6761 sbbl/day	439.6761	3305.968
6	WCUT=75 % Flowrate=35.3219 sbbl/day	35.3219	3418.288
7	UNCONVERGED WCUT=85 % Flowrate...		

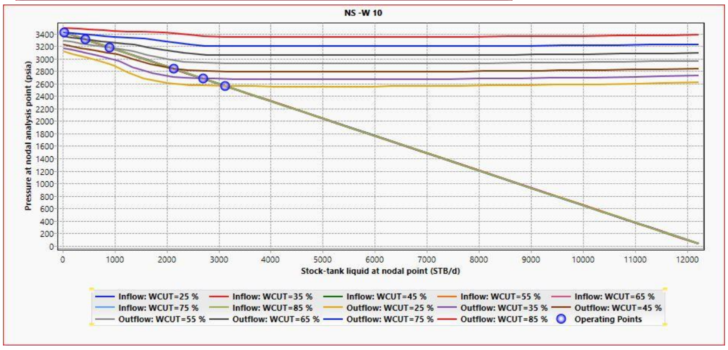

Fig.19 water cut sensitivity for NS-10

When reservoir pressure decline to 2500 psi so production doesn't flow

	Operating point	ST Liq. at NA	P at NA
		STB/d	psia
1	PWSTATIC=3428 psia Flowrate=3999.599 sbbl/day	3999.599	2317
2	PWSTATIC=3000 psia Flowrate=2413.816 sbbl/day	2413.816	2329.496
3	UNCONVERGED PWSTATIC=2500 psia Flowrate...		
4	UNCONVERGED PWSTATIC=2000 psia Flowrate...		
5	UNCONVERGED PWSTATIC=1000 psia Flowrate...		

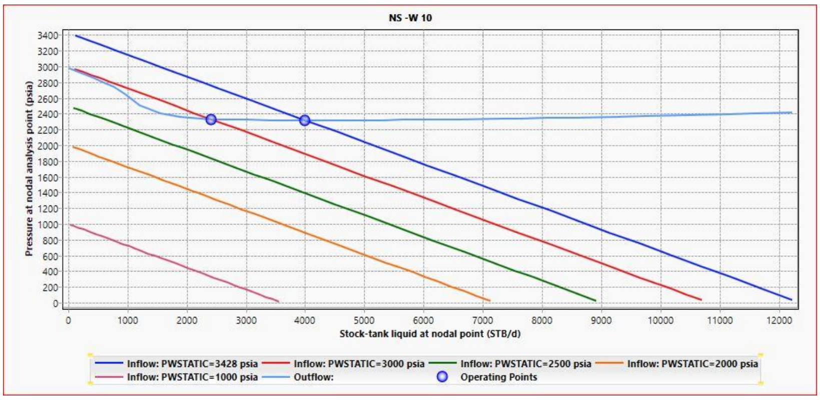

Fig.20 show reservoir pressure drop (Pressure sensitivity).

It can be open chock to (64/64) if reservoir pressure drop to 3000 psi with well head pressure it isn't less than 260 psi.

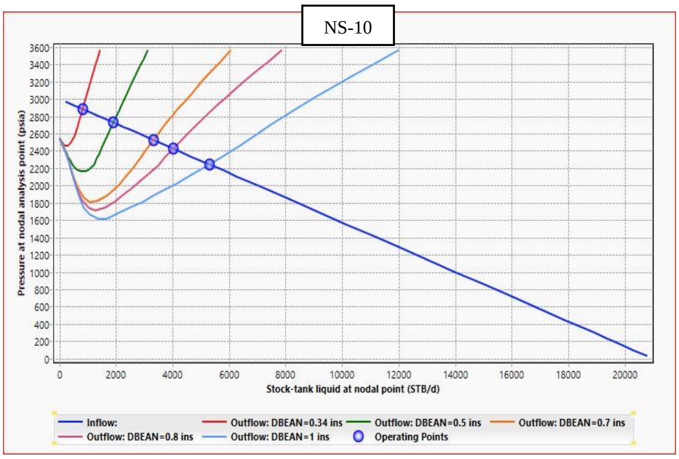

Fig.21 show sensitivity of chock size when reservoir pressure decline to 3000 psi for NS-10

IV Conclusions

- In NS-7 when the water cut reaches 85%, the production rate is about 65 STB/d.
- In NS-7, when reservoir pressure decline to 2700 psi so production doesn't flow.
- In NS-8 when the water cut reaches 75%, the production rate is about 500 STB/d ,
- In NS-10 when reservoir pressure decrease to 2500 psi, production doesn't flow.
- In NS-9 when reservoir pressure decrease to 2750 psi.
- In NS-6, the well stops producing when reservoir pressure reach to 2600 psi.
- All five well when reach reservoir pressure to 3000 psi it can be open chock size to (64/64) without problems provided that well head pressure must be not less than (WHP of NS-7 = 530 psi , WHP of NS-8 =500 psi , WHP of NS-10 = 250 psi , WHP of NS-9 = 490 psi , WHP of NS-6 = 520 psi).

V. Recommendations

The recommendations that should be carried on for future studies:

- The field data taken in the future should be new and more accurate.
- The production rate must be maintained above Bubble point pressure.
- This research worked on just five wells of Nasiriya field so it’s important to work on all wells of field.
- Using Prosper software with PIPESIM to compare between results and errors values of actual data and calculated.

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