Resolving Early-time Well Performance Rate Issues Using Mer Test

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ABSTRACT

Maximum Efficient Rate (MER) is the maximum rate at which oil and gas can be produced without damaging the reservoir's natural energy. Wells in the past quit production early due to high production offtake rate. Above the MER, natural pressure of the reservoir gets declined which results to early water breakthrough and decrease of amount of oil which is ultimately recoverable. However to truly ascertain the MER, the bottom hole flow rate is required as most flow models are structured on it. Moreover. Logic would suggest that the rate at the bottom hole will be higher than that at the surface for this to work, a "Top-down" approach is taken to estimate the critical rates needed to curb the early water breakthrough based on an analysis of the exhibited signature by the most likely causes. A case study of the is presented based on field "X" IN THE NIGER DELTA.

INTRODUCTION

Early Production of associated water from the oil wells is a common but an undesirable occurrence. If the drawdown exerted on the reservoir exceeds a limiting value, the water cone can become unstable and water can start replacing the oil in the production stream as shown in Fig1. Remediation of well water problem is usually difficult and costly, the basic approach should be preventive. To achieve this goal, the entire process of production needs to involve extensive pre-planning, MER / Production test, and a biannual follow-up. Failure to control the operating rate will be a misstep. A high oil production rate may cause water to be produced mixed with oil (Ould-amer et al., 2003).

This phenomenon is known as water coning. A water cone through a producing well is caused by the pressure drawdown exerted on the reservoir. If the production of water with the produce oil becomes a severe problem, production from the well is stopped In order to control the coning (Permadi, 1996). Other production Problems like sand production and reduction in productivity are often triggered by water coning into the producing zone. (T. W. Muecke 1978). In his work T. W. Muecke explained this as destabilization effects of water flow in media containing immobilized water-wet fines.

The Government of the Federal Republic of Nigeria Imposed a Statutory Requirement in Part IV of Decree 51 (1969) which deals with Oil and Gas Field development this includes: Maintenance of equipment and conduct of field operations, Field development program, Production of crude oil and natural gas, Pressure decline study and report.
Decree 51 (1969) provides for the following:

- Carry out field development plan (FDP) before field development.
- Carry out the six weeks production test before a DPR allowable is granted for a particular Well.
- Carry out effective oil and gas well surveillance to optimize productivity at minimum operating cost.

To cause every pool in each Well to produce within the limits of its maximum efficient potential or rate as may be determined from time to time by the licensee or lessee and to submit his determinations to the Chief Petroleum Engineer half yearly. Hence the need for the six weeks tests to determine maximum efficient rate and regular BHP surveys is statutory.
The Maximum efficiency rate test (MER), is done by letting the well flow at increased rate at different choke sizes until there is water or gas production.

This paper demonstrates how utilizing an efficient MER test in the oil and gas industry can regulate the flow rate so as to maintain well allowable, protect surface equipment, prevent water and gas coning, provide the necessary back pressure needed to avoid formation damage due to excessive drawdown.

The Field
The case study presented here is from a field X located onshore in the Niger Delta Depobelt as shown in Fig 2 the field has several reservoirs but only one reservoir is

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considered in this study. The reservoir has two wells. MER test was conducted on these wells in other to assign allowables to the wells. The field data available are shown in Table 1.

Coning Study

The flow rate (Q) is a measure of the rate at which a reservoir fluid is produced and is a function of the perforation density, reservoir pressure, tubing size, choke/bean size, diameter of flow-line, and separator pressure. This implies that changing any of these variables will alter the performance of the well. (Idongesit et al).

Water coning is a term used to describe the mechanism underlying the upward movement of water into the perforations of a producing well. Coning is a rate-sensitive phenomenon generally associated with high producing rates. It is strictly a near-wellbore phenomenon, it develops once the pressure forces drawing fluids toward the wellbore overcomes the natural buoyancy forces that segregate gas and water from oil.

Coning study predict a "critical rate" at which a stable cone can exist from the fluid contact to the nearest perforations. The theory is that, at rates below the critical rate, the cone will not reach the perforations and the well will produce the desired single phase.

A cone may develop but may not move towards the perforation. Whether a cone will move toward perforations or not depends on the relative significance of viscous and gravitational forces near a well see Fig 3. The pressure drawdown at the perforations which tends to cause the undesired fluid to move toward the perforations. Gravitational forces tend to cause the undesired fluid to stay away from the perforations. Coning occurs when viscous forces dominate.

The variables that could affect coning are:

- Density differences between water and oil, gas and oil, or gas and water (gravitational forces)
- Fluid viscosities and relative permeabilities
- Vertical and horizontal permeabilities
- Distances from contacts to perforations.

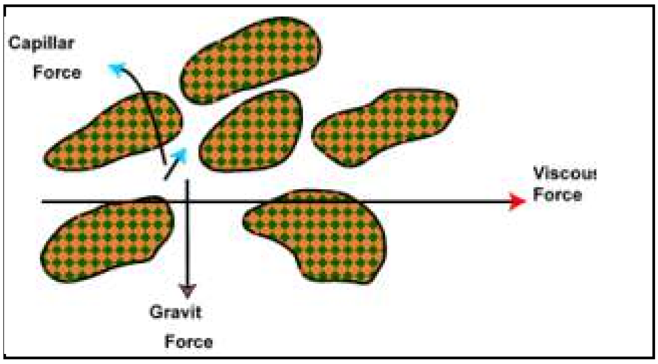

Figure 1: Variables that affect coning.

Coning Model

Coning study was carried out on the wells of interest to determine the critical flow rates using the reservoir data and properties of fluid four conning models were used namely: Meyer and Gardner, Chaperson, Schol, Ozkan and Raghavan. This calculations provided some insight on the potential for the wells to cone

Model 1: Meyer and Gardner (1954)

Meyer and Gardner (1954) derived a correlation for the critical oil rate required to achieve a stable water cone. They found that the critical rate for a well was determined by: the length of well penetration, density difference of oil and water and the oil zone thickness. Their correlation for critical oil rate is expressed as:

$$Qoc = 0.246x10^{-4}\left(\frac{\rho_w - \rho_o}{\ln\left(\frac{r_e}{r_w}\right)}\right)\left(\frac{K_o}{\mu_o B_o}\right)\left(h^2 - h_p^2\right)$$

Qoc: critical production rate in stb/day
hp: perforation height in ft
h: oil column thickness in ft
μ_o: oil viscosity in cp
B_o: oil formation volume factor $\frac{vol}{vol}$
ρ_i: density of fluid i, lb/ft3
r_e, r_w: drainage and wellbore radius in ft

Model 2: Chaperon (1986)

Chaperon developed an equation to estimate the critical oil rate given by

$$Qoc = 0.0783x10^{-4}\left(\frac{K_h\left(h^2 - h_p^2\right)}{\mu_o B_o}\right)(\Delta\rho)q_c^*$$

Where

Qoc: critical production rate in stb/day
hp: perforation height in ft
h: oil column thickness in ft
μ_o: oil viscosity in cp
B_o: oil formation volume factor $\frac{vol}{vol}$
ρ_i: density of fluid i, lb/ft3
r_e, r_w: drainage and wellbore radius in ft
K_h: Horizontal permeability in mD
K_v: Vertical permeability in mD
$\Delta\rho$: Difference in density

Model 3: Schols (1972)

Presented an empirical critical rate correlations for partially penetrated wells in isotropic and anisotropic reservoirs. These correlations were based on laboratory experiments, model and mathematical simulations.

$$Qoc = 0.0783x10^{-4}\left(\frac{(\rho_w - \rho_o)K_h(h^2 - h_p^2)}{\mu_o B_o}\right)\left(0.432 + \frac{3.142}{\ln\left(\frac{r_e}{r_w}\right)}\right)\left(\frac{h}{r_e}\right)^{0.14}$$

Qoc: critical production rate in stb/day
hp: perforation height in ft
h: oil column thickness in ft
μ_o: oil viscosity in cp
B_o: oil formation volume factor $\frac{vol}{vol}$
ρ_i: density of fluid i, lb/ft3
r_e, r_w: drainage and wellbore radius in ft
K_h: Horizontal permeability in mD
K_v: Vertical permeability in mD
$\Delta\rho$: Difference in density

Model 4: Ozkan and Raghavan (1990)
Ozkan and Raghavan proposed a correlation for estimating the coning rate of a well given by

$$Qoc = \frac{\Delta\rho K_v h^2}{325.7\mu_o B_o}\left(0.546 - 0.021\left(\frac{h_p}{h}\right) - 0.2807\left(\frac{h_p}{h}\right)^2\right)$$

Results of the coning study as seen in Table 2 and Table 3 shows that well 1 is expected to cone water at rates in excess of 1457 BOPD, from Chaperon's correlation while well 2 is expected to cone water at rates in excess 393 BOPD from Ozkan and Raghavan correlation. The coning rate from the models are lower as compared with the MER rates the permeability gradient and limited entry effects are considered, as the reason for lower rate calculated by the coning models. This study shows clearly that some of the empirical correlations can be considered more reliable than the others.

Well Model Results
The well model for well 1 and 2 was matched to the latest test data and the match can be seen in Figure 3 and 4. The model was constructed using Vogel IPR model and Petroleum Expert for VLP correlation. IPR/VLP was matched with PI of 2.97 stb/day/psi and 0.75stb/day/psi for well 1 and 2 respectively.

MER Determination
Choke sizes were obtained from choke performance graph using the step rate testing without shutting in the well. The different chokes sizes and their corresponding rate were recorded, as shown in Table 3. The choke performance model was built and their corresponding Liquid rates and Tubing Head Pressures were matched during a nodal analysis of both wells. The Maximum Efficiency Rate point is highlighted as shown in figures 8 and 9. The VLP performance curve generated for the optimal choke size was matched to an IPR curve for the reservoir model. The optimum rate was gotten by plotting the choke sizes and their corresponding tubing head pressure against the corresponding rate. The MER rate was obtained from the intersection of the choke and the THP plot against rate as shown in the figure 5 and 6.

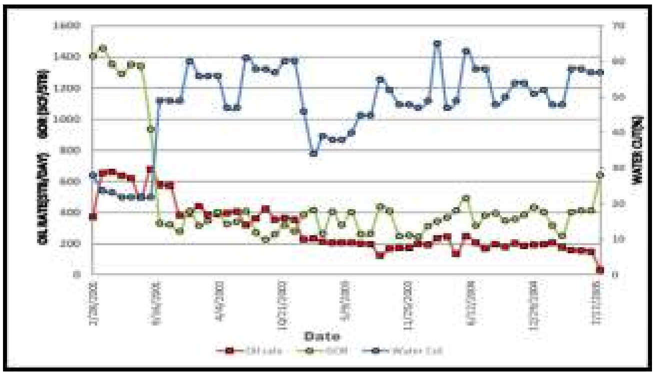

Figure 2: Effect of water breakthrough on oil production.

Figure 3: Field X location Map.

Table 1: Reservoir X parameters.

PARAMETER	VALUE
Thickness (ft)	92
NTG	0.91
Porosity	0.2
Average Permeability (md)	1000
Connate water saturation	0.2
Oil formation volume factor (Rb/stb)	2.66
Average reservoir pressure (Psia)	4033
Oil viscosity (cp)	0.205
Kv/Kh	0.08

Table 2: Well 1 properties.

CONING CALCULATION MODEL FOR WELL 1

INPUT	MODELS	MEYER AND GAR	Chaperon	Schol	Ozkan and Raghavan
RHO OIL	44.7	0.428392938	1457.2161	0.6332	135.982209
RHO WATER	62.4				
RE	1360				
RW	0.25				
Ko	0.66				
oil viscosity	0.205				
Bo	2.66				
h	84				
hp	8				
Kh	1357				
Kv	30				

Table 3: Well 2 properties

CONING CALCULATION MODELS FOR WELL 2					
INPUT	MODELS	MEYER AND GARDER	Chaperson	Schol	Ozkan and Raghavan
RHO OIL	44.7	0.423788481	1007.316221	0.63097265	383.4983506
RHO WATER	62.4				
RE	1000				
RW	0.25				
Ko	0.66				
oil viscosity	0.205				
Bo	2.27				
h	76				
hp	8				
Kh	1000				
Kv	82				

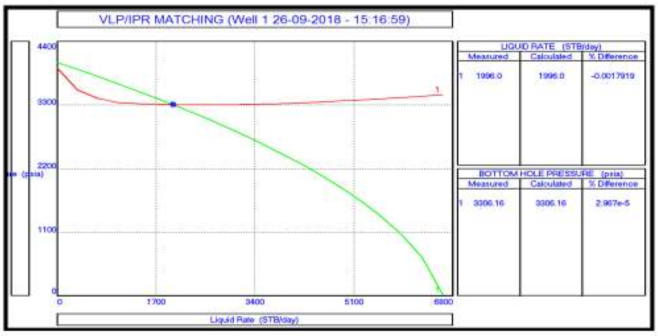

Figure 4: Well 1 IPR/VLP match.

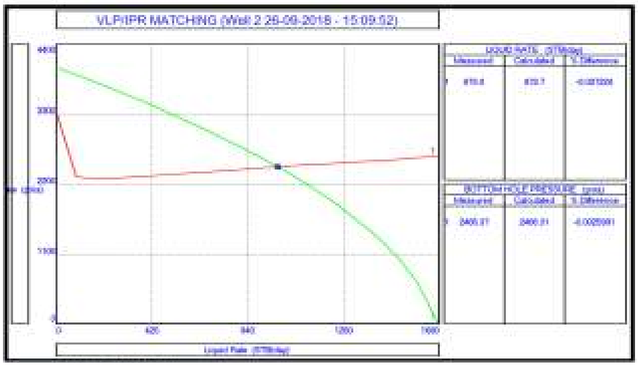

Figure 5: Well 2 IPR/VLP match.

Table 4: MER parameters for the wells.

WELL	RESERVOIR	CHOKE	OIL RATES	GAS RATES
Well 1	X	28	2168.00	3.652
Well 2	X	24	900.00	2.214

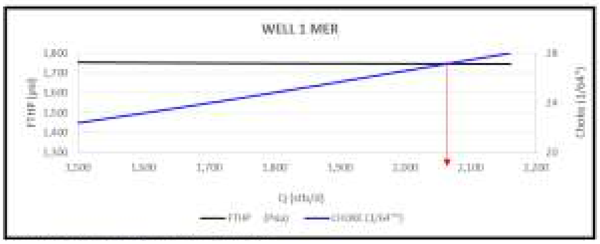

Figure 6: Well 1 MER rate determination.

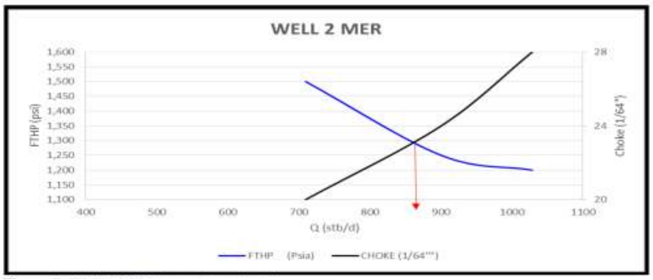

Figure 7: Well 2 MER rate determination.

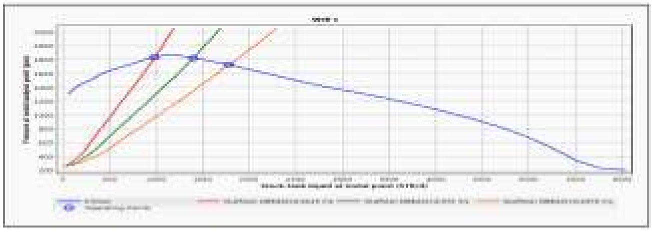

Figure 8: Choke performance model plot for Well 1.

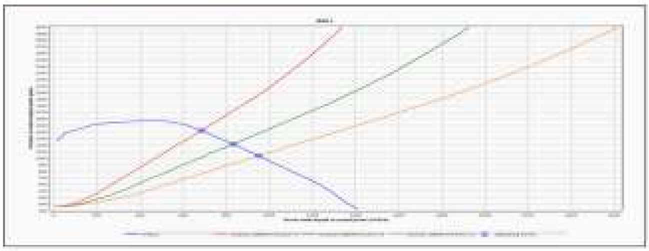

Figure 9: Choke performance model plot for Well 2.

CONCLUSION

The evaluation of resolving early-time well performance rate issues using MER was performed on two oil wells 1 and 2 as shown in this paper:

1. Models for calculating critical oil rate for an oil wells are stated
2. Calculated critical rate is lower than MER rate.
3. The permeability gradient and limited entry effects are considered, as the reason for lower rate calculated by the coning models
4. This study shows clearly that some of the empirical correlations can be considered more reliable than the others
5. Maximum Efficiency Rate (MER) were determined by a plot of obtained from the intersection of the choke and the Tubing Head Pressure (THP) plot against rate
6. Maximum Efficiency Rate (MER) obtained may cone water depending on the standoff of the perforated interval from the contact

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