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A New Gas Lift Design Pradigm: Moving from Static Based Modeling to Dynamic, Realtime Modeling to Achieve Operational Excellence in Field X

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Abstract

Offshore North West Java is a mature oil and gas field located in northern part of Java Island. Most of the wells are producing with gas lift system from the abundant source of gas in the field. Through forty years production life of this field, the conventional gas lift spacing design is found out to be not optimum. Many unloaders at the upper part of the completion aren't necessary during its production stage and usually will be changed into a dummy valve during gas lift valve redesign (GLVR) operation. These excessive number of valves may cause many problems, such as limited gas that can be delivered through the orifice, higher probability of valve and installation failure, and many more. These conditions will lead to un-optimum production rate.

A new innovative method of gas lift spacing design is proposed to solve the problem by optimizing the number of gas lift valves installed in the completion. In conventional gas lift spacing design, completion fluid level is often represented static at the surface using a static fluid model. In fact, completion fluid level tends to change over time due to fluid infiltration into the reservoir. By emphasizing this fluid infiltration into the reservoir, equalized method is created.This equalized method alters the spacing design starting depth from the surface into the depth which equalized condition between bottom hole and reservoir pressure is reached. By combining Darcy' law and hydrostatic pressure formula, a new equation is derived. It is able to forecast the time needed to reach the equalized depth and also the depth itself.

To verify the newly developed method, a case study of Well-X is presented. To enhance Well-X production, a gas lift system is required. Using a predetermined compressor pressure, the conventional gas lift spacing method yields a total of eight unloader valves. In contrast, the equalized method reduced the number of unloader valves required to a total of four. The example has proved that the equalized method is not only able to reduce the chance of failure in the installation, but it also results in a higher gas lift operating pressure, higher gas injection capacity, and in the end, 5.6% of higher oil production rates obtained compared to the conventional method

Introduction

TM Field is one of the biggest oil and gas field in Indonesia. The field has many challenges due to its complexity, due to its marginal nature. With the abundant source of gas in this field, gas lift is used as the main artificial lift method to improve oil production. However, there are two main problems in gas lifted wells, namely due to limited compressor pressure and difficulties to perform gas lift valve replacement in highly inclined wells.

Previously, it is a common practice to use conventional method of gas lift design for infill and workover wells. The conventional design neglects fluid infiltration movement into the reservoir, resulting in a high number of gas lift mandrels required which in turn, lower gas lift operating pressure and gas lift injection rate. Therefore, an innovation for gas lift spacing design is necessary to optimize gas lift performance.

The authors propose a new spacing method to optimize gas lift application called "the equalized method". This method follows Le Chatelier's Principle of corresponding pressure, in which an addition of pressure will shift the equilibrium towards the opposite condition; that is the pressure and volume will decrease toward the reservoir (Prigogine, 1954). Using this new equalized method, it is hypothesized that it will not only decrease the required unload valve amount, but also increase the possible operating pressure, gas injection rate, and production potential.

Data and Method

Spacing method model derivation consists of deriving equation model to calculate the equalized time for the equalized method of spacing design. The equalized time is defined as waiting time required for killing fluid to infiltrates the reservoir completely. This calculation is an essential calculation that differentiate between equalized method and conventional method. Therefore, the author derives an equation model to calculate the equalized time.

In this procedure, the calculation for this method is conducted by presuming that killing fluid behaves as a single-phase incompressible fluid. Eq.5 shows the flow in porous media occurring from well to the reservoir. Note that injectivity index (K) value is assumed identical to productivity index (J) value, yet the difference lies only in flow direction.

$$Q_{inj} = K(P_{wf} - P_{res}) \quad ...(1)$$

The bottomhole pressure is then assumed that it is exerted from the hydrostatic of the killing fluid only, while the reservoir pressure is assumed that it is equal to the hydrostatic of the final static fluid level. By combining with hydrostatic pressure equation (Streeter, 1966), the equation is shown by Eq.2.

$$Q_{inj} = K\gamma_l(h^* - h_f) \quad ...(2)$$

The superscript * indicates that fluid level needs to be corrected with respect to head loss due to friction, denoted below (Manning, 1991).

$$h_L = f_D \frac{8}{\pi^2 g} \frac{Q^2}{D_c^5} \quad .....(3)$$

Where friction coefficient, f_D, can be estimated by Colebrook Equation (Colebrook, 1933) as follows

$$\frac{1}{\sqrt{f_D}} = -2\log\left(\frac{2.51}{Re\sqrt{f_D}}\left(1 + \frac{Re}{3.3}\right)\right) \quad .....(4)$$

Volumetric flow rate (Q) is defined as the volume of fluid which passes through a single control volume (Benedict, 1984). Assuming constant tubing annulus size, the equation of volumetric flow rate in the tubing shown in Eq.5

$$Q = \frac{dV}{dt} = -A\frac{dh}{dt} \quad ...(5)$$

Equalizing Eq.3. Eq. 4 and Eq. 5, Eq.6 is then obtained.

$$-A\frac{dh}{dt} = K\gamma_l(h^* - h_f) \quad ...(6)$$

Eq.6 is then rearranged and integrated for both LHS and RHS, shown in Eq.7.

$$\int_0^t dt = \frac{-A}{K\gamma_l} x \int_{h_0}^{h_{eq}} \frac{dh}{(h^* - h_f)} \quad ...(7)$$

Thus, the equalized time, or the waiting time, equation for vertical wells is shown in Eq.8.

$$t = \frac{A}{K\gamma_l}\ln\left[\frac{(h_o + h_L - h_f)}{(h_{eq} - h_f)}\right] \quad ...(8)$$

The equation can be modified further for deviated wells, assuming no build up angle required in drilling process (the well deviates at the desired angle right after the kick off point), using the same calculation process as above, the equation can be written as Eq.9.

$$t = \frac{A}{K\gamma_l}\ln\left[\frac{(h_o + h_L - h_f)}{(h_{KOP} - h_f)}\right] + \frac{A}{K\gamma_l \times cos(\theta)}\ln\left[\frac{(h_{KOP} - h_f)}{(h_{eq} - h_f)}\right] \quad ...(9)$$

For θ < 90°, the following Eq.10 equation will be achieved.

$$\frac{A}{K\gamma_l}\ln\left[\frac{(h_o + h_L - h_f)}{(h_{KOP} - h_f)}\right] + \frac{A}{K\gamma_l \times cos(\theta)}\ln\left[\frac{(h_{KOP} - h_f)}{(h_{eq} - h_f)}\right] \le \frac{A}{K\gamma_l \times cos(\theta)}\ln\left[\frac{(h_o - h_f)}{(h_{eq} - h_f)}\right] \quad ...(10)$$

Thus, the equalized time equation for deviated wells could be stated below in Eq. 11. This simplification of Eq.9 to Eq.10 works as a safety factor to compensate the assumptions made to construct the equation, such as the assumption of no build-up period. It is also worth noting that this Eq. 15 serves as a universal function for both vertical and deviated wells.

$$t = \frac{A}{K\gamma_l \times cos(\theta)} \ln\left[\frac{(h_o + h_L - h_f)}{(h_{eq} - h_f)}\right] \quad ...(15)$$

Result and Discussion

In order to evaluate the validity of equalized method, the author presents a case study of Well X, using both conventional and equalized method. Well X is an offshore producing well from a depleted reservoir with low formation pressure. Well X needs an artificial lift in order to produce commercially. Due to the abundance of gas available on the field, gas lift will be chosen as the artificial lift method. However, the well has a limited compressor pressure of only 670 psi. Therefore, and optimized gas lift application must be used. The well, reservoir, and other supporting data are given in Table 1.

Table 1 Properties of Well X

No.	Parameter	Values
1	Well Name	"Well X"
2	Reservoir Pressure (Psi)	900
3	Formation GOR (scf/stb)	100
4	Killing Fluid Gradient (psi/ft)	0.465
5	TVD/MD of Mid Perf. (ft)	2523/3090
6	Packer Depth Estimation (ft TVD)	2402
7	Prod.Casing Outer/Inner Diameter (in)	7/6.538
8	Tubing Outer/Inner Diameter (in)	3.5/2.991
9	Max. Kick Off Pressure available (psia)	600
10	Water cut (%)	50
11	Injectivity index (bbl/psiday)	6
12	Gas specific gravity	0.8
13	FTP (psi)	110
14	Ambient/BH Temp. (°F)	80/158
15	Available Gas Lift Valve Port Size	0.1875;0.25;0.3125

From the data and information acquired, the equalized method can be hypothesized to be able to run effectively. This case study on Well X is analyzed using both conventional and equalized method so that the comparison between both methods can be seen. The result of the case study using both conventional method and equalized method will be compared based on the number of gas lift mandrel and valves to be used, gas injection rates, and liquid production

The equalized level (h_{eq}) is determined to be 1933 ft TVD or 2367 ft MD. The equalized time is obtained using the Eq.13, Resulting in 0.088 day or approximately 2.404 hours. This indicates that operational needs to be delayed before deploying gas lift, however further analysis is then done to provide an insight on how beneficial is this project.

Spacing design is then conducted using both methods after determining equalized fluid level and equalized time. The spacing design starts at the equalized level for the equalized method while the design starts from the surface level for the conventional method. The spacing designs' comparison of both methods are shown in Fig.1 and Fig. 2.

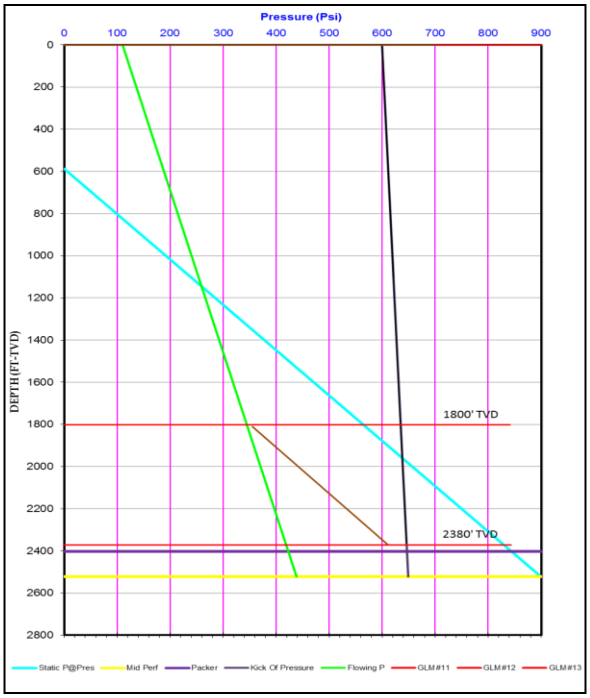

Figure 1 Equalized Method Based Spacing Design

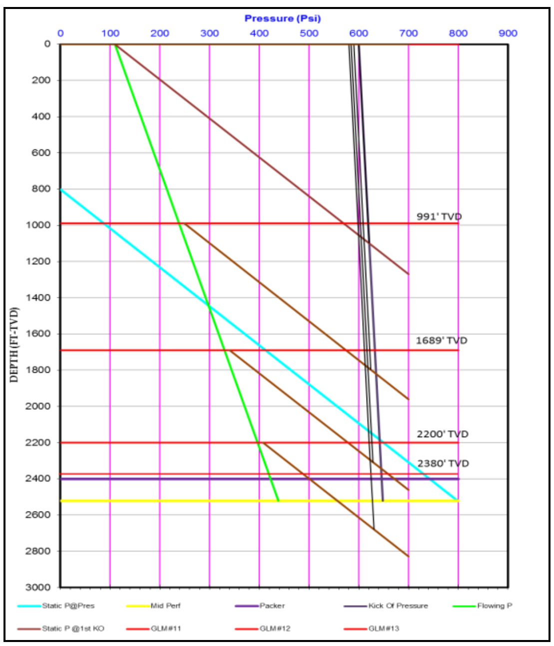

Figure 2 Conventional Method Based Spacing Design

From Fig.1 and Fig.2, it is shown that using different methods will result in a different amount of gas lift valves. The number of gas lift valves required in the equalized method is less than the number required in conventional method. Using the equalized method, the number of gas lift valves required is 2 valves while the conventional method requires 4 valves.

The theoretical gas injection rate available for the equalized method is higher than the conventional. The gas injection rate for the equalized is 575 MSCFD while for the conventional method is barely 438 MSCFD. Gas lift performance curve is generated based on the injection rate from both cases as presented in Fig.3.

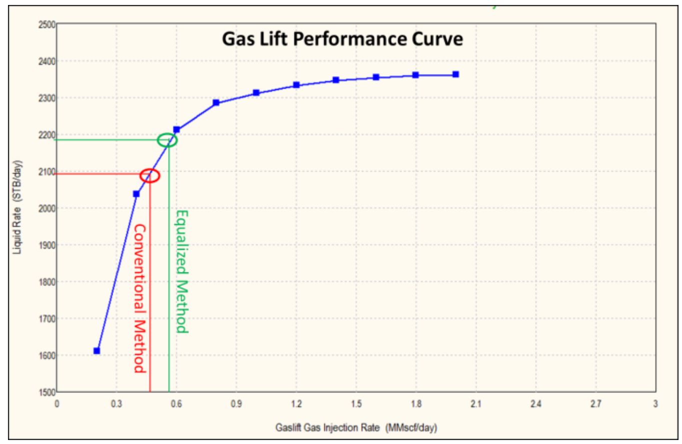

Figure 3 Production Increase After Gas Lift Design

The liquid rate comparison between the two methods is presented in Table 2. It is shown from the Table 2 that using the equalized method on this case study will boost the production rate potential of the well up to 117 STB/day, from 2084 STB/day to 2201 STB/day, or a 5.6% production increment compared to the conventional method.

Table 2 Notes on Well Performance

Method	Liquid Rate (STB/day)	Note
Without Gas Lift	-	• Cannot Flow Naturally • Needs artificial lift
Conventional Method	2084	• Using injected gas rate of 438 MSCFD (Max. Gas Passage Available)
Equalized Method	2201	• Using injected gas rate of 575 MSCFD (Max. Gas Passage Available) • 117 STB/day production boost • 5.6% production increment compared to the conventional method

Conclusion

This work presents a novel implementation of equalized method to optimize gas lift spacing design. This method can be the ideal solution for wells in depleted reservoirs, with high productivity and limited compressor pressure. From the case study results, the equalized method has been successful on increasing well production rate up to 5.6% in a deviated well with relatively low-pressure reservoir and slightly high water cut level.

The equalized method is better that conventional method because this new method has been proven to provide lower number of valves, lower operation cost, faster and easier gas lift intervention operation, and lower operation risks. Higher gas lift injection rate available is also obtained, thus equalized method results in higher production rate and higher profit for gas lifted wells. This new method can be applied in most well cases with gas lift system, for better operational and economic benefits.

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