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Parametric Consideration While Designing Wells for Optimized Production

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Abstract: Transferring benefits of engineering knowledge and its advancements has always been a point of concern for the companies rather than providing direct information which can make general public capable of successfully solving various issues in the most economical way. Water is one of the major sources of nutrition and considered as utmost constituent of life. Therefore, in this study, petroleum engineering knowledge is discussed and implemented to calculate the water flow rate with reference to different surface pressures. Further investigating the influence of well trajectory (angle of inclination) and tubing/pipe diameter on water production rate. This research shows that as the angle of inclination varies from vertical; water production rate increases. It is also observed that change in diameter also have strong influence on water production rate. This study shows that the angle of inclination and diameter can be varied to increase the water production rate under prevailing conditions, to meet the demand of water supply and its utilization; as a major nutrition source and hence developing subsurface reservoirs for optimized production.

Key words: Well trajectory, tubing diameter, angle of inclination

INTRODUCTION

Production engineering is one of the prime areas of petroleum engineering which deals with designing subsurface and surface facilities to lift hydrocarbons from deep down the earth to the surface (Brown, 1977; Economides, 1994; Guo *et al*., 2007). The designing involves, using complex correlations to execute the designing in the most optimized and economical manner. Further such drilling processes, if not executed in an appropriate manner can contaminate the fresh water sources, as also recently highlighted by Haris *et al*. (2013).

However, with reference to general public and farmers, they are mainly concerned with drilling water wells; as one of the main source of fresh water supply. Generally, water is produced by drilling vertical wells. Water is one of the major source of life; used for drinking, irrigation purposes and in almost every sphere of life (Plappally *et al*., 2012). With the passage of time the drinking water level beneath the earth is decreasing, as a result requiring drilling at higher depth as compared to the past and at the same time, demand of water in terms of its production and utilization is increasing (Biswas *et al*., 2011; Roger *et al*., 2002). Such scenario's leads to a situation where one have to optimize the water production from drilled wells. Therefore, in this study the resulting pressure drops to lift the water from the subsurface to surface has been analyzed, while incorporating the effect of angle of inclination and pipe diameter (used for producing water).

MATERIALS AND METHODS

Water is generally considered as incompressible liquid for which the following equation can be used to calculate the pressure drop required to lift water from the bottom of the well to the surface (Economides, 1994):

$$\Delta P = P_{bottom} - P_{surface} = \Delta P_{P.E} + \Delta P_{K.E} + \Delta P_f \quad (1)$$

[ΔP = Total pressure, $\Delta P_{P.E}$ = Potential energy loss ΔP_f = Kinetic energy losses and frictional losses]

The above equations describes that the total pressure drop is a summation of potential energy loss kinetic energy losses and frictional losses. If the constant diameter pipe is used for producing water (which is a very valid assumption for such cases), then kinetic energy losses can be neglected, so above equation becomes:

$$\Delta P = P_{bottom} - P_{surface} = \Delta P_{P.E} + \Delta P_f \quad (2)$$

In this equation, potential energy losses can be calculated as follows (Economides, 1994):

$$\Delta P_{P.E} = 0.433\ SL, \text{for vertical wells} \quad (3)$$

While for deviated or inclined wells, Eq. (3), can be written as:

$$\Delta P_{P.E} = 0.433 SL \sin\theta \quad (4)$$

Where, "S" is the specific gravity of water which is normally taken as equal to "1", for water. "θ" is the angle

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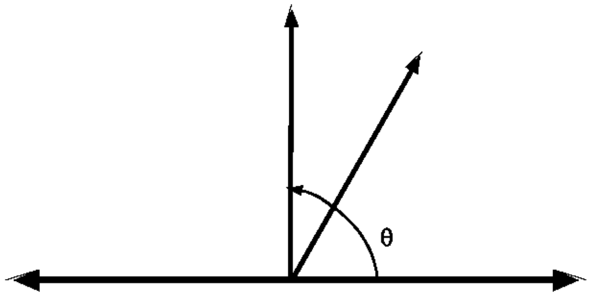

Fig. 1: Measuring angle of inclination with reference to horizontal

of inclination and can be measured in an anticlockwise direction with reference to horizontal axis, as explained with the help of Fig. (1).

As described in Fig. (1), vertical wells which are usually drilled for obtaining water from the subsurface formations have an angle of 90°, therefore, sin (90°) is equal to 1.

Frictional pressure drop in Eq. (2), can be calculated by using the following equation (Economides and Nolte, 2000):

$$\Delta P_f = \frac{518\times10^{-3}\rho^{0.79}q^{1.79}\mu^{0.207}L}{D^{4.79}} \quad (5)$$

The above equation for water wells can be re-written as, by assuming water density and viscosity equals to 1 gm/cm^3 and 1 cp, for simplicity:

$$\Delta P_f = \frac{518 \times 10^{-3} q^{1.79} L}{D^{4.79}} \quad (6)$$

So, by incorporating Eq. (4) and (6), in Eq. (2), we have:

$$P_{bottom} - P_{surface} = 0.433\,S\,L\,Sin\theta + \frac{518 \times 10^{-3} q^{1.79} L_{(ft)}}{D^{4.79}_{(in)}} \quad (7)$$

Re-writing the above Eq. (7), to calculate water production rate (q), we get:

$$q = \left[\frac{(P_{bottom} - P_{surface} - 0.433\,S\,L\,Sin\theta) \times 1000\,D^{4.79}_{(in)}}{518\,L_{(ft)}}\right]^{1/1.79} \quad (8)$$

RESULTS AND DISCUSSION

Case 1: Effect of angle of inclination on production from deepest well: Consider a well having depth of 1285 feet (deepest well as mentioned on http:// en. wikipedia.org/wiki/Water_well, as accessed on 30th Oct. 2012) and assuming pressure at this depth is 600 psia and pipe diameter is 0.5 ft, then the surface pressure required to lift same amount of water by drilling vertical wells and drilling an inclined well has been calculated by using Eq. (8) . The obtained results have been shown in Fig. (2). Graph is plotted between surface pressure and the water production rate, while changing the angle of inclination. The obtained results show for the same amount of water produced, lesser pressure drop is required as the well trajectory shifts from vertical to inclined. Which is inferred by high surface pressure, as lesser the pressure drop, greater will be the surface pressure.

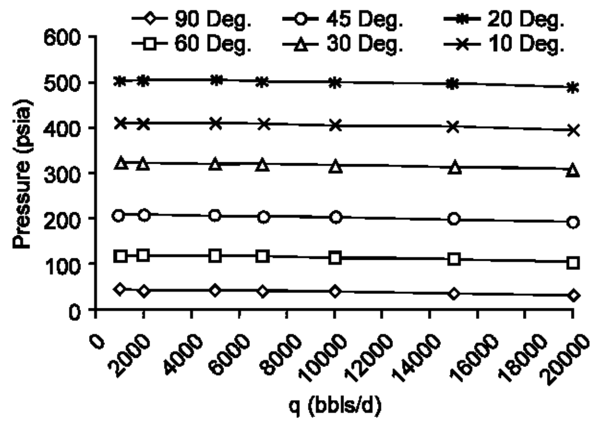

Fig. 2: Effect of well inclination on water production and surface pressure

For further analysis the study has also been extended by incorporating the variation in pipe/tubing diameter in addition to analyzing the effect of angle of inclination, while considering a shallow reservoir as discussed below.

Case 2: Effect of angle of inclination and tubing diameter on production from shallow reservoirs: Water production rate has been estimated while analyzing the effect of small variation in angle of inclination and keeping the surface pressure constant at a value equal to standard pressure, i.e., 14.7 psia. The depth of subsurface production source is taken as 78 ft and the pressure at that depth is taken as 49 psia. The angle of inclination has been varied from 90° to 80° in a step of "2.5°" each. The obtained results based on this study are presented in Fig. (3) which shows that even a small change in angle of inclination can have significant effect on water production rate.

Furthermore, for in-depth analysis, the effect of variation in pipe diameter used to produce water from the subsurface has been investigated, while including the change in angle of inclination at the same time. The obtained results show the change in diameter has direct relationship with water production rate (Fig. 4), i.e., as the pipe diameter increases water production increases.

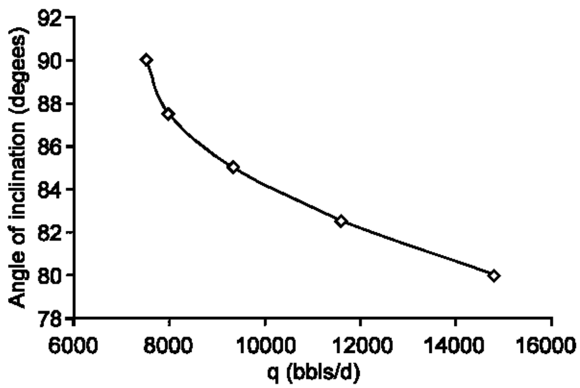

Fig. 3: Effect of angle of inclination on production rate, while keeping surface pressure constant

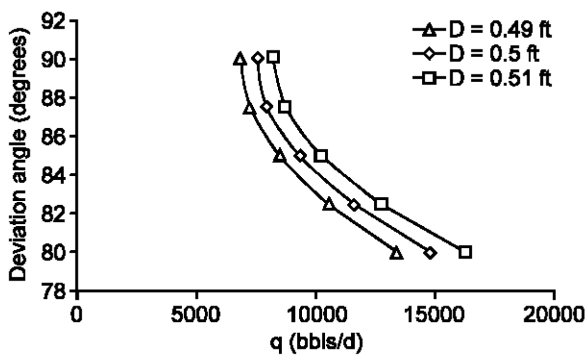

Fig. 4: Effect of pipe diameter on water production

Conclusions and recommendations: The research shows that the production of water which is one of the main sources of nutrition, can be optimized in different ways. This study shows that a slight change in angle of inclination from vertical can have a significant impact on water production rate. As the angle of inclination decreases, water production rate increases. Further it can also be inferred from the obtained results that the pipe diameter is also of critical significance and a slight increase in the diameter can increase the water production from a well. Therefore, based on this study and the obtained results it is highly recommended to drill water wells having an angle of inclination lesser than 90° and while designing the well trajectory, option of increasing the pipe diameter should also be taken into account. By incorporating the above mentioned parameters while drilling a well, water production from the subsurface formations can be increased. Thus the increase in demand of water supply for various purposes can be fulfilled by exploiting the subsurface fresh water reservoirs in an optimized manner.

Nomenclature:

D : Diameter
L : Depth
P : Pressure
q : Water flow rate
S : Specific gravity
θ : Angle of inclination/deviation angle

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