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Diagnosis of Excessive Water Production in Horizontal Wells Using WOR Plots

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Abstract

Many oil fields in Oman are developed with horizontal wells to maximize productivity and develop wider drainage areas for more cost effective recovery. Premature water breakthrough either from water injectors or from water aquifer reduces the wells profitability because of both reduction in net oil rate and additional cost for water handling. To determine the best solution to shut-off, source and nature of the water entries must be well identified.

The flow dynamics and fluid entry mechanisms in horizontal wells are complex and identification of water inflow zones is challenging even when using the best production logging technology available today. Traditionally, when the water cut increase becomes abnormally high, production logging tool (PLT) is run to identify water inflow zones. However interpretation of PLT logs in horizontal wells is not an easy task for log analysts because of the complex flow dynamics and logging tool's limitations in measuring downhole fluid velocities and fluid holdups coverage across the borehole.

This paper discusses the limitations of PLT and focuses on diagnosing excessive water production problems using water-oil-ratio (WOR) plots, which is commonly used for screening and selecting water shut-off candidates. A 3-D simulation model was used to investigate the effect of water arial coning and channeling through fractures on WOR and WOR derivative trends in vertical and horizontal wells. Simulation results are in good agreement with field data, which are also presented in this paper.

Introduction

Excessive water production is one of the major factor contribute in reduction of wells productivity. Increasing water cut in general impacts both the inflow and outflow curves negatively. Higher water production increases the cost of fluids lifting to surface, water treatment, and disposal. Water production is also related to scale problems at various production system components.

Excessive water production can be resulted from either a problem of the well (mechanical failure) or other reasons related to the reservoir like Water channelling from water table to the well through natural fractures or faults, water breakthrough in high permeability zones, or water coning.

In general, water production problems related to wells integrity easier to solve and it gets more complicated to control water production if it is related to the reservoir characteristics. Various water control techniques were developed to shut-off or reduce excessive water production. However, the rate of success of water shut-off jobs is still considered to be low. In some publications, that was reasoned as the mechanisms that contribute to excessive water production are not well understood [(1)]. Water coning, multilayer channeling and near wellbore problems are the main three contributors to excessive water production [(2)]. Obviously, the understanding of excessive water production mechanism and identifying the water entry in the well are the two major factors make the shut-off job successful.

The common practice for many operators is using production logging tools (PLT) to define water entries and then select the shut-off technique and design the job. It is very important to notice that the high technology PLT available in the market still have some limitations in horizontal wells due to complex fluid entry mechanisms and flow dynamics of multi-phase flow in the wellbore. To aid understanding excessive water mechanism, several methods and techniques have been developed. Majority of the techniques are specialized plots such as linear water cut vs. time [(3)];, linear WOR plots [(4)], semi-log WOR [(5)], X-plot [(6)], Wilhite's WOR [(7)], Novotny's method (8), log-log plots of the WOR (2), Egbe and Dulu method (9), Yortsos et al. method (10) .

Use and limitation of Production Logging Tool (PLT)

PLT is one of the most common practices to identify the source of excessive water production. The most advanced PLTs have very complex tools that measure instantaneous fluid hold up, fluid density, flow velocity and temperature in highly deviated and horizontal wells [(11 - 13)].