Analysis of indicators of the impact of residual water during oil production from flooded formations

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ABSTRACT

This article presents information on the influence of the thickness of the conventional film layer of water on the oil recovery indicators remaining in the reservoir layers during oil production, depending on the geological composition of the layers.

Keywords: Surface, residual, water, film layer, rocks, formation, displacement, oil, wells.

Introduction

When solving issues related to calculating oil reserves and oil recovery, it is necessary to know the amount and distribution of residual water. As studies have shown, the coefficient of displacement of oil by water increases not only with increasing temperature and permeability of the porous medium, but also with increasing amount of residual water.

Residual water is understood as total moisture: adsorption, or physically bound, initial capillarity and pore angles [1].

The formation of adsorbed or bound water on the surface of rock particles is determined by both chemical and physical forces, which are electrical in nature [2]. Pore corner water can also be called capillary-disconnected or capillary-immobile state of free formation water.

In cemented and uncemented rocks, the binding of liquid to dispersed particles results in a decrease in the open cross-section of capillaries (pores), which leads to a decrease in the filtration of fluids through porous media.

Method

Studies by a number of authors show that the less substances subject to hydration in sandy-siltstone reservoirs, the less residual water they contain. The amount of residual water also depends on the grade and roundness the clastic material composing the rock, as well as the size of the pores. The amount of residual water increases with increasing density of sediments and with increasing content of fine pores in them.

The distribution of water in the reservoir is determined by the difference in capillary pressure curves for individual layers of the formation. More macroporous and permeable layers have lower displacement pressure, and in order for capillary pressure equilibrium to occur between different fluid phases, less pressure is required. water saturation .

The thickness of the layer of bound water depends on the hydrophilicity of the mineral composition of the skeleton, external conditions, the conditions of equilibrium between the force that takes away water and the force that binds water at the solid surface, on the presence of certain cations, the degree of concentration of electrolytes in the formation water, as well as on the particle size breeds [3].

Direct measurements of the thickness of wetting films of water or oil on the surface of rock particles have not yet been made.

Measurements of the equilibrium thickness of wetting films carried out by the optical method for water and aqueous solutions of salts by B.V. Deryagin and M.M. Kusakov , as well as measurements of various individual hydrocarbon liquids carried out by M.M. Kusakov on various hard smooth surfaces (quartz, diamond , glass, etc.), showed that the thickness of such layers is about 0.1 microns. The size of rock pore channels can be obtained from the formula $r = 0.9\sqrt{k/m}$ (r – average radius of pore channels in micropores, μm; k – permeability in μm 2 ; m – porosity in percentage).

The thickness of the conditional film layer of water (assuming the existence of a continuous film of water on the surface of the rock) according to K.G. Orkin [1, 2] can be calculated using the formula

$$\delta_{CB} = \frac{\sigma_{CB} \cdot m}{s \cdot 100} \qquad (1)$$

where σ_{st} - residual water saturation , % (by volume); m – porosity in fractions of unity; s – specific surface area of the rock, cm^2/cm^3; δ_{St} - thickness of the conventional film layer of water, cm.

Based on data about residual water saturation of rock samples from wells drilled for oil, K.G. Orkin established the thickness of the water film to be 0.45 microns.

L.I.Rubinstein for Devonian quartz sandstones, characterized by good sorting of clastic material and a low content of pelitic particles, established a film thickness of 0.19 microns.

I.A.Mukharinskaya calculated the thickness of the conventional film layer for rock samples of the Podkirmakinskaya suite (Apsheron Peninsula) from two wells in the Khorasan area , drilled for oil. Received values. The obtained values of the conventional film layer of water ranged from 0.10 to 0.87 μm, averaging 0.454 μm for 33 samples.

M.M.Kusakov and L.I.Mekenitskaya studied the average film thickness of distilled water in porous media of varying permeability. The average film thickness of distilled water was calculated from the difference between the total amount of residual liquid and the specific surface area of the rock samples. It turned out to be equal to 10–5 cm (0.1 μm).

Solutions

The state of residual water and the initial distribution of oil, gas and water in the porous medium of the formation is determined by numerous properties of the porous medium and formation fluids - the pore structure and composition of rocks, the physicochemical properties of rocks and formation fluids, the amount and composition of residual water, etc. [4].

The initial distribution of oil, residual water and gas in the porous medium of the formation affects the processes of oil movement and its displacement by water from the formation. The molecular nature of the surface of reservoir rocks depends on the amount, composition and state of residual water. If residual water in the formation in the form of a thin film covers the surface of the pore channels, then the surface of the solid phase remains hydrophilic. If there is no film of water, then the oil is in direct contact with the solid surface and, due to the adsorption of surfactants, the surface of the oil reservoir becomes significantly hydrophobic.

On the issue of the type of residual water found in porous media and other dispersed bodies, various researchers express different opinions. However, most of them come to the conclusion [5] about the existence of:

capillary bound water in narrow capillary channels, where capillary forces are intense;

adsorption water, retained by molecular forces at the surface of a solid and firmly bound to particles of a porous medium (the properties of adsorption water differ significantly from the properties of free water);

film water covering hydrophilic areas of the surface of the solid phase;

free water retained by capillary forces in a dispersed structure (limited by menisci at the water-oil, water-gas interface).

However, when analyzing core material in a rock sample, the total amount of residual water is usually determined without quantifying its different types. This is explained by the uncertainty of the conditions of existence and classification of residual water and the difficulty of separately identifying it by type.

The total amount of different forms of bound water in a rock depends on the composition and properties of the rocks and formation fluids. For rocks with a different pore structure and containing different amounts of clayey material, the dependence of residual water saturation on permeability may differ quantitatively from those given. However, the nature of the dependence in most cases is the same - with increasing permeability, the amount of residual water in the rock decreases.

Approximately residual water saturation of sands σ_{opv} , sandstones σ'_{opv} and limestones σ_{ovi} depending on their absolute permeability k_0 and open porosity m_0 recommended determined by formulas (in fractions of a unit)

$$\sigma_{ovp} = 0.437\text{-}0.155 \lg \frac{k_0}{m_0},\ \sigma'_{ovp} = 0.283 - 0.1\lg \frac{k_0}{m_0} \qquad (2)$$

$$\sigma_{ovi} = 0.183 - 0.1\lg \frac{k_0}{m_0}. \qquad (3)$$

They show that the less substances subject to hydration in sandy-siltstone reservoirs, the less residual water they contain. The amount of residual water also depends on the grade and roundness the clastic material composing the rock, as well as the size of the pores. The amount of residual water increases with increasing density of sediments and with increasing content of fine pores in them.

In terms of its chemical composition, residual water can differ greatly from circuit water and from water produced along with oil and gas. Studies show that residual water is significantly saltier than sea water (3–10 times). Normal sea water contains on average 3.5% (by weight) NaCl with a total mineralization reaching 35,000 mg/l. The salt content in formation waters of oil fields ranges from 10,000 to 200,000 mg/l.

The increased salinity of residual water is explained by the evaporation of water molecules, as well as the influence of the geochemical gradient. Residual water is characterized by a high chlorine content. However, deviations from these patterns are also noted for some deposits.

Conclusion

Experience in the development of oil and gas fields, especially the use of physical and physico-chemical methods of influencing the formation, indicates that residual water plays an important role in the processes of oil and gas extraction. According to the degree of hydrodynamic mobility in relation to the processes of displacement of oil by water, it can be classified into phase-mobile, which affects development indicators in the initial period of well operation, and phase-immobile, which moves only due to mixing with water, displacing oil.

In real conditions of heterogeneous oil reservoirs, residual water does not form a single continuous shaft at the displacement front. Most often, it arrives at the bottom of wells, having varying degrees of dilution with injected water. Only at high displacement rates, when water breaks through individual interlayers , or with a very stable displacement front, residual water can form accumulations in the form of a shaft in front of the injected water.

When moving along the displacement front, residual water can flow from a more permeable layer to a less permeable one . The intensity of flows depends on the ratio of capillary and hydrodynamic forces.

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