The mathematical model of the filtration process in horizontal wells for the high viscosity oil fields

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***Abstract* -** The main objective of the design of oil fields development is correctly predict the future production rate of a horizontal well. In conditions of heavy oil and horizontal well this forecast is very often inaccurate. Describes a new method for determining the start of the forecast production rate of horizontal wells for heavy oil.

Forecast of oil production is the Main indicator of economic efficiency of development of each individual field.

The calculations made according to an existing formula showed their complete unsuitability for fields with high-viscosity oil. The calculation error of the flow rate of horizontal wells currently used methods reaches an average of up to 95%, indicating the inadequacy of the proposed solutions to determine the flow rate.

Thus, the search for a solution to the problem of maximum approximation of the calculated data flow rate horizontal wells to the actual indicators is a very important task in the modern design of the oil fields. With the aim of finding a reliable formula for determining the flow rate of horizontal wells, drew attention the law of the classical filtration J. Dupui. Based on the assumption by S. Joshua corning to which the drainage area of a horizontal well is an ellipse, the area of the drainage zone of horizontal well were calculated. The definition of the radii of the semi-axes of drainage was determined according to the accepted theory. The namely radius of the minor radius of drainage was defined as half of the thickness of the oil reservoir, and the radius of the larger semi-axis of the drainage as the sum of half the length of the horizontal well and equivalent drainage radius of the imaginary vertical wells, which depends on the reservoir properties. The rate of fluid filtration was determined from the equation A. Krasnopolsky and limit the pressure gradient at which there will be filtering is determined according to the proposed method V. Devlikamova. The result of this work was a new method of calculating the flow rate of horizontal wells in conditions of nonlinear filtering, which significantly reduce the error in the estimated values of almost zero.

The new method of calculation considers the following factors influencing at the flow rate of horizontal wells: determined the exact drainage area, the record kept of the rheological properties of filtered liquids, calculated features of the medium through which it filtered. Thanks to all of the above, the calculations made by a new technique performed for the exaltation of the Deposit has shown excellent results, reducing accuracy from 95% to 7%

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INTRODUCTION

The history of the use of horizontal wells for production of hydrocarbons has more than 50 years.

Since the late 70-ies, the technology of oil and gas development using horizontal wells began to flourish around the world. Abroad there are currently more than 60 different firms mastering this technology.

In the early 90-ies in Russia, drilled dozens of horizontal wells and put into operation of such wells produced 180 thousand tons of oil.

Thanks to the technology of horizontal drilling in some fields the oil reserves that previously considered unrecoverable, can now produce on an industrial scale.

Over the last decade, the technology of field development using horizontal wells tested in many oil and gas producing regions.

The profitability of developing oil and gas fields depends significantly on the productivity of wells. During the development of the fields located in the offshore area, having a small thickness, low filtration properties occurring at greater depths and also in the development of oil rims using vertical wells in most cases becomes unprofitable due to high cost of production of oil and gas, low productivity and erratic operation of such wells.

For the development of oil and gas deposits horizontal wells has been widely used since the 80-ies of the last century. The necessity of the use of horizontal wells each year and is linked to the fact that a large proportion of hydrocarbon production accounts for reservoirs with low permeability reservoirs, their location within the waters of the seas, with a slight thickness of the oil rim reservoirs with bottom water.

Design features of horizontal wells unlike vertical to allow the flow rates several times greater than productivity of vertical wells. Moreover, the increase of the production rate of horizontal wells provided by increasing the filter surface.

The filter surface vertical wells is limited by the thickness of the reveal of their formation and the diameter of the barrel, while for a given value of thickness and the hole diameter, the geometric parameters of the filtering surface of horizontal wells are dependent on the length of the horizontal section of the trunk.

These features of the horizontal wellbore underlined by virtually all researchers.

Therefore, the search and selection of reasonable designs of horizontal wells (Fig. 1), taking into account the capacitive and filtration properties of a porous medium. The heterogeneity and the anisotropy parameter, contamination of bottom-hole zone during drilling, the placement of the horizontal barrel on the thickness and on the contours of the drainage zone, the profile of the horizontal section and complete dissection of the fragment can be carried out only if the exact formulation of the problem of the fluid flow to a well using the theoretical foundations of multidimensional and multiphase flow.

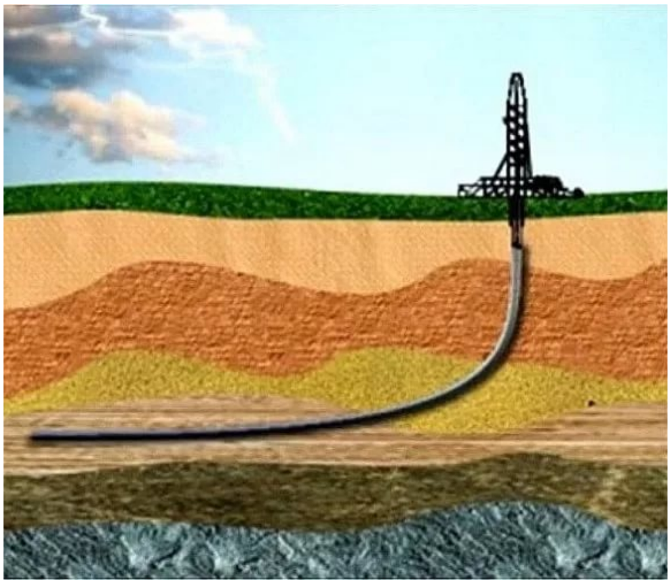

Fig. 1 The horizontal well

Production and design of systems of development of deposits of heavy oil is one of the most promising directions of development of domestic fuel and energy complex.

Typically, oil of this class possess distinct rheological properties due to the presence of high molecular weight components, the asphaltenes and resins.

Simulation of the development of such reservoirs is difficult, as in most modern hydrodynamic simulators the description of isothermal filtration of fluids were based on the linear Darcy's law, which fails to rheological complex environments.

The theoretical bases and methods of determining the productivity of horizontal wells is closely associated with the adopted schematization oil flow into the horizontal well.

The fundamental difference between the flows of oil to the bottom of a horizontal well from the inflow to the bottom of the vertical is that, as a rule, the horizontal well is always significant, up to several thousand meters interval inflow.

The length of the filter, where the flow of oil to the barrel, causes the necessity of creation of corresponding depression on the layer, the maximum value of which must be at the point of transition of the barrel from horizontal to vertical in the absence of the fountain pipe in the horizontal part of the trunk.

If its value were limited by any factor other than the presence of bottom water or unstable manifolds, for a considerable length of the horizontal part of the stem due to pressure losses due to friction arising from the movement of oil through the barrel depression on the end portion of the barrel may be negligible. In some cases, it is possible that at the end of the barrel, P_w is close to P_c. In such cases, the length of the horizontal part of the trunk should be limited to the depression on the layer in the transition region of the trunk from a horizontal position to the vertical and pressure loss in the horizontal part of the trunk.

Taking into account the various factors influencing the performance of horizontal wells, depending on the specific properties of layer: its thickness, the presence of near bottom water, sustainability of reservoirs, length of the wellbore, the laws of oil filtration to the horizontal well are becoming more important than filtering to a vertical well penetrated a layer with limited thickness.

I. Theoretical background

The search for approximate analytical methods of determining the productivity of horizontal wells that discover oil and gas reservoirs aimed at the selection of this model of the considered problem, which, without distorting the physical nature of the filtration process, will allow us to obtain simple formulas for determining the flow rate of such wells.

However, one of the most common ways of schematization task of filtering is to replace the true filtration of the reservoir area, ensuring equivalent resistance proposed by Z. S. Aliyev, V. V. Bondarenko and B. E.Somov [1] .

Simplify mapping tasks of oil flow to horizontal wells that have penetrated the strips layer, can be represented in the following ways. For a symmetric location within of radius R=h/2 the flow of oil along the length of the horizontal wellbore can be represented as locoregionally, and outside this circle, the inflow can be considered as plane-parallel filtering to the enlarged borehole.

Great practical interest is the study of the influence of the horizontal barrel on the thickness of the layer on the production of the well.

The share of scavenger stocks in the global structure of the raw material resources is constantly increasing. The heavy oil reserves with a viscosity more than 30 cP are exceed by more than five times than remaining recoverable reserves with middle and low viscosity. At these fields of hydrocarbons were drilled by horizontal wells to maximize oil recovery and to reduce the drilling cost.

The production from each individual horizontal well (Fig.1) is one of the main parameters in the techno-economic evaluation of deposits. In the article authors, represent a new perspective on the problem of determining the forecasting production rate of horizontal well using well-known approaches.

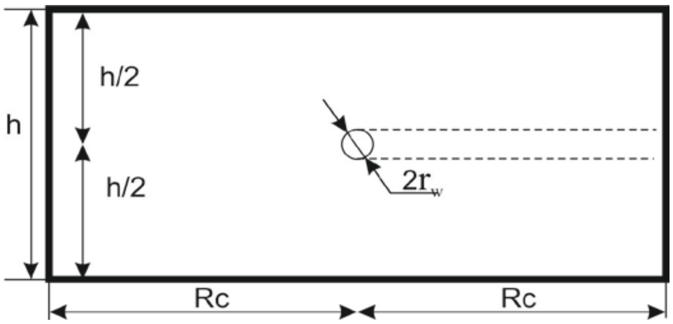

Fig. 2 The inflow of fluid into a horizontal well

Determine the production rate of a horizontal well of length L. The well located in the reservoir thickness h, a circuit of wells we make the radius Rc, the pressure on the circuit - Pc, with absolute permeability k, dynamic viscosity of fluid drained -μ, the pressure on the bottom hole is the Pw, the radius of bore – rw. Assume that the well is located symmetrically relative to the roof and the soles of the reservoir (Fig. 2).

Y. T. Borisov, V. P Pilatovsky and V. P. Tabakov [2] were worked over the solution of this problem. According to their research, the production rate of horizontal wells is expressed by the formula:

$$q = \frac{2\pi kh}{\mu} \cdot \frac{P_c - P_w}{\ln\frac{4R_c}{L} + \frac{h}{L}\ln\frac{h}{2\pi r_w}} \quad , \qquad (1)$$

The first term in the denominator reflects the external filter resistance and the second term is the internal resistance of the well.

Externally, the filtration resistance consistent with the resistance of the vertical well, differing only in that instead of the radius of the bore of the r_w were used the radius $r_w = L / 4$. The internal resistance of a horizontal well were taken by the method of equivalent seepage resistance Y. P. Borisov equal to the internal resistance of a battery of vertical wells of width L, the distance between wells 2 h.

Formula (1) has the disadvantage that, regardless of the length of the horizon-the rest of the well circuit, it assumed radial. The accuracy of the formula should decrease with the increase in the ratio L/R_c.

For horizontal wells, the outline of oil needs to be ellipsoidal and not circular in nature.

Considering the fact that F. M. Giger [3] put forward the assumption, according to which the power circuit is of a horizontal well is ellipsoidal and not circular, he presented his formula for calculating horizontal wells:

$$q = \frac{2\pi kh}{\mu} \cdot \frac{P_c - P_w}{\ln\frac{1+\sqrt{1-\left(\frac{L}{2R_c}\right)^2}}{\frac{L}{2R_c}} + \frac{h}{L}\ln\frac{h}{2\pi r_w}} \quad , \qquad (2)$$

There R_c is the circuit representing the semi-major axis of the ellipse.

S. Joshi [4] has suggested that there is the semi major axis of the ellipse of a similar area of a circle with a radius of drainage R a, substituting that in the formula (2), he received the expression:

$$q = \frac{2\pi kh}{\mu} \cdot \frac{P_c - P_w}{\ln\frac{a+\sqrt{a^2-\left(\frac{L}{2}\right)^2}}{\frac{L}{2}} + \frac{h}{L}\ln\frac{h}{2r_w}} , \qquad (3)$$

Where a - is the semi major axis of the ellipse:

$$a = \frac{L}{2}\left[\frac{1}{2} + \sqrt{\frac{1}{4} + \left(\frac{2R_c}{L}\right)^4}\right]^{\frac{1}{2}}$$

I.A. Charny [5] proposed the following formula for the condition when the horizontal wellbore is located symmetrically to the circuit:

$$q = \frac{2\pi kh(P_c - P_w)}{\mu\left[\frac{2\pi H}{h} + \ln\frac{h}{2\pi r_c}\right]} , \qquad (4)$$

Calculate the production rate of horizontal wells using the above formulas for the exaltation of the field.

II PROBLEM DEFINITION

The bobrikovsky horizon (B2) is formation of Vozdvizhenskoe field. A feature of this field is a heavy oil. There are few uplifts at this field. (Fig. 3)

Fig. 3 The B2 is formation of Vozdvizhenskoe field.

The reservoir properties of Vozdvizhenskoe field vary changed from well to well. (Table 1)

Table 1 The initial information for calculations

The results of the calculations of Vozdvigenskoe field summarized in table 2.

Table 2 The calculation of production rate by the classic formulas

At the preliminary design stage, a feasibility study of the feasibility of drilling horizontal wells in many cases it is sufficient to use approximate calculations on the above formulas.

However, because of the many formulas, there is the task of comparing them with the aim of identifying the range of applicability in practical calculations.

As can be seen from table 2, the classical formula for determining the flow rate of horizontal wells is inapplicable for calculations because there are large errors. Hence it is necessary to seek new approaches to solving this problem.

III PROBLEM SOLUTION

To determine the flow rate of horizontal wells, back to basics, namely, consider the formula for flow of liquid in a hydrodynamically perfect well J. Dupui [16]. Who claimed that the production rate is the product of the square shape through which is filtered fluid filtration rate.

$$q = SV, \qquad (4)$$

As previously stated – drainage zone of horizontal wells, according to S. Joshi [4] is an ellipse. The area of the ellipse calculated classically.

According to the law, as derived by P. Forchheimer [16] describing the dependence of the pressure gradient of the speed of filtration, we can distinguish some critical velocity above which will be a violation of the current regime:

$$gradp = \frac{\mu}{k}V + \frac{\beta\rho}{\sqrt{k}}V\bar{V}, \qquad (5)$$

In the case of movement of high-viscosity oil using a linear filtration law is not possible, in our case, more accurately, the change in the velocity of the fluid were described by the formula A. A. Krasnopolsky [16]:

$$\overline{V} = \alpha\sqrt{gradp}, \qquad (6)$$

The accuracy of the calculation of the debit in the formula directly depends on the accuracy of determining the forecast of the rate of filtration of fluid. We offer a solution to this problem.

But first a bit of history, until the mid-XX century the development of science was on the way to take into account various geological and physical parameters of the reservoir. However, in 1949, leaves the work of V. N. Shelkacheva and B. B. Lapuk "Groundwater hydraulics" [14], which produces a synthesis of knowledge about the filtration of liquids which do not obey the law of viscous friction Newton.

Among the foreign scientific works of the time, the most important is the work of O. L. Bingham co-authored with R. V. Olson, "A model study of viscous fingering" ("a Model study of viscous liquids) [15], where the descriptions of the different types of rheological fluids, one of which was later called "Bingham".

So, based on these works, the filtration for high-viscosity oils is possible only if the pressure gradients exceeding a certain value H, which is called the initial (limiting) gradient. At lower values of pressure gradient for filtration is missing.

It is necessary to determine the law of the liquid filtration in the reservoir. The filtration of high-viscosity oil is based on the law with limit (initial) pressure gradient - the nonlinear filtration law [6-9,15]:

$$v_i = -\frac{k}{\mu}\left(1 - \frac{H}{|grad\ p|}\right)\frac{\partial p}{\partial x_i} \quad with \quad |grad\ p| \geq H, \qquad (7)$$
$$v_i = 0 \quad with \quad |grad\ p| \leq H.$$

As follows from relations (7), filtration flow is possible only at pressure gradients exceeding the certain value H, that called the initial (limiting) gradient [6-9,15].

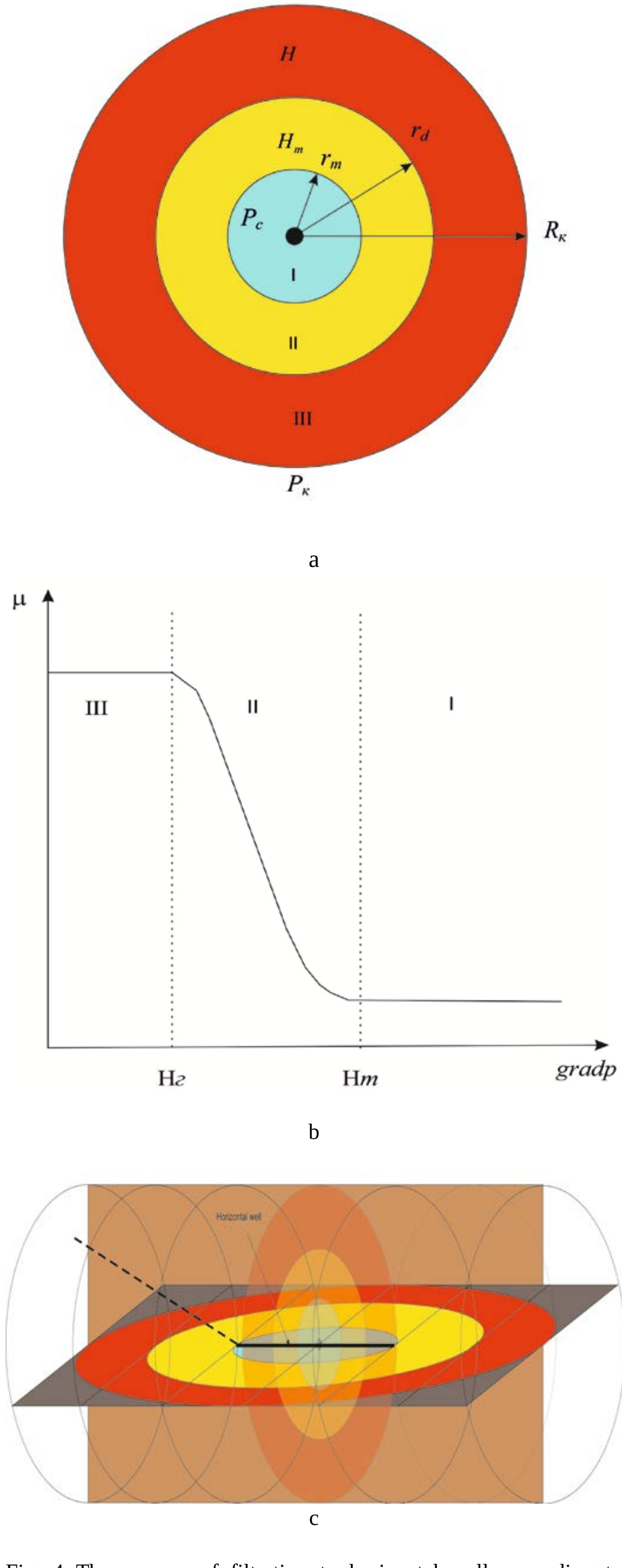

Fig. 4 The process of filtration to horizontal well, according to viscosity properties (a - the distribution of the zones filter in the vertical plane, b –zones of filtration with variable viscosity, c - the distribution of the zones filter in the plane of horizontal well)

Let us consider the figure 4. Figure 4 shows the analogy of fluid motion in the vertical 4a and in horizontal wells 4c. Consider in more detail these drawings. On resource 3a schematically illustrates the oil flow to a vertical well. Region the flat radial filtering of oil flow is conventionally divided into three annular zones surrounding production well.

Within the near-field zone I with a radius of r_m, the oil moves with minimal viscosity µm and completely destroyed the structure, i.e., the actual pressure gradient greater than or equal to H_m. In the transition zone II ring with an inner radius rm and an outer radius r_d, the viscosity of the oil µ variable, its value increases as the distance from the well and reduce the pressure gradient to the value of H.

Within zone III, a limited radius of the power circuit is R and inner boundary with a radius r_d, the oil moves with a maximum viscosity µ and the most solid structure formed by the asphaltenes and resins, the actual pressure gradient is less than H.

By analogy with the flat radial filtering in a vertical well in Fig. 1c presents areas of fluid flow in horizontal well.

The oil is filtered with a constant minimum viscosity μ_m in the first zone where the Darcy's law runs.

In the second zone the oil is filtered with variable viscosity.

In the third zone, the oil is filtered with a constant maximum viscosity.

The filtration with lower values of pressure gradient lacks off. The value of the initial gradient depends on the initial shear stress τ0 of the fluid and the effective diameter deff of the capillary [6-12].

The task is to determine what moment of time and upon reaching a horizontal pressure gradient will change the nature of the flow behavior. It is necessary to perform the curve speed filtering nonlinear viscoelastic oil from the pressure gradient. (Fig. 5).

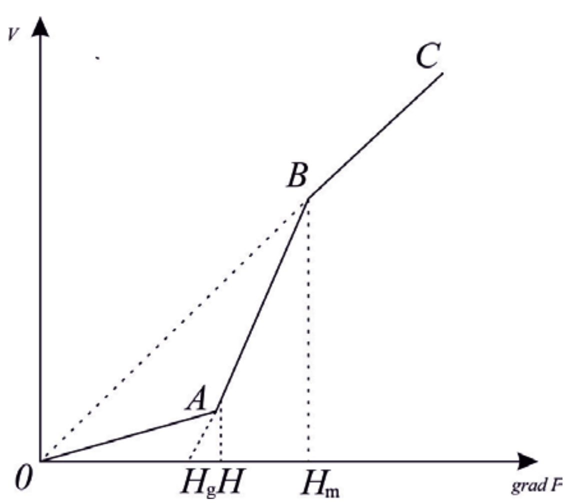

Fig. 5 Three phases of nonlinear filtration

This dependence is nonlinear. There are three phases in the figure 5:

OA - is the area where the liquid filtered with a low rate and the highest viscosity due to the almost intact structures. There is the phenomenon of creep.

AB – is the area where the filtered fluid with variable viscosity. There are the phenomenon of recovery and destruction of the structure and the filtration rate increases sharply.

BC - is the area where the liquid filtered with a completely destroyed structure and has the lowest viscosity. The continuation of the plot passes through the origin which corresponds to about the Newtonian nature of the flow.

There are two critical pressure gradients in this chart:

Hg – is the pressure gradient boundary strength virtually destroyed structure;

Hm – is the pressure gradient limit destruction of the structure.

It is known that the non-Newtonian behavior of oil due to the increased content of high molecular components (asphaltenes, resins and paraffin) mainly.

Accordingly, for the calculation of critical pressure gradients we will need to know:

As and R – are mass content in the oil asphaltenes and resins, wt.,%,

Cn and Cm and Ce – are content in the oil, respectively, dissolved nitrogen, methane and ethane m3/m3;

t - is the temperature of the oil in the reservoir where it is filtered, °C, kн - is the permeability of oil in the reservoir, D.

We used the empirical correlations represented by oil carbon, as basically most of the deposits located in the Carboniferous age for the calculation of critical pressure gradients. (Table 3)

Table. 3 The calculated dependence

Parameters	The calculated dependence
The ultimate saturation pressure of the degassed oil, Pa	1. $\theta_0 = a\frac{As}{R}$, where $a = 0{,}012$
	2. $\theta_0 = a\frac{As}{R}$, where $a = 0{,}033$
The ultimate saturation pressure of oil with respect to the quantity and composition of dissolved gas, Pa	1. $\theta' = \theta_0 + 10^{-3}\left[-5{,}16\left(\frac{As}{R}\right)^2 + 4{,}08\left(\frac{As}{R}\right) - 0{,}28\right]\left(C_n^2 + C_m + C_e\right)$
	2. $\theta' = \theta_0\left[1 + 0{,}286\left(\frac{As}{R}\right)^{0,9} * (1{,}1C_n + 0{,}8C_m + 0{,}7C_e)\right]$
The limited pressure of oil saturation at with given temperature , Pa	1. $\theta'' = \theta'\left(\frac{24}{t} - 0{,}04\right)$
	2. $\theta'' = \theta'\left(\frac{22}{t} + 0{,}12\right)$
The dynamic pressure gradient of shift, MPa/m	1. $H = \frac{0{,}052}{k^{0,62}}\theta''$
	2. $H = \frac{0{,}047}{k^{0,56}}\theta''$
The pressure gradient of structure limited destruction, MPa/m	1. $H_m = \beta + \alpha H$, where $\alpha = 1{,}21$, $\beta = 7{,}81 \cdot 10^{-4}$ MPa/m
	2. $H_m = \beta + \alpha H$, where $\alpha = 1{,}33 \div 1{,}39$, $\beta = (4{,}0 \div 6{,}0) \cdot 10^{-4}$ MPa/m

IV. CALCULATIONS

Lets calculate filter specific oil.

The B2 is formation of Vozdvizhenskoe field. The parameters for this layer are shown in table 2. Vozdvizhenskoe oil field are developed in a natural mode. Layer B2 developed by seven horizontal wells were drilled on the four domes: wells 100 and 234 on the East of the exaltation dome, p-n of SCR.67; wells 200 and 205 on the Central dome of the exaltation, p-n of SCR.69; wells 238 and 240 on the Central dome of the exaltation, p-n of SCR.86; bore 1 in the North-Chistovskoe the dome. (Table 4)

Table. 4 The parameters of Vozdvizhenskoe field

Parameters	The value	the units
Reservoir pressure	15.9	MPa
Reservoir temperature	28	°C
Mass content of asphaltenes in oil	2.91	%
Mass content of resins in the oil	11.97	%
Mass content of waxes in the oil	4.47	%
The content of oil dissolved nitrogen	0.003	m^3/m^3
The content of oil dissolved methane	0.008	m^3/m^3
The content of oil dissolved ethane	0.03	m^3/m^3
The density of the reservoir oil	913.8	kg/m^3
The dynamic viscosity of reservoir oil	0.2093	Pa•c.
Permeability	2.04E-13	D

The results of the calculations are summarized in table 5.

We define the effective diameter of the grains according to the method of Kruger-Conker sandstones Vozdvizhenskoe field.

The filtration rate is not linear and not obey of the law of filtration Darcy, so calculate the filter parameters according to the equation Forchheimer and knowing the values of the limiting pressure gradient calculated above, determine the rate of filtration of fluid according to equation Krasnopolsky [11-12,16].

Table. 5 The results of calculation

Parameters	The results of the calculations (1)	The results of the calculations (2)
Bingham yield point, Pa	$8.02*10^{-3}$	$2.92*10^{-3}$
Bingham yield point of oil based on the number and composition of dissolved gas , Pa	$8.04*10^{-3}$	$2.93*10^{-3}$
Bingham yield point of oil with setted up temperature, Pa	$7.03*10^{-3}$	$2.39*10^{-3}$
The dynamic pressure gradient of shift, MPa/m	$2.18*10^{-2}$	$1.24*10^{-2}$
The pressure gradient of structure limited destruction, MPa/m	$3.02*10^{-2}$	$1.58*10^{-2}$

Having constructed the dependence of the pressure gradient from the velocity one can notice that the filtration rate increases with increasing differential pressure (Fig 6).

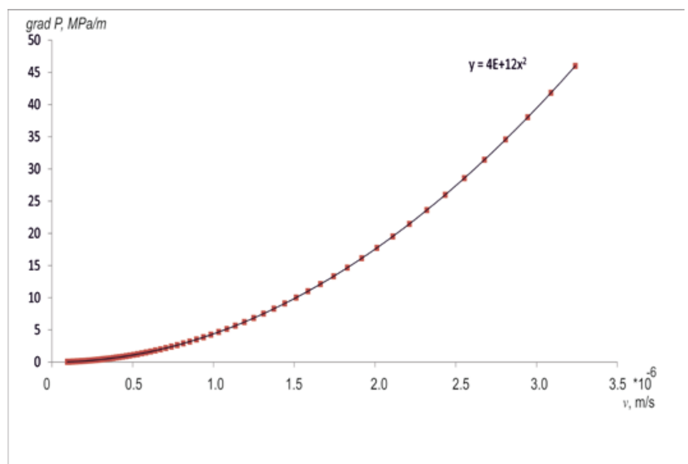

Fig. 6 The dependence of the pressure gradient from the velocity

We define the effective diameter of the grains according to the method of Kruger Zunker sandstones of Vozdvizhenskoe field. Data for the calculations are summarized in table 6.

Table. 6 The calculation of production rate

The diameter of particles, mm	0,01-0,04 mm	0,04-0,1 mm	0,1-0,25 mm	0,25-0,5 mm
% weight	15,2	2,9	79,5	2,4

The effective diameter of the grains is calculated as the arithmetic average between the percentage of all fractions. The effective diameter is determined by the formula

$$\frac{100}{d_{ef}} = \sum \frac{\Delta q_i}{d_i}, \qquad (8)$$

Where di is the average particle diameter of the i-th fraction, equal to the sum of the extreme diameter of this fraction, qi - % of weight.

$$d_i = \frac{d_i^{'} + d_i^{''}}{2}, \qquad (9)$$

Thus the effective diameter of the grains calculated according to the method of Kruger Zunker sandstones were 0.09 mm

Let’s define the initial production rate of horizontal wells, determining drainage area based on the approval Joshi [5-8], given the characteristics of Vozdvizhenskoe field. The initial data for calculation of the wells, and the calculation of production rates of horizontal wells are shown in table 7.

Table. 7 The calculation of production rate

№ bore	length of the mountains. plot, m	formation thickness, m	radius, minor radius of drainage, m* (according to Joshi)	the radius of the larger semi-axis of the drainage, m (according to Joshi)	Permea bility, мкm^2	Initialtion flow rate calculation, m^3/day	Initial tion rate of the fact, m^3/da y	an error, m^3/day
100	225	3.4	1.7	339.5	1.284	120	122	2
200	230	2.4	1.2	342	1.599	101	102	1
1	210	5	2.5	332	2.263	265	256	-9
231	205	1.8	0.9	329.5	1.2	59	55	-4
238	248	2	1	351	1.599	86	88	2
240	235	1.8	0.9	344.5	1.599	76	71	-5
205	220	2.6	1.3	337	1.599	108	105	-3

• The radius minor of drainage wells depended on the quality of drilling the horizontal section of the wellbore within the reservoir, and determined by calculating the total thickness of the layer multiplied by the success rate of penetration in the reservoir. This ratio varies within wide limits from 30 to 80 %. And very much affects the real well production.

CONCLUSION

Horizontal wells can be effectively used in the following conditions [13].:

- in naturally fractured reservoirs for communication and engagement in a single drainage system existing in the reservoir cracks;

- in strata in which there is a possibility of consobrina water and gas;

- during the exploitation of gas deposits in low-permeability and high-permeability reservoirs;

- in deposits with low-permeability reservoirs, horizontal wells improve drainage area per well, thereby reducing the total number of wells needed for reservoir development;

- in deposits with high permeability reservoirs that are characterized by high speed in the borehole, horizontal wells can be used to reduce these speeds that cause turbulence in the gas flow with increasing flow rate;

- in the application of EOR, especially thermal. The effectiveness of the use of horizontal wells in this case is a large area of contact with the formation and increase in throttle response.

Here you can see a new method of determining the initial flow rate of horizontal wells in conditions of high-viscosity oils:

1. Let’s define the calculation method parameters from table 3;
2. Let’s define the effective diameter of the sand grains of the reservoir through which will be filtered according to the method of Kruger-Conker
3. Let’s find the coefficients a and b, from the formula of Forchheimer.
4. Let’s determine the rate of filtration of fluid, according to the law Krasnopolsky (nonlinear filtering) using the values of the boundary pressure gradients.
5. Let’s determine the flow rate of horizontal wells, calculating the area of the zone filter according to the assumption Joshi.

Calculations by this method showed very acceptable accuracy of calculations has allowed to determine the production rate of a horizontal well producing heavy oil with a minimum error. For comparison, the calculation of the rate of filtration by the classic formulas didn’t show good results. Table 2

It is very important to make the right forecast of production of each individual field. For this it is necessary to calculate the fluid flow in each hole. The above proposed method of determining the flow rate of horizontal wells in conditions of a nonlinear filter was first tested on the Vozdvigenskoe field of high-viscosity oil.

The above method of calculating flow rate of horizontal wells in the oil fields with high-viscosity oil allows to increase accuracy of the design calculations and to bring the level of their errors to a minimum: from 95% to 3%.

This technique should be recommended to determine the flow rate of horizontal wells in heavy oil fields.

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