

Table 1

Results of the investigation of anisotropy of permeability from core samples

Model number	Reservoir characteristics			Kr / Kz	Direction of anisotropy
	φ, %	Kr,z, мД	Swc, %		
1230-02-A//	18,6	768,8	29,1	2,1	NE
1230-02-B//	18,4	371,2	28,6		NW
1232-02-A//	17,5	165,8	37,4	2,2	NE
1232-02-B//	17,4	74,6	32,7		NW
1234-02-A//	17,5	231,2	36,9	2,1	NE
1234-02-B//	17,5	112,7	32,2		NW
1236-02-A//	18,6	464,7	34,5	2,2	NE
1236-02-B//	18,5	211,5	31,8		NW
1237-02-A//	19,0	594,9	30,5	2,3	NE
1237-02-B//	19,1	256,4	28,6		NW
1250-02-A//	19,0	273,9	24,9	1,9	NE
1250-02-B//	19,1	141,2	26,8		NW

From Table 1 it follows that the predominant direction of anisotropy (with an average coefficient of 2.13) is the northeastern direction. These data correspond to the directivity roses diagram of the long-particle and microcrack diagrams that were formed during the formation of the deposit.

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## TURBULENT FLOW OF HYDROCARBON FLUIDS WITH POLYMER ADDITIVES

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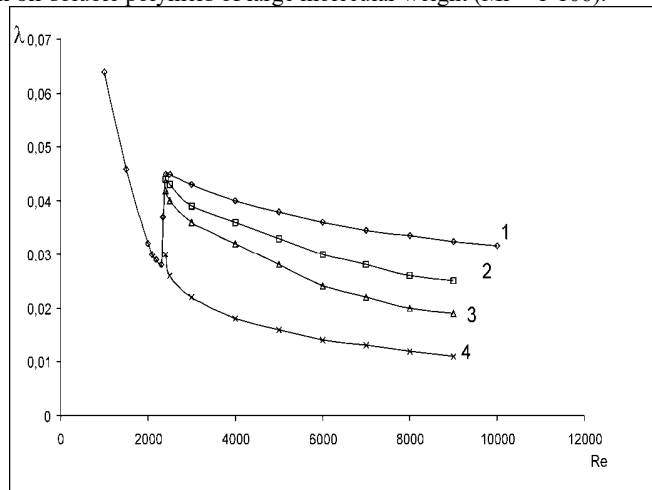
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The introduction of an extremely small amount of polymer (~10 g/m<sup>3</sup> or 0,001% mass.) in a turbulent oil stream leads to partial laminarization of the flow [4] and, as a result, to a decrease in the hydraulic resistance coefficient of the polymer solution (λ<sub>P</sub>) as compared to the coefficient of the pure solvent (λ<sub>S</sub>). In accordance with the Darcy-Weisbach equation (1) a decrease in the resistance coefficient is accompanied by a decrease in pressure loss due to friction (ΔP) at a constant volume flow rate (Q = constant) or an increase in the volumetric flow velocity at a constant pressure drop (ΔP = constant)

$$\Delta P = \lambda \cdot \frac{L}{4\pi^2 \cdot R^5} \cdot \rho \cdot Q^2 \quad (1)$$

The numerical values of  $\lambda_P$  at  $Re > 2300$  fall in the region above the Blasius curve (Fig. 1). The region below the curve is a hypothetical extension of the laminar flow curve to the turbulent region i.e. for the resistance coefficients of polymer solutions to satisfy the condition  $64/Re < \lambda_P < 0,3164/Re^{0,25}$ . The higher the molecular weight of the polymer sample ( $M_r$ ) and the greater its concentration ( $C$ ) are, the closer value  $\lambda_P$  to the laminar flow curve and the greater difference  $\Delta\lambda = \lambda_S - \lambda_P$ , are, the lesser internal friction between the layers of the liquid. To reduce the resistance of hydrocarbon liquids and their mixtures is a capability of all oil-soluble polymers of large molecular weight ( $M_r > 1 \cdot 10^6$ ).

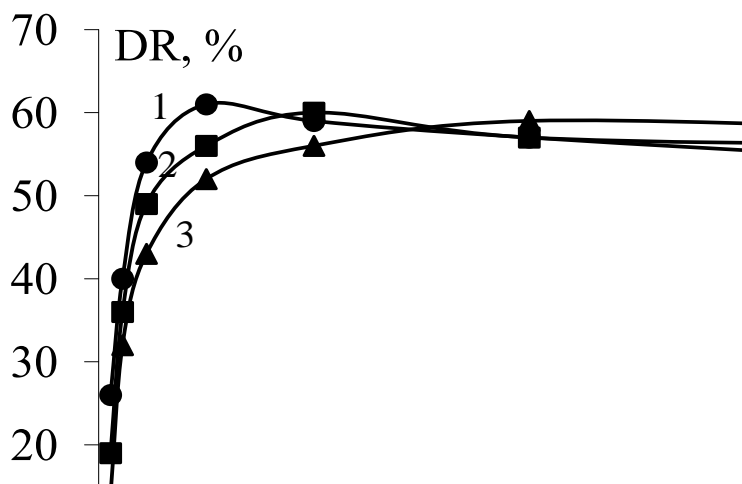


**Fig. 1** Dependence of the coefficient of hydrodynamic resistance of solution of polyisoprene in oil on the Reynolds number at different polymer concentrations: 1 – Blasius curve  $\lambda = 0,3164/Re^{0,25}$  for turbulent flow of Newtonian liquids (solvents); 4 – Poiseuille curve  $\lambda = 64/Re$  for laminar flow of Newtonian and non-Newtonian fluids; Concentration of polymer solutions: 2 –  $C = 0,05 \kappa z/m^3$ ; 3 –  $C = 0,1 \kappa z/m^3$ .

Quantitatively, the magnitude of the Toms effect (DR) is usually estimated by a relative change in the coefficient of hydraulic resistance (2), shown as a percentage. The value of DR characterizes the decrease in energy costs for transporting a unit volum (2)

where  $\lambda_S = \lambda_{pipe}$  – coefficient of hydraulic resistance of pure solvent;  $\lambda_P$  – coefficient of hydraulic resistance of polymer solution.

In recent times, pipeline transport of not only crude oil with polymer additives is carried out on an industrial scale [1], but separate fractions of oil (gasoline, kerosene and diesel fuel) with anti-turbulent additives are also pumped along the product pipelines. It has been experimentally established that the higher the efficiency of the same polymer sample is, the lighter the oil fraction. In the hydrocarbon series, gasoline-kerosene-diesel fuel-oil, a decrease in the efficiency of the polymer additive is observed. As shown in Fig. 2 (curves 2 and 3), with increasing density and boiling point of individual fractions of petroleum (gasoline – 50-150 °C and  $\rho \sim 710 \text{ kg/m}^3$ , kerosene – 150-250 °C and  $\rho \sim 780 \text{ kg/m}^3$ ) the optimum polymer concentrations ( $C_{opt}$ ) at which the maximum value of the drag reduction effect (DRMAX ~ 60 %) is reached in these liquids, is shifted to the region of higher concentrations. For gasoline, the optimal concentration for gasoline is  $C_{opt} = 20 \text{ g/m}^3$ , and twice the value for kerosene,  $C_{opt} = 40 \text{ g/m}^3$ .



**Fig. 2.** Dependence of the drag reduction effect (DR) at  $\tau W = 10 \text{ Pa}$  = constant on the concentration ( $C$ ) of polyhexene in hydrocarbon liquids: 1 - liquefied natural gas (LNG); 2 - gasoline; 3 - kerosene.

Hydrocarbon mixtures (gasoline and kerosene) under normal conditions exist in liquid state, therefore the hydrodynamic laws related to their transfer through pipelines, with polymer additives and without polymer additives, are studied well and they are typical for liquid media. Currently, liquefied natural gas (LNG) technologies are rapidly developing for its transportation in a liquid state through pipelines and in tankers. To reduce the energy costs for LNG transportation and to reduce the downtime of tankers during the loading and unloading of products, we first carried out laboratory studies of the influence of the oil-soluble polymer (polyhexene) on the flow velocity of the liquefied propane-butane mixture and calculated the magnitude of the hydrodynamic resistance reduction effect. Experiments with solutions of LNG containing different amounts of dissolved polyhexene (Fig. 2, curve 1) were carried out in the closed airtight laboratory bench at room temperature and elevated pressure. It was established (Fig. 2) that in order to achieve maximum effect, an even lower polymer concentration is required, i.e. total  $C_{opt} = 100 \text{ g/m}^3$ . Thus, to intensify the transfer of liquefied natural gas, it is also possible to use drag-reduction additives based on high molecular weight petroleum-soluble polymers.

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### EFFECT OF TEMPERATURE ON THE RESERVOIR PROPERTIES OF THE SHALE ROCKS DURING PYROLYSIS

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Development and application of non-traditional technologies are required to extract hydrocarbons that contain in deposits in Western Siberia of the Bazhenov suite and other geological formations. One of the innovative solution of the aim is the development of a method that based on thermal action. The method suggests an improvement in reservoir properties by increasing the void space and converting kerogen to light oil as a result of initiating the pyrolysis process.

The process conversion of kerogen to synthetic oil can be achieved by thermal dissolution, hydrogenation or pyrolysis [5]. Pyrolysis is most closely related to the natural conversion of kerogen, using the high temperatures to compensate for the geological time frame [2,7]. During pyrolysis the kerogen is heated in the absence of oxygen to produce a substance that decomposes kerogen.

High temperatures provide a fast conversion of kerogen. It has been found that shale treatment increases product quality at lower temperatures for a long time. A high pressure also improves the quality of oil, since evaporation prevents the stimulation of secondary cracking reactions. Nevertheless, a low temperature and a high pressure reduce the overall yield [8].

The aim of this work is to analyze the effect of high temperatures on the reservoir properties of shale rocks.

Laboratory experiments were carried out on crushed samples taken from the core of exploratory wells of the Southern and Southern Kinyaminskoye oil fields (Tyumen region). Experiments determine the open porosity, bulk and mineralogical density, gas permeability.

Matrix permeability of the crushed samples was carried out by the method - Gas Research Institute (GRI) in accordance with GRI-95/0496 "Development of Laboratory and Petrophysical Techniques for Evaluating Shale Reservoirs" [3,4]. The samples were heated to a certain temperature in a muffle furnace. The experiments were carried out on a matrix permeate SMP-200 on the determination of gas permeability.

The effect of heat treatment on core samples was investigated. One sample of the Southern deposit was heated to the temperature of 350 °C in one stage, and the other sample was heated to stepwise to the same temperature at an interval of 150 °C. At each stage, the permeability of the sample was measured by the GRI method. Similar processing was carried out for samples of the Southern Kinyamin deposit. As a result of the experimental work, graphs of the pressure changes were obtained with time, from which the permeability coefficient for gas was calculated.

The bulk density of the core samples of the Southern deposit increased by 28.7% to 2.648 g/cm<sup>3</sup> when it was heated by 32.7% to 2.729 g/cm<sup>3</sup>. The values of the mineralogical density and the tendency of their change do not significantly differ from the bulk density. The overall density of the samples of the Yuzhno-Kinyamin deposit increased by 3.6% to 2.302 g/cm<sup>3</sup> when it heated in one stage by 9.2% to 2.428 g/cm<sup>3</sup>. Mineralogical density rose by 5.5% to 2.387 g/cm<sup>3</sup>, with stepwise heating - by 10.9% to 2.51 g/cm<sup>3</sup>.

When the core sample of the Southern Deposit was heated (Fig. 1) to 350 °C, the coefficient of open porosity increased from 0.46% to 22.55%, and the gas permeability coefficient, that changed from  $2.28 \cdot 10^{-9} \text{ mD}$  to  $1.77 \cdot 10^{-2} \text{ mD}$ . The coefficient of open porosity and permeability reached of 24.14% and 0.32 mD with stepwise heating, consequently.