**PROJETO DE ENSAIO EXPERIMENTAL DE TECNOLOGIA DE INUNDAÇÃO DE
POLÍMEROS EM DEPÓSITOS DO CAZAQUISTÃO OCIDENTAL****EXPERIMENTAL SUPPORT OF FIELD TRIAL ON THE POLYMER FLOODING
TECHNOLOGY SUBSTANTIATION IN THE OIL FIELD OF WESTERN KAZAKHSTAN****ПРОЕКТ ОПЫТНО-ПРОМЫСЛОВОГО ИСПЫТАНИЯ ТЕХНОЛОГИИ ПОЛИМЕРНОГО
ЗАВОДНЕНИЯ НА МЕСТОРОЖДЕНИЯХ ЗАПАДНОГО КАЗАХСТАНА**

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Received 01 May 2020; received in revised form 23 May 2020; accepted 19 June 2020

RESUMO

Um dos métodos químicos de impacto no reservatório para melhorar a eficiência do processo de desenvolvimento de campos de petróleo é inundação de polímeros. Este artigo descreve um estudo de viabilidade da eficácia da aplicação da tecnologia de inundação de polímeros no campo no Cazaquistão Ocidental. Este campo é caracterizado por alta viscosidade do óleo do reservatório, corte de água e heterogeneidade dinâmica do reservatório. A experiência mundial na aplicação de inundações de polímeros em campos análogos mostra alta eficiência tecnológica. São apresentados os resultados da análise da experiência da aplicação da tecnologia em campos análogos, estudos físico-químicos de polímeros, estudos de filtração em tubos cheios de areia, modelagem hidrodinâmica de inundações de polímeros e a relação custo-benefício esperada da introdução da tecnologia, aplicada às condições do campo de Karazhanbas com alta viscosidade do óleo de reservatório. A análise baseada na experiência de aplicação de inundações de polímeros em campos de petróleo de alta viscosidade, estudos de laboratório e cálculos estimados da produção esperada no modelo geológico e hidrodinâmico do setor mostra a diminuição no corte de água, o aumento na produção de petróleo e na recuperação atual e final de óleo.

Palavras-chave: estudos de filtração, modelagem hidrodinâmica, eficiência técnica e econômica, inundação de polímeros, ensaio de campo.

ABSTRACT

One of the chemical methods of stimulating the reservoir to increase the efficiency of the oil field development process is polymer flooding. This article conducted a feasibility study of the effectiveness of the application of polymer flooding technology in one field in Western Kazakhstan. This field is characterized by high viscosity of reservoir oil, water cut, and dynamic heterogeneity of the reservoir. World experience in the application of polymer flooding in analogous fields shows high technological efficiency. Presented results of the analysis of the experience of applying technology in analogous fields, physicochemical studies of polymers, filtration studies on bulk models, hydrodynamic modeling of polymer flooding and the expected cost-effectiveness of introducing the technology, as applied to the conditions of the Karazhanbas oil field with high viscosity of reservoir oil. The analysis based on the experience of applying polymer flooding in high-viscosity oil fields, laboratory studies and estimated calculations of the expected production in the sector geological and hydrodynamic model shows a decrease in water cut, an increase in oil production, and an increase in current and final oil recovery.

Keywords: *filtration studies, hydrodynamic modeling, technical and economic efficiency, polymer flooding (PF), field trial (FT).*

АННОТАЦИЯ

Одним из химических методов воздействия на пласт для повышения эффективности процесса разработки нефтяных месторождений является полимерное заводнение пластов. В данной статье проведено технико-экономическая оценка эффективности применения технологии полимерного заводнения на одной месторождения Западного Казахстана. Данное месторождение характеризуется высокой вязкостью пластовой нефти, обводненностью и динамической неоднородностью пласта. Мировой опыт применения полимерного заводнения на месторождениях аналогах показывает высокую технологическую эффективность. Приведены результаты анализа опыта применения технологии на месторождениях аналогах, физико-химических исследований полимеров, фильтрационных исследований на насыпных моделях, гидродинамического моделирования процесса полимерного заводнения и ожидаемой экономической эффективности внедрения технологии, применительно к условиям месторождения Каражанбас с высокой вязкостью пластовой нефти. Проведенный анализ на основе опыта применения полимерного заводнения на месторождениях высоковязкой нефти, проведенных лабораторных исследований, оценочных расчетов ожидаемой добычи на секторной геолого-гидродинамической модели, показывает снижение обводненности, увеличение добычи нефти, прироста текущей и конечной нефтеотдачи.

Ключевые слова: *фильтрационные исследования, гидродинамическое моделирование, технико-экономическая эффективность, полимерное заводнение (ПЗ), опытно-промысловое испытание (ОПИ).*

1. INTRODUCTION

Traditional methods for increasing oil recovery in high-viscosity and heavy oil fields are aimed at reducing its viscosity and increasing mobility by injecting the heat into the reservoir. In some cases, thermal methods do not give a good result, for example, for thin-layered or deep-seated formations. Currently, the chemical methods of stimulation are the most commonly used to increase the efficiency of oil field development.

It was previously believed that polymer flooding was limited to use only in fields with light oil or with medium viscous oil, and thermal oil recovery methods were strictly applied in fields characterized by high viscosity oil (Babaytsev *et al.*, 2017; Kuznetsova and Rabinskiy, 2019; Formalev *et al.*, 2017; Gendler *et al.*, 2019). However, recently in world practice, this provision is no longer observed in connection with the successful use of polymer flooding for high-viscosity oil, where thermal methods do not seem feasible (Radyuk *et al.*, 2019; Samarin *et al.*, 2019). With the accumulation of new knowledge about the process, the development of new polymer compositions, and the reassessment of the rationality of polymer flooding parameters, this technology becomes economically viable when oil is extracted from reservoirs with a viscosity exceeding 100 mPa·s (Buzinov and Umrikhin,

1984).

This article presents the results of an analysis of the experience of applying technology in analogous fields, physicochemical studies of polymers, filtration studies on bulk models, hydrodynamic modeling of polymer flooding and the expected cost-effectiveness of introducing the technology, as applied to the conditions of the Karazhanbas field with high viscosity of reservoir oil. The results of experimental studies and hydrodynamic modeling of the polymer flooding process shows high technical and economic efficiency and gives the basis for field trial (Delamaide *et al.*, 2015; Orlov *et al.*, 2001; Lazarenko *et al.*, 2019; Formalev *et al.*, 2019; Bulychev, 2019; Sultanbekov *et al.*, 2020).

The experience of using analogs at deposits, to compare the results of the technology implementation at analogs deposits, the main technological parameters were summarized in Table 1 (Moe Soe Let *et al.*, 2012; Delamaide *et al.*, 2013). In this article, according to the author, we present the most striking example of the application of polymer flooding technology in a field with high viscosity of reservoir oil. The Pelican Lake field is similar to the Karazhanbas field in geological and physical parameters and is located 250 km north of Edmonton, Alberta, Canada. Development began in 1980. The field covers an area of 177.000 hectares and is part of the significantly larger "Wabasca" oil field. Geological

reserves are estimated at 6.4 billion barrels, and oil recovery factor is in the range of 5-10% (Delamaide *et al.*, 2013).

The dissolved gas is used as the development mode. However, the initial reservoir pressure is low, and very little dissolved gas is contained in the oil. Also, due to the high viscosity of the oil, the first vertical wells drilled in 1980-1981 were unprofitable with a flow rate below 30 barrels per day, characterized by an intensive drop to 10 barrels per day. The use of thermal methods could not improve oil recovery due to heat loss in such small thickness deposits. The introduction of horizontal well drilling yielded slightly better results in oil production by increasing coverage over the area.

2. MATERIALS AND METHODS

Despite the high oil viscosity, the conditions and characteristics of the field were ideal for polymer flooding: low formation temperatures, low water salinity, lack of active water (aquifer), and high permeability values (Wei *et al.*, 2007; Manichand *et al.*, 2010; Xiaodong and Jian, 2013). The first polymer flooding test was launched in 1996 in a cell with one injection well and two responsive production wells. This FT was unsuccessful due to the failure to achieve the planned viscosity (100-200 mPa*s) (Akulshin, 2000). In addition, aquifer water in this area contained a large amount of Fe^{2+} . In this regard, preliminary aeration of the solution was started with the aim of changing Fe^{2+} in $\text{Fe}(\text{OH})_3$. Despite this, the injection decreased significantly due to the clogging of the incorrectly installed filter by iron particles, and the FT was stopped due to a change of management and incorrect conduct of the FT (Azga and Settari, 1982; Orlov *et al.*, 2003; Wassmuth *et al.*, 2007; Delamaide, 2014; Sheng *et al.*, 2015; Sultanbekov and Nazarova, 2019).

The second FT was launched in May 2005 with a planned initial solution viscosity of 20 mPa*s, followed by a decrease to 13 mPa*s. After analyzing the results of the first FT and laboratory studies, it was found that there is no need for high values of the viscosity of the polymer solution to improve the mobility coefficient. In order to avoid colmatization, it was also decided to reduce the molecular weight of the polymer to 12.5×10^6 Daltons. A cell of 5 horizontal wells with a horizontal stem of 1.400 m and a borehole distance of 175 m was selected as the FT site. The response of production wells to injection was observed in February, April, and September 2006 for each of the three wells. In the first well, oil

production increased from 18 bbl/day to 232 bbl/day, from 9 bbl/day to 364 bbl/day in the central well, and from 16 bbl/day to 139 bbl/day in the last well (Figure 1).

The main indicator of the success of applying the PF is the relatively low rate of water cut growth for all three wells compared to the adjacent plot of water flow with normal flooding (Figure 2) (Amelin *et al.*, 1978; Amelin and Subbotina, 1986; Barashkin and Samarin, 2005). The cumulative injection is 0.3 d. pore volume (PV), the final predicted oil recovery factor reaches 25%. Based on the results of the successful conduct of the FT, it was decided to expand the impact area and start the PF in new areas.

A FT was also conducted at Pelican Lake to determine the effectiveness of the PF from the very beginning of development instead of the usual waterflooding and the regime of dissolved gas and to determine the variability of the effect of the PF with even more highly viscous oil. According to the results, it was found that the efficiency of oil production and improved oil recovery as a whole increase. The use of oil and gas at the present time indicates that the efficiency becomes lower compared to an increase in the viscosity of the oil, but nevertheless, the oil recovery becomes higher compared to a traditional refinery.

Based on the results of the successful conduct of several field trials at the Pelican Lake field, the effectiveness of PF was also proven for oil with a viscosity of up to 10,000 cPs. However, the effectiveness of PF in areas with an oil viscosity from 1000 cPs to 2000 cPs remains better and is characterized by a low rate of increase in water cut (Bagrintseva, 1982; Amelin *et al.*, 1991; Amelin *et al.*, 1994). With increasing viscosity, this effect decreases, but in the end, a significant increase in oil recovery is still achieved. In the case when the PF is used as the primary method of oil recovery from the very beginning of development, the effectiveness of the PF reaches its maximum value and is accompanied by a long and stable selection of oil.

To align the injectivity profile and regulate the waterflooding process, was used a technology with polymer systems based on a water-soluble AN-132 brand of acrylamide. Area of use, collector type is terrigenous – porous. Productive zone of the well occurring in the chalk deposits. They are represented by sandstones and argillaceous sandstones, characterized by alternating formations with medium and high porosity and permeability. The artificial bottom hole is 1330 m,

the current bottom hole is 1291.5 m. The accumulated injection is 4 056 344 m³ of water.

3. RESULTS AND DISCUSSION:

3.1. Site-Specific Conditions of the Karazhanbas Deposit

The effectiveness of polymer flooding technology is largely determined by the properties of the reagents used. The selection of reagents should be carried out, taking into account the individual characteristics and development status of a particular field (Balakin *et al.*, 1998). Associative polymers are one of the promising types of polymers for highly viscous deposits. These polymers have in their structure hydrophilic and hydrophobic units of macromolecules and consist of a long hydrophilic chain with a small number of hydrophobic groups located along with the main chain or at its ends (Barenblatt *et al.*, 1984; Barenblatt *et al.*, 1992).

Associative polymers have a high thickening ability in waters of various salinity, and this fact is an advantage of associative polymers over hydrolyzed polyacrylamides. Another advantage of associative polymers is their higher resistance to mechanical degradation due to the more rigid structure of macromolecules (Figure 3).

The authors propose to test the technology of polymer flooding with a combination of straightening of the injectivity profile deep in the reservoir. To do this, you need to choose two types of polymer, one for displacement (PF), the other conformance control (CC). When selecting a polymer for the conditions of a particular field, one should take into account: physico-chemical properties of produced and injected water; reservoir temperature; permeability and porosity of the formation; pore size; reservoir heterogeneity; mineralogical composition of reservoir rocks (Barenblatt *et al.*, 1960; Buzinov and Umrikhin, 1984; Bourdais and Algoa, 1984; Bourdais *et al.*, 1984; Basniev *et al.*, 1993).

For flooding at the Karazhanbas field, its own produced water is used (Table 2), the studied water according to the Sulin type is referred to as calcium chloride, with a total salinity of 26 g/l (at a density of 1.018 g/cm³), with a predominant content of chloride ions (15.7 g/l), pH of water at the neutral level – 7.1 units. The reservoir temperature of the Karazhanbas deposit in the zones of water injection does not exceed 30°C. The temperature regime of the reservoir is favorable for polymer flooding.

3.2. Application of Polymer Flooding Technology

Permeability, porosity, the pore size of the collector are interrelated factors, and their magnitude influences the choice of molecular weight and polymer size (Bourdais *et al.*, 1983). The molecular size of the polymer decreases with increasing salinity of the water while increasing the restriction on permeability. The molecular size of the polymer is selected according to the existing size range of the pore channels. Existing types of polymers for PNP have a limit on the permeability of at least 50 mD and injectivity of at least 50 m³/day (Vakhitov *et al.*, 1980; Victorin, 1988). The permeability of the productive horizons of the field (against core, well logging, well test) vary widely from units to several thousand mD. In the areas of water injection, the injectivity is an average of 50 m³/day with restriction by the nozzle and can potentially take more than 200 m³/day and higher. Existing ranges of permeability and injection well regimes are favorable for polymer flooding (Vlasov *et al.*, 1997; Vlasov *et al.*, 1998; Volkov *et al.*, 1998).

To assess the effectiveness of polymer flooding in this work, we tested two types of polymer: 1) for oil displacement (PF) – AR-RV-1 with a molecular weight of 7.39 million Daltons; 2) for conformance control (CC) – AR-RV-2 with a molecular weight of 15.15 million Daltons. The experiments used real formation water purified from oil products, solids, and iron ions (Table 2). The dynamic viscosity of the solutions was measured on an Anton-Paar automatic high-precision viscometer in the ranges of shear rates of 0-100 s⁻¹ and temperature of 40°C. Measurement of the rheological properties of each sample was repeated twice and averaged under the condition of the minimal discrepancy; in the opposite case, the measurement was repeated. All samples of the polymer solution were prepared under atmospheric conditions. The results of physico-chemical analyzes and rheological studies are presented in Tables 3-5 and in Figure 4. As follows from the presented tables and figures, associative polymers have high thickening ability, good filterability, excellent solubility, and high resistance to aging under reservoir conditions of the Karazhanbas field.

In this work, a series of filtration studies were carried out to assess the effectiveness of filtration in the low-permeable part of the reservoir, the blocking coefficient of the high-permeable part of the reservoir, and to replace the residual oil after flooding. Bulk models with layered heterogeneous permeability, which are typical for the

Karazhanbas field, were used as a reservoir model. Model size: 4.5x4.5x30cm, permeability by layers: 100/500/1200 mD, thickness by layers: 0.75/3.15/0.6 cm (Figure 5). The viscosity of the model reservoir oil was 881.7 cps, a combination of oil and diesel was used as model oil, the temperature was 28°C. Figures 6-7 and Tables 6-10 show the results of the studies. As follows from the presented table and figure data, these experiments confirm the positive ability of the polymer solution to be filterable in the rock. This can be seen by the pressure gradient of the injection and its stabilization through 7-10 pore volumes of pumping the solution.

The results of filtration studies are presented in Tables 8-10 and Figure 7. As follows from the presented figures and tables, the optimal concentration of AR-RV-1 polymer in water was 2000 mg/l, and the optimal rim size was 0.3 units. Pore volume (PV), the optimal concentration of the CC rim, is 0.1 PV at a concentration of 3000 mg/l of AR-RV-2 polymer. With this design of injection, the maximum increase in the displacement coefficient is reached and amounts to 19.07%.

The thickness of an effective oil-saturated formation is not less than 10 m; weighted average permeability over the thickness of the reservoir is more than 200 mD; formation temperature – not more than 70°C; bedding – more than three layers; the coefficient of variation by bedding is less than 0.5; weighted average current oil saturation – more than 0.45; absence of a gas cap; absence of underlying water; absence or low degree of fracture.

Based on the selection criteria, a site with four conjugate elements of a 7-point waterflooding system was selected. The calculation of development indicators was carried out on the model of non-volatile oil (Black oil model). The prediction of polymer flooding was carried out on the “Polymer flooding” module, with setting the parameters of adsorption on the rock, polymer viscosity, mechanical destruction, resistance coefficient according to the results of laboratory studies of this work.

The forecast of the main technological development indicators was carried out in two ways:

- 1) The basic option is to continue flooding to 12/31/2034, while the injectivity and production rates of the wells remain constant and equal to the levels of December 2018.

- 2) Polymer flooding – from 01/01/2019 to 03/18/2020 injection of a polymer solution AR-

RV-2 with a concentration of 3.000 mg/l (viscosity 561.44 cPz), from 03/19/2020 to 10/24/2023 injection of a polymer solution with a concentration of 2.000 mg/l (viscosity 39.56 cPs), from 10.25.2023 to 12.31.2034 water injection.

In the basic option, by December 31, 2035, cumulative oil production will amount to 514.862 thousand tons, oil recovery factor 26.4%. In the case of polymer flooding, by December 31, 2035, cumulative oil production will amount to 724.2 thousand tons, an oil recovery factor of 37.1%. The increase in oil recovery due to polymer flooding will amount to 10.8%, additional oil production – 209.338 thousand tons. The dynamics of the development indicators for the base case and polymer flooding option are presented in Figure 8.

4. CONCLUSIONS:

The polymer solution AR-RV-2 shows excellent blocking ability of highly permeable channels, on average, when pumping from 0.2 to 0.6 units. The pore volume blocking coefficient is more than 99%. Filtration studies on oil displacement were carried out in three stages:

1. Tests to add oil with a polymer solution of various concentrations after pumping two pore volumes of water in order to determine the optimal ratio of the mobility of displaced and displacing phases and optimizing the concentration (viscosity) of the polymer rim.

2. At the same concentration of the polymer solution according to step 1, after pumping two pore volumes of water, pumping the polymer solution with different volumes of the rim, in order to optimize the rim volume.

3. Modification of the design of rims with the complex effect of PF and CC – pumping of different variants of the rim and polymer concentration (CC) during polymer exposure taking into account stage 1 and 2.

The optimal concentration of AR-RV-1 polymer in water made up 2000 mg/L; the optimal rim size was 0.3 units. Pore volume (PV), the optimal concentration of the runway rim is 0.1 PV at a concentration of 3000 mg/l of AR-RV-2 polymer. With this design of injection, the maximum increase in the displacement coefficient is reached and amounts to 19.07%.

To select a site for the field trial of polymer flooding (PF FT), a two-stage screening of the field was performed according to a number of geological, physical, and technological criteria.

During the first stage, an analysis was made of the current state of development of the field by objects in order to determine the site, and then, during a detailed analysis of the site, waterflooding elements were selected for the water treatment.

The analysis based on the experience of applying polymer flooding in high-viscosity oil fields, laboratory studies and estimated calculations of the expected production in the sector geological and hydrodynamic model shows a decrease in water cut, an increase in oil production, and an increase in current and final oil recovery. An economic analysis, taking into account the existing market situation, shows that the payback index is 4.8 units, and the payback period is 5 years. This direction for increasing oil recovery is promising and requires further testing at the Karazhanbas field.

5. ACKNOWLEDGMENTS:

The authors would like to thank the Ministry of Education of the Republic of Kazakhstan (MOERK), SATBAYEV UNIVERSITY Almaty, Kazakhstan, to support this study through a research management grant. Competition for grant funding for scientific and technical projects for 2018-2020, AR 05130483 "Scientific and technical foundations for reducing the viscosity of Kazakhstani oils, providing a significant increase in oil recovery".

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Table 1. Technological parameters of the most famous works on the use of PF

Deposit occurrence	Country	PF status	Depth, m	Bed temp., °C	Effective depth, m	Porosity coef. , %	Permeability coef. , mD	Initial pressure, bar	Density, API	Keservoir oil viscosity, cPs	Injected amount, PV
Pelican lake	Canada	All deposits	300-450	12-17	1-9	28-32	300-5000	18-26	12-14	800-10000	>0.35
Marmul	Oman	All deposits	900	46	20	25-30	100-2000	80	22		0.63
Bodo	Canada	FT	770	25	3.2	27-33	1000	68	14	400	
Suffied Caen	Canada	FT	950	21	2-9	26.5	500-2000	104.4	17	70-100	
El Corcobo	Argentina	FT	650	38	0.5-18	27-33	500-4000	32.4	18	160-300	
SZ36-1, Bohai bay	China	FT	1300-	65	61.5	28-35	2600	143	11.4-19	13-380	>0.067
JZW, Bohai bay	China	FT	1700	57	20	22-36	10-5000		17-22	10-30	>0.18
Diademina	Argentina	Ext. FT	1020	50	4-12	30	10-5000		20	100	0.8
Karazhanbas	Kazakhstan	Project	300-400	26	8-20	33	510-1500	38-48	19	378-541	0.4

Table 1. The results of physico-chemical analysis of wastewater for pressure maintenance method

Index	Results
pH medium	7.1
Density, g/cm ³	1.018
Calcium content (Ca ²⁺), mg / dm ³	1 202.4
Magnium content (Mg ²⁺), mg/dm ³	608.0
The amount of potassium and sodium (K ⁺ +Na ⁺), mg/dm ³	7 894.8
Chloride content (Cl ⁻), mg/dm ³	15 714.6
Sulfate content (SO ₄ ²⁻), mg/dm ³	Not detected
Hydrocarbon content (HCO ₃ ⁻³), mg/dm ³	561.2
Mineralization, mg/dm ³	26 008.0
Sulin type	Cl-Ca
Total water hardness, mg-Equiv/l	110.0
Total iron content(Fe ²⁺ , Fe ³⁺), mg/dm ³	50.4

Table 2. Physico-chemical analysis of polymers AR-RV-1, AR-RV-2

Parameter	AR-RV-1		AR-RV-2	
	Fact	Valuation	Fact	Valuation
Molecular weight, mil. Daltons	7.39	-	15.15	-
The content of the main substance, %	92.51	>90	90.31	>90
Degree of hydrolysis, %	20.6	15-25	16.96	15-25
Intrinsic viscosity, dl/g	12.6	10-30	22.3	10-25
Insoluble residue, %	0.88	<1	0.31	<1
Filterability, ea	0.6	<=1.5	1.04	<=1.5
Dissolution time, hr	3	3	3	3
Compliance with the requirements	Match		Match	

Table 3. Viscosity of polymers at various concentrations

Polymer concentration, ppm	Dynamic viscosity at 7,34c-1, cPs	
	AR-RV-2 (CC)	AR-RV-1 (PF)
1000	27.5	13.3
2000	242.6	47.0
3000	540.6	70.0
5000	1162.0	199.8

Table 4. The results of determining the resistance to the aging of polymers within 15 days

Polymer	Resistance to aging, %		
	0 days	7 days	14 days
AR-RV-1 (PF)	100%	99%	93%
AR-RV-2 (CC)	100%	97%	97%

Table 6. The results of the injection test of the polymer solution AR-RV-1 on the core

Polymer concentration, mg/l	Permeability, mD		Porosity, %	Polymer viscosity, cPs		Injection stabilization pressure, mPa	Coefficient, U.	
	for gas	for water		in	out		resistance	residual resistance
2000	200	29	16.2	47	34.5	2.07	213.32	31.53
2000	200	31	16.12	47	33.1	1.35	150.53	27.88

Table 5. Studies on the blocking ability of the polymer solution AR-RV-2

Sample permeability, mD	Pore volume pumped, unit fraction	Injection pressure, mPa	Permeability after, mD	Blocking coefficient, %
370.2	0.2	0.379	3.5	99.05
352.9	0.4	0.79	1.8	99.49
419.2	0.6	1.06	2	99.52

Table 6. Results of filtration studies of the 1st stage

Concentration, mg/l	Viscosity, cPs	No. spec.	Water permeability, mD	Porosity, %	Oil saturation %	Displacement ratio, %		
						before	after	growth
0	1	6	213	15,46	59.77	26.79	30.19	3.4
1000	12	7	209	14,54	60.1	28	37.8	9.8
1500	23	2	205	14,76	60.36	27.65	40.98	13.33
2000	35	3	218	14,57	60.8	27.71	43.94	16.23
2500	48	1	212	15	60.4	27.25	44.15	16.9
3000	64	5	201	14,22	59.81	27.76	45.1	17.34

Table 7. Results of filtration studies of the 2nd stage

Polymer rim size, PV	No. sp.	Water permeability, mD	Porosity, %	Oil saturation %	Displacement ratio, %		
					before	after	growth
0	6	213	15.46	59.77	26.79	30.19	3.4
0.1	8	198	14.7	59.86	27.6	35.2	7.6
0.2	9	197	14.13	59.78	27.29	49.49	13.2
0.3	3	218	14.57	60.8	27.71	43.94	16.23
0.4	16	206	14.76	60.2	26.92	44.32	17.4
0.5	4	203	14.34	60.36	27.06	45.64	18.58

Table 8. Results of filtration studies of the 3rd stage

AR-RV-2 CC + AR-RV-1 PF	Visco-sity, cPs	No. spec.	Water permeability, mD	Poro-sity, %	Oil saturation %	Displacement ratio, %		
						before	after	growth
0 PV+0.3PV2000 mg/l	-/35	3	208	14.57	60.8	27.71	43.94	16.23
0.05PV2000mg/l +0.3pv2000mg/l	173/35	14	210	14.15	59.86	27.77	44.66	16.89
0.1PV2000mg/l+0.3PV2000mg/l	173/35	10	203	14.39	60.43	27.2	45	17.8
0.05PV3000mg/l +0.3pv2000mg/l	505/35	15	193	14.44	60.02	27.2	45.6	18.4
0.1PV3000mg/l +0.3PV2000mg/l	505/35	30	209	16.11	60.44	27.04	46.11	19.07

Figure 1. Scheme of the implementation of the FT (a) and production dynamics by wells: (b) – well 15-34; (c) – well 14-34; (d) – well 16-34

Figure 2. Scheme for the implementation of the water supply injection (a) and production dynamics in the area (b)

Figure 3. The molecular structure of associative polymers

Figure 4. Comparison of the viscosity characteristics of polymers AR-RV-1, AR-RV-2

Figure 5. Three-layer artificial heterogeneous reservoir model of the Karazhanbas field

Figure 6. Studies on the blocking ability of polymer solution AR-RV-2

Figure 7. The results of filtration studies of the 1st (a) and 2nd (b) stage

Figure 8. Oil production dynamics according to base and polymer flooding options