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Justification of the choice of demulsifier and technology for effective emulsion destruction in the borehole production collection system

Liliya Yusupova[1*], *Elvira* Almukhametova[1], and *David* Amelchenko[1]

[1]Institute of Oil and Gas FSBEI of HE "Ufa State Petroleum Technological University", (Branch in the City of Oktyabrsky), 54a, Devonskaya Street, Oktyabrsky, Republic of Bashkortostan, 452607, Russian Federation

Abstract. The presented work examines the causes of the formation of petroleum emulsions, their classification and properties. An overview of methods for combating water-oil emulsions is given. The characteristics of demulsifier brands, such as purpose, appearance, kinematic viscosity and pour point, have been studied. The characteristics of the field oil, gas and water collection system are described, as well as a diagram of a booster pumping station and its specific reagent injection site. The characteristics influencing the destruction of oil emulsions by means of a demulsifier are discussed. The article presents the selection and analysis of the studied demulsifiers. The qualitative state of the interphase boundary, the content of residual water and the ability to destroy the emulsion are investigated. The calculation of the operating flow rate and dosage of the most cost-effective demulsifier, as well as the supply of a dosing pump, is given.

1 Introduction

A characteristic feature of modern oil production is the increase in the share of hard-to-recover reserves in the global structure of raw materials, which mainly include heavy and highly viscous oils. In industrialized countries, they are considered not so much as a reserve for oil production, but rather as the main basis for its development in the coming years. The reserves of heavy and high-viscosity oils significantly exceed the reserves of light and low-viscosity oils and amount to at least 1 trillion tons. Russia has significant hard-to-recover oil reserves, which are projected to account for about 55% of the total reserves.

The gradual decrease in reserves of easily accessible light and medium oil fields leads to the need to develop sound technology and equipment for the treatment of heavy oil. During the development of oil fields, oil production is carried out with associated reservoir waters. As the time of field development increases, the waterlogging of well products also increases. Oil and raw water are mixed during production and form water-oil emulsions with high aggregative stability and high viscosity. As the water content of the oil-water emulsion increases, problems arise in preparing it to marketable conditions.

* Corresponding author: shalilya@yandex.ru

One of the cheapest and most widespread methods of destruction of stable water-oil emulsions is the use of various demulsifiers. The method of gravity settling of an emulsion is also widely used in the oil industry. Horizontal cylindrical devices are widely used as settling equipment, which are used as a base for the stages of preliminary discharge of water and the stages of dewatering and desalination of a water-oil emulsion. When developing deposits with complicated physico-geological conditions, significant difficulties arise that severely limit the possibilities of using standard equipment.

Therefore, the urgent tasks are to create a complex-acting reagent, and for further effective settling of the emulsion, to intensify the internal devices of gravity settling devices.

2 Methods and Materials

Oil and water are practically insoluble in each other. Therefore, their mixtures form emulsions. Types of oil emulsions: water in oil (hydrophobic); oil in water (hydrophilic) [1].

The stability of emulsions is determined by: the physico-chemical properties of the mixture (FCS) (the higher the density and viscosity of the oil, the more stable the emulsion); the degree of dispersion (the smaller the particle diameter of the emulsion, the more difficult its destruction due to the formation of "armor shells"); temperature (an increase in temperature contributes to a faster destruction of the emulsion); lifetime (an increase in exposure time leads to a more complete destruction of emulsions) [2].

Since a water-oil emulsion is an unstable system that tends to form a minimal interface, it is quite natural to expect it to have a tendency to delamination. However, in the actual operation of oil production equipment, emulsions with high stability are formed in many cases. This largely determines the choice of technology for their further processing, as well as the depth of separation of the aqueous phase from the oil.

The aggregative stability of emulsions is measured by their lifetime until complete separation of the emulsifying liquids. In the case of emulsions obtained from different oils, their stability can range from a few seconds to a year or more. The reasons for the aggregative stability of petroleum emulsions include: the formation of a structural and mechanical layer of emulsifiers at the interfacial boundary of the globules; formation of a double electric layer on the interface in the presence of ionized electrolytes; thermodynamic processes occurring on the surface of globules of the dispersed phase; the wedging pressure that occurs when the globules of the dispersed phase, covered with adsorption-solvate layers, approach [3].

The most common and widely used reagent is a demulsifier designed for the effective destruction of resistant water-oil emulsions. During processing, oil is mixed twice with water to form emulsions.: when exiting the well together with the accompanying reservoir water and during desalination, i.e. rinsing with fresh water to remove chloride salts. The use of demulsifiers in the oil collection system has been practiced for a long time and widely. Such a technological technique at a late stage of field development makes it possible to destroy the emulsion in the pipeline, which reduces its viscosity and reduces hydraulic losses. The previously released water is discharged at a booster pumping station (DNC). The more the emulsion collapses in the pipeline, the lower its viscosity and more water will be in a free or coarse state, in which it is able to separate at the refinery and the oil treatment plant [4].

Methods of emulsion destruction: mechanical (settling, centrifugation, filtration), the Stokes equation is used to determine the deposition rate of emulsion particles in the gravity field and the separation factor for deposition in the field of centrifugal forces; thermal – under the influence of high temperature; chemical – through the chemical interaction of the demulsifier with the emulsion molecules; electrical – under the action of a constant or alternating electric field between the electrodes, with high voltage (30-50 kV) [5-6].

Next, consider the brands of demulsifiers. Demulsifier DMO-86416 is a reagent used to destroy emulsions that are formed from mutually insoluble (poorly soluble) substances, one of which is fragmented in the other in the form of small droplets (globules). Purpose – destruction of highly viscous heavy emulsions stabilized by mechanical impurities, preparation of commercial oil ("final drying" and desalination) at oil treatment plants. Demulsifier DMO-86416 is a composition of various surfactants in an alcoholic aromatic solvent. Demulsifier DMO-86416 is used for field treatment of high-viscosity oils in collection systems and oil treatment plants. In terms of toxicity, DMO-86416 belongs to the 3rd hazard class (moderately dangerous substances). Main Features: appearance: pale to light brown; kinematic viscosity: no more than 45 mm^2/s; solidification temperature: no higher than minus -40 °C [7]. The SEPAROL demulsifier is a compound based on nonionic surfactants, high molecular weight derivatives of axylene oxides (block copolymer).

It is intended for sulphurous and non-sulphurous, resinous and paraffinous high-viscosity oils and can be used in collection systems and oil treatment plants. Provides deep dehydration over a wide temperature range at low specific flow rates. The composition consists of nonionic surfactants, high molecular weight derivatives of oxides of axylenes (block copolymer). Application – the demulsifier is continuously fed into the preparation system through a dosing pump directly from barrels or reagent tanks. The introduction of a demulsifier is possible at the reception of the feed pump. The SEPAROL demulsifier belongs to the 3rd hazard class (excessively dangerous substances). Main Features: appearance: yellow liquid with xylene odor; kinematic viscosity: no more than 50 mm^2/s; solidification temperature: no higher than minus 50 ° C [8].

Demulsifier Pralt-11 M. A1-120A is a composite mixture of oxyethylated block copolymers based on alcohol-hydrocarbon solvents. It is a complex mixture of surfactants developed for high-quality oil and water separation in the preparation of crude oil. It is designed for the destruction of water-oil emulsions in collection systems, transportation and oil treatment plants. Demulsifier Pralt-11 M. A1-120A is a mixture of nonionic oxyalkylated surfactants in methyl alcohol. It is used in collection systems and oil treatment plants, as well as for in-line track demulsification by feeding reagent into pipelines. Demulsifier Pralt-11 M. A1-120A belongs to the 3rd hazard class of danger (moderately dangerous substances). Main Features: appearance: homogeneous liquid from light yellow to brown color; kinematic viscosity: no more than 40 mm^2/s; solidification temperature: no higher than minus 50 °C [9]. KEMELIX-3417MM demulsifier is an oil–soluble, water-dispersible reagent for the preparation (dewatering and desalination) of highly viscous, resinous and paraffinic oils. Designed for the preparation (dewatering and desalination) of highly viscous, resinous and paraffinic oils. The KEMELIX-3417MM demulsifier is a composition of nonionic surfactants in a mixture of aromatic and alcoholic solvents. It is an oil-soluble reagent. It does not contain organochlorine compounds.

The KEMELIX-3417MM demulsifier is used for the preparation (dewatering and desalination) of highly viscous, resinous and paraffinous oils in oil extraction systems and oil treatment plants. Toxicity: KEMELIX-3417MM demulsifier belongs to the 3rd hazard class (moderately dangerous substances). Main Features: appearance: transparent liquid from light yellow to brown color; kinematic viscosity: no more than 54 mm^2/s; solidification temperature: no higher than minus 45 °C [10]. The HPD-005 demulsifier is a reagent for separating an emulsion into its components. It helps to remove water from the oil and water emulsion during oil extraction and refining. Purpose – demulsifier brand HPD-005 – dewatering and desalination of oil during its extraction and processing. The demulsifier provides fast and complete separation of reservoir water with minimal consumption. It also destroys the armor layer surrounding the reservoir water droplets and prevents its formation around the droplets of the newly supplied flushing water. The HPD-005 demulsifier is used in oil collection, transportation and treatment systems for the destruction of water-oil emulsions and the production of commercial grade oil. Demulsifier HPD-005 belongs to the 3rd hazard class (moderately dangerous substances). Main Features: appearance: homogeneous liquid from yellow to brown color; kinematic viscosity: no more than 50 mm^2/s; solidification temperature: no higher than minus 55 ° C [11].

3 Results and Discussion

The full name of the hazardous production facility is "The site of booster pumping station No. 7 of the Key Deposit, the territorial production enterprise of the Chamber of Commerce and Industry "Pokachevneftegaz". The technological regulations for booster pumping station No. 7 of the Key Field were developed by TIU NIPI Neftegazproekt in 2019. The facility is operated by the Chamber of Commerce and Industry "Pokachevneftegaz". The DNS site is a complex of buildings, structures and technological equipment designed to receive a water and gas-oil mixture from the territories of the Klyuchevoye and Nivagalskoye fields.; oil separation and transportation to the Pokachevsky central collection point (CPS); water separation and transportation to a block cluster pumping station; preparation and transportation of associated petroleum gas to the Lokosovsky Gas Processing Plant (GPC). The operating mode is continuous around the clock. Design capacity: 36,000 m^3/day for liquid; 2,550 tons/day for oil; 250,000 nm^3/day for gas. The operating mode is continuous around the clock. The actual capacity of DNC No. 7 of the Key field is 24,000 m^3/day for liquid, 1,700 tons/day for oil, and 192,307 nm^3/day for gas. The DNS-7 project was developed by Vnipineftepromchem. The date of commissioning of the installation is May 1988 – DNS, November 1997 – Installation of pre-discharge of water. In 2014, the project "Technical re-equipment of the separation site of DNS-6 of the Key field" was completed, developed by the Tyumen State University NIPI Neftegazproekt. In 2017, the project "Reconstruction of the DNC-7 facilities of the Key field" developed by TIU NIPI Neftegazproekt was completed.

These regulations are a document that establishes the basic requirements for the operation of a water treatment plant with a pre-discharge system (UPV) in order to maintain optimal operating parameters, ensure the achieved level of reliability, safety, fire safety and environmental protection. Characteristics of the raw materials, materials, reagents, manufactured products. The raw material for the DNC is a water-oil and gas mixture coming from the well bushes of the Klyuchevoye and Nivagalskoye fields through the oil collection system. Figure 1 shows the technological scheme of DNC-6 of the Key deposit, which consists of a chemical reagent block, chemical injection pumps, a separator of the first stage of separation, settling tanks, a gas separator, and a separator of the second stage.

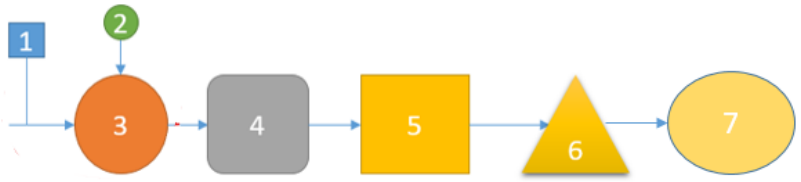

Fig. 1. Simplified technological scheme of DNS No. 7 of the Key deposit.

The dynamics of water availability from 2005 to 2022 at the Key Field is shown in Figure 2.

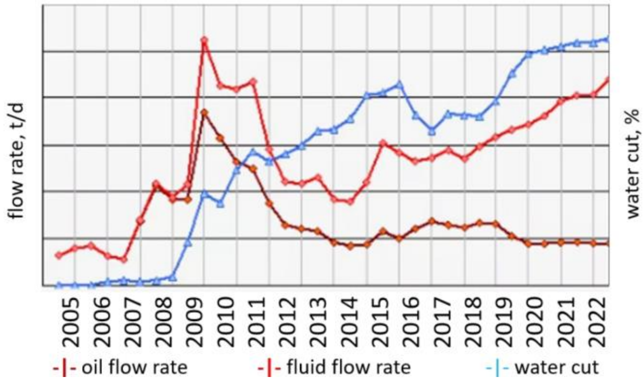

Fig. 2. Dynamics of water availability of the Key deposit.

The reservoir temperature during deep sampling at the Key Deposit varies from 68 °C to 97 °C. Waterlogging affects the physico-chemical properties of oil emulsions formed during the extraction and collection of products from oil and gas producing wells. As the water content in the oil increases, the viscosity of the resulting emulsion increases. This is especially noticeable when water levels exceed 20%. At the same time, when oil is emulsified in wells with increasing viscosity, oil production decreases, and when pumping, operating costs increase due to increased pressure at the pump outlet.; when the water content reaches 75% or more, the emulsion loses its stability. Oil is dispersed in water with a low viscosity; waterlogging also causes intensive formation of asphalt-resin-paraffin deposits, increases the solidification temperature of the oil, creating additional problems during its transport and storage. Waterlogging negatively affects the system of product collection and preparation. Here are some of the consequences: increased transportation costs. This is due to the increasing volumes of liquid being pumped. increase the viscosity of the mixture. This makes it difficult to process hydrocarbon raw materials.; complication of the hydraulic operation of the pipeline.

With increasing waterlogging of the extracted oil and an increase in the volume of the transported liquid, the hydraulic mode of operation of the pipeline becomes more complicated; corrosion of the pipeline. When the water level is above 70%, a three-phase gas-liquid stream moves through the collection communication systems, in which the liquid phase is represented by concentrated petroleum emulsion and free (non-emulsified) water.; the difficulty of gas separation and pre-discharge of water [12-14].The main types of complications, failures in operation, or other disruptions during the operation of systems for collecting and preparing products from oil and gas producing wells in a given field, such as: asphalt-resin-paraffin deposits (AFS); salt deposits; emulsion formation; pulsation in field oil pipelines; corrosion destruction of oilfield equipment. Some of the reasons for complications and failures in the collection and preparation system are the inconsistency of technology and techniques for separating well products.

The specific properties of gas-liquid systems, their diversity and the complexity of forecasting during flooding, mixing of oils and waters of various horizons of the field are not taken into account; changes in the physico-chemical properties of mixing oils and reservoir waters. For example, deterioration of desalination processes is associated with a high salt content in reservoir waters; accumulation of solid paraffins in apparatuses. They fall on the desalination unit with oil and act as emulsion stabilizers.; salt precipitation in the discharge lines of oil wells, in the automatic group measuring unit and in the separators of the separation unit. Increased mineralization of neutral reservoir waters and their instability stimulate the deposition of salts and sediments. When analyzing the complications, I will consider in more detail such problems as the formation of emulsions and deposits of AFS in the system of collection and preparation of borehole products. The formation of an emulsion in the system of collecting and preparing downhole products occurs as a result of both condensation and dispersion processes.

Condensation occurs when the pressure and temperature of the flow decrease during the movement of the flooded gas-liquid mixture from the bottom of the well to the oil treatment point. In this case, gas is released from the solution, and paraffin, resins and asphaltenes pass from a molecular dissolved state to a colloidal one and then form suspensions that are deposited in pipelines. Dispersion occurs when the gas released from the solution inside the oil globules "explodes" them. The DNC has adopted a technological scheme for two-stage separation of oil from associated gas (0.6 and 0.2 MPa, respectively) and pre-discharge of water. The liquid from the group measuring units under wellhead pressure enters the first stage separation unit of the DNC, consisting of a gas pre-extraction device (UPOG) and oil and gas separators. Next, the emulsion enters pressure horizontal settling tanks (OG - 2), where associated reservoir water is deposited to a residual content of 10-15% at the natural temperature of the product. To increase the efficiency of emulsion removal in the reagent farming unit in front of the separators of the first stage, a HPD-005 demulsifier with a dosage of 17-22 grams per ton of oil in concentrated form is provided for use (Figure 3).

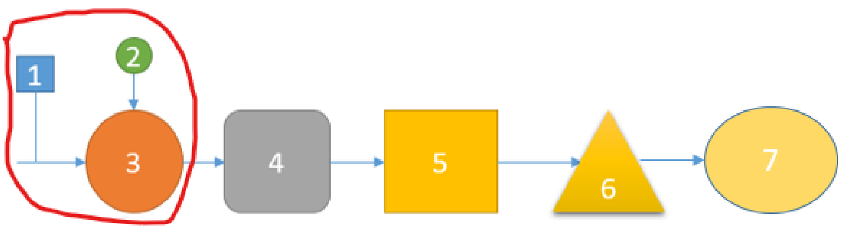

Fig. 3. Reagent injection site.

During the work, the range of demulsifiers was tested, their comparative analysis was carried out and the most cost-effective was identified. The tests were performed on Baker Petrolite equipment in the chemical analysis laboratory at the Yuzhno-Mayskoye field of Imperial Energy LLC. The test procedure was in accordance with the Baker Petrolite internal standard. A "Bottle test" was used to evaluate the effectiveness of oil treatment with a chemical reagent [15]. For this purpose, 5 different demulsifiers were tested, and their comparative analysis was carried out in Figure 4.

Fig. 4. Optimal demulsifiers from Baker Petroleum.

The oil emulsion was mixed and five 50 g samples were weighed. Each sample was placed in a thermostatically controlled bottle. Demulsifier DMO – 86416 was added to the first bottle with a sample, demulsifier SEPAROL was added to the second bottle, demulsifier Pralt–11 M. A1-120A was added to the third bottle, demulsifier KEMELIX-3417MM was added to the fourth bottle, and demulsifier HPD–005 was added to the fifth bottle. At the end of the settling time, the bottles are removed from the bath. A 5 ml sample of oil is taken from each bottle with a special syringe from a level of 70% (in some cases 80%) of the height of the liquid column to determine the residual water content of the oil (modeling the selection of settled oil from the reservoir). The selected oil samples are poured into centrifuge fingers filled with 50% gasoline beforehand. Figure 5 shows the result of a study of the SEPAROL demulsifier, its ability to destroy the emulsion.

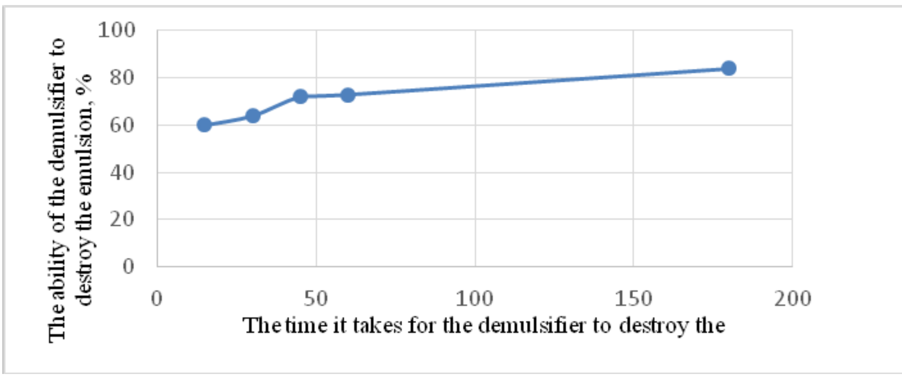

Fig. 5. The dynamics of emulsion destruction using a demulsifier SEPAROL.

The qualitative state of the interphase boundary, that is, the presence of an intermediate layer consisting of an undisturbed emulsion and its thickness – the boundary is clear, 1.5 ml. The water content was 0.3%. When examining the KEMELIX-3417MM demulsifier at a temperature of 55 °C and a reagent consumption of 50 g/t for 180 minutes, we can observe 94% emulsion destruction.

4 Conclusion

As a result, the consumption of the demulsifier Pralt-11 m. A 1-120A was 20.1 m^3/h with an actual flow rate of 500 m^3/h in the booster pumping station. Based on the technological regulations, the dosage of the demulsifier was 17 g/t and when calculating the demulsifier Pralt-11 m. A1-120A, the dosage was 8.8 g/t, it can be concluded that it is more profitable to use the demulsifier Pralt-11 m. A1-120A. A comparative analysis of experimental data conducted according to the Baker Petrolite internal standard showed that of all the tested samples, the most technically and economically advantageous and effective was the demulsifier Pralt-11 M. A1-120A. When using this demulsifier, the greatest ability to destroy the emulsion is achieved over a certain period of time with good phase interface quality.

The initial temperature of the reservoir ensures the technological regime due to the fact that the temperature allowed water separation to be achieved.

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