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Case of Physical Fields Application to Accelerate Oil Preprocessing

Alexey Viktorovich Dengaev and Vladimir Sergeevich Verbitsky, Gubkin Russian State University of Oil and Gas National Research University; Andrey Alexandrovich Getalov and Boris Viktorovich Sargin, NPO, Volna LLC; Ivan Viktorovich Grekhov, Gazprom Neft NTC, PJSC; Alexander Vladimirovich Bogdanov, Gazprom Neft, PJSC; Sergei Alekseevich Tarasevich, Gazprom Neft NTC, PJSC

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Summary

The separation of water-oil emulsions in the fields is considered to be a significant part of the costs associated with the production and transportation of the produced fluid. This is mainly connected to the use of chemical reagents (demulsifiers), which accelerate the process of the emulsion separation. The paper proposes a technological solution regarding the method of microdosing of demulsifier, which allows to reduce the concentration of the reagent input and, most importantly, to reduce the volume of the intermediate layer within the process of field oil processing. The proposed device is based on the use of ultrasonic vibrations.

In the laboratory, and later in the field conditions, the tests had been conducted to determine separation efficiency depending on the type of emulsions, oil viscosity, temperature, emitter power and the availability of a demulsifier, etc.

The obtained results make it some possible to reduce the volume of used demulsifiers, as well as increase the efficiency of oil processing.

Introduction

Organization of an effective performance of oil production, preparation and processing, optimization of existing processes that ensure the improvement of technical and economic indicators and the quality of stock-tank oil (Filippova T. V., 2016) are urgent tasks for oil companies worldwide during oil fields operation.

One of the practical tasks, which required the solution, is not only to reduce the rate of demulsifier input during the separation of well fluid, but also to provide the so-called intermediate layer (IL) stabilization, which is a stable layer of water-oil emulsions at the "water - oil" border line upon field oil processing (Cronin A. N., 2013; Filippova T. V., 2016; RD 39-0148311-605-86).

At the moment, the average consumption of the demulsifier at the full cycle flow is set as ~38-40 gr/tonne (~160 kg/day) of the SNPH 4460 type demulsifier at the reviewed oil processing unit (OPU). Where unstable level of the intermediate layer (IL) within the steel vertical vessels (SVVs) is observed. The task is not only to reduce the input rate of the demulsifier by 20% down to levels of ~ 30 g/ton (~ 120 kg/day), but also to increase the stabilization of the level of the industrial layer with a change in the input flow of water-oil emulsion from the stock of producing wells.

The Audit of the Field Oil Processing System at the Current Facility

It is well-known, that the effectiveness of the demulsifier on the separation of water-oil emulsions substantially depends on two factors: the content of the water phase and its degree of dispersion (Ismayylov G.G. et al., 2017). Considering the water cut factor, which at the time of the field trials (December 2019) was 50–52% and is a relatively slowly growing value, the main parameter to be studied should be the structure of the water-oil emulsion (WOE) (Dengaev A.V. et al., 2018, 2020; Levchenko D.N. et al. 1967).

For described purposes, studies of the structure of well products, which enter the input of the oil-processing unit (OPU) and at the outlet of the furnaces PTB-10A type before being transported to the SVV, were conducted. Figure 1 shows a photomicrograph of the structure of the input WOE in the input main pipe OPU-1.

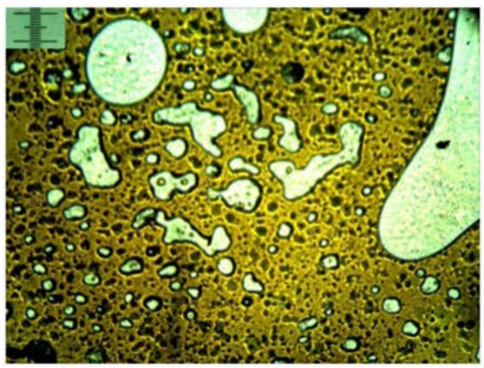

Figure 1—The structure of the water-oil emulsion input within the main pipe of the oil processing unit

The structure was fixed using optical microscopes with x4, x10, x40-fold lenses and a DCM500 digital nozzle (5 Mpc) using the specialized ScopeFoto program. Calibration was carried out for each lens using an object micrometer with a grid interval of 10 µm.

In Figure 1 (a calibration grid interval of 10 µm), water globules of various sizes and impurities (identified as mechanical impurities and asphalt-resinous deposits (ARD)) are clearly visible, and the presence of armor shells at the oil-water phase boundary also attracts attention. We shall note that deposits of mechanical impurities and asphalt-resinous deposits are very significant factors for stabilization of intermediate layer (Karpenko I.N. et al., 2017). Figure 2 shows the size distribution of water globules.

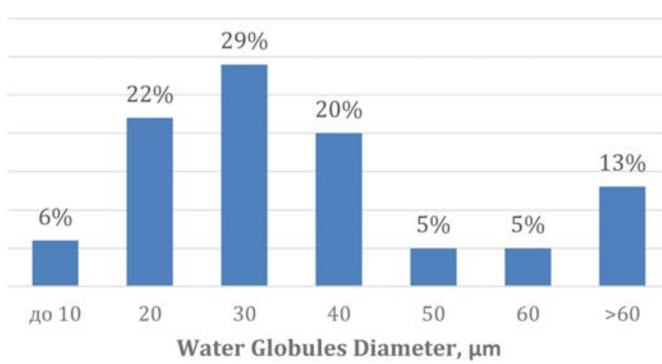

Figure 2—The size distribution of water globules within the initial WOE

The analysis of the sizes of water globules in the products supplied to the OPU shows that ~60% of the total amount have a characteristic size of 30 μm or less. Such a finely dispersed structure of water globules is an additional stabilizing factor of the intermediate layer to a significant amount of mechanical impurities and asphalt-resinous deposits. Figure 3 shows microphotographs with an increased resolution obtained using x10 and x40 fold zoom.

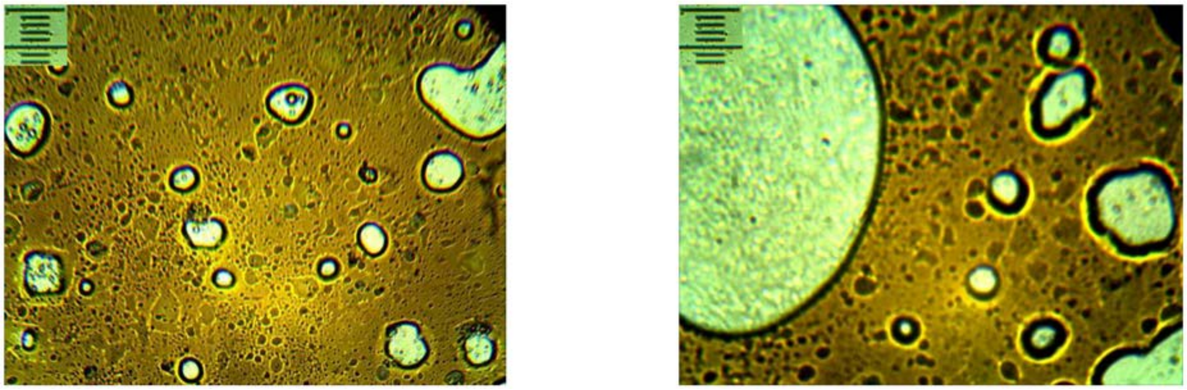

Figure 3—The structure of the WOE under x4, x10-fold zoom lenses, respectively

A more detailed visualization demonstrates that the sizes of mechanical impurities and asphalt-resinous deposits have even finer dispersion than water globules.

The next step in studying the structure of the incoming emulsion is the analysis of the samples after the input of the demulsifier SNPH 4460 and primary water separation. This sample was taken after gas separators (OGS). The kinetics of water separation showed that within 20 minutes at a temperature equal to the temperature of the inlet WOE, only 2/3 of the water globules fall out of the total volume of water, the largest in size, i.e. ~ 37% of the total water content (50-52%).

Microphotographs of the structure of the WOE obtained after the primary water separation phase with the input of the demulsifier SNPH 4460 are shown in Figure 4.

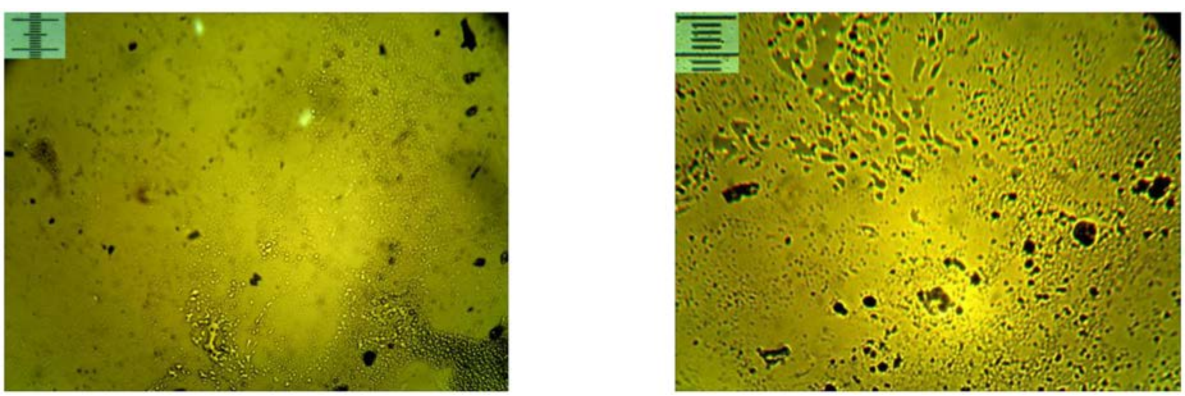

Figure 4—The structure of WOE with an increase in lenses of x4, x10-fold after input of the demulsifier before heating in furnaces

The products still contain significant scope of mechanical impurities and asphalt-resinous deposits.

The water content in the emulsion decreased significantly, which means, that the first "fast" phase of the demulsifier operation contributed to the loss of the largest water globules, which volume amount was ~ 67% (2/3) of the total water content. This led to a redistribution of the sizes of the remaining water globules (Figure 5) into the zone of smaller inclusions.

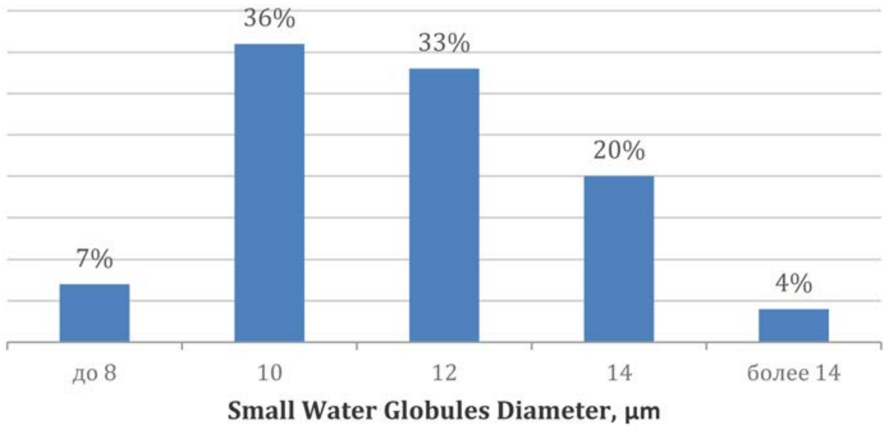

Figure 5—The Distribution of Water Globules after Primary Water Separation

The main proportion of water globules is 10-14 µm in their size. As it is known, the globules of below 20 µm in their size fall into the category of the most finely dispersed and inclusions difficult to be deposited. It is worth recalling that in this fine-grained category, ~ 30-33% of the initial amount of water will be remained.

The next technological stage is heating of the incoming OWE in the furnaces PTB-10A type. A special feature of PTB-10A furnaces is the absense of a water jacket within the coil with its WOE passing, which leads to local overheating of the emulsion. Figure 6 shows a microphotograph of the WOE with the maximum X40-fold lens zoom.

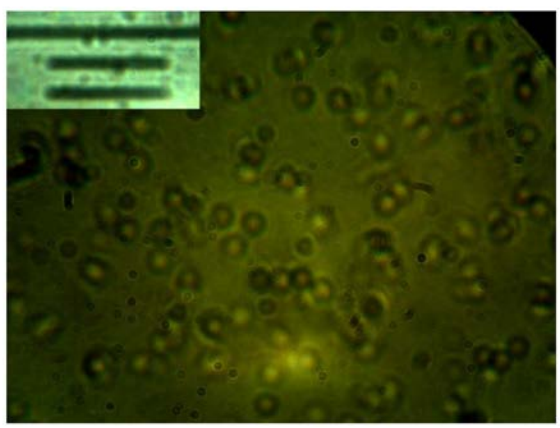

Figure 6—The Structure of PWE after Passing throughout the PTB-10A Heating Furnace

It is observed, that the water globules after heat treatment not only did not undergo fusion, but, on the contrary, acquired a finely dispersed structure. This is clearly seen in the graph (Figure 7) obtained after processing the microphotograph (Figure 6).

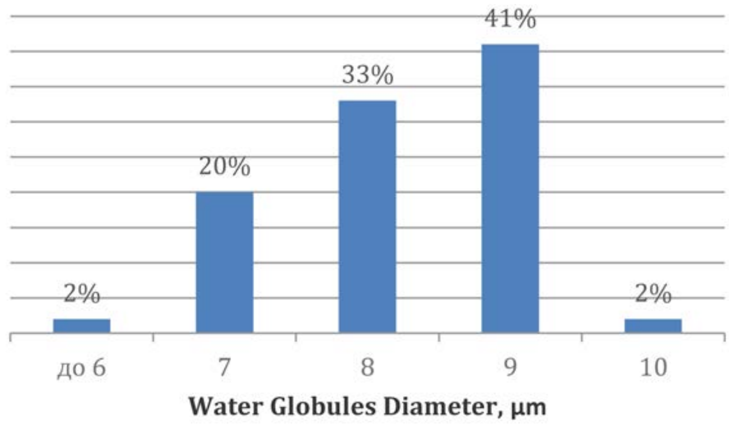

Figure 7—The Distribution of Water Globules past Heating Furnaces

Almost all globules are concentrated in the range up to 10 μm. This confirms that the used demulsifier SNPH 4460 effectively leads to the deposition of only relatively large water globules (30 μm or more), and small water globules remain in the emulsion for a long time, even after thermal heating. Microphotographs also show that many water globules have protective armor shells.

Thus, the instability of the intermediate layer at the reviewed object with a full oil treatment cycle is most likely is the result of several factors: a large proportion of the content of small water globules in the WOE (less than 30 μm), a large amount of mechanical impurities and asphalt-resinous deposits, and not optimal time synchronization of the demulsifier SNPH 4460 activation from the input point through the stages of the technological cycle. The samples obtained before gas separator (OGS) indicate a significant proportion of the separated water after the demulsifier was used. According to the available work experience and literature data (Usova L.N. et al. 2007), the last mentioned factor is quite significant.

The Solution Proposed

The conducted analysis of the WOE structure allows to formulate the requirements regarding dispersion indicators when inputting the demulsifier. The usual method of the demulsifier inputting by the dosing plunger pump through the pipe feedthrough is quite simple from operation point of view, but considered to be not the most effective. The size of inputted demulsifier drops shall be equal or smaller than size of water globules (Sorush Ahmadi, 2018). The energy and hydrodynamics of the input WOE flow contributes to the granulation of demulsifier droplets into smaller particles, but has a physical limitation, depending on many factors.

To solve this problem, one of the steps is to create an effective method and device for input of the demulsifier (with a dispersion of up to 20-30 μm) of the "liquid-liquid" type and justify the location of its installation, taking into account the existing technological stages of oil preparation. This statement of the problem can be attributed to the class of tasks "flooded stream" (Abramovich G.N., 2011) and effective spraying of liquids (Dityakin Yu.F. et al., 1977; Pazhi D.G.et al., 1984). The vast majority of technical solutions leading to the finely dispersed spraying of liquid-reagent is based on the creation of a two-phase flow, that is, in addition to the liquid, a high-intensity gas flow is required. It is the energy of the gas stream that contributes to the granulation of the liquid into a finely divided state. In this case, various nozzles are used as spraying devices. So, to obtain a dispersion of the liquid phase of ~ 20 μm, a gas flow velocity of ~ 250-300 m/s (Pazhi D.G.et al., 1984) and a nozzle hole diameter of ~ 0.4 mm are required. In the case of introducing a demulsifier through nozzles, the introduction of an additional gas stream changes the entire technology of oil processing, which is unacceptable. The practice of using nozzles also showed their operational disadvantage - this is a clogged nozzle hole.

The alternative method of liquid spraying proposed by the authors of this article is the use of ultrasonic systems (Khmelev V.N. et al. 2010; Patent RF No. 2441490).

Structurally (see Figure 8), an ultrasonic (US) point dispersant (SMART) consists of a housing 1, where a piezoelectric exciter of ultrasonic vibrations, a waveguide with an internal demulsifier supply channel, which through a lubricator 2 and a wedge-shaped valve 3 (installed by the cold tapping), is lowered into the main pipe until it reaches at the lower inner part of the pipe, at the end of the waveguide there is a spray head 4 (nozzle). Also, the ultrasonic disperser has a system for cleaning and supplying a demulsifier, pressure control, power is supplied from an ultrasonic frequency generator via a two-wire line. The internal volume of the housing is filled with transformer oil to remove heat from the piezoelectric exciter of ultrasonic vibrations and to ensure electrical explosion safety.

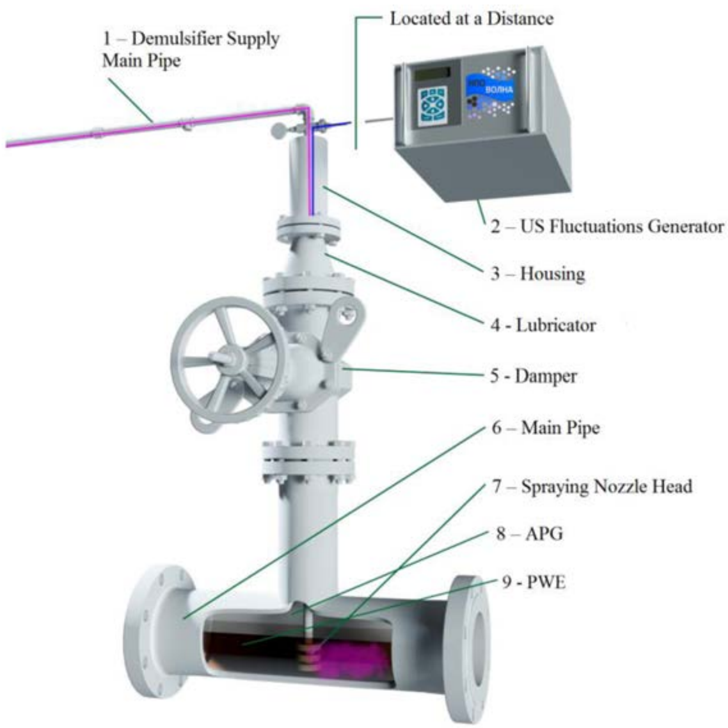

Figure 8—The Block Diagram of the Ultrasonic Dispersant Installation

The principle of the spray head operation is based on pressurizing within the liquid demulsifier between the plates while it is performing relative micro-vibrations with ultrasonic frequency.

As shown by the calculations (Popov V.S. et al. 2011), the excessive pressure can reach ~ 2 atm in case of only one plate vibrates. In our case, this effect is enhanced due to the sound-capillary effect with cavitation (Rosina E. Yu, 2011) and with the addition of bending vibrations of the sprayer plates (Ilgamov M.A., 2018).

The spray head is adjusted to a liquid flow rate, which is equal to the planned demulsifier flow rate and takes into account the planned flow rate reduction. For this purpose, a test bench has been developed, which includes a plunger dosing pump with an adjustable dosing rate, a flow meter, a pressure meter in the discharge line, a measuring bar for measuring the dimensions of the spray torch and obtaining dispersion characteristics. Figure 9 shows photographs at consecutive moments during the dispersion of the oil-water system. The choice of motor oil is based on the added, in relation to demulsifiers, viscosity of the product. Similar tests were carried out for other systems, for example, "water-diesel fuel".

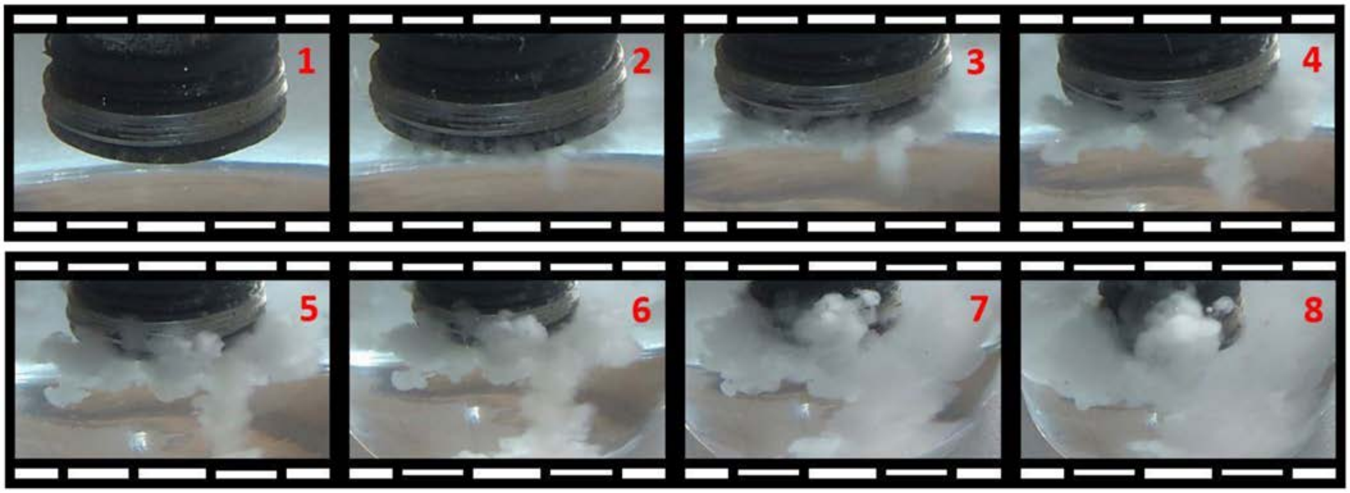

Figure 9—The US Disperser Spray Torch for "Oil-Water" System Dispersion

Figure 10 shows a photomicrograph of the structure and the dependence of the particle size distribution.

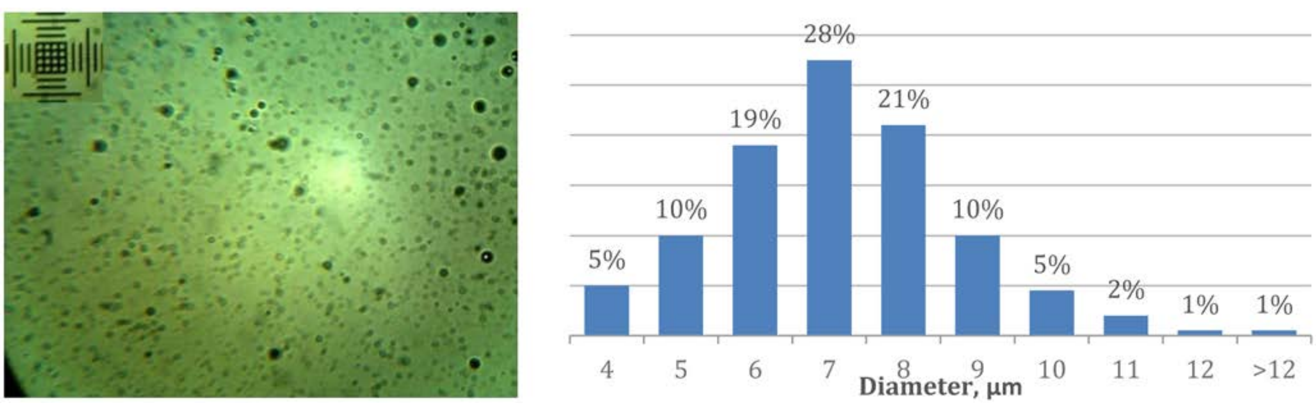

Figure 10—Photomicrograph of US Spraying Structure and Dispersed Liquid (Oil) Droplets Size Distribution

Throughout the conducted experiments, it can be noted that the dispersion of the particles of the input liquid (chemical reagent) does not exceed ~ 15 µm for various physicochemical characteristics of liquid medium and a temperature range of 10-50 °C. The sprayer design provides for various flow characteristics (l/min) at a given level of dispersion.

Thus, the proposed design of the Ultrasonic Point Dispersant (SMART) provides parameters of demulsifier input at the Oil Processing Unit (OPU) comparable to the size of water globules of OWE both at the inlet of the facility and at all subsequent stages of technological preparation.

Conclusions

The analysis of the structure of the WOE entering the full oil processing cycle at the existing facility (OPU) shows a number of factors contributing to the emergence of a stable, substantial in volume and insufficiently predicted intermediate layer (IL). These factors include a large proportion of small water globules in WOE (less than 30 µm), a large amount of mechanical impurities and asphalt-resinous deposits (an additional source of IL stabilization), and not optimal time synchronization of the demulsifier activation from the input point through the stages of the technological cycle. It is proposed to input a demulsifier using an ultrasonic dispersant, which ensures the dispersion of the inputted demulsifier at the level of the smallest water globules (up to 15 µm) into the WOE stream at the input main pipe. The results are expected to be obtained in the course of the completion of the trial at the facility in the near future.

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Legend

IL	*Intermediate Layer*
SVV	*Steel Vertical Vessel*
WOE	*Water-Oil Emulsion*
OPU	*Oil Processing Unit*
ARD	*Asphalt-Resinous Deposits*
OGS	*Oil and Gas Separator*
US	*Ultrasound*

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