



## DEVELOPMENT OF A NEW REAGENT AGAINST ASPHALTENE–RESIN–PARAFFIN DEPOSITS

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### ABSTRACT

High-molecular-weight asphaltene, resin, and paraffin (ARP) compounds present in produced crude oil tend to deposit on the surfaces of tubing strings, flowlines, sucker rods, and other production equipment as a result of temperature changes. Sand particles suspended in the oil, mechanical impurities, and inorganic salt crystals act as crystallization nuclei, further accelerating the deposition rate of asphaltene-resin-paraffin deposits (ARPD). The formation of these deposits reduces well productivity, leads to equipment failures, increases additional energy and material consumption, and decreases the mean time between repairs (MTBR). Several methods exist to mitigate these issues. Among the known approaches, the chemical method is the most advanced. It is considered one of the most efficient and promising approaches for controlling paraffin deposition in pipelines and wells. This method is characterized by high efficiency, relatively simple operational technology, and long-term effectiveness. To address the aforementioned problems, this study presents the laboratory test results of a newly developed reagent, NDP-22M-2, applied to several crude oil samples for the mitigation of ARPD, along with an explanation of its mechanism of action and determination of its optimal dosage. The mechanism of action of NDP-22M-2 is based on the formation of a polar layer on the surface as it renders the internal surface of equipment hydrophilic through wetting. Its operating principle relies on continuous dosing into the oil stream, which alters the surface properties of paraffinic crude oil and slows down the crystallization of solid phases. As a result, paraffin deposition is prevented, and the freezing point of the crude oil is significantly reduced.

**Keywords:** asphaltene–resin–paraffin deposit; reagent; near-wellbore zone; viscosity.

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### Introduction

Crude oil is a complex mixture of light and heavy hydrocarbons and exists in a state of thermodynamic equilibrium under reservoir conditions. During upward flow in the tubing, gradual gas separation from the oil is observed, accompanied by a temperature decrease. This reduces the solubility of ARP components and accelerates the deposition process. Over time, asphaltene-resin-paraffin deposits (ARPD) formed in production equipment reduce the effective cross-sectional area of the tubing, leading to flow restrictions and blockages. ARPD typically consists of 40–60 wt.% solid paraffin and 10–56 wt. % resins, asphaltenes, water, sand, and inorganic salts. These deposits form under changing thermobaric conditions. When the temperature inside the well drops below the initial crystallization temperature, paraffin crystals begin to form, creating nucleation centers [1–3]. The composition of deposits includes paraffinic, naphthenic, and aromatic hydrocarbons, asphaltenes, resins, and metallic particles. Depending on the crude oil type, the density of

deposits ranges from 0.95 to 1.03 g/cm<sup>3</sup>, with a coke content of 8–26 % (wt.%) and a melting point between 12 and 55 °C.

Research has shown that paraffin solubility decreases in heavy crude oils, leading to more intense paraffin deposition. Consequently, the concentration of paraffinic compounds in the oil increases further. Ultimately, this disrupts well operating conditions, leading to reduced economic efficiency, shorter turnaround time between workovers (TAM), and decreased production rates [4].

### Relevance of the problem

Conventional methods used to mitigate asphaltene-resin-paraffin deposits (ARPD) are unable to fully resolve this problem. Most reagents currently in use demonstrate limited effectiveness. The absence of a proper classification system for ARP deposits based on group composition and morphology further complicates field operations. Therefore, the scientific investigation of the formation mechanisms of complex ARP deposits and the development of scientifically grounded technological solutions for eliminating ARP deposition during water-cut crude oil production remain highly relevant and important issues.

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ARPD primarily forms in various sections of oilfield equipment. During oil production, deposits formed in wells, production facilities, and pipeline systems reduce both oil output and the overall efficiency of transportation systems [5–7]. ARPD accelerates equipment wear, increases energy consumption, and leads to higher system pressure. Currently, this issue is considered one of the most critical challenges in hydrocarbon production and transportation.

The development of new and efficient formulations aimed at reducing the freezing point and viscosity of high-paraffin crude oils during production, transportation, and storage, as well as the expansion of the raw material base and the range of depressant additives based on various hydrocarbon derivatives, remains an important scientific and industrial challenge [8–13].

### Applied reagents

The most widely used approach for the removal of ARPD is the chemical method. These methods include individual organic solvents, natural solvents, petroleum refining products and by-products, surfactant-enhanced organic solvents, water-based cleaning agents, and others. Chemical methods are based on the diversity of reagents used.

Chemical methods rely on the dosing of chemical compounds that reduce or, in some cases, completely prevent deposit formation during production. The effectiveness of paraffin deposition inhibitors is based on adsorption processes occurring at the interface between the liquid phase and the metal surface of the tubing [14–21].

Considering these factors, a new reagent, NDP-22M-2, has been developed for high-paraffin crude oils. It consists of a multicomponent polyester mixture, a nonionic surfactant (NIS), an organic solvent, heavy pyrolysis resin obtained from petroleum feedstock pyrolysis in ethylene-propylene production containing up to 80% aromatic hydrocarbons, and an additional component with depressant properties [22–27].

The NDP-22M-2 reagent improves the flow of highly viscous paraffinic crude oils, prevents paraffin deposition, and reduces both the freezing point and viscosity of the oil, thereby enhancing its flowability. The physical properties of the NDP-22M-2 reagent are presented in table 1. The mechanism of action of the NDP-22M-2 reagent is associated with adsorption processes occurring at the phase interface. The injected reagent adsorbs onto the metal surface, rendering it hydrophilic; as a result, the probability of asphaltene-resin-paraffin deposits (ARPD) formation on the hydrophilic surface is reduced [28–30]. The main reason for this effect is the weakening of intermolecular interactions between n-paraffins and asphaltenes due to the penetration of the reagent into the system.

### Experimental procedure and discussion of results

Laboratory tests were conducted in two stages. The first stage was considered a rapid preliminary method. According to this method, the solubility of the inhibitor in petroleum products and solvents was determined. To prepare the compositions, the components were introduced into a flask in predetermined mass ratios and mixed for 0.5–1.0 h at room temperature. If necessary, mixing was carried out at 40–45 °C. As research objects, the physicochemical properties of crude oil samples from Well No. 441 of the N.Narimanov Oil and Gas Production Department (OGPD) of “Azneft” Production

№	Physical property	Properties
1	Appearance	Dark brown, free-flowing liquid
2	Odor	Slight odor
3	Density at 20 °C, g/cm <sup>3</sup>	0.9367
4	Dynamic viscosity, mPa·s	72.5
5	Kinematic viscosity, mm <sup>2</sup> /s	77.39
6	Hydrogen index, pH	5-7
7	Pour point, °C	< -25

Union, Well No. 2680 of the Neft Daşları OGPD, and Well No. 450 of the Salyanoil II field were initially studied in accordance with the applicable methodological standards. First, the freezing points of the investigated crude oils were determined. Subsequently, their dynamic and kinematic viscosities and densities were analyzed using an Anton Paar SVM 3000 Stabinger viscometer. The results of the study are presented in table 2.

Although natural surfactants are present, the high content of asphaltenes, resins, and paraffins complicates the inhibition process of crude oil samples. In the next stage, three crude oil samples were taken in the laboratory. Each sample was individually heated to 40–50 °C and then gradually cooled to room temperature (20–22 °C). Each cooled crude oil sample was separately treated with the reagent NDP-22M-2 at dosages of 200 and 400 g/t for samples designated as No. 1, No. 2, and No. 3. The mixtures were then stirred for 10 min using a magnetic stirrer. Subsequently, samples were taken from these oils and their physical parameters were determined. The physical properties of crude oil samples with and without reagent treatment are presented in tables 3–5.

As can be seen from tables 3–5, after the addition of the reagent, the dynamic and kinematic viscosities of the paraffinic crude oil samples decreased significantly, while the freezing temperature was effectively reduced. Comparative analysis of the laboratory results confirms that the performance of the NDP-22M-2 inhibitor are superior to those of other inhibitors.

The interaction of the inhibitor with formation waters, i.e., its dispersibility in produced water, was also evaluated. In the initial stage, the dispersion and washing efficiency of ARPD was assessed based on the behavior of the inhibitor in produced water. These studies examined the degree of inhibitor dispersion in formation water, its tendency to form a separate phase without dissolution, or its complete solubility. In this context, an inhibitor exhibiting dispersion in produced water may be recommended for pilot-scale and industrial testing.

The particle size distribution of paraffin dispersed in produced water containing 1% reagent is characterized as follows:

- excellent, if 60% of paraffin particles are within 0.1–3 mm;
- good, if 100% of particles are within 0.1–5 mm;
- satisfactory, if 100% of particles are within 0.1–7 mm;
- unsatisfactory, if particles are larger than 7 mm.

In the first stage, the fact that 60% of paraffin particles fall within the 0.1–3 mm range confirms the feasibility of further testing.

Table 2

Physical properties of the studied crude oils					
No.	Sample source	Kinematic viscosity at 20 °C, mm <sup>2</sup> /s	Dynamic viscosity at 20 °C, mPa·s	Density at 20 °C, g/cm <sup>3</sup>	Pour point, °C
1	Neft Daşları OPC, Well 2680	105.095	91.460	0.8435	+2
2	Salyanoil II Field, Well 450	374.63	345.785	0.9237	+15
3	N. Narimanov OPC, Well 441	364.75	317.81	0.8713	+22

Tables 3

Laboratory tests of newly developed compositions on paraffinic crude oil from well No. 441, N. Narimanov OPC, Azneft Production Unit

Reagent	Dose, g/t	Pour point, °C	Dynamic viscosity at 20 °C, mPa·s	Density at 20 °C, g/cm <sup>3</sup>
Without Reagent	-	+22	317.81	0.8713
№1	200	+10	158.52	0.8692
	400	+4	106.23	0.8535
№2	200	+14	218.86	0.8607
	400	+8	164.79	0.8502
№3	200	+15	232.80	0.8692
	400	+7	111.54	0.8511
NDP-22M-2	200	-3	83.29	0.8665
	400	-5	45.29	0.8501

Tables 4

Laboratory tests of newly developed compositions on paraffinic crude oil from well No. 2680, Neft Daşları OPC, Azneft Production Unit

Reagent	Dose, g/t	Pour point, °C	Dynamic viscosity at 20 °C, mPa·s	Density at 20 °C, g/cm <sup>3</sup>
Without reagent	-	+2	91.460	0.8435
№1	200	-1	33.116	0.8412
	400	-4	22.404	0.8401
№2	200	-1	32.168	0.8409
	400	-3	30.337	0.8415
№3	200	-2	30.270	0.8411
	400	-4	20.921	0.8325
NDP-22M-2	200	-7	17.119	0.8315
	400	-4	21.479	0.8345

Tables 5

Laboratory tests of newly developed compositions on paraffinic crude oil from well 450, Salyanoil II Field

Reagent	Dose, g/t	Pour point, °C	Dynamic viscosity at 20 °C, mPa·s	Density at 20 °C, g/cm <sup>3</sup>
Without reagent	-	+15	345.785	0.9237
№1	200	-11	137.58	0.9124
	400	-10	112.45	0.9035
№2	200	-9	86.75	0.9013
	400	-7	76.88	0.9010
№3	200	-7	119.31	0.9122
	400	-10	102.44	0.9109
NDP-22M-2	200	-13	69.14	0.8433
	400	-15	61.66	0.8235

In subsequent stages of the study, curves describing the dependence of kinematic viscosity of paraffinic crude oil samples on reagent dosage were constructed. The graphical representations of the obtained results are shown in figures 1–3.

The dependencies shown in figures 1–3 allow for the determination of the optimal dosage of the NDP-22M-2 reagent.

The efficiency of reagents against paraffin deposition was investigated using the “cold finger” method [8, 9]. This method is more suitable for field conditions and enables both qualitative and quantitative evaluation of the efficiency of paraffin deposition inhibitors. It also facilitates the development of application technology for effective inhibitors and allows the establishment of a relationship between efficiency and reagent dosage.

Laboratory studies of the reagent samples for paraffin deposition inhibition were conducted using a crude oil sample taken from Well No. 441 of the N.Narimanov Oil and Gas Production Department (OGPD). The paraffin content of the oil was 20%. The results of the laboratory investigations of the inhibitor samples against paraffin deposition are presented in figure 1. Although the efficiencies of the investigated inhibitors are relatively close, their dependencies on dosage differ.

As shown in figure 4, among the investigated reagents, the NDP-22M-2 reagent exhibits the highest efficiency against paraffin deposition.

In addressing key technical challenges arising during the production and transportation of paraffinic crude oils, one of the most important parameters to be evaluated is rheological behavior. The rheology of paraffinic crude oils primarily depends on temperature and the crystallization process [31–34].

In the next stage, the rheological properties of a crude oil sample taken from the N. Narimanov Oil and Gas Production Department were investigated at 20 °C both without reagent addition and with NDP-22M-2 dosages of 200 and 400 g/t. The studies were carried out using an Anton Paar rotational viscometer. The obtained results are presented in figure 5.

Without reagent (curve 1), the crude oil sample exhibits viscoplastic behavior, i.e., the condition  $\tau \leq \tau_0$  is satisfied. In this case, the liquid does not exhibit flow. Here,  $\tau$  denotes the shear stress, while  $\tau_0$  represents the yield (initial or static) shear stress.

At a reagent dosage of 200 g/t (curve 2), the strength of the paraffin structure decreases, indicating a reduction in yield shear stress. In addition, the viscosity of the disrupted structure during flow also decreases.

At a dosage of 400 g/t, maximum efficiency is achieved. In this case, complete dissolution of paraffins occurs, accompanied by system homogenization, and the oil behaves as a Newtonian fluid (curve 3). Under these conditions, the viscosity of the liquid becomes independent of the shear rate. Thus, the condition  $\tau > \tau_0$  is satisfied, and the flowability of the crude oil is ensured.

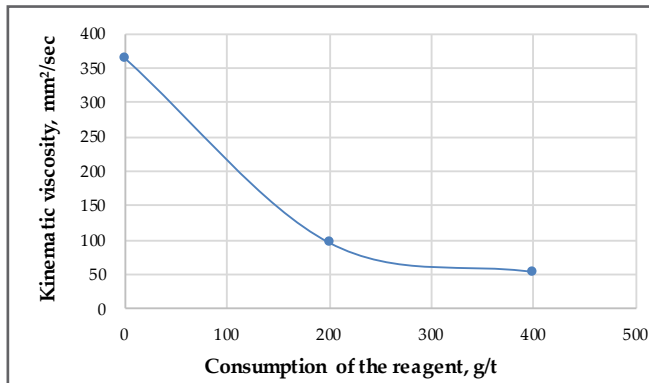


Fig. 1. Dependence of kinematic viscosity on reagent consumption in the paraffinic oil sample from well No. 441 of the N. Narimanov OGPD

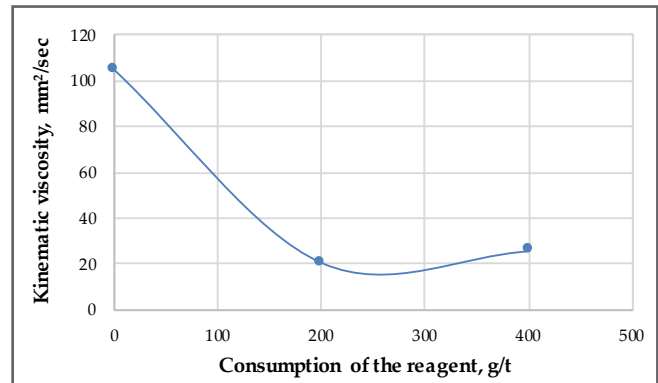


Fig. 2. Dependence of kinematic viscosity on reagent consumption in the paraffinic oil sample from well No. 2680 of the Neft Dashlari OGPD

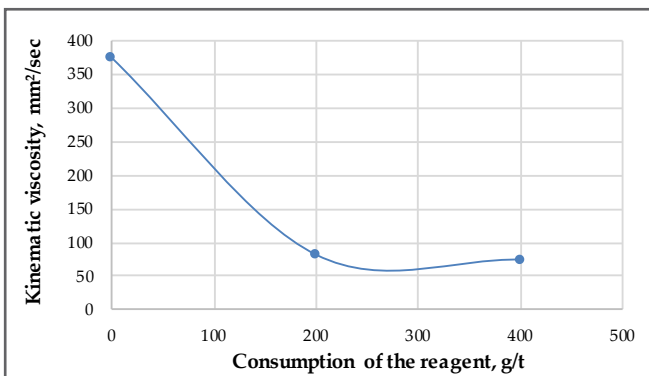


Fig. 3. Dependence of kinematic viscosity on reagent consumption in the paraffinic oil sample from well No. 450 of the Salyanoil OGPD

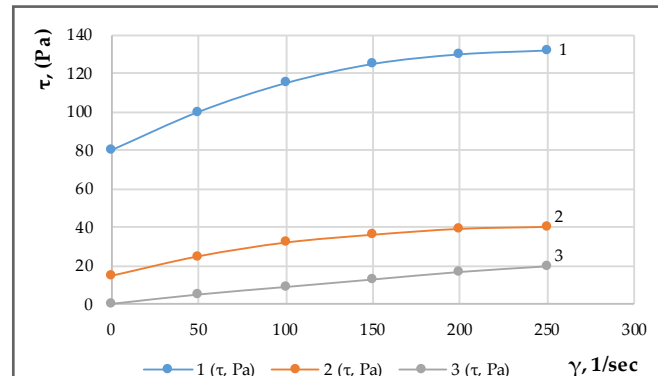
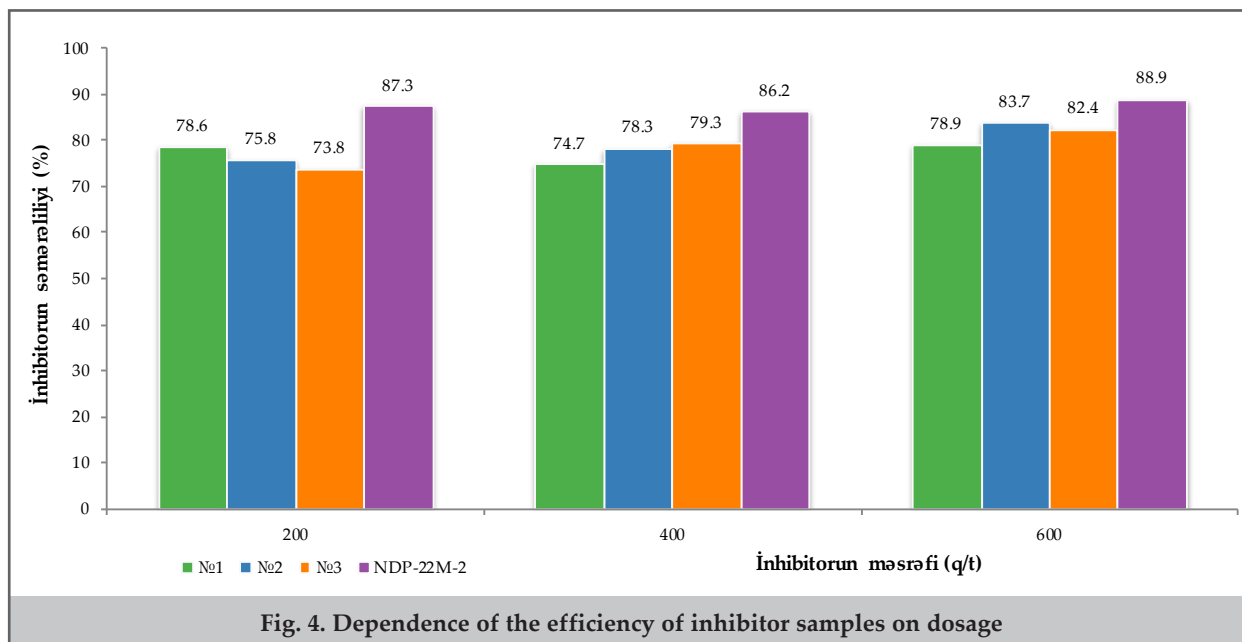


Fig. 5. Dependence of sliding density on velocity gradient



### Conclusions

- A more efficient NDP-22M-2 reagent has been developed to prevent complications associated with asphaltene-resin-paraffin (ARP) deposits in oilfield equipment.
- The mechanism of action of the newly developed polyester- and pyrolysis resin-based NDP-22M-2 reagent against ARPD is explained by its penetration into the paraffin structure, where it weakens intermolecular interactions between crystals and promotes their transition into the liquid phase. Based on these factors, the optimal dosage for various paraffinic crude oils was determined to be 200–400 g/t.
- The NDP-22M-2 reagent significantly improves the rheological properties of high-paraffin crude oil samples, which is essential for their subsequent transportation.

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