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Selection Of Efficient Reagent Compositions Reducing Hydraulic Resistance In Poly-Phase Liquid Stream

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Abstract- During the present period in connection with electric power price increase especially timely is a question of pipeline overall performance increase for the purpose of decrease in operational expenses when pumping naphtha and oil products. One of this problem solution ways is using the additives reducing hydraulic resistance as dopant to pumping naphtha and oil products.
The oil emulsion is characterized by high pitch and paraffin content. In spite of the fact that oil emulsion set point is low, its transportation on pipelines, especially in cold season, is strongly complicated owing to rod waxes formation. The pitches and asphaltenes present in naphtha aggravate this process, which leads to structuring liquid and increase in its viscosity. Experiments on Toms effect defining were made on equipment similar to presented in work [1]. In the oil-extracting industry for decrease in hydraulic resistance during naphtha pipeline transporting high-molecular polymers, soluble in naphtha are most often used. As shown in work [2], they are destruction-inclined and are not effective in circulation loop. Also it should be noted that the oil emulsion is poly-phase liquid, therefore the reagents applied to uniphase liquids are much less effective, and in some cases – are absolutely inapplicable. Besides with increase in water content in emulsion also the probability of naphtha direct emulsions formation that leads to padding complications of main product transportation process increases. In this case use of water-soluble and oil-soluble reagents composition [1-4] is justified

Keywords: emulsion, Toms effect, physics-chemical properties, reagent, flow turbulence, fluid structuring

Preparation of an oil emulsion.

As the pumping environment oil emulsions with various water content are used. The physical and chemical characteristics of naphtha used for emulsions preparation are presented in table 1.

Table (1). Physical and chemical characteristics of oil emulsions

Characteristics	Value		
	Naphtha No.1	Naphtha No.2	Naphtha No.3
Density, kg/m^3	0,849	0.895	0.973
Sulfur content, % mass.	0.55	0,24	3,77
Water content, % mass.	0	23.2	26
Mechanical impurities, % mass.:	0.35	0.5	0.5
Freezing temperature, ̊C	-11	-7	-7
Paraffin, % mass.:	3.2	9.6	8.09
Pitch, % mass.:	20.1	31.5	16.51
Asphaltene, % mass.:	1.54	0.88	4.53

The oil emulsion is characterized by high pitch and paraffin content. In spite of the fact that oil emulsion set point is low, its transportation on pipelines, especially in cold season, is strongly complicated owing to rod waxes formation. The pitches and asphaltenes present in naphtha aggravate this process, which leads to structuring liquid and increase in its viscosity. Experiments on Toms effect defining were made on equipment similar to presented in work [1]. When carrying out trial experiments at first naphtha without water content was pumped. Experiences showed low turbulence of stream (Re<10000). It is known that the Toms effect shown only

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in developed stream turbulence is the main condition for carrying out experiments [1,2]. Therefore for this condition realization the decision to reduce viscosity of naphtha by dilution with diesel oil was made. In mixture of different naphtha and diesel oil ratios the kinematic viscosity of each test was defined. During the made experiments the optimum ratio was found: naphtha - diesel oil (30:70). It is also necessary to note that in actual practice pumping of naphtha on Reynolds number pipelines in average equals Re = 40000. Thus it is possible to make the assumption that the Toms effect shown under laboratory conditions in actual conditions will be higher. Definition results for kinematic viscosity are given in table 2

Table (2). Kinematic viscosity of oil emulsion

Ratio Naphtha Diesel oil	kinematic viscosity coefficient v, mm^2/s	Reynolds number, Re
50:50	10.25	2732
40:60	6.39	4929
30:70	5.07	9155

Degree of stream turbulence is determined by a Reynolds number by formula 1:

$$\Re = \frac{V*d}{\nu}; \qquad (1)$$

where V – the peripheral speed, m/s; d – diameter of the pipeline, m; d = 0,01 m;

ν – kinematic viscosity of oil emulsion, mm^2/s;

During oil emulsion preparation one of conditions is its stability during transfer on circulation loop. Therefore the ratios of naphtha and diesel oil had to satisfy to these factors. The prepared emulsions with various maintenance of aqueous phase at periodic hashing were steady within 2-3,5 hours.

Choice of reagents.

In the oil-extracting industry for decrease in hydraulic resistance during naphtha pipeline transporting high-molecular polymers, soluble in naphtha are most often used. As shown in work [2], they are destruction-inclined and are not effective in circulation loop. Also it should be noted that the oil emulsion is poly-phase liquid, therefore the reagents applied to uniphase liquids are much less effective, and in some cases – are absolutely inapplicable. Besides with increase in water content in emulsion also the probability of naphtha direct emulsions formation that leads to padding complications of main product transportation process increases. In this case use of water-soluble and oil-soluble reagents composition [1-4] is justified

The reference property high molecular weight surfactant is a destruction (destruction of macromolecules) which leads to falloff or complete cessation of their influence on hydraulic resistance [3-7].

As reagents cellulose glicollic acid (CGA), glycerin, tri-sodium phosphate (TSP), monoethanol amine (MEA), polyox, diproxamine - 157, triethylene glycol (TEG), pentadecylic acid, RENT and reapon-IK were used.

The choice of reagents for carrying out experiences was caused by the following reasons:

– These are effective at small concentration. As a rule, with concentration growth the decrease effect of resistance increases, reaching its maximum, and then decreases practically to zero.

– They reduce turbulence level in the pipeline without reacting with its internal surface, and do not change property of pumped product [3-7]. Researches were conducted with water in the hydrodynamic mode of "developed turbulence" of Re>15000, mean time of circulation (time of one turn) in working water discharges makes 1 … 3 minutes. Nature of system parameters change after importation of corresponding additive on time was as a result established, thus time of carrying out one experience made 1 hour. According to the experimental data we constructed graphic dependencies which are shown on fig 1.

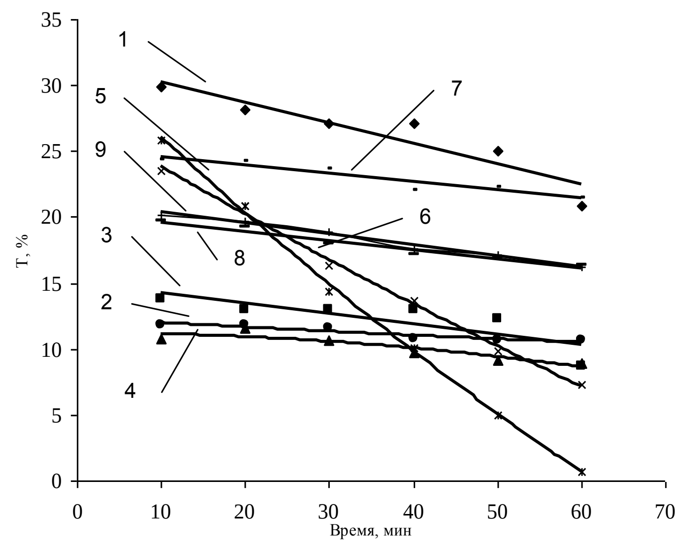

Fig. (1). Dependence of reagents effectiveness on pumping time in circulation loop at t=25^{0}C and concentration of 5mg/l, where
1 – CGA, 2 – TEG,
3 – TSP, 4 – MEA,
5 – PAA, 6 – polyox,
7 – D-157, 8 – reapon,
9 – RENT.

Under pic.: Time, min.

oil emulsion. For these purposes experiments for the fitted reagents at various water contents in oil emulsion were made, by one concentration of reagents and pressure of 4 kgf/cm^2 for each part.

Results of the experiments are represented in figures 2 a and b.

The carried-out analysis showed that reagents (TEG, TSP, MEA, CGA, RENT, reapon, D-157) show high stability and resistance to destruction in long-lived use.

Cellulose glicollic acid (CGA) represents ether of cellulose and glycolic acid of the common formula $[C_6H_7O_2(OH)_{3-x}(OCH_2COOH)_x]_n$, dissolved in water relatively slow. Water solubility no less than 98%. CGA-85/700 – compact-grained fibrous or powdery material

Tri-sodium phosphate (TSP) with the common formula$Na_3PO_4{\bullet}H_2O$ (twelve-water). The flakes or crystals capable of clodding.

Reapon - IK represents the mix consisting of nonionic surfactant, inhibiting composition and liquid solvent, water and alcohol soluble. Set point from-35 to -45 ° C.

Diproxamin 157 – copolymer of ethylene oxides and propylene on the basis of ethylene diamine: $[H(C_3H_6O)n(C_2H_4O)m]_2NCH_2CH_2N[(C_2H_4O)m(C_3H_6O)n]$. The transparent homogeneous liquid without foreign particulates. Set point - 45^{0}C.

Triethylene glycol - 2-[2 (2-hydroxietox) ethoxy] ethanol, encore - (hydroxietite) glycol ether, triglycol } $H(OCH_2CH_2)_3OH$, molecular mass - 150,18. Colorless thick hygroscopic liquid. Melting point -5 ^{0}C,

Glycerin - (1,2,3-trihydroxipropan; 1,2,3 pro-pan-triol) – a chemical combination with a formula $HOCH_2CH(OH)\text{-}CH_2OH$. Represents thick transparent hygroscopic liquid, beyond all bounds water soluble.

Polyethylene glycol (macrogoal, poly(ethylene oxide), PEO). Depending on an average molecular mass of polymer – thick liquid, gel or solid matter. Constitutional formula: HO-CH2-(CH2-O-CH2)n-CH2-OH

Ethanolamine $HO\text{-}CH_2CH_2\text{-}NH_2$ (2 aminoethanol) – organic compound, the representative of amino alcohols class, a heavy-bodied oleaginous fluid, mixes up with water in every respect, possesses the strong alkaline properties.

RENT - represents the mix consisting from nonionic and ionogenic surfactant, liquid of yellow color which is rather slowly dissolved in hydro-carbonic part of oil emulsion.

Pentadecylic acid – monobasic saturated carboxylic acid $C_{14}H_{29}COOH$ with molecular mass – 242. Melting point - 55^{o}C.

For a choice of experiments carrying out mode for water-soluble and oil-soluble reagents we select conditions of water content in

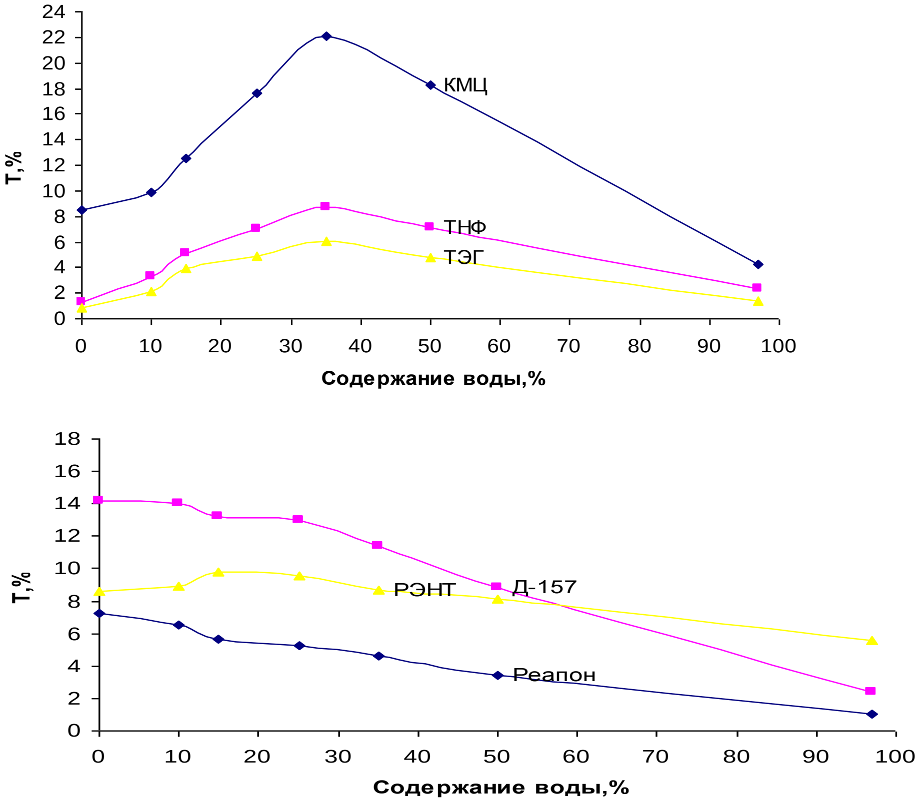

Fig. (2). Dependence of Toms effect on water content
a – for water-soluble reagents, on the example of reagents (CGA, TSP and TEG).
b – for oil-soluble reagents, on the example of reagents (RENT, D-157 and Reapon).

Under pic.: КМЦ — CGA, ТНФ - TSP, ТЭГ - TEG, Содержаниеводы % - Water content %, РЭНТ - RENT, Д-157 — D-157, Реапон - Reapon, Содержаиеводы % - Water content %.

From graphics it is visible that the best indexes of Toms effect for water-soluble reagents are shown at 35%, and for oil-soluble at 0% of water content, further the effect of reagent decreases. Therefore we choose oil emulsion with water content of 35% for carrying out further experiments.

Experiments were made on equipment [1] for definition of Toms effect, as pumped liquid used tank anhydrous oil and in advance prepared emulsion with the maintenance of water part of 35%. Concentration of reagents made 5 mg/l.

Results of the performed experiments are presented to Table 3

Table (3). Experiment results

Reagent	Water content, %	Concentration mg/l	Pressure, kgf/cm^2	T, %	Re
CMC	0	5	1	5.34	4577
			2	7.53	6621
			3	6.35	8232
			4	8.54	9025
CMC	35	5	1	9.85	3761
			2	11.83	6219
			3	19.84	7810
			4	22.07	8783
RENT	0	5	1	5.82	4462
			2	6.96	6586
			3	7.54	8129
			4	7.82	8929
RENT	35	5	1	6.88	3665
			2	8.58	6042

			3	9.12	8254
			4	9.81	8872
TSP	0	5	1	0.33	4215
			2	0.56	6588
			3	1.68	8754
			4	2.56	9128
TSP	35	5	1	1.15	3874
			2	1.25	6458
			3	2.87	8098
			4	3.32	8821
Reapon	0	5	1	2.76	4189
			2	3.34	6099
			3	4.58	8012
			4	6.88	8941
Reapon	35	5	1	4.52	4152
			2	5.12	6101
			3	6.85	8236
			4	7.36	9016
TEG	0	5	1	0.58	4187
			2	0.72	5822
			3	0.87	8103
			4	0.99	8836
TEG	35	5	1	0.23	3875
			2	0.49	5786
			3	0.96	8025
			4	1.32	8791
MEA	0	5	1	6.05	4225
			2	6.26	5896
			3	9.23	8036
			4	11.36	8965
MEA	35	5	1	3.85	3986
			2	4.64	6154
			3	5.12	8971
			4	5.63	9102
D-157	0	5	1	9.73	4203
			2	11.4	6047
			3	12.28	8985
			4	14.15	9155
D-157	35	5	1	3.65	4006
			2	4.4	5876
			3	8.54	8127
			4	9.74	8823
Polyox	0	5	1	0.41	4108
			2	0.65	5982
			3	0.89	8014
			4	1.32	8965
Polyox	35	5	1	0.45	3874
			2	0.48	5878
			3	0.69	7984
			4	0.85	8758
Glycerin	0	5	1	4.12	3982
			2	5.69	6023
			3	8.65	8215

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			4	10.87	9144
Glycerin	35	5	1	3.36	4102
			2	4.58	5896
			3	7.84	8025
			4	9.65	8863
Pentadecanoic acid	0	5	1	1.05	3996
			2	1.24	5921
			3	1.25	8017
			4	1.36	8974
Pentadecanoic acid вая к-та	35	5	1	0.74	3989
			2	0.87	5812
			3	1.08	8101
			4	1.14	8837

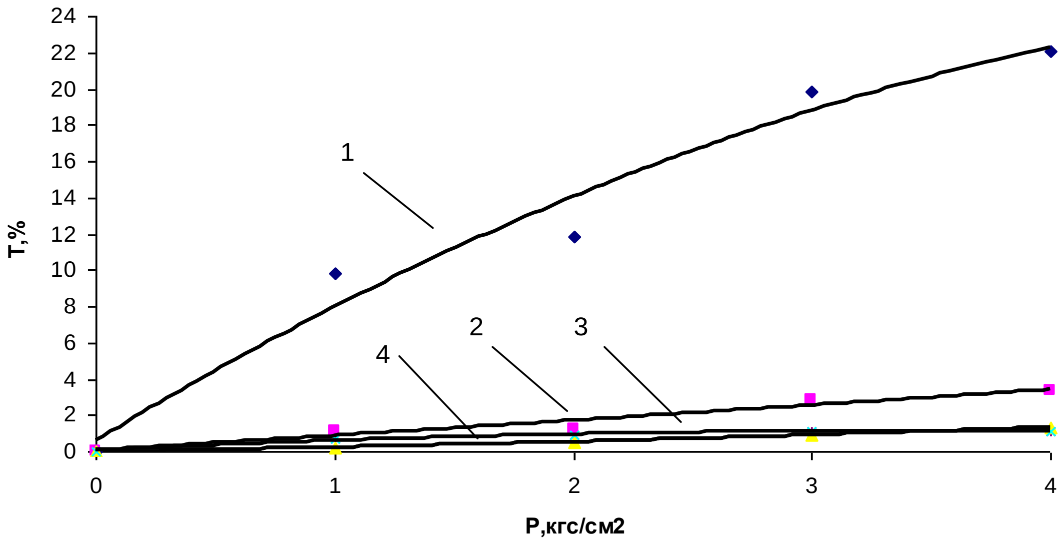
The conducted researches showed that effectiveness of Toms effect in circulation loop is expressed in flow rate increase at pressure preservation in contour points. In this regard the size of Toms effect is calculated by formula (2):

$$T = \frac{(Q\text{реаr} - Q\text{исх})}{Q\text{реаr}} * 100(2)$$

Where $Q_{исх}$ oil emulsion use without reagent;

$Q_{реаr}$ oil emulsion use with reagent;

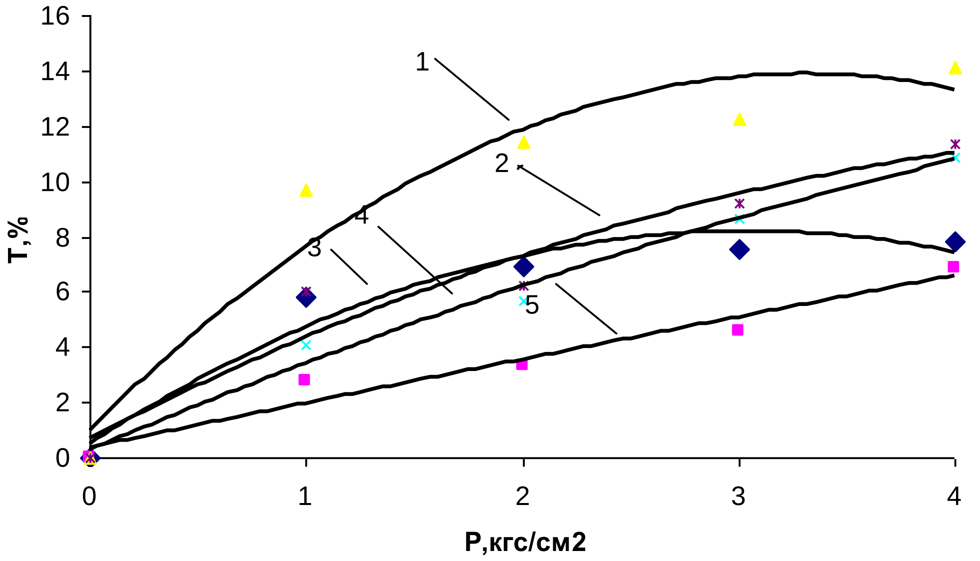
Data values of Toms effect with various pressure in system were conducted from these experiments. Separately for water-soluble (fig. 3a) and oil-soluble (fig. 3b) reagents.



Under pic.: P, kgf/cm^2

Fig. (4). Toms effect at various values of pressure for water-soluble reagents, where 1-CGA, 2-TSP, 3-TEG, 4-polyox.

Apparently from the graphic, CGA showed the best result. Therefore for making reagent composition for water part we choose CGA.



Under pic.: P, kgf/cm^2

Fig (5). Toms effect at various pressure values for oil-soluble reagents, where 1-MEA, 2 D-157, 3 RENT, 4 Glycerin, 5-Reapon.

The choice of reagents is caused by oil emulsion being two-phase, therefore we select composition from two reagents working in two-phase system. For water part of emulsion CGA, which proved itself in aqueous phase, was chosen, and for the hydro-carbonic MEA, glycerin and D-157 showed approximately identical effectiveness.

Research of reagent compositions

Experience showed that effectiveness of additive depends on its concentration in oil emulsion and on the stream current mode. The Toms effect is shown only in developed stream turbulence is the main condition when carrying out experiments, including turbulence existence (Re > 2300) as necessary and natural condition of Toms effect manifestation.

According to the received values it is possible to draw a conclusion that it is better to carry out experiments of the studied reagents and their compositions under pressure of 4 kgf/cm^2 as at this value the developed turbulence mode of stream and reagents manifest themselves better.

Usually reagent effectiveness is measured at various concentration under conditions of the same transfer efficiency. At further increase in reagent concentration growth of effectiveness is slowed down and, starting from particular concentration, practically stops, which signifies of saturation effect, i.e. each reagent in each case can give particular maximal effect.

With increase in reagent concentration the channel capacity increases to particular maximum and hydraulic resistance decreases in the pipeline, which allows transfer costs decrease, and, therefore, income grows.

The maximum size corresponding to reagent concentration, as well as profitability range width depend on the cost of reagent quantity unit and transfer tariffs: the cost of reagent is higher and transfer tariffs are lower, the use of reagent [12] will be less profitable.

That size of concentration where use of reagent will be profitable is selected. Therefore use of reagent concentration of 5 mg/l will be more expedient for carrying out experiments. Further strengthening from the economic point of view is unprofitable. These features should be considered for reagent use economic effect optimization.

For the chosen reagents working in different environments, we make a series of experiments at various values of water content.

Results of the performed experiments with reagents compositions are reported in table 4.

Table (4). Experiment results

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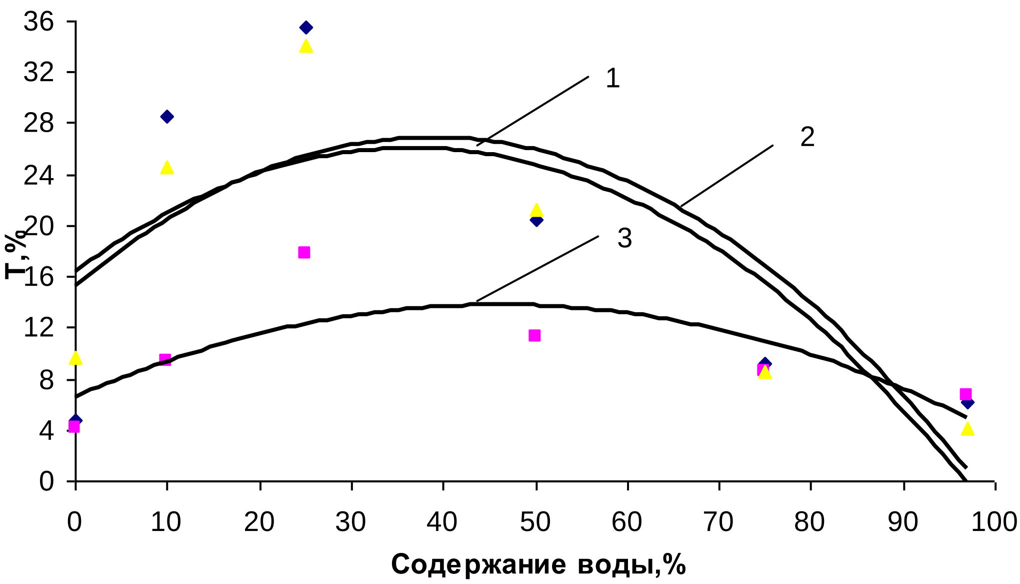
Reagent	Water content, %	ΔP, atm.	Electric power quantity, kW	T, % mas
D 157+CGA	0	3.75	0.2	9.6
	10	3.78	0.2	24.6
	25	3.78	0.35	34.1
	50	3.75	0.45	21.3
	75	3.75	0.75	8.6
	97	3.73	0.8	4.2
MEA + CGA	0	3.8	0.1	4.8
	10	3.84	0.2	28.5
	25	3.84	0.25	35.6
	50	3.84	0.35	20.45
	75	3.85	0.65	9.2
	97	3.85	0.85	6.14
Glycerin + CGA	0	3.69	0.1	4.2
	10	3.68	0.25	9.4
	25	3.65	0.3	17.7
	50	3.68	0.4	11.23
	75	3.68	0.65	8.5
	97	3.7	0.8	6.7

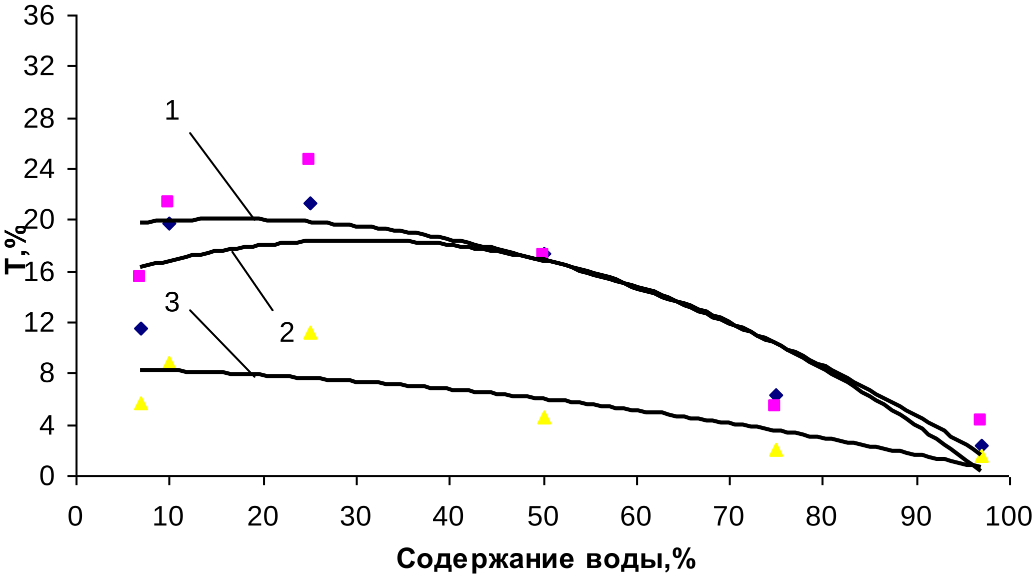
By results, provided in the table, we constructed the values graphic for Toms effect at various water content.



Under pic.: Water content %

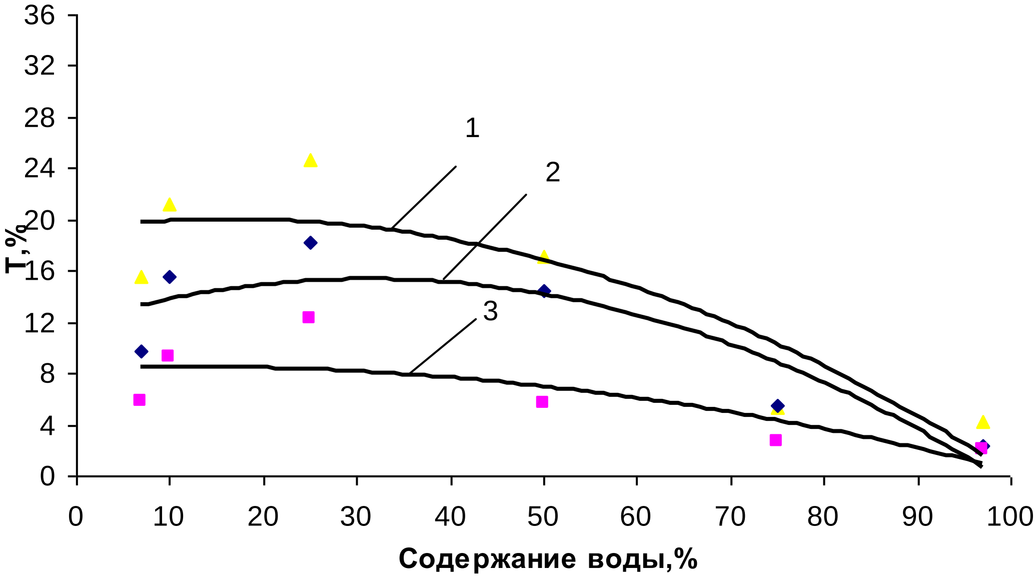
Fig (6). Dependence of Toms effect on water content, where 1 – CGA + D-157, 2 – CGA + MEA, 3 – CGA + Glycerin.

For check of effect from application of reagent composition we made experiments with two other oil emulsions. Results of experiments are explained in the form of schedules on fig 7 and fig 8.



Under pic.: Water content, %

Fig (7). Dependence of Toms effect on water content with naphtha No. 2, where 1 – CGA + D-157, 2 – CGA + MEA, 3 – CGA + Glycerin.



Under pic.: Water content, %

Fig (8). Dependence of Toms effect on water content with naphtha No. 3, where 1 – CGA + D-157, 2 – CGA + MEA, 3 – CGA + Glycerin.

3. SUMMARY

On the basis of the performed work it is possible to draw the following conclusions:

- the best effectiveness on decrease in resistance in the conditions of closed circulation loop was shown by composition D 157+CGA and MEA+CGA;

- at increase in water content to 35%, increase of Toms effect is observed; according to the theory of action water-soluble in water part and oil-soluble in hydro-carbonic part of oil emulsion, it is possible to choose ratio of reagents in composition, for achievement of particular Toms effect.

- at increase of water content in oil emulsion from 70-90%, addition of reagent becomes inefficient;

4. CONCLUSION

On the basis of experiment results it is necessary to expect high economic effect of practical reagent use as effectiveness of some reagents in comparison with transfer of oil emulsion without reagents reaches 35%;

CONFLICT OF INTEREST

The author confirms that the presented data do not contain the conflict of interests.

ACKNOWLEDGMENTS

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